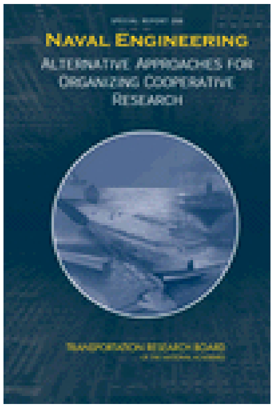


**Naval Engineering: Alternative Approaches for Organizing Cooperative Research -- Special Report 266**

Committee on Options for Naval Engineering Cooperative Research, The National Academies

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SPECIAL REPORT 266

# NAVAL ENGINEERING

## Alternative Approaches for Organizing Cooperative Research

Committee on Options for
Naval Engineering Cooperative Research

Marine Board

TRANSPORTATION RESEARCH BOARD
*OF THE NATIONAL ACADEMIES*

TRANSPORTATION RESEARCH BOARD
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This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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# Preface

Naval engineering is a unique discipline that encompasses all the arts and sciences applied in the research, design, construction, and operation of ships, submarines, support vessels, combat systems, ocean structures, and related shore facilities.

The Office of Naval Research (ONR) supports naval engineering science and technology development programs to enable the Navy to build and operate an effective and capable fleet. It is a major challenge for ONR to carry out needed high-quality research and ensure the continuing availability of the necessary human capital. The Navy has long-term requirements for more innovative and capable warships and a total ship design capability that are not being met under the current ONR naval engineering program. The Navy is facing serious limitations related to an adequate supply of the creative talent and knowledge base needed. ONR also lacks sufficient personnel with broad, interdisciplinary experience.

To address these problems, ONR asked the Transportation Research Board (TRB) of the National Research Council (NRC) to investigate and evaluate alternative approaches for structuring cooperative research programs in naval engineering. Under the auspices of the Marine Board of TRB, NRC convened an 11-member Committee on Options for Naval Engineering Cooperative Research, with appropriate scientific and technical expertise in engineering research and administration, naval defense, naval engineering and architecture, ship production, and ship operations. The committee had a balance of expertise and experience in industrial research and academia (see Study Committee Biographical Information at the end of this report).

ONR stressed the importance of an approach to research that incorporates total systems aspects of the naval engineering discipline. ONR also asked that the study be accomplished within a very short time so that the results would be available in early 2002 and agreed that, in order to accommodate this schedule, the committee would present options for consideration rather than recommendations. Because of this time constraint, the committee was able to describe and evaluate only the alternative organizational models that were presented to it and that are the leading contenders for consideration by ONR. Consequently, it was understood that ONR will be responsible for taking the examples presented in this report and implementing them under its own development process with appropriate input from the stakeholder community.

The committee began its review and evaluation with the understanding from ONR that a key national responsibility of ONR is to maintain a robust capability in naval engineering and improve the Navy's abilities to translate creative research into innovative warships. This capability includes a research community that will advance the state of the art of technology, engineering, and science and generate an adequate supply of new scientists and engineers. In its investigations, the committee was also sensitive to ONR's concern that any research program proposed incorporate input from all stakeholders in order to establish firm links to the total ship production system. The background of the study is discussed more fully in Chapter 1.

The committee met three times between November 2001 and February 2002. The first and second meetings included extensive presentations in sessions open to the public, during which experts from government, academia, and industry presented a variety of issues and views to the committee, including formal presentations on cooperative research options. The presentations included several from the naval engineering stakeholder community that described organizational proposals developed to address the needs of ONR. Within each presentation were references to existing programs that illustrated how each proposal might perform. In addition, the committee heard separate presentations from experts describing existing programs from other disciplines (e.g., the Engineering Research Centers Program managed by the National Science Foundation, the National Oceanographic Partnership Program managed by the Consortium on Oceanographic Research and Education, and the offshore oil and gas industry's cooperative research programs). The information concerning these programs and relevant reference materials are available to ONR and the general public and are identified in Appendix A. ONR can use this material for further detailed evaluation of an organizational concept after an implementation decision.

After the committee reviewed and discussed the information from the presentations, it undertook an analytical examination of the goals, objectives, and attributes of successful and effective research organizational models. The method of analysis and outcomes of this analysis are described in Chapters 2 and 3. The evaluation of the alternative models is presented in Chapter 4. Since the committee could not find significant evaluative literature concerning existing models, it relied on its own expertise to consider their merits. The committee also noted that, for each of the models described, there are examples of existing programs that ONR could investigate further should it decide to implement one of the organizational approaches.

Issues related to implementing a cooperative research program are discussed in Chapter 5. The committee was not asked to make formal recommendations and, therefore, limited its discussion to a description of advantages and disadvantages of each model and an identification of key findings. These are presented in the Executive Summary.

The final report represents a synthesis of information gathered by the committee, along with analysis of the information based on committee members' relevant expertise and experience. Organizational models for structuring programs in naval engineering research that would provide a venue for cooperative research and development are evaluated. The basic organizational concepts inherent in each of four models are presented, and the advantages and disadvantages of each are identified. In addition, comments are made on features in each model that satisfy the goals and objectives of ONR to revitalize the field of naval engineering and improve naval ship design and production.

## ACKNOWLEDGMENTS

The committee wishes to thank the many individuals who contributed their time and effort to this project. Representatives of federal and state agencies, as well as private companies, provided invaluable assistance to the committee and the staff. Thanks are especially due to Dr. Albert Tucker of the Office of Naval Research, who responded promptly and with a generous spirit to the requests for information from the committee.

The study was performed under the overall supervision of Stephen R. Godwin, Director of Studies and Information Services. Susan Garbini and Peter Johnson served as project directors.

This report has been reviewed by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the authors and NRC in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The content of the review comments and draft manuscript remains confidential to protect the integrity of the deliberative process. The committee wishes to thank the following individuals for their participation in the review of this report: Steve Bohlen, Joint Oceanographic Institutions, Inc.; Jack E. Buffington, University of Arkansas; Roger Compton, Webb Institute; Billy Edge, Texas A&M University; Duane Laible, Glosten Associates; and William W. Rogalski, Jr., Northrop Grumman Litton Ingalls Shipbuilding Company. While the individuals listed above have provided many constructive comments and suggestions, responsibility for the final content of this report rests solely with the authoring committee and NRC.

The review of this report was overseen by Lester A. Hoel, University of Virginia. Appointed by NRC, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered.

Suzanne Schneider, Assistant Executive Director of TRB, managed the report review process. The report was edited by Norman Solomon and prepared for publication under the supervision of Nancy Ackerman, Director of Reports and Editorial Services. Special thanks go to Amelia Mathis for assistance with meeting arrangements and for production of the final report.

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# Executive Summary

The Office of Naval Research (ONR) supports naval engineering science and technology development programs to enable the Navy to build and operate an effective and capable fleet. This mission requires ONR to define research goals and themes, support innovative and high-quality research, and ensure the continuing availability of the necessary human capital. ONR also needs to ensure that the results of its research are useful in the design of advanced naval warships for the future. The current ONR naval engineering program faces serious limitations regarding its ability to provide an adequate supply of the creative talent and knowledge base as well as to manage the broad-based, total ship systems research programs that the Navy needs.

To address these problems, ONR asked the Transportation Research Board (TRB) of the National Research Council (NRC) to investigate and evaluate alternative approaches for organizing and managing cooperative research programs in naval engineering. ONR stressed the need for an approach to research that promotes innovation, incorporates total systems concepts in naval engineering, and involves all stakeholders in the decision-making process. ONR believes that such programs would attract talented researchers and enable stakeholders (government, industry, academia) to collaborate and guide the research process. This study is intended to provide ONR with a basis for evaluating available cooperative research organizational options and selecting the most effective approach to meet its goals.

To respond to the ONR request, TRB convened the Committee on Options for Naval Engineering Cooperative Research. The committee received extensive presentations from experts in government, academia, and industry with a variety of perspectives on cooperative research organizations. After the presentations, the committee undertook an analytical examination of the goals, objectives, and attributes of successful and effective research organizational models. The committee was not asked to make formal recommendations and thus limited its evaluation to examining the advantages and disadvantages of selected organizational models.

This final report represents a synthesis of information gathered by the committee, along with its analyses drawing on committee members' relevant expertise and experience. The committee first evaluated the basic organizational concepts inherent in the current system, which employs the individual investigator approach, as well as three selected models that provide a venue for cooperative research. It then identified the advantages and disadvantages of each model. Finally, it commented on features in each model that satisfy the goals and objectives of ONR to revitalize the field of naval engineering and improve naval ship design and production.

## GOALS AND OBJECTIVES FOR COOPERATIVE RESEARCH ORGANIZATIONS

The government and the private sector have used a number of different approaches to organize and execute research programs and projects to meet their goals and objectives. Each organizational model has characteristics that make it more or less effective in achieving stated goals and objectives.

ONR has two overall goals that it needs to achieve in adopting a model for naval engineering cooperative research: (*a*) to maintain and develop human capital and (*b*) to revitalize naval engineering and improve ship design and production. To compare approaches for organizing naval engineering research, the committee further defined these two goals in terms of specific objectives and sets of attributes against which possible organizational models could be evaluated.

Ensuring an adequate supply of human capital for advanced naval ship systems design and production into the future is a multifaceted problem. The key objectives embodied under this goal include attracting students, attracting and retaining faculty, providing continuing education opportunities, and fostering the development of "total ship engineers." Naval engineering graduates and practicing professionals need to approach ship design, development, and production/construction from the "total ship" point of view in order to meet the challenges of the future Navy. Hence, the concept of "total ship engineer" must be infused into the education and professional development of future naval engineers.

With regard to the second ONR goal, there is a critical need for the U.S. ship design community to revitalize its ability to accomplish creative new research and to support higher-performing, cost-effective designs and more innovative ship systems engineering. In addition, research results need to be transferred to the next stage of technology development and used in actual ship designs.

## DESCRIPTION OF THE SELECTED ORGANIZATIONAL MODELS

After reviewing an array of existing organizational models and several proposed new approaches, the committee decided to focus on a small number of core strategies for organizing cooperative research programs. It first identified the individual principal investigator model as the one currently used by ONR for most of its research programs, and thus that model became the base or reference model for purposes of the committee's discussions and evaluations. Next it selected three cooperative models to evaluate that represent three different underlying organizational approaches and that incorporate the features of most existing and proposed models. The three models are the professional society/community of practitioners model, the consortium model, and the project-centered model. The committee made two assumptions about the functioning of all three models: (*a*) they would all perform the contracting functions for individual projects funded by ONR and (*b*) they would all propose annual research themes, present them to ONR for approval, and then contract for and manage the individual projects that make up the program defined by the themes.

The professional society model is characterized by being directed by the community of practitioners in the field. This community is usually organized into professional societies such as the American Society of Naval Engineers and the Society of Naval Architects and Marine Engineers. In this model, the professional society would establish a research council, typically a not-for-profit organization, to organize and manage the research program. The council is typically made up of representatives from the various stakeholders. It would have an administrative support staff, and its composition and leadership would be structured to achieve a desired balance. In this model, committees are used to perform various tasks in support of the research council, and committee membership can be drawn from society membership.

In the consortium model, the basic organizational structure is a permanent entity, or center, that provides ongoing management of the research, education, outreach, and technology transfer activities. Typically, a director would lead the consortium and be supported by an administrative and contract management staff. The director would normally report to an executive committee composed of representatives from the various stakeholders. To solicit input and disseminate information to the wider community, the executive committee would establish affiliate committees, advisory boards, industrial liaison groups, and outreach specialists.

In the project-centered model, an executive council similar in composition to that in the consortium model would establish research themes and handle the processing and review of proposals. The council would be permanent but typically would have staged, rotating membership. The council chair would provide the principal leadership for the committee and oversee a small administrative support staff. Additional input on research themes would be handled via workshops and open forums, through professional society committees, or by industry associations. This model would usually focus on large, multidisciplinary projects. For each project a technical review committee would be established to prepare requests for proposals, evaluate the proposals, and assess ongoing performance. The technical review committee would remain in existence as long as the project is active but would cease when the project is completed or terminated. Individual project organizations would be added as projects are approved and funded but disbanded as they are completed.

## FINDINGS

### Evaluation of Models

The committee evaluated each model on the basis of how well it appears to accomplish the ONR program goals and objectives. It is clear that some models are better at fulfilling certain objectives while others are better at fulfilling other objectives. Thus the overall selection of one of the models as superior to another is only possible by weighing the relative importance of each objective and thus justifying such a selection. The committee's evaluation of the selected models leads to the following general findings concerning their overall advantages and disadvantages.

*Baseline Model*

The committee found that the individual investigator model (the baseline for this study) is excellent at promoting innovation and will continue to provide this value if it is maintained as a part of any future naval engineering research program. However, the committee found it to be inadequate to meet all of the program objectives under the ONR goals as stated above. Thus, it is desirable to consider cooperative organizational models that may have the capacity to remedy the deficiencies in the current system.

*Cooperative Research Models*

All three models for cooperative research organizations that were evaluated by the committee were found to be capable of meeting all of the ONR program objectives. With regard to their ability to meet human capital and naval engineering and design objectives, the consortium model was found better than the professional society model, but both were significantly better than the project-centered model. Table ES-1 shows how well each of the three models fulfills the stated objectives. The absolute ranking of these models, however, will depend on the relative importance given by ONR to each objective.

*Evaluation Based on Specific Objectives*

In its evaluation process the committee found that the three cooperative research models had the following attributes for meeting certain specific objectives:

- Both the consortium and project-centered models encourage innovative research. However, one key to implementing the research into innovative ship design is the ability of the Navy and other stakeholders to overcome the natural tendency of an organization to resist change such as that associated with the use of new technology in ship acquisition.

**TABLE ES-1 Summary of Cooperative Research Organizational Models and How Well They Meet Objectives**

| | Baseline Model | Professional Society Model | Consortium Model | Project-Centered Model |
|---|---|---|---|---|
| Human capital objectives | | | | |
| Attract students | Medium | High | High | Medium |
| Retain and attract new faculty | Medium | Medium | High | Medium |
| Provide continuing education | Low | High | High | Medium |
| Foster total ship engineers | Low | High | High | Medium |
| Naval engineering design objectives | | | | |
| Create new research opportunities | Low | Medium | High | Medium |
| Promote innovation | High | Medium | High | High |
| Ensure research useful to ship design | Low | Medium | High | High |

• All of the cooperative models possess characteristics in varying degrees that encourage research useful to advanced ship technology and design development. However, the consortium and project-centered models involve a higher degree of stakeholder participation in important areas that will be described in the body of the report. Therefore, they have a higher probability of meeting the Navy's needs in this area.

• Total ship engineers are developed through a combination of a formal total ship design curriculum and hands-on design experience gained in working on multidisciplinary projects. Regardless of the model selected, the ability to foster total ship engineers depends on the opportunities available to all stakeholders that enable them to obtain the necessary formal education in total ship design and hands-on design experience.

*Particular Merits of the Three Cooperative Research Models*

In its evaluation process, the committee found that each of the three cooperative research models possessed the following particular merits:

• The professional society/community of practice model excels in meeting the need to develop human capital. This model has the potential to be particularly strong in attracting and retaining students, in supporting continuing education and training programs, and in fostering the education and development of total ship engineers. This strength is based on the fact that these are principal missions of professional societies.

• The consortium model is well suited to meeting all the human capital development and naval engineering design objectives. Its success in meeting these objectives will be principally determined by the leadership of the consortium and its ability to adequately represent and balance the needs of the various stakeholders.

- The project-centered model has the potential to excel in promoting both innovation in naval engineering design and research that is useful to ship design and production. This strength is based on the large-scale, interdisciplinary project focus inherent in this model, which includes participation and encourages collaboration of the key stakeholders.

### *Possibility of Hybrid Models*

The committee found that desirable features and attributes of the models might be combined to create hybrid models. Such models might be used to maximize the performance of the research organization in meeting program objectives. The hybrids, however, generally increase the complexity in managing the research enterprise. Examples of hybrids might include embedding the individual investigator model into any of the three cooperative models discussed, including the project-centered approach in the consortium and professional society models, and embedding both the project-centered and individual investigator models into the consortium or professional society models. The committee has not evaluated these hybrids but has only noted that such combinations are always available to a creative manager.

## Operational Considerations in Implementing Research Models

During its evaluation of the selected cooperative research models, the committee found that successful operations and functioning of an organization are often independent of the selection of its fixed structure. Therefore, regardless of which cooperative research model ONR chooses to implement, certain overall factors are critical to the success of its naval engineering research program and should be carefully considered in the implementation process. The following operational or functional elements are critical to the ability of any organization to meet ONR's goals and objectives.

### *Management Issues*

The mechanisms outlined in this report for the contracting, the managing, and the oversight of cooperative research organizational models can allow ONR to meet the Navy's needs without adding significantly to its current management burden. In particular, the annual reviews, which are part of all models, allow for directing the research themes toward successful and pertinent results as well as providing flexibility to meet future changes. These management mechanisms, however, will need to be reviewed and evaluated to ensure that they fit the particular models selected.

*Setting a Research Agenda*

A fundamental issue in structuring a cooperative research program to meet ONR's goals is the process and manner of setting the research agenda. The committee found that in a true cooperative program, all the major stakeholders have both a shared interest and shared ownership in the research agenda. For any of the organizational models to be successful, it must provide a structure and mechanism to allow appropriately balanced representation and input to the research agenda from stakeholders.

*Selecting a Host Location*

The committee found that, independent of which cooperative research organizational model or combination of models ONR selects, the location of the research organization host is very important. The choice of venue has a strong potential impact on all stakeholders, especially academia, because of the small size of the naval engineering community and the dependence of each institution on the Navy for funding. Careful consideration should be given to the choice of location, to the establishment and maintenance of an appropriate balance of participation from all the stakeholders, and to potential rotations in membership of the governing bodies.

*Conducting Merit Reviews*

The committee found that, to be successful, merit review of the research in all models should take place at three stages in the process: when the proposal is approved, annually during the course of the research work, and when the project is completed. A merit review panel should be carefully balanced to ensure that innovative high-risk ideas are not lost and that the results address the Navy's needs. In addition, the merit review process will be affected by the fact that the naval engineering community is small and the number and variety of quality research institutions are limited. The committee found that, regardless of model selection, the small size of this community will necessitate resourcefulness in assembling a qualified and conflict-free group of individuals with balanced biases as reviewers for research proposals, progress, and outcomes.

*Executive Council Balance*

The committee found that, to promote cooperative work, balance in the leadership of the executive council, or governing body of the organization, is critical.

The leadership of each of the three cooperative research organizations that the committee reviewed would be vested in an executive council under a variety of names. Alternative strategies in establishing the size, composition, tenure, leadership, and decision-making process of this council will strongly affect the overall success of the organization and the R&D programs it manages. The representation of the three principal stakeholders on the council will affect the degree to which the constituencies are served and the philosophy, priorities, and direction that the research program will follow.

*Perception of Balance*

The committee found that it is inherently difficult for the stakeholders in this enterprise to collaborate because they have not had a record of cooperative work and their governing bodies have few continuing relationships. Therefore, any new cooperative research organization should develop the needed collaborative process from the beginning. In addition, the perception of balance is often as important as actual balance. For example, if the headquarters of a consortium is located at one of several universities, companies, or laboratories that are in competition for resources, the perception of imbalance in favor of that organization is inevitable. Steps to offset this perception would need to be included in the organizational structure and operations planning.

*Education*

The committee found that the educational objectives of ONR are important to its long-term success, and each model has some attributes that will contribute to the objectives if they are given adequate attention. The individual investigator model will probably have a moderate impact on the education of naval engineers in the overall sense, by which is meant primary, secondary, undergraduate, graduate, and continuing education. The consortium model has a high potential to promote educational objectives. The professional society model also has a high potential, but its actual effectiveness would depend on the provisions of individual proposals. The project-centered model by itself is expected to have little or no direct impact on education without special or additional efforts.

# 1
# INTRODUCTION

In this chapter, background information concerning the study is given, and the study scope and approach are described.

## BACKGROUND OF THE STUDY

The Ship Hull, Mechanical, and Electrical Systems Division of the Office of Naval Research (ONR) sponsors basic and applied research and technology transfer in naval architecture, marine engineering, and related fields. This division supports research in solid mechanics, structural acoustics, structural dynamics, computational mechanics, control of dynamic systems, dynamics of electric power networks, and control of acoustic and nonacoustic signatures. In addition, the division supports exploratory development of technology for ships and submarines in the following areas: structural systems, power and automation, signature control, maneuvering, and seakeeping. This division of ONR has three sets of stakeholders in its research program: the U.S. Navy, industry, and academia. Each group has different objectives and seeks somewhat different outcomes from the research.

With the continuing retrenchment of the large, oceangoing commercial shipbuilding industry in the United States, the Navy has become the major customer for new ships in U.S. shipyards. About 90 percent of the shipbuilding undertaken in this country is done for the U.S. government, most of it for the Navy. The consensus is that investment in design and innovation in this sector is inhibited because “the acceptance of one failure is very low” and “there are too few opportunities for a return on that investment” (MIT 2000). This is in contrast to the commercial sector—particularly the recreational boat industry—where there is extensive innovation, although on a smaller scale (MIT 2000). The Navy’s interests are to create innovative ship concepts that can take advantage of new technologies to improve the Navy’s combat capabilities. The operational Navy wants to see more useful products in the near term and therefore has a more active interest in the applied research aspect of the ONR programs than in longer-term, more fundamental research.

The major shipyards, most of which now build ships exclusively for the Navy, also depend on ONR research to develop new concepts, but find that they have little direct influence on the nature of the ONR program. These shipyards provide a major component of design today for the Navy. To the extent that the Navy expects them to introduce new technologies, the shipyards strongly support more research in applied areas of ship design, production, and new materials.

A small number of universities teach ship design and naval engineering. The Navy recognizes the importance of maintaining a university infrastructure incorporating faculty and students with expertise in the fields the Navy requires, but with the continuing decline in the shipbuilding industry, the schools are finding it difficult to maintain faculty and programs in naval architecture (MIT 2000). ONR funding of research has been a critical component of supporting the university base to educate undergraduate and graduate students. However, there is a continuing decline of engineering graduates who become the future naval engineers in government and industry. ONR has recognized a critical need to improve human capital for developing future Navy ships.

Within the context of the Navy's national defense mission, future naval and maritime capabilities depend on innovative operational systems, which, in turn, depend on creative ship designers with adequate and continuing research support. The naval environment is unique and complex, and in order to ensure U.S. superiority the Navy must maintain the following:

- A robust and focused research community to advance the state of the art in critical technologies,
- An adequate pipeline of new scientists and engineers in naval engineering disciplines, and
- The ability to implement advanced technology products needed by operational forces to enhance fleet performance.

ONR has been concerned about the eroding base of creative ship designers and the limitations of the naval engineering research community for some time. In 1996, the Marine Board completed a study for ONR on shipbuilding technology and education that focused on the need for improved competitiveness in the U.S. shipbuilding industry and recommended that universities become more involved with the shipbuilding industry through cooperative efforts (NRC 1996). In 2000, a report prepared by a Massachusetts Institute of Technology group under ONR sponsorship examined naval engineering research and education and noted problems in maintaining an adequate research base for the future and providing the necessary educational programs and environments (MIT 2000). In addition, under ONR sponsorship, the Marine Board hosted a workshop on naval engineering research and education in May 2001 (TRB 2001). It explored multiple aspects of this problem and offered members of the involved community an opportunity to describe their concerns and present ideas that might lead to an acceptable solution.

The above efforts have indicated that the existing ONR system of supporting mainly single-discipline research projects has certain limitations that may be corrected through a new institutional approach to organizing and managing research in naval engineering (ASNE 1998; NRC 2000). In October 2001, ONR decided to take national responsibility to maintain the health of this naval-critical science and technology area and establish the Naval Engineering National Naval Responsibility to ensure that the following objectives are achieved:

- "A robust research expertise is sustained in the U.S. working on long-term problems of importance to the Department of Navy (DON);
- An adequate pipeline of new researchers, engineers and faculty continues;
- ONR can continue to provide superior S&T [science and technology] in naval architecture and marine engineering."

The memorandum describing this action (ONR 2001) also calls for ONR to take the following actions:

- "Develop University/Industry/Laboratory Consortia for S&T in naval engineering; and
- Encourage Industry/University partnership for career development of future naval engineers."

The Navy's primary goals for this initiative are to maintain and develop human capital in naval engineering and to stimulate innovation in new ship designs in order to meet future national defense needs.

Among the actions called for to achieve this responsibility is the development of new cooperative research venues. ONR asked the Transportation Research Board of the National Academies to investigate and evaluate alternative approaches for organizing and managing cooperative research programs in naval engineering. ONR believes that such programs would attract talented researchers and enable stakeholders to collaborate and guide research and development of naval and maritime technology. This study is intended to provide ONR with a basis for evaluating available options and selecting the most effective approaches to meet its goal. The approaches set forth are not intended to address some of the broader issues concerning a general decline in the U.S. maritime industry; rather, they are more specifically intended to help meet the Navy's needs for developing a more capable and effective future fleet.

## STUDY SCOPE AND APPROACH

The committee began its review and evaluation of cooperative research programs with the assumption that a key national responsibility of ONR is to maintain a robust capability in naval engineering. This capability includes a research community that will advance the state of the art, generate an adequate pipeline of new scientists and engineers, and provide the necessary science and technology to enhance the fleet. It also encompasses a research program that incorporates input from all stakeholders in order to establish firm links to the total ship production system.

In the context of this study, naval engineering includes all arts and sciences applied in the research, development, design, construction, operation, maintenance, and logistic support of ships, submarines, support vessels and craft, combat systems, ocean structures, and related shore facilities. In its work, the committee stressed the importance of total systems aspects of the naval engineering discipline.

ONR asked the study committee to identify options for structuring programs in naval engineering research to provide a venue for stakeholders to collaborate, cooperate, and guide research and development of naval and maritime technology. The committee was asked to consider how such programs could assist the Navy in maintaining and developing the human capital in naval engineering that is required to meet current and future national security needs. The committee was also asked to comment on specific proposals to revitalize the field of naval engineering and improve ship design and production.

The two goals of developing human capital and revitalizing naval engineering were used by the committee to provide a foundation for evaluating how well each option for structuring a cooperative research program will serve the Navy's needs.

In its review and evaluation of cooperative research options, the committee did not reevaluate the underlying problem that was presented to it by ONR and that is supported by several previous investigations. As a starting point, the committee accepted the ONR definition of the problem because ONR had accomplished sufficient previous analyses (Bernitsas 2001; MIT 2000; NRC 1996; NRC 2000; ONR 2001; U.S. Department of Commerce 2001) and the committee did not have time within the project schedule for additional work on that aspect. These reports support ONR's view that cooperative research offers a number of benefits that are not available through other approaches.

To accommodate the sponsor's request for an accelerated schedule, the committee also restricted this study to a description of the options and the identification of advantages and disadvantages of each option. The report thus contains findings resulting from its analyses and deliberations but does not contain conclusions or recommendations. Such an outcome provided ONR with the information it needs in a timely manner while allowing the committee to accomplish its work in a shorter time.

The committee focused its efforts on identifying the possible institutional models that would provide the intended results and could be adopted to support ONR's mission. It then identified the features of each model and analyzed whether and how these features provide the mechanisms to best address ONR's objectives.

As a starting point for identifying models and their features, the committee asked each of the various stakeholders to present what they considered to be the most appropriate cooperative research organizational approach. Several of these stakeholders presented proposals to the committee and described their views on key attributes that would address ONR's objectives. The committee took these presentations into account in its process of identifying appropriate models but did not specifically evaluate the individual proposals.

Because of the short time frame for the study, the committee relied heavily on past work and expertise of the industry, government, and academic communities represented by stakeholders who addressed the committee in presentations and who provided additional information and documentation. (See Appendix A.) The committee also relied heavily on the expertise of its membership to render judgments based on a broad range of experience and education.

## REFERENCES

### Abbreviations

| | |
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| ASNE | American Society of Naval Engineers |
| MIT | Massachusetts Institute of Technology |
| NRC | National Research Council |
| ONR | Office of Naval Research |
| TRB | Transportation Research Board |

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# 2

# Attributes for Naval Engineering Cooperative Research Organizations

A number of models have been used by federal agencies, professional societies, and private organizations to organize and execute research programs and projects to meet their goals and objectives. Each of these organizational models has characteristics that make it more or less effective in its ability to achieve the goals and objectives of the research program.

The Office of Naval Research (ONR) supports most of its R&D today using the traditional individual investigator model. ONR has two overall goals in adopting a new model for a naval engineering cooperative research organization and the programs and projects it is designed to accomplish. The two goals are to

1. Maintain and develop human capital, and
2. Revitalize naval engineering and improve ship design and production.

To compare approaches for organizing naval engineering research, the committee further defined these broad goals in terms of specific objectives and sets of attributes against which possible organizational models can be evaluated.

## GOAL 1: MAINTAIN AND DEVELOP HUMAN CAPITAL

Ensuring an adequate supply of human capital for advanced naval ship systems design and production into the future is a multifaceted problem. First, there must be a steady flow of students into the naval architecture and engineering education pipeline; second, there must be a highly qualified and capable faculty to educate them; and third, there must be opportunities for continuing education for practitioners in the field. Finally, in terms of the scope of education and training for new graduates and practicing professionals, there is the need to approach ship design, development, and production/construction from the “total ship” point of view in order to meet the challenges of the future Navy. Hence, the concept of “total ship engineer” must be infused into education and professional development throughout the career path, from students to new graduates to existing professionals.

Thus, the goal of maintaining and developing human capital embodies achieving four general objectives:

1-1. Attract students to the naval architecture and engineering profession.
1-2. Retain existing and attract new faculty to naval architecture and engineering degree programs.
1-3. Provide continuing education and training to existing professionals.
1-4. Foster the development of "total ship engineers."

The effectiveness of various organizational approaches in meeting these objectives depends on how well that approach performs in terms of a number of the key attributes that are embodied in the achievement of each objective. The committee's definitions of the attributes for each objective are given in the following subsections.

**Objective 1-1: Attract Students**

The committee has identified the following attributes that will support this objective. The subsequent paragraphs comment on each attribute.

- Ensure understanding of naval engineering career paths and opportunities and support outreach programs at the primary and secondary education levels.
- Encourage and stimulate interaction between the shipbuilding industry and students.
- Provide undergraduate research opportunities.
- Present career and research opportunities to students.
- Develop scholarship, fellowship, and research assistantship support.
- Develop and support study- and work-abroad programs.

The challenge of attracting students into the naval engineering program pipeline is, at least in part, the same as that faced by engineering programs in general. Enrollment of all engineering students has been declining since the mid-1980s (MIT 2000). Perceptions of the attractiveness of engineering professions and the declining interest and ability of students in mathematics and science have been key contributors to the problem. Student recruitment is even more difficult for naval engineering because it is a relatively small and focused area among the other major engineering disciplines. Furthermore, naval engineering programs exist in only a handful of engineering schools and have comparatively small enrollment, making them a less visible part of the engineering professions. Potential students also tend to see the area of naval engineering as old-line, staid, and unexciting compared with other engineering areas that appear more high-tech and cutting edge. If student enrollment in the program drops below critical levels, institutional pressure mounts to eliminate programs and reallocate faculty resources.

Attracting new students into naval engineering and retaining them in the program will require concerted efforts all the way along the pipeline. Raising public awareness and understanding is a broad challenge faced by all the engineering disciplines. Naval engineering professionals need to communicate the complex and interesting technical challenges in ship design and production in order to recruit undergraduate majors. Another problem is that engineering majors appear to have a high dropout rate (MIT 2000). Retaining students requires strong advising and mentoring at the undergraduate level and encouraging qualified B.S. graduates to pursue graduate degree programs. Against this background, the following are seen as desired attributes for cooperative research organizations to help increase the numbers of students in naval engineering programs.

Research and education are closely related activities, and each one feeds the other. Educators and researchers have come to recognize that they must help plant the seeds that will blossom into professionals and researchers. These seeds need to be sown in young minds in ways that capture the imagination, much as the space programs have done.

The pipeline for the future flow of human capital needs to be built by current professionals and academicians in interactions with potential new talent, and the process should be supported by educational programs at the primary and secondary levels. Many science and engineering research organizations have recognized this need and have incorporated an outreach dimension into their work programs. College student motivation and retention in the educational pipeline increase significantly when students have direct experiences with professionals who have expertise in their chosen field. The theory learned in the classroom and the experiment performed in the laboratory become more meaningful in the context of real applications. Student co-op and internship programs that engage industry with students can be an effective mechanism for providing these kinds of experiences.

Student retention at the undergraduate level and recruitment into graduate programs are both greatly enhanced when undergraduates become involved in research experiences. Certain research organizations can be in a unique position to structure research opportunities for students to work on open-ended problems under the close supervision of faculty. Such research experiences foster interest in and excitement about the engineering design process and build confidence, resulting in higher rates of degree completion.

Another attribute that is likely to increase students' commitment to completing degrees is the visibility of career opportunities. Appropriate research activities and projects can be a window for students into the range of careers and professional opportunities in naval engineering.

The costs of college education continue to rise faster than the rate of inflation. Correspondingly, the lack of financial resources is one of the leading reasons why students who are otherwise succeeding in academic programs drop out of higher education. Institutions are working to provide more financial aid to students, and students will be attracted to programs where money is available. Some research organizations can use student labor and can position themselves to support students on projects through scholarships, fellowships, or direct employment.

Industry today must compete in a global economy that is strongly driven by technological change and productivity. Ship production is no exception. Responding to these realities, students are seeking opportunities to study abroad as part of their college education. Through involvement in international professional meetings and research conferences, a research organization can be in an excellent position to foster contacts and relationships with foreign institutions with naval engineering programs to develop study- and work-abroad experiences for students.

### Objective 1-2: Retain Existing and Attract New Faculty

The following attributes support this objective:

- Guarantee commitment of sponsors to research, including robustness and continuity of research funding.
- Offer broad research opportunities, ranging from basic to applied.
- Support and develop new technology and facilities and support existing infrastructure (e.g., equipment, technology, and staff).
- Provide a clear faculty incentive and reward structure (e.g., endowed chairs, professional development opportunities, and other recognition).
- Create a steady supply of highly qualified students.
- Encourage faculty teaming opportunities (multidisciplinary and interdisciplinary research projects).
- Develop consulting opportunities and career development via industry and government teaming.

The second critical link in the human resources chain is the faculty of naval engineering programs. They are responsible for undergraduate and graduate education, as well as for mentoring those students in graduate programs who may become their future colleagues and leading researchers and engineers in industry. Recruiting and retaining qualified faculty are essential to keeping high-quality naval engineering programs viable. The recruitment of capable engineering faculty is in itself an expensive process, involving not only salary offers that are competitive with other institutions and industry, but also start-up funding packages to provide new faculty with laboratories and equipment. New and junior faculty are faced with the challenges of establishing themselves as both teachers and researchers and achieving professional and peer recognition for their work, which will move them successfully through the tenure and promotion processes. Most faculty are continually struggling to secure the necessary resources, laboratory facilities, and equipment to maintain their research productivity, improve course offerings and develop new courses, and support graduate students. The main elements of an environment that encourages faculty performance and success are continuity of opportunity and incentives and rewards for achievements.

The ability of faculty to build successful research programs that attract and support a steady cadre of graduate students requires dependable and stable funding. Continuity in research project support over 3- to 4-year cycles allows faculty to develop new research ideas, involve and mentor graduate students to completion of degrees, and transfer results to users. Although funding must always be contingent on performance and results to maintain scientific excellence, the way in which research programs are structured and funded over time can either reinforce or negate the benefits of continuity.

Attracting and retaining faculty involvement in a research enterprise are enhanced by a broad array of available research areas and opportunities. Ship design and production cover multiple technologies and disciplines that need to be integrated into ship systems. The most effective research organization will accommodate broad-based research opportunities and at the same time provide adequate focus on specific projects to meet strategic needs.

Research infrastructure includes both physical facilities (laboratories and equipment) and administrative and technical support. If infrastructure is inadequate or lacking in a research program, faculty productivity is severely hampered, and recruiting and retaining faculty become difficult.

Research and scholarly activity is a generally accepted part of a faculty member's role, and the way research is organized can improve the ability of faculty to be productive researchers. However, the basis for evaluating and rewarding scholarly productivity may be viewed differently from institution to institution. Some organizations place high value on the individual author, while others encourage teaming and multiple authors. A research organization will enhance faculty retention if it is aligned with the institutional rewards systems and provides faculty with incentives for participation in research that contributes to achieving tenure, promotions, and salary increases.

Research scientists and engineers are more typically employed in academia and government laboratories than in industry because of the flexibility to pursue their research interests. In addition, they may be stimulated and motivated by the opportunity to teach and mentor highly qualified students. Faculty recruitment and retention are enhanced by any research organization that can contribute to a reliable supply of high-quality students. A research organization that incorporates many of the attributes discussed above would likely be successful in increasing the supply of quality students.

Most engineering work is a team endeavor, and designing and building ships are prime examples. A research environment that mirrors this reality has benefits for both faculty and students. If a research organization can include teams that provide mutual support of faculty by mentors and peers, it increases the chances for success of the individual faculty member and hence improves professional progress and retention. The opportunity for faculty to consult in the industrial world, which is the customer for naval engineering program graduates and research, helps ensure that these products meet customer needs and expectations. Consulting is also an opportunity for faculty to build industry relationships that often lead to program support and income enhancement, which encourage faculty to remain in academia. If a research organization facilitates appropriate faculty consulting opportunities, faculty retention will be enhanced.

### Objective 1-3: Provide Continuing Education and Training

The following attributes support this objective:

- Involve professional community in merit review of R&D projects.
- Facilitate professional involvement in course development.
- Create opportunities for distance learning and on-site instruction.
- Build collaboration among stakeholders in teaching and research.
- Foster networks and communities of practice.
- Encourage exchange of personnel among academia, industry, and government.

Education for the practicing professional does not end with the awarding of a degree or the achievement of professional licensure. The technology of ship design and production is continually driven forward by research and innovation. Obsolescence is a common problem among all engineering professions and can only be solved by providing and encouraging continuing education opportunities for professionals at all levels, in both industry and academia. Those in academia need to be exposed to the real-world issues encountered by industry in the design and production process. At the same time, industry engineers need to stay abreast of innovative ideas, tools, and methods coming from academic research. The key to bridging the knowledge and experience gaps between industry and academia is to build collaborative networks for continuing education.

The process of reviewing research project proposals offers an excellent continuing education opportunity for both faculty and industry participants by exposing reviewers to new research and technology development ideas and requiring them to critically evaluate their merits. In this way, practicing professionals who spend most of their work time solving near-term engineering problems can be exposed to basic research issues and the difficulty of creating new concepts. Development of the R&D agenda within a research organization, through a strong peer review process, is an excellent way of involving industry and academic professionals in an intellectual environment that promotes education and professional development.

One of the benefits of research is supplying new information back into education, especially at the graduate level. This feedback is greatly facilitated by a research program that is closely coupled with related engineering degree programs. The involvement of faculty researchers and industry professionals in course development both directly and indirectly benefits the continuing education of the stakeholders.

Distance delivery of education and training through various media has greatly enhanced the opportunities for professionals to upgrade their knowledge and engineering skills. A research organization that is creating new knowledge and methods can be a source and a catalyst for distance learning opportunities.

A great deal of learning about new methods and approaches takes place when there are opportunities for interaction among professionals. A research organization that facilitates collaboration among industry, academia, and professional organizations in teaching and research programs will at the same time provide a rich environment for continuing education.

Another mechanism that can contribute to a strong continuing education environment is development of networks and communities of practice (i.e., groups of professionals who are involved in similar areas of ship system design). Often research organizations will have particular strengths and areas of expertise if they align with communities of practice and act as the catalyst in creating networks and central sources for information exchange.

Personnel exchanges—visiting professors, industry engineers in residence on campus, faculty in residence with industry, guest lecturers—have long been an effective means of sharing knowledge among academic institutions and between academia and industry. Research organizations again can position themselves to create and coordinate exchange opportunities.

### Objective 1-4: Foster "Total Ship Engineers"

The following attributes support this objective:

- Encourage "total ship design" in the curriculum.
- Strive for synthesis of multidisciplinary knowledge.
- Provide interdisciplinary design team experience.
- Provide broad access to advanced design tools and training.
- Integrate research projects into total ship system concepts.
- Sponsor design competitions.
- Foster university/industry/Navy communication on advanced designs.
- Design for ease of manufacture and operation.

Total ship design involves the integration of multiple systems requiring multiple disciplines. The common theme throughout the manpower chain is the need to educate naval engineering professionals who understand and function as "total ship engineers." The total ship engineer must recognize and understand the levels of complexity and the need to integrate many technologies and subsystems into ship systems in order to design one of the largest and most complex total systems built by humans. The following are the key attributes of a research organization that will contribute to the development of total ship engineers.

An effective naval engineering research organization must be adept at forming and managing multidisciplinary research teams that can integrate focused research into advanced total ship concepts. By its nature, most research is focused on fairly narrow areas of inquiry with the goal of increasing depth of knowledge rather than breadth. But to be adopted and implemented, in-depth research needs to be put into the context of total ship design. A research organization can facilitate this connection by relating research programs and projects to design of the total ship and supporting total ship design in the academic curriculum so that students gain experience in all aspects of total ship engineering, in addition to an understanding of fundamental engineering concepts and methods of analysis.

Total ship design is in reality a synthesis of broad knowledge by multidisciplinary design teams. In naval engineering research, an effective research organization must be adept at forming and managing multidisciplinary research teams that can integrate focused disciplinary research into advanced total ship concepts.

An interdisciplinary design team experience, usually as part of a senior or capstone design project, has become an integral part of engineering program curricula. Nevertheless, formulating challenging design problems that student teams can complete in a senior year is not a trivial exercise. The research activities and resources of a naval engineering research organization could contribute significantly to the development of interdisciplinary student design problems and to mentoring teams.

The practice of total ship engineering involves the use of advanced design tools and software. A naval engineering research organization should be involved in the development of such tools, as well as a user of tools in carrying out research. For example, to develop total ship engineers, it is important to have these tools accessible at all levels, from undergraduate education to professional practitioners. When such tools are proprietary products, it may be possible for academic and research organizations to develop no-cost or low-cost licensing agreements to make them available.

The principal payoff of naval engineering research is its application in operational ship systems. Transfer of research results and new technology to ship acquisition programs is the hardest bridge to cross in the R&D process. A research organization has a clear responsibility to the sponsor to develop mechanisms for technology transfer, or in other words, integration of its research into ship systems.

One of the proven ways to achieve an interdisciplinary design team experience for undergraduate students is participation in design competitions. Many engineering professional societies organize and sponsor annual design competitions, with regional winners moving on to national finals. The design problems are challenging and provide an arena in which students can further develop their technical and creative skills in that field of engineering. Design competitions either sponsored by or facilitated by a naval engineering research organization can be structured in a way to contribute to educating total ship engineers while also accommodating various academic schedules and priorities.

The total ship engineer cannot accomplish successful work without communication and coordination among the members of the design team, nor can total ship design become fully embedded in the culture of naval architecture and engineering without communication among the professionals of stakeholder groups—academia, shipbuilders, and the Navy. The naval engineering research organization is in a position to create opportunities for communication among professionals through research seminars, conferences, project advisory panels, and reviews.

Naval engineering is no longer viewed as a sequential process in which systems design engineers pass their work along to systems integrators, who then turn the project over to manufacturing and production engineers, who then deliver the final product (the ship) to the customer's engineers for operation and maintenance. A total ship engineering philosophy considers all of these aspects in the design concurrently and involves all the appropriate engineering disciplines in the process. Likewise, the projects and programs of a naval engineering research organization should incorporate the same consideration of the production and operational aspects of implementing research results and new technologies in advanced total ship systems.

## GOAL 2: REVITALIZE NAVAL ENGINEERING AND IMPROVE DESIGN AND PRODUCTION

The United States has a critical need to support more creative new naval engineering research, to develop higher-performing and more cost-effective new ship designs, and to accomplish more innovative total ship system engineering. The product of naval engineering research must be readily transferred to the next stage in technology development. The committee organized these needs into three challenges. First, a process should be established to create new research projects that directly support the design of advanced ships for the Navy. Second, these research projects should be focused on innovative technologies combined into innovative ship concepts. Finally, from the beginning, research should be done with the end product in mind. Thus, the goal of revitalizing naval engineering and improving design and production requires achieving three general objectives:

2-1. Create new research opportunities.
2-2. Promote innovation.
2-3. Ensure research useful to ship design.

### Objective 2-1: Create New Research Opportunities

The following attributes support this objective, and the subsequent paragraphs comment on them.

- Establish a process for setting priorities, establishing a vision, and strategic planning.
- Provide shared decision making by stakeholders.
- Provide mechanisms for bringing in new talent and innovative ideas.
- Provide structure and incentives for collaboration among the stakeholders.

The committee selected attributes for this objective on the basis of the need to establish a strategic research planning process that would involve shared decision making by all the major stakeholders. The plan should include mechanisms for bringing new technology ideas and professional talent into the research work. The organizational structure and well-developed incentives should support collaboration among the stakeholders.

The key to the initial success of a cooperative research program is to establish a consensus strategic plan among the participants. The strategic plan should be developed with the help of strategic planning experts and through the use of a carefully deliberative process involving all the major stakeholders. Major stakeholders include the Navy and key representative industry and university players. A proven consensus-building procedure that ONR could adopt would be to conduct a facilitated strategic planning workshop with experienced and responsible participants from all major stakeholders and key players in the R&D and educational processes. The resulting consensus plan would include a vision, a mission statement, objectives, goals, and strategies for implementation. It could carefully define the R&D areas of strategic interest and assign priorities to these research areas. During the solicitation for, selection of, and review and evaluation of a research project, the government and shipbuilding industry, as well as the universities, all need to be participants in the decision-making process.

It is not sufficient to establish a research program, staff it with qualified personnel, and direct it to innovate. Creative new ideas and technologies are most often developed by individuals and small groups of individuals on the basis of their talent, experience, and motivation. Often the best technologies are developed by relatively independently operated organizations outside of the university community. To be successful, an organizational model should have mechanisms to bring in new talented people, concepts, and technologies.

To be most effective, an organizational model should encourage meaningful and ongoing collaboration among stakeholders, including government, industry, and academia.

### Objective 2-2: Promote Innovation

The following attributes support this objective:

- Flexibility of funding (fast response and limited bureaucratic requirements),
- Tolerance for risk,
- Incentives and rewards for new ideas and approaches,
- Opportunities to learn from other fields,
- Promotion of change, and
- Stimulation of design leadership.

One of the desired results of any research activity is innovation in the design, performance, or production of products. Yet innovation is a significant challenge because of its very nature and because of the inherent characteristic of organizations to resist change. James Utterback points out that change does not come easily to human societies and concludes that to succeed, the organization must focus not on its products but on its people (Utterback 1994, 89). The committee identified several factors that might enable organizations to induce innovation, including flexible research funding, tolerance for risk, adequate employee incentives, support of interdisciplinary work, and flexible organizational structures.

Flexibility of funding can avoid the limitations of narrow guidelines and strict standards in pursuit of new ideas and approaches. Funding flexibility can provide quick support for good new ideas and ideas of unknown impact. Funding mechanisms also must have the ability to terminate failed projects promptly.

Research programs aimed at innovative approaches seldom have guaranteed results. Consequently, R&D programs need to have room for failure as well as success. Projects that do not deliver the intended results might have value in the sense that they provide learning and can help in planning subsequent research. Overly intense screening of proposed research will limit results to predictable outcomes with limited benefits.

An organization demonstrates its ability to tolerate risk by rewarding new ideas and approaches. Such procedures must be tied to risk taking and not exclusively to success, and they should include recognition and reward systems. Such systems should identify effort and quality of work, not just the result.

It is important that organizations understand that innovation can take place by incremental changes. Small elements of research may reap small but important improvements (Kanter et al. 1997, 89). Reward system measures, therefore, should recognize that incremental changes are themselves valid innovations even though the result might appear small. Some studies indicate that organizations that focus on incremental innovation may bypass the older established firm because of this flexible approach (Leifer et al. 2000). Also, major changes can create organizational resistance, which might not be the case for smaller changes. Therefore, a practical approach to encouraging innovation is to recognize each event, even though it may be small, and encourage it to grow.

Research programs are typically targeted to achieve results within particular disciplines. Perhaps more difficult is the ability of an avenue of research to open itself to input and ideas from other technologies. To exclude such input is to put limits on innovation. Programs that reach out to other technologies and that might create new areas of investigation should be part of the research structure. This "out of the box" approach will be one of the keys to innovation. Synergistic effects might be obtained from the U.S. Navy and successful commercial exchange of design strategies and fabrication technologies. Professional societies might be a vehicle for implementing this concept.

To promote adoption of change within an organization, an adaptable culture must be encouraged. Kanter et al. (1997, 89) point out that "innovation happens on the fringes in out of the way places away from the dampening influences of bureaucracy and politics. There are many reasons why companies lack innovation; failure of human imagination is not one of them. The failure is in the culture and structure."

Innovation finds a home in organizations that encourage openness and cross-communication. An example of this is described in "Gunfire at Sea, a Case Study in Innovation," a short article on the development of naval gunnery (Morrison 1966). The example describes a proposal for improvement of naval gunnery by a junior officer in a remote assignment. Repeated efforts to obtain recognition and broad application were refused. In fact, the reference describes the process of refusal as (*a*) ignoring the proposal, (*b*) studied rational (sounding) rebuttal, and (*c*) argument and name-calling. Ultimately, the frustrated innovator submitted his ideas to President Roosevelt, who saw to their application. The development resulted in great benefit to the Navy.

Many organizations have evolved with research groups separate from the business side, reporting separately to management. This provides some insulation from commercial pressures and may allow an atmosphere more tolerant of risk. There is a popular assumption that such is the case (Leifer et al. 2000). It is vital, however, that open lines of communication exist between the operational and research areas. To support innovative research, typical measures applied to operational or business organizations may need to be modified to better fit the more flexible goals of research organizations. Funding flexibility, tolerance for risk, and acceptance of failure are all prerequisites of an innovative research organization that should be recognized and promoted.

Excellent research is unlikely to produce design leadership if there is no outlet for implementing innovations resulting from the research. An avenue is needed in the organization that translates research into operating equipment, on the basis of a strong linkage between research and design activity. Those organizational relationships should be carefully examined to ensure that the proper connections exist. A substantial program of personnel movement between ONR and the Naval Sea Systems Command would help improve understanding and communication between those entities. Routine meetings to encourage exchange of ideas and to build relationships should help achieve this goal.

As is the case for most organizational issues, great leadership can obviate inherent difficulties. It is the Navy's and the naval engineering community's challenge to stimulate design leaders and allow them the opportunity to overcome the innate challenges of the bureaucracy.

### Objective 2-3: Ensure Research Useful to Ship Design

The following attributes support this objective:

- Promote shared decision making and resource allocation by stakeholders.
- Provide merit review by experts and stakeholders.
- Provide mechanisms for technology transfer and deployment.
- Promote prototype testing to produce empirical data.
- Link research to design and production.

R&D resource allocation should be a shared responsibility of all the stakeholders. Joint participation in the research selection process and the review of research results is critical to ensure that results are of value to the next stage in the development process. The R&D results should be linked to design and eventually production, although not to the extent that creative and innovative ideas are discouraged in the early development process. Universities will typically accomplish the majority of the research work, but the government and the shipbuilding industry should be involved in the decisions on funding and strategic planning. While the government and industry should be involved in this decision process, a tolerance for higher-risk, higher-payoff research should be maintained.

It is important for any organization to provide merit reviews by experts and stakeholders to ensure that the research fulfills the goal of producing better ship designs. Review and evaluation by stakeholders and technical and business experts are most effective if they begin at the solicitation, proposal evaluation, and project implementation stages. They should continue throughout the R&D process.

It is essential that the approach to R&D include meaningful techniques for transferring the data and knowledge of basic and applied research done by academia, supporting contractors, and independent technology companies to the users of the resulting technology in ship design and production. For this to take place, the research results must be relevant and useful to the ship owner and operators and to the shipbuilding industry.

In the early 1950s, the Navy operated an experimental destroyer to develop, test, and operationally evaluate advanced ship design features such as high-pressure steam propulsion plants (Knox 1954; Knox 1956). Since that time, the U.S. technology community has developed powerful new analytical tools but has done few or no full- or large-scale tests to validate the analytical calculations. Most researchers support more prototype testing to demonstrate concepts and validate analytical models. Subsystem prototypes can be tested on existing operational ships, or a dedicated test ship could be built for this purpose. Advanced ship concept prototypes should also be built and tested. A research program including prototype testing has the benefit of promoting an active technology transfer mechanism.

To meet the Navy's needs, the definition and selection of R&D projects should be based on their usefulness and application to designing and constructing innovative ships. To achieve this goal, the research projects should be managed to make the resulting technology, knowledge, and data directly support advanced ship design through the research, development, engineering, and design chain. In ONR's vision of National Challenge Initiative, innovative ships are strongly endorsed. Examples are high-speed ships, littoral warfare ships, and advanced electric drive, including superconducting motors and generators. These initiatives produce the added benefit of ensuring a direct connection from research results to ship designs.

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| | |
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| MIT | Massachusetts Institute of Technology |

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# 3
# Organizational Models for Naval Engineering Cooperative Research

In an effort to understand the various options available to the Office of Naval Research (ONR) to strengthen its naval engineering cooperative research programs, the committee solicited proposed strategies from the stakeholders in the naval engineering field, including representatives from academia, industry, professional societies, and the Navy. In response to this request, the following groups provided abstracts of proposed approaches and made oral presentations to the committee. Each proposal is identified below, and the stakeholder group that was the principal proponent of the proposal is noted in parentheses.

- The individual investigator model (university investigator);
- Council for Cooperative Research in Naval Engineering [Society of Naval Architects and Marine Engineers (SNAME), American Society of Naval Engineers (ASNE)];
- Marine Research Consortium for Advanced Ship Design (university group);
- Ship Design USA—A Collaborative Enterprise for Innovation in Ship Development (Naval Sea Systems Command);
- Naval Engineering Research and Education Cooperative (National Shipbuilding Research Program); and
- Distributed Marine Research Consortium for Naval Engineering (university group).

In addition, the committee solicited and received presentations and information on other cooperative research models that have been successful in meeting national needs, similar to those of interest to ONR in the field of naval engineering. These included summaries of the National Science Foundation's Engineering Research Centers Program (www.eng.nsf.gov/eec/ecm.htm), the newly formed National Ocean Partnership Program (www.nopp.org), and strategies used in the oil and gas industry for cooperative research.

Finally, the committee performed a review of selected other options. These included European strategies for thematic and program research and development in marine technology and education (Ferreiro 2001; Birmingham

2001; Goldan 2001), the National Shipbuilding Research Program (NSRP 2001), and selected literature on the development and characteristics of applied research programs (TRB 2000; Deen and Harder 1999; NRC 2000).

In the interest of making the task more manageable and focusing on the core strategies to conduct cooperative research programs, the committee elected to describe and evaluate a small number of underlying organizational models, rather than each of the specific proposals noted above. Each of these organizational models was evaluated on the basis of its ability to meet the goals and objectives that were identified and discussed in Chapter 2. The two overall goals for these models are to maintain and develop human capital and to revitalize naval engineering and improve ship design and production. Given this goal orientation and using the strategy of identifying core organizational models, the committee selected the following four models for discussion and evaluation:

1. Individual principal investigator,
2. Professional society/community of practitioners [this model incorporates the features of the proposal presented by the professional societies (SNAME and ASNE)],
3. Consortium or center (this model incorporates the features of the proposals offered by the Naval Sea Systems Command, the National Shipbuilding Research Program, and the university group), and
4. Project-centered (this model incorporates the features of the proposal offered by the second university group).

The first model on this list (principal investigator) is the one currently used by ONR for most of its research projects and is considered the base or reference model for the purposes of the committee's discussion and evaluation. The other three models represent various approaches for cooperative research organizations. The individual principal investigator model and the three cooperative research organization models are presented and evaluated in this report.

In this chapter, the principal features of each of the above organizational models are presented and discussed. Each model is described in terms of its basic organization and an organizational flowchart that shows the process by which research topic areas or themes and individual proposals are solicited, reviewed, and funded, and performance is assessed; the approach used to foster education of future professionals; and the principal mechanism for transfer of technology to the shipbuilding industry. An assessment of the ability of each organizational model to meet ONR goals and objectives is presented in Chapter 4.

As noted in the description of each model, many variations in the structural details and the way in which the organizational model is implemented strongly influence the success of the approach. As an example, central to many organizational models is an executive/steering committee or council. Alternative strategies in establishing the composition, leadership, and authority of this committee can strongly affect what constituencies are best served and what direction the research program will follow. In this presentation no attempt has been made to give a full overview of the organizational details that might be implemented in such cases, but only to present what might typically be employed if this model were selected.

In presenting the various cooperative research models, the committee has made two fundamental assumptions that it applied to all cooperative models in order to make them consistent and responsive to the needs of ONR's overall mission:

Assumption 1. The cooperative research organization will perform the contracting functions for the individual projects that are funded by ONR.

Assumption 2. The cooperative research organization has the responsibility for proposing the annual research themes and submitting them to ONR, which will review and approve these themes before projects are selected and funded. The research organization will then review proposals for individual projects, award contracts, and evaluate performance.

## INDIVIDUAL PRINCIPAL INVESTIGATOR MODEL

### Organization and Management

In this model, an individual investigator or small team of investigators, typically working for a university or research organization, submits a proposal to ONR for funding. ONR reviews the proposal and funds the project on the basis of ONR's assessment of the quality of the proposal and the relevance of the work to its needs. Figure 3-1 shows the basic organizational structure of this model, and Figure 3-2 shows a flowchart of the steps that would typically be taken from project initiation through completion. The relationship between

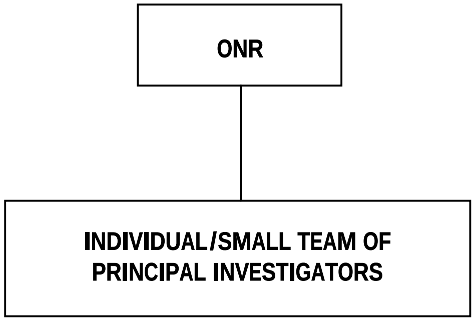


**FIGURE 3-1 Individual principal investigator organizational model.**

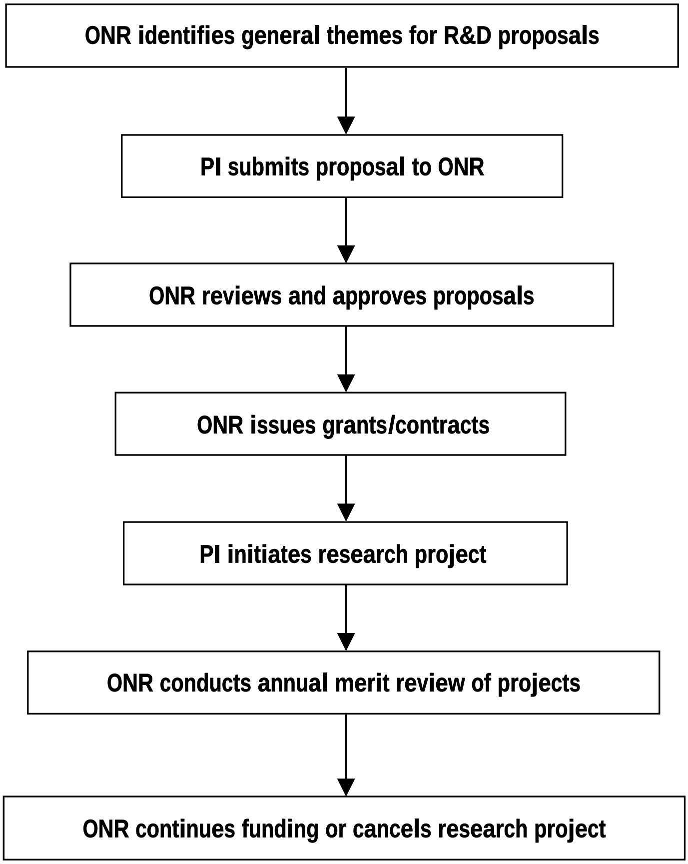


**FIGURE 3-2 Individual principal investigator (PI) flowchart.**

ONR and the investigator's organization is in the form of a contract/grant that has a discrete start and end.

In this model, the typical individual investigator is a university professor assisted by one or more graduate student research assistants. However, the category could also refer to an individual in a government laboratory or a private R&D company. The distinguishing feature is that the research is initiated and led by an individual (in some cases there may be co-principal investigators) while the parent organization provides the necessary support in the form of secretarial, library, shop, computing, and physical laboratory facilities. In the university example, the educated graduates must be considered the most important output of the research program. Perhaps the most common occurrence of this type of program is the case of an especially talented and outstanding individual who is the sole representative of the interest area (e.g., naval hydrodynamics or marine structural dynamics) in a large or small department or college. Such an individual, for many reasons, might wish to remain in his or her present situation and would be unwilling to move to another institution that may be chosen by ONR to establish a large cooperative research program.

### Research

In this model, the focus is typically on researcher-generated ideas for fundamental research. Topic areas proposed by the investigator are based either on the investigator's own assessment of ONR's needs or on an ONR solicitation of interests in given topic areas. Proposals are submitted by the investigator through the parent organization's research office and are reviewed by ONR technical personnel and potentially others (peer review), and a funding decision is made by ONR. A contract/grant is established between the investigator's organization and ONR to perform the research. Project performance is based on a review by ONR technical personnel or their designees. The work is typically summarized in terms of progress reports, presentations at professional meetings, and publication in the peer-reviewed literature. In this model, ONR manages the individual research projects that make up its research portfolio to meet its overall program objectives.

Typically, the research undertaken by an individual principal investigator will be of a fundamental nature, without necessarily having an immediate application to a real-world problem. This is partly because of the philosophies and constraints in a university environment that tend to encourage the creation of new knowledge over the application of existing knowledge to the solution of practical problems. In addition, fundamental research is often more suited in scope and methodology to an individual or small group effort and to the graduate thesis research concept.

### Education

The principal contribution to education, inherent in this model, is the support of graduate students (tuition, fees, wages) and the development of professionals with advanced education and research experience in the field. The project principal investigator also serves as a mentor to the graduate students. Additional benefits include support of the development of the university's physical (equipment, laboratories, shops) and human (faculty, staff, laboratory technicians, ship crews) infrastructure.

### Technology Transfer

Technology transfer to industry is generally a secondary consideration in this model in the short term, but may be significant in the long term. The degree of technology transfer is based primarily on the interests of the investigator and those of the ONR technical representative.

## PROFESSIONAL SOCIETY/COMMUNITY OF PRACTITIONERS MODEL

### Organization and Management

The organization and management of the research enterprise in this model is performed under the direction of the community of practitioners in the field. For many technical areas, the community of practitioners is organized into professional societies—in this case ASNE and SNAME. In this approach, the professional society establishes a research council, usually a not-for-profit organization, which serves as the vehicle to organize and manage the research program. Figure 3-3 shows the basic organizational structure of this model, and Figure 3-4 is a flowchart of the typical steps in the process from project initiation to completion. The research council is typically made up of representatives from the various stakeholders, including individuals from academia, industry, government (funding agency and others), and professional societies. The composition and leadership (chair and vice chair, or executive committee) of the research council can be structured to achieve the required

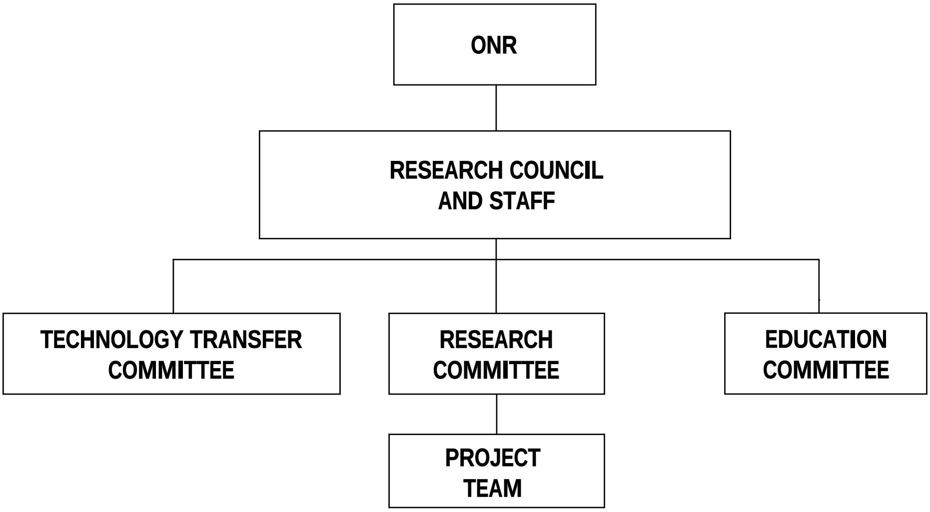


**FIGURE 3-3 Professional society/community of practice organizational model.**

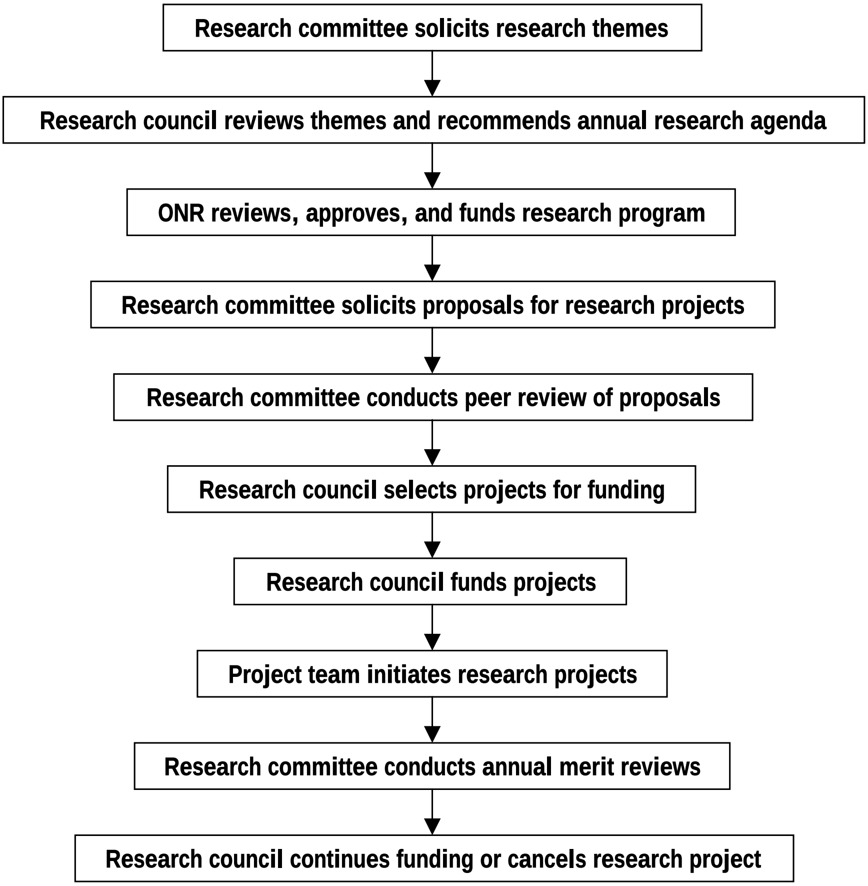


**FIGURE 3-4 Community of practice organizational flowchart.**

balance in the program's direction. In this model, committees, either newly formed or currently part of the professional society's structure, are used to perform various tasks in support of the research council. Committee membership is usually broad-based, drawn from society volunteer membership. The committee structure is typically organized to address the various key constituencies and objectives of the program and to divide the workload equitably. In this case committees on research (requirements and assessment), technology transfer, and education would likely be established. These individual committees would report to the research council.

## Research

In this approach, research themes are solicited, evaluated, and proposed by a research committee. This committee's proposed themes are then reviewed and evaluated by the research council. The council then selects the research agenda to be pursued and submits it to ONR for approval and funding. The research committee then solicits proposals from the research community in the theme areas via the professional society using standard government procedures for announcing solicitations and requesting proposals. The research committee directs the peer review of proposals submitted by individual investigators and project teams within the research themes and makes recommendations to the research council for funding.

This process will likely be some form of peer review. The research council then reviews the funding recommendations and makes final decisions. Contract management is typically performed by the council's staff. Evaluation of research progress is performed by the research committee, typically on an annual basis, with feedback provided to the research council. The research council may continue support for the work or terminate research that is not making acceptable progress.

### Education

At the individual investigator or project team level, the educational contributions are similar to those for the individual principal investigator model described above. In addition, most professional societies have education committees that foster collaboration between various educational institutions and industry to ensure that their undergraduate and graduate degree programs are producing the professional workforce necessary to meet industry's needs. This model would foster these kinds of educational programs either through an existing society education committee or one appointed to complement the features of a specific project. In addition, this model could be used to provide direct support for educational initiatives if so desired.

### Technology Transfer

As in the education arena, one of the committees in this organizational model would have prime responsibility to ensure that advancements made in the research program are rapidly and effectively transferred to industry and that industry needs are clearly articulated to the research community.

## CONSORTIUM OR CENTER MODEL

### Organization and Management

In the center or consortium model, industry, university, or the government can serve as a host to the center. Figure 3-5 shows the basic organizational structure for this model, and Figure 3-6 is a flowchart showing the steps in the process from project initiation to completion. The center is a permanent

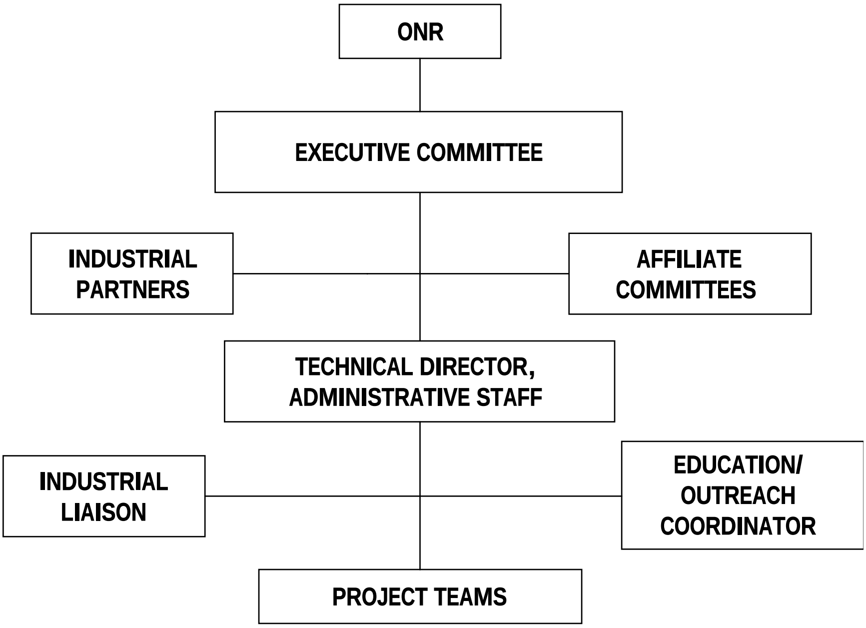


**FIGURE 3-5 Center or consortium organizational model.**

entity and provides ongoing management of the research, education, and outreach and technology transfer activities. Typically, a director would lead the center with support from a deputy or associate directors, or both. The director is also supported by a small administrative staff and, in some cases, a contract management staff. The director of the center normally reports to, and serves at the pleasure of, an executive committee. The executive committee, similar to the research council in the professional society model, is usually composed of representatives from the various stakeholders, including those from academia, industry, government (funding agencies and others), and professional societies. To solicit input and disseminate information to a wider portion of the community, the executive committee may establish affiliate committees, advisory boards, industrial liaison groups, and outreach specialists.

## Research

In this approach research themes are solicited, evaluated, and proposed by the executive committee and affiliate committees, to the extent that they are included in the center's organizational structure. After approval of the theme areas and funding of the consortium by ONR, proposals are solicited from the research community in the theme areas by the executive committee. Peer

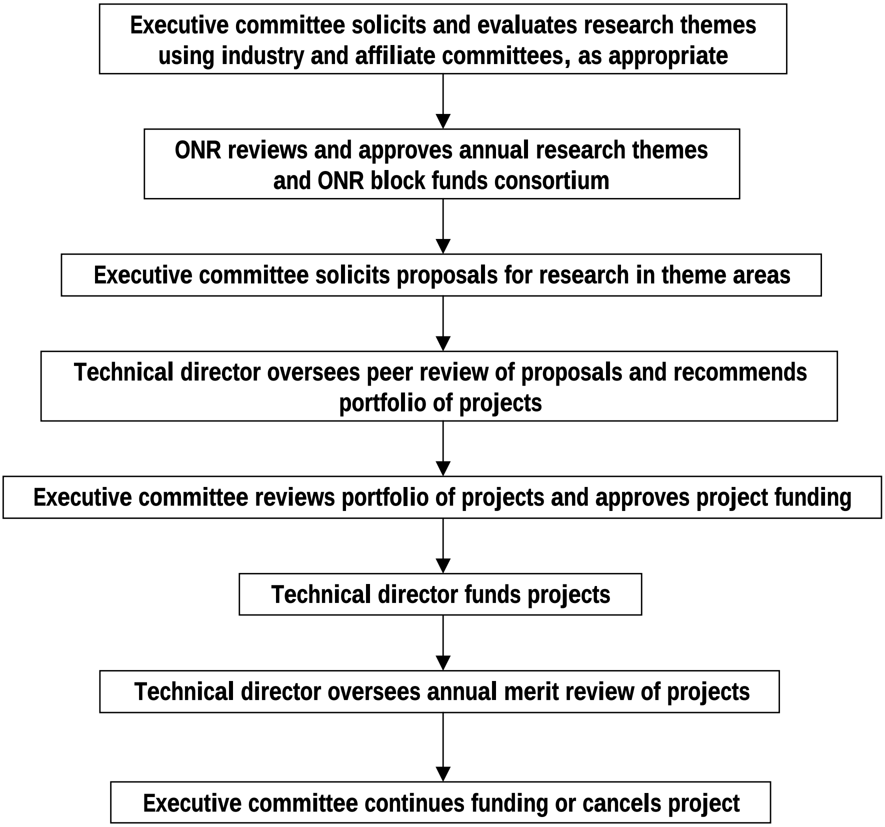


**FIGURE 3-6 Consortium organizational flowchart.**

review of proposals submitted by individual investigators and teams is performed under the supervision of the technical director with the assistance of the support staff. The technical director then prepares a portfolio of research projects to be funded, on the basis of the research themes and the availability of funds. The individual projects that make up the portfolio and the overall integration of the research projects into a research program are reviewed and approved by the executive committee. Core support for the center management, outreach and technology transfer initiatives, and selected educational initiatives (scholarships, internships, sabbatical leaves) are provided by the institution hosting the center. The technical director oversees the evaluation of research performance either via a peer-review process of products generated through the research program or some other appropriate process. Affiliate committees might be used to serve this function as well for projects where the affiliates have a strong interest. The executive committee determines continuation or cancellation of projects.

### Education

At the individual investigator or project team level, the educational contributions are similar to those for the individual principal investigator and professional society–based models described above. The center can directly support education initiatives by soliciting and funding them through the request for proposal process, establishing an educational committee, assigning an individual (e.g., assistant director) to support education coordination, and providing support directly to students and faculty (scholarships, fellowships, postdoctorate positions, visiting scholars programs, sabbatical leave positions).

### Technology Transfer

Technology transfer in the center model is normally handled by an industrial liaison manager, through an industrial affiliates committee, or through professional society committees that are focused in the area of interest. Combinations of these strategies may also be used. Centers often include an industrial affiliates program that allows industrial representatives to have input in setting the research themes, preferential access to the results of the research programs, and early identification of and access to graduates being produced by the program. The technology transfer is often strongly linked to the host's intellectual property development program.

## PROJECT-CENTERED MODEL

### Organization and Management

In the project-centered model, an executive council similar in composition to that in the center model establishes research themes and handles the processing and review of proposals. Figure 3-7 shows the basic organizational structure for this model, and Figure 3-8 is a flowchart showing the typical process from project initiation though completion. The executive council is permanent but typically has staged, rotating membership. The executive council chair provides the principal leadership for the council and may oversee a small administrative staff that supports the council's work. Additional input on research themes is handled through workshops and open forums, professional society committees, or industry associations. For each project theme a technical review committee is established to prepare the request for proposal, evaluate project proposals, and assess performance on the projects. The technical review committee remains in existence as long as projects are active and disbands when projects are completed or terminated.

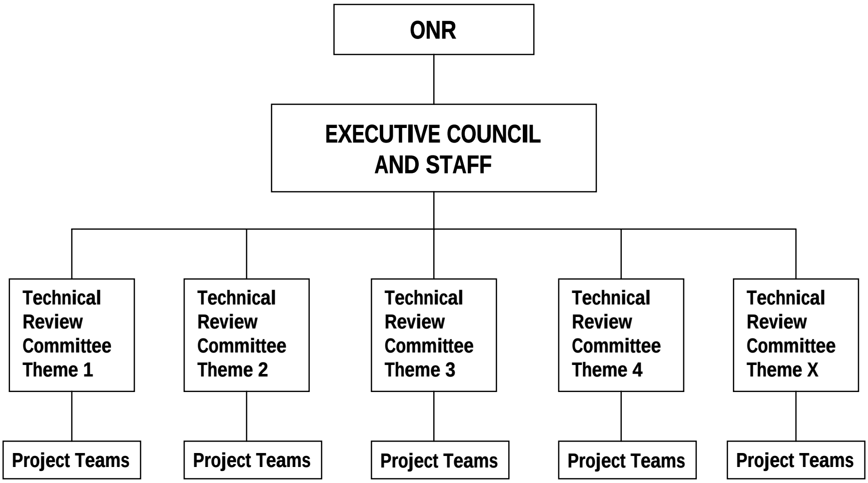


**FIGURE 3-7 Project-centered organizational model.**

## Research

In the project-centered model, the executive council solicits input from the stakeholders and develops a research agenda. The agenda includes one or several annual themes or National Challenge Initiatives and perhaps an open solicitation for ideas. The themes are reviewed and approved by ONR. The executive council next establishes a technical review committee for each theme or National Challenge Initiative. This committee drafts a call for proposals in the theme area. The request for proposals is subsequently reviewed, approved, and issued by the executive council. Proposals submitted under the call would typically be required to have multidisciplinary teams that represent the stakeholders. The technical review committee would review and rank the proposals and provide this information to the executive council. The executive council would then select proposals for the theme area and make decisions on funding. The executive council staff would handle the contracting. The technical review committees would perform an annual review of each project and summarize the progress made in relationship to the project milestones to the executive council. The technical review committee for each theme area would remain in existence throughout the duration of the projects funded under that theme.

## Education

At the project team level, the educational contributions are similar to those for the individual investigator model, described above. The project-centered

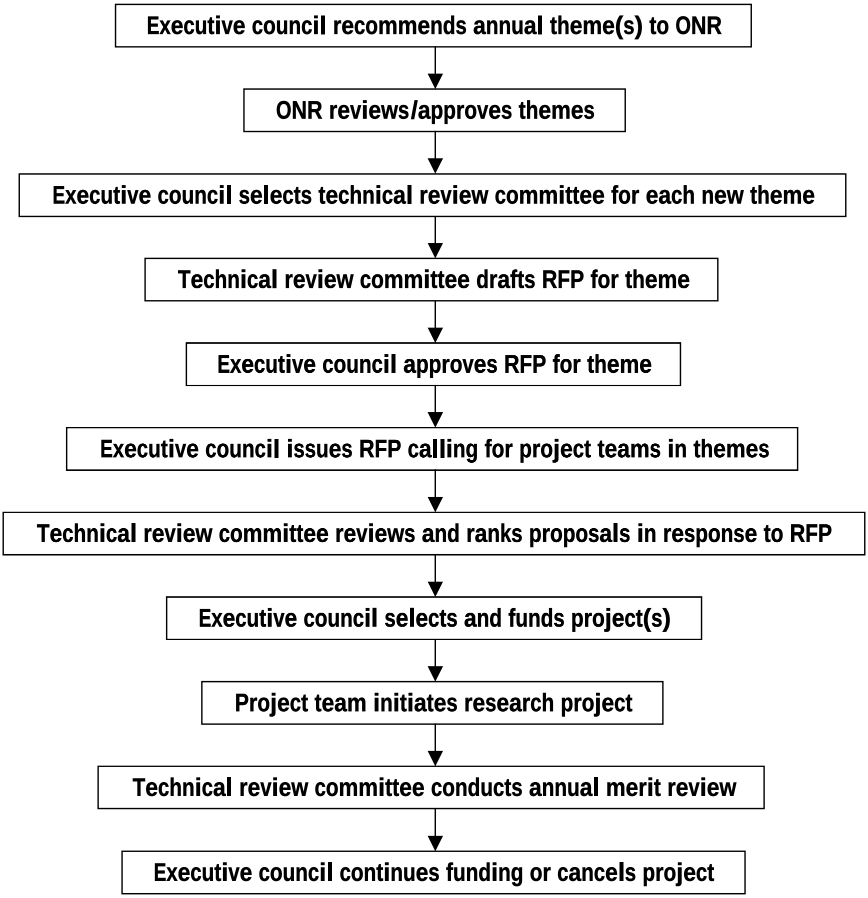


**FIGURE 3-8 Project-centered organizational flowchart (RFP = request for proposal).**

model can directly support education initiatives by specific requirements in the call for proposal, as in the center model. This might take the form of specifying that a certain amount of the project budget be devoted to graduate and undergraduate student funding, supporting scholarship and fellowship programs, or requiring projects to develop educational outreach efforts.

### Technology Transfer

Technology transfer in the project-centered model is handled on a project-by-project basis. Technology transfer is automatically included in the project organization and encouraged by the multi-institutional nature of the project team investigators. Technology transfer can be enhanced if the requests for proposals or broad area announcements include requirements and rewards for such features.

## SUMMARY

Three separate cooperative research organizational models and the baseline individual investigator model were identified and described in this chapter. Each model has features that make it unique and independent of the others. On closer inspection, however, there are common threads among the models in terms of project management, research theme selection, use of peer review, processes to engage stakeholders, and use of councils and committees to make recommendations and decisions. These issues are discussed further in Chapter 5.

It is possible to have hybrids or mixes of the above models under which practices typical of one model are embedded in the operation of another. The most common version of this practice is investing some portion of the research portfolio in principal investigator–generated ideas (individual principal investigator model) that are important to the general field but may not be central to any one of the research themes. The latter activities are characterized by the fact that they are long term, high risk, and potentially high payoff.

Another likely strategy would be to include a major project in either the professional society/community of practice model or the consortium model. The review of proposals and evaluation of research results could be performed by using the approaches inherent in those models or the technical review committee employed in the project-centered model. This hybrid approach is best suited to research programs where several large, complex projects need to be performed within the professional society or consortium model. Finally, the professional society and consortium models can include both the individual investigator and project-centered approaches. This strategy can provide more flexibility in accomplishing the goals of the research program, but it usually increases the complexity in managing the research program.

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### Abbreviations

| | |
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| NRC | National Research Council |
| NSRP | National Shipbuilding Research Program |
| TRB | Transportation Research Board |

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# 4

# Evaluation of Research Models

The committee's overall evaluation of each of the four core research models that were identified and described in Chapter 3 is presented in this chapter. Each model is evaluated on the basis of how well it accomplishes the program goals and objectives of the Office of Naval Research (ONR) that were discussed in Chapter 2. The structure for evaluating each follows the format of Chapter 2. Each model is evaluated separately, and no attempt is made to compare or rank the models relative to one another. The discussion makes clear that some models are better at fulfilling certain objectives while others are better at fulfilling other objectives. Thus the overall selection of one of the models as superior to another is left to the judgment of ONR, which must weigh the relative importance of each objective to justify a selection.

## INDIVIDUAL INVESTIGATOR MODEL

In general, the objective that is best served by this model is that of providing the means for talented individuals (faculty, graduate students, professionals in industry) to focus on a specific research topic, bringing in the best knowledge and methods from the entire breadth of disciplines represented on a university campus or in a private R&D organization. The model is aimed at developing analytical and creative thinking in the individual that can later be applied in solving new design and engineering problems, rather than at equipping the individual with a set of design tools to be applied in immediate, but more or less standard, design situations. The approach might be described as one of developing human capital in universities and research firms.

### Goal 1: Maintain and Develop Human Capital

The individual investigator model, overall, provides good support to this goal by attracting talented and enthusiastic students and by retaining and attracting quality faculty, because a main focus of the model is on a close and nurturing student–faculty educational relationship. The model supports creative talent in industry and government by promoting similar relationships there. However, the model is less capable of supporting continuing education and training and fostering total ship engineers because those objectives are seldom emphasized in the typical university or private research organizational setting. The evaluation details for each objective are discussed below.

### *Objective 1-1: Attract Students to the Profession*

The model provides only limited opportunity for public education except possibly through media coverage of research results. It can provide good opportunities for career path presentations to both undergraduate and graduate students. The only opportunities for outreach at the primary and secondary education levels may be through media coverage of research projects and university recruiting publications aimed at school counselors. Interactions between students and industry are possible, depending on the nature of the research; examples involve data gathering or observations in shipyards or at sea.

The model can provide excellent opportunities for undergraduate research, since this is an important way in which universities attract graduate students. Similarly, the model provides an excellent introduction to career and research opportunities at both the undergraduate and graduate levels through faculty contacts, seminar speakers, and other normal aspects of the university experience. The provision of scholarships, fellowships, and research assistantships is fundamental to this model since the students supported by such means are the primary research workers. The provision for support of study and work abroad is very much dependent on the nature of the research. A graduate research assistant might spend some time working at another institution in order to work for a limited time with a specific individual or group to learn a new discipline or procedure that is useful to the project under which he or she is supported.

### *Objective 1-2: Attract and Retain Faculty*

The individual investigator model has an excellent potential for supporting this goal because it provides the sponsor commitment needed to attract and retain good faculty. It has broad scope for research opportunities that appeal to faculty and that are central to successful career development in a university environment. Depending on the nature of the individual research, there may be good support for developing the research infrastructure, such as laboratory and other physical facilities. The model also provides the optimum incentives and reward structure for academic professionals. Opportunities for faculty teaming across disciplines are limited but may exist in the case of co-principal investigators. Career development is most strongly enhanced within the university context, where research productivity is a cornerstone of professional advancement. Outside consulting opportunities are not likely to be developed directly as a result of research under this model, but they are always a possibility for talented investigators.

*Objective 1-3: Provide Continuing Education and Training*

The individual investigator model does not normally contribute directly to this objective. The professional community is not normally involved in merit review except in the form of peer review of publications that may come out of the research. Usually, no courses are developed, so professional involvement in course development is not a relevant issue. Opportunities for distance learning and on-site instruction may be developed only incidentally to the research as a result of certain outputs, such as video records that may be incorporated in university distance learning programs. The individual investigator model provides little or no opportunity for collaboration among stakeholders in teaching or research; the fostering of networks and communities of practice; or the exchange of personnel among government, academia, and industry.

*Objective 1-4: Foster Total Ship Engineers*

Rather than fostering total ship engineers, the individual investigator model is more likely to foster engineers who can deal with unprecedented design problems. Except in a research project specifically concerned with developing methods of total ship design, it does not encourage development of a total ship design curriculum. Similarly, the model does not inherently strive for synthesis of multidisciplinary knowledge, provide interdisciplinary design team experience, or provide access to advanced design tools and training. It also has limitations with regard to the integration of research projects into total ship systems because it would not usually be used to sponsor design competitions or enhance university–industry communication on advanced designs.

**Goal 2: Revitalize Naval Engineering and Improve Design and Production**

The model, overall, appears to support the objective of stimulating innovation while being less supportive of objectives that require collaborative efforts and the creation of links from research to ship production. The following discussion provides details of the evaluation under each objective.

*Objective 2-1: Create New Research Opportunities*

The stimulation of new research ideas is a hallmark of the type of individual involved in typical programs within this model. By the nature of the model, the setting of priorities and the sharing of decision making among stakeholders are not part of the process but are normally performed by the sponsor. However, the model provides excellent means for bringing in new talent and innovative ideas. The structure and incentives for collaboration are limited except in the case of co-investigators.

Cross-fertilization may present a special problem for the individual or small group that may be somewhat isolated. Thus it is especially important for the principal investigator and students to visit other investigators doing related work and to attend technical meetings where their own and other researchers' results are presented and discussed. To enhance technical interchange under this model, it is important to bring in distinguished guest researchers from other institutions. Support for such contacts should form a part of any project accomplished under this model.

### *Objective 2-2: Promote Innovation*

Innovation is often the key element of research under this model, since the individual involved is usually an original and creative thinker. The funding decision usually involves only ONR and the investigator who proposes the work, so the process is, in principle, inherently flexible and capable of fast response. Tolerance for risk is usually high, if only because the amount of funding involved is small. Incentives and rewards are built into the university system, where advancement is strongly dependent on research productivity. Continuation of funding is based, at least in part, on the ONR research supervisor's knowledge of the subject area and thus his or her ability to critically evaluate the results. Direct knowledge of the investigator's reputation and ability similarly is a characteristic of ONR's oversight personnel and process. These have traditionally been key parts of the ONR process in support of university-centered research.

The university environment in which the individual investigator works normally provides excellent opportunities for learning from other fields through such means as library resources and consultation with colleagues from diverse disciplines. However, the opportunity for the direct promotion or adoption of research outcomes is limited. The results are usually disseminated through publications and reports rather than through direct contact between research personnel and potential users. Some of this material may find its way into regular course work as well as continuing education courses. The direct development of design leadership is not a significant output of this research model. The graduate students may develop, incidental to their work, some useful management and leadership skills depending on the nature of their work assignments and the degree of responsibility that they are given.

### *Objective 2-3: Ensure Research Useful to Ship Design*

There is no sharing of decision making by stakeholders under the individual investigator model, except that ONR generally performs the proposal review. Merit review by experts and stakeholders will, in general, take the form of peer review of publications that result from the research. Such publications as well as professional conference proceedings are the principal means of technology transfer. Depending on the particular research, prototype and other testing to produce empirical data may or may not be a part of the research, but in some cases, the production of such data may be the principal objective. Except in research related to specific design problems, linking of research to design and production is not typically an output of this model. In most cases, results are published in professional journals, and linking of the research to design is left to the designer or industry user.

## PROFESSIONAL SOCIETY/COMMUNITY OF PRACTITIONERS MODEL

This model provides an excellent venue for involving many elements of the profession in selecting appropriate research topics, evaluating proposed projects, and linking research and production organizations. This is because the professional societies and communities of practitioners usually represent a wide spectrum of engineering disciplines in ship design and production. Professional societies maintain many technical committees that contain experts in every discipline of design and construction and therefore would be uniquely able to provide these functions in a cooperative research organization.

### Goal 1: Maintain and Develop Human Capital

The professional society model provides good support to the goal of developing human capital because of its ability to involve many areas of the profession within the process of operating a research organization. These linkages to the profession, inherent in this model, would also be a valuable asset to incorporate into other models. The model will be effective in supporting this goal as described under the following objectives.

#### *Objective 1-1: Attract Students to the Profession*

The professional society model could excel in promoting public education and suggesting career paths to students. It could also, with some reconfiguration of existing professional societies, do well in supporting primary and secondary education outreach because of the geographic distribution and the large number of members. Most professional societies already support the goal of interaction between students and industry, and this model should improve present programs. The model will provide undergraduate research opportunities only if it is explicitly designed to do so because typical professional societies do not support such opportunities, although they do sponsor design competitions and could build on them. The task of presenting career and research opportunities to high school students could be carried out by this model with good results, again, because of the geographic distribution of the membership. Similarly, the model could do well in identifying candidates for scholarships and fellowships for students and research assistants. By using international connections already present in professional societies, the model could also support study and work abroad.

*Objective 1-2: Attract and Retain Faculty*

The professional society model could provide only modest support for this objective because it has no easy connection to faculty networks and incentives. The model is seen as having a limited role in developing a supportive infrastructure because present societies do not have close working relationships with universities. Similarly, the task of developing an incentive/reward structure for faculty could be given only limited support. The supply and quality of students would only be moderately supported by the model because of the distribution of membership as noted above. At the same time, the professional society model could do well at supporting faculty teaming opportunities across disciplines through its technical committees. Faculty consulting opportunities and career development could be moderately supported by the model.

*Objective 1-3: Provide Continuing Education and Training*

The professional society model would excel in involving the professional community in merit review for continuing education and training because that function is inherent in the societies already. It could also facilitate professional involvement in course development and in opportunities for distance learning and on-site instruction through its broad connection to industry and technical committees. While this model could be excellent at fostering networks and communities of practice, it could probably only be moderately successful at providing collaboration among stakeholders for teaching and research because its connections to university systems are weak. However, encouraging the exchange of personnel among government, academia, and industry should be an easy task since the professional societies maintain membership data that would be useful in carrying out this objective.

*Objective 1-4: Foster Total Ship Engineers*

The professional society model should do well at encouraging a total ship design curriculum, because it could readily provide a synthesis of multidisciplinary knowledge and interdisciplinary design team experience. Such support would be provided by members who are identified to have this experience.

The model could only slightly support access to advanced design tools and training and could only moderately help the integration of research projects into the total ship system, since there are no direct connections to the end users. On the other hand, this model is in an excellent position to sponsor design competitions (as professional societies do now) and to coordinate university and industry communication on advanced designs.

The objective of supporting design for manufacture and operation is only moderately supported by this model. There could be some support by providing industry contacts through the technical committees.

### Goal 2: Revitalize Naval Engineering and Improve Design and Production

In general, the professional society model provides moderate support to the goal of revitalizing naval engineering and improving ship design and production because, although it has opportunities for meeting the underlying objectives, it has no significant features that would lead to superior attributes. The professional society model is seen more as a continuation and affirmation of existing R&D practices than as a vehicle for innovation and new research opportunities.

#### *Objective 2-1: Create New Research Opportunities*

This model is seen as only moderately helpful in establishing a process for setting research priorities, because there is usually no direct tie between societies and universities. The community that is expected to provide leadership for this model tends to focus on mature technology and thus would not be particularly adept at establishing mechanisms for bringing in new talent and innovative ideas. The model might do well at supporting shared decision making by stakeholders if specific committees were established. Similarly, it is seen as having an excellent opportunity to provide structure and incentives for collaboration.

#### *Objective 2-2: Promote Innovation*

The professional society model has a limited capability for providing flexibility in funding or fast response to financial changes because of the inherent bureaucracy in the organization. This factor would also result in a moderate tolerance for risk. Most professional societies have only a moderate capability to provide rewards and incentives for new ideas and approaches. The relatively closed character of most societies would be expected to limit learning from other fields to a moderate level. However, this model would do well at promoting avenues for adoption of outcomes because of its strong connection to industry and design professionals.

*Objective 2-3: Ensure Research Useful to Ship Design*

The professional society model could support shared decision making by stakeholders if balance in stakeholder input were given high priority in the research council and the technical committees. The timeliness and effectiveness of this are of concern. For merit review by experts, this model could support mechanisms for technology transfer and deployment. Both of these tasks could be supported by the technical committees. Similarly, good support could be provided by the model for prototype testing and for linking research to design and the product, because the community of practitioners forming the basis of this model have the depth of experience and background to accomplish this objective.

## CONSORTIUM MODEL

In general, the consortium model offers significant promise for achieving most of the stated objectives under both of the ONR goals. It has the flexibility to solicit internally and support both individual investigator and multidisciplinary team research. The committee believes it to have excellent abilities to support most of the attribute measures that are important to developing human capital and promoting collaborative and innovative work. It is seen as having no serious deficiencies in achieving the attributes discussed in Chapter 2. However, government sponsors need to develop working relationships within any cooperative agreement to sponsor a consortium that account for the different organizational cultures found in a university, government, or industry setting. Some of these factors are included in the evaluations below under the individual goals and objectives.

### Goal 1: Maintain and Develop Human Capital

The consortium model has excellent capabilities to support this goal because it can be organized with all of the key objectives as inherent operating principles. Leadership qualities among senior and student researchers can emerge naturally and be nurtured within this kind of organization. However, it is important to pay close attention to the detailed organizational structure for this model so that each objective is recognized as important and adequate incentives and rewards are provided.

*Objective 1-1: Attract Students*

This model has an excellent potential to suggest career paths to students and for outreach to primary and secondary students because the initial organization can be done with these objectives in mind. The model can do an excellent job in promoting interaction between students and industry via co-op programs, internships, colloquia, mentoring, and collaborative networks. Some advance understandings with ONR would be necessary concerning the combinations appropriate for the specific academic institutions involved in any consortium. The model could also provide excellent undergraduate research opportunities and could do well at presenting career and research opportunities to students. It would be excellent in administering funds for scholarships, fellowships, and research assistantships as part of a cooperative agreement. Since interest in and the capability to provide opportunities for study and work abroad might be uneven across the academic community, the overall potential of the model is judged to be moderate.

### *Objective 1-2: Retain and Attract New Faculty*

The potential for sponsoring commitment to research in the case of new faculty is excellent, and the consortium model is excellent in providing continuity of research funding for its participants. This model is also viewed as excellent in providing broad research opportunities, both basic and applied, and in developing new infrastructure (e.g., equipment, technology, and staff). The caveat here for the more prestigious research institutions must be an advance agreement that new faculty who do applied research will be included in the institutional reward system; otherwise, they will likely hesitate to take this work on at the beginning of their academic careers. The capability to develop new infrastructure will depend on the financial resources provided to the participants in many, if not most, cases. The supply and quality of students and faculty teaming opportunities are viewed as excellent features of this model. Other good features include career development via industry and government teaming and consulting opportunities.

### *Objective 1-3: Provide Continuing Education and Training*

The consortium model provides an excellent opportunity to involve the professional community in merit review of R&D projects through its oversight committee structure, which involves representatives of industry, government, and academia. It is viewed as having similarly excellent potential to facilitate professional involvement in course development, opportunities for distance learning and on-site instruction, and collaboration among stakeholders in teaching and research, and to encourage exchanges of personnel among academia, industry, and government. It should also do well at fostering networks and communities of practice as long as there is a concerted effort to do so within the governing and management process.

*Objective 1-4: Foster Total Ship Engineers*

A consortium has good potential to encourage total ship design in the curriculum, as long as the requirement to do so is built into the cooperative agreement with ONR. It is also an excellent way to obtain a synthesis of multidisciplinary knowledge and to provide interdisciplinary design team experience and access to advanced design tools and training. The model is judged good in integrating research projects into the total ship system, sponsoring design competitions, understanding design in the context of manufacturing and operations, and facilitating university–industry communication on advanced designs.

### Goal 2: Revitalize Naval Engineering and Improve Ship Design and Production

In general, the consortium model has a good to excellent capability to support this goal because it can be organized in a way that stimulates new research through collaborative planning and merit review mechanisms. The details of evaluation are discussed below.

*Objective 2-1: Create New Research Opportunities*

The model is excellent in such specific aspects as setting priorities, establishing a vision, doing strategic planning, including stakeholders in the sharing of decision making by providing structure and incentives for such collaboration, and offering mechanisms for bringing in new talent and innovative ideas. In the latter connection, it is recommended that ONR require the consortium management team to reserve contingency funds for this purpose in every yearly budget.

*Objective 2-2: Promote Innovation*

Even though the committee could not make accurate and absolute evaluations, it believes that this model has certain inherent abilities to create an innovative atmosphere and to reward innovative behavior among involved professionals. This needs to be accomplished through flexibility of funding and thoughtful approaches to supporting new research topics. Innovation could be a result of a well-organized, well-operated consortium.

The consortium model could promote innovation by providing flexibility and fast response to funding changes. It could do this by closely integrating the administrative staff with the program director. With its broad and flexible programming capabilities, the model should have good tolerance for risk and could be excellent in applying incentives and rewards for new ideas because of its internal flexibility in decision making. The opportunities for cross-disciplinary research inherent in this model should make for excellence in learning from other fields. The model also would do well at promoting avenues for adoption of outcomes, most likely through a formal technology transfer program. Using multidisciplinary teams, it should be excellent in stimulating and developing design leadership qualities.

*Objective 2-3: Ensure Research Useful to Ship Design*

The model provides an excellent opportunity for shared decision making by stakeholders regarding resource allocation through the selection of membership in the governing bodies. It offers excellent potential for merit review by experts and stakeholders, as well as mechanisms for technology transfer and deployment. It should do well at producing empirical data via prototype testing and at linking research to design and production.

## PROJECT-CENTERED MODEL

In general, the committee found that this model had reasonable capabilities to support some ONR goals and objectives but was lacking in other key attributes. This is mainly because of the project-centered approach to the basic organization, which creates limitations for a dedicated long-term commitment to both human capital development and integrated and collaborative research programs.

### Goal 1: Maintain and Develop Human Capital

The project-centered model of cooperative research, overall, provides somewhat less support to this goal than does the professional society model and considerably less than does the consortium model. The evaluation details for each objective are discussed below.

*Objective 1-1: Attract Students to the Profession*

This model could do well in the areas of public education and suggesting career paths to students. The combined public relations capabilities of the university, government laboratories, and industry would be available to develop and promulgate educational information. Practitioners from both government and industry would be expected to be enthusiastic in recruiting new students at the university partnered with them. It would be expected to do poorly on outreach at the primary and secondary education levels because there would be no long-term educational activity. Both the finite life of the project and the concentration on a single subject work against the creation and maintenance of a broadly based program aimed at these levels. This model should do well at fostering interaction between students and industry. On the basis of the close relationships inherent in a project-oriented organization, there should be both opportunity and motivation to develop these interactions. The model should be excellent at providing undergraduate research opportunities, including summer jobs and activities yielding academic credit. But the project-centered model would be only moderately successful at presenting career and research opportunities to the students because there is unlikely to be outreach beyond those students directly connected to the project. The model should do well at providing scholarships and fellowships or research assistantships. Projects of this type typically provide for such stipends in their budgets and could readily include scholarships for undergraduates as well as graduate student support. The time span of the project would typically be long enough to support a student throughout either an undergraduate or a masters degree program. This model would be expected to have only a slight influence on study or work abroad. Except in rare instances where significant work is being undertaken in another country that would enhance the project at hand during that project's life span, there would be little attraction in expending funds on these activities.

*Objective 1-2: Retain and Attract New Faculty*

The project-centered model would have only a slight commitment to research continuity because the project organization would terminate at the end of the project cycle, which might be 3 to 5 years. The interest of individuals might well continue beyond this point, but there would be no organizational structure to facilitate continuing the work. The model should do well at providing broad research opportunities, both basic and applied. The projects would be expected to encompass multiple engineering disciplines and be large in scope and duration in comparison with typical single-investigator projects. This model would provide only slight opportunities to develop supportive infrastructure. Investments in major facilities, as opposed to the specialized equipment that the project would fund for its own needs, are hard to motivate when the program is of a finite length and cannot offer guarantees that similar work will be funded in the future.

The project-centered model would be expected to have a poor capability to create incentives and rewards. Researchers and project leaders would be removed from their line organizations temporarily and made part of an ad hoc team that would typically have no responsibility for determining incentive or reward structures. These responsibilities would be retained by the project members' home organization. The model would have slight influence on the supply and quality of students. As explained previously, the project would have limited impacts outside those students actually engaged in the project. The model could do a moderate job of creating faculty teaming opportunities across disciplines. The nature of the project selected would obviously determine the scope of this opportunity, but the lack of a formal and permanent academic program within the participating university would make working across disciplines more difficult.

The project-centered model would do well at providing consulting opportunities and influencing the career development of faculty. This would be greatly enhanced by the close cooperation between faculty and professional researchers. Expertise developed during the life of the project could offer faculty participants improved visibility and utility to potential consulting clients.

### *Objective 1-3: Provide Continuing Education and Training*

The project-centered model will be excellent at involving the professional community in the merit review process because the technical review committee, which contains dedicated professionals, is maintained for the life of the project. Their principal function, once the work has begun, is to ensure that the research work is proceeding satisfactorily. But the model would be poor at facilitating professional involvement in course development. The relatively short lifetime and the lack of a formal academic unit associated with this model would give little incentive or power to influence the development of new courses. That would not preclude professionals associated with the project from participating in teaching, but such participation would not be an inherent attribute of the organizational structure.

The project-centered model will be poor at creating opportunities for distance learning and on-site instruction. The lack of a continuing program at the host university would not be conducive to the strong faculty and management commitment necessary to develop and sustain these activities. The model can be expected to have a positive influence on collaboration among stakeholders in both teaching and research. Relationships developed during the project term may be expected to continue under other funding arrangements in the future. The model would be expected to have only a slight influence on the fostering of networks and communities of practice because of the temporary nature of the organization and the relative narrowness of its aims. The model should do well at encouraging the exchange of personnel among government, academia, and industry because of the inherent creation of multiple research teams involving all the stakeholders.

### *Objective 1-4: Foster Total Ship Engineers*

The project-centered model would be expected to have no significant influence on the establishment of a total ship design curriculum. As previously discussed, the organization is poorly structured to bring about curriculum changes. The model could be moderately successful in enhancing the synthesis of multidisciplinary knowledge and in providing interdisciplinary design team experience, provided that project selection favors these activities. The model should do well at providing access to advanced design tools and associated training through the exposure of students, faculty, and other research personnel to the current industry state of the technology. The model would be moderately successful in the integration of its research projects into a total ship system. The relative success here would depend on other organizations implementing the integration strategy after the project team is disbanded. The model would not be expected to sponsor design competitions related to total ship design. It should enhance university–industry communication on advanced designs and design for manufacturability and operation because of the close connections between stakeholders that are inherent in the organizational structure.

## Goal 2: Revitalize Naval Engineering and Improve Ship Design and Production

The project-centered model is expected to do slightly better at this goal than the professional society model but to be less effective than the consortium model. The detailed evaluation of the objectives for this goal follows.

### *Objective 2-1: Create New Research Opportunities*

The model is expected to be moderately successful in establishing a process for setting priorities, in sharing decision making among the stakeholders, and in establishing mechanisms for bringing in new talent and innovative ideas. All of these factors depend on the capabilities and interests of the project team and are not fundamentally influenced, either positively or negatively, by the organizational structure. The project-centered model should do well at providing structure and incentives for collaboration because it clearly enhances performance of the project and the decisions can all be made within the project team.

### *Objective 2-2: Promote Innovation*

The project-centered model would have only moderate capabilities to provide flexibility and fast response to funding changes. With ONR funding approval for large projects, shifting funds between projects would be cumbersome. The size of the projects and the personal identification of the technical review committees with their projects would produce only a moderate tolerance for risk. These same characteristics, however, should result in good performance in providing incentives and rewards for new ideas and approaches. The organization would limit the model to only moderate capability to learn from other fields. The direct connection to industry should make this model excellent at promoting adoption of outcomes. Although the lack of exposure to other projects in this model's organization would somewhat limit the breadth of technical knowledge gained from working on each of several projects, the management focus required to lead a major project in this model would stimulate design leadership. Professionals leading these large projects will learn to motivate corporate managers to commit their best people and other resources to programs beyond their immediate control, and then they will have the challenge of leading a staff on temporary assignment.

*Objective 2-3: Ensure Research Useful to Ship Design*

The project-centered model should do well at shared decision making by stakeholders in this area, given that all parties are represented at all project management levels. The continuing technical review committees for each project should provide good support to merit review by experts and stakeholders. The model is expected to be excellent in technology transfer and deployment, in prototype testing to produce empirical data, and in linking research to design and production. In many cases, National Challenge Initiative research projects could result in large-scale models or small prototypes of advanced ships or major systems. The strong presence of industry at all levels in the organization structure should help achieve success in these objectives.

## SUMMARY

The committee's evaluation of the three selected cooperative research organizational models shows that there are fundamental differences inherent among the models but also that there are common features and benefits among them. Taken together, the common features indicate that all of the models are able to meet the goals and objectives set out by ONR to some degree. Only the specific measures of that ability to meet objectives set the models apart from each other. Table 4-1 summarizes the capability of each of the three cooperative models (and the baseline model) to meet the stated objectives.

**TABLE 4-1 Summary of Cooperative Research Organizational Models and How Well They Meet Objectives**

| | Baseline Model | Professional Society Model | Consortium Model | Project-Centered Model |
|---|---|---|---|---|
| Human capital objectives | | | | |
| Attract students | Medium | High | High | Medium |
| Retain and attract new faculty | Medium | Medium | High | Medium |
| Provide continuing education | Low | High | High | Medium |
| Foster total ship engineers | Low | High | High | Medium |
| Naval engineering design objectives | | | | |
| Create new research opportunities | Low | Medium | High | Medium |
| Promote innovation | High | Medium | High | High |
| Ensure research useful to ship design | Low | Medium | High | High |

The committee found that all three models for cooperative research organizations that it evaluated are capable of meeting all of ONR's program objectives. With regard to the ability to meet human capital and naval engineering and design objectives, the consortium model was found better than the professional society model, but both were significantly better than the project-centered model. Table 4-1 illustrates how well each of the three models fulfills the stated objectives. The absolute ranking of these models, however, will depend on the relative importance given by the sponsor to each objective.

In its evaluation process the committee found that the cooperative research models had many attributes that would be useful in meeting certain specific objectives. Both the consortium and project-centered models have abilities to encourage innovative research through their inherent structure. However, one key to implementing research into innovative ship design is the ability of the Navy and other stakeholders to overcome the natural tendency of an organization to resist change. The overcoming of such resistance can be encouraged by the management of an organization but must be continually reinforced.

All of the cooperative models possess characteristics in varying degrees that encourage research useful to advanced ship technology and design development. However, the consortium and project-centered models involve a high degree of stakeholder participation and therefore have a higher probability of meeting the Navy's needs in this area.

Total ship engineers are developed through a combination of formal total ship design curriculum and hands-on design experience in multidisciplinary projects. Regardless of the model selected, the ability to foster total ship engineers depends on the opportunities available to all stakeholders that enable them to obtain the necessary formal education and design experience.

In its evaluation process, the committee found that each of the three cooperative research models possessed certain particular merits unique to that model. For example, the professional society/community of practice model can excel in meeting the need to develop human capital. This model has the potential to be particularly strong in attracting and retaining students, supporting continuing education and training programs, and fostering the education and development of total ship engineers. Such strength is based on the fact that these are principal missions of professional societies. The consortium model has characteristics that are well suited to meeting all human capital development and naval engineering design objectives for cooperative research programs. However, its success in meeting these objectives will be principally determined by the leadership of the consortium and its ability to adequately represent and balance the needs of the various stakeholders. Finally, the project-centered model has the potential to excel in promoting innovation in naval engineering design and in promoting research that is useful to ship design and production. This strength is based on the strong, large-scale, interdisciplinary project focus inherent in the model, which includes participation and encourages collaboration of the key stakeholders.

If ONR implements one or more of the organizational models discussed above, it will need to develop additional details for the structure it selects. While the committee has not investigated the functioning of several existing programs that might be considered examples of each organizational structure, a number of such examples do exist, and descriptions can be found in references to this report. It might be useful for ONR to investigate these examples. Examples of the consortium model include the National Science Foundation's Engineering Research Centers Program, the National Shipbuilding Research Program, and the National Oceanographic Partnership Program. Examples of the professional society model include the Civil Engineering Research Foundation, the Council for Chemical Research, and the American Society of Mechanical Engineers Center for Research and Technology Development. Examples of the project-centered model can be found in work by Ferreiro (2001).

## POSSIBILITY OF HYBRID MODELS

The committee found that the desirable features and attributes of the models might be combined to create hybrid models. Such models might be used to maximize the performance of the research organization in meeting program objectives. The hybrids, however, generally increase the complexity in managing the research enterprise. Examples of hybrids might include embedding the individual investigator model into the cooperative agreement organizational models, including the project-centered approach into the consortium/center and professional society models, or embedding both the project-centered and individual investigator models into the consortium or professional society models. The committee has not evaluated these hybrids but has only noted that such combinations are always available to a creative manager.

## REFERENCE

Ferreiro, L. 2001. *Point Paper on the Organization of Research and Development in Europe.* Office of Naval Research.

5

# Operational Considerations for Implementing Research Models

All of the cooperative research organizational models considered by the committee possess operational or functional elements that affect their ability to accomplish the goals and objectives of the Office of Naval Research (ONR). In general, the implementation of these elements is independent of the structure of the organization. The success of any model, therefore, will be affected by such factors as how the governing bodies are constituted; what decisions are made on administrative processes and controls; and how decisions are made about personnel, location, and other management attributes. Thus, the committee elected to discuss these elements separately from its evaluation of the three models themselves. In this chapter these key operational elements are presented, and the implications of each are discussed.

## SETTING A RESEARCH AGENDA

A fundamental issue in structuring a cooperative research program to meet ONR's goals is the process and manner of setting the research agenda. In the context of a cooperative research program, stakeholders [Navy (ONR, Naval Sea Systems Command, Laboratories), academia, industry, and professional societies] all have a shared interest and ownership in the research agenda. Successful organizational models have structures and mechanisms to ensure appropriately balanced representation and input to the research agenda from stakeholders.

A research agenda usually includes various levels of specificity. At the highest level are research themes that define broad areas of research in systems and technologies essential for future naval capability. At the next level may be several specific projects within these themes that incorporate research to further knowledge in a system or field of application. The responsibility for developing the research agenda within a research organization should be shared among stakeholders. It can be established either top-down (ONR-defined) or bottom-up (investigator-defined).

Under the baseline individual investigator model, while general guidance for a research agenda usually comes from ONR, the impetus for specific projects is generated from proposals coming from individuals or teams of researchers. This places the burden of project review and funding decisions on ONR and thus leads to an ONR-defined agenda. Under the cooperative models, however, most of this effort is usually shifted away from ONR to the host organization and thus leads to shared responsibility for setting an agenda.

In the case of the professional society model, a research council comprising the stakeholders would assume the responsibility for defining research themes. Similarly, under the consortium model, the executive committee, again representing the stakeholders, develops the research themes for ONR's approval. The solicitation, review, and selection of individual projects under the themes are responsibilities of the executive committee. In the case of the consortium and professional society models, the executive committee would be established and facilitated by the host organization. The project-centered model represents a somewhat different approach in starting up the organization. ONR would need to create an executive council of stakeholders to oversee the process of identifying the annual project theme; then, a technical review committee would be established to review and recommend projects to promote the annual theme. Therefore, the professional society and consortium models generally produce a more coordinated research agenda than the portfolio of individual projects that might be expected under the project-centered model.

## SELECTION OF HOST LOCATION

The venue and institution selected to host a cooperative research organization would be expected to provide administrative, accounting, and human resource services. Under most models, the fixed facilities would be minimized to provide more operational flexibility. The nature of total ship systems naval engineering is such that it does not require an extensive laboratory infrastructure, so the existence of major facilities would not normally be a major consideration in selecting a location. Since the naval engineering community is very small and diverse, the number of locations from which to choose is small, and there are few logical central locations where many professionals are concentrated. Therefore, the decision to choose one institution among the few available options will be difficult and contentious.

No matter what organizational model is used, the location of the research organization generates exceptional stature for the host entity while reducing the stature of those entities not selected as host. Because of the small size and fragile condition of the community, a reduction in the competitive stature of an institution could endanger one of the schools currently engaged in naval engineering education. To ameliorate this effect, the organization's committee structure should very seriously consider the location of the research center and the structure of the decision-making groups within the organizational model. The goal would be to create a balance in the influence of participating entities.

A cooperative research organization would have several locations to choose from. Three of the more obvious options include a university, a neutral (nonstakeholder) location, and a federal government facility.

A university location could be either on or off campus. An on-campus location has the advantage that existing infrastructure and administrative staff might be available and thus reduce center start-up time and cost. An off-campus location might require more investment in infrastructure. Both types of location would provide strong support to the existing marine, ocean, or naval engineering department faculty and students at that university. The resulting increased strength and technical capability in naval engineering and related subjects at a host university could lead to the development of a total ship systems center of excellence or a similar initiative that would benefit the community. In addition, the Navy would benefit from the knowledge and research capability available at a university.

A major concern of selecting one university as the host is the potential negative effect on the naval engineering departments at universities not selected. There may be a tendency toward diminished participation in naval engineering research and cooperative participation by the universities not selected as host. There is even the potential for the total loss of naval architecture and marine engineering education and research at one or more of the nonhost universities.

A "neutral" venue, meaning one not located at a university or industry stakeholder, has certain advantages. One is that the administration and contracting functions might be more efficient if done by a professional management services company on the basis of commercial business practices. A second is that the potential negative impact on the universities not selected would be avoided. In addition, there may be better acceptance by and resource support from industry. The shipbuilding industry has had good success with operating a neutral host organization to manage its National Shipbuilding Research Program on shipbuilding process improvement. Depending on the chosen location, a neutral venue might gain better support from the Navy and the professional societies. In fact, the professional resources and technical capabilities of society membership might be best utilized through a research center at a neutral location. One disadvantage of a neutral location would be the difficulty of obtaining the faculty and student resources and support that a host university could provide.

A third choice of location for a cooperative research organization would be a government facility. This location might stimulate support from such Navy groups as the Naval Sea Systems Command and other Navy laboratories. The use of existing infrastructure in a Navy facility might reduce capital investment costs. In addition, the Navy has extensive naval ship engineering research experience and data, which would be available as part of the center's knowledge base. If the location were a Navy laboratory, the organization might be able to take advantage of its existing focus on ship design, production, and operational support for the fleet and its concern about the need for well-educated and capable total ship system engineers.

The disadvantage of a government location is that it might be difficult to avoid costly government agency administrative practices and procedures. There also might be a tendency toward less tolerance for taking risks because of the close ties to designing and building ships for today's fleet. This might be contrasted with pushing technical boundaries, developing new empirical performance data, or developing new materials and production processes. Another disadvantage is that the location might be far from the major university stakeholders, which could create difficulty with close and continuous coordination.

A final factor related to selecting the host location is the perception of how power is being shared among stakeholders. A perception of imbalance can be nullified to some degree by the selection of a neutral location, but such a selection could bring inefficiencies. If a nonneutral host location is selected, the perception can be offset by careful attention to balance in public presentations, websites, and letterheads; by rotating associate directorships; and by rotating the location of annual merit reviews.

## CONTRACTING ISSUES

For all of the organizational models it reviewed, the committee assumed that ONR would issue one overall funding agreement to the organization, which would, in turn, fund each research project as it was selected. The primary impact of giving this contracting responsibility to a cooperative research organization, rather than having it remain with ONR, is that the administrative responsibility, work, and cost can be transferred from the government to the private sector. The transfer might be either to a university or to a third-party program management group. The committee believes that this will most likely result in an overall improvement in efficiency. It also would place the contract administration function closer to the research work, which would reduce the administrative burden. The contracting resources of ONR could thus be relieved because nongovernment organizations would perform most of the contracting functions.

The federal government has developed a number of contracting vehicles to support cost-shared research with universities and industry. One common vehicle that may be suitable for this initiative is a cooperative research agreement. Such an agreement provides for sharing both the costs and the rights to use the results of the research done under the agreement. This type of agreement has been used by ONR on ship development and technology development programs in the past.

An advantage of using cooperative research organizations and agreements is their ability to accommodate both government and industry funding. Cost sharing between government and industry might improve the relevance of research themes and results to ship production needs. The use of a single cooperative research agreement between ONR and a centralized research organization might be an efficient way for ONR to contract and administer work because it would transfer administrative burdens from ONR to private organizations. It may also make contracting functions more responsive to the needs of stakeholders.

## ADMINISTRATIVE ISSUES

The day-to-day activities of carrying out a cooperative research program under any of the organizational models requires administrative support, such as procurement, accounting, personnel, travel, computers, and office infrastructure. In all models, these functions would be directed by the host organization. In the case of the professional society model, the society host could provide the administrative support. In the consortium model, the host institution could provide the administrative support. The host institution could be a university, a private firm, a government agency, or a third-party program administrative firm. However, under the project-centered model, because there may not be an existing host organization, it would be necessary to create an organization or contract with a private firm to carry out the administrative support functions.

## LEADERSHIP DEVELOPMENT

The three cooperative research models described in this report provide a broad-based organizational structure that can foster naval engineering leadership in both the government and the private sector. The consortium model appears best able to do this, because it can provide a stable organizational structure in which total ship system knowledge and technical management skills can be developed. The professional society model is also broad-based and covers all aspects of ship systems design, but it is more of a loose confederation and relies on significant volunteer effort. The project-centered model also has opportunities for leadership development. However, because it uses separate project groups, it does not provide the broad-based technical and management coordination inherent in the other models. Properly managed, a consortium model would draw in both industry stakeholder talent and the educational skills from university stakeholders.

All of the proposed models encourage leadership by professionals who have an overall understanding of ships and ship systems. Specialists in specific technologies will have an opportunity to grow into systems managers in ship design if they so choose. They can gain broad-based knowledge and a vision of what technical development should be done by understanding the interests of all the stakeholders. With proper motivation, they are more likely to obtain the commitment of the stakeholders to contribute their best-trained and most capable personnel and resources to the cooperative research.

In summary, visionary program leadership with total ship systems knowledge is not nurtured adequately within the baseline individual investigator model of the current ONR research program. The committee finds that all of the cooperative models, if properly structured and implemented, would encourage the needed program leadership. However, the consortium model appears to offer the most potential for addressing this objective.

## CONTROL OF RESEARCH QUALITY

Several factors contribute to the ability of all cooperative research organizations to control research quality and maintain it at a high level. First, there are unique problems associated with the small community of technically qualified individuals in the field of naval engineering. This situation makes it difficult to find a group of qualified and conflict-free individuals with balanced biases when seeking reviewers for proposals or a merit review panel. A possible solution is to look outside the immediate specialty area of a research project. This approach has the added advantage of supplementing traditional methodologies with fresh perspectives from other disciplines. Another solution, particularly in the consortium case, might be to encourage the involvement of the practitioner community in the review function. Finally, in the project-centered model, a solution might be to vest quality control authority in the technical review committee.

The panel that reviews research proposals should be carefully balanced so that innovative, high-risk ideas are not screened out and all stakeholders' interests are considered. Among stakeholder interests are the importance of academic rigor to university researchers and the applicability of the research product to the Navy's needs.

All cooperative research models include a mechanism to review research effectiveness. An annual review of each research project is considered a minimum for any of the models. The review process in the project-centered model will be the responsibility of the technical review committee. In the other two models, an external review committee appointed or approved by the executive council will meet and review all projects on a regular basis and submit a written report with recommendations for improvements to the executive council. If the review is properly constituted, its value appears to be equal for all models.

In addition to annual merit reviews of projects, postproject reviews of research utilization are important. An executive council should undertake a review of the impact of a completed research project after an appropriate interval. The review should consider the impact on education as well as the utilization of the technology in professional practice.

## EXECUTIVE COUNCIL BALANCE

The leadership of each of the three cooperative research organizations is vested in an executive council, under a variety of names. Alternative strategies in establishing the size, composition, tenure, leadership, and decision-making process of this council will strongly affect the overall success of the organization and the R&D programs it manages. The representation of the three principal stakeholders on the council will affect the degree to which the several constituencies are served and the philosophy, priorities, and direction that the research program will follow.

Too large a council will unnecessarily increase administrative cost and make decision making more difficult. Too small a council will increase the difficulty of adequately representing the diverse views of the stakeholders. If equal representation is desired and the three principal stakeholders are each represented by two persons, the minimum council size would be six. It might be desirable to add other members to the council, such as a professional society representative.

Whatever model is selected, the process and criteria for selecting council members must be carefully considered, along with their tenure and the process for replacing a member who leaves the council for any reason. The willingness to take risks to develop innovative ship design curricula, design concepts, and design techniques should also be a consideration in selecting council members. Knowledge and experience in the following areas should be factors in the selection:

- Early stage total ship design,
- The R&D process and the transfer of technology to ship development programs, and
- The education of naval engineers.

Council leadership is an important issue. Presumably, a council chair will be designated. Whether special powers should be vested in the chair and how the chair will be selected must be decided. The chair could be rotated among the stakeholder communities or might always represent a single stakeholder—academia, the shipbuilders, or the Navy. How the council will make decisions is also an important issue. Unanimity, consensus, or a simple majority might be required. The governing body of the research organization can operate efficiently and effectively if the interests and input of stakeholders are properly considered in the structure that is established. In whatever organizational model is selected, ONR should establish processes to ensure that research funds are fairly allocated and conflicts of interest are excluded from the processes affecting funding decisions, including setting the research agenda. Finally, the selection of dedicated and committed council members is crucial to the success of the enterprise. Those who are asked to serve must not only represent the range of stakeholder interests, but also be willing and able to devote their time, energy, and talent to making the organization function effectively.

## EDUCATION

All of the cooperative research models that the committee examined have a positive impact on the education of naval engineers, but their strengths and weaknesses are determined for the most part by how each one is connected to university educational systems and their managers. The ability of the baseline model to improve education depends on the unique interests and departmental influence of the individual investigator. For this reason its overall impact on the educational enterprise is expected to be moderate. The consortium and professional society models would usually establish education committees as components of their organizational structure, whereas the project-centered model probably would not. Because of its project focus, it is expected that the latter model will have a minimal impact on education.

Within the professional society model, an education committee would normally be the channel for research to find its way into university programs and courses. Such a committee is any professional society's normal access to the academic community. Depending on the nature of the proposed education committee in this model, educational input could take several forms that would require evaluation by a proposal review committee. Within the consortium model, a similar committee would be expected to perform the same functions. The committee finds that this model has a significant ability to affect education in general. It could establish permanent mechanisms and use academic stakeholders in the overall decision-making process. The consortium model has the ability to affect education on a continuing basis.

# Appendix A

# Presentations at Committee Meetings

***First Committee Meeting, November 15–16, 2001, Washington, D.C.***

The following presentations were given by guest speakers:

Sponsoring Agency Goals and Expectations for the Study
*Albert Tucker, ONR*

Perspectives of Marine and Naval Engineering Communities
*Philip Kimball, SNAME; Dennis Kruse, ASNE*

Summary of the TRB/Marine Board Naval Engineering Research and Education Workshop
*Malcolm MacKinnon, Marine Board*

Perspective of the Naval Sea Systems Command
*Robert Keane, Naval Sea Systems Command*

***Second Committee Meeting, December 12–14, 2001, Washington, D.C.***

The following presentations were given by guest speakers:

The Engineering Research Centers Program
*Lynn Preston, National Science Foundation*

The National Oceanographic Partnership Program
*Penny Dalton and Cynthia Decker, Consortium on Oceanographic Research and Education*

Cooperative Research Programs in the Offshore Oil and Gas Industry
*Skip Ward, Offshore Technical Research Center, Texas A&M University*

Ship Design USA—A Collaborative Enterprise for Innovation in Ship Development
*Greg Hagedorn, Naval Sea Systems Command*

Marine Professional Mentorships
*David Helgerson, The Naval Systems Associates Joint Venture*

The National Shipbuilding Research Program (NSRP)
*Rick Self, NSRP*

Naval Engineering Research and Education Cooperative
*Rick Self, NSRP*

Council for Cooperative Research in Naval Engineering
*Dennis Kruse, ASNE, and Philip Kimball, SNAME*

Marine Research Consortium for Advanced Ship Design
*Michael Bernitsas, University of Michigan*

A Distributed Marine Research Consortium for Naval Engineering
*Chrys Chryssostomidis, Massachusetts Institute of Technology*

The Individual Investigator Research Model
*J. Randolph Paulling, Committee Member*

# Study Committee Biographical Information

**Richard J. Seymour,** *Chair,* is Head of the Ocean Engineering Research Group at Scripps Institution of Oceanography of the University of California, San Diego, where he is also the principal investigator on a wave measurement project. From 1991 to 1996 he was the Director of the Offshore Technology Research Center (a National Science Foundation Engineering Center jointly operated by Texas A&M University and the University of Texas at Austin). He held the Wofford Cain Chair in Ocean Engineering and is an emeritus professor of civil engineering at Texas A&M University. Dr. Seymour was the Program Director of the Nearshore Sediment Transport Study, a multi-institution field research program funded by the National Sea Grant Program. Dr. Seymour has served on a number of National Research Council (NRC) committees and was Chair of the Marine Board Committee on Beach Nourishment and Protection. He was a member of the Marine Board from 1984 to 1990 and served as its chair from 1994 to 1996. Dr. Seymour holds memberships in a number of professional societies including the American Society of Mechanical Engineers, where he served as chairman of the Ocean Engineering Division. He is a Fellow of the American Society of Civil Engineers and the Marine Technology Society. He received the California Shore and Beach Preservation Association's Joseph Johnson Award in 1997 and the Moffatt and Nichol Harbor and Coastal Engineering Award from the American Society of Civil Engineers in 2000. Dr. Seymour earned a B.S. in engineering from the U.S. Naval Academy and a Ph.D. in oceanography from the Scripps Institution of Oceanography of the University of California, San Diego.

**A. Bruce Bishop** has served as Dean of the College of Engineering at Utah State University (USU) since September 1982, where he directs the activities of five academic departments and seven research units involving 90 full-time faculty. From July 1993 to July 1995, Dr. Bishop also served as Acting Provost with responsibility for the academic programs, budget, and operations of USU's eight colleges encompassing 42 departments of instruction and a school of graduate studies. A USU faculty member since 1971, Dr. Bishop is Professor of Civil and Environmental Engineering and was Associate Director of the Utah Water Research Laboratory from July 1981 to September 1982. Taking a leave of absence from USU in 1978, Dr. Bishop assumed the post of Executive Director of the New York State Energy Research and Development Authority. Throughout his career, Dr. Bishop has been involved in a variety of research and development projects and assignments focusing on water resources, transportation, energy, environment, and institutional and economic development in the United States, South America, Africa, and Asia. Dr. Bishop holds B.S. and M.S. degrees in civil and environmental engineering from USU and a Ph.D. in civil engineering from Stanford University.

**John W. Boylston** is currently Vice President of Ship Construction for Totem Ocean Trailer Express, Inc., which owns ships that run between Washington State and Alaska. Mr. Boylston was previously President of Argent Marine Operations, Inc., where he oversaw the refurbishment and return of liquefied natural gas vessels to be deployed for trade; managed tanker design projects; and was responsible for the design, construction, and conversion of tanker ships. Mr. Boylston has an extensive background in naval architecture and has served on many Marine Board committees addressing navigation, tank vessel design, ballast water controls, and replenishment of combatant vessels by containerships. He is a member of the Society of Naval Architects and Marine Engineers (SNAME) and the American Bureau of Shipping. He received a B.S. in marine transportation from the U.S. Merchant Marine Academy, a B.S.E. in naval architecture and marine engineering from the University of Michigan, and an M.B.A. from Johns Hopkins University.

**Roger H. Compton*** is currently the Dean and Professor of Engineering at the Webb Institute of Naval Architecture in Glen Cove, New York. He was formerly Professor in, and Chairman of, the Department of Naval Architecture, Ocean, and Marine Engineering at the U.S. Naval Academy. While on the faculty of the Naval Academy, he participated on the conceptual design team for the Ship Hydromechanics Laboratory, directed the Academy's involvement in the design of the 108-foot Yard Patrol Craft, and was a strong proponent and adviser of midshipman research. Dr. Compton received the Meritorious Civilian Service Award twice and the Superior Civilian Service Award once while at the Academy and was named Professor Emeritus in May 2000. He maintains active membership in a number of engineering societies and is a recipient of the Distinguished Service Award from SNAME, the E. L. Cochrane Prize, and the Solberg Award of the American Society of Naval Engineers (ASNE). He presently serves on the ASNE national council. Dr. Compton holds a B.S. in naval architecture and marine engineering and an M.S. in naval architecture from the Webb Institute, and a D.Eng. in ocean engineering from Catholic University.

**Peter A. Gale** is Chief Naval Architect of the Naval Ship Design and Engineering Operation at John J. McMullen Associates, Inc. Mr. Gale has an extensive background in planning, performing, integrating, managing, and

* Committee member until January 8, 2002.

reviewing naval ship designs. He spent nearly 29 years as a naval architect employed by the Naval Sea Systems Command (NAVSEA) and its predecessor organizations, where he worked in design project management and played key roles in several major aircraft carrier design projects. After leaving NAVSEA in 1988, Mr. Gale taught naval architecture and ship design courses at the Webb Institute for 3 years. Mr. Gale has an international reputation for expertise in early stage ship design and hydrodynamics in ship design. He has written and lectured extensively on these subjects. He holds a B.S. in naval architecture and marine engineering from the Webb Institute of Naval Architecture and an M.S. in nautical engineering from the Stevens Institute of Technology.

**John B. (Brad) Mooney, Jr.,** NAE, is an independent consultant to ocean engineering and research managers. RADM Mooney retired from the U.S. Navy in 1987 after more than 34 years of professional, commissioned officer experience including a total of six commands both at sea and ashore, and various diverse staff assignments in the fields of management, research, education, training, manpower planning, and very deep ocean operations. RADM Mooney was President of the Harbor Branch Oceanographic Institution from 1989 to 1992, Chief of Naval Research from 1983 to 1987, and Oceanographer for the Navy and Navy Deputy of the National Oceanic and Atmospheric Administration from 1981 to 1983. He directed all Navy training and education activities and manpower requirements planning for the Chief of Naval Operations from 1978 to 1981. RADM Mooney is a member of NAE and has served on numerous NRC committees, boards, and commissions. He was chair of the Marine Board Committee on Undersea Vehicles. He received a B.S. from the U.S. Naval Academy and has been honored by a number of societies and associations.

**J. Randolph Paulling,** NAE, is Professor Emeritus of Naval Architecture, Department of Naval Architecture and Offshore Engineering, University of California, Berkeley. Previously, he served as Chairman of the Department of Naval Architecture and as Chairman of the Faculty at the College of Engineering. Dr. Paulling held positions with the research department of Det Norske Veritas, Oslo, Norway; the National Maritime Institute in London; the University of Tokyo; and the University of New South Wales. He is a member of numerous professional societies, including SNAME, where he was Vice President from 1985 to 1988. Dr. Paulling is a member of NAE and was Chairman of the Marine Board Committee on Assuring the Safety of Innovative Structures. He was awarded the David W. Taylor Gold Medal for Notable Achievement in Naval Architecture by SNAME in 1985. Dr. Paulling holds B.S. and M.S. degrees in naval architecture and marine engineering from the Massachusetts Institute of Technology and a D.Eng. from the University of California at Berkeley.

**Irene C. Peden,** NAE, is Professor Emerita of Electrical Engineering at the University of Washington, Seattle, where she also served as Associate Dean of the College of Engineering and as Associate Chair of the Department of Electrical Engineering. She was Director of the Division of Electrical and Communications Systems of the National Science Foundation while on leave from the University from 1991 to 1993. Dr. Peden was the first woman principal investigator to do field work in the Antarctic interior (1970). She is on a number of advisory boards to the Army and the Navy and was chair of the Army Science Board. She was a member of NRC's Polar Research Board and the Commission on Engineering and Technical Systems and has served on a number of NRC committees. She was a member of the Kings Point Advisory Board. Dr. Peden was honored as the National Science Foundation's Engineer of the Year in 1993 and is a member of NAE. She is a Fellow of the Institute of Electrical and Electronics Engineers, the American Association for the Advancement of Science, the American Society for Engineering Education, and the Society of Women Engineers. She received a B.S. in engineering from the University of Colorado at Boulder and M.S. and Ph.D. degrees in electrical engineering from Stanford University. She holds two honorary doctorates: D.Eng. from Michigan State University and D.Sc. (Honoris Causa) from Southern Methodist University.

**Edwin J. Roland,** currently with Elmer-Roland Maritime Consultants, is the former President of Bona Shipping (U.S.), Inc., a tanker operating company in Houston. He has extensive experience in the oil transportation business, having previously served as Vice President of Operations, Planning, and Transportation for Amoco Oil Company; President of Amoco Transport Company; Vice President of Holland America Line; Vice President of Coastal Corporation; and Vice President of Conoco Shipping Company. Before that, he served 11 years in the U.S. Coast Guard. He is a member of the American Bureau of Shipping, Lloyd's American Committee, the Webb Institute Board of Trustees, and the boards of the U.S. Chamber of Shipping and the Liberian Shipowners' Council. He served on the Marine Board Committee for the Oil Spill Risks from Tank Vessel Lightering study and is a member of the Marine Board. Mr. Roland has a B.S. from the U.S. Coast Guard Academy, an M.S. in nuclear engineering and naval architecture from the University of Michigan, and an M.B.A. from Iona College.

**Malcolm L. Spaulding** is Professor and Chairman of Ocean Engineering at the University of Rhode Island, where he has been a member of the faculty since 1973. He is an expert in numerical modeling of nearshore and coastal processes, including hydrodynamics, oil and pollutant transport and fate, waves, and sediment transport. In 1979, he founded Applied Science Associates, Inc., to provide engineering and marine science services to government and private clients. He has managed numerous government research programs and has many publications and honors to his credit. Dr. Spaulding has served on many NRC committees and was chair of the Marine Board Committee on Marine Transportation of Heavy Oil. He was a member of the Marine Board from 1996 to 2001. He received a Ph.D. in mechanical engineering and applied mechanics from the University of Rhode Island.

**Richard W. Thorpe** is Vice President and Principal Consultant at Herbert Engineering Corporation (HEC), a naval architectural and marine engineering firm based in Alameda, California. He manages the east coast office for HEC in Annapolis, Maryland. Mr. Thorpe previously was the Executive Engineer and Principal Consultant with Kvaerner Masa Marine. Mr. Thorpe has more than 45 years of experience in all phases of shipbuilding, naval architecture, and marine and nuclear engineering. He has served three shipbuilders in various roles including nuclear engineering manager, naval ships contract administrator, commercial ship program manager, shipyard operations manager, shipyard strategic planning manager, and research director. Mr. Thorpe served on the Marine Board Committee on Shipbuilding Technology and Education. He holds a B.S. in naval architecture and marine engineering from the Webb Institute, a graduate nuclear engineering certificate from the Oak Ridge School of Reactor Technology, and an M.B.A. from Harvard.