Research in a Mission Agency

ONR — Deep Institutional Commitment to Basic Research

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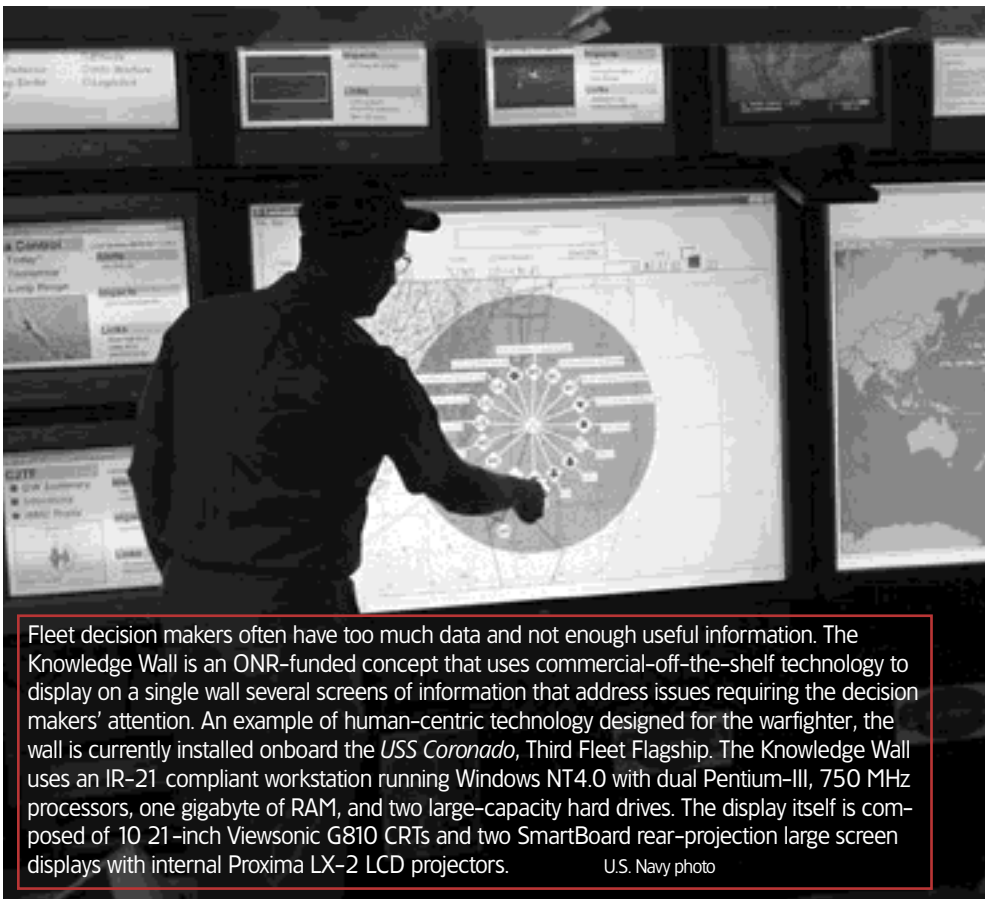
Alphonso the Wise is famously reported to have said, after completing a study of Ptolemy's epicyclic system of astronomy, that he could have offered the Lord some useful suggestions had he been present at the creation. National science policy, which can also seem to be comprised of wheels within wheels, turning to serve a variety of eccentric purposes, is currently undergoing a kind of re-creation at the instigation of Congress.

Discussion of the structure that the policy will assume might benefit from suggestions offered by the agency that was present at the creation of the existing system. Between 1946 and the founding of the National Science Foundation in 1950, the Office of Naval Research (ONR) was the federal government's only agency whose principal mission was the support of research, and so it may well stand in as an institutional version of Alphonso the Wise.



Fleet decision makers often have too much data and not enough useful information. The Knowledge Wall is an ONR-funded concept that uses commercial-off-the-shelf technology to display on a single wall several screens of information that address issues requiring the decision makers' attention. An example of human-centric technology designed for the warfighter, the wall is currently installed onboard the *USS Coronado*, Third Fleet Flagship. The Knowledge Wall uses an IR-21 compliant workstation running Windows NT4.0 with dual Pentium-III, 750 MHz processors, one gigabyte of RAM, and two large-capacity hard drives. The display itself is composed of 10 21-inch Viewsonic G810 CRTs and two SmartBoard rear-projection large screen displays with internal Proxima LX-2 LCD projectors. U.S. Navy photo

ONR - First Agency of Its Kind

Congress passed legislation establishing the ONR on Aug. 1, 1946.[1] An immediate legacy of Vannevar Bush's comprehensive assessment of national science policy, ONR was the first permanent federal agency devoted to the support of scientific research. ONR is also a mission agency; it has a responsibility to sponsor scientific work in the interest of the Navy and Marine Corps. As the first organization of its kind, ONR developed policies and procedures 50 years ago that have become the organizational models for the National Science Foundation and other research agencies.

ONR continues to manage the Navy's scientific research resources. It maintains liaison with the scientific community both in this country and abroad, and it supports research in nearly every major field of science and technology. The purpose of this article is to discuss how and why a mission agency operates.

Historical Context

When Vannevar Bush wrote *Science, the Endless Frontier* for President Franklin

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Delano Roosevelt in 1945, he argued that federal support of basic research would be essential to continued American security, prosperity, and public health.[2] Bush did not, as many people believe, argue that basic science ought to be pursued merely for its own sake. He certainly believed that science was an inherently fulfilling human activity; however, that was not why he thought the federal government should support it.

The Shoaling Waves Experiment (SHOWEX) is a five-year field-oriented departmental research initiative (DRI) by ONR to improve scientific understanding of the properties and evolution of surface gravity waves in intermediate and shallow water depths. These three photos depict researchers aboard the Canadian survey vessel *Frederick G. Creed,* collecting data off the North Carolina coast. The research serves a range of Navy needs: improving wave forecasts, understanding the interactions between waves and acoustical and optical processes; air and sea interaction; remote sensing; forces on vessels and structures; and sediment transport.

ONR photos

Bush understood very clearly that science eventually enriched human life in directly practical ways. His three examples of this, for his 1945 audience, were radar, penicillin, and pay envelopes. He also understood that the specific benefits of basic research were imperfectly predictable at best, and that they were realized only in the relatively long term.

Bush also had the ruins of totalitarian science in Germany to provide a lurid example of what happens when you let ideologues and demagogues tell scientists and engineers what to think. That kind of political involvement strangles science. People say that totalitarian governments are more efficient than democracies, and that their scientific achievements are always ahead of our own. That's false.

Totalitarian regimes, by their nature, eliminate alternative sources of power, organization, and legitimacy—those parts of civil society we recognize as universities, foundations, professional societies, and even informal teams of like-minded investigators. Bush recognized the strength of dispersed authority. "Support of basic research," he advised the president, "in the public and private colleges, universities, and research institutes must leave the internal control of policy, personnel, and the method and scope of the research to the institutions themselves. This is of the utmost importance."

The national science policy Bush proposed was therefore open and institutionally pluralistic, a way of doing business that suited both science and democracy. The federal government would support scientists in a variety of institutions. It would choose whom to support mainly on the basis of the scientific merit of their work. The results would be applied to important public purposes, not all of them chosen or pursued by the government.

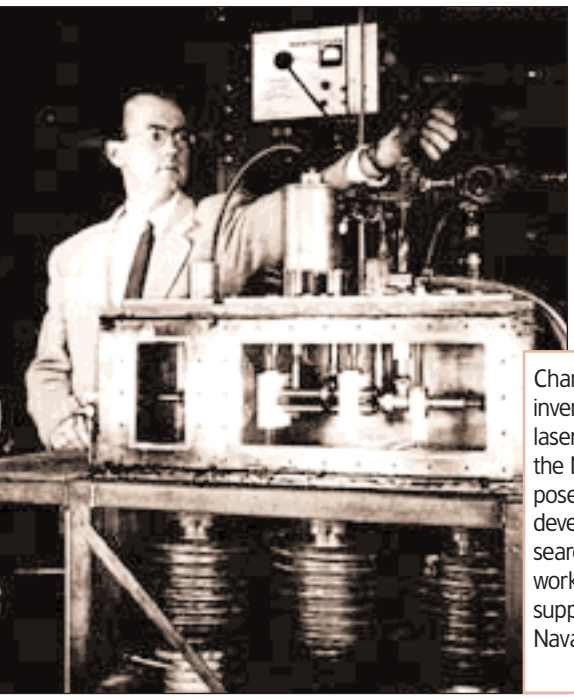
Combining Bush's foresight with their own wartime experience, a small group of Navy officers—some regulars and others wartime reservists who went on to distinguished civilian careers—invented ONR and modern research administration. Known as the "Bird Dogs," they took this name because their wartime duties had included making inspection visits to research facilities on behalf of the Secretary of the Navy's Coordinator of Research and Development—"bird-dogging" the labs for the Coordinator.[3] They were all relatively junior officers with a lot of talent and a lot of energy. Some of their names will be familiar; all of them ought to be: James Wakelin, Bruce Old, John Burwell, Ralph Krause, Thomas Wilson, James Parker, and Gordon Dyke. Their leader was the remarkable Capt. Robert Dexter Conrad, after whom the Department of Navy (DoN) named its top award for scientific achievement.

When the war ended, this resourceful group sought, largely on its own initia-

The "Bird Dogs," a small group of Navy officers — some regulars and others wartime reservists who went on to distinguished civilian careers — invented ONR in the late 1940s as well as research administration. They took this name because their wartime duties had included making inspection visits to research facilities on behalf of the Secretary of the Navy's Coordinator of Research and Development — "bird-dogging" the labs for the Coordinator. Five of the "Bird Dogs" are in this photo: Lt. James Wakelin (standing, third from left); Lt. Bruce Old (standing, second from right); Lt. Cmdr. John Burwell (standing, far right); Lt. Cmdr. Ralph Krause (seated, far left); and Lt. Cmdr. H. Gordon Dyke (seated, far right). The sixth Bird Dog, Lt. Thomas Wilson, is not in this picture. Cmdr. Robert Dexter Conrad, in whose honor the Navy's highest award for scientific achievement is named, is seated next to Gordon Dyke. ONR photo

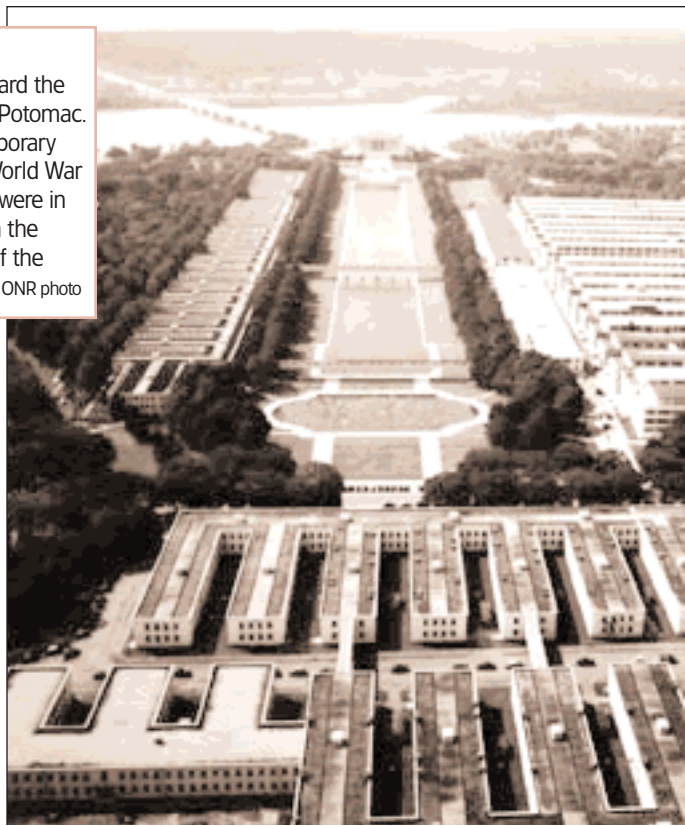
Vannevar Bush (center) photographed while visiting the National Advisory Committee on Aeronautics (NACA) research facility at Langley Field, Va., in 1938. Bush directed America's research efforts during World War II. His study, "Science, the Endless Frontier," has shaped national science policy since its publication in 1945. NASA photo

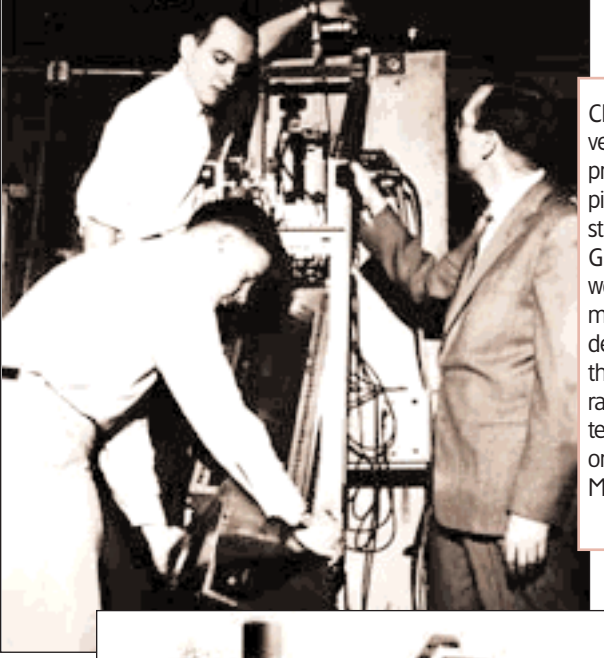
Roger Revelle (inevitable cigarette in hand) at work with a student at Scripps in the mid-1950s.
Scripps Institution of Oceanography photo



Charles Townes, whose inventions of the maser and laser were recognized with the Nobel Prize in physics, poses with an early maser he developed with the Naval Research Laboratory. Townes' work on the laser was long supported by the Office of Naval Research.
Columbia University photo

Looking west down the Washington, D.C., Mall toward the Lincoln Memorial and the Potomac. The Mall is covered in temporary buildings erected during World War II. ONR's original quarters were in Bureau of Ships spaces on the upper right-hand corner of the lower block of buildings. ONR photo





Charles Townes (right), inventor of the laser and its precursor, the maser, is pictured with graduate students L.E. Alsop and J.P. Giordmaine. They are working with an early ruby maser (circa 1957) designed for installation on the Naval Research Laboratory's 50-foot radar telescope. Townes collaborated with NRL's Cornell Mayer on the project.
Columbia University photo

A young Bruce Heezen on a Woods Hole scientific cruise in the early 1950s. With Marie Tharp, Heezen would produce the famous Heezen-Tharp map of the ocean floor. Their work received substantial naval support. In 1998, the Navy's newest T-AGS 60 class oceanographic vessel was named *USNS Bruce Heezen* in his honor. Nine fifth graders from Oak Lawn Elementary School in Cranston, R.I., suggested the name to the Secretary of the Navy.
Woods Hole Oceanographic Institution photo

Jacques Piccard (left) and Navy Lt. Don Walsh standing atop the bathyscaph "Trieste." On Jan. 23, 1960, Piccard and Walsh dove in Trieste to the ocean's deepest point– Challenger Deep in the Marianas Trench – 35,800 feet below sea level. ONR photo

Research Platform FLIP tilting into its working position. A ship-sized spar-buoy with accommodations for a scientific team on board, FLIP is owned by the Navy and operated by Scripps Institution of Oceanography. FLIP has been in service since the early 1960s. ONR owns several famous research vessels and platforms, including the famous submersible ALVIN, operated by Woods Hole Oceanographic Institution. Scripps Institution of Oceanography photo

tive, to make sure the Navy's beneficial relationship with academic scientists continued. They knew three crucial cultures well: the Fleet, the federal government, and the universities. These three groups not only have different interests, but they often seem to speak completely different dialects of English. Luckily the Bird Dogs proved fluent translators.

Recognizing that nothing in Washington gets done without legislation and a budget, Conrad succeeded in getting both. He and his people then had to develop a system whereby the government could support scientists in a way that met both the government's responsibility for fiscal accountability and the scientists' need for intellectual freedom — a seemingly impossible task.[4]

The government contracts that had been used until the end of World War II were cumbersome and restrictive instruments. The wartime collaboration between the DoN and various universities, while undeniably successful, had not been without friction, and many university researchers formed a set determination to forego further work on military research programs. In many cases, their reluctance to continue working with the military was founded on their experience with a cumbersome contracting system.

Conrad decided to develop a new kind of contracting system that would eliminate most of the restrictions that grated on university scientists during the war. He sold Congress, the DoN, and the universities on a system that would permit one overall contract to be issued to a university, with individual tasks for scientists attached. Such contracts would permit support of basic research. The work done under them would be unclassified, and the scientists could publish it. This was a new way of doing business, and it probably did as much as anything else to make federal support of science possible and successful.

One of ONR's early program officers, the great oceanographer Roger Revelle, formulated five typically curmudgeonly rules for ONR to follow — *Guiding Principles for Evaluating Research Proposals*:[5]

- Emphasis should be on the merit of the scientific approach. Navy relevance will follow.
- If the proposal emphasizes Navy relevance, turn it down.
- If it's fewer than $5,000, fund it.
- No peer review. It leads to the lowest common denominator. [That is, the lowest common denominator in a mission agency. Peer review works fine for the National Science Foundation, but they are not a mission agency.] Rely on good program managers.[6]
- Long-term individual and institutional support are essential if a field is to survive and grow.

If you make allowances for overstatement, these guiding principles are not a bad summary of that early approach to funding basic research. With due allowances for inflation and comptrollers' discipline, this is roughly speaking how ONR has done business for the last 54 years.

The original permanent research establishment, ONR has evolved over the last 54 years into something more diversified and in some respects closer to its operational customers than its founders envisioned. The greatest change occurred in fiscal 1992, when the Office of Naval Technology (ONT) and the Office of Advanced Technology (OAT), separate agencies that reported to the Chief of Naval Research, were folded into ONR. With the absorption of ONT and OAT, ONR picked up responsibility for applied research and technology development. Since then, ONR has worked to integrate the research it supports and to produce an investment portfolio that does justice to its several constituencies such as Congress, the Fleet, industry, and universities — all while retaining its deep institutional commitment to basic research.

Research in a Vertically Integrated Organization

As their names imply, ONT and OAT had been responsible for research that had a clear and relatively short-term payoff: hull coatings, radar masts, and missile control surfaces. Development of such items falls into the Department of Defense (DoD) budget activities known as 6.2 and 6.3 funding — applied research and advanced technology development respectively. ONR, by contrast, had been largely involved with 6.1 funding — basic research.

(It's worth noting here that our vocabulary has changed over the last half century. In 1946, when ONR was founded, "research" meant what we would nowadays call "science and technology." In the 1960s, "research" increasingly appeared in the phrase "research and development," which represented the later stages of technological development, and included such activities as prototyping and engineering development.)

Roughly speaking, in the DoD lexicon, basic research seeks to advance understanding of fundamental aspects of processes and properties. Applied research then seeks ways of altering, manipulating, or using those processes and properties in such ways as may meet a specific, recognized need. Advanced technology development involves taking the results of applied research and actually fabricating things that perform some useful function, that provide some desirable capability, and trying them out in *demonstrations* that judge their utility or feasibility.

Higher numbered budget activities, 6.4 and up, no longer belong to the administrative world of science and technology proper, but rather to acquisition, operations, and maintenance. They lie outside the scope of this discussion, but we should keep in mind that results from 6.1, 6.2, and 6.3 ultimately feed projects in those other categories as well.

The picture the budget activities suggest when one lays them out like this is an eminently rational one. Each level hands on the product to the next for refinement in a smooth, linear, efficient progression — a kind of assembly line that mills concepts into hardware. In fact, however, the research enterprise is so notoriously difficult to integrate in such a straightforward manner that counsel against naive optimism is common. Nobel laureate Joshua Lederberg is often quoted among

research managers as advising that "the best way to achieve scientific progress is to resist the temptation to control it."

Paul Nitze, Secretary of the Navy in the mid-1960s, encountered the perennial challenge of showing that research pays by demonstrating that basic work actually generated some particular weapon, tool, or system. He talked about this when he addressed ONR's vicennial celebration in 1966. "I would note," he said, "that the exercise of actually attempting to trace such parentage is often more academic than fruitful, for the trace quickly becomes dim, and no rational sequence seems to prevail. This is inevitably the nature of creative ideas, basic answers, and basic data for which, once we have them, applications are seen. Yet data by themselves are sterile; it is the ephemeral idea that makes them useful."[7]

Nitze' words were by no means a counsel of despair, and were not taken as such. ONR's assumption of responsibility for research, applied research, and advanced technology development suggested anew that efficiencies might be realized from vertical integration. If work supported from all three budget activities — 6.1, 6.2, and 6.3 — could become mutually supporting, all of the customers would win.

ONR believes it has found the appropriate agents of such integration in the staff scientists who serve as its project managers. They have the appropriate technical expertise and scientific credibility to administer awards and recognize quality; in the marketplace of science and technology, they are the Navy's ultimate smart buyers. They continue to work in the spirit of Roger Revelle (albeit with modifications to his third rule — there aren't that many $5,000 research proposals anymore).

Preserving Effectiveness, Showing Results, Making a Difference

Defense support for science and technology is no longer as dominant as it was in the palmy days of the late 1940s. Budgets have declined in relative terms, particularly since the Vietnam War brought with it both high operating costs and public disaffection with military-supported research. Even during the small renaissance the Defense establishment enjoyed in the waning days of the Cold War, Defense investment in research and development had begun to be eclipsed by industry investment. We must note that the growth in industry research and development has occurred largely in rapid product development, and less so in the research, or science and technology end of the spectrum.

ONR's goal is to keep naval science and technology healthy so that the United States retains a robust capability to work on long-term scientific and technological problems of importance to the Navy and Marine Corps.

Budgets have remained tight during the retrenchments of the past decade. Recently, however, there have been some positive signs: the President's requests for science and technology funding have improved, and Congress has spoken out loudly for real growth in this area.

A sensible investment strategy would be to aim first and most obviously at stabilizing funding. Stable funding, less obviously but most importantly, is essential to establishing a strong, solid 6.1 and 6.2 technical base. On this base, and only on this base, can one build an appropriately focused science and technology program that preserves a balance between long- and short-term objectives.

ONR, therefore, thinks of its work as divided broadly into two mutually supporting and integrated parts: the discovery and invention on the one hand and the exploitation and delivery on the other. In this discussion, we will concern ourselves mostly with discovery and invention, but as we do we must understand five principles:

- ONR's program is integrated. Discovery and invention not only feed exploitation and delivery, but are reciprocally guided by the awareness of operational needs that exploitation and delivery provide.
- ONR's program officers are the locus of integration. Only first-rate scientific and engineering talent, steeped in a naval mission organization, is capable of integrating science and technology.
- ONR exists to serve the Fleet and the Marines. It can do so by continuing the Bird Dogs' tradition of serving as translators between the very different worlds of academic science, military operations, and industrial production.
- ONR seeks to foster the development of "disruptive technologies" — new capabilities not envisioned by operators' requirements. In order to do so, it works closely with the Naval Warfare Development Command and the Marine Corps Combat Development Command.

Awareness – Key to Discovery and Invention

Two important elements of the DoN's discovery and invention program that rest immediately on the 6.1 and 6.2 technical base are the National Naval Responsibilities (NNR) and the Naval Science and Technology Grand Challenges (NSTGC). NNRs are research areas like ocean acoustics that the Navy has to cover because the nation expects and requires it, and because no other agency or private enterprise can be expected to do so. The NSTGCs, which help ensure that the Navy and Marine Corps are unlikely to be caught short 50 years hence, are a set of very difficult, but probably achievable, scientific and technical chal-

lenges ONR proposes to the research community. They are intended to be visionary, designed to meet what will in all likelihood prove to be compelling needs of the Navy and Marine Corps After Next, and to afford many participants (from a broad range of disciplines) multiple opportunities for exciting, creative, risky research.

The NNRs and the NSTGCs have an irreducible requirement for the highest quality basic and applied research, and the DoN is determined to sustain the technical base that can provide it. This technical base is also the locus of what might be called "vision" — the ability of a program officer to recognize a promising line of research even before it has been summoned by a formally declared requirement.

Such vision is more than serendipity. ONR's Mike Shlesinger, for example, saw the potential importance of chaos theory many years ago, and had the vision to invest in this new, and then high-risk, area. He was the first federal investor in chaos research. The DoN is currently well on its way to using the work he pushed in his capacity as a program officer in order to solve the problem of resupplying ships in sea state 3.

About half of the DoN's science and technology budget goes to the longer-term efforts of invention and discovery.

Executing a Balanced Program

ONR sponsors all of the Navy's science and technology. Any discussion of ONR's project selection process must recognize the fact that ONR is a mission-oriented sponsor of research. It encourages the acquisition of fundamental knowledge needed to solve future military problems for the Naval Services After Next in areas like communications, surveillance, targeting, propulsion, mobility, guidance and control, navigation, energy conversion, materials and structures, personnel support, and (again) the disruptive technologies needed for leap-ahead naval innovations.

Because of ONR's mission, project selection must be a two-step process. First,

Naval science and technology remains an irreplaceable national asset.

ONR must establish broad programmatic thrusts and priorities reflecting a suitable balance between naval need and relevant scientific opportunity. Next, it must select specific research projects and tasks to implement those broad thrusts and priorities. Both steps are essential.

ONR depends primarily on its program officers for the selection of specific research projects. Academic peer reviewers cannot be expected to be knowledgeable about the naval mission and its research implications. ONR's exceptional cadre of program officers made its past record of achievement possible. ONR program officers are encouraged, as a matter of policy, to be active researchers and to play a leadership role in the scientific and engineering communities while establishing and maintaining close communication with the naval acquisition and operations communities who will ultimately use the products of their research programs.

Partnership in Research

In 1998, Congress took a long look at Vannevar Bush's legacy and issued a thoughtful report on how that legacy might be preserved and enhanced. *Unlocking Our Future: Toward a New National Science Policy*, commonly called the Ehlers' Report, substantially endorses the vision of *Science, the Endless Frontier.* But it also adds a new concern for the environment, education, the importance of partnerships in science and technology, and the need to make the best science available for public debate and decision on policy.[8]

Collaboration among government, industry, and academia permits each partner to bring distinctive strengths to bear on common problems, and to discharge their distinctive responsibilities while they do so. The government can set requirements — in our case naval requirements — to catalyze science and technology, and to provide a degree of program stability. Program stability is very important when the sciences are being expected to inform national policy on matters that involve decadal trends. Industry knows commercial requirements and markets, brings considerable economies of scale, and above all contributes expertise in design to component and system production. And academia brings ideas, imagination, creativity, and a willingness to take intellectual risks.

ONR program officers play the key role in project selection and management. They are given broad discretion in the selection of external projects for support, and are then held responsible for their results. Although there is no formal peer review process of proposals at ONR, the program officers do seek the advice of associates within the DoN and of appropriate outside experts. The methods employed to seek expert advice, which may be highly structured or informal, are determined by the program officer to meet the particular needs of his or her program.

Since the whole point of peer review is to ensure technical integrity, ONR meets this important requirement through peer review, not of proposals from investigators, but of the program officer's portfolio. Thus the program officer, and not the individual scientist in a university, laboratory, or institute, undergoes the review. We have found that this policy — peer review of portfolios, not proposals — lets ONR take a chance on young investigators who haven't yet established the kind of reputation and publication record that peer reviewers commonly look for in proposals. It also permits ONR to take a shot at potentially disruptive technologies that have yet to find their way into mainstream thinking. This avoids sinking to the lowest common denominator that Roger Revelle warned mission agencies against back in the early 1950s.[9]

External and internal program reviews are both helpful. The program officers

are ultimately responsible for a project's contribution to naval goals. Department Directors, Division Directors, and external Boards of Visitors review their decisions, but their decisions on proposals are rarely second-guessed. The program officers themselves stay close to their investigators and performers through frequent contact, including site visits, and they are well prepared to answer for their programs.

Because of the requirement to select programs that have outstanding technical merit and fit into an overall set of programmatic priorities, program officers cannot be passive and simply react to proposals as received from the academic community. They must play a very active role in communicating ONR's programmatic interests and priorities to the academic community and in seeking out technical opportunities relevant to Navy priorities.

Not only do they spend considerable time visiting university laboratories, scientists, and engineers for this purpose, they also organize special workshops and conferences, and monitor and participate in relevant activities of the National Academy of Sciences, professional societies, and other organizations. To do this effectively, they must have established a certain level of visibility and stature in their research communities.

The program officers also belong to the DoN, and they very actively seek current awareness of what the Navy and Marine Corps need.

Final Thoughts

ONR certainly has the management tools in place to ensure that it supports high-quality science and technology on behalf of the DoN. While it stands on its founding principles, it works toward collaboration with national and international partners, alert for opportunities to better meet the needs of the DoN. But fundamentally, its record of accomplishment depends more on the outstanding quality of its program officers, and the authority given to them, than on any particular process for project review and selection.

Robert Frosch, a former Assistant Secretary of the Navy, who later served as a NASA Administrator, and more recently, Director of Research for General Motors, summed it up by saying, "Style is much more important than organizational detail and process, and style is what ONR always had."

ONR's goal is to keep naval science and technology healthy so that the United States retains a robust capability to work on long-term scientific and technological problems of importance to the Navy and Marine Corps. We seek to keep an adequate pipeline of new scientists and engineers in disciplines of uniquely naval importance, and to continue to provide the scientific and technological products necessary to ensure continued superiority in naval warfare.

What would happen if the DoN's science and technology budgets were eliminated? Would they be transferred to other agencies? History gives us little cause for optimism on this point. And even if the funds were to go elsewhere for application to research, it is unlikely that other agencies— no matter how competent, well-intentioned, and hard-working —would soon be able to replace the networks of support, communication, and cooperation that have evolved within the naval research community over the past 50 years. Naval science and technology remains an irreplaceable national asset.

Editor's Note: The authors welcome questions or comments on this article. Contact Gaffney at **gaffneyp@ndu.edu**; Saalfeld at **saalfef@onr.navy.mil**; and Petrik at **petrikj@onr.navy.mil**.

ENDNOTES

1. Public Law 588-79th Congress, Chapter 727-2nd Session (H.R. 5911). The Office of Naval Research is now authorized in 10 §5022, United States Code. Its present organizational form was established in SECNAVNOTE 5430, Dec. 4, 1992.
2. Bush, Vannevar, *Science, the Endless Frontier: A Report to the President*, Washington, D.C., July 1945.
3. This account of the Bird Dogs is drawn from ONR's institutional memory, confirmed by "The Evolution of the Office of Naval Research," *Physics Today*, Volume 14, No. 8, August 1961, pp. 30-35. The author of this article is given simply as "The Bird Dogs."
4. Harvey M. Sapolsky recounts this period of ONR's history in *Science and the Navy: the History of the Office of Naval Research*, Princeton: Princeton University Press, 1990. For a contemporary account of the system that evolved under Conrad's leadership, see Roger D. Reid, "Freedom and Finance in Research," *American Scientist,* Volume 41, No. 2, April 1953, pp. 286-292. For a somewhat earlier account of how ONR's success caused it to serve as the model for the National Science Foundation, see John E. Pfeiffer, "The Office of Naval Research," *Scientific American,* Volume 180, No. 2, February 1949, pp. 11-15.
5. Revelle, Roger, "Guiding Principles for Evaluating ONR Research Proposals," circa 1948, and preserved by Douglas L. Inman of the Scripps Institution of Oceanography.
6. And not only Revelle. Many reflective scientists and observers of science have commented on the stultifying effect of peer review. For a good presentation of this argument, see Deborah Shapley and Rustum Roy, *Lost at the Frontier: U.S. Science and Technology Policy Adrift* (Philadelphia: ISI Press, 1985), especially pp. 54-55 and 102-107. Roy's views on the subject appear at length in his "Alternatives to Review by Peers: A Contribution to the Theory of Scientific Choice," (*Minerva*, Volume XXII, No.3, 4, Autumn-Winter 1984, pp. 316-327).
7. Nitze, Paul A., "Perspectives on Naval Research," in *Research in the Service of National Purpose*, Washington: Office of Naval Research, 1966.
8. House Committee on Science, *Unlocking Our Future: Toward a New National Science Policy.* Washington: U.S. House of Representatives, Sept. 24, 1998.
9. Robert Frosch makes a related point about technological progress in "The Customer for R&D is Always Wrong!" *Research -Technology Management,* November-December 1996, pp. 22-27.