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ROLES OF IN-HOUSE R&D INSTITUTIONS IN A FREE ENTERPRISE SYSTEM

As our nation has moved from an agricultural to an industrial and now to a high-technology society, the Navy has been similarly transformed. It is interesting to look at the high technology R&D process and to consider the roles for the various institutional components of that process, particularly an in-house organization such as the Applied Physics Laboratory of The Johns Hopkins University.

To analyze the process, it is useful to have a model. Donald K. Price provided one such model.[1] In his discussion he looks at the process of going from the generation of basic knowledge, or what one would consider research-level science, to the exercise of arbitrary decision making or power. In our democratic system, that arbitrariness is reserved for people in the political process. In particular, the raising and allocation of funds to support research and development is the province of Congress. Within the spectrum defined by Price, there are two other key elements—the technologists who translate basic knowledge into useful products and the administrators who are the coordinators of the overall process.

Each of these four communities of people who operate in the high-technology R&D process—scientists, technologists, administrators, and power brokers—has a unique perspective and function. The scientists are driven by their internal search for basic knowledge, take pride in peer group acceptance, and value knowledge for its own sake. The technologists or engineers tend to be interested in utility and find their satisfaction in developing a product. These communities of scientists and engineers are linear-rational thinkers who believe in causality. They tend to be idealists. The third community is made up of the administrators, who have neither the fundamental knowledge nor the output of useful products, but who are responsible for bringing together the first two communities to accomplish specific objectives. The administrator community tends to be made up of people who have moved out of the scientists' or the technologists' fields. Often they are not appreciated because they are viewed as people who, in some fashion, have taken on a role that the scientists and technologists do not respect. The fourth community is made up of the power people. In a democratic system they are the politically elected officials. They are often denigrated by the science and technology community, which does not understand their different concept of reality.

It is critically important in all of these communities to appreciate and respect the perceptions of the others. At the extremes of the spectrum, with the scientist on the "truth" end and the politician on the "power" end, there is often a great deal of misunderstanding. The orientation of the scientists tends toward the long term. They may seek new knowledge over a long period of time and conduct many experiments before reaching any conclusions. In contrast, the politicians' horizon is bounded by about two years. Anything longer than this time span for the members of the House of Representatives represents an improbable world. Many times scientists feel strongly about having ideas that would be of great value to society if only they were appreciated by people in positions of administrative or political power and were provided with the necessary funds to follow them up. What they often do not appreciate is that the politicians, in the true sense of the meaning of politics, exist by mediating values. For them, scientific truth is only one item of value to society. In comparing these values, in the politicians' concept of political reality, they may not come down on the side of support for the scientists. There tends to be an arrogance or ignorance on the part of the scientists, who equate this lack of support with lack of understanding, when in fact the politicians may understand quite well. Conversely, administrative and political communities must have both appreciation and tolerance for the failures that go with research and development, particularly scientific research, and for the necessity of an extended time frame.

Our institutions often use neat deterministic processes such as program planning and budgeting, where unforeseeable scientific breakthroughs are expected to fit

Based on a lecture to the APL Principal Professional Staff, December 12, 1983.

neatly into five-year plans. But scientific research is a probabilistic process. It is neither neat nor orderly, and it certainly includes many failures in explorations that do not pan out. Therefore, when politicians or administrators seek to fit this unpredictable process too closely into programmatic structures and make it too neat and orderly, they have failed to understand the nature of the scientific process.

In looking at the nature of science and technology within our society and in particular within the Navy, one wonders where the in-house institutions fit. The Navy is driven by technology and it must depend on the scientists for its future means of performing its function of war at sea. The Navy occupies in the technological marketplace a position of purchasing things it may never consume or may consume only once. It is not possible to purchase them, try them in combat, and then select from a series of alternatives as one might purchase and try a fleet of automobiles and compare them under realistic operating conditions. Therefore, it is critical that the Navy decision makers, as they are equipping the Fleet to fight wars at sea, have at their disposal the best knowledge possible when they are buying in the technological marketplace. It must be a knowledge that is a combination of competence and integrity and is objective without question. It is not reasonable to go to the free enterprise marketplace from which the Navy will buy its tools and ask it to advise which tools to buy. This is what dictates the need for in-house institutions.

The Navy has many of these in-house institutions. One is the Applied Physics Laboratory (APL), which belongs to a class called research and development centers. A few others are associated with universities and nine are civil service centers attached to the Naval Material Command. In order to be able to advise the Navy on how to buy weapons, it is necessary that these R&D organizations not only do research and development, but also interact with the Fleet in a support role. This has led to the in-house institutions of the Navy, which have a full-spectrum role from research and development through Fleet support.

Laboratories tend not to be populated predominantly by scientists but by technologists who translate knowledge into form and therefore must have a product that is usually something other than written reports. As we move more and more into computer science, the form may be a computer program in contrast to a hardware prototype.

Since most of the people in the research and development centers are technologists and not scientists, it is critical for their sense of well-being and worth to develop some form of product, preferably as visible prototypes. It is also critical that the involvement of R&D centers continue beyond prototype development in order to get the full understanding of the implications of a technology after it has been tested in prototype form. Since the Navy uses its in-house institutions as its advisors, they must have full knowledge of the implications of technology, which cannot be gained by mere observation. There must also be basic research in areas that are of particular interest to the Navy and are of little commercial value, in areas that have not received sufficient attention in a commercial world, and in areas of such high risks that commercial institutions will not invest funds in them. There are many examples of these, e.g., chemical explosives and propellants, mines, large caliber guns, and various other tools that are unique to the craft of war and foreign to the commercial marketplace.

One of the questions that is asked is "Where is the balance between research and applications orientation at an institution such as APL?" It is always difficult to obtain sufficient support for basic research. Several years ago Alvin Weinberg proposed that we tax technology to provide funds to support basic research.[2] He argued that an institution should take a portion of its cash flow in the applications end of its work and apply that to basic research. We tend to do it differently within the Navy by appropriating funds specifically for research, handled primarily through the Office of Naval Research. But in looking at an institution rather than at the source of the dollars, the character of an institution— particularly one associated with a university—must strike a balance between its basic research and its technological orientation.

There is a great temptation to want to do only basic research because there is a certain element of elitism and intrigue about it. The university flavor also encourages some of the more brilliant scientists in the laboratories to push for research. But historically, institutions have never been able to survive effectively by performing research only; this goes back well beyond the origin of APL or the other research and development centers of the Navy. The long-term nature of research and the high percentage of failures in terms of discovery and useful products resulting from the investment are such that only an institution that can establish its worth through other endeavors can properly insulate its research from the critics of the environment in which it exists. The Navy is no different in this regard. The Navy would probably not long support an institution from which it did not see some short-term gains. If there is enough short-term value, then that institution can probably afford to support, without criticism, a reasonable percentage of its workers in long-term basic research.

University-associated laboratories play a very special role within the Navy. They are tied to the source of scientists and engineers. They have a certain intellectual appeal that gives them an influence within the system that the in-house civil service laboratories do not have. They also avoid having to deal with a national equity system like civil service, making them more flexible in attracting and retaining top-rate scientists and enabling them to modify their pay system on the basis of the marketplace as opposed to a politically-driven system. However, there is a place for both types of laboratories. There is a negative side to the university association. There have been instances when university-affiliated institutions refused to do work for the Navy or had difficulty supporting the work while retaining their association with the university because of the political unpopularity of the military.

Overall, university-associated research and development centers play a vital and critical role. The process of going from truth to power, to translate science and technology into useful products, provides tools that the Navy may use to carry out its mission, which is to wage war at sea. It is critical that the Navy have the best advice available when selecting those tools. Research and development centers such as APL provide not only technological options but competent advice that is given without concern for future profit and therefore is unquestioned in its integrity. To be able to translate knowledge into useful products is to have both truth and power.

REFERENCES

[1] D. K. Price, "The Spectrum from Truth to Power," *Science, Technology and National Policy,* Cornell University Press, Ithaca, pp. 95-130 (1981).

[2] A. Weinberg, *Criteria for Scientific Development: Public Policy and National Goals,* The MIT Press, Cambridge, Mass., pp. 81-91 (1968).