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Developing a National Marine Electronics Agenda: Proceedings of the Marine Instrumentation Panel Meeting September 12 - 14, 1989.

edited by

Arthur G. Gaines and Kristina L. C. Lindborg

December, 1990

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Arthur G. Gaines and Kristina L. C. Lindborg

Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

December, 1990

Technical Report

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James M. Broadus III, Director
Marine Policy Center

PREFACE

This volume contains collected papers from the 1989 meeting of the Marine Instrumentation Panel (MIP) covering aspects of competitiveness in the marine electronics instrumentation industry. Topics addressed at the meeting had been identified largely at the previous year's MIP meeting; presentations were by invitation. The 1989 meeting was convened at Woods Hole, Massachusetts, from September 12-14. A complete agenda as well as the attendance list are given in appendices I and II. As evidenced by their absence from this volume, a few papers were regarded as inappropriate for publication by their authors.

Deliberations of the Panel are an integral part of our program, *Developing a National Marine Electronics Agenda*, which aims to develop a prescriptive set of recommendations to help invigorate and strengthen the marine electronics industry. Our interest in this industry stems from the fact that it supplies products to the oceanographic (aquatic) research and monitoring community; acts as a conduit through which instruments developed by ocean scientists and engineers are commercialized; and constitutes a significant economic factor in parts of the United States and other nations.

Our program is funded through the Office of NOAA Corps Operations and organized through the Massachusetts Centers of Excellence Corporation (MCEC). MCEC is a partnership program linking government, academia, and the private sector in joint programs whose vitality springs from the collaboration. Our program has included participation by three academic/research institutions: The Oceanic Institute (Hawaii); Florida State University; and the Woods Hole Oceanographic Institution. Participation by industry and government comes through the Marine Instrumentation Panel at events such as this conference, and through review of written program products.

Papers in these proceedings were compiled and edited by Ms. Kristina Lindborg, who was enlisted specifically for this task. Ms. Theresa McKee, a Research Assistant at the WHOI Marine Policy Center provided crucial help in organizing the conference and finalizing the camera ready draft, including editorial work and graphics.

Arthur Gaines
Program Manager
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ABSTRACT

Thirteen short papers address aspects of competitiveness in the marine electronics instrumentation industry. Topics include activity and status of government initiatives in Japan and Europe to promote this industry; and the possible role of federal-state collaboration in the U.S. Papers address technology transfer between research institutions and the commercial sector; the role of "strategic alliances" in this process; and the "dual-use" concept in effective technology development and commercialization. Other papers address electronic technology applications in specific marine areas, such as the use and implications of the COMSAT mobile satellite communication infrastructure; electronic charts and safety of tanker operations; and instrumentation applications in aquaculture and environmental monitoring.

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Developing a National Marine Electronics Agenda

Gary Glenn
Massachusetts Centers of Excellence Corporation

Background

The proposal to the National Oceanic and Atmospheric Administration (NOAA) to create this project, entitled, *Developing a National Marine Electronics Agenda*, was submitted in final form just over two years ago. The final proposal was the fifth draft we had submitted. The problem was apparently a conceptual gap between the questions we wanted to ask and NOAA's need for some operational specificity. We, as the proposers, had what amounted to a sequence of questions marks and unknowns. We knew that our central questions all revolved around issues of competitiveness.

For instance, why could some sectors of the U.S. economy compete successfully with foreign commercial interests while others could not? Why did technologies originally developed with strong U.S. government financial involvement so often end up benefitting non U.S. companies? And, what was the proper balance to be struck between governmental, private, international security, and other interests?

NOAA, on the other hand, wanted more than just open questions. It also wanted an indication of what direction would be taken, what data would be collected, and where the whole enterprise was headed. We finally managed to compromise on a project description that had a good deal of specificity in terms of method but also allowed the various investigators wide latitude to follow the logical outcomes of their research.

The core of the proposal to NOAA can be summarized as follows:

The project described in this proposal is designed to assess the competitive position of the U.S. marine instrumentation industry in order to obtain empirical baseline data required for preparation of policy guidelines relevant to increasing the competitiveness of the United States in the worldwide marine instrumentation market.

Our concern on the specific level was to identify factors and circumstances in the marine electronics industry which related to the competitive status of the U.S. industry. On a broader level, we also hoped to determine the extent that this industry could be used as a real world case study to trace the affects of the many factors influencing U.S. industrial competitiveness in the world economy -- especially toward the close of the 20th century.

During the two years we have been at this task, other relevant activities, some parallel and some tangential, have also been underway. I would like to mention three activities that directly relate to the current study.

First, one of the most significant recent actions by the federal government has been the passage of the Omnibus Trade and Competitiveness Act of 1988. This legislation contains over 400 sections, divided into ten major titles. It fills 149 pages in the Congressional Record and another 156 pages of Explanatory Comments. A quick review of these titles will demonstrate the scope of the legislation and its relevance to our current task.

Title I deals with "Trade, Customs and Tariff Laws," and contains several subsections of interest to our deliberations in this project. Subtitle C contains legislation relating to "unfair international trade practices," and Sections 1303, 1305, and 1306 all target Japan as a potential violator of good trade relations. Subtitle C also contains legislation concerning the protection of intellectual property rights. Title II focuses on "Export Enhancement" and contains 71 sections which deal with everything from support for the Overseas Private Investment Corporation and negotiations with COCOM to sanctions against Toshiba and Kongsberg. Title III deals with "International Financial Policy" and includes a number of sections of importance to current and perspective exporters.

Section IV covers "Agricultural Trade" and includes some legislation of interest to U.S. aquaculture interests, especially in terms of establishing precedents for certain policy formulations. Title V deals with both foreign corrupt practices and what is generically called "investment and technology." Under this rubric, the Act broadens and redefines the National Institute for Standards and Technology (out of the old National Bureau of Standards) and establishes a number of technology related programs and policies. Subtitle C of Title V is the "Competitiveness Policy Council Act," and Subtitle D is the "Federal Budget Competitiveness Impact Statement," which in turn has two parts -- the National Trade Data Bank (Part I) and the requirement for competitiveness impact statements (Part II).

Each of the other titles contains at least some legislation of interest to us: Title VI is "Education and Training for American Competitiveness." Title VII is the "Buy American Act of 1988." Title VIII is "Small Business." Title IX is "Patents." Title X is "Ocean and Air Transportation".

Needless to say, given the objectives of our project to "develop a national marine electronics agenda," our deliberation will be enhanced by a thorough understanding of the Omnibus Trade and Competitiveness Act.

Second, in the past year there has been a major outpouring of books, articles, essays, and miscellaneous writings on various aspects of competitiveness. One of the most influential has been, "Made in America: Regaining the Competitive Edge," prepared by the Massachusetts Institute of Technology Commission on Industrial Productivity. In testimony before Congress in May of 1989, four authors of the book told the Senate Committee on Labor and Human

Resources that their study indicated six principal across-the-board weaknesses in major U.S. industries -- most of which appear to afflict the marine electronics industry as well.

As a result, the Commission recommended five "imperatives" to restore U.S. competitiveness. These include cultivating a new, economic citizenship through more extensive worker training and participation in firms, and learning to live more effectively in a world economy. The Commission also recommended a series of specific policy steps, such as rebuilding the nation's technological infrastructure and making a major commitment to improve education at all levels, with special emphasis on grades Kindergarten through 12.

It is clear from a review of "Made in America" and many other writings on the subject that certain themes are universal. The problem then is how to make the importance of this issue more apparent next to the many other priority issues competing for attention at the state and national levels.

Third, there is a sentiment in Congress and in the home districts of many Congressmen that favors increased government involvement in trade issues and support for 'Buy American' policies. The House of Representatives bill authorizing \$310 million for the Maritime Administration requires purchase of U.S. manufactured goods if the cost differential is no greater than 6 percent. There is a mood for action in Congress -- regardless of what that action might be. There are currently five major bills pending in Congress that deal with the various aspects of competitive positioning. The "National Cooperative Innovation and Commercialization Act" would facilitate joint production, distribution, and marketing activities of U.S. firms by relaxing antitrust laws. It would also establish a procedure by which the Department of Justice and the Federal Trade Commission, in consultation with the Department of Commerce, could review proposed joint ventures. If the agencies were to approve a venture, the participating firms would be relieved of all potential civil and criminal penalties for activities performed within the scope of the agreement.

Similarly, "The Cooperative Productivity and Competitiveness Act" would amend the National Cooperative Research Act of 1989 by allowing joint production of products, processes, and or services.

Overall, U.S. business practices are being examined much more closely. It has been widely reported that in the early 1980's, U.S. chip manufacturers such as Intel, Motorola, National, and Zilog licensed their microprocessor technology to Japanese companies in order to secure short term financing, without negotiating any reciprocal exchange of technology. This short-sighted action boomeranged when the intellectual property was used by the Japanese companies to capture market share.

More recently, NeXT Computer accepted \$100 million from Canon for 16.7% equity, and virtually every major U.S. computer manufacturer (the list includes Hewlett Packard, TI, Cray, Tandy, Sun and Maxtor) either has entered into joint deals, or is now negotiating such a deal.

There is currently a major debate raging over so-called strategic alliances, which allow individual companies to make their own deals, versus "industrial base protection" (supported by techno-hawks.) The effort by Fujitsu to buy Fairchild was thought to be too great a threat, but many other such deals are pending. One very controversial deal involved the sale by Atlantic Richfield of its photovoltaics (PV) subsidiary, Arco Solar, to Siemens AG of West Germany. Arco Solar has received millions of federal dollars for PV research and is the leading U.S. PV company. Major breakthroughs have occurred in PV technology in the past year and many applications are opening up for PV devices. However, the U.S. funded technology is now German owned.

There are many parallels between the PV situation and marine electronics and instrumentation companies that may be purchased by foreign companies after receiving major amounts of federal funding, or where technology finds its way into foreign hands in other ways.

The point is that significant parts of the competitiveness problem are receiving close attention in Washington, and legislation is being drafted, written, debated -- and in some cases passed -- which is designed to deal with various parts of the whole dilemma. What we might hope for is a coordinated, cohesive, and continuing set of policies rather than short-term, ad hoc solutions that address only a fraction of the problem.

Summary

In summary, it seems to me there are some basic questions we need to keep asking. In policy terms, there will be some kind of answer eventually, because even inaction has its consequences.

The first basic question has to do with defining the relationship between the military and the private sector. As "Determining the Structure of the United States Marine Instrumentation Industry and its Position in the World Industry," (produced by this project) points out, the military plays a major role in marine electronics -- from funding research to identifying products to procuring products and services. That amounts to about three quarters of the \$3 billion U.S. market for marine instruments. Given the military's primary role as the protector of national security and its secondary but growing role as the promoter of U.S. economic strength, the question then is, what affect does this have on the development and purchase of marine instrumentation? Can any level of security be sacrificed for economic and commercial gains? If so, who decides, and on what basis?

The second question repeats the first, excepting that it applies specifically to the scientific community. According to the "Chronicle of Higher Education," the United States will pay 50 percent of the \$450 million cost of the World Ocean Circulation Experiment (WOCE). The same article states that "thousands of scientific instruments will be deployed in WOCE." We can also add to that list the Tropical Ocean and Global Atmosphere and the United States Global Change Research experiments.

Do U.S. companies get 50 percent of the market? Should they? Are U.S. scientists willing to give up any level of accuracy in order to 'Buy American'? Do U.S. scientists have any

obligation to work with U.S. companies to develop new instrumentation?

Do U.S. government funding sources that support scientific research have any such obligations? Merely raising these questions is heresy in some quarters, but many foreign countries demand exactly these sorts of relationships between government and the scientific community.

Finally, you may ask, what does all this have to do with *Developing a National Marine Electronics Agenda*? I would reply that the agenda we are seeking must be developed within a context of the economic and political realities we live in. There is currently great flux in the relations within the U.S. economic structure and the various institutions of government. For those of us interested in marine electronics, there is a great challenge and a real opportunity to make a difference. A chance to inform policy with facts and reasoned approaches, rather than just slogans. We have already made an outstanding beginning.

The Influence of Japanese Industrial Targeting and Trade Policy on the Markets for Marine Electronic Instruments

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Background

In Broadus et al. (1988), we presented a broad overview of the organization of firms and industrial networks through which products in the field of marine electronic instrumentation (MEI) are marketed. The research that went into the preparation of that report has been continued with, among other things, an emphasis on technological histories. These histories (or "case studies") have been directed at determining the origins of research and development (R&D) activities, identifying the sources of research sponsorship, and understanding the means by which funding for technological development has crossed the boundaries of end user sectors.

In addition to the technology histories, we have begun to analyze technology transfer among private, nonprofit, and public sectors in this field (Kite-Powell and Hoagland, in this volume) and the role of foreign governments in the promotion of their own MEI industries. Elsewhere in this volume, Hoagland and Kite-Powell report on the preliminary results of their fact-finding mission to six European countries and the Commission of the European Communities. We were unable to conduct a similar mission to Japan this summer. However, we are able to outline some of the technological developments that currently are taking place in the MEI field in Japan and to identify some of the major issues facing U.S. industry there.

Japanese government involvement in the MEI field, as in other advanced technology fields, can be divided into two elements (ACTPN, 1989; Heaton, 1988). The first is government involvement in the research endeavor, especially through its "intertwined", but coordinated relationship with the industrial establishment, the "targeting" of broad-scale research opportunities, and the direct sponsorship of R&D, product development, and marketing. The second element is trade policy.

Japanese Government Research and MEI R&D Targets

In the MEI field, the high-volume, low-margin consumer electronics markets have been most subject to Japanese competition. Consumer electronics is the kind of market in which the Japanese excel -- it's the paradigm of Japanese international competitiveness. (U.S.

manufacturers look for very specific high volume niches for their survival in that industry.)

We have not identified any initiatives in Japan that portend increased efforts by its government in the marine consumer electronics industry. However, there is some reason to believe that the Japanese government has begun to target the oceanographic and environmental monitoring instrumentation sector through government-sponsored R&D efforts. This may be particularly troubling for U.S. manufacturers of these technologies, because this is not the typical mass market toward which most Japanese government support has been targeted in the past.

In the defense and military systems sector, there is mixed news. We expect to see increased competition from the Japanese in terms of components included in western defense systems. It is conceivable that there may be some market opportunities for U.S. vendors as Japan expands its participation in the western alliance antisubmarine warfare (ASW) efforts (although this is a sensitive area not usually talked about openly).

The principal sponsor of marine technology development efforts in Japan is the Science and Technology Agency (STA), particularly through its subsidiary body, the Japan Marine Science and Technology Center (JAMSTEC) (Okamura, 1987; Saeki, 1984). Table 2 in Hoagland and Kite-Powell's paper gives a general impression of the size of funding for oceanographic research in Japan (and compares it to the levels of other countries). STA is the primary sponsor of a number of MEI-relevant projects that include the participation and partial sponsorship of Japanese industrial corporations (STA, 1987). These projects are worth describing:

1. The Japanese are at the cutting-edge of marine submergence technology. JAMSTEC has operating experience with its own 2000m capable deep diving manned submersible and has just taken delivery of its "world class" 6500m deep diving submersible, the Shinkai 6500. This submersible will be equipped with the capability for sending television signals acoustically.
2. JAMSTEC has constructed and successfully operated a 300m remotely operated vehicle (ROV), the Dolphin 3-K. Beginning in 1992, R&D efforts are planned for a 10,000m capable ROV. The development and manufacturing budget for this ROV has been estimated at \$20 million.
3. JAMSTEC is involved in several instrumentation projects as components in the design of a much larger "marine environmental control system." These include marine remote sensing technologies, related particularly to earthquake prediction, and geologic and seismic sensors.
4. There are several interagency projects, including one directed at the development of new oceanographic instrumentation for exploitation of the Japanese EEZ (Chijiya and Odamaki, 1988). These include fast collection and processing systems for ocean data and ocean "condition" observational instruments. Among the specific instrument types are composite optical sensors for seawater analysis, a ship-mounted acoustic doppler current

profiler, an ocean acoustic tomography system, and an "intelligent" sonar system for the measurement of oceanic fish and plankton populations. This line of research has been postponed but may resume in the future.

In addition to JAMSTEC, MEI technologies are under development or are being sponsored by several other government research institutions (Westwood, 1989). Detailed descriptions of these institutions can be found in STA (1988). Among these, the Ministry of International Trade and Industry (MITI) has a number of projects involving deep sea minerals and offshore oil and gas development. However, the Japanese industry has suffered the same kind of downturn in the oceans sector as the U.S. industry. MITI's deep seabed mining project, one of its targeted national large-scale R&D efforts, was initially planned as a nine year, \$100 million large-scale project to start in 1981. Funding dropped to roughly one third of the initial level after the third or fourth year and has never been increased. The project is now approaching its terminus.

The Maritime Safety Agency (MSA) (located in the Ministry of Transportation) will become a major player in ocean instrumentation. MSA's Ocean Surveys Division and Coastal Surveys and Photography Division are responsible for integrated marine survey and research for bathymetric charting and marine surveys. MSA is heavily involved in the development of instrumentation to serve its missions. These technologies include GPS and interactive editing systems for nautical charts. Other government agencies include the Japan Weather Association (drift buoys for wave observation); the National Research Institute of Fisheries Engineering (echo sounders and sonar for fisheries resource surveys; physical oceanographic sensors); the Geological Survey of Japan (ocean thermal energy conversion research); the National Research Institute for Pollution and Resources (manganese nodule recovery system research); the Ship Research Institute (integrated navigation systems; artificial intelligence); the Port and Harbor Research Institute (a "walking robot" for undersea observation); the Geographical Survey Institute (hydrology and coastal sea mapping). The major marine trade association, the Japan Ocean Industries Association, is not involved in ocean instrumentation development, although it does sponsor research in offshore oil and gas production and pollution control technologies (JOIA, 1987).

Japanese Trade Policies

There are two primary strategies that can be employed by the Japanese to shift the competitive advantage in their favor (ACTPN, 1989). One strategy involves the imposition of tariffs and quotas that can act to shut down home markets. The other strategy involves so-called "invisible" barriers to trade, and these may be the most important to U.S. manufacturers in the MEI field.

In Table 1, relative average tariff levels in the United States are compared with those in the European Community countries and Japan for raw materials, semi-manufactures, and finished manufactured goods (Balassa and Michalopoulos, 1986). Notably, Japanese tariffs really are not out-of-line with those in the United States. In fact, these data do not reflect reforms that have been instituted in Japan during the past year that actually have the effect of lowering tariff barriers in Japan.

Table 1: Relative Average Tariff Levels
(% Ad Valorem)

	USA	EC	<u>JAPAN</u>
RAW MATERIALS	0.2	0.2	0.5
SEMI-MANUFACTURES	3.0	4.2	4.6
FINISHED MANUFACTURES	5.7	6.9	6.0

Source: Balassa and Michalopoulos (1986)

However, as shown in Table 2, the degree of specialization in Japanese industry is not nearly as high as in other countries. Lawrence (1987) measures the degree of specialization using an "intra-industry manufacturing trade index." Using 1980 data from 94 industries, the index is a weighted measure of the balance between exports and imports across those industries. In effect, the index measures the extent to which there is an export-import balance within a country's industries. For Canada, Finland, France, West Germany, Italy, Norway, the United Kingdom, and the United States, the index is between roughly 0.5 to 0.8. This indicates a higher export-import balance within industries in these countries in comparison to Japan with an index of 0.25. What this means is that, within Japanese industries, there is a lot of exporting, but this is not accompanied by importing from abroad. These industries are supplied with components or other supplies manufactured in Japan. The primary implication of this kind of analysis is that trade barriers may exist.

Table 2: Intra-Industry Manufacturing Trade
Indices, 1980
(94 Industries)

CANADA	0.68
FINLAND	0.49
FRANCE	0.82
FRG	0.66
ITALY	0.61
<u>JAPAN</u>	0.25
NORWAY	0.51
UK	0.78
USA	0.60

Source: Lawrence (1987)

In Japan, there is a distinct preference for Japanese goods and services. Balassa and Noland (forthcoming) have found that, based upon national attributes, a model of import penetration in

manufacturing would predict between 25 to 40 percent more imports than what is currently observed in Japan. Much of this effect may be attributed to the fact that the Japanese have been tremendous savers. Until the last few years, Japanese tax laws have systematically encouraged personal savings (earnings on these accounts were tax exempt). But these laws have changed recently, and we can begin to see a more consumer-oriented economy in Japan, with a narrowing difference between the relatively high savings rate in Japan and the much lower rate in the United States.

What about the invisible barriers? The most significant one probably is "administrative." It emerges from the intimate relationship between the governmental agencies and the industrial organizations in Japan. It implies that the government officials tell (perhaps informally) Japanese companies whether or not to import and from which Japanese companies to purchase supplies. This is just another manifestation of governmental economic coordination.

Standards testing and certification is another area in which there have been complaints about Japanese practice. The standards required by the Japanese for imported products are not always clearly articulated, and frequently they are written in such a way as to appear to favor Japanese products and to "lock-out" U.S. products. Invisible barriers tend to crop up in public procurement as well. Such barriers involve the use of single tenders, short bid times, complex qualifying procedures, and a general lack of transparency in the procurement process. Furthermore, in Japan there is a systematic "defense" of depressed industries. Among these is included the shipbuilding industry, and electronics instrumentation for ships may be favored through support for this industry.

Two more invisible barriers are important to mention. One concerns the lag between invention disclosure and patent issuance. In Japan this period averages about six years (compared with two in the United States). Thus there is concern that the longer lag period leads to imitation and quasi-infringement of technologies developed outside Japan.

Finally, the complexity of distribution channels may have a significant effect on the extent to which U.S. products can compete in Japanese markets. Balassa and Noland (forthcoming) have explained that:

Commercial practices, many unique only to Japan, had severely inhibited the ability of companies wishing to enlarge their share of the market. For example, it is virtually impossible to sell to Japan without having an affiliated company doing the marketing and distribution...the structure of Japan's distribution network is a major impediment to our exporters gaining a fair share of the market. The distribution network is so complex that the imported product becomes very expensive by the time it reaches the consumer.

Conclusion

It is important to point out a trend in Japan concerning the decline in the strength and depth of the market faced by marine technologies. In order to fill a gap in the market, the Japanese have

targeted "fallbacks". These are coastal development projects, including airports and urban developments in the near-shore zone. These projects are primarily civil engineering and not related to the development of high-tech instrumentation. Thus they will not necessarily present an opportunity for the sale of U.S. MEI manufactures. But neither will they necessarily result in the development of instruments to compete with U.S. manufactures.

In the United States, there has been a tendency to view the Japanese style of government-industry coordination as a guarantee of success. But this is not necessarily the case. Using the Japanese deep seabed mining large-scale project as an example, R&D targets are not immune to worldwide economic conditions. Moreover, there are indications in this field that targeting and invisible barriers are necessary for the Japanese to build up technological capabilities. (A recent Japanese government RFP for seabeam technology appears to have been wired specifically for a Japanese company with no production history in this technology.) Thus U.S. firms still may have technological advantages in many areas.

There exist constitutional barriers to the sale of defense technologies, such as ASW systems, which may give U.S. firms a competitive advantage in international defense markets. The resilience of this advantage is subject to question, however.

Finally, many of the success stories heard from U.S. firms about penetration into the Japanese market almost always concern either an affiliation with a Japanese firm (to circumvent problems with distribution channels) or a case where the U.S. product mimics existing Japanese products (to comply with the strong preference of Japanese consumers for Japanese products). We hope to examine these conclusions in greater depth during a series of interviews with Japanese government and industry officials in the near future.

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The Advanced Marine Electronics Instrumentation Industry and the European Market: Government Policies and International Competitiveness¹

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Abstract

Here we present the preliminary results of a series of 39 interviews with government officials and industry representatives in seven European countries concerning the influence of national and international government policies on the nature and development of the European marine electronic instrumentation (MEI) markets. We describe the importance of the marine sector to European countries producing MEI technologies. Using some very restrictive assumptions, we estimate the size of the MEI market in Europe (about \$1.2 billion in 1987) to be roughly half the size of the U.S. market. European institutions are undergoing rapid changes, including recent increased emphasis on collaborative "technology transfer" type research efforts across sectors (following the U.S. lead) and across national borders. We expect broadly defined marine markets to grow in Europe, thereby having a positive effect on the markets for marine electronics. But the extent to which U.S. firms can continue to participate and maintain their position in the markets for MEI products and services in Europe remains unanswered. The best policy for U.S. firms may well be one of cautious optimism and close attention to the potential for strategic alliances with established and emerging European firms.

Introduction

Already, the European storm has begun to brew. The restructuring of its defense electronics industry is one tocsin for the world outside Europe. Before it passes, we can only speculate on the rearrangement of the economic and political structures that will occur. Because there will

¹ Presented at the meeting of the Marine Instrumentation Panel, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, 12 September 1989. We thank Jim Broadus and Arthur Gaines for their assistance in organizing and planning this research. Funding was provided by the Marine Policy Center of the Woods Hole Oceanographic Institution and The National Ocean Service/NOAA through a grant to the Massachusetts Centers of Excellence Corporation, grant No. NA87-AA-D-M00037.

be both winners and losers from the integration of the "common market," cries only of alarm perhaps seem premature.² But whenever the "old world" threatens institutional innovation, it behooves the "new" to proceed with vigilance and understanding.

In August of 1989, the General Electric Company PLC (GEC) of Great Britain and Siemens AG of West Germany made a final "sweetened" tender offer of over \$3 billion to purchase their rival, the British defense and electronics concern, Plessey Company. The offer culminated a five year hostile takeover battle initiated by GEC. Later that month, the French defense electronics giant Thomson CSF announced its planned acquisition of the defense electronics assets of N.V. Philips, the major Dutch electronics concern. Because European defense ministries traditionally have been loathe to approve foreign takeovers of defense contractors, the Plessey takeover and the Philips acquisitions are watersheds.

These events are important more for their symbolism than their economic significance. They are representative of an envisaged "new" Europe—one in which consolidation and restructuring in fundamental industrial sectors is expected to lead to enhanced economies of scale and improved international competitiveness. These events demonstrate conclusively that European governments are ready to begin "liberalizing" their public procurement process, at least within the common market. It is significant too that these governments perceive savings through the concentration of an industry in which "buy national" procurement policies are permitted under the GATT multinational trade negotiation process.³ As Europe accelerates its own unification, we can expect to see similar events in other industrial sectors. Here we examine the implications of the integration of Europe for one such sector: advanced marine electronics.

Although we draw upon examples from the advanced marine technology field, our topic is of wider significance. The public policy issues we describe are identical to those faced by firms in any advanced technology sector (although perhaps their relative weights may differ). As is

² At a July 1989 meeting of the American Defense Preparedness Association, an industry group, a U.S. Department of Commerce official called for American defense firms to "scramble" if they were interested participating in the European common market before January 1993 (NNUT, 1989).

³ The economic significance of this restructuring is extremely uncertain, and the symbolic effect may be of greater importance. However, a study sponsored by the European Community (EC) estimated that in 1984 alone two-thirds of a 6 billion European currency unit (BECU; 1 ecu is roughly on a par with the dollar) "savings" from liberalized procurement policies would have accrued from a "long term restructuring" effect in the defense equipment industry. Such a savings appears small in comparison to the \$3 billion Plessey tender offer, but it represents only one year. The savings is roughly between 3-9 percent of the estimated expected total "gains" from the removal of the common market's internal market barriers (EC, 1988). These snapshot estimates should be regarded as only extremely speculative approximations.

the case with many advanced technology industries, the industrial organization of the MEI field is complex and does not lend itself easily to analysis. There are in fact several identifiable, overlapping markets, and the field is "unified" through end user similarities as well as product complementarity or substitutability. Here we do not attempt a complete description of the industrial organization of the European MEI industry.⁴ Our purpose is to characterize broad economic parameters of relevance to this industry and to examine domestic and international government policies that may influence the competitiveness of products manufactured by U.S. firms in European markets.

European Marine Sectors

The markets for advanced marine technologies in Western Europe are large and growing. The capabilities for research and development, manufacturing, and marketing of marine technologies are well established in France, Germany, Italy, Norway, and the United Kingdom. Similar capabilities are nascent but growing in Denmark, Finland, and the Netherlands. Traditionally, U.S. firms have maintained strong competitive positions in advanced marine products markets worldwide -- including Europe.⁵ However, the structure of the European market is changing rapidly, due mostly to government influences as well as other factors.

In the United States, based upon a preliminary review, we estimate total sales of MEI products to be approximately \$5 billion annually.⁶ Comparable estimates for the size of economic activity in the European MEI industry are rougher than those for the United States because of a paucity of similar industry data. Several Western European countries are "leaders" in the MEI field. These countries are important not only because of their production capabilities but also

⁴ Such a description will be even more difficult for the industry in Europe than for the industry in North America because of data inadequacies. Recent attempts to begin describing the structure of the MEI industry in Europe have been initiated by the Department of Trade and Industry (DTI) in the United Kingdom, IFREMER in France, and the European Communities in Belgium. We report on some of these studies below.

⁵ Based upon limited trade data obtained from the U.S. International Trade Commission, we estimate that in 1987 of the total U.S. exports of MEI products (about \$1 billion) about 30 percent went to European end users. We have only limited and incomplete data on trade balances, but these data appear to suggest that the U.S. has a trade surplus in MEI products with Europe and a trade deficit with Japan and Canada.

⁶ Several methods have been used for this estimation, resulting in a range of estimates of from \$3-5 billion. The world market is estimated at roughly double the U.S. market. Methods for making these estimates are described in Broadus et al. (1988). Two fundamental statistical sources have been the U.S. government's "Current Industrial Reports" and "Census of Manufactures" series. It has been possible in many cases to identify the value of U.S. "shipments" down to the seven digit industrial classification level. Statistics are available on U.S. exports and imports as well, although the coverage is less complete.

because they are major end users of MEI products and services. Table 1 presents these countries and compares various indicators of the significance of the marine sector to each of these countries.

Table 1: Importance of the Marine Sector to MEI Countries: Some Indicators

	1989 Estimated Merchant Ships ¹	Number of Ports		1984 Estimated Fishing Vessels	1988 Estimated Offshore Production (\$USx106)		Coast (kmx103)	Exclusive Economic Zone (km2x103)
		Major	Minor		Oil	Gas		
Denmark	300*	16	44	340	277	107	3	69
France	300*	23	165	480	--	--	3	341
Germany	850	10	11	125	51	4	1	41
Italy	550	16	22	260	296	64	5	552
Neth.	450*	8	5	440	88	993	0.5	85
U.K.	950	23	350	340	9939	2760	12	943
Finland	150*	11	15	20	--	--	1	98
Norway	750	9	69	600	4304	1748	6	2025
Canada	100*	19	300	490	365	--	91	4699
Japan	3100	53	large	2820	6	29	12	3862
U.S.A.	1300	25	large	3130	5357	6519	20	7621

* Based on 1984 data.

Sources: Fairplay(1989); Offshore(1989); Mangone(1986); Lloyd's(1984); Borgese and Ginsburg(1982).

¹Includes ships registered under Panamanian or Liberian flags of convenience.

Even with a lack of industry data on production, consumption, and trade, qualitative indicators drawn from primary marine end use sectors suggest that the European MEI industry has the potential for growth.⁷ First, pressures are building for a reduction of the U.S. military presence in Europe (Morrison, 1989). Although the effect of these pressures are uncertain, there are movements toward increased European independence from a defense security standpoint. This alone could improve the market for MEI technologies, which are predominantly defense related, as European nations, particularly members of the Western European Union (WEU), seek to position their defense institutions to fill potential future gaps. It may also work to support local MEI producers, to the plausible exclusion of U.S. firms. For example, since 1983 the U.S. trade surplus with Europe in defense manufactures has been dwindling. (Total U.S.-European trade in defense manufactures has been declining as well.)

Secondly, even with the recent world hydrocarbon market production surpluses, offshore oil and gas production in the United Kingdom and Norway are economically important and together surpass the total value of U.S. offshore production. Forecasts for North Sea offshore oil and gas exploration, development, and production have begun to brighten. Although many factors can influence North Sea hydrocarbon potential, LeBlanc suggests that, in comparison with older producing regions worldwide, "the North Sea will have the reserves to support a strong exploration and development pace far into the next century." Particular emphasis will be placed on the development of natural gas fields offshore, even in light of current pipeline transmission inadequacies. Offshore discovery costs are competitive with major onshore fields. Offshore drilling is expected to continue strongly unless prices soften considerably below their present levels (about \$18-20 per barrel). Both Norway and the United Kingdom have instituted national policies of support for offshore development and associated service industries.

Thirdly, the commercial fisheries sector in Europe remains strong. Although no individual European country ranks with the majors, combined European fish catches have been level at about 12 million metric tons annually, exceeding those individually of Japan, the Soviet Union, or China. Marine transportation, too, is important to the European economy, and Rotterdam and Antwerp are two of the world's busiest ports, making the Netherlands and Belgium major world entrepôts. In numbers of registries, the combined merchant fleets of Norway, the United Kingdom, France, Italy and Spain rival the flags of convenience: Liberia, Panama, and Greece. European countries have remained steadfast in their subsidization of the shipbuilding industry, as they consider it a source of general public benefits. Europe even has developed its own discipline, "hydrography", concerned with mapping and navigational problems of the oceans.

⁷ For example, a recent study conducted for the U.K.'s DTI on international programs and markets in ocean technology has concluded that, worldwide, even the most mature ocean technology industries, such as mariculture and submarine cables, are growing strongly (Westwood et al., 1989). The DTI study is a survey of ocean technology in ten "sectors" but does not focus specifically on MEI. All ten sectors employ MEI technologies, and the authors suggest that there is potential for future growth in ocean technology.

A final, but not insignificant, set of ocean activities concerns the study of the oceans and applications of ocean science and technologies to improve environmental quality and enhance the productivity of existing ocean uses. Oceanographic science and engineering are the showcases of national involvement in advanced marine technologies. In a recent study conducted by the Organization of Economic Cooperation and Development (OECD), oceanography was examined as a "big science" in comparison with nuclear and particle physics and astronomy and astrophysics.⁸ In Europe, numerous multinational cooperative marine science and technology development projects have been initiated recently. Nearly all have as yet undetermined influences over the pace of technological advance in the MEI field. Multinational R&D programs in marine sciences are an important form of industrial development "targeting", if merely for their appreciable promotional value.

The MEI Industry in Europe

European commercial firms are involved in the full range of MEI products and services. These include communication and navigation instruments (marine radios and radars, satellite navigation receivers, electronic charts), sensors (sonar transponders, current meters, video imaging systems), data management instruments ("marinized" computer hardware and tailored software), and services (hydrographic surveys, equipment leasing, robotic underwater inspection and repair). Many of these products and services are combined into integrated "systems" for defense or commercial end users. Some, such as commercial fishfinding sonars, are manufactured in high volume production runs. In other cases, such as customized remotely operated vehicles (ROVs), lifetime production runs of under 10 items are not uncommon.

In Table 2, we attempt a crude estimation of the MEI market in Europe and compare this with other leading countries, including Canada, Japan, and the United States. (Notably, we have excluded the Soviet Union in this comparison. The Soviet Union must be an important producer and end user of MEI technologies, given its extensive navy, merchant marine, and fisheries sectors. Yet, except for Finland, there is little electronics trade with the west and little opportunity for examining the industry there. This situation may be changing.) In Table 2, we include a very rough estimate of public defense sector expenditures on marine electronic instrumentation.⁹ Based upon U.S. relationships concerning the size of market sectors (the ratio

⁸ This classification was based primarily on the capital intensive attributes of research vessels (OECD, 1988).

⁹ This estimate is included only for a general comparison. We have estimated "MEI defense expenditures" using a rule which has been of use in estimating the same sector for the United States (Broadus et al., 1988: 48, 57). We attribute 30 percent of defense spending to national navies. Then, based upon our work with the U.S. marine electronic industry, we estimate 5 percent of navy expenditures are for marine electronic instruments. Working from the U.S. defense budget, we found that the U.S. estimate was roughly double the expected amount. Therefore, we have normalized the data for the other countries by cutting the estimates in half.

of the defense sector to all other sectors combined is 2.5:1), we estimate the market size for marine electronic instrumentation in Europe. These estimates should be regarded with great caution, as they depend strongly upon an assumption that the markets in Europe are structured in a similar fashion to those in the United States. Yet these estimates do give a broad impression of the significance of this sector to selected European countries.

Table 2: Marine Electronic Instrumentation: Market Size Estimates

	1987 Defense Budgets (\$USx109)	1987 Estimated MEI Defense Expenditures (\$USx106)	1987 Estimated MEI Other* Markets (\$USx106)	1987 Estimated Total MEI Market (\$USx106)
Denmark	2	15	6	21
France	31	234	94	328
Germany	30	225	90	315
Italy	16	118	47	165
Neth.	6	46	18	64
U.K.	31	230	92	322
Finland	1	8	3	11
Norway	3	19	8	27
"MEI Europe"	120	895	358	1253
Canada	10	73	29	102
Japan	22	163	65	228
U.S.A.	288	2160	864	3024

Sources: NATO (1988); Broadus et al. (1988).

European Programs in Marine Science and Technology

One of the most salient policy issues faced by the MEI industry within the European common market concerns whether industrial "targeting" occurs in this or related fields and the extent to which it is permitted. Marine science and technology programs are areas in which governments and international organizations can sponsor R&D to achieve the public purposes of national defense or environmental protection and at the same time foster the growth of a nascent industry, marine electronic instrumentation. In Table 3, we present comparisons of public R&D expenditures for the MEI countries. Total R&D as a proportion of GNP and marine science and technology (MST) R&D as a proportion of total R&D are presented.¹⁰ Most of the MEI countries spend only about one percent of their total R&D expenditures on marine sciences. Yet the marine sector is important to these countries, and increasing recognition of the adverse effects of marine pollution, the depletion of fish stocks, and other problems have heightened this importance (Peet, 1986).

Table 3: Marine Science and Technology: Estimated Expenditures and Publications
(all figures in 1986 \$USx106)

	1986 World Bank GNP (\$x10e9)	1986 OECD Total R&D	1986 Total R&D Compared to GNP (%)	EEC Estimated MST Research	MST Share of Total R&D (%)	1984 OECD "Publications" in Oceanog. and Limnol.	Publications per \$10 million Marine R&D
Denmark	79	860	1	43	5	6	1
France	722	15215	2	220	1	22	1
Germany	898	20828	2	220	1	53	2
Italy	597	7467	1	52	1	5	1
Neth.	175	3817	2	83	2	3	<1
U.K.	553	15221	3	110	1	59	5
EEC	--	1100*		5*	<1	--	--
Norway	69	1133	2	--	--	5	
Finland	69	939	1	--	--	3	
Canada	352	5893	2	150*	3	55	4
Japan	1962	41734	2	331*	1	13	<1
U.S.A.	4219	114705	3	1300*	1	418	3

* Our own estimate based on various unpublished sources.

Sources: UNCTAD (1988); OECD (1989,1988); EC (1986); World Bank (1988).

¹⁰ As a sidelight, following OECD (1988), we consider publications per R&D expenditure inputs as one kind of very approximate "output" indicator of marine science in these countries.

Although individual countries maintain their own research programs, increasingly, the European approach to R&D has become a quasi-cooperative one, in which large-scale, well-promoted projects are organized by international organizations. National scientific efforts thus are "coordinated" to reduce the potential for duplicated efforts. These projects are heavily "leveraged" in the sense that participants must bring substantial financial and in-kind contributions to the project and international funds account for only a small proportion of the total. Cross-sectoral technology transfer is emphasized and encouraged. Most of these research investments are only beginning to provide "returns" in a qualitative sense, and the success of these programs has not been fully determined.

Most Western European countries are members of the European Community (EC) or "common market".¹¹ In October of 1986, the European Parliament issued an advisory resolution on the establishment of an EC marine research institute. The European Parliament found that:

. . . there is a serious lack of Community coordination in this field, leading to a substantial waste of funds, a surplus of logistical capacity and, hence, reduced economic and scientific efficiency. . . . [T]he oceans represent an area with vast potential to which access can be gained and which can be exploited only through advanced technology. . . . [H]igh technology projects in the field of oceanography can have a mobilizing effect both on growth industries and among the peoples of Europe (emphasis added) (EP, 1986).

Under the provisions of the Single European Act of 1987, the EC increased its own efforts (distinct from but in concert with its member states) in such areas as R&D, environmental protection, and others. In 1987, the Commission of the European Communities (CEC) proposed its third five year "Framework Programme of Community Activities in the Field of Research and Technological Development" (Andre, 1987). For the first time, the Framework Programme

¹¹ Four other countries, including Norway and Finland, are members of the European Free Trade Association (EFTA), a second important combination of European political jurisdictions for the purposes of trade enhancement. Since 1966, EFTA members have engaged in free trade in industrial goods among themselves. Individually, each EFTA member has negotiated agreements with the EC for free trade in industrial goods, and, under the provisions of the "Luxembourg Declaration" of 1984, EFTA and EC have agreed to foster increased free trade and to cooperate in R&D and other areas. However, EFTA differs from the EC in that its formation was a result of what Wallace describes as "negative reasons" directed toward the rejection of "positive and extensive" collaboration. Much more than EC members, EFTA countries see themselves as economically independent, politically sovereign, and militarily neutral. These factors act to distinguish EFTA members from their EC counterparts and may preclude the full participation of EFTA members in the potential benefits of an integrated common market. As a result, EFTA, like the United States and Japan, finds itself on the outside looking in at EC92 with concern.

proposal included a line item specifically for marine science and technology (MAST). In March of 1989, the MAST program was adopted officially by the EC Council of Ministers with a budget of roughly \$50 million to be spent over the remaining three years of the Framework Programme.¹² (This budget is just under one percent of the total EC Framework Programme budget--in line with the proportional spending of national governments on marine science and technology as shown in Table 3.)

The MAST program is administratively housed within the EC's Directorate General for Science, Research and Technological Development.¹³ The "technical content" of the program itself is quite ambitious, encompassing a full array of basic and applied marine science research areas. MAST is intended to operate as a science "foundation" by funding research proposals up to a level of 50 percent of the total project cost. The proposals must involve a combination of institutions (from any sector--public, nonprofit, commercial) from at least two countries. Of special importance to the MEI industry is the inclusion of a set of projects that will be funded under the umbrella: "instrumentation for science." These projects will provide funding for: (1) physical, chemical, and biological sensors; (2) modular integrated sensor systems (including instruments for use on ROVs); (3) long term in situ measurement instruments; and (4) nondisturbing sampling instruments (including laser and acoustic techniques). The EC itself will conduct "technico-economic feasibility studies" including a comprehensive study of the oceanographic instrumentation sector of the European MEI industry (MAST, 1988).

An even larger program of research has been organized through the EUREKA framework. EUREKA is a set of unique advanced technology R&D projects that have been organized as collaborative research efforts. Nineteen European countries and the EC are members of the EUREKA framework (Laurent, 1987). It was established ostensibly as a response to the U.S. strategic defense initiative (SDI) effort, but EUREKA does not focus on defense technologies. One of its projects, EUROMAR, was organized in 1985 to sponsor transnational, advanced technology projects with "application in the protection, exploitation or management of the marine environment and resources." EUROMAR is composed of 18 separate research projects, eight of which include the development of MEI technologies. The latter projects will last from one to five years and total approximately \$50 million (about 1 percent of funding for all EUREKA projects). Funding for EUROMAR comes primarily from member governments and participant institutions, with only a small proportion (probably less than 10 percent) from pooled EUREKA funds (cf. Dickson, 1988).

¹² A stated objective of the MAST program as adopted by the Council of Ministers is "to strengthen industrial competitiveness" (MAST, 1989).

¹³ The EC has its own research entity, the Joint Research Centre, which increasingly has begun to focus on "prenormative" research. The JRC does not conduct marine research specifically, although it does have a program of satellite remote sensing that includes the monitoring of ocean pollution. At the JRC research center in Ispra, Italy, a spectroradiometer has been developed as part of this work.

The North Atlantic Treaty Organization (NATO) was established in 1949 as an international organization for the common defense of all members. It includes as members a number of western European countries as well as Canada and the United States. NATO serves as a forum for the planning and discussion of military, political, and economic issues. France participates only in nonmilitary activities. NATO includes a Division of Scientific and Environmental Affairs which advises NATO's secretary-general on scientific issues and which sponsors a program of scientific exchanges among members. In 1969, NATO organized the Committee on the Challenges of Modern Society (CCMS) which has sponsored cooperative research leading to policy proposals on environmental problems.

In 1959, NATO established an antisubmarine warfare (now "undersea") research center at La Spezia, Italy, known as the Supreme Allied Commander Atlantic Undersea Research Centre (SACLANTCEN). SACLANTCEN has an annual budget of approximately \$25 million, with much of its technical and financial support coming from the U.S. and British navies. The Center has been involved primarily in physical oceanographic and ocean engineering research. Some of its specific technological emphases have included the development of prototype instruments such as long-range towed hydrophone arrays; moored and bottom mounted sonar sensors; doppler sonar buoys; and towed oscillating bodies for continuous profiling. SACLANTCEN has recently taken delivery of a new, state-of-the-art oceanographic research vessel, the R.V. Alliance.

The Nordic Council (NC) was founded in 1952 primarily on the basis of existing informal relationships among member states. The NC and its affiliate, the Nordic Council of Ministers (NCM), were founded to enhance cooperation among Scandinavian countries and to set up jointly-sponsored economic and scientific institutions. The NC issues "recommendations" to the NCM and to its member governments. Denmark's membership in both the EC and the NC is believed by some observers to facilitate the harmonization of national economic policies across the EC frontier. In this sense, the NC may provide an additional boost to the efforts of EFTA members. In 1973, the NCM organized the Nordic Fund for Industrial and Technological Development (NFITD) to issue grants, loans, and subsidies for industrial R&D projects that are of interest to more than one member. Sometimes referred to as a "Nordic Eureka," in 1986 the fund supported 40 percent of 130 R&D projects costing \$45 million.¹⁴

The European Science Foundation (ESF) draws its membership from some 50 grant-making agencies in 18 European countries, including Finland and Turkey. This membership gives the ESF a degree of influence much greater than its own budget of roughly \$2 million would suggest: projects backed by ESF seed money are likely to receive favorable attention from national funding agencies. In the marine sector, the ESF supports activities in geoscience and ocean circulation. The ESF Consortium for Ocean Drilling (ECOD), consisting of organizations

¹⁴ In 1987, NFITD published a brochure describing several kinds of advanced technologies including MEI technologies such as multibeam echosounders, subsea positioning systems, ship earth stations, INMARSAT coast earth stations, and naval technologies (NFITD, 1987).

from 12 European countries, has been a full member of the Ocean Drilling Program (ODP) since June 1986. (FRG, France, and the U.K. are individual members of ODP.) ECOD representatives participate in JOIDES Science Advisory activities to guide the ODP, and scientists from ECOD member states participate in ODP cruises. The ESF Committee for the World Ocean Circulation Experiment (WOCE) was set up in June 1988 to coordinate European involvement in what is perceived to be a central element of world climate research. The Committee is promoting a series of EURO-WOCE workshops to discuss the scientific content and organizational aspects of European participation in WOCE (ESF, 1988).

In West Germany, an interesting cross-sectoral institution named GEOMAR has been established to conduct marine scientific research and technological development. At present, GEOMAR is structured as two distinct institutions: the GEOMAR research center ("Institute") is intended to conduct scientific research and the GEOMAR Technologie GmbH (GTG) will develop and spin-off technologies, such as electronic instruments. The Institute is informally affiliated with the nearby University of Kiel. Its budget has been funded at DM 5 million over five years by the federal ministry for research and technology, the BMFT, and the local laender government of Schleswig-Holstein. GTG is a joint venture among several private companies and has been capitalized at DM 600,000 for 1988-89. The two institutions will be bound together through a joint venture agreement that currently is under negotiation. The principals of GEOMAR plan to model the development of the joint institution after the large oceanographic institutions in the United States, such as WHOI and SIO.

Analysis: Trade and Investment Implications

A fundamental question for U.S. firms is whether or not the integration of the common market will change existing trade and investment implications significantly. U.S. MEI firms already compete with firms in Europe, especially those in France, West Germany, Italy, the United Kingdom, and Norway (and to a much lesser extent in Finland, the Netherlands, and Denmark), for sales in the latter's home markets.¹⁵ In each of these countries, except the United Kingdom (14%), the U.S. share of imports into that country is below 10 percent. U.S. direct investment in the electric and electronic equipment sector is small, in all cases under 5 percent. Moreover, the United States has overall trade surpluses only with the Netherlands and France (DoS, 1989).

Two general issues that traditionally have affected the competitive position of U.S. firms in international trade in MEI deserve our attention here, albeit briefly. These issues concern the procurement policies of national governments (for example, "buy national" rules) and the establishment of technical standards. These and other nontariff barriers to trade (NTBs) are being addressed within the common market itself. The final form of revised or harmonized trade barrier policies will be subject to review through the General Agreement on Tariffs and Trade (GATT) multilateral trade negotiation process, although the extent to which common market

¹⁵ Although we note that the size of the market for marine electronics in the United States is much larger than that in any of the individual countries of Europe.

barriers will bend to such review remains in question.

Procurement policies currently are undergoing close scrutiny by the Commission of the European Communities (CEC). However, the focus of this scrutiny is directed primarily at those (nondefense) areas in which changes in procurement policies can make the largest difference: telecommunications, transport, energy, and water (CEC, 1989). Under the provisions of the GATT, a "buy national" procurement policy for defense manufactures is not necessarily considered a nontariff barrier to trade. Because traditionally much of the international trade in MEI has involved defense manufactures, we do not expect that the harmonization of procurement policies within the common market will have much of an additional effect on the competitive position of U.S. firms in the MEI industry.

A special type of nondefense procurement policy is relevant to the MEI industry. One source of support for R&D in marine electronics results from the offshore oil and gas lease allocation policies of the United Kingdom and Norway. In these countries, offshore exploration and development licenses are not distributed by competitive bid, as in the United States, but instead through a discretionary process (OTA, 1985). There is no official requirement for North Sea offshore energy producing firms to fund R&D as part of their British lease obligations, but R&D expenditures are used as one criterion in allocating offshore entitlements. As a result, the U.K. oil majors generate some \$20 million in annual external marine R&D funds--an order of magnitude larger than direct British government R&D expenditures in this area. In Norway, the government keeps records (voluntarily supplied) of offshore firms' support of R&D conducted by Norwegian companies and considers both the quantity and quality of this support when making lease allocations. This has resulted in substantial financial and technical assistance from energy companies for product development at Norwegian firms, although resulting products have not always been successful commercially (Cook and Surrey, 1983).

The United Kingdom also has used offshore lease allocations to enforce its policy of preferential treatment for "British-based" offshore service and supply firms. The U.K. Offshore Supplies Office (OSO) monitors interactions between energy companies and service firms and influences offshore entitlement allocations for the purpose of maintaining and supporting the existence of an offshore service industry. In 1985, the "British-based" requirement was changed to "majority British-owned," prompting several U.S. companies to reorganize their operations in the United Kingdom (DoS, 1989). OSO activities represent an explicit effort to keep Britain at the forefront of new offshore technology developments.

There has been little evidence to date of technical standards¹⁶ affecting MEI sales to Europe,

¹⁶ Technical product standards are important for several reasons. Governments or nonprofit standard setting institutions may require that products meet minimum standards to protect public health, safety, and the environment. By decreasing information asymmetries between producers and consumers on complicated high technology products, public standards also may be important in the prevention of consumer fraud. Industry groups can play an important role in market

but other industries have been affected adversely by the imposition of standards established by the EC (WSJ, 1989). In the marine electronics field, the internationally accepted Automatic Radar Positioning Aid (ARPA) standards established by the International Maritime Organization (IMO) under the provisions of the Convention on Safety of Life at Sea (SOLAS) helped British, West German, and U.S. firms achieve leading positions in the "upper end" of the large, deep-sea radar market.

A major worry for U.S. manufacturers is that European products will become more competitive as a result of the standardization process. If U.S. firms are placed on an unequal footing as a result of standardization, international trade disputes could result. Hinson and Platzer identify five potential problems with the process of standard setting in the EC. These include restricted access to European markets, restricted participation in standard setting, the isolation of American standards, the setting of higher standards in Europe ("upward harmonization"), and testing and certification problems.

In the past, the EC has been involved directly in the setting of detailed technical product standards. This centralized approach proved unsuccessful because of the inordinate amount of time and effort involved. More recently, the EC has revised its approach to issue directives that identify "essential requirements" for broad product categories. The EC has stated its intention to issue its standards, where possible, so that they are in conformity with international standards-setting organizations. More detailed technical standards can be issued by private European-wide or national standard setting bodies.¹⁷

The EC's new Marine Science and Technology (MAST) research program has included as one of its agenda items the preparation of norms and standards for oceanographic instrumentation and oceanographic methods (MAST, 1988). This agenda item presents an unusual case, because

development through the setting of technical standards. Such standards increase the interchangeability of electronic product components, for example, and facilitate the comparison of products from different suppliers. In both public and private standard setting, there is considerable potential for the use of technical standards as a nontariff barrier to international trade.

¹⁷ The two most important international standard-setting groups are the International Standards Organization (ISO) and the International Electrotechnical Commission (IEC). The three major European standard setting bodies are the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC), and the European Telecommunications Standards Institute (ETSI). For defense technologies within an alliance such as NATO, the Conference of National Armaments Directors (CNAD) exists to set standards on military technologies. Because France does not participate in NATO's military activities, the Independent European Program Group (IEPG) was established in 1976 to play a role similar to CNAD.

there is no existing international standard setting body in this area.¹⁸ As a result, the potential for the EC to act as the centralized standard setting organization is enhanced.

For U.S. firms in the MEI industry, institutions outside of the EC can have important influences on the competitive position of U.S. firms. For example, the U.S. Radio Technical Commission for Maritime Services (RTCM) has participated in the construction of international technical standards for GPS receivers, electronic chart display systems, and "standard C" INMARSAT receivers, among others. Ironically, in the case of the "standard C" receivers, foot-dragging by the U.S. Federal Communications Commission (FCC) has been one factor hindering the early entry of U.S. firms into this market. This is because the related "land mobile" receiver market in the United States is thought to be large enough to justify the investments necessary to manufacture both the marine and land receivers. But the FCC, which would regulate the land-mobile market, has refused to issue regulations.¹⁹ As a result, European (Danish, French, Norwegian, and British) and Japanese firms have been the first out of the box (Fuechsel, 1989).

Conclusions

We can make several conclusions from our study of the effects of shifting government policies and institutions on the competitive position of U.S. firms in the MEI industry. The industry in Europe has potential for growth, based upon our evaluation of the primary end use sectors, including defense, offshore oil and gas, commercial fisheries, merchant marine, and oceanography. The European market for advanced marine electronics is approximately \$1 billion, as measured by total sales--this is about 30-40 percent of the size of the U.S. market. U.S. firms supply perhaps 25% of the European market, and there probably is a trade surplus with Europe as a whole (this is heavily influenced by sales of defense manufactures).

The restructuring of the European defense electronics industry is symbolically significant, representing an envisioned "new Europe" characterized by enhanced economies of scale and improved international competitiveness. This restructuring may be evidence of a changed attitude on the part of European governments with regard to European integration. However, differences still exist among the member states of the European Communities, and these differences may hamper full integration as a true common market. The integration itself may have a minimal impact on trade and investment in Europe for U.S. firms selling into the common market.

¹⁸ In the United States, oceanographic instruments are calibrated to meet the needs of scientific or environmental monitoring end users by manufacturers, at oceanographic research institutions, at NORDA in Bay St. Louis, Mississippi, or at the Northwest Regional Calibration Center in Seattle. The NATO Undersea Research Center (SACLANTCEN) at La Spezia, Italy maintains a calibration center for conductivity, temperature and depth (CTD) sensors.

¹⁹ In the United States, the FCC regulates telecommunications on land. INMARSAT regulates telecommunications by satellite at sea. COMSAT, a quasi-public corporation, participates as the U.S. member (and contributes 25% of the budget) in INMARSAT.

Indeed, if barriers fall, the effect could be positive. Other institutions, especially those setting standards for marine electronic instruments or those sponsoring R&D efforts, may have a larger impact on the competitiveness of U.S. firms. Here again, the direction of the impact--positive or negative--still is uncertain.

Public marine science and technology R&D "investments" in Europe are small, but not insignificant. Increasingly, we see these investments being combined in international, cross-sectoral research efforts designed to reduce duplication, widen the distribution of resulting benefits, and enhancing a goal of "technology transfer." This policy is largely a reaction to the large scale research efforts mounted in the United States and the recent great commercial success of Japanese companies in markets in Europe and in the United States. This policy is not peculiar to advanced marine electronics but spans all advanced technology fields. The effectiveness of such a policy remains to be demonstrated. However, it is fairly clear that firms from the United States, Canada, and Japan will be watching these research efforts, not participating directly.

Addendum

In the period since the presentation of this paper, there have been major changes in the political structure of Europe. While it is beyond our scope to analyze the potential effects of these changes on the markets for MEI technologies, we can outline a few points here. The apparent success of Soviet glasnost, the razing of the Berlin wall, and the "democratization" of Eastern European countries have resulted in a different economic environment than that which existed only months before. There is news of the possibility of reduced defense spending, the relaxation of export controls, and improved links between EC and EFTA countries in a new "European Economic Space." But whether these changes will result in opportunities for U.S. firms in MEI technologies is extremely uncertain. Given the severe environmental problems faced by many Eastern European countries, we expect that there is substantial need for increased environmental monitoring and oceanographic research technologies, for example. However, existing governmental and financial institutions, lack of technological capabilities (especially computers), and lower standards of living will make it difficult, if not impossible, for such needs to be backed by hard currency and revealed in expanded markets. It is clear that firms in some Western European countries, especially West Germany (and possibly also Finland to a lesser extent), may already have head starts and locational advantages in the establishment of trading and joint venture relationships with Eastern European countries. The opening of the Eastern European markets will be yet another important factor for future consideration of the competitive position of U.S. firms in the MEI field.

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Technology Development: A Blueprint for Federal-State Collaboration

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Background

A year ago when I was asked by the Congressional Economic Leadership Institute to address a national audience about state initiatives in technology development, my topic was considered something of a novelty.

This is no longer the case. After a decade of operating in relative obscurity, the states' activities in promoting new commercial technologies are now being acknowledged as playing a major role in our country's economic future. And for good reason. In 1988 alone, \$440 million was invested by 44 states in technological innovation. In turn, this investment has leveraged billions of dollars in private sector support. A Massachusetts Centers of Excellence Corporation (MCEC) biotechnology grant for \$300,000, for example, has been directly responsible for attracting \$8 million of private investment -- a better than 25:1 ratio. Pennsylvania's Ben Franklin Partnership, Ohio's Thomas Edison Program, New York's Science and Technology Foundation and Michigan's Strategic Fund have all experienced similar results.

The states are assuming the role of entrepreneur and not a moment too soon. In fact, there are those who say it's too late and that America has already lost the future to foreign competition. One can understand the pessimism. Statistics released by the U.S. Bureau of Labor are not reassuring:

	Domestic Product Per Employed Person Ratio	Manufacturing Output per hour Ratio
U.S.	1.2	2.8
W. Germany	3.1	4.6
Japan	5.5	7.9

Other statistical indicators cited by the Office of Technology Assessment (OTA) are equally disturbing. A recent report shows the U.S. losing its lead in the number of innovations, the number of patent grants, the number of science and engineering degrees and the percent of GNP allocated to non-defense R&D.

These statistics became a reality during our recent efforts to equip and renovate our MCEC office. As a state agency created to promote economic development, we thought it only fitting to adopt a "Buy American" policy. This was the result: after nine months we were still replacing faulty new computer equipment; the copier arrived with a dead battery; the telephone system was missing a line; the two-year-old air conditioners we inherited stopped functioning in hot weather. The lighting company, when asked why they delivered only 15 of our 16 lamps, gave the excuse that "we can't count that high."

What can be done to restore America's once respected "know-how?" In Massachusetts, as in many other states, solutions are being sought through industry/education partnerships with state government serving as a catalyst. It is an ideal role for the states to play: they understand their own economic needs; they know the players, the small as well as the large companies and educational institutions; they can monitor results closely and above all, they can experiment. "The process has little to do with ideology and everything to do with trial-and-error, seat-of-the-pants pragmatism," says David Osborne in his book, *Laboratories of Democracy*.

The models which states have adopted to promote technological innovation vary widely, depending on need, resources and commitment. They range from technical assistance with limited funding to a comprehensive \$76 million dollar program. General appropriations, bond issues, state lottery funds, pari-mutuel gambling receipts, state employee pensions and unemployment compensation reserves, in addition to taking equity positions and royalties, have been used to provide funding.

The major components of these state initiatives include: advanced technology centers to strengthen the academic base; research and development grant programs to speed the transfer of technology from the laboratory to the marketplace; and technology research parks and incubators to provide space, equipment and managerial expertise.

As an example of an advanced technology center in Massachusetts, a partnership of industry, an engineering school and state government has established a \$52 million Massachusetts Microelectronics Center, which provides state-of-the-art training to students in design, processing and fabrication of semiconductors and other microelectronics devices. Students enrolled in relevant courses can tap into an advanced computer-aided design network and use semiconductor processing laboratories. A newly completed integrated circuit fabrication facility will produce student-designed integrated circuits. Many of the state's engineering students will thus be graduating with extensive hands-on experience in the full design and production cycle.

In the area of competitive R&D matching grants, the Massachusetts Centers of Excellence Corporation currently funds more than 50 joint industry-university projects to accelerate technology transfer with grants ranging from \$20,000 to \$300,000.

To illustrate, MCEC recently awarded \$80,000 matched by \$110,000 from a research group and its industrial partner to develop and test a pilot-scale, solar-powered wastewater treatment system that uses a natural biological process to treat septage and sewage. Test results have been

sufficiently encouraging to attract national and international attention, including \$5 million in private investment to build a full-scale prototype facility. Should this program succeed, it could have a major impact on treating water pollution throughout the country and the world.

As an example of the incubator program, MCEC has awarded a \$165,000 matching grant to a consortium of regional educational institutions and a city chamber of commerce to establish a "superincubator" for start-up biotechnology companies. In addition to the usual incubator services, such as below market rates for office space, shared equipment and clerical assistance, this private, for-profit corporation provides managerial assistance and seed capital through limited partnerships and invests in the later stages of the company together with other investors. In its first year of operation the corporation has invested in four start-up companies, one of which recently went public. This project is part of a Massachusetts effort to promote the biotechnology industry for which the projected product sales nationwide by the year 2000 are estimated to be \$100 billion.

I have used illustrations from Massachusetts because I am most familiar with our programs, but in each case other states are similarly engaged.

The Federal Role

States are clearly demonstrating their skill and resourcefulness in stimulating technology development. But they lack the mandate and resources for tasks such as funding significant generic research, building or maintaining major research facilities and keeping abreast of rapidly changing technologies that are essential to economic revitalization. Recognizing states' strengths and limitations, the National Governors' Association (NGA) in 1985 established the Working Group on State Initiatives in Applied Research. Composed of governors' representatives from 49 states and territories, the working group meets regularly to share experiences and to develop ways to increase cooperation between the federal government and the states.

Based on Working Group discussions and my own experience as the director of a state technology program, I have proposed a series of federal initiatives that will accomplish what the states cannot do and make it easier for states to implement what they can do.

First and foremost, the President must make an unequivocal commitment to improving the nation's industrial competitiveness. This commitment must be backed up with specific assignments of responsibility to the relevant federal agencies and adequate resources for them to do the job. Several agencies, including the National Science Foundation (NSF) and the newly reconstituted National Institute of Standards and Technology (NIST -- formerly the National Bureau of Standards), have made admirable attempts to respond to state needs--but much more could be done.

In the 1988 Omnibus Trade Act, Congress gave the Department of Commerce primary responsibility for supporting civilian technology development and created the position of Undersecretary of Commerce for technology to lead this effort. Such a high ranking official

should make it easier to coordinate federal efforts and give technology concerns the prominence they deserve. By creating the NGA Working Group, the states established a focal point for state interactions; the Undersecretary is the obvious focal point on the federal side. The states await the filling of this position with great interest.

Second, the federal government must take more responsibility for the quality of U.S. education. The deficiencies in the nation's schools in adequately preparing its students for careers in science and technology have been sufficiently documented by literally hundreds of reports. High technology companies complain that they must steal personnel from one another because too few qualified individuals are emerging from the educational system, that many of the best graduates of science and engineering programs are foreigners who return home and that far too few women and minorities are receiving technical training. What is eventually at stake, in the words of MIT's Philip Morrison, is the "essence of democracy" dividing our society into "islands of the trained...with a sea of onlookers--bemused, indifferent and even hostile."

NSF is working to reverse these disturbing trends, but it needs more resources to do the job. NSF's 1990 budget request for its traditional programs for students and faculty at the undergraduate through postdoctoral levels should be considered a minimum. In addition, NSF's pending plan to provide financial support to states that are undertaking comprehensive K-12 school reforms deserves, and I am pleased to report, has received, Congressional support and funding.

Equally important are NSF's efforts to assist minorities through increased university fellowships, research assistantships for high school students, planning grants for applicants and the newly created minority research centers of excellence program.

Scientific literacy for all Americans should be the nation's long-term goal. As the leading federal agency for improving science and math education, NSF should be given the resources it needs to see that this goal is reached. It seems incredible to me that a country that can put men on the moon and send a satellite to Neptune cannot educate its citizens to be able to compete in a world that is rapidly being transformed by science and technology.

Third, the federal government should increase its investment in research facilities and equipment. The federal share of capital spending for university research facilities has fallen from more than 20 percent in the 1960's and 1970's to less than 10 percent today. NSF estimates that the bill for presently needed repairs or renovations will come to \$3.6 billion--more than four times what universities have budgeted. In addition, universities need \$8.1 billion to build new facilities, but they have less than a third of the necessary funds. Only the federal government has the resources to meet such a large shortfall.

Congress has begun to respond by authorizing a 5-year \$800 million academic research facilities modernization program administered by NSF to fund repairs, renovations and, in exceptional cases, replacement of obsolete science and engineering facilities. Universities will have to provide 20-50 percent matching funds, no award can exceed \$7 million, and preference will go

to institutions that have received little R&D funding in the past. This is an encouraging beginning, but we should be aware that no program funds have yet been appropriated and that the amount authorized will cover only a fraction of the need. What's more, the program does not address the need for new construction.

National Academy of Sciences president, Frank Press, estimates that a federal five-year investment of \$1.25 billion annually is necessary to bring the nation's research infrastructure up to date.

Fourth, the federal laboratories must become more effective at transferring technology to industry. With a combined budget of about \$20 billion and one-sixth of the nation's science and engineering professionals on staff, the nation's more than 700 federal laboratories have vast potential for transferring technology to industry--if mechanisms are in place to facilitate the process.

A closer working relationship between the federal labs and state technology programs would enable state officials to learn more about the labs' research capabilities; they could then serve as brokers between the labs and industry. By facilitating cooperative research agreements, joint use of laboratory facilities, access to technology databases, simplified patent and licensing procedures, and personnel exchanges, states could speed technology transfer as well as stimulate new research activity.

Models for such a relationship between the federal labs and the states already exist. In Ohio, the Thomas Edison Materials Technology Center has signed an extensive memorandum of understanding with the Air Force Wright Aeronautical Laboratory for materials processing R&D. The New York Science and Technology Foundation has assigned one of its staff to Rome Air Development Center to assist in technology-transfer activities. The Massachusetts Centers of Excellence Corporation and the U.S. Army Natick Research, Development, and Engineering Center have signed a cooperative agreement with industry to develop high-protein foods from fish wastes.

From the states' perspective, however, even more progress in developing such relationships could be achieved if greater authority were vested in the individual laboratory directors to enter into collaborative and mutually beneficial arrangements with the states and local industries. Bureaucratic delays and overly complex regulations imposed from Washington limit the labs' ability to work with industry whose competitive advantage depends on rapid decision-making and risk-taking.

Fifth, Congress could extend and increase the funding of the small business innovation research (SBIR) program. SBIR directs federal research funds to small and medium-sized companies (which have often been the leaders in technology innovation) by requiring federal agencies with research budgets of more than \$100 million to set aside 1.25 percent of these funds to support research at companies with fewer than 500 employees. Having proved its worth, SBIR should be renewed well in advance of its scheduled termination in 1993. And since half of the

proposals submitted to SBIR and approved on merit go unfunded, its budget should be increased by raising the set-aside to 2.5 percent and lowering the threshold for agency participation to \$50 million.

Finally, the federal government needs to develop a strategy for direct, overall support of state technology programs. Such a strategy could include a federal grants program, most appropriately located within the office of the Undersecretary of Technology and assisted by an advisory committee that included representatives of the NGS Working Group. As an indication of the importance of this effort, the federal government should make available to the states a sum of at least equal to what the states are currently investing themselves. New sources of revenue dedicated to this purpose should be developed. For example, it has been estimated that 5 percent of a proposed transfer tax on leveraged buyouts and other stock transactions would generate \$10 billion annually. This money could be used to provide the necessary funds and at the same time tax a generally unproductive use of capital in order to invest in new productive technologies.

Federal funding would be contingent on the state providing matching funds and enlisting support from industry. Criteria for such funding should be broad enough to allow states to continue to pursue their own diverse efforts. Letting states decide how to spend the money would not only increase the likelihood that it would be spent effectively but would reduce the specter of a centralized federal agency trying to pick winners and losers.

As Senator Dale Bumpers (D-Ark) pointed out in last year's debate on the trade bill, "There is no monopoly here in Washington on how to make America competitive. In fact, we here in Washington may know less about how to meet the competitiveness challenge than do state and local officials. We should be careful not to undertake federal government initiatives when it would be more effective to provide support to state and local government initiatives." While the states wait for the federal government to recognize the wisdom of this position, we will continue to support technology development as best we can. Global competition no longer allows us the luxury of delay.

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An Overview of Technology Transfer and Intellectual Property Management Between Marine Science Research Institutions and the Commercial Sector²⁰

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In this paper, we examine nonprofit/commercial interactions in the field of oceanography, using the Woods Hole Oceanographic Institution (WHOI) as an example. The technology transfer and intellectual property management policies and practices of WHOI are examined and compared to those of universities, federally funded R&D centers, and nonprofit scientific organizations in other fields of research endeavor.

By way of introduction, we outline a number of issues that face nonprofit research institutions when they consider ways to enhance technology transfer. These issues are not necessarily novel, but they may be receiving renewed attention as a result of changing national trends in research sponsorship (a growing share of private vs. public funding for R&D) or modifications of government policies (patent law changes, tax code amendments, and federal technology transfer policy changes). The pursuit of private funding in the present time of tight public budgets is leading many nonprofit research institutions to look more closely at technology transfer as a potential source of revenue. These and other changes in the marine technology development climate are described in greater detail in Broadus, Hoagland and Kite-Powell (1988).

Technology Transfer: Issues and Questions

Conflicts of interest: The potential for conflicts of interest in interactions between research institutions and the commercial sector depends strongly on three parameters: the legal environment, the goals of the individual institution, and the "norms" of scientific research. Conflicts of interest may involve the channels of disclosure for research results, the modification of research directions at nonprofit institutions by scientists who also have interests in related private ventures, the relative weights of scientific merit and commercial payoffs in the selection of research topics, etc.

²⁰ The contents of this paper are abstracted from a working paper on technology transfer and intellectual property management in the field of oceanography by Hoagland and Kite-Powell (1989).

Dissemination of research results: There is an expectation among the scientific community and the general public that the results of research conducted either with sponsorship by public agencies or at institutions that receive an exemption from income taxes should be disseminated as early and as widely as possible. There are instances, however, where exclusive license arrangements with commercial firms may be the most expedient way in which to benefit the public. This is most often the case when the technology exists at an early stage of development, continued public sponsorship of development is unfeasible or unwarranted, or subsequent investment to commercialize the technology would not take place without establishing exclusive property rights (at least temporarily).

Balancing royalty distributions: To the extent that an institution's policy is to distribute some portion of the royalties from intellectual properties (patents, copyrights, etc.) away from inventors/discoverers, there may be disincentives for inventors/discoverers to develop ideas within an institution and cause for them to leave or create spin-off firms. Conversely, if the institution allows most of the royalties to flow directly to the inventor/discoverer, this may discourage the communication and sharing of ideas among staff members.

Tangible research properties: The issue is whether tangibles such as biological organisms, unpatentable engineering designs, and unpatentable instrument prototypes should be treated in the same manner as other intellectual property with respect to licensing and royalties.

Flexibility versus policy specificity: In all forms of the technology transfer activity, a balance must be struck between the specificity of over-arching institution policies and the potential for flexibility in the face of innovative or unique nonprofit/commercial relationships. A more general policy may allow institutions to be more flexible and to realize benefits when extraordinary situations are encountered. Costs may arise, however, when decision-making authority is too decentralized or when policy statements are too general and technology transfer relationships are allowed to contravene overall institutional goals or the norms of scientific research.

Intellectual property management organization (IPMO): Independent IPMOs provide a patenting and licensing service for a prospective royalty share. There is evidence that some large IPMOs may ignore patentable inventions if the expected value of future royalties is too small. On the other hand, "patent committees" or IPMOs established within the institution may not have the time or resources to procure patents (especially in foreign countries) and aggressively seek licensees.

Technology transfer organization (TTO): Some institutions (especially universities) have established external nonprofit or for-profit TTOs, which are involved not only in licensing intellectual property but also in incorporating commercial spin-off firms. Some have been successful; others have encountered both legal and ethical conflicts-of-interest.

Industrial liaison programs: To the extent that such programs involve membership from one particular industry, their potential as a source of funds or mutual transfer of know-how may

follow the fortunes of that industry. Recent criticism of MIT's Industrial Liaison Program points to possible difficulties with widely based foreign corporate memberships.

This summary of issues helps to set the context for the following discussion of specific technology transfer and intellectual property management mechanism in oceanography, as exemplified by WHOI and other institutions.

Technology Transfer: Policies and Practices

There is great variety in the mechanisms of technology transfer, and we cannot claim to be inclusive of every mechanism in this paper. Our objective is to describe a number of successful mechanisms that have been or might be used in the field of oceanography. Figure 1 shows a schema of technology transfer mechanisms in a simplified form specifically for WHOI.

For our discussion, we model these mechanisms as linkages (agreements or other interactions) between commercial firms and research institutions. Non-profit research institutions or universities are represented as rectangles, government sources of sponsored research as diamonds, and commercial firms as circles. Linkages are shown as line segments or arrows between institutions. The most important form of technology transfer at a nonprofit research institution is the publication of research results, represented by an arrow emerging from the bottom of the WHOI box. Because this does not involve explicit links with industry, we ignore it in our discussion with the realization of potentially being misleading. A discussion of the other mechanisms follows.

WHOI is an extraordinary institution, one which shares characteristics of other research institutions but cannot be "pigeonholed" as either a typical nonprofit research institution (such as Battelle), a university (such as MIT), or a Federally Funded R&D Center (FFRDC, such as MITRE). Nevertheless, it comes closest to resembling a university, and many useful lessons can be learned from the extensive literature that has been written about university-industry relationships.

Outside Professional Activities (OPAs). OPAs are an important and widely-used channel for interaction of academic and research staff with commercial ventures. These activities include serving on corporation boards and advisory committees to corporations, and external consulting arrangements. The consultant acts independently, not as an official institution representative, and receives income from the consulting work for personal gain. Consulting can be very lucrative, representing a significant portion of the income of some faculty and research staff at universities.

WHOI permits staff members to undertake consulting and places no upper limit on the amount of time spent on this outside activity. (An unwritten rule has been that consulting activities which take up more than 40 percent of a staff member's time will be considered inappropriate.) WHOI requires all staff to report annually on their outside professional activities in order to identify potential conflicts of interest.

At universities, consulting is considered a legitimate outside professional activity and in some cases actively encouraged as a supplement to university salaries. Some schools, including MIT, Harvard, and Columbia (including Lamont-Doherty), place an upper limit of 20 percent (or no more than one day each week) on time spent consulting. Outside consulting usually is prohibited or strongly discouraged at FFRDCs and university-affiliated, government-sponsored research labs, both of which are likely to perform research predominantly for single federal agency "sponsors." These prohibitions may originate from the perceived need to maintain impartiality when asked by federal agencies to evaluate commercial bids for R&D or procurement contracts.

Research Contracts. Contracts are the most direct form of collaboration between a scientific institution and an industry sponsor. Contracts usually are directed at the performance of a specific task, such as the design and testing of an oceanographic instrument. Contracts can take a number of forms, depending upon the needs of the commercial sponsor and the capabilities of the research institution. Generally, institutions engaged in fundamental scientific research may have only limited interest or proficiency in conducting applied research or engineering development. The boundary between basic and applied research is not sharp, however, and numerous examples of industry-sponsored research in oceanography exist.

Presently industry contracts account for only a small part of WHOI's sponsored research. Many industry contracts at WHOI have been subcontracts on federal agency contracts to a prime source.

Initial negotiations with industry for contract research often involve discussions over two kinds of "nondisclosure" restrictions. These concern (1) the use of proprietary data or resources that belong to the commercial firm and (2) the extent to which research results may be disseminated. As a general rule, WHOI does not agree to any restriction on the public dissemination of the results of research conducted at WHOI, unless the restriction is related to a national security classification requirement.

A different approach is taken at many universities, where industry contracts can represent significant proportions of overall funding. Prepublication review clauses usually are accepted by universities on industry contracts in order to identify potentially patentable technologies and to scan publications for company-proprietary information (Nelsen, 1988). The time period for such review is usually limited to 30 days, and is viewed as a means of expediting the movement of basic technology from the research environment to the commercial sector, where it can be disseminated more widely and efficiently than by publication alone. Some universities, including Harvard, perceive prepublication review to conflict with the university's basic research mission and obligation to the public, and therefore disallow it.

Research Grants. The bulk of research grants involve industrial liaison programs, which are discussed below. At WHOI, some grants have originated from industrial trade associations (the American Chemical Society) or molecular biology firms. We distinguish grants from research contracts because grants tend to give more discretion to the researcher than do contracts in

choosing research paths. In general, industrial sponsors who make grants do not expect to review research results prior to publication. However, industry sponsors often expect this kind of relationship to enhance contacts with researchers at universities or nonprofit institutions and thereby to facilitate the transfer of know-how.

Industrial Liaison Programs (ILPs). ILPs, also known as industrial associates programs or subscription groups, are a common mechanism for technology transfer. Generally, these programs involve financial contributions from commercial firms to a scientific institution in the form of a membership fee. In return, industrial associates receive the results of information developed at the research institution through formal seminars, informal discussions with researchers, raw or partially interpreted data, etc.

It is likely that most of the direct industry funding at WHOI is a result of grants from commercial firms involved in industrial liaisons. The Ocean Industry Program (OIP) at WHOI is the best-known example. OIP has members drawn exclusively from the oil and gas industry. The program was initiated in 1971 primarily at the urging of an official from Shell Exploration who was interested in facilitating access to unprocessed geophysical data obtained and stored by WHOI in its marine geological investigations. Associates programs were established concurrently at Scripps and Lamont-Doherty for the same purposes. Cutbacks in commercial exploration and R&D budgets, oil company mergers, and the availability of data from other sources have caused a decline in OIP membership and income since the late 1970s.

One of the most successful examples of ILPs is MIT's Industrial Liaison Program. Founded in 1948, it provides industrial firms with access to MIT's expertise and resources, as well as comprehensive information about research and educational activities at MIT. MIT faculty and staff receive revenue sharing from the ILP (10 percent of gross revenues) based on their participation in the Program's activities. Recently, the program has come under criticism for its role in transferring results of U.S.-funded research to foreign ILP-members, particularly to Japanese firms.

In the oceanographic field, industrial liaison programs appear to be most useful in situations where the volume of data collection exceeds existing capacity of the research infrastructure to process and analyze.

Intellectual Property Protection and Licensing. The protection and licensing of intellectual property includes seeking patent and copyright protection for the results of work performed at the institution and the licensing of such intellectual property to commercial ventures. In return for the grant of licenses, research institutions receive financial or other resources from licensees. These resources can assume many different forms, including fixed fees, obligations to support research at the institution, royalties, equity shares, etc.

WHOI seeks patent (and copyright) protection, in its own name, for research results that appear to have commercial potential. This is accomplished either through WHOI's internal Patent Committee or, at the recommendation of the Patent Committee, by an outside intellectual

property management organization (IPMO), the Research Corporation. Either the IPMO or WHOI then actively pursues the commercial licensing of the patent. During the life of the institution, WHOI has had only a few patents which have not been assigned to sponsoring government agencies. For the most part, therefore, royalties or other compensation flowing to WHOI for patent licenses has been small.

Royalties from the licensing of intellectual property are distributed internally according to a set formula. This formula varies greatly from one institution to the next; the inventor's share can range from all of the royalties to 15 percent or less. At WHOI, the inventor receives 50 percent of net royalties from internally pursued patents or 15 percent of the gross plus 50 percent of additional net royalties from patents licensed through the Research Corporation. One reason for this diversity in royalty distribution policies has to do with the search for an elusive "balance" between two distinct phenomena. It is believed that awarding full royalties to an inventor may create a disincentive for researchers to work together and share ideas and research results within an institution as they try to avoid the dilution of royalties. On the other hand, the traditional solution to this problem -- a policy requiring the sharing of royalties -- may create an incentive for researchers to leave an institution and claim full royalties for themselves (Farrow, In Prep., 1989).

Universities generally follow the same policy as WHOI, although there appears to have been a trend in the last decade away from the use of IPMOs and toward the establishment of technology licensing and transfer offices within each university (Johnston and Edwards, 1987). Large universities such as MIT, Stanford, Harvard, and Columbia all have technology licensing offices. Some of these offices limit their activities to the licensing stage, as does WHOI, while others pursue the establishment of spin-off commercial ventures (see below).

Intellectual property created by FFRDCs and other laboratories, which are funded predominantly with government support, usually is owned by the government and made available to the public through non-exclusive licenses, unless it is kept secret for national security reasons.

A relatively new issue concerning tangible research property (TRP) has gained increasing attention. TRP may include biological organisms, such as those developed through biotechnological techniques, or unpatentable research designs. WHOI has had some limited experience with the licensing of instrument designs for royalties and with the "trading" of bacteria obtained from the deep sea, hydrothermal vent, biological communities for grants from biotechnology companies. TRP is a developing area of intellectual property and deserves close attention.

Cooperative Research Centers. These centers are important technology transfer mechanism at the national level. Because there are no national centers established at WHOI, these and some other technology transfer mechanisms (discussed below) are represented in Figure 2.

Cooperative research centers established at universities include the Engineering Research Centers (ERCs) and the Science and Technology Centers (STCs), started by the National Science

Foundation (NSF) in 1985 and 1988, respectively. ERCs are designed to stimulate applied engineering research and include financial support, advice, research direction, and active participation in research by commercial sponsors. To date, 18 such centers have been established, including an offshore technology center at the University of Texas at Austin and Texas A&M. STCs are not required to include industry sponsorship or research participation, but they are expected to transfer technology to the industrial sector (Walsh, 1988). Eleven STCs have been established thus far.

The Ocean Drilling Program (ODP) is another example of collaborative research in the field of oceanography (Figure 1). ODP is an international partnership of governments that takes worldwide samples and conduct analyses of geological ocean basin cores. Industry collaboration in ODP is minor, and mostly takes the form of financial commitments from industry in the United Kingdom. Similarly, there is minor but occasionally significant industry sponsorship of research at academic institutions through the National Sea Grant College Program. There are several examples of technologies which have been commercialized from Sea Grant research efforts or which have helped marine-related industries become more productive.

Figure 1. Types of Technology Transfer at Woods Hole Oceanographic Institution.

Technology Transfer Organizations (TTOs). TTOs can take the form of for-profit or nonprofit corporations, foundations, partnerships, or consortia that are established internally or as independent entities. Unlike IPMOs and their internal equivalents, the primary mission of a TTO is the creation of spin-off firms (Figure 2).

Other Possible Forms of Technology Transfer

Figure 2. Technology Transfer Organizations (TTOs).

Because there usually is no corporate link between a wholly independent spin-off firm and the institution from which it emerged, spin-off firms represent, in a sense, discrete technology transfers. However, there often is a continuing relationship between spin-off firms and the "parent" institution; the firms often find their first customer in the "parent." In many situations, scientists can retain some connection with a spin-off firm that is commercializing their technology development, such as serving on the board of directors or as an advisor, without creating a conflict of interest.

In the field of oceanography, spin-off firms may be the most prevalent form of TTO. Many small oceanographic equipment firms are spin-offs from oceanographic research institutions (Broadus, Hoagland and Kite-Powell, 1988). At WHOI, the Public Information Office has estimated the total annual revenues produced by commercial spin-off firms from WHOI at approximately \$50 million, a figure of the same magnitude as WHOI's annual budget. Whether this phenomenon is widespread in the field of oceanography as a whole remains to be determined.

A number of universities and other non-profit organizations have established external TTOs as nonprofit Technology Transfer Foundations. Unless profits are plowed back into research at the parent institution, these foundations may be found ineligible for nonprofit tax exemptions. In many cases, these foundations are established to provide a buffer between a nonprofit research institution and a commercial venture, thus limiting liability and protecting the parent's tax exempt status. Among the oldest of these foundations, the Wisconsin Alumni Research Foundation (WARF) recently has expanded its role beyond traditional IPMO functions to the creation of a fully taxable subsidiary, which engages in a joint venture to design, manufacture, and market hearing aids. Profits earned by the subsidiary are added to WARF's income; all net income from WARF is distributed back to the university in the same manner as intellectual property royalties are distributed in other institutions.

Partnerships account for approximately 50 percent of industry sponsored research conducted at universities (TCF, 1984). One form of partnership, the R&D Limited Partnership, has received special attention because of its limited liability for investors. R&D limited partnerships are structured so that one "general" partner manages, supplies technology and other capital, and, most importantly, assumes liability for the actions of the partnership (Reams, 1986). "Limited" partners supply financial contributions or technology in return for an equity share and immediate tax write-offs for investing in "research and experimentation." Universities or nonprofit research institutions generally participate as limited partners, primarily because of concerns that their endowments could be prime targets for potential commercial product liability suits.

It is unknown whether oceanographic research institutions have established R&D limited partnerships as a means for technology transfer. As an institutional form, R&D limited partnerships appear to hold great promise both for attracting research funds and for commercializing research results. However, considerable effort is involved in the organization of such partnerships, and to date, the verdict on their final success is still out.

Conclusions

As a first step toward an understanding of technology transfer in the marine sector, we have focused on specific linkages between institutions in the field of oceanography (WHOI) and industry. Some preliminary conclusions are presented here.

The proportion of industrial support for basic scientific research in oceanography probably is smaller than the national average for all disciplines. (Estimated direct and indirect industrial

support for scientific research at WHOI averages about one percent of total sponsored research, well below the national average of six percent for all disciplines.) It is possible that the presence of only minimal industry support of or interest in technology transfer in a basic research-intensive field, such as oceanography, will be perceived as an indicator of the lack of "usefulness" or "value" of research done in that field. In this case, *technology transfer activity may be an inadequate measure of the usefulness or value of research*. For example, fundamental research directed at understanding global scale oceanic-atmospheric interactions would have limited commercial value, at least in the early stages. Other criteria based upon scientific merit, such as those currently employed by NSF, ONR, NOAA, and other government sponsors, may be more appropriate methods for determining the usefulness or value of research results in this field.

Opportunities for technology transfer do exist in the field of oceanography. These include:

- increased use of government-brokered technology transfer programs such as cooperative centers and Sea Grant;
- concentration of research in industry-supported fields such as marine biotechnology and microelectronics;
- establishment of industrial liaison programs where the rate of data accumulation exceeds current processing capacity;
- establishment and use of external TTOs; and
- establishment or expansion of aggressive internal IPMOs.

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"Strategic Alliances" as an approach to R&D by Electronic Instrument Companies

Malte von Matthiessen
YSI, Inc.

Background

YSI has established a series of strategic goals and objectives for itself.

- to become a leader in the field of sensor measurement technology, especially in the areas of temperature, biosensor, dissolved oxygen and conductivity measurement.
- to compete in the global marketplace by entering markets outside the United States, including Europe and the Pacific Rim, making the world our marketplace.
- to consult financial business, that is, to generate internal capital needs using the world economy.
- to dedicate ourselves to the concept 'strategic alliance' within our business philosophy.

Strategic Alliance

By the term 'strategic alliance,' I'm referring to the classical Greek use of the word 'strategy' - a general leading an army. In other words, employing a military science or art to the overall planning of large scale operations to achieve the stated objective.

An alliance can be thought of as a pact, or confederation among nations cooperating for a common cause. There are military alliances, such as the North Atlantic Treaty Organization (NATO), economic alliances like the European Economic Community (EEC), technological alliances, and alliances between government and industry, such as Japan's national trade organizations. We've seen the emergence of business alliances and, of course, there are alliances in our personal lives, such as marriages.

What do global and strategic alliances have to do with electronic instrument companies? Markets are becoming increasingly global in their orientation. The United States is competing in a global economy and will continue to do so for the foreseeable future. That all adds up to increased

competition, and all of the competitors are positioning themselves to take advantage of the same market segments.

Added to this stiff competition is a rapidly changing technology. Product life cycles that at one time were perceived on a scale of ten years are often three years or less now. This constantly changing technology is extremely costly. People with new ideas want to commercialize these ideas, facing the cost of capital as yet another challenge. Every company, large or small, is competing for the same resources, and as competition intensifies, the resources become more scarce.

Then there are the internal problems that beset most companies, such as inwardly focused and inbred attitudes. There are several steps we have taken at YSI over the past four years which I believe could address some of these challenges which I have just outlined. For example, we've made a 50 percent investment in joint venture with a United Kingdom distributor, making our distributor a joint venture manufacturing company. We believe it will be helpful to us in the long run to expand our presence in the European economic community. Recently, we have also invested in a small research group, working on miniaturized electrodes, on the campus of the University of Kansas. This investment was made in exchange for stock, with the option for an additional 15 percent of their company.

We have also invested in a small venture start-up operation in Pasadena, California in exchange for equity position. That company is researching ways to commercialize a product to permit a diabetic to take a blood sample without having to invade the body.

We have a joint venture with a company in Japan that manufactures temperature sensors; and an agreement with a biotechnology center at the University of Leeds in England to jointly develop biosensor equipment, a market in which England is emerging as a major contributor. Considerable research is going on at Cambridge, Oxford, and the University of Surrey.

We are also forming a joint research institute with Antioch College in Yellow Springs, Ohio. Scientists and professors at that institute may apply for research grants from the National Science Foundation, the National Institute of Health, or from private foundations.

We have signed a joint marketing agreement with a hospital supply company. They will market one of our products -- a temperature probe with intensive care application.

Finally, in the past year, we also acquired ENDECO, an oceanographic instrumentation company in Marion, Massachusetts. We are hopeful that this new presence on the east coast will attract technically-skilled employees to the company and also expand the uses for YSI's products to oceanographic purposes, for example, for data logging and telemetry.

Putting all this into perspective then, there are a number of requirements for successful strategic alliance. There must be a shared purpose and common values among the participants. Mutual goals should be established. Willingness to take risks and trust in each other must exist. In

summary then, the desired result of strategic alliance -- accessibility to new markets and development of new resources -- can be achieved. Examples of companies and countries working together come to mind -- alliances that have articulated a national agenda. Alliances which have truly worked together in all areas: labor, management, government, education, the public and private sector.

We are all aware of such collaborations which take place in Japan, but it also takes places successfully in other countries. Sweden is one very good example. Some twenty years ago, Sweden was heavily dependent on its primary industry -- automobile, steel, machinery, etc. But little by little, and without much fanfare, a number of Swedish corporations have been assuming prominence on the world marketplace as major leaders in certain areas of technology.

But for some reason, we cannot seem to do that here in the United States. There is little encouragement at the national level for such collaboration, so it must be assumed independently. And I do believe that the issue of survival is an important part of this process.

Finally, I would like to emphasize three points in terms of this concept of strategic alliance: (1) enhance your deployment of resources (2) learn to subordinate your own priorities through collaboration, and (3) strive for the creative application of new technologies.

Competitiveness, Security, and Dual-Use Technologies

Gerald L. Epstein
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Harvard University

I notice that the title for this session is "Alternative Applications and Avenues for Instrument Spin-off." What I will be talking about this morning is spin-off in its largest sense: the entire relationship between defense and commercial technology development. The study I am directing at Harvard concerns dual-use technologies -- those technologies having important applications to both national defense and international competitiveness. Since we are still in the middle of our analysis, all of our work to date must be considered preliminary. However, I would like to share some of our thinking about these issues with you and the committee.

Our group at the Kennedy School²¹ is concentrating on dual-use technologies because we believe that understanding the relationship between the nation's military and commercial technology development processes is important for developing policies that will improve both of them. We are not presupposing that the optimal course is to seek greater integration between defense and commercial activities. That path is certainly plausible in some cases, just as an opposite one may be called for in others. What we hope to do at Harvard is create a sound basis for formulating dual-use technology policy in the United States and perhaps develop some general criteria by which we may judge which technologies would benefit from military-civilian synergy.

Motivation

We are looking at the defense/commercial relationship in the first place because the nation's science and technology system is facing two serious problems today. On the defense side, weapons systems are climbing in cost at a rate consistently exceeding inflation at the same time that future defense budgets are dropping. We seem to have difficulty building systems that are both affordable and cost-effective. Cost aside, many wonder whether our systems are as effective as they could be strictly from a military standpoint. On the commercial side, our

²¹Principal investigators of the Dual-Use Technologies Project are Lewis Branscomb, Harvey Brooks, Ashton Carter, Paul Doty and Dorothy Zinberg of the Science, Technology and Public Policy Program and the Center for Science and International Affairs at Harvard's Kennedy School of Government. Funding is provided by the Carnegie Corporation, the Sloan Foundation and several corporations.

international economic competitiveness -- according to such measures as balance of trade, productivity growth and world market share -- is eroding.

These two problems -- fielding effective and affordable defense systems and producing commercial products that are better or cheaper than their competitors -- are the ones that deserve our focused attention. Understanding the dual-use relationship is interesting only if it helps us solve the problems faced individually by our defense and commercial sectors.

The Defense Department and Dual-Use Technologies Today

In the decades following World War II, Department of Defense (DoD) investments in fields such as jet aircraft, computers and industrial electronics, advanced the state-of-the-art and contributed to significant U.S. advantages in foreign trade. Notably, DoD procurement dollars were often more effective than research and development (R & D) dollars in stimulating these fields. The United States dominated the world technologically and the Defense Department led U.S. industry in several areas of technology.

Since the 1950's and 1960's, however, other industrialized democracies have caught up with -- and in places surpassed -- the United States. And technology in civilian high-technology industry has caught up with -- and in places surpassed -- that in the defense sector. Since the 1960's, for example, Japan and West Germany have spent a larger fraction of their Gross National Product (GNP) on civilian R&D than did the United States. Since the 1970's, the fraction of GNP spent on R&D in these countries has matched or exceeded the total U.S. proportion, even when the enormous U.S. defense R&D investment is included.

A vibrant and increasingly internationalized civilian high-technology industry exists today, with DoD now being a minor customer in many areas (such as microelectronics) that it had originally pioneered and for which it was for many years the dominant customer. To keep abreast of the latest technological advances, the Defense Department must be able to draw on commercial technologies developed in corporations that may not need, or even be particularly interested in, DoD's business. In some areas of technology, one might say that the tail has become the dog. The Department of Defense finds itself attracting increasing attention, much of it self-generated, as the possible or principal agent for revitalizing our commercial technology base. This attention is in part due to DoD's historical role in pioneering advanced technology; for better or worse, the national security apparatus of this country has become the government's prime repository for managing large-scale technological enterprises. For others, DoD's managerial experience is less important than its political expedience: national security provides a rationale for the federal government to engage in activities it might not otherwise pursue, particularly with respect to involvement in commercial business. And there is always the lure of what Professor Lewis Branscomb calls the "Willy Sutton" theory of industrial policy, with the Department of Defense being "where the money is."

Dual-Use Interactions

Unfortunately, terms such as "dual-use" and "technology transfer" imply that the application of defense technology to commercial purposes (and vice versa) is a relatively straightforward process; that "dual use technologies" are black boxes into which defense or commercial activities can be plugged interchangeably.

The interactions we are looking at are more complicated and occur on many levels; they are impossible to describe fully in a diagram. By dual-use technology, we mean not only artifacts that can be found in both weapons systems and commercial products but also the underlying knowledge base, analytical techniques, technical processes and design and manufacturing experience by which we apply our knowledge to solve problems. Focusing on artifacts without considering the underlying base of technical knowledge can be very misleading.

Figure 1, taken from ongoing work by Professor Ashton Carter at the Kennedy School, illustrates some of these relationships.²² On this figure, the main problems facing the nation are in the horizontal direction -- ensuring that both the defense and the commercial sectors function effectively. Dual-use linkages are represented here by vertical lines. Note that we are conjecturing that the strongest linkages are those at the sub-tier levels -- the subcontractors and component suppliers that deal with both military and commercial clients. We believe these interactions to be significant, but have not been able to find much quantitative analyses at these levels. Also noted on this diagram are the more indirect linkages between the commercial sector and military funded research in universities and national laboratories. Much of the national "technology transfer" debate focuses on how well technologies developed in the national laboratories or in universities becomes utilized in products. However, it is important to note that the "horizontal" problems I have mentioned are probably more associated with product and process design and with production that they are with the research and development. Therefore, even if these "technology transfer" linkages are strengthened, the most important problems may remain. Focusing primarily on research and development misses the essence of our problem.

²²Ashton B. Carter, "Anatomy of the Dual-Use Relationship," Science, Technology, and Public Policy Program Discussion Paper 88-05, Figure 8, p. 25.

TECHNOLOGY RELATIONSHIPS

Figure 1. The Defense/Commercial Technology Relationship

Modes of Dual-Use Interaction

Dual-use interactions take on many forms. Table 1, modeled on a similar table in Professor Carter's discussion paper,²³ lists several different modes by which military activities affect commercial technology development and vice-versa.

Table 1: Modes of Dual-Use Interaction

Mode	Example
"Spin-off"	Microwave Oven
Procurement Pull	Boeing 707 Semiconductors Supercomputers
Co-Development	Jet Engine
"Cross Subsidization"	Communication Satellites Nuclear Power
Generic "Overhead" Research	Artificial Intelligence Tool Development Finite Element Analysis
"Commercial Off-the-Shelf"	MILVAX Jet Engine Lubricants
Forced Diffusion	VHSIC Program
"Bootleg" Industrial Policy	SEMATECH High-Definition TV

Spin-off: "Spin-off" refers to those relatively infrequent instance in which a military product finds direct application in a civilian product with little modification. A good example is development of the microwave oven by the Raytheon Corporation. Raytheon built military radars during and after World War II. To assure reliability, the magnetron tubes that powered

²³This figure, and much of the discussion in this section, are modeled on "Anatomy of the Dual-Use Relationship," footnote 2, esp. figure 7.

the radar were "burned in" for a period of time before the radar was shipped out. The engineer in charge of the laboratory that ran these tests realized that the energy these tubes produced could be used to cook food. However, this innovation didn't automatically become a commercial success. It took considerable investment on Raytheon's part, including the acquisition of the Amana Corporation, to give Raytheon the experience in consumer product design and provide it with the necessary distribution system.

Another example of "spin-off" in this sense would be the enormously successful Boeing 707 airliner, which is closely related to the KC-135 tanker ordered by the Strategic Air Command to refuel nuclear bombers on the way to their targets.²⁴

Procurement Pull: The contribution made by the military to the growth of the semiconductor industries -- and later, the supercomputer -- took a very different path. Many of the most important technical advances that led to the present day industries in these fields were not the result of government funded research, but rather followed from private R&D investments made with the expectation of government purchases. The mere knowledge of a potentially large market, particularly one less price-sensitive than typical civilian markets, was sufficient to motivate considerable private research and development investment by firms that hoped to capture that market. Production for the military enabled companies to lower prices and improve performance and reliability to the point where a commercial market was created.

Co-development: The third mechanism listed here is co-development, where both military and commercial markets are clearly identified and have their respective technical demands coincide. In such a case, a single development program driven more or less equally by both users can satisfy both. Jet engine development followed this model.

Cross-subsidiation: "Cross-subsidiation" refers to the development of an expensive technological infrastructure by the government that then becomes available to the commercial user with a modest marginal investment. Commercial communications satellites would have been impossible without the investments made in space launch infrastructure -- boosters, launch sites and ground support -- by the military and by the National Aeronautics and Space Administration (NASA). The civilian nuclear power program similarly began by building upon the existing nuclear weapons infrastructure. Note, however, that subsequent investments in commercial nuclear power could hardly qualify as modest.

²⁴The 707 is not, however, just a civilian version of the KC-135. Both planes derive from the same Boeing financed 367-80 prototype tanker, which was first flown in 1954 and early studies showed that an optimum diameter for both planes would be 144." The KC-135 was produced with this dimension and first flew in 1956. However, subsequent studies indicated that the commercial airliner should be 4 inches wider, a change that precluded the 707 from using most of the KC-135 tooling. The 707 first flew in 1958.

Generic Research: Basic and applied research funded by the government in association with missions such as space exploration or national defense can, in a very indirect way, lead to commercial applications. Artificial intelligence (AI) research had been funded in universities by the Defense Advanced Research Projects Agency (DARPA) for some twenty years before commercially successful applications of the technology, albeit modest ones, began to be marketed. Indeed, ambitious military AI objectives such as autonomously operating vehicles and automated target recognition have yet to be achieved.

Development of Tools: Besides their R&D activities, the mission agencies of the federal government have also been responsible for the development of tools that have subsequently taken on widespread application. NASTRAN is a public domain computer program originally developed by NASA to analyze mechanical structures (NASTRAN is an acronym for NASA STRuctural ANalysis). NASTRAN is the parent of several important structural analysis programs that are now marketed, supported and maintained by private suppliers.

COTS: In some cases, military users are able to satisfy their requirements by purchasing components or systems that are available "commercially-off-the-shelf" (COTS). Raytheon Corporation hoped to enter this market when, under license from the Digital Equipment corporation, it released a militarized version of a new model VAX computer on the same day that DEC released the civilian version. In providing the full functional capability of the VAX in a package acceptable for military use, Raytheon was able to give the military access to state-of-the-art technology in a field where military systems traditionally lag behind their civilian counterparts by many years. Moreover, this approach permits military users to use the vast body of commercial VAX compatible software.

Forced Diffusion: The military on occasion has mounted a program to force the diffusion of new technological practices or techniques. Some describe the military's Very High Speed Integrated Circuits program as an attempt to bring the level of technology used by military micro-electronics producers up to that being embodied in commercial products.

Bootleg Industrial Policy: Finally, the last category on this list is "bootleg" industrial policy, where what otherwise would be deemed unacceptable federal intervention in commercial industry becomes legitimized by an ostensible national security motivation. The Defense Department began funding SEMATECH, a consortium of semiconductor manufacturers formed to pursue R&D in semiconductor manufacturing, at a level of \$100 million per year. That was done after a Defense Science Board (DSB) report in 1987 warned of the growing dependence of U.S. weapons systems upon foreign made semiconductors. DoD's requirements for secure supplies of semi-conductors, argued the DSB, mandated that it take some responsibility for ensuring that the U.S., retain a competitive industry in this area. Similar arguments are advanced in support of DoD participation in efforts to create a viable high-definition television industry in this country.

Differences between the Defense and the Commercial Sectors

Any analysis of the relationship between the defense and the commercial sectors -- and in particular, any proposals to seek greater integration between the two -- must recognize the fundamental differences between the two. Table 2 summarizes some of the most significant of these. Whereas, the commercial marketplace is pluralistic and competitive, with many suppliers and consumers in a great many classes of product, the military market is a monopsony with the U.S. government being the only buyer. As a result, government involvement in the defense sector is heavy and direct. Although governmental policy certainly affects activities in the commercial marketplace as well, the interactions are indirect; in this country, the government has studiously avoided any activities that might be construed as direct intervention in commercial markets.

Table 2: Comparisons between Defense and Commercial Production

	<u>Defense</u>	<u>Commercial</u>
Market	Monopsonistic	Pluralistic and competitive
Government Involvement	Heavy and Direct	Indirect
Time scales	Decades	Years or months
Emphases	Shelf Life Unique Function	Manufacturing Cost; Quality Reliability
Production Rate and Volume	Low	High
Relationship between R&D and Production	Separated	Integrated and Interactive

The time scales relevant to typical defense systems are much longer than those pertaining to commercial activities. Decades can elapse between the first formulation of a new military requirement or the retirement of the subsequent system from active inventories. On the commercial side, however, product life cycles can be measured in years and a few months can spell the difference between success and failure.

The technical goals sought by designers of defense systems typically stress unique technical capability and a long shelf life. Minimizing cost has been a secondary goal. Commercial products, on the other hand, are much more cost-sensitive. Low manufacturing cost is paramount and quality and reliability are emphasized to a greater degree than they have been in

weapons systems. Lot sizes and production rates for military systems are low and budget cuts often lower rates still further as production is stretched out over a longer period. Commercial products are typically built in larger quantities and at higher rates, although many commercial products are produced in far smaller quantities than the consumer electronics devices and cars that are often held out as "typical" commercial products.

Finally on this list, defense procurement policy has enforced a separation between a system's R&D and its production: to prevent contractors from deliberately underestimating R&D bids in the secure knowledge that they could recover their costs and then some in the subsequent procurement, legislation has decreed that military production contracts be recomputed once the R&D has been completed. In the commercial world, however, a company does not go through the effort of designing a new product without some expectation that the product will eventually be manufactured. Furthermore, R&D does not stop once the system is in production; market competition promotes continued redesign and improvement.

Differences between the Interests of National Security Policy and Economic Competitiveness Policy

In addition to the structural differences between defense and commercial activities described above, dual-use technology policies also must account for those areas where military security interests call for policies that differ from, or even conflict with, policies for improving this country's international economic competitiveness. Such differences or conflicts might make it preferable to decouple certain fields of military technologies from their commercial counterparts, for example, or to limit the Department of Defense's role in commercial technology policy.

Conflicting Goals

A well known example where the goals of seeking military superiority and of promoting American high-technology industry collide is the issue of export controls. Limiting the export of high-technology products or components in order to limit the technological development of potential adversaries inherently conflicts with attempts to promote this country's export sales and improve its balance of trade.

Differences in Critical Technologies

Although many dual-use technologies can be identified that are vital to both military and commercial activities, other areas of technology do not find equally strong support in both sectors. For example, DoD is heavily involved in the aerospace and the electronic industries, with the federal government estimated to fund 82 percent of the former industry's R&D and 43 percent of the latter's for 1989. Other industries are oriented much more strongly towards the commercial sector. For example, the government will fund only an estimated 3 percent of the

chemical industry's 1989 R&D.²⁵ Barring significant changes in its mission, DoD would not be expected to be the focus of progress in many areas of technology important to the commercial economy.

Institutional and Cultural Mismatches

Considerable differences have developed between military activities and commercial activities in terms of corporate strategy and structure, business practices and engineering design philosophy. Many of these differences were discussed in the previous section and many of those are fundamental to the different missions of the defense and the commercial sectors. Other reasons for divergence between the defense and commercial sectors may not be inherent, but they nevertheless loom large today.

Much of the business activities of the two sectors, for example, are segregated. although most defense contracting is done with companies having significant commercial business (of the 78 firms with the highest military sales in 1987, only 12 had more military sales than commercial), these firms tend to conduct defense business in separate divisions, usually having very different administrative practices and technical and business "cultures" from those used on the commercial side.

Reasons for the separation include procurement regulations, accounting standards and business practices mandated by the government. No matter how much some may wish government to adopt the practices of the private sector and the efficiencies that market demands impose, there are fundamental and inherent differences between the government and the private sector that may prevent substantial integration of the defense sector with the rest of the economy.

Summary

My colleagues and I believe that understanding the relationship between the military and the commercial technology development systems can provide useful insight in formulating policies that will leave us better able both to defend ourselves and to improve our standard of living. We are hopeful that areas of synergy can be identified and exploited. However, intelligent policy-making will also require that conflicts between defense technology policy and our strategy for promoting civilian economic competitiveness be understood as well.

²⁵Battelle Memorial Institute, Probable Levels of R&D Expenditures in 1989: Forecast and Analysis, December 1988, p. 12.

Basic Services and Instrumentation Opportunities in Mobile Satellite Communication

John Fuechsel
Maritime Service, COMSAT

Background

COMSAT is the designated representative of the United States to both INTELSAT (International Point Satellite System) and INMARSAT (International Maritime Satellite System). In addition to being a maritime satellite system, INMARSAT is also becoming a mobile system for aeronautical and land mobile uses.

COMSAT's products have definite potential for application to marine instrumentation. We do not supply the equipment to our clients, just satellite access. Equipment manufacturers sell terminals which are type approved for use in the INMARSAT system.

COMSAT has extensive oversight by U.S. governmental agencies. The Department of State directs positions to be taken in meetings of the council -- INMARSAT's board of directors. The FCC regulates COMSAT as a common carrier, approves COMSAT's tariffs and limits market entry through its jurisdictional process.

The National Telecommunicating and Information Administration (NTA) is the chief of staff for government telecommunications policy. Housed within the Department of Commerce, its role is to act as a liaison between the various government oversight agencies and COMSAT. The Coast Guard oversees safety issues. Since INMARSAT began as a safety system it has taken on a major safety role under IMO (International Maritime Organization).

COMSAT's Role

COMSAT's service offerings, for Standard-A ship-earth stations in the INMARSAT system have both telex and voice capabilities; these are interconnected with public switched networks. Telex can be thought of as the common denominator -- one can send a message anywhere in the world with telex. Telex, however, is not a particularly efficient service since it only runs at 50 baud and cost \$4.00 per minute. High volume customers do much better transmitting data using the voice channel since it is easier to achieve a throughput of 2400 bits per second at \$10.00 per minute.

We are seeing a high use of facsimile, which, like other data applications, are transmitted over the high quality voice channel -- that is, higher quality compared to the public switched telephone network. When running medium speed data, the quality of the dial up line will probably be sacrificed. For higher data rates, a conditioned line to COMSAT's earth station is needed.

COMSAT will facilitate interconnection with other networks at its two earth stations in California and Connecticut. The Department of Defense has expressed interest in AUTOVON and DDM connections; the civil government has expressed interest in FTS, and there are certain packet data networks that the oceanographic community intends to use.

What Comsat has to offer

Generally speaking, COMSAT can offer many "high tech" services which people in this country want to use and, of course, our public switched network will support these better than the networks of other countries.

COMSAT is also being used by law enforcement agencies, disaster relief agencies, for collection of environmental reports and volunteer weather observer messages. In addition, it is employed for the dissemination of warnings and alerts and the general facilitation of clearance of ships, cargo, passengers, crew and crew effects.

We plan to introduce a small, compact Standard-C terminal which uses an omni-directional antenna. Much of the existing service over the past twelve years has used what we call a Standard-A terminal which has a tracking, stabilized, 85 centimeter dish under a radome and supports both telex and data services.

Approximately 10 percent of our terminals are land transportables. The FCC scrutinizes applications fairly closely. In remote areas, it is relatively easy to obtain a license. In metropolitan areas, however, use of other existing facilities will be encouraged.

Oceanographic Applications

We find that the oceanographic community tends to use the highest state-of-the-art technology; due in part to a greater familiarity with computers and modems, and a desire to get the maximum efficient use from a system. There are some new and noteworthy trends emerging in oceanography -- many of the sensors have a high volume output. The current profiler puts out too much data to pass through the GOES satellite or in the ARGOS system.

There has been a big surge in hydrographic surveying capability which facilitates many other things, such as electronic charts. We have worked jointly with NOAA and a private contractor on developing expendable bathythermograph observations. And we have also worked closely with the University National Oceanographic Laboratory (UNOLS) organization and their research vessel operators.

Global Maritime Distress and Safety System

I consider this Distress and Safety System to be a major initiative which is long overdue. We are now at the threshold of its introduction and expect it to make a significant impact on the marine equipment market. It is the first significant overhaul of the Maritime Distress System since the days of the Titanic. The original safety treaty specified in great detail how the system would work: it called for specific safety equipment aboard the ships and mandated a radio operator to be able to use manual Morse Code. These mandates became mired within the bureaucratic language of the international treaty to the point that changing any part of them meant a major overhaul.

The radio unions were reticent about making changes for several years and it took quite awhile to get to the point we are at now, which is the result of a diplomatic conference. For instance, phasing out manual Morse telegraphy is going to mean a new training role for the maritime academies. We expect that the third mate will inherit the duty previously provided by the radio operator. The presumed absence of the radio operator on ships in the future will mean a financial saving to the ship operator which is more than sufficient to pay for the new equipment. One vessel manager reported that it cost \$200,000 a year to keep a radio officer on each one of his ships. However, that doesn't mean there won't be a role for radio officers on certain select ships where management chooses to retain on-board maintenance services voluntarily. The treaty only requires maintenance for safety equipment; it does not address electronic cargo monitoring devices and engine controls and other sophisticated equipment for which the operator may elect to keep a maintenance capability on board.

We are finding that much of the modern modular equipment for the GMDSS is not particularly susceptible to shipboard maintenance. It will not be a treaty requirement that a qualified maintainer be on board, provided the ship has access to in-port repair services in the course of its normal route.

The changing philosophy of GMDSS from what was basically a ship-to-ship alerting system to a ship-to-shore alerting system puts the responsibility of search and rescue assistance for ships in distress on the shore authorities.

Implementation of these measures will begin in 1992 and extend through 1999. Generally speaking, the developed countries preferred to move rapidly to minimize the overlap period during which both systems have to be supported and to take advantage of the savings in the technology as soon as possible. Underdeveloped nations sought to stretch the transition out as long as they could. I look for significant implementation early in the transition period to avoid last-minute problems.

GMDSS

There are four basic GMDSS areas -- A1, A2, A3, and A4. A1 is within VHF range of the shore and A2 is within MF range of the shore. A3 is the area of satellite coverage, which is

pretty nearly global. Except for the polar areas -- A3 includes virtually all of the navigable water. A4 is that part of the high seas outside of INMARSAT coverage. We have a small pie-shaped gap in the southeastern Pacific which will be closed before the transition begins by creating a fourth operating region in the western Atlantic.

I mentioned that our Standard-A terminal was the existing one; either a Standard-A or a Standard-C terminal will meet the treaty requirements. Standard-C will be a much smaller terminal, -- it has an omni-directional antenna about the size of a football, and the below-decks equipment resembles a modem. The whole package will probably sell for about \$5,000, while the Standard-A terminal will command \$35,000 to \$40,000.

Some of the GMDSS equipment requirements would include either a satellite terminal or a high-frequency radio teletype system with automated digital selected calling. The philosophy here is to transition radio watches to a ringer type service, rather than a 'line' audio watch.

We find that ships maintaining a watch using voice frequency invariably have problems with the volume being turned down or the squelch adjusted improperly. The system is a fairly loose one at present and distracting for the listener.

Additional equipment

Certain auxiliary equipment that will be required includes a NAVTEX receiver for coastal dissemination of marine safety information and distress alerts. It has a range of 50 to 200 miles, depending on how much power is being used. The broadcast is on the MF frequency 518 KHZ and is directly printed aboard ship. NAVTEX is now available and must be carried aboard ship by 1993.

The Safety NET receiver is basically a receive-only Standard-C INMARSAT terminal. It has very attractive selective alerting features which I mention because it will give insight into other ways this system might be used.

When it is called Safety NET, it is a system that disseminates distress alerts and marine safety information on the high seas. Fleet NET refers to the commercial counterpart.

We expect that most ships will fit a full Standard-C transceiver in addition to the Standard-A. A receive-only terminal is adequate, but the extra transmitter probably costs just \$2,000, and is a wonderful back-up for the Standard-A system which has a tracking, stabilized antenna. If there is ever any trouble with the terminal it is usually the fault of the tracking mechanism. Furthermore, having a backup system onboard relieves one from onboard maintenance requirements.

Safety NET can alert ships selectively in a geographical area and address all ships in any one of 16 NAV areas. You rarely want to alert a whole ocean region but you can alert all ships within 100 miles of a given geographical point. If there is no response the first time, the alerting radius

can be increased. The watch has to key in the position of the ship periodically or connect a navigation receiver to the Standard-C terminal.

Another GMDSS equipment required aboard ship in 1993 is the satellite Emergency Position Indicating Radio Beacon (EPIRB), operating with the COSPAS-SARSAT satellite transmitters which are not part of the INMARSAT system. The orbiting satellites locate the EPIRB while receiving its alerting signal. At present, EPIRBS work on the old frequency of 121.5 MHZ, and the satellite must be in sight of both the person in distress and the shore receiving station simultaneously; otherwise, nobody hears the signal since it is not recorded on the satellite. When the new 406 MHZ EPIRBS come out, there will be a refined locating capability onboard and the readout facility, which will mean truly global coverage for the first time.

In addition to these features, the existing medium frequency voice system based on 2182 KHZ is retained but with digital selective calling. The MF coverage area we call A2, -- the coastal zone to about 100 miles offshore. The VHF installed is also retained with digital selective calling and serves the A1 coverage which is within that zone covered by VHF from shore, -- about 20 miles.

I mentioned that A1 and A2 are not very significant areas in this country because there is real doubt about whether the Coast Guard will implement their shore network to provide alerting services for the A1 and A2 areas. If we should have an A1 or A2 area, ships that do not leave those coastal zones would not have to be equipped with the high seas equipment.

Standard-C System

I would like to mention a few things about the Standard-C system now, because it will have many applications in oceanography. It is a data-only store-and-forward system which operates in near real time. The new INMARSAT Standard-C service is a system which uses the same satellites as the Standard-A system which I have described, but with much smaller and less expensive terminal equipment on the ship.

Standard-C is a digital data only service with a through-put of 600 bits per second,--that's about 10 times the speed of the Standard-A Telex Service.

Standard-C is attractive from several standpoints; it will open the satellite communication market to much smaller vessels such as yachts and fishing vessels. It is identical technology to what will be used to serve the emerging land mobile community. This could create a hybrid market in which certain users operate a terminal primarily aboard a vessel but occasionally from a land vehicle. However, the greater significance of a combined market has to do with economy of scale. Because the land mobile market is potentially many times larger than the maritime market, we will benefit from lower equipment and operating costs than would be the case if we had to depend on the maritime market alone.

Standard-C will disappoint some users who prefer a voice capability but there are many positive aspects of a data service that deserve mention. Data is a precise mode with a printed record of traffic exchanged and not as vulnerable to the misinterpretation and poor recollections often associated with verbal exchanges. It is also much more efficient in use of the space segment and therefore less costly than voice service.

Standard-C is a true computer-age service which utilizes personal computers as an input-output device and operates in a near real time store-and-forward mode, typical of electronic mail box applications. The store-and-forward application also avoids the need to get a direct connection with the message addressee, which can be a real problem with full duplex communications. The usual satellite data integrity can also be expected since the Standard-C system operates at 1200 bits per second with half of the capacity dedicated to forward error correction.

There is currently a pre-operational Standard-C service in the Atlantic ocean region which is available for demonstration purposes. There is no charge for use of the space segment during the pre-operational period but telex land-line access charges must be paid. In addition to telex, the operational service will be accessed by packet data networks.

Some technical characteristics of the Thrane and Thrane Standard-C Ship Earth Station include the following:

<i>Omni-directional antenna:</i>	Rx G/T -24dBK
<i>Small Size:</i>	Electronics 3" X 8.4" X 10.9" Antenna 15.6" X 5.5"
<i>Lightweight:</i>	Electronics 4.5 pounds Antenna 3.5 pounds
<i>Typical Power Requirements:</i>	5-40 VDC 15/50 Watts 9-33 VDC
<i>Typical Interfaces:</i>	Centronics RS 232 C NMEA 0183 T-Bus Interface (CCI ~ V.10)

(Interfacing a navigation recliner such as LORAN-C or GPS for fleet management and Safety NET locating is a specific application.)

While the foregoing Thrane and Thrane specifications describe the only terminal currently type-accepted by INMARSAT, several other manufacturers have equipment in various stages of development, including SNEC, JRC, FURUNO, TOSHIBA and EB Nera. Note, however, that no U.S. manufacturers have entered the Standard-C market as yet. Terminal costs are currently

running \$6,000 to \$8,000 without input-output devices but are expected to run below \$5,000 with competition.

The Standard-C Ship Earth Station will meet equipment carriage requirements specified by the IMO for the new Global Maritime Distress and Safety System, and the receive portion of the terminal, if equipped with Enhanced Group Calling (EGC) software is the Safety MET receiver specified by IMO for receipt of high seas navigational warnings and distress alerts. Fleet NET is a commercial counterpart to the Safety NET broadcast service. The charge for broadcast services applies only to the originator,-- vessels receive the broadcast without cost.

The pre-operational service in the Atlantic will end when the first Coast Earth Station is ready for full commercial service. This is likely to be the British Station in the spring of 1990. COMSAT is currently modifying its two earth stations in Connecticut and California to provide Standard-C service and we hope that work will be completed by the summer of 1990, which is also the target date for full operational service in the Pacific. The Indian Ocean Standard-C service should also go into operational status through the Norwegian Coast Earth Station early in 1990.

COMSAT has not yet filed Standard-C tariff proposals with the FCC but expects to do so soon.

The projected tariff filings will call for:

Ship to Shore	\$1.05 per kilobit
Shore to Ship	\$1.25 per kilobit
Safety NET Broadcast	\$.45 per kilobit
Fleet NET Broadcast	(to be determined)
Brief Data Reports	\$10 per report (not exceeding 32 bytes or 256 bits)

The brief data reports are quite affordable and are intended to facilitate the collection of synoptic environmental data, Fleet management and similar services needing recurring brief reports.

The Status and Promise of Electronic Charts

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Introduction

The maritime world is about to enter a new decade with the expectation that it will benefit from new technology applied to ship handling and safe navigation. These changes will result from the introduction and widespread use of a variety of systems of electronic charts.

Electronic charts are the equivalent of conventional paper nautical charts that are created by a computer on board a vessel and displayed to the user by means of an electronic screen. They are almost always coupled to an electronic navigation system, resulting in the display of the vessel's position on the electronic chart and as an option can also be connected to the vessel's radar. Doing so adds an image of the situation surrounding the vessel, showing other vessels and the position of aids to navigation and objects on shore.

An electronic chart system is endowed with varying degrees of capability and sophistication, depending upon the use for which it is designed, the standards it is intended to meet and the price at which it is offered. These range from the units intended for use aboard yachts and pleasure craft to those designed to be installed on large, deep draft ocean-going vessels that move around the world. The units on recreational vessels generally possess just one smaller display screen of medium to low resolution and are intended to be an additional aid to the navigation of the vessel. At the other extreme, larger systems placed on commercial vessels may possess two or even three displays, use large screens of high resolution, employ a radar overlay and are intended to be the legal equivalent of a paper nautical chart.

An important aspect of electronic charts -- a quality that sets them apart from virtually all other forms of maritime electronics -- is the fact that the nautical chart is a legal document. Paper charts are accepted in courts of law as the means for describing vessel movements before and at the time of accidents and in some cases may actually be the cause of legal action if the charts are found to be in error. The legal nature of the electronic chart implies that if it is to be widely accepted by users, it must be acceptable to legal authorities. Fortunately, this is increasingly the case and provisional standards prepared by international and national bodies are being issued.

The world of electronic charts divides itself into two categories: those that are intended to be used as the legal equivalent of a paper chart, and those that are an aid to navigation where the conventional paper chart meets the legal carriage requirement.

This paper will discuss both types in order to describe the status and future development of this emerging field of application in the maritime electronics industry.

The Technology of Electronic Charts

Electronic Chart systems are derived from computer technology and in particular from the strengths and capabilities of the personal computer. An electronic chart system involves the following elements:

1. A stored replica of a nautical chart in digital with various features held in a set of files all related to the area covered by the digitized chart. Thus, the location and description of buoys, lights and other aids to navigation are each kept in a separate file and called to the screen whenever the particular feature is selected for viewing. Some items, like the coastline, are generally always in view; others may be selected at the user's option.

The scale of the display is selectable by the user, and it adheres closely to the scale of the chart of data from which it was created. If radar is employed, the scale of the chart will match the scale of the radar image being added to the display.

The program that controls the on-board computer incorporates a scheme for the automatic selection of the displayed chart based upon the location of the vessel. In this mode of operation, the chart in view always includes the current position of the vessel. In other cases, the user can select any area contained in the computer's files to display other places of interest.

2. A positioning system that locates the vessel and which generates a symbol on the display that represents this position. This electronic system can be Loran, the newer Global Positioning System (GPS), one or more of the other satellite positioning systems, or a Dead Reckoning estimate of position based upon an input of vessel speed and course.
3. An electronic display that combines chart information with the vessel's position. Color is generally employed to distinguish shore from water areas and to display buoys and lights in their actual colors. However, some of the lower cost systems may offer only a monochrome display.

The resolution of the display determines the degree of detail that can be incorporated in the electronic chart.

4. A radar image that is overlaid on the electronic chart is an optional feature of some systems. This image is displayed in characteristic colors in order to clearly differentiate the presence of other vessels or objects from the shoreline, water, and the vessel's own symbol.
5. A computer program that provides the ability to make the computations associated with voyage or route planning, with a prediction of the vessel's future position as it maneuvers in restricted waters and that records the historic position of the vessel during the journey.

Electronic Chart Systems Used as the Legal Equivalent of a Paper Chart

The larger, more expensive and more sophisticated electronic chart systems are intended to be the legal equivalent of a paper chart. These systems meet or exceed the requirements set forth in the Provisional Standard for Electronic Chart Display and Information Systems (ECDIS) issued by the International Maritime Organization (IMO). To meet these requirements, the ECDIS must display the minimum required set of chart features, must utilize a high resolution screen (at least 1000 x 1000 pixels), be capable of simultaneous display of the situation in the immediate vicinity of the vessel and of other areas to be used for route planning or position look ahead, optionally display a radar overlay while maintaining the resolution level of the chart and other technically demanding features.

The computer memory (i.e., mass storage in the form of hard disks, optical disks, etc.) required for storing chart files in these larger systems must be sufficiently extensive to cover the needs of the intended routes. All ships must carry charts of the areas involved in their journey. Ocean going, deep-draft vessels engaged in world commerce would be expected to have on file electronic chart data for all of the ports to be encountered on a voyage. This might involve hundreds of chart files consisting of the data for these ports compiled in separate files at separate scales.

Large ECDIS systems that are used in place of paper charts will be equipped with facilities for automatically updating it's chart data and displays. Ships arriving at a port will have had these files updated by radio broadcast while en-route, thereby displaying any chart changes appropriate to that harbor. Also, any warnings of temporary danger or hazards to navigation will be broadcast resulting in suitable displays on the ECDIS screens.

These systems will also be equipped with data files containing supplementary information, such as the data contained in Light Lists, Coast Pilot, Tidal Tables, etc., all in a format suitable for display on dedicated displays or on the charts themselves.

Electronic Chart Systems Used as an Aid to Navigation

Probably the largest number of users of electronic charts will be those mariners who use them as an aid to navigation, rather than as a replacement or substitute for a paper chart. When the paper chart is on board it fulfills the legal requirement for chart carriage. When an electronic chart system is also available many of the conveniences and safety features and benefits of the ECDIS are also present.

These smaller systems are characterized by reduced memory requirements (since they need carry fewer charts of reduced resolution), they may use smaller, monochrome displays instead of full color and they may, or may not, have provision for utilizing a radar overlay. Since they are not considered to be the legal equivalent of paper charts, they may not include all of the chart features deemed to be essential for a legal ECDIS. Nevertheless, these systems are effective in displaying vessel position, the progress made towards waypoints or destination and in performing calculations normally associated with charts.

Updating the Electronic Chart

One of the great conveniences resulting from the use of electronic charts is the ability to revise data contained within the files of the shipboard equipment and the subsequent display of updated information. Electronic displays can be altered by the receipt of radio data messages that contain permanent or temporary changes within various harbors. Updating the charts in this manner provides the mariner with the assurance that he possesses the latest information concerning the status of the harbor, aids to navigation and the presence of newly identified hazards as he transits the harbor.

While updating is technically feasible it does require an administrative infrastructure that has not yet been established. Radio broadcasting of Notices to Mariners is provided now by the Defense Mapping Agency (DMA) in the United States. These are in the form of radio teletype messages that can be printed on board ship for use in the manual correction of nautical charts. Notices to Mariners are published in printed form each week and Local Notices to Mariners applying to local areas in the United States are available each week from Coast Guard Districts as a printed publication.

In addition, there are a number of radio broadcasts of warnings to maritime interests relating to the meteorological or navigational hazards, essentially of a temporary nature, that are of a concern but not the subject of permanent changes to nautical charts.

None of these existing means are designed to transmit digital data messages in a format compatible with an on board computer in order to alter electronic displays. The existing administrative structure is designed to place updating data in the hands of shipboard personnel who can make manual changes to paper charts. Changes in this environment will be required

in order to take full advantage of the automation of updating implicit in the use of electronic charts.

There will be trials and demonstrations of updating electronic charts held in connection with various projects during the next few years that will explore the parameters involved in automatic updating. Such questions as data volume, frequency of updates, appropriate modes and formats of radio data transmission, etc., will all be explored in order to establish the basis for a permanent national and international activity of this type.

The Benefits Resulting From the Use of Electronic Charts

The principal benefits resulting from the use of electronic charts can be summarized as follows:

Enhanced Safety of Maritime Operations. Safety is affected in two ways: there is much more effective communication of the tactical situation concerning ship operation and control. The display clearly and continuously shows vessel's position relative to hazards and the safe route to the selected destination. The increased level of effectiveness of the display will translate into an enhanced level of safety, especially when the vessel is operating under difficult conditions.

The ability to update the chart display assures the existence of knowledge on the bridge of any hazards that might have just appeared, which, if not known, might endanger the vessel.

Convenience of Operation. The electronic chart is clearly a more convenient source of information concerning the operation of a vessel. Its displays concentrate in one location all of the facts required for safe navigation. This is especially the case when operation under conditions of reduced visibility in areas of high traffic and reduced maneuvering room. The displays are ergonomically effective; color is used to differentiate between land, sea and the presence of objects in the water.

The fact that the chart is generated by an on board computer adds versatility to the act of using a nautical chart. For example, the calculation of distances and bearings -- a common use of a paper chart -- is done expeditiously on an electronic chart by simply moving a cursor from one point to another. The computer rapidly calculates and displays the course and distance between the selected points. Similarly, the identification and storage of waypoints along a desired track is done easily and rapidly by keystroke (without the need to measure and enter latitudes and longitudes) and storage in the computer's memory.

Convenience of Chart Storage and Use. The electronic format of the nautical chart is a far more compact form of storage and a far more convenient means of access to stored charts than is the paper counterpart. A single compact disk can store hundreds of charts in contrast to the storage volume required for the paper variety. Moreover, more than one chart area can be studied at once by exploiting the "window" features of modern, high-resolution electronic displays.

The Probable Future of the World of Electronic Charts

Electronic charts are just moving into an era of acceptance and exploitation. This advance can be attributed to the following factors:

1. Recognition by national and international hydrographic and regulatory agencies of standard forms of electronic charts.
2. Continued progress in the field of personal computers and computer components, resulting in greater processing power in physically smaller enclosures at lower cost. Also, the continuing improvements in graphics display devices and associated graphics processing components.
3. Improved availability of electronic positioning systems, such as the Global Positioning System and other satellite systems.
4. The increasing availability of digital chart databases from a variety of sources.
5. An increased awareness that electronic chart systems can make a major contribution to the safety of ship operations and can also make a significant contribution to the prevention of ecological damage to shoreline areas.

Given these factors, we can expect to see a rapid increase in the installation and use of electronic chart systems. Both classes of systems will benefit. The legal ECDIS, now much closer to approval by governments as a replacement for the paper chart, will be installed on many deep-draft ocean going vessels. Indeed, in some cases, they will most likely be required. There is a good probability that future legislation or regulation will mandate the use of ECDIS on large vessels carrying hazardous cargoes in or near shore and harbor areas.

The operating cost reducing potential of ECDIS will appeal to ship owners and operators. Avoidance of collisions or groundings, attributable to the use of ECDIS, will result in substantial economies. Similarly, the elimination of the labor involved in continuous chart correction and updating will contribute to cost reduction in ship operations. Finally, the increased effectiveness of the ECDIS display will encourage both operators and administrators to approve the reduction in manning on the bridge, resulting in significant labor cost savings.

Those ship owners that install electronic chart systems as an aid to navigation, rather than as a substitute for paper charts, will rapidly grow in numbers. This is already the case for yachtsmen who have installed tens of thousands of these systems around the world. These numbers will increase as more and more areas are covered by the new positioning systems, providing easy access to vessel location marked as a symbol on the electronic chart. The yachtman's navigation problems are easily solved by these systems and the large number of installations attest to this fact.

Fishermen and operators of workboats, ferryboats, and tugs are all potential users. With product costs rapidly dropping, the increased availability of authentic digital charts and the automatic broadcasts of chart updates on the horizon, it is a near certainty that, in time, electronic chart systems will become a standard fixture on ships of all sizes and nationalities.

Program to Improve the Safety of Tankers and other Hazardous Liquid Cargo Carriers Operating in U.S. Waters

William M. Pease
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Background

The Port and Tanker Safety Act of 1978 was enacted to reduce the likelihood of accidents involving oil tankers and other hazardous liquid cargo carriers in U.S. waters. Among other provisions, the act required a full complement of modern electronic navigation aids, including collision avoidance equipment. It also required Vessel Traffic Services (VTS) to be installed in the major U.S. ports.

Ten years of experience gained since the enactment tells us that despite whatever progress in safety was made, much more needs to be done. Oil spills, large and small, are occurring many hundreds of times each year in U.S. waters. The EXXON VALDEZ catastrophe²⁶ was the largest of what is now recognized as the most prevalent type of accident -- vessel groundings involving navigation or piloting errors of judgment from misinformation or neglect. In some cases, the competency of ship's officers or pilots has also been called into question.

In view of these circumstances, land-based traffic monitoring systems are the only means to bring about a significant increase in the safe operation of ships and thus reduce the threat of spills and their impact on the marine environment. This is not to say that ship board systems should be ignored. It is important to improve the automation of the myriad routine details involved in a ship's operation. Doing so would free ship's officers for accurate and timely watchkeeping which is key to efficient navigation. Also, shipboard and land based systems will have to be designed for the cooperative actions necessary to achieve maximum safety.

At present, VTS and other shore-based radar coupled with appropriate communication are the principal means for monitoring marine traffic from land. At this time, only a few harbors and a tiny fraction of the coastline are covered by VTS. Each of these installations includes radar and communications as the principal facilities. Expanding this radar and communications coverage to monitor all coastal zones may seem to be the obvious direction to take to improve the coverage by shore-based monitoring facilities. However, this in fact is not the case because

²⁶Well publicized grounding incidents in New England waters were the ARGO MERCHANT off Cape Cod in 1977 and the WORLD PRODIGY entering Narraganset Bay in 1989.

of the inherent limitations of radar. The range of radar is limited to the horizon, and visibility can be obscured by topography and structures. Even using towers of maximum height, it would require a great number of them to cover the essential navigable waters -- and then adequate coverage couldn't be guaranteed. Clearly, a better approach to the problem is needed.

The Port and Tanker Safety Act requires the following navigation equipment on board all vessels of 10,000 or more gross tons:

- a dual radar system
- an ARPA (automatic radar plotting aid to IMO specifications)
- an electronic position fixing device
- adequate communications equipment
- a sonic depth-finder
- a gyrocompass
- up-to-date charts

All of the equipment and systems available to meet these seven requirements have been improved since 1978. Position fixing by LORAN-C and GPS and communications by INMARSAT have improved most dramatically in both performance and in reduced cost. Improvement in charting will also occur as electronic chart data is employed in conjunction with the data from other equipment to enhance the safety and accuracy of on-board navigation.

One concept of a system to accomplish comprehensive shore-based monitoring of all tankers and other hazardous liquid cargo carriers is based on the mandatory reporting of position of all such vessels in U.S. waters. The reporting of position can be made manually or it can be automated by a device connected to a LORAN-C and/or GPS receiver(s). This makes it possible to periodically collect and format position data (and possibly data from other sensors) for transmission via INMARSAT'S low-cost Standard-C service to ground-based facilities where the data would be processed automatically. Possibly as few as two such facilities located one on each coast could handle the traffic. The position reports would be monitored by a computer relative to defined permissible navigation areas. Any vessels out of, or approaching the limits of, these areas would then be flagged for manual interrogation via an INMARSAT Standard-A voice channel.

Such a position reporting system does not eliminate the need for radar based VTS' for harbors. At short range, radar determines position relative to shorelines, buoys and structures more accurately than does LORAN-C or GPS. Furthermore, radar images accurately superimposed on electronic charts show position of traffic relative to depth contours, underwater hazards, and the boundaries of navigation channels.

In addition to the safety improvements made possible by shore-based traffic monitoring are the improvements on-board the vessels themselves. Ships equipped for automatic position reporting should further equip themselves with integrated navigation systems to conform accurately to their intended route plan. Full automation of the integrated navigation function is important on ships with reduced bridge personnel. Both visual and electronic watch keeping will continue to be extremely important for safety. The less time that's spent in routine navigation and operational tasks the more time there is available for watch keeping.

Integrated navigation systems of varying degrees of sophistication exist today. All of the technologies required for fully automatic integration are sailing today. Route planning is done by reference to data extracted from paper charts. This is adequate for the present but will be greatly improved with the advent of electronic charts. The only deterrent to immediate widespread use of integrated navigation is the necessity to prove that such systems have the required reliability and performance. Vessels so equipped and sailing are now being carefully followed for the data that will provide that proof.

When considering the value of updating the Port and Tanker Safety Act to establish new, higher levels of safety, it is apparent that there's a need for a thorough study of the entwined policy and technical issues involved. Some of the issues that should be addressed in that study are the following:

1. In U.S. waters, should government (e.g. Coast Guard) exercise some degree of control over route plans for tankers and hazardous liquid cargo carriers? For example, should route plans of tankers and hazardous liquid cargo carriers be filed before departure from U.S. ports or upon entry into U.S. waters? Would this result in improved safety because of the greater care that would be exercised? A study of past grounding incidents should reveal this.
2. Should the reporting of position be made mandatory? Should this reporting be made automatic? Should such position reports be automatically received at a central data processing site and used to determine the relationship to the route plan and safe navigation areas? What frequency of reporting would be required? What other data besides position, time, and ship's identification should be included (e.g., equipment failure reports)?
4. Should VTS be extended to more harbors and congested waterways? Would the present and future VTS systems be improved by employing the latest available technology? What coordination would be required between VTS and a comprehensive position reporting system?
5. Because other studies aimed at improving safety and reducing damage to the environment are being initiated or are underway, the merits of all promising approaches should be compared on a formal basis to assist in the determination of the most effective and feasible one.

One example is an American Petroleum Institute task force report which was made following the EXXON VALDEZ grounding of Bligh Reef in Prince William Sound. That study asked for more stringent government regulation. Specifically, the following were recommended:

Mandatory participation of all tankers in the Coast Guard 'advisory traffic systems' that use radar and radio to monitor and advise vessels as they move through port and harbor areas, and possible expansion of these systems into more regions.

Federal legislation to establish uniformly high qualifications for all state pilots who operate in U.S. waters.

Zero tolerance of substance abuse, including drug and alcohol testing as part of officer licensing procedures.

Improved training standards for all personnel involved in cargo handling and bridge management.

Tug assistance or suitable maneuvering equipment in areas where Coast Guard sees unusual navigation hazards.

The first of these recommendations is consistent with the suggested position reporting system and VTS augmentation described here. For the reasons given, it is not sufficient or practical to rely on VTS augmentation alone. Much greater coverage and safety can be achieved through the addition of position reporting and improvement of on-board navigation and bridge management.

Instrumentation in Intensive Aquaculture: Computerized Monitoring and Control in Round Pond Shrimp Culture

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Background

Aquaculture is widely recognized as an industry which has very large growth potential for the United States. This growth is being driven by a consistently increasing demand for seafood products in the face of leveling and/or declining fisheries catches from the wild. U.S. demands for seafood in excess of domestic supply have caused burgeoning importation of seafood products. This has resulted in ever increasing annual trade deficits in the area of fisheries and aquaculturally produced products.

Most of the aquaculturally produced seafood imported to the U.S. comes from lesser developed countries (LDC). Supported by low operating costs for land, labor and feed, aquaculture production has been growing rapidly in such countries, providing them with export revenues and providing the additional supplies of seafood demanded by the U.S. market. Most of these LDC settings operate extensive production systems because the infrastructure cannot support the stability required by more intensive production systems.

Within the last decade, increasing attention has been directed at developing aquaculture systems within the U.S. which are economically compatible with the business climate prevailing in our domestic setting. One of the foremost barriers to market entry is the development of production systems which can overcome the higher production costs and provide products at costs competitive with the foreign imports. This has involved focusing attention on the development of intensive production systems which produce more pounds of product per area per unit time. Indeed, intensification is generally recognized as being the principle opportunity for economic feasibility of aquaculture within the U.S. business climate.

The growth of aquaculture in the United States has direct growth implications for several key attendant industries in addition to the commercial producers themselves. The feeds and instrument industries are only two which show promise for coat-tailing on the increases in domestic aquaculture industry. Both of these areas represent mature industries having limited growth potential within the existing markets, yet both represent areas where the U.S. technology is some of the best in the world. Both industries also figure heavily in the need for

intensification of domestic aquaculture, because both the quality of feeds and the requirements for system monitoring and management are requisite needs for the intensification process.

These conditions (i.e., the growth of domestic aquaculture, the need for intensive production systems and the automated monitoring needs for controlled management of such systems) together with the effluent monitoring requirements for environmental protection, argue for the opportunities for a substantially increased market for marine instrumentation. As aquaculture grows, so will the need for instrumentation to automate many of the otherwise labor-intensive aspects of production.

A critical component of intensive production systems is the development of automated monitoring systems to provide the enhanced water quality maintenance required to mitigate the risks potentially associated with intensification. Computerized monitoring/management systems take advantage of the U.S. technological infrastructure to provide the required management of multiple intensive aquaculture production systems with a minimum of manpower. Such capability encourages domestic economic growth opportunities for both the aquaculture and electronics industries.

Project Objectives

The objectives of The Oceanic Institute component are to inform both current and potential instrument uses in the aquaculture and fisheries areas of the available technology in marine instrumentation. Secondly, we want to improve the communication interface between these end-users and the instrument manufacturers. Thirdly, we will survey the instrumentation uses and needs of those involved in stock enhancement activities.

Project Tasks

The project tasks to be performed during the second year include:

1. convening an international workshop at WAS '89 to document world state-of-the-art in instrumentation uses and publish proceedings;
2. establishing a state-of-the-art aquaculture monitoring demonstration system;
3. documenting aquaculture activities and instrumentation needs; and --
4. assessing the market for instrumentation technology in stock enhancement related areas.

In reference to task 2 above, as part of the NOAA funded program entitled, *Developing a National Marine Electronics Agenda* with the Massachusetts Centers of Excellence, the Oceanic Institute (Hawaii) conducted a verification trial to demonstrate the operation of computerized water quality monitoring in conjunction with a prototype intensive marine shrimp production system. The objectives of this activity were to illustrate the effectiveness of a commercially available system in the routine water quality management of such systems and to provide feedback to the instrument manufacturer (Royce Instruments, Inc.) on the effectiveness of the system in an intensive aquacultural application. This presentation presents a brief description of the system configuration, the water quality results obtained and a video which details the installation and operation of this system.

Objectives

The objectives of task 2 were to (1) demonstrate the effectiveness of an off-the-shelf computer-based water quality monitoring system in the routine management of an intensive shrimp pond system; (2) provide feedback to the instrument manufacturer on the functionality and effectiveness of the system in an aquaculture setting; and (3) produce a video showing the system design and operation for the information of potential system users.

System Components

The system components consist of a computer system, operating software and water quality sensors; the elements of each are specified below:

Computer System

IBM compatible 286 computer
40 meg hard disk
VGA monitor
Printer
RS-485 interface

Operating System Software

Royce System VI monitoring package
QNX-DOS multi-tasking operating system

Water Quality Sensors

Royce #9019 Dissolved Oxygen Sensor
Royce #7010 Total Suspended Solids Sensor
Royce #3670 ph Sensor
Omega Thermocouple Probes

System Output

The system output includes: (1) real-time monitoring of water quality parameter values; (2) alarm for low/high parameter conditions; (3) record keeping of daily, weekly, monthly parameter values; and (4) graphic presentation of time-series data.

Results of System Operation

The system operation will result in decreased man hours spent on manual monitoring of water quality. Detailed dissolved oxygen time-series data has led to changes in operational patterns for paddle wheel aeration and temperature data indicates well-mixed conditions under all paddle wheel operational schedules.

The remainder of this presentation included a video showing the design and operation of this system in conjunction with our intensive marine shrimp production system located at the Oceanic Institute.

Electronic Instrumentation and Coastal Resources Management in the 1990s

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This paper deals with the growing need for electronic instruments designed for use in monitoring and managing coastal resources. Increased activity in monitoring U.S. coastal waters is evident at many levels of government as well as in private organizations. For example, the EPA "bays program" beginning with Chesapeake Bay is a monitoring/management concept that has spread to regional water bodies around the country, such as Puget Sound, Narragansett Bay, Buzzards Bay, Massachusetts Bay and others. The very strong social context of environmental issues around the world, including eastern Europe and the Soviet Union, suggest a more vigorous monitoring and management effort will be forthcoming, as governments respond to citizen based priorities. In this article, we focus on smaller local programs which will be needed in large numbers in the years to come.

Small harbors and brackish ponds along the U.S. coast play a vital role in sustaining the economies of coastal towns and communities. In fact, the value placed on comparatively minor coastal features by residents of these areas goes well beyond the associated market value of the coastal-dependent goods and services. For many communities, the meaning of pollution has been brought home by closed shellfish beds or swimming beaches, discolored water and unpleasant smells or accumulations at the shoreline. With increased congestion of harbors by boats, the threat of contamination from marine toilets and antifouling compounds are growing concerns.

Local Resource Management

A number of factors suggest that the town level of government will play an increasing role in coastal and harbor management in the future. Among these are: more state requirements and financial incentives for harbor and other coastal management planning at the local level; inadequate state or federal programs (or funding) to address local environmental concerns; and growing impatience by local citizens and officials to wait for outside groups to take action, at a time of unprecedented pressure for coastal development. Most of these comments apply equally to thousands of small lakes and ponds around the nation.

Although the geographical scale of problems faced by towns is small, their need for technical information is not. The areas in which we anticipate expanded activity involve management of nutrient enrichment of natural waters, oxygen depletion, fecal contamination, metal and pesticide pollution, as well as assessment and management of flushing small water bodies to alleviate pollution.

To explore the possible use of oceanographic sensors and equipment by local resource managers, the Marine Policy Center of the Woods Hole Oceanographic Institution and ENDECO/YSI have begun a cooperative program in Edgartown Harbor, Massachusetts. Our cooperative program, joining academia and business, in itself holds challenges and opportunities, and calls for patience and accommodation of different needs, motives, time frames, and operational and professional constraints. The program is supported by ENDECO/YSI and by contributions from the Edgartown Harbor Association, a private group formed to promote sound management of coastal assets on the island of Martha's Vineyard.

Our objectives are to determine what kinds of information are most relevant to harbor management, and how electronic instruments can help provide it. We hope to answer such questions as, what constitutes user-friendly monitoring electronics, given that personnel involved are not likely to have extensive technical backgrounds; and how should acquired data be stored, processed and presented to be most useful for coastal managers and planners. What kinds of assistance and services will be needed in the long term to support instrument operation, and data analysis and interpretation in the management context?

The Edgartown Harbor Project

Edgartown Harbor (Figure 1) is in many ways typical of small harbors in New England and around the U.S., except it exemplifies some of the problems faced elsewhere with unusual clarity. The Inner Harbor contains nearly 500 moorings for recreational boats during summer months, of which about 100 moorings are rentals for transients; on a busy summer weekend an additional 100 transient boats can anchor in adjacent parts of the Harbor. Although both shoreside and mobile pumpout facilities are available for recovery of human wastes from boats, their use to date appears limited. The southern terminus of the harbor (Katama Bay) consists of extensive shallow shellfish beds, valued both commercially and recreationally for their productivity of hard clams, scallops and in recent years, whelks.

The village waterfront of Edgartown is shared among public municipal wharfs, private marina docks, shops and restaurants, a yacht club, private residences and docks, and town finger piers. An increasing number of new homes and condominiums surround the 17th century village center. A municipal sewage system installed during the late 1960s is currently operating at full capacity; and a storm sewer system debouches surface and street runoff at four locations along the waterfront.

Figure 1. The Edgartown Harbor coastal complex, Martha's Vineyard, Massachusetts.

In contrast with the heavily used waters of the Inner Harbor, an adjacent lagoon (Cape Poge Bay) is only lightly used by pleasure boats (because of limiting depth at the entrance) and has very sparse shoreline residential development. This contrast in use for these water bodies provides a useful basis for impact assessment, given that both embayments share a common source of incoming tidal water. A second significant aspect of Cape Poge Bay is its very high yield of the bay scallop--in 1988 this single water body reportedly produced nearly half of the commercial landing of bay scallops for the state of Massachusetts. The singular importance surrounding protection this industry represents a special element for our program.

Electronic Monitoring in Edgartown Harbor

Our approach has been to begin using "off-the-shelf" ENDECO/YSI instruments designed primarily for use by scientists and environmental engineers, and to modify or add to these instruments as appropriate to arrive ultimately at an instrument package suitable for wide application in coastal monitoring.

Two basic ENDECO/YSI instrument packages monitoring atmospheric and aquatic variables are deployed around the harbor, with radio telemetry linking the instruments to a receiver base station located at the Woods Hole Oceanographic Institution (WHOI), 12 miles away. The receiver base station controls sensor operation, monitors sensor status, and serves as a data logger. It is linked by modem via telephone directly to ENDECO/YSI headquarters in Marion, Massachusetts, where performance of the system can be observed and controlled. This has turned out to be extremely valuable and cost effective for problem shooting and servicing by ENDECO/YSI engineers.

The four remote monitoring sites at Edgartown--one meteorological station and three aquatic ones--are polled via a two-way VHF radio link using a protocol which ENDECO/YSI markets under the name "ADAPTIVE PACKET*" telemetry system. The instrument array is controlled by a receiver base station housed within a standard portable personal computer, whose overall features are:

- menu driven systems programming*
- imbedded programming language*
- interactive digitally synthesized voice communications via telephone or hand held radio*
- remote on-off control outputs*
- conditional and boolean logical alarm statements*
- discrete historical data archival*
- user customized display screens*
- networking of base stations*
- built in text editor*

The primary sensors at each field site are interfaced to a weather tight field station, marketed by ENDECO/YSI for use in remote site telemetry applications. The field station accommodates multiple sensor inputs and remote on-off control outputs. Its main features include:

- dual purpose operation as a data collection platform and radio repeater*
- 8 input channels, 2 output channels*
- ultra low power consumption*
- weatherproof NEMA-4X enclosure*

Sensors deployed at Edgartown Harbor, initially, include several product categories manufactured by ENDECO/YSI, including:

- water level recorder, salinometer, thermistor*
- pulsed dissolved oxygen sensor (and temperature sensor)*
- ENDECO/YSI, Inc. meteorological sensors*

In addition, three ENDECO/YSI current meters are deployed in the Harbor, measuring current speed and direction, water temperature, salinity, and instrument depth.

Most of these products are stand alone products, capable of internal recording of measured parameters. In our application, these instruments have their digital output interfaced to the field station for real-time telemetry in lieu of on-board recording. In the case of the current meters, for which acoustic telemetry is under development and testing, data are off-loaded to an MS-DOS compatible PC for off-line processing and analysis.

Our initial thrust was installation of the instrument array and testing of its operational features by staff of the Woods Hole Oceanographic Institution. Deployment of the aquatic monitoring field stations includes a fixed station located at the village waterfront at the yacht club; a mobile shore based field station to be sited on docks or pilings around the Harbor complex; and a mobile floating field station for instrument deployment from a floating laboratory facility that can be anchored in open water (for monitoring closed topographic basins and in support of other monitoring activities). The meteorological station, located at the Cape Poge lighthouse, can also serve as a radio repeater.

Initial Results and Management Implications

Although monitoring and coastal management are our primary focus, we have welcomed involvement by the staff of the scientific departments at the Oceanographic Institution. The data discussed here in the context of management carry many more basic scientific implications as well.

Figure 2 illustrates one month of selected data from the meteorological station and the yacht club field station located at the Edgartown waterfront. These data give us a first integrated view of how this coastal complex responds to meteorological events, an important clue to how the Harbor

"works." The tidal data (Figure 2, panel H) provided us with information on usual tides for the waterfront, as well as a storm surge that occurred on July 17 (winds exceeding 45 mph were recorded at Cape Poge: panel C). The July 17 storm was accompanied by rainfall of about 1.5 inches (panel E), one effect of which is seen in the salinity data (panel F). There is considerable quantitative information to be derived from this data set. Since the aquatic monitoring station was located near the mouth of the harbor, it alternately sampled water from inside the harbor and from outside the harbor, with the reversing tidal flow. Because many water borne pollutants move through coastal systems along with freshwater, the flushing out of rainwater contains information on how certain pollutants could be flushed from the harbor as well. In the management context flushing is an asset; it represents one measure of the Harbor's capacity to cleanse itself. Development of methodologies and software to use monitoring records to address flushing are important aspects of marketing the electronic hardware itself.

A crucial focus of many environmental impact studies for residential and commercial development at the coast is to assess the impact of nutrient discharge on dissolved oxygen in the receiving waters. A common management objective is to prevent related oxygen depletion--hypoxia or anoxia--which strongly alters the ecosystem and leads to loss of fish and shellfish and production of undesirable odors. The pulsed oxygen electrode deployed at Edgartown Harbor allows convenient and direct monitoring of dissolved oxygen, eliminating the need to infer it from nutrient data.

A one month record of dissolved oxygen and solar radiation (which drives oxygen production through plant photosynthesis) is shown in figure 3. This record represents the first substantial field data set obtained using this ENDECO/YSI instrumentation. These data indicate, among other things, that the Harbor showed no inclination toward significant oxygen depletion at any stage of tide, day or night, or after prolonged cloudiness.

We have also been able to make use of electronic data to address another major concern--fecal contamination of Harbor water from marine toilets. Although it is presently illegal to discharge marine toilets into near coastal waters, enforcement of this law is difficult and many yachts do not have the capacity to hold sewage on board. Given the proximity of the shellfish beds in Katama bay to the anchorage of the Inner Harbor, many Edgartown residents were concerned that the magnitude of fecal contamination from boats remained poorly defined.

Figure 2. Monitoring results for the month of July, 1989, for selected sensors at Edgartown. Panels A-E, Cape Poge meteorological data; panels F-H, tidal and aquatic variables at the Edgartown Yacht Club field station.

Figure 3. Dissolved oxygen data (2 meters depth) near the mouth of Edgartown Harbor; and solar insolation at Cape Poge, a few miles away. September, 1989.

Electronic instrumentation is not currently capable of monitoring fecal coliform bacteria (a bacterial index used by regulatory agencies to trace human contamination). However, we were able to employ the traditional culture techniques along with tidal and current data to attack the problem. Figure 4 shows the complex relationship between tidal displacement and tidal currents for the mouth of Edgartown Harbor, as defined by ENDECO/YSI instruments, a relationship that would not be obvious from casual observations. This record reflects complex shallow water harmonics of the principal tidal constituents affecting the Harbor. Having defined this relationship, we were then able to interpret coliform bacterial data gathered over the 4th of July holiday, 1989, at the entrance to Edgartown inner harbor. The results, when processed statistically, show an overall trend in bacterial count that follows the rise and fall in numbers of transient boats. A more startling result, however, was that many of the highest counts were associated with flood tide, for the first time suggesting an important source of fecal contamination outside the Harbor.

Figure 4. Tidal elevation and currents at the mouth of Edgartown Harbor, Massachusetts, August 12-19, 1989.

Concluding Remarks

Obviously we are at an early stage of our project, but initial results have been quite encouraging. It appears to us that simplifications are needed for these instruments to be suitable for use by coastal resource managers. An improved instruction and training manual would be useful to assist novice users in the maintenance and operation of equipment, and in the use of accompanying software. An important part of remaining work for us will be to check calibration and instrumental drift resulting from fouling of sensors by organisms and other variables. Durability and maintenance requirements, to be assessed in the future, are other considerations in the acceptability of electronic instruments. A final point is the cost of monitoring instruments and sources for funding. The coastal planning and management work being conducted at Edgartown is supported by a private group, the Edgartown Harbor Association, Inc., which has raised \$120,000 per year for a three year program. Although in this instance the funds were not used to purchase monitoring instruments, it does indicate local groups are willing to make substantial expenditures in the interest of coastal protection. Reductions in instrument cost will obviously be a major factor in the growth of this market. Telemetry can be an important cost saving feature, and modem or r/f linkages to service centers can save on troubleshooting costs.

Acknowledgements

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* Portions of this paper also appeared in the October 1989 issue of SEA TECHNOLOGY magazine as an article by A. Gaines and R. Butler entitled, "Edgartown Harbor Provides Model for Harbor Resources Management."

New Alliances and Partnerships in American Science and Engineering

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Background

All sectors of society -- the federal government, state governments, industry, universities, and the general public -- have a growing interest in the capacity of science and engineering to contribute to the international competitive posture of the United States. The sectors have two principal expectations of the enterprise:

1. Advancement of knowledge, and education and training of the next generation of scientists and engineers; and
2. Achievement of specific national and local goals and the development of new products and processes.

The vitality of the enterprise is determined by the extent to which it can meet these demands and opportunities.

University-industry alliances are suggested as one means through which the scientific and engineering enterprise can enhance its ability to fulfill the second expectation. This paper examines these alliances from three perspectives: 1) operational characteristics and procedures; 2) principles guiding the contractual terms and conditions between the parties; and 3) the impact of these alliances on universities, industry, and competitiveness.

Observations on University-Industry Alliances

Three central themes have emerged from Roundtable inquiries into University-industry cooperative programs.²⁷

²⁷Government-University-Industry Research Roundtable, Academy Industry Program, National Academy of Sciences, *New Alliances and partnerships in American Science and Engineering*. National Academy Press 1986).

All is not new. Commentators sometimes write as if relationships between universities and industry were totally new. In fact, recognizable antecedents go far back in time. For example, academic chemistry has, from the beginning, been closely tied to industrial chemistry. Much of modern biology is also deeply rooted in the search for solutions to practical agricultural, medical, and industrial problems. Similarly, computer science is closely tied to applications. And, of course, the set of applied scientific fields which call themselves "engineering disciplines" are also by their origin and their nature oriented to applications. Propositions about a natural chasm between academic science and industrial science have often been drawn too sharply and too globally. Indeed, academic science and industrial science in the United States grew up together.

It is certainly true, however, that we are currently seeing an explosion in the number of alliances between universities and industry, and we are observing qualitative changes in their form. What lies behind this recent surge of new arrangements among universities and industry? Universities are seeking new sources of support for research, including equipment and facilities, ways to strengthen their education programs, new outlets for faculty interested in commercial and entrepreneurial activities, and increased effectiveness in contributing to local, regional, and national technological, economic, and social goals. Industry looks to the new alliances as a source of talent (both students and faculty), as a window on new areas of science and engineering, and as a source of specific ideas for improvements in products and processes. Federal and state governments look to enhanced linkages between industry and universities as one means to maintain or regain technological primacy in a variety of industries and thereby to nurture state, regional, and national economic growth.

Variation and diversity. The alliances are characterized by a great deal of variety and diversity. University cultures vary as do their attitudes towards the kinds of relationships with industry that are, or are not, appropriate. Those institutions with long standing liberal arts traditions tend to avoid relationships other than those that support basic research. The technical universities have shown a greater willingness to engage in applied research with industry funding, a greater respect for the proprietary interest of the funding source, and a greater interest in continuing close interactions with industry. Companies also differ in their views toward research, toward in-house and externally sponsored research, and toward collaboration with other companies and with universities.

Given this cultural variation, it is not surprising that the new partnerships vary considerably in the kinds of activities and arrangements that are involved. Some are largely concerned with basic research. In other arrangements, the purpose of the work is to solve a well-defined practical problem. Training of undergraduate and graduate students may, or may not, be part of the program. Consulting by the involved university personnel is in some cases restricted, but in others, consultation is an important aspect of the arrangement. Similarly, in some cases constraints are imposed to limit faculty entrepreneurship, while in others the arrangement is designed to channel or facilitate entrepreneurship.

One might say that is due, in part, to this variety and diversity that the collaborative programs generally appear to be working so well. Participating institutions indicate that they have not found it necessary to compromise significantly the cultures and values they deem essential to their missions. They seem to have managed matters by selecting partners and arranging programs best suited to their particular goals and responsibilities. The key to achieving these matches is to "talk early and talk often."

Beneficial experiments. The positive attitude that currently prevails in both industry and academia, to participate in cooperative programs without distorting the institutions' cultures and values, is a change from the pessimism expressed ten years ago when the number of these arrangements was beginning to escalate. At the present time, the dominant view concerning these alliances appears to reflect the fact that the nation is currently engaged in a broad-based and diverse series of experiments that should be continued. They have potential to be good for business, helpful and appropriate to universities, and in the public interest. However, there are two major concerns with these alliances: 1) that the experiments will be judged too quickly; and 2) that there may be unrealistic and inappropriate expectations regarding the impact of these new arrangements.

Selected Characteristics of University-Industry Alliances

Financial support. Overall, corporate support for university research, currently about 5 percent of total support for academic research, will perhaps never exceed 7 to 8 percent. Industry funding for university research comes largely from corporate research budgets, which are nearly always quite small relative to development budgets and are likely to remain so. Still, corporate funding is significant at some schools, reaching levels of over 20 percent, and is more prominent in some fields than in others, notably semiconductors and biotechnology. For example, the Semiconductor Research Corporation estimated that the consortium is funding nearly 50 percent of U.S. academic research on silicon-based integrated circuits. A survey by the Council for Chemical Research showed that industry accounted for 11 percent of the total extramural funding of basic academic research in chemistry in 1985 and that industry accounted for 44 percent of the total extramural funding for chemical engineering. A survey by David Blumenthal (then of Harvard University's Kennedy School of Government) of over 100 companies involved in biotechnology revealed that these companies provided about \$120 million annually to support academic research in that field. That amount is about 30 percent of aggregate industrial funding of academic research and about 20 percent of all extramural funding of biotechnology research in academe during 1984.

There is concern about the sustainability and the breadth of this industrial funding. The new alliances are concentrated in a few industries -- for example, biotechnology, microelectronics, and special materials. Will sufficient short-term results materialize to maintain industry's involvement with universities over the long-term, even as the fields of interest may change? We currently see signs of changes in industrial support for Research and Development (R&D), both in-house and externally. Industrial support for academic R&D must be considered as a complement to, not a substitute for, federal support. The general view is that federal funding

of academic research is critical, both for the long term vitality of research and graduate education and for attracting industrial support.

Industrial influence on academic research. A major concern raised by university-industry cooperation is that corporate values will divert academic research from its proper role, the search for knowledge. It does not appear that this is occurring. University and industrial participants are in the main agreeing on the research that warrants support. One view is that a major cultural change in universities came after World War II, when agencies like DoD and NIH began to support "really fairly directed basic research." In this light, industrial support is only "a small perturbation."

Faculty loyalties and incentives. There has been a change in faculty loyalties over the past forty years. Prior to WW II, little funding was available outside the university, and faculty concerns were directed toward their own institutions. With the significant increase in federal support, there came incentives for promoting individual disciplines and growth in professional and scientific societies. Faculty loyalties were directed toward their disciplines, their colleagues in the relevant societies, and their program officers in the federal funding agencies. Now, the potential for significant increase in academic salaries through alliances with business and the financial community may diminish faculty loyalties to their universities and their disciplines. To some this is a major concern; others see this as the exception rather than the rule. They see faculty loyalties to science and engineering running high in spite of the possibility for individual financial gain.

Freedom of communication. The alliances do not appear to be imposing unacceptable constraints on publication and communication, except perhaps in highly competitive fields like biotechnology. Here, however, views differ as to whether these constraints are brought on by commercial or scientific competition. In one sense, industrial-academic connections have served to increase communications among scientists and engineers between sectors and between disciplines.

Educational functions. The education of graduate students and post-doctoral fellows, including foreign students, is a central feature of all the collaborative programs examined by the roundtable. Students are going on after graduation in significant numbers to work for the participating companies. The programs have stimulated the development of new courses and have brought about an increase in interdisciplinary, interdepartmental, and interuniversity collaboration.

Cooperation among companies. Obtaining cooperation among competing companies in academic-industrial alliances has not been a serious problem. Fear of antitrust regulations has dissipated, and cooperation among competitors that involves academe is viewed favorably within current antitrust policies. Participation in the alliances by foreign companies varies. The Massachusetts General Hospital-Hoechst program is an example where participation by foreign company is working. On the other hand, a senior official of a collaborative program in the

electronics field states that he finds it "very beneficial for (his) program to work with U.S. based companies."

Industry-university symmetry. The capacity of a company to assimilate advances in research is related to the internal technical capabilities of the company. A breakdown in symmetry between the technical capabilities of cooperating companies and universities will inhibit the ability of the company to transfer innovative ideas into technology. Internal industry R&D is an important component of technological innovation, and industry must maintain its investments in in-house research if it is to benefit from participation in collaborative programs with universities. Participation in such programs by industry cannot be viewed as a substitute for internal industry R&D.

Personal contact. All the collaborative programs view personal contact between industrial and university scientists as an essential mechanism for moving research results from universities into industry. Experience indicates that there are difficulties in achieving this, especially when the cooperating institutions are geographically distant, but there is evidence of progress and a willingness to participate.

Contract negotiations. Industry and university officials report an increase in time and effort devoted to negotiating agreements for cooperative research programs. In an attempt to decrease this effort, the Research Roundtable and the Industrial Research Institute have just jointly published *Simplified and Standardized Model Agreements for University-Industry Cooperative Research*.²⁸

Simplified and Standardized Agreements

The Roundtable has devoted considerable effort to simplifying and standardizing the administrative procedures for the sponsorship of university-based research by the federal government. To address the increasing bureaucracy and red tape in industry-sponsored research in universities, the Roundtable formed an ad hoc industrial committee charged with creating a model university-industry research agreement. The thought was to have industry, as the financial supporter of the research, take the lead for simplification of the process. The intent was that such a model will decrease the time required for negotiations and provide companies and universities new to research alliances with a sense of what is reasonable to consider in establishing a contract. The agreement that resulted and that was published jointly by the Research Roundtable and Industrial Research Institute must be viewed as a non-binding model that is a starting point for the discussion between university and industry parties seeking to carry out cooperative research activities. The model will be considered successful if modifications required to suit particular cooperative programs can be achieved easily and quickly. As a

²⁸Government-University-Industry Research Roundtable, Industrial Research Institute, National Academy of Sciences, *Simplified and Standardized Model Agreements for University-Industry Cooperative Research*. (National Academy Press 1988).

starting point, the model allows the players to learn about each other through dialogue, reaching agreement without having to "reinvent the wheel." The industrial committee recognized that negotiation, like courtship, is necessary for the resulting collaborative programs to operate effectively.

- University researchers have the right to publish their research findings. Sponsors have the right to insure that inadvertent disclosure of confidential information does not occur and have the right to assess whether the research findings include any potentially patentable information or materials;
- The university has the right to own title to all patents;
- The specifics of the publication and patenting clauses will most likely need to be negotiated on a case by case basis. The goal of the model was to offer reasonable starting points;
- The sponsor has first rights to license (whether exclusive or non-exclusive) since the sponsor has paid for the research. In deciding on an exclusive or non-exclusive license, the terms must be "mutually agreed upon" by the company and the university. Thus, the university has some control over whether the license will be exclusive or non-exclusive. The committee felt that the specific terms of a license did not have to be worked out in detail at the outset of an agreement but that they could be dealt with on a case-by-case basis after the research had progressed to a point at which it was possible to determine whether or not licensing would be appropriate;
- If university and industry participants are unable to come to agreement on specific clauses, then no collaboration should ensue.

We have received many thoughtful comments on the model agreement and are considering the publication of a revised version sometime in 1989. Some of those comments are as follows:

- Some universities feel that industry should have no say concerning publication, particularly informal publication and seminar presentations;
- Some companies prefer to own the patent themselves and not allow the university to own the patent;

- Many universities feel that the sponsor should not have an option for non-exclusive, royalty-free license because it prevents any other company from acquiring an exclusive license. In addition, any other company offered a non-exclusive, royalty bearing license will consider the advantage of a royalty-free license to the sponsor as too great an economic advantage and time lag to be overcome and will reject the offer;
- More attention needs to be given to dealing with ownership of intellectual property resulting from joint inventions; and
- State governments will have trouble with the liability clause. States will not be able to set up an agreement where they will ever be liable even as a result of state negligence.

Impacts of the New Alliances

All the participants in the new alliances, federal and state governments, universities and industry, are asking the question, "What are the results?" A straightforward and expected question, but there are no simple answers. First, consider the following three general observations: (1) It has been stated earlier that cooperation has taken a number of forms. Any answer to the question -- "What are the results?" -- must take into account this variation and diversity. Each type of collaborative program must be considered separately; (2) We should not try to answer this question too quickly, at least in a conclusive manner. We need to continue to watch the experiments, make adjustments based on preliminary observations, and continue to improve and strengthen collaboration between universities and industry; (3) Each collaborative program should set reasonable goals and objectives; the program accomplishments should be measured against appropriate expectations. Unreasonable expectations, which will lead to failing marks for the collaborative programs, will do significant harm to the participating industrial and academic institutions and to the overall science and technology enterprise.

At this early stage in the operation of the programs, one can only monitor program operations and take readings of work in progress.²⁹ The programs will have near-term or proximate objectives that focus on the program structure and operating procedures such as strengthening graduate education in university research, creating "centers of research excellence" in selected areas of science and technology, changing university and industry culture to promote a true spirit

²⁹Government-University-Industry Research Roundtable, National Governors Association, National Academy of Sciences, *State Government Strategies for Self-Assessment of Science and Technology Programs for Economic Development*. (Proceedings of a workshop held Apr. 10, 1987 in Washington, D.C.) (National Academy Press 1988).

of exchange among the university and industry scientists carrying out the collaborative research, achieving a certain ratio of industrial support to government support and achieving a certain fraction of small and large companies participating in the program. These types of proximate objectives should be stated clearly at the outset of the program and they should provide the focal point for the assessment of program progress and accomplishments in its early years of operation.

The processes through which R&D partnerships can contribute to technological innovation and economic development are varied and complex and require patience and a long-term perspective. Demonstrating such contributions will be difficult.³⁰ In this regard, it is important to point out another dimension of variation in this complex system of university-industry cooperation--the process of innovation and the sources of technical change vary by industry sector and even by the individual firm within a given sector. Understanding the contributions of the new alliances to innovation requires an examination that looks at different industries separately. For example, many new organizational forms are emerging to promote industry-industry and industry-university cooperation in the micro-electronics and biotechnology industries. In the chemical industry, however, there is a long history of industry-university cooperation that continues through more traditional mechanisms. Consideration must be given to the rationales for the different approaches used and to what the industry expects from each such approach.

Expectations for Economic Development

What should we expect of these alliances with respect to technological innovation and economic development? Perspectives of Ralph Gomory, senior vice president for science and technology at IBM, and Harold Shapiro, president of Princeton University, may be considered in answering this question.³¹

According to Harold Shapiro: ...if we want to get economic growth out of new science and technology, we have to pay attention to what I call "everything else, and the everything else really could not be summarized better than by saying "how groups work together" -- how we relate to each other, how we treat each other, and how we trust each other.

...what may not be in our best interest is the belief that superiority in science alone -- at the expense of "everything else" -- will ensure this country's economic strength.

The lessons of history tell us otherwise. For example, it was not Britain's science and technological superiority that made it first in the Industrial Revolution. It was political stability, it was the society's concept of private property, it was decentralization of authority in British

³⁰Id.

³¹Gomory and Shapiro, *A Dialogue on Competitiveness*, Issues in Science and Technology, Summer 1988 (National Academy Press 1988); Gomory and Schmitt, Science and Product, SCIENCE, May 27, 1988.

institutions. It was not that the British had better science than did Belgium and France. It is very, very seldom that a monopoly on science alone has produced a tremendous spurt in sustained economic and social dividends. Why is it that we do not read that lesson?

According to Ralph Gomory: ...*"pull" (by a company) consists of people who know what they need going out and looking for it -- and finding it -- in a vast universe, rather than asking outsiders who don't know the company's situation to throw pieces at it. "Pull" is much more likely to succeed, moreover, because the burden of finding uses for research belongs not with universities but with the companies themselves.*

A strong science base...cannot make up for inadequacies in the functioning of the development and manufacturing cycle (within companies).

With these thoughts in mind, it may be useful to think of the university-industry alliances and competitiveness in the following manner. The university-industry alliances should be viewed as a new and creative way to contribute to excellence in both academe and industry and not as the major national effort to solve our competitiveness problems. The nature of research, of technology development, and of education is changing in many areas of science and engineering - particularly those areas -- electronics, biotechnology and materials, for example, which many of the alliances are forming. These changes may reflect the fact that boundaries between the underlying disciplines and between basic research and applied research are blurring, advances in fundamental knowledge are becoming relevant to technology development in the near term, R&D is dependent on, and in some cases limited by, sophisticated and expensive instrumentation; talented scientists and engineers are in short supply, and product life cycles are becoming shorter. Within this environment, maintaining research capacity at the frontiers of knowledge and maintaining technological capacity at the frontiers of product and process innovation require greater collaboration and interaction between academic and industrial scientists and engineers than has been the norm.

The emerging new alliances, therefore, are essential to maintaining the nation's scientific, technological and educational base. To the extent that this base contributes to our international competitiveness, the alliances are an important part of the strategy. But, we know that the strategy for economic competitiveness must include many other factors of equal and perhaps even greater importance.

Strategic Role for Universities

Finally, a word about universities. The alliances are making their lives more complicated and more exciting. As parts of these new alliances, universities are assuming visible and explicit strategic roles in state, federal and industrial economic and technological development programs. This has resulted in increased expectations put upon universities and in greater political currency given to university affairs, which in turn has produced both strains and benefits within the university community. Strains result from the differing views over the issue of university-industry ties and by the increasing political interest in universities for possible research facilities

and programs. Benefits, on the other hand, come in the form of new state and industrial investments in university programs and the excitement from working with new people on new scientific and technical problems. Reaching the right balance in these forces on the universities will require care, nurturing and thoughtfulness by the universities themselves and by the patrons and policy makers that influence universities.

Appendix 1

**Agenda - Marine Instrumentation Panel Meeting, September 12-14, 1989,
Woods Hole Oceanographic Institution, Woods Hole, MA.**

***MARINE INSTRUMENTATION PANEL MEETING
Massachusetts Centers of Excellence Corporation***

DEVELOPING A U.S. NATIONAL MARINE ELECTRONICS AGENDA

***September 12-14, 1989
Woods Hole Oceanographic Institution
Clark 507***

Tuesday, September 12

08:30 Assembly & Logistics

**09:30 Introduction, Overview, Format and Objectives
*Arthur G. Gaines, Program Manager, MPC/WHOI***

**09:40 A National Marine Electronics Agenda
*Gary Glenn, MCEC***

**10:00 Marine Electronics Business Overview
*Richard Shamp, President MTS***

**Foreign Government Initiatives
in Marine Electronic Instrumentation**

**10:40 Japan
*James Broadus, Director, MPC/WHOI***

**11:20 The European Common Market
*Porter Hoagland, Research Associate, MPC/WHOI***

12:00 Luncheon Carriage House

**Technology Transfer
in Marine Electronic Instrumentation**

**13:30 National Laboratories
*Megan Jones, Director, MCEC***

14:10 Technology Transfer and Intellectual Property Management in the Field of Oceanography.
Hauke Kite-Powell, Research Assistant, MPC/WHOI

15:00 Break

15:15 Taking Technology to the Market Place - Some Alternatives
Kenneth Prada, Senior Research Specialist, AOP&E/WHOI

16:00 "Strategic Alliances" as an Approach to R&D by Electronic Instrument Companies.
Malte von Matthiessen, President, YSI, Inc.

17:00 Reception Clark 507

18:00 Dinner (no host)

19:30 Discussion Group Meetings

Wednesday, September 13

Alternative Applications and Avenues for Instrument Spin-off

08:30 Competitiveness, Security and Dual-Use Technologies
Gerald Epstein, JFK School of Government, Harvard University

09:15 COMSAT: Basic Services, and Instrumentation Opportunities in Mobile Satellite Communication.
John Fuechsel, Assistant Director, Maritime Services, COMSAT

10:00 Global Positioning System (GPS)
Thomas Curry, Chairman, Electrical Engineering Department, Southeastern Massachusetts University

10:40 Break

U.S. Trade Policy and Export Controls

11:00 Recent Developments in U.S. International Trade Policy
William Cooper, Specialist in International Trade and Finance, Congressional Research Service

11:40 Export Controls and the U.S. Office of Foreign Availability
Donald Brychczynski, Industrial Analyst, Bureau of Export Administration, U.S. Dept. Commerce*

12:30 Luncheon Clark 507

**I - Electronic Chart Digital Information System: Technology and Policy Issues
in Integrated Navigation**

13:30 Prepared Statements:
Mortimer Rogoff, Chairman, SY 109 Radio Technical Commission for Maritime Services

William Pease, Director, Digital Technology, Raytheon Company

14:15 Discussion

II - Instrumentation in Environmental Monitoring and Control

13:30 Instrumentation in Intensive Aquaculture: Computerized Monitoring and Control in Round Pond Shrimp Culture.

*Paul Bienfang, The Oceanic Institute, and
James Dartez, President, Royce Instruments, Inc.*

14:00 Instrumentation in Coastal Water Quality Monitoring: A Demonstration Project for the New Market in Coastal Resources Management.

*Marc Mason, Vice President, ENDECO, and
Arthur Gaines, MPC/WHOI*

14:30 Discussion

Developing a National Marine Electronics Agenda

15:00 Related U.S. Efforts on Industrial Competitiveness

James Broadus, Director, MPC/WHOI

15:30 Where do we stand now?
Gary Glenn, MCEC, Discussion Leader

16:15 Adjourn

(If desirable, the evening can be used for follow up discussions)

Thursday, September 14

0900 Program Staff Meetings

* Invited

Appendix 2

List of Participants - Marine Instrumentation Panel Meeting, September 12-14, 1989, Woods Hole Oceanographic Institution, Woods Hole, MA.

Mr. John Alden	Alden Products Co.
Mr. Bob Black	Massachusetts Maritime Academy
Dr. Paul Bienfang	Oceanic Institute
Mr. Paul Boutin	Woods Hole Oceanographic Institution
Mr. Lawson Brigham	Woods Hole Oceanographic Institution
Dr. James M. Broadus	Woods Hole Oceanographic Institution
Mr. Neil Brown	Woods Hole Oceanographic Institution
Mr. Terrence L. Burch	EG&G Marine Instruments
Mr. David Butler	University of Rhode Island
Mr. Mark Chramiac	Raytheon, Inc.
Mr. William Cooper	Congressional Research Service
Dr. Thomas Curry	Southeastern Massachusetts University
Mr. James Dartez	Royce Instruments Corporation
Mr. Gerald Epstein	Harvard University
Mr. John Fueschel	COMSAT Maritime Services
Dr. Arthur G. Gaines	Woods Hole Oceanographic Institution
Mr. Gary Glenn	Massachusetts Centers of Excellence Corporation
Dr. James Griffin	University of Rhode Island
Mr. Donald Grossman	Coastal Leasing, Inc.
Mr. James Hannon	Sippican, Inc.
Mr. James Hanlon	ENDECO/YSI, Inc.
Mr. Paul Dudley Hart	Woods Hole Oceanographic Institution
Mr. Porter Hoagland III	Woods Hole Oceanographic Institution
Dr. Hartley Hoskins	Woods Hole Oceanographic Institution
Prof. John Huguenin	Massachusetts Maritime Academy
Mr. Kenneth Johnson	University of Rhode Island
Ms. Megan Jones	Massachusetts Centers of Excellence Corporation
Mr. Hauke Kite-Powell	Woods Hole Oceanographic Institution
Mr. Marc Mason	ENDECO/YSI, Inc.
Ms. Terry McKee	Woods Hole Oceanographic Institution
Mr. Frank MacPherson	Pacer Systems, Inc.
Mr. William Pease	Raytheon Executive Offices
Mr. Don Phillips	Government, University, Industry Research Roundtable, NAS
Mr. Bernard Polanin	NOAA/ONCO
Mr. Chris Polloni	USGS
Mr. Kenneth E. Prada	Woods Hole Oceanographic Institution
Mr. Mortimer Rogoff	Radio Technical Commission for Maritime Services
Mr. Richard Shamp (MTS)	Engineering Services Associates, Inc.

Dr. Allyn C. Vine	Woods Hole Oceanographic Institution
Mr. Malte von Matthiessen	ENDECO/YSI, Inc.
Dr. A.J. Williams	Woods Hole Oceanographic Institution
Mr. P. W. Wilson	ABS (ret.)

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