WHOI-88-6

A Broad-Scale Profile of the Marine Advanced Technology Industry

by

Hauke Kite-Powell

Marine Policy Center
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

March 1988

Technical Report

Funding was provided by the Massachusetts Centers of Excellence Corporation and the Marine Policy Center of the Woods Hole Oceanographic Institution.

Approved for Distribution:

James M. Broadus, Director
Marine Policy Center

TABLE OF CONTENTS

LIST OF FIGURES

PREFACE

Within the maritime sector of the United States economy, in which many industries are largely moribund (shipbuilding), flagging (international shipping), or often in disarray (fisheries), electronic marine instrumentation stands out as a field showing outstanding growth performance and potential. Marine instrumentation may well be an area of international competition in which United States companies can achieve sustained growth. While U.S. companies have been playing a dominant role in this market in the past, virtually no systematic study has been devoted to the sources or durability of their competitive advantage, or to the steps that might be taken to promote their future competitiveness. A Marine Policy Center project funded by the National Oceanic and Atmospheric Administration (NOAA) through the Massachusetts Centers of Excellence Corporation (MCEC) is now beginning to provide some of this information. The Marine Policy Center project is attempting to describe and analyze the industry structure and competitive position of U.S. marine electronics companies. The first cut at a definition of the marine advanced technology industry detailed in this technical report represents part of the background research for this project. Complementary studies by researchers at Florida State University and Hawaii's Oceanic Institute will project areas of future market potential for marine electronic instrumentation. By building on and refining the industry profile presented in this technical report,the NOAA/MCEC project will provide greater insight into the important features of the "high technology" sector of the U.S. marine industry, and into the factors that determine its competitive position in the American and international markets. The resulting understanding of the industry will enable industry and government to make better informed policy decisions to nurture the continuing viability and competitiveness of U.S. marine electronics firms in the years to come.

James M. Broadus
Director
Marine Policy Center

INTRODUCTION

Industries and activities related to the exploration and exploitation of the world's oceans are playing an increasingly important part in the economic life of many nations. While extensive use of the seas has been limited historically to the more advanced or "developed" countries, other nations are now also becoming more aware of the potential of ocean resources, and the recent worldwide interest in Law of the Sea activities bears testimony to the growing importance of marine activity of all kinds on this planet. As land-based resources become more scarce and expensive, it is likely that nations will continue to look to the sea for energy, food, minerals, and other resources in the future; and it is out of this effort to recover and utilize the oceans' resources that the international marine technology industry has grown and continues to evolve.

Pontecorvo et al (1980) have estimated that a broadly defined "ocean sector" contributed some $30.6 billion to the $1171.1 billion gross national product of the United States in 1972. Some of the larger elements of this ocean sector activity were the government (primarily the Navy) (35%), retail trade (24%), real estate (15%), and offshore oil and gas (7%). All of these elements, as well as the bulk of other ocean activities worldwide, make use of various levels of technology to achieve their objectives. Such technology may have been adapted from pre-existing land-based fields (for example, the early drilling rigs), or it may be entirely new technology developed specifically for marine applications (such as acoustic instrumentation). This report examines a specific sector of the large marine technology industry. It

attempts first to define and then to characterize the "high technology" part of the marine technology field.

Motivation

"High technology" is a concept that is often used but rarely well defined. In spite of the lack of a universally accepted clear definition, "high technology" is an important notion in many economic and industrial policy considerations today, particularly in the United States. A good part of this country's economic strength rests on its leading role in technological advancement and the development of various branches of high technology. The importance of the high technology industries to the future of the United States is generally recognized (High Technology,1984). Questions of industrial policy, regarding the possible public subsidization of high technology enterprises to "strengthen America's comparative advantage" are frequently raised and debated. For instance, the State of Massachusetts is currently in the process of "sowing the seeds of new high tech centers," including a marine science center near New Bedford (Boston Globe, 1985). In order to be able to make reasonable decisions in national and international policy questions regarding high technology, it is necessary to have an accurate understanding of the nature of the industries in question.

From this point of view, there are several reasons why a study of the international marine high technology industry might be of interest. First, there is the challenge of attempting to define such an industry, thereby answering the question of whether a distinct (and describable) high technology sector does in fact exist within the marine field. Although there may be some empirical evidence that such a sector does exist, it is not immediately clear that the "high

technology" label is appropriate to these activities. Once the industry has been defined, it can be analyzed and compared to other fields commonly considered to be "high tech." For instance, high technology competition is generally considered, particularly in this country, to be an important issue in international trade and economic relations. By examining the marine high technology industry at the international level, one may begin to answer questions about the United States' position in this field relative to other nations. Other questions that might be answered by such an examination include: what is the level of R&D effort among the companies making up this industry, and how does it compare to that of other technological areas? What is the growth history of marine high technology companies, and what areas of the industry are showing the greatest potential for future growth? What is the extent of international business in this industry?

The major sources of data for this profile of the international marine high technology industry were a survey mailed to companies in the marine technology field, discussions with people associated with the marine technology industry, and some existing literature on the topic. This report begins with an attempt at a definition of the industry, followed by the profile itself (including a discussion of the survey), and concludes with a discussion of some possible implications and suggestions for further work on this subject.

A DEFINITION OF THE MARINE ADVANCED TECHNOLOGY INDUSTRY

The Antitrust Approach

One well-established method of defining an industry is simply to include all companies that serve a particular, well-defined market. Market definition is commonly attempted in antitrust investigations, where the main focus is on the competitive behavior of the companies comprising the industry. The goal of such an analysis is to measure the levels of competitiveness and cross-price elasticities within an industry to determine the extent of market power (the ability of a real or hypothetical monopolist to raise the price of a product) in a particular market.

Unfortunately, this approach at first does not appear to be particularly suitable for the marine high technology industry. As a rule, the procedure is to begin with a product or set of products, and to define an industry in terms of a geographical region and a set of companies currently serving or capable of serving the market for said products in the specified region. The geographical region and set of companies are then expanded until a sufficient level of market power becomes evident in the system to call it an industry for antitrust purposes. In order for this approach to make sense, the products being considered must show at least a certain degree of substitutability, since the concepts of cross-elasticity and product substitution could not otherwise be applied.

In the case of the marine high technology industry, one might expect that many of the industry's products are in fact not paricularly substitutable; furthermore, the precise

products are not exactly known at the outset. This difficulty lies in the formulation of the problem: marine high technology products are sometimes defined in terms of their own "high tech" characteristics, and more frequently in terms of the characteristics of the firms that produce them. Not knowing the products, then, it is not possible to apply the antitrust method directly. In order to overcome this problem, some attention must be given to the notion of "high technology," and how it might help to define the products that constitute marine high technology.

The Concept of High Technology

Marine technology is not too difficult to define -- given enough time, it would not be impossible to construct a fairly exhaustive list of those technologies used in and around the marine environment. "High technology" is another matter. How is one to differentiate the subset of marine technology that constitutes high tech?

According to Dan Dimancescu (High Technology, 1984), two principal characteristics are commonly used to define high technology firms. One is a large proportion of professional and skilled technical employees, with typical ranges from 40 to 65% of a high technology firm's total employment. The other is a high percentage of sales reinvested in research and development (R&D) projects, generally from 5 to 15%. These percentages are from two to five times as high as comparable quantities for non-high technology firms.

However, there is no general agreement as to how high technology firms, not to mention products, should be defined. The U.S. Department of Labor's Bureau of Labor Statistics uses three broad criteria to identify high technology firms: manufacturers of computers and other "high tech" products,

technology intensive companies such as turbine makers, and high technology services such as software companies (High Technology, 1984). Note the vagueness and circularity in this definition. The Massachusetts Department of Employment Security, by contrast, confines high technology to some 20 manufacturing industries and excludes service companies altogether (High Technology, 1984). Depending on the definition used, it appears that "high technology" companies employ some three to six million workers in the United States and contribute between six and 12% of the gross national product (High Technology, 1984).

The Massachusetts High Technology Council

The Massachusetts High Technology Council was founded in 1977 with the stated goal of helping to make Massachusetts "the world's most attractive place in which to live and work, and in which to create, operate, and expand high technology business" (from Council brochure). It consists of the chief executive officers of Massachusetts high technology companies and currently has a membership of about 150, along with some 40 associate members representing service and financial institutions closely associated with high technology. The Council lists five characteristics of high technology firms as its criteria:

- high ratio of scientists and engineers to total workforce
- high ratio of R&D investment to sales
- manufactures and/or markets high value added products or services
- at least 30% of sales to markets outside the United States
- relatively rapid growth rate in employment and sales.

With the exception of the somewhat puzzling stipulation about foreign sales, these criteria are qualitative rather than

specific. In a telephone conversation, a representative of the Council claimed that "companies know whether they are high technology or not," that the Council had never had to turn down an applicant because they "were not high tech," and that the Council therefore had not had any occasion to produce a more quantitative set of criteria.

The Engineer's Perspective

An attempt was made to determine what criteria professionals in the marine field use personally to distinguish "high technology" products. The following list of such criteria mentioned in an informal survey of ocean engineers and scientists at the Woods Hole Oceanographic Institution and the Ocean Engineering Department at the Massachusetts Institute of Technology is indicative of the wide diversity of approaches that the marine scientific community takes to the subject. (See Appendix A for the survey form used and a list of respondents.)

Marine high technology products are:

- products that greatly enhance system or subsystem performance
- based on technlogy drawn from recent scientific discoveries
- highly mechanized, using state of the art computers, etc
- products that involve the use of advanced non-mechanical systems
- products that represent a significant state of the art advancement
- capable of enabling a significant advancement in the ability to work in a frontier area
- products that utilize technologies transferred from the aero-space and computer industries, including:
    a. new materials (carbon filament, ceramics)

concentrate on American and Canadian companies but also lists firms from many other nations. In addition to an alphabetical listing of these companies, the Guide also groups firms into some 80 areas of technology, each firm being listed under an average of four areas. Using the 1984/85 edition of the Guide, the six basic technology groups selected for this study can be further elaborated by listing under each group the more disaggregate technological areas from the Guide:

1. Oceanographic Instrumentation
   - bathythermographs
   - depth indicators and recorders
   - geophysical instruments
   - hydrophones, sonar, sonobuoys, sound sources
   - equipment lease and rental
   - survey and exploration services
2. ROVs/Robotics/Underwater Inspection Systems
   - simulators and trainers
   - design engineering services
   - marine ocean engineering
   - photographic and television equipment
   - underwater photography services
3. Data Processing
   - amps and pre-amps
   - analyzers, acoustic
   - analyzers, chemical
   - analyzers, electrical and electronic
   - computers
   - data converters
   - data indicators and recorders
   - oscilloscopes and oscillographs
   - data processing services
4. Engineering/Design
   - design engineering services
   - marine ocean engineering
   - calibrations, standards, and test equipment
   - testing and evaluation services

5. Communication/Navigation
   - antennas
   - communications equipment
   - navigation equipment
   - position fixing, tracking, and plotting systems,
   - telemetry instrumentation
   - transponders
   - positioning and navigation services
6. Advanced Military Technology
   - countermeasures, acoustic and electronic
   - explosives and ordnance.

There is of course some overlap between the listings under each of the six technology groups, and the items listed under each are undoubtedly not all-inclusive, but they do demonstrate a reasonable correspondence between the Guide's high technology areas and the technology groups selected for this study. (More will be said about the Guide later, as it was also used to produce a mailing list for the survey.)

Other Methods of Classification

To check for completeness, the proposed classification system was also compared to those systems used by other organizations dealing with marine technology. Two of them are mentioned here.

:: Oceans '84 ::

The Oceans '84 Conference is an annual event sponsored by the Marine Technology Society (MTS) and the Institute of Electrical and Electronics Engineers (IEEE), at which a wide range of marine technological developments are presented and discussed. Oceans '84 conference planners organized its

discussions by nine major groups, each with some ten subtopics beneath it. The major groups are as follows:

- information systems (see group 3)
- remote sensing and instrumentation (see group 1)
- marine environment and ocean energy
- EEZ special program and marine resources
- offshore structures, diving, and vehicles (see group 2)
- ocean engineering (see group 4)
- socio-economic and policy issues
- science and technology: plans and progress
- special interest sessions.

It can be seen that, in so far as these groups might contain elements of marine high technology, they are covered fairly well by the six areas proposed for this study.

:: Marine Technology Society ::

The Technical Affairs section of the Marine Technology Society divides its scope into four major divisions, each encompassing several committees. The major divisions are as follows:

- advanced marine technology
- ocean and coastal engineering
- marine resources
- marine policy and education.

The first two divisions bear closer inspection, and are listed below with their respective committees:

Advanced Marine Technology

- artificial intelligence and robotics (see group 2)
- ocean energy
- oceanographic instrumentation (see group 1)
- satellite and aircraft remote sensing (see groups 1,5)

- undersea physics
- underwater photography and sensing (see groups 1,2)
- undersea vehicles (see group 2)

Ocean and Coastal Engineering
- buoy technology
- cables and connectors
- defense technology (see group 6)
- diving
- marine minerals
- marine salvage and tow
- moorings
- offshore structures
- seafloor engineering (see group 4).

Again, a fairly good fit is evident between the potential high technology entries of this classification scheme and the proposed seven groups of marine high technology.

Standard Industrial Classification (SIC) System

For a number of reasons, it would be helpful if the U.S. government's SIC system of classifying industrial activities also could be compared to the proposed high technology groups. (The SIC system uses four digit codes to classify all industrial activity for purposes of statistical recordkeeping and analysis.) Not only would this allow a further check for completeness, but it could also yield a wealth of information about the appropriate SIC groups that could later be used to make comparisons with the postulated marine high technology industry. Unfortunately, the SIC system does not lend itself to any close comparison with the classification schemes preposed here, because SIC tends to be too broad in its categories for the technologies in question. For instance, "engineering, laboratory, and scientific and

research instruments and associated equipment" are lumped into one category (3811) without further subdivision. In the same way, "mechanical measuring and controlling instruments, except automatic temperature controls" (3821) and "radio and television transmitting, signaling, and detection equipment and apparatus" (3662) are not further subdivided and thus make any comparison with marine technology difficult, if not impossible. The usefulness of the SIC system is thus extremely limited for the purposes of this study.

AN INDUSTRY SURVEY

In order to collect the data for an industry profile, a short survey was prepared (see Appendix B). This survey consists of 30 questions, most of them "multiple choice" or "one word answer," covering four basic areas:

- the company's size and background
- the company's line of business
- the company's marine technology operations
- the nature of the company's markets.

Separate cover letters were prepared for domestic (U.S.) and foreign companies (see Appendix B), and for the domestic mailings, business reply envelopes were included to save the respondents the cost of returning the survey.

The Mailing List

The Sea Technology Buyers Guide/Directory was used to produce the mailing list for the survey. It was assumed that the Guide was afairly complete and representative listing of companies engaged in the marine technology business, since it had been published for some 20 years. Actually, of course, the Guide is not all-inclusive: of the roughly 1500 questionnaires sent out by Compass Publications prior to the printing of their 1984/85 edition, only about 1000 were returned and included. Still, this was an increase of about 10% over the number in the 1982/83 Guide. In any event, the Guide is the best source available from which to compile the mailing list.

From the 1034 companies listed in the Guide, 396 were

selected for the mailing. The selection process was somewhat subjective, based on the companies' own description of their activities and how well these appeared to match the high technology groups described previously. Of the 396 mailings, 328 went to U.S. based companies in 31 states (85 of them in California, 37 in Massachusetts, 35 in Texas), and 68 went to foreign companies in 13 countries (29 of them in Canada, 20 in Britain). Appendix C gives a complete breakdown of the survey destinations.

The Mailing and Returns

The complete surveys were sent out by first class mail, and the first responses arrived about a week later. Responses continued to come in at a fairly steady rate for the following two weeks, and then tapered off rapidly. The overall reply rate was roughly 23%, though only about 16% of the responses were actually useful to this project (others were either incomplete or else the companies proved to be non-high technology vendors). Interestingly, the useful response rate among the foreign companies (at close to 28%) was more than twice that of domestic companies, in spite of the fact that foreign respondents had to provide their own envelopes and postage to return the questionnaires. See Appendix C for a precise breakdown of the response rates from each mailing destination.

The surveys were, for the most part, addressed to the president of the company in question, either by name (if known) or by title. The objective was to obtain company-wide information from as competent a source as possible. As can be seen from Figure 1, this objective was attained quite well: over 55% of the responses were completed by the president of the company, and over 65% by either the president or vice president.

For a listing of all useful survey data, see Appendix D. An initial analysis of selected survey data appears below, supplemented in places by information from other sources.

Fig. 1: Position of Respondents within the Company

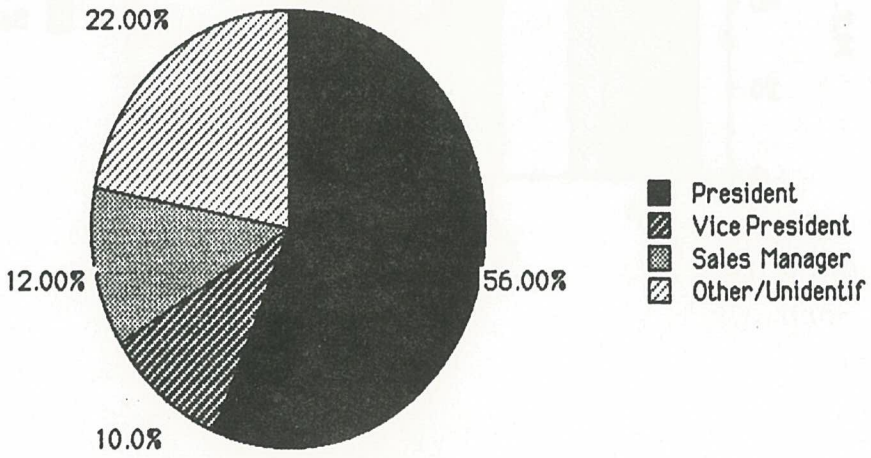
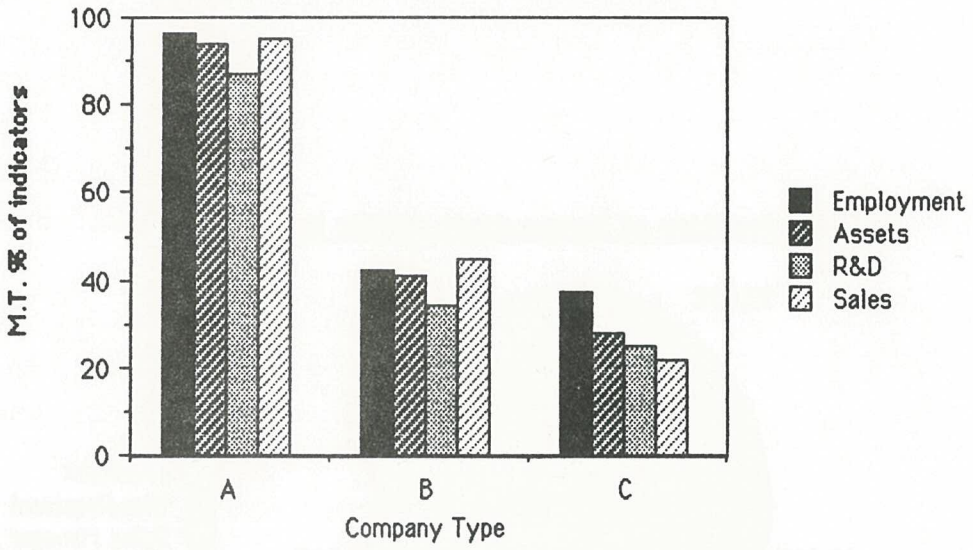


Fig. 2: Characteristics of Company Groups



SURVEY RESULTS: A MARINE HIGH TECHNOLOGY INDUSTRY PROFILE

Company Types and Groups

In addition to dividing the respondents into six technology groups (a few of them have actually been placed in more than one of the groups), each company is also placed, by its own choice in the survey, in one of three "company types." (See question II-2 on the questionnaire.) A "type A" company is one that deals exclusively with marine technology products and/or services. "Type B" companies are those that have a distinct marine technology division within a larger line of offerings. Finally, "type C" companies are those that do not have a marine technology division, although some of their products or services are also used in the marine field. Figure 2 shows the average percentage of employment, assets, R&D, and sales associated with marine technology for each company type. Some 50% of the respondents placed themselves in the "type A" category, with about 30% in "type B" and the remainder in "type C." Oceanographic instrumentation and navigation/communication companies tend to be largely "type A," whereas there is no significant pattern among the other technology groups.

Although no definitive statements can be made about the worldwide distribution of marine technology companies on the basis of this survey (the source of the mailing list undoubtedly favored companies in English-speaking nations), some claims about the existence of certain types of technology in various nations can be made on the basis of the survey responses. The United States appears to be one of the leaders, if not the leader, in each of the fields of technology considered in this study.

Oceanographic instrumentation companies are perhaps the most numerous of the six groups, accounting for roughly half of the survey responses. In addition to the U.S. and Canada, several Western European countries as well as Scandinavia appear to be represented in this field. Further, oceanographic instrumentation firms also appear in such Pacific nations as Japan and Australia. These companies support a wide range of scientific exploration in and around the oceans, including geophysical surveys for mineral resources, environmental monitoring, biological research, etc.

Companies involved in remotely controlled vehicles (ROVs) and robotics are far less numerous at this point and often tend to be only a few years old. The ROV concept emerged in a significant way only in the last decade or so. It was motivated largely by the need for offshore platform maintenance vehicles that did not have the depth and time limitations of human divers or the high cost of manned submersibles. ROVs are now used, although only to a limited extent, in other areas such as marine research and underwater filming as well. Some of the technology for these "robot submarines" comes from other industries such as aero-space, and this has prompted several companies from those industries to try to break into the ROV market with their existing expertise. Canada is a leader in this field, and the use of ROVs has been perhaps most widely accepted in the Canadian offshore industry. Several European nations and Japan also have active companies in this area.

Underwater inspection systems are frequently used in conjunction with ROVs, or in stationary applications on marine structures. This part of the marine high technology industry often "borrows" technology from other sectors, such as the nuclear industry, where problems of system inspection in inaccessible or hazardous environments have been addressed

for some time. Accordingly, firms in this group often are of the "type C" kind. Again, North America and Europe appear to be most heavily represented in this industry sector.

Data processing technology and services related to marine technology take a variety of forms, from electro-mechanical data converters and storage devices to extremely complex computer systems and programs used to analyze geophysical survey and other data. At the less complex end of the spectrum, a fairly large number of companies exist, though they appear to be concentrated in the United States. The more complex end of the spectrum is dominated by a small number of firms in the United States, France, and Britain that are capable of supporting the very expensive equipment needed to provide geophysical data analysis services. These companies tend to be international in the scope of their operations.

Engineering and design firms in the marine high technology field tend to be small and numerous, with about half concentrating exclusively on marine work and the other half being more general in their scope. In addition to the United States, Europe and Japan have a number of such companies. A number of larger manufacturing firms also offer engineering and design services as part of their business. Engineering/design firms may be called on to perform the engineering work for a conceived piece of equipment, or they may be asked to work on a given problem and come up with the solution "from scratch."

Communication and navigation equipment and services constitute a well-established part of the marine high technology field. Ranging from radio and television links to acoustic navigation and positioning systems and satellite navigation and data transmission, this field has expanded into a new dimension in recent years with the increasing use of remote sensing techniques from aircraft and satellites.

Military marine high technology companies manufacture and design various types of marine weapons systems and information and training devices of interest to the world´s navies. Many of the companies in the other five groups are partialy supported by military sales and see this as only one part of their general business. On the other hand, a number of diversified companies known in the United States as principally "defense contractors" have the military as their primary customer and occasionally sell civilian products as a sideline. Within the marine high technology field, military products cut across many of the other groups, but also include a number of special productssuch as anti-submarine systems or programmable training simulators that have little application elsewhere.

Sales and Markets

In comparing and analyzing the measures of a company´s size and performance, such as sales, assets, growth, etc, a problem is encountered in the case of companies of the "B" and "C type" (see discussion above). In some cases, these companies are quite large with only a small marine technology division, which works with products of a nature substantially different from the company´s other lines of business. In this case, to use this company´s total assets or employment figures, for example, as representative of the marine high technology industry could be misleading. Because of this, a separate analysis has been conducted for the total values reported by the respondents on the one hand, and for the adjusted "marine technology values" on the other hand. On the plots, this is indicated by a reference, for example, to "total sales" as opposed to "M.T. sales" (meaning "marine technology sales"). In most cases, slightly different trends are detected for the "total" and "marine technology"

relationships. These differences tend to be quite small, however, and it is doubtful that they are statistically significant. Standard tests for significance have not been applied, since these tests are based on assumptions of random selection from normally distributed populations. The first of these assumptions is certainly not valid for this survey, and the second cannot be established either.

One further cautionary note is in order concerning the relationships plotted in the sections below. Since not all of the survey responses selected for analysis were filled out completely, it was not possible to use the same set of companies for each plot. A firm that listed its assets but refused to specify its annual sales volume, for instance, would not be included in the plot of sales vs. R&D, whereas it would be included in the assets vs. R&D graph. This can lead to slight apparent inconsistencies in the plots and should be kept in mind when various graphs are compared to each other.

The trends reported in the discussion below are based on least squares regression fits. The results of these regressions should be understood as being purely descriptive, and not explanatory. Attempts to develop explanatory relationships between three or more variables in the survey data by means of least squares regressions did not produce any valuable results.

Note that several plots, particularly those involving dollar figures related to the size of the companies, are presented in logarithmic form for greater clarity.

:: Annual Sales and Assets ::

Figures 3a and 3b show the relationship of annual sales to company assets for marine high technology companies.

Fig. 3a: Total Sales vs. Total Assets

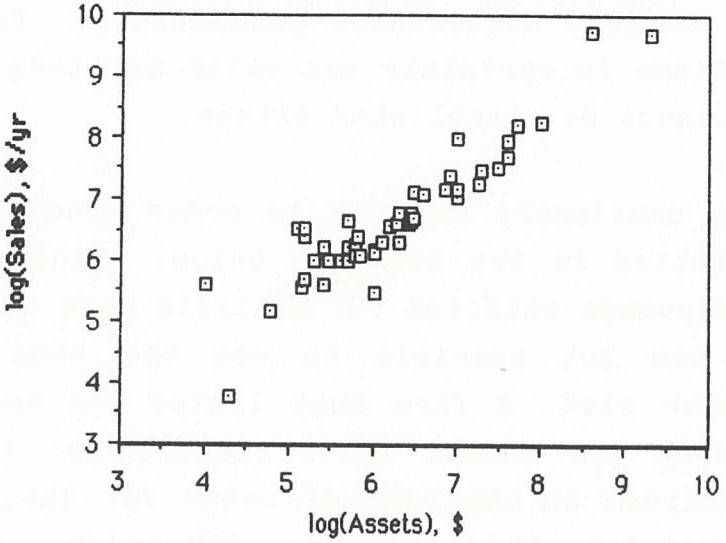
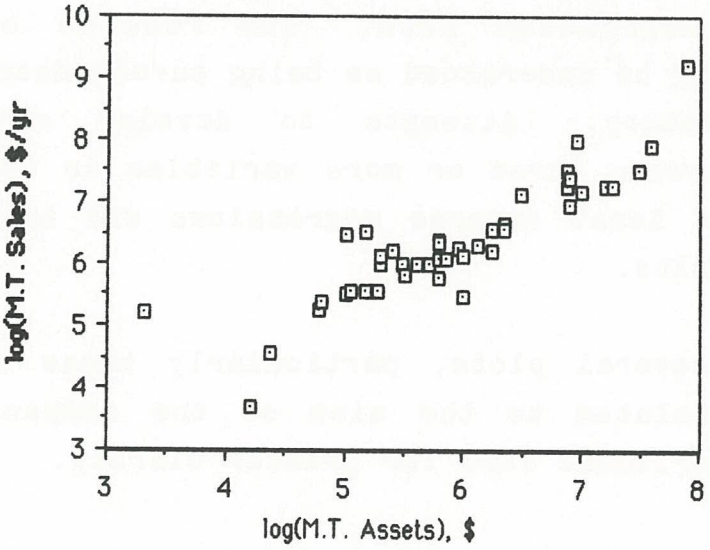


Fig. 3b: M.T. Sales vs. M.T. Assets



There is some scatter, especially in the marine technology plot; but a general trend is discernable. For the total sales/assets relation, the trend seems to be a sales/assets ratio of slightly more than two, with average annual sales of about $15 million. For the marine technology plot, the sales/assets ratio is slightly below two, with average annual sales close to $10 million.

:: Sales Productivity ::

An indication of sales productivity can be obtained by comparing the number of employees of a company to its annual sales. This relationship is plotted in Figures 4a and 4b for marine high technology companies. The correlation coefficients relating sales to workforce are quite high (above 0.95) for these trends. Sales productivity among all responding companies appears to be around $65,000 per employee-year, whereas the same measure corrected for marine technology operations is slightly higher at $70,000 per employee-year.

:: Domestic and Foreign Sales; Competition ::

Figure 5 breaks down typical annual marine technology sales per company for each technology group, and shows graphically the ratio of domestic to foreign sales. Military technology companies tend to be by far the largest in terms of average annual sales ($75 million), followed by communication/navigation firms ($18.8 million). Data processing, ROV, and oceanographic instrumentation companies fall close together, just below $10 million in average annual marine technology sales. Engineering/design firms appear to be the smallest in terms of sales ($2 million). The highest percentage of foreign sales is found in the ROV group (41% foreign sales), while other groups range from 13%

Fig. 4a: Total Sales Productivity

Fig. 4b: M.T. Sales Productivity

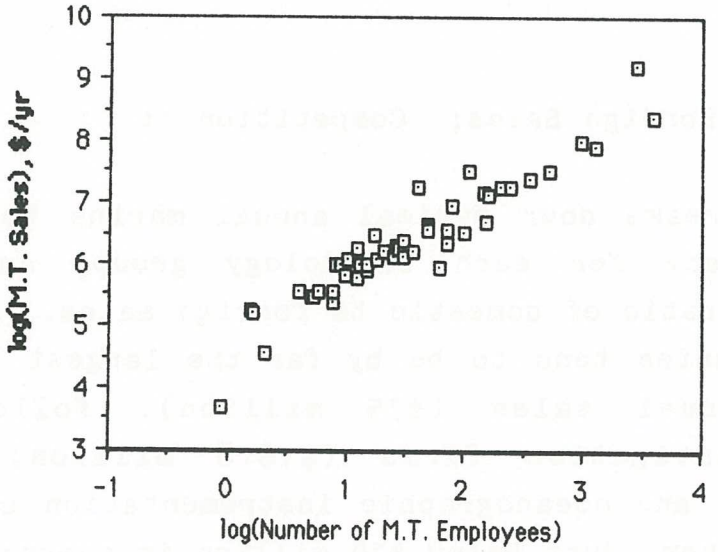


Fig. 5: Domestic and Foreign Sales by Technology Group

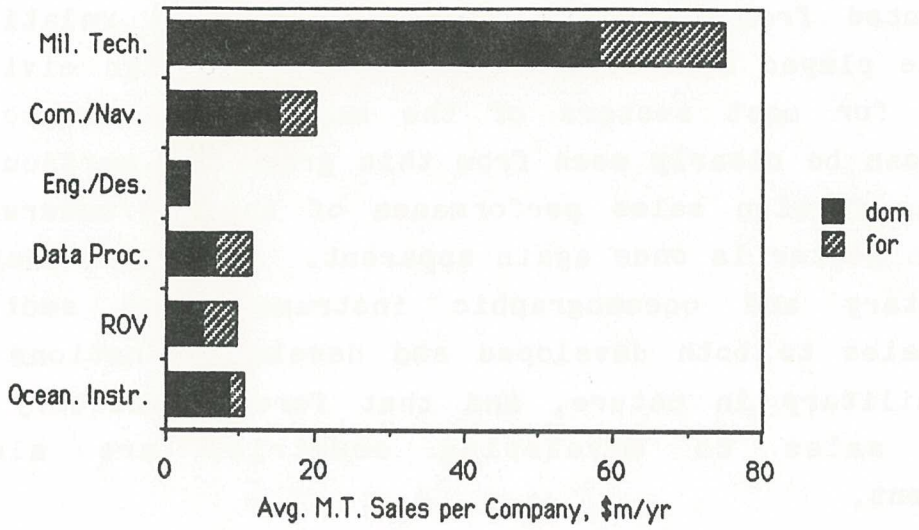
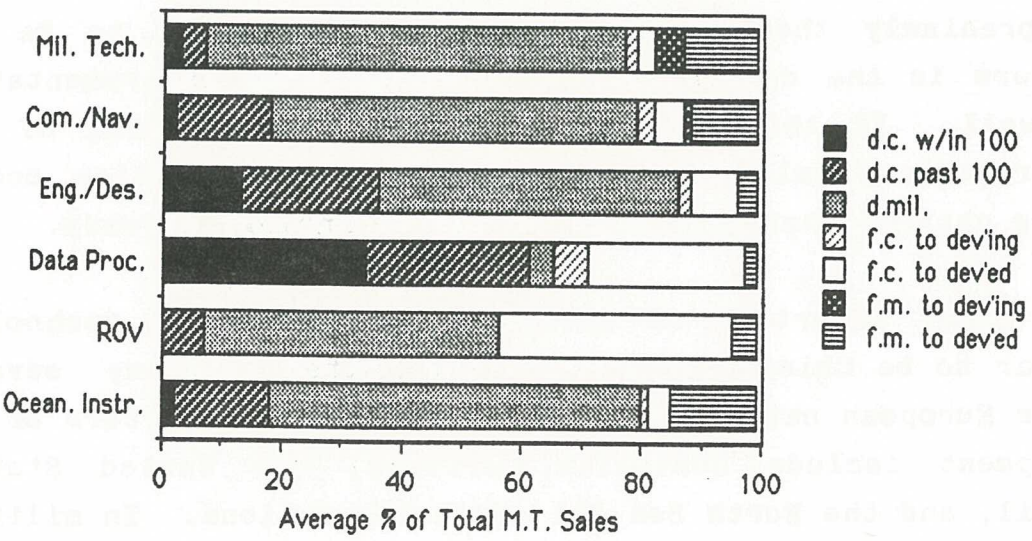


Fig. 6: Breakdown of Sales Destinations by Technology Group



(engineering/design) to 34% (data processing).

In Figure 6, marine technology sales are broken down in terms of their destinations for each technology group. (See Appendix E for the method by which these data were reconstructed from the survey responses.) The relatively large role played by domestic military and foreign civilian customers for most sectors of the marine high technology industry can be clearly seen from this graph. In particular, the strong foreign sales performance of the ROV/underwater inspection sector is once again apparent. Note also that in the military and oceanographic instrumentation sectors, foreign sales to both developed and developing nations are largely military in nature, and that foreign military and civilian sales to developing countries are almost non-existent.

The respondents in the oceanographic instrumentation sector listed 19 distinct foreign customers for civilian technology, covering much of North and South America, Europe, Scandinavia, the Soviet bloc, and the Asian Pacific nations. Importing nations mentioned most frequently were Canada, Britain, Japan, West Germany, France, and the United States -- precisely the nations that have been shown to be the leaders in the development of oceanographic instrumentation as well. It therefore appears that a great deal of the international sales in oceanographic instrumentation occurs among nations that have much of the technology already.

Chief importers of navigation/communication technology appear to be China, Norway, and the United Kingdom; several other European nations were also mentioned. Importers of ROV equipment include Australia, Britain, the United States, Brazil, and the North Sea oil producing nations. In military technology, the importers listed most often in the questionnaires were France, Italy, Germany, and Canada. Foreign sales in engineering/design services apparently went

mostly to China and the United States, with other European nations also mentioned. Finally, some of the importers of data processingservices and equipment include Argentina, Brazil, Australia, the U.S., and several European nations.

Figures 7 and 8 give an indication of the level of "internationalism" of the three company types (A, B, and C, as discussed above). Figure 7 shows that the percentage of foreign marine technology sales appears to be largest for the most diversified companies. This might be explained by a greater international presence or existing representation on the part of these generally larger companies. Figure 8 implies that "type B" companies have, on average, a greater number of rivals in their foreign marine technology sales than the others. It also shows that, as one might expect, the majority of all marine high technology companies' rivals in foreign sales are, in fact, foreign companies.

Oceanographic instrumentation respondents listed a large variety of companies as rivals in marine technology sales; very few of them, however, were mentioned more than once (see Appendix D). This seems to point to a tendency within this sector of the industry for each company to find a particular market niche and operate there, generally without a great deal of fierce competition (more on this below). A similar situation seems to exist in the communication/navigation sector, although the evidence is less clear there. In the ROV/inspection branch of the industry, it appears that this trend is not present; only a small number of companies were mentioned as competitors, most of them by more than one of the respondents, and competition in this part of the industry is likely to be much greater. In the miliary sector, the nature of competition is probably affected by the presence and status of one chief customer. In the engineering/design firm group, competition appears to be considerable and rather international, as respondents listed numerous rivals both within and outside their own nation. Finally, in data

Fig. 7: M.T. Sales to Foreign Customers

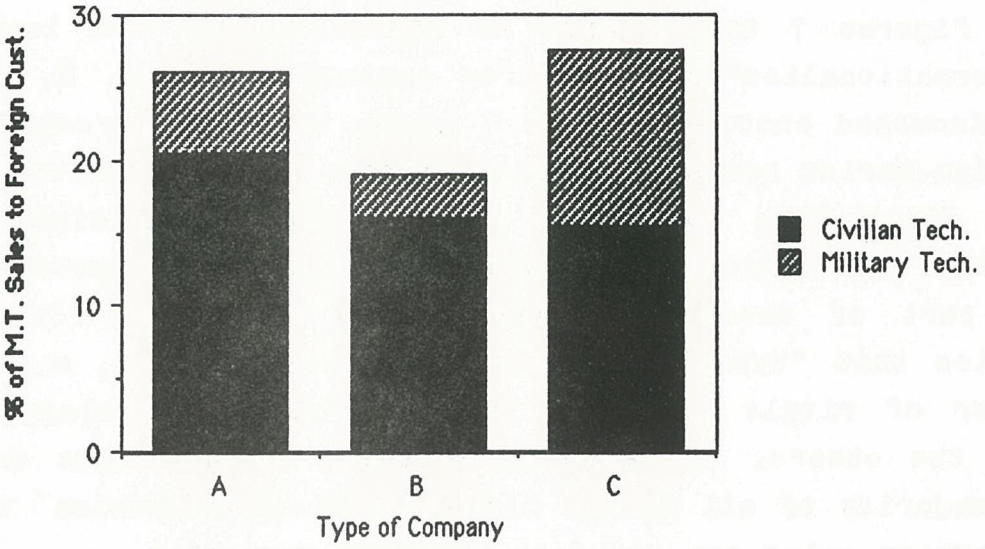
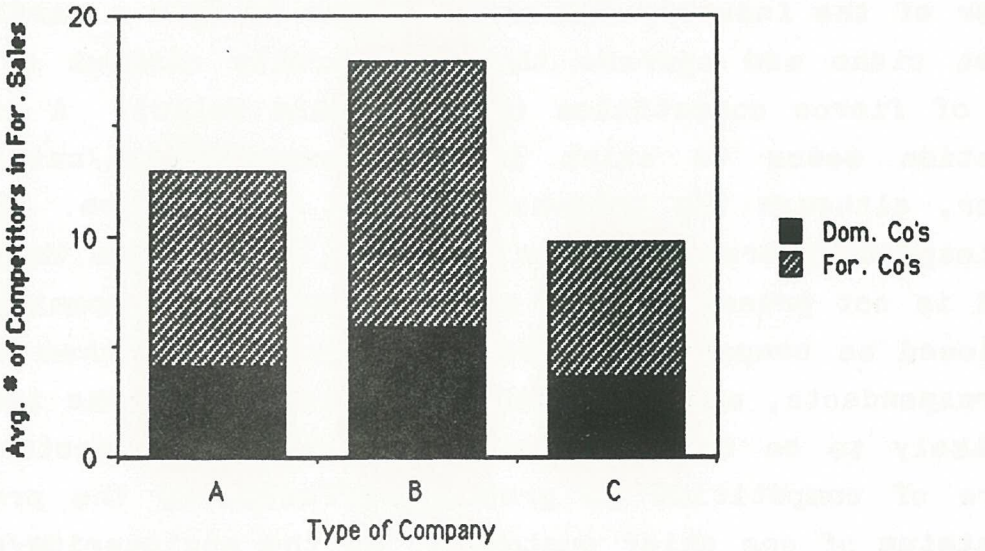


Fig. 8: Foreign Sales Competition



processing, the competition is somewhat limited in terms of numbers of firms, but most major competitors are quite well known by the members of this industry sector.

The completeness of the listings in the Sea Technology Buyers Guide/Directory can best be addressed at this point. The names of competitors listed on the questionnaires were compiled and checked against the Guide's listing. It was found that about 40% of the competitors mentioned by respondents were not included in the Guide's list, and therefore were not included in the survey mailing list. An additional 20% of the competitors mentioned by respondents were included in the Guide's list but were not included in the mailing because their self-description in the Guide did not make them appear to be "high technology" companies. The remaining 40% of competitors identified by survey respondents were also listed in the Guide and were included in the mailing list. It will be recalled that the editors of the Guide only received responses to about two thirds of the 1500 questionnaires they sent out prior to publication. The remaining third not responding to the Guide's questionnaire is close in terms of proportion to the 40% of competitors listed by the survey respondents but not found in the Guide's final listing.

:: Company Growth ::

The growth of marine high technology companies in terms of sales is analyzed again, both for total sales and for marine technology sales. Figures 9a and 9b correlate the companies' recent annual growth (averaged over the past five years) to their expected growth (average anticipated growth over the next five years). Although the observations are somewhat scattered, a certain trend is evident in both plots: for companies whose recent growth has been in therangefrom zero to 20%, expected growth is aboutthe same; whereas for

Fig. 9a: Expected Total Growth vs. Recent Total Growth

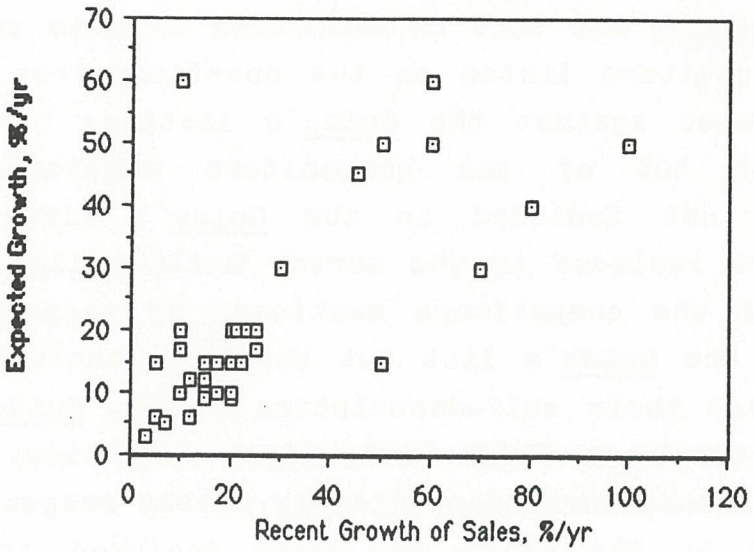
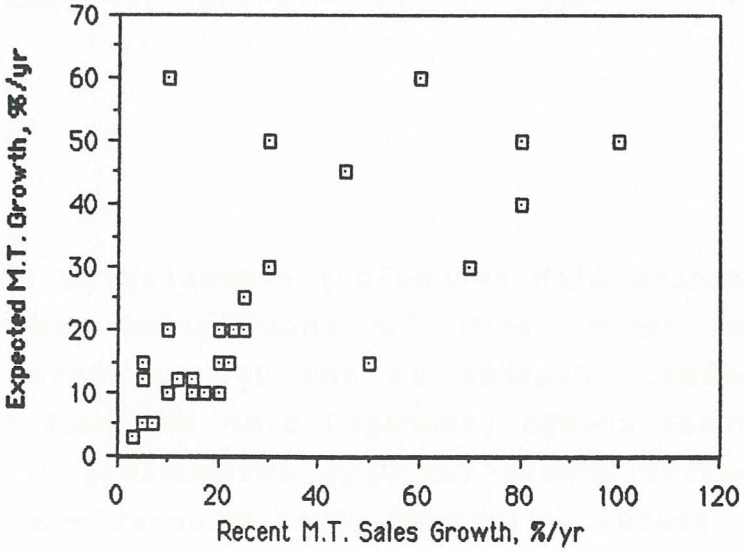


Fig. 9b: Expected M.T. Growth vs. Recent M.T. Growth



companies with recent growth much higher than 20%, the expected growth tends to be only about half of the recent growth. Although information about long-range expectations for growth (next 20 years) was solicited on the survey, most respondents did not provide any information on this, or else actually stated that they could not begin to guess what that growth might be.

Figures 10a and 10b show the average recent and expected growth rates of marine high technology companies as a function of the date of establishment of the company. These plots appear to bear out the implications of Figures 9a and 9b once again in a different fashion: relatively new companies (and many of these are from the ROV sector) tend to grow quite rapidly at first, and then to settle toward the industry average rate of growth, slightly above 10% per year in sales. If they do not, they presumably go out of business.

Marine technology sales growth rates are broken down by technology groups in Figure 11. The relatively higher growth rates of the ROV/underwater inspection and oceanographic instrumentation sectors are evident from this plot, as is the high expected future growth rate for the ROV sector, the most recent addition to the marine high technology field. This optimism about the future of the ROV industry is echoed, though somewhat more cautiously, by the 1984/85 Sea Technology Buyers Guide/Directory, which calls for a growth of some 50% over the next three years in the ROV/diving sector (p. A/10).

Research and Development (R&D) Efforts

As pointed out earlier in this thesis, measures of the

Fig. 10a: Total Salesgrowth vs. Age of Company

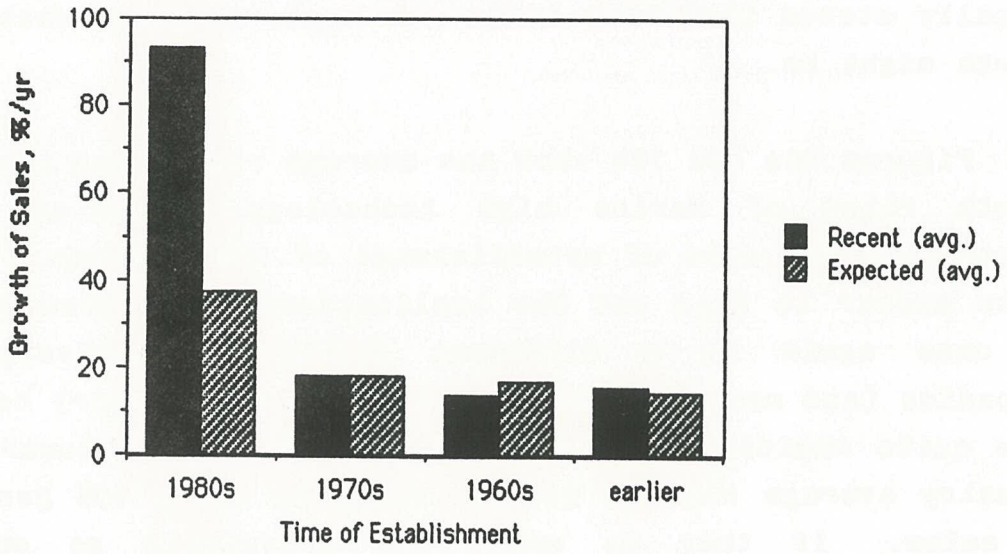


Fig. 10b: Growth of M.T. Sales vs. Age of Company

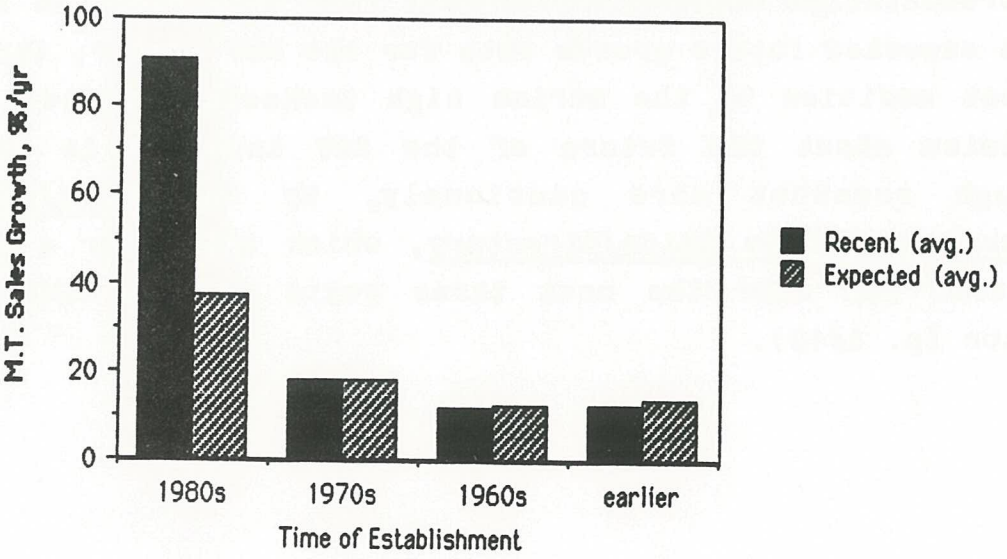
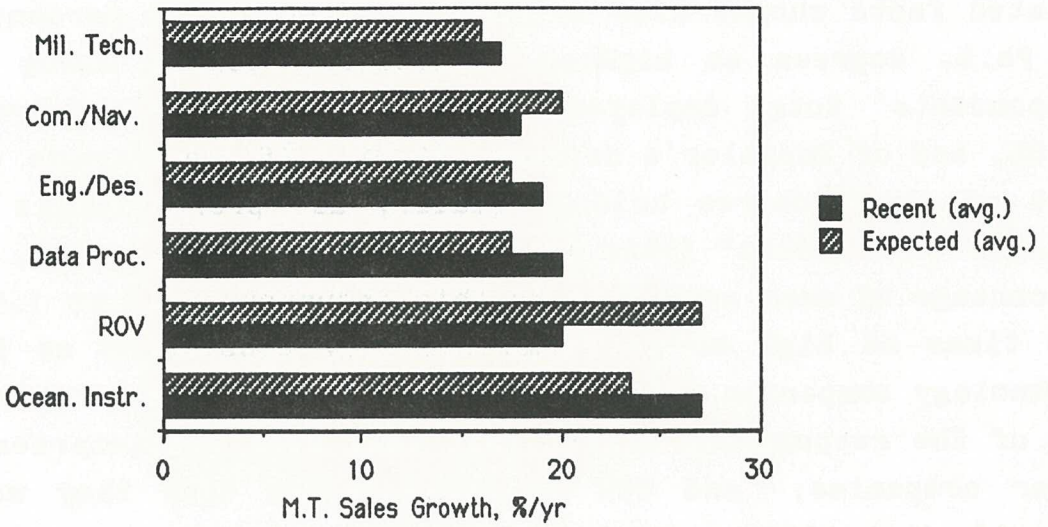


Fig. 11: Growth by Technology Group



R&D spending and the educational/professional level of the employees of a company are frequently used to determine whether or not the company belongs to a high technology industry. In this section, the reported R&D spending patterns of the survey respondents will be analyzed. Several related facts should also be mentioned here. The percentage of Ph.D. degrees as highest educational degree among the respondents' total employees is 3.8%, of master's degrees, 18.0%, and of bachelor's degrees, 60.0%. If one assumes that most of these degree holders qualify as "professionals and skilled technicians" (this is not necessarily the case), the percentage of such employees in this industry could be 1.5 to two times as high as in firms commonly considered as high technology companies (High Technology, 1984). Also, close to 30% of the respondents stated that they were subsidiaries of other companies; and 95% of them claimed that they would classify themselves as high technology companies.

:: Growth of Sales and R&D Effort ::

Figures 12a and 12b show plots of the recent sales growth as a function of the companies' R&D effort, measured in terms of R&D spending as a percentage of sales. The trend, if any, is vague to be sure, and the correlations in both cases are poor. The extreme outliers that show recent growth of near to or greater than 100% are recently established U.S. companies serving specialized corners of the oceanographic and geophysical sectors. The correlations are only slightly better for Figures 13a and 13b, showing the expected annual sales growth as a function of R&D effort. It appears that the variability in these relationships is too great to permit any valid generalizations about industry-wide trends.

Figures 12 and 13 are also useful in showing the wide spread in the level of different firms' R&D intensity,

Fig. 12a: Recent Total Sales Growth vs. Total R&D Effort

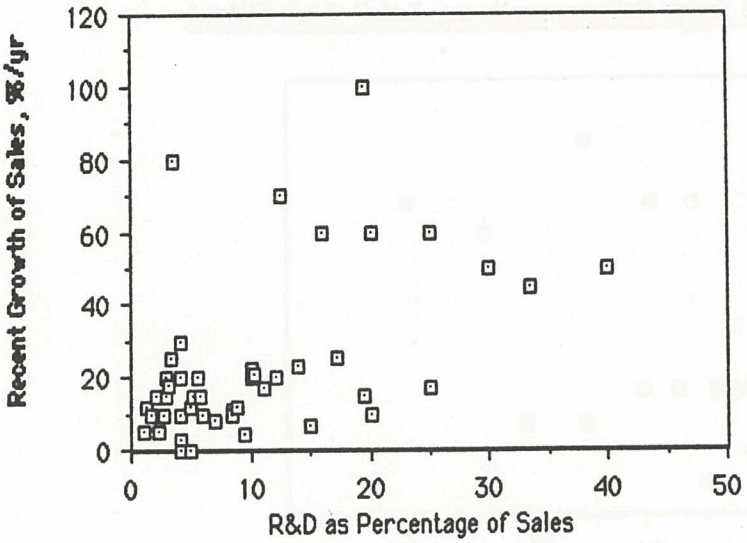


Fig. 12b: Recent M.T. Salesgrowth vs. M.T. R&D Effort

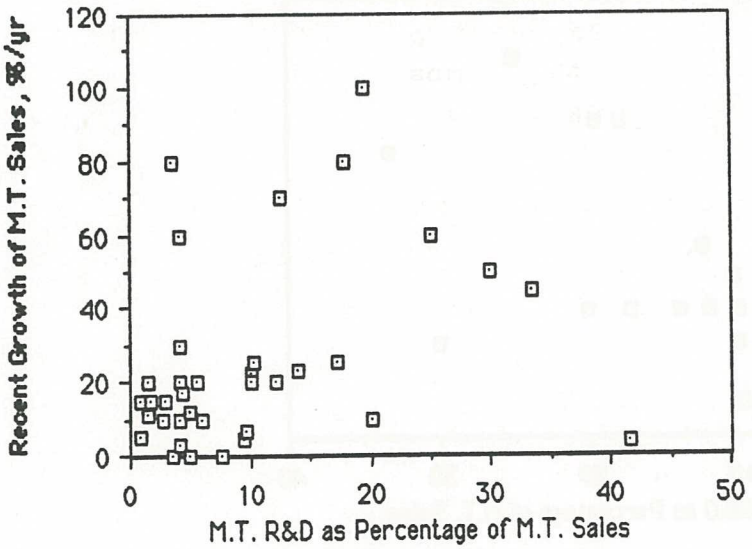


Fig. 13a: Expected Total Salesgrowth vs. Total R&D Effort

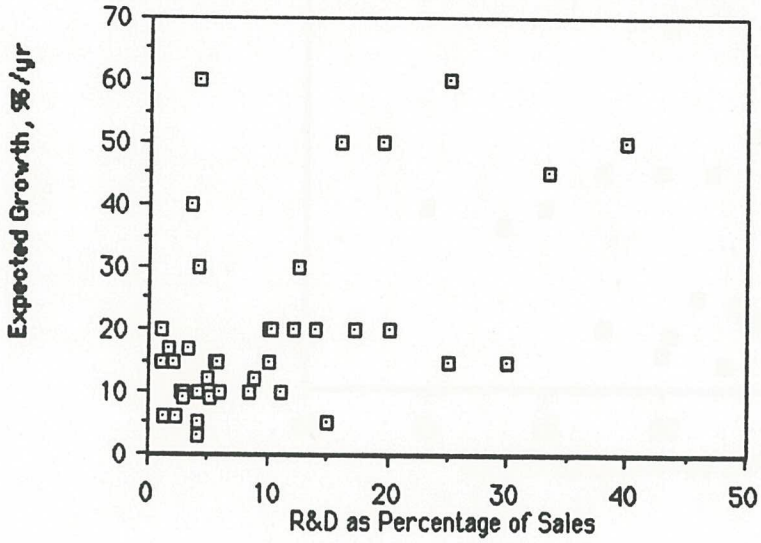
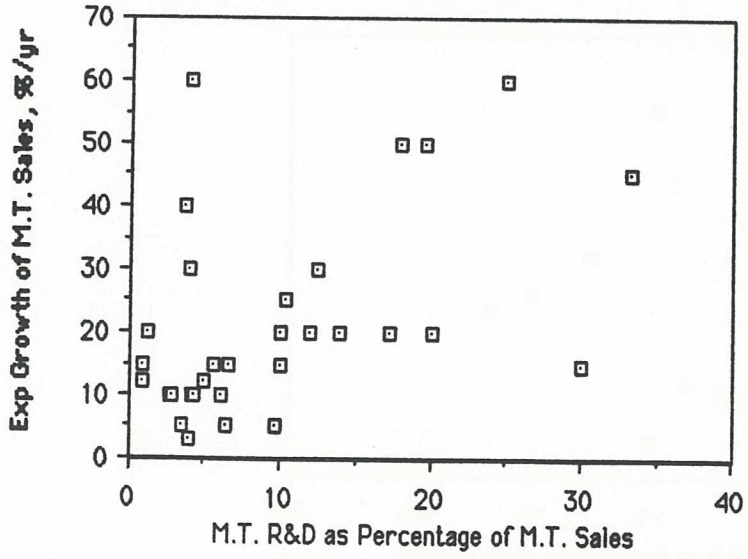


Fig. 13b: Expected M.T. Salesgrowth vs. M.T. R&D Effort



measured as a percentage of their sales volume. Although the bulk of the firms are in the 0 to 10% range of this indicator, a substantial number of them lie between 5 and 15%, with some outliers as high as 20 to 40%. These extreme cases are often companies that receive R&D contracts as part of their regular business (such as engineering or military contractors), thus boosting their R&D spending considerably.

:: Assets and R&D Spending ::

Figure 14 shows a breakdown of the average level of marine technology assets and annual R&D spending for each technology group. It appears that communication/navigation and data processing companies require a relatively larger ratio of assets to R&D (probably expensive computer equipment, etc) than the others, while the engineering/design group tends to be the least asset-intensive (as one might expect). The high expenditure of R&D funds by military technology companies can probably be explained by the nature of their funding: Navy contracts for new product R&D could be strongly augmenting these companies' R&D commitments.

Plots of R&D spending as a function of assets for the entire industry showa great deal of scatter with only poorly correlated trends, as evidenced by Figures 15a and 15b. When trends are fitted to these plots, the result is that total R&D spending is around 9% of total assets, while marine technology R&D lies around 13% of marine technology assets.

:: Sales and R&D Spending ::

The correlation is somewhat better for the plots of R&D spending as a function of sales, Figures 16a and 16b. Although there is still some scatter, the trends for the industry appear to make more sense here than they do for R&D

Fig. 14: M.T. Assets and R&D by Technology Group

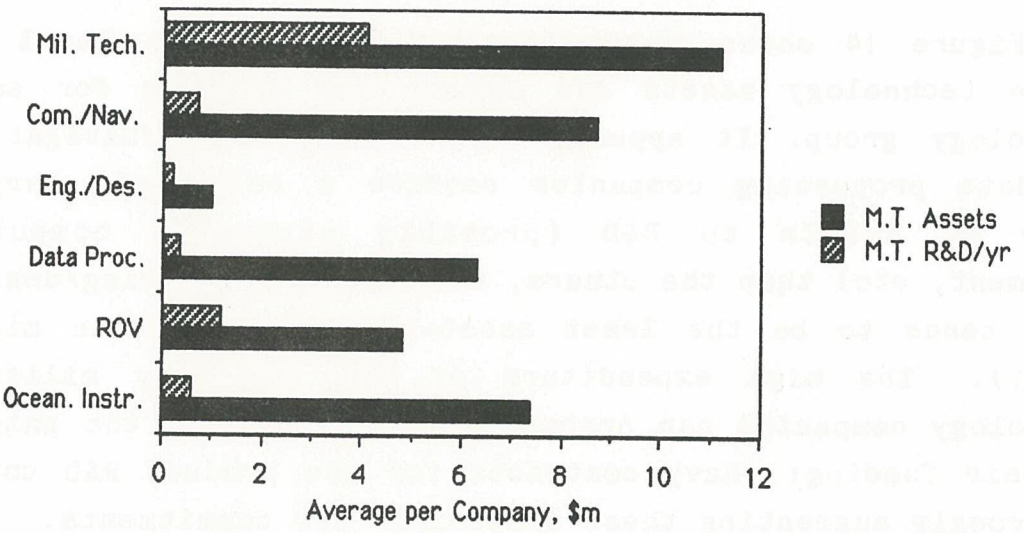


Fig. 15a: Total R&D Spending vs. Total Assets

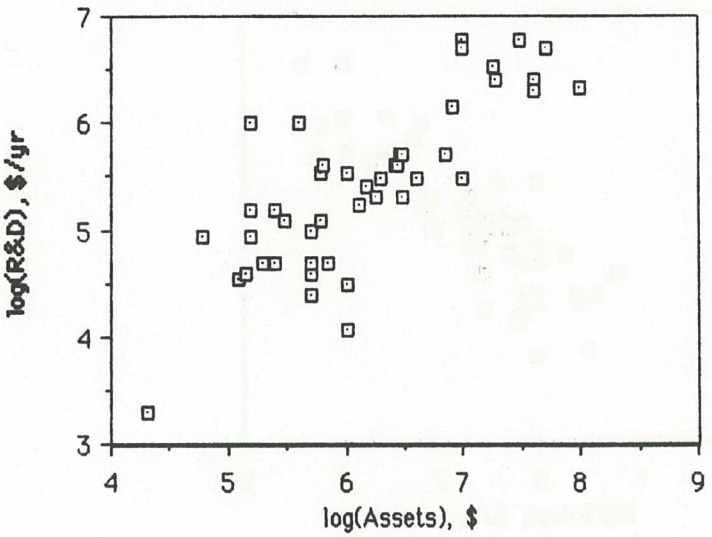


Fig. 15b: M.T. R&D Spending vs. M.T. Assets

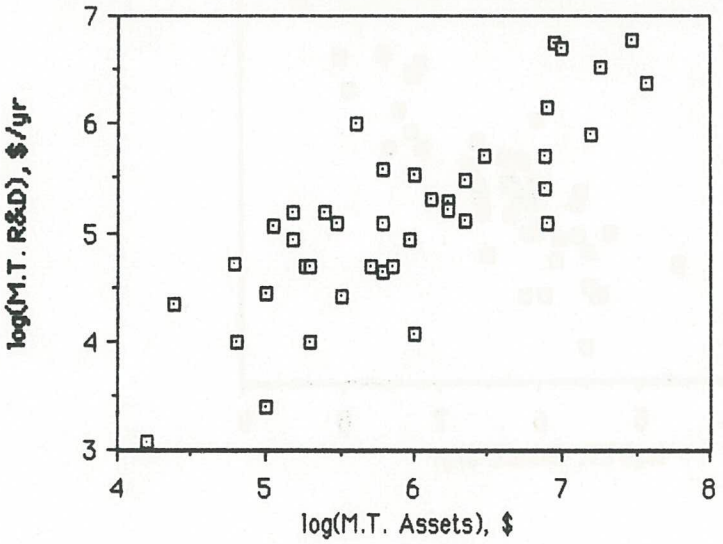


Fig. 16a: Total R&D Spending vs. Total Sales

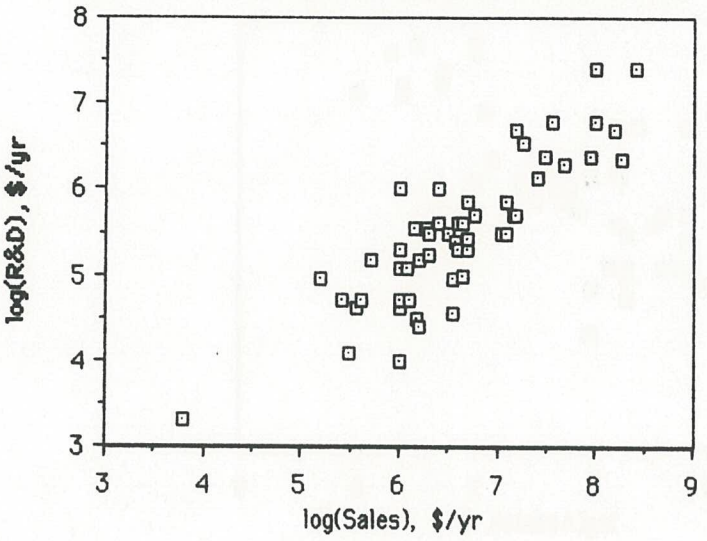
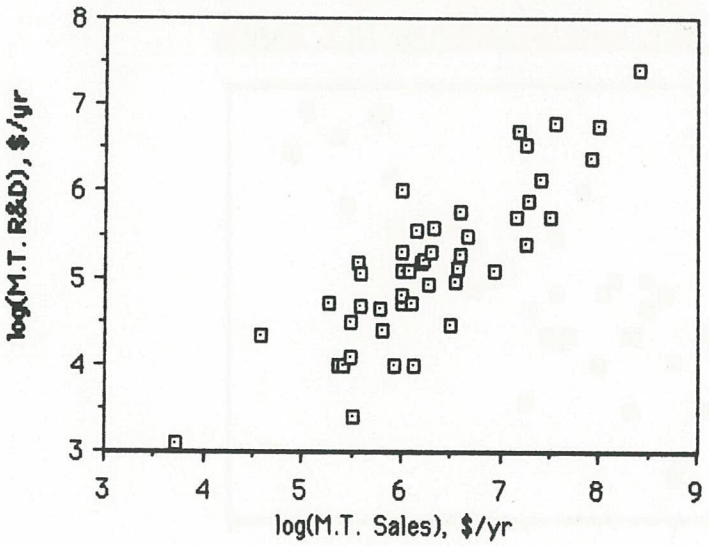


Fig. 16b: M.T. R&D Spending vs. M.T. Sales



and assets. For total R&D spending and total sales, the trend is around 7% of sales; for marine technology operations, it lies around 9% of sales. For comparison, Griliches et al (1984) report the following levels of R&D effort:

drugs and medical instruments	4.5% of sales
office, computer, and accounting equipment	6.1%
communication equipment	4.0%
aircraft and aerospace	4.2%
professional and scientific equipment	5.1%

and, from another database,

drugs (SIC 283)	7.5% of sales
computers (SIC 357)	5.3%
electronic equipment (SIC 36)	4.7%
instruments (SIC 38)	5.5%.

It appears that the level of R&D effort in the marine high technology industry matches or exceeds the levels reported for any of these groups.

:: Employees and R&D Spending ::

Finally, Figures 17a and 17b plot the annual R&D spending against the companies' number of employees. The average number of employees per company in the marine high technology industry as represented by this sample is around 480, with the median much lower at about 50. Some 30% of the companies claimed fewer than 20 employees, 15% between 20 and 50, 20% between 50 and 100, 15% between 100 and 1000, and the remaining 10% over 1000. For the industry in general, the trend seems to be a little below $5000 in R&D spending per employee-year, while for the marine technology part it is close to $6000 per employee-year.

Fig. 17a: Total R&D Spending vs. Total Employees

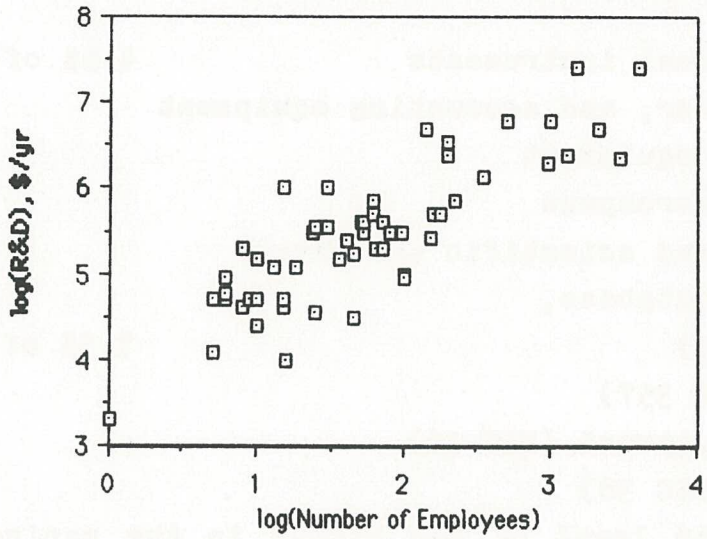
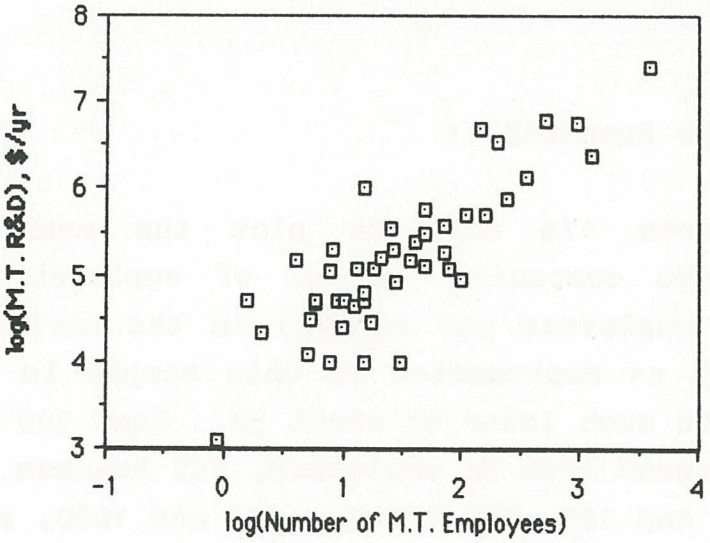


Fig. 17b: M.T. R&D Spending vs. M.T. Employees



Industry Company Social Structure

From discussions with members of the industry and professionals closely associated with certain sectors thereof, it was possible to gain some information about the social structure of certain parts of the marine high technology industry. A summary of these findings follows below.

As one industry representative put it, "if you work for a year in the oceanographic instrumentation industry, you will know 75% of the people in the field." Communication between companies in this sector is open and virtually continuous; everyone seems to know what the other is working on and where their particular strengths and weaknesses lie. Perhaps because of this, it appears that competition between members of this industry sector is rarely fierce and, if it is, then usually only for a brief time and on a specific product; each company tends to find its niche and work there, largely unmolested. Individual employees tend to stay within the industry and move among oceanographic companies when they do change jobs. This "people network" extends internationally as well. In the United States, oceanographic instrumentation companies are clustered in four main areas: in southeastern Massachusetts, in California, around Seattle in Washington, and to a lesser extent on the Gulf Coast around Houston. The original oceanographic instrumentation companies sprang up in these locations because of their proximity to centers of marine research, from which the founding engineers usually came. Today, their location has less significance, since most of them do business all over the United States and frequently the world. (See Figure 6 for an indication of the small percentage of "local business" that most of these firms do today.) The reason for the continued clustering of these firms probably lies in the

"breeding effect" by which this sector of the industry grows: engineers at existing companies, seeing a market niche that is currently unfilled or perhaps a product that can be made more economically, will form a new company -- and usually be unwilling to leave the area in which they are established. This is, in fact, the principal means by which this part of the marine high technology industry develops and evolves.

A rather close relationship usually exists between the customers and the company, as most companies in the oceanographic instrumentation sector do a great deal of customized work for specific applications. For many of these firms, a production run of 15 or 20 pieces of identical (complex) equipment may be considered large. As a rule, a company will have several basic systems which can then be customized for a number of different applications. Some companies choose to enter the service market as well, leasing equipment (and frequently operators) for certain types of work; other firms avoid this altogether.

The ROV sector has been fairly close to the oceanographic instrumentation field, and several companies have been active in both areas. However, some significant differences are apparent. Competition in the relatively younger ROV area may be more intense, in part because a number of companies established in other areas (such as aero-space) are trying to break into the expanding ROV market. This is also bringing new people into the marine high technology field, since the ties between ROV work and other areas like instrumentation remain quite strong. The ROV industry has flourished in a number of nations, such as Canada, under the encouragement and with the help of a governmental effort to foster new high technology industries. Future growth is virtually assured by the existence of hundreds of offshore oil and gas rigs, many of which are presently being inspected and maintained by more expensive or less effective methods; unlike the offshore supply industry,

for example, ROV companies will be relatively unaffected by fluctuations in the drilling and exploration efforts. The current trend in ROV design reflects a continuing evolution of designs and a focusing on specific purposes: ROVs are becoming either smaller and less expensive (some currently sell for under $100,000) or larger and capable of greater depths (presently up to 3100 meters). Manned submersibles will probably be made obsolete in the offshore industry by the continuing refinement of ROVs; while typical dayrates for a manned sub (including crew and mothership) are about $50,000, an unmanned vessel can be operated for some $2000 per day (Sea Technology Buyers Guide/Directory, 1985).

Companies within the military technology sector, and in particular those defense contractors dealing almost exclusively with the Navy, tend to be somewhat removed from the rest of the industry since they often are tuned to one particular customer and the associated products and procedures.

Another close group exists in the geophysical survey and data processing sector. Here, the number of large firms is limited and competition, especially between some of the major energy companies, is strong. Nonetheless, a relationship similar to that in the oceanographic sector seems to exist between the people working in this field.

Related Organizations

Organizations related to the marine technology industry, such as the Marine Technology Society (MTS) or the industry's trade association, the National Ocean Industries Association (NOIA), appear to play largely peripheral roles to the lives of marine high technology companies, at least those in the oceanographic instrumentation sector. These companies may

hold a membership in NOIA, but they usually do not maintain active contact with the Association.

CONCLUSIONS AND IMPLICATIONS

The evidence in the preceding profile suggests that the proposed marine high technology industry as defined near the outset of this thesis can in fact be distinguished as a discrete subset of the larger marine technology field, and may legitimately be referred to as a "high technology" industry. The relatively high levels of R&D effort (about 8% of sales) demonstrated by this group of companies and the substantial proportion of professionals and skilled technicians in the industry's workforce (perhaps as high as 80%) appear to qualify this sector of marine technology for the "high tech" label, at least by the most commonly accepted measures. Most representatives of the industry also agree with the assessment that a "marine high technology industry" does exist, and that they and their companies were in some way members of this industry. Other factors, such as the high level of foreign business and the rather strong geographical concentration of the associated companies (both nationally and internationally) further support this conclusion.

Based on theevidence assembled for thisprofile, the international marine high technology industry appears to consist of several technology groups, including oceanographic instrumentation, ROV/underwater inspection, data processing, navigation/communication, etc. Geographically, the companies of this industry are concentrated in specific clusters in western industrialized nations. They range from small, specialized marine engineering firms to large, diversified companies for whom marine technology is only one of several lines of business. Average annual marine technology sales per company are near $10 million, while median sales are

closer to $2 million. The sales/assets ratio for the industry appears to be close to two. Average employment per company is near 500, while the median employment is only about 50. Companies spend an average of $5000 to $6000 per employee-year on R&D, and each employee accounts for close to $70,000 in annual sales. The industry average growth rate of sales lies around 10% per year, although companies less than five year old (many of them in the ROV business) often show growth rates more than ten times higher than this.

The way in which the marine high technology industry was defined for the purpose of this thesis is by nature somewhat conservative and thus probably represents a "small" or "core" version of such an industry. It is possible -- perhaps even likely -- that some facets of marine technology that would qualify as high technology were not captured by the six technology groups selected for this study. On the other hand, it is not unreasonable to assume, based on the fact that all of the "high tech" companies from the Sea Technology Buyers Guide/Directory did "fit" into one of the six groups, that this definition of the marine high technology industry is at least fairly comprehensive. One might say, therefore, that the definition put forth in this thesis does delimit a "high technology subset" of the general marine technology industry, and that this subset probably does contain most of the high technology activity within the marine field.

A few important implications for industrial policy decisions can also be drawn. The United States has been and continues to be a leading force in the field of marine high technology. Other nations, such as France, Germany, Canada, Britain, and Japan, also have a strong marine high technology base, and international competition in the field is not unusual. Overall, there were no indications in the data collected for this study that the United States was not among the leaders in any subgroup of this high technology sector.

On the other hand, some of the recent developments, especially in the relatively new ROV area, bear further watching. American companies are facing perhaps their stiffest competition in this part of the industry. As one representative of an American firm involved in ROV work put it, no one has any monopoly on innovation or invention, either between companies within a nation such as the United States, or between different countries. Several industry membersemphasized the education/training base and the propensity to develop and test creative and innovative solutions as the keys to success in marine high technology areas. However, there seems to be a correlation between nations that have recently made great advances in the ROV field and governments that have taken active steps to create economically favorable conditions for the establishment and growth of high technology companies (Canada might be the leading example of this).

To date, the vast bulk of international trade and technology transfer in the marine high technology industry has occurred between a few developed nations, largely in North America and Western Europe. Although there is no indication that developing nations have any difficulty in obtaining marine high technology equipment when they wish to (and are financially able to), the geographic distribution of the companies in this field also shows an almost complete lack of marine high technology production in developing nations.

Suggestions for Further Work

One obvious direction of further work on this topic is the mailing of a follow-up survey to substantiate the results found here. A new expanded mailing list could be put together from the listings of competitors, and the response

rate could be further improved by following the mailing with phone calls.

Phone calls and personal visits (the latter are more useful) could also be used to substantiate and expand the findings presented herein, especially in the industry social structure area, by calling on a wider range of companies. In a similar way, the data base could be expanded for non-U.S. companies, and more detailed comparisons between industry members in different nations (and hence different economic environments) could then be made to gain greater insight into the effects of national policies on high technology company development.

APPENDIX A

Engineers Survey and List of Respondents

LIST OF RESPONDENTS TO ENGINEERS SURVEY

Ocean Engineering Department, MIT:

- Prof. Whiddon
- Prof. Milgram
- Prof. Kildow
- Prof. Chryssostomidis
- Prof. Vandiver
- Prof. Carmichael
- Prof. Karr

Ocean Engineering Department, WHOI:

- Robert Spindel
- Jules Jaffe
- Albert Williams
- Yogesh Agrawal

APPENDIX B

Survey and Cover Letters

Marine Policy
and Ocean Management
Center

Woods Hole
Oceanographic Institution
Woods Hole, MA 02543

Woods Hole, July 16, 1985

Dear Member of the Marine Technology Industry,

As a summer student fellow at the Woods Hole Oceanographic Institution's Marine Policy and Ocean Management Center, I am currently working on a definition and characterization of the international marine high technology industry. In order to obtain some of the information needed for this project, brief questionnaires such as the one included in this letter are being sent to selected companies engaged in various aspects of advanced marine technology products and services.

This form has been kept very short, and the information it is designed to collect should prove to be of interest to all members of the marine technology field. I would greatly appreciate it if you, or someone else at your company, could take the few minutes needed to complete and return the questionnaire. A return envelope is provided for your convenience, and I will be happy to furnish you with the results of the survey if you are interested. Because of the time constraints associated with this project, I would ask that you please mail the completed form by the first week of August at the latest.

If you have any questions about the survey or the project itself, please call me at (617) 548-1400, x2773.

Thank you in advance for your time and help.

Sincerely,

Hauke Kite-Powell

Hauke Kite-Powell

Telephone: 617-548-1400 Telex: 951679

Marine Policy
and Ocean Management
Center

Woods Hole
Oceanographic Institution
Woods Hole, MA 02543

Woods Hole, July 16, 1985

Dear Member of the International Marine Technology Industry,

As a summer student fellow at the Woods Hole Oceanographic Institution's Marine Policy and Ocean Management Center on Cape Cod, USA, I am currently working on a definition and characterization of the international marine high technology industry. In order to obtain some of the information needed for this project, brief questionnaires such as the one included in this letter are being sent to selected companies engaged in various aspects of advanced marine technology products and services.

This form has been kept very short, and the information it is designed to collect should prove to be of interest to all members of the marine technology field. I would greatly appreciate it if you, or someone else at your company, could take the few minutes needed to complete and return the questionnaire to me at the address on the letterhead above. I will be happy to furnish you with the results of the survey if you are interested. Your response is especially important since the project is to produce as broadly international a data base as possible. Because of the time constraints associated with the project, I would ask that you please mail the completed form by the middle of August at the latest.

If you have any questions about the survey or the project itself, please call me at (617) 548-1400, x2773.

Thank you in advance for your time and help.

Sincerely,

Hauke Kite-Powell

Hauke Kite-Powell

Telephone 617-548-1400 Telex: 951679

Marine Policy
and Ocean Management
Center
Hauke Kite-Powell

Woods Hole
Oceanographic Institution
Woods Hole, MA 02543

MARINE TECHNOLOGY INDUSTRY SURVEY

Organization:

The thirty questions below are divided into four sections designed to provide a basic picture of your company's background and the nature of its operations and sales, especially with respect to marine technology products and services. None of this information will be made public with any specific reference to your company. Please be as accurate and complete in your responses as your time allows (it should take only about 20 minutes). Thank you very much for your help.

I. YOUR COMPANY'S SIZE AND BACKGROUND

1. When was your company established? _____

2. Is your company a subsidiary of another firm? Please circle: Yes No

   If yes, what is the ultimate parent company? _____

3. About how many employees are now with your company? _____

4. Approximately how large are your company's assets? $_____

5. What are its approximate annual sales or revenues? $_____

6. What is its approximate annual spending on research and development (R&D)? $_____/year

7. What has been your company's average annual growth rate of sales over the last five years? _____%

8. What is your outlook for sales growth for the next:

   five years? _____

   twenty years? _____

Telephone: 617-548-1400 Telex: 951679

II. YOUR COMPANY'S LINE OF BUSINESS

1. Please give an overall, "capsule" description of the products and/or services marketed by your company. _____

_____

2. Please circle the letter next to the statement that best describes your marine technology operations:

   A. This company deals exclusively with marine technology products/services.

   B. Our marine technology operations constitute a distinct division in the company's larger line of offerings.

   C. We have no formal marine technology division, although some of our products are used in the marine field.

3. Would you classify yourself as a "high technology" company? Please circle: Yes No

4. Please indicate about what percentage of your company's marine technology employees have the following highest formal education:

   Bachelor's Degree: _____

   Master's Degree: _____

   Doctor's Degree: _____

5. What label do you use to describe the particular industry of which your company is a member? _____

_____

6. About how many domestic companies do you consider to be your competitors: in domestic sales? _____

   in foreign sales? _____

7. About how many foreign companies do you consider to be your competitors: in domestic sales? _____

   in foreign sales? _____

8. Who are your company's closest competitors in the marine technology field? _____

_____

III. YOUR MARINE TECHNOLOGY OPERATIONS

1. If different from your overall business, please give a brief, capsule description of the marine technological products and/or services marketed by your company. _____

_____

2. About what percentage of your employees is now associated with your marine technology operations? Please check along the line below:

/——/——/——/——/——/——/——/——/——/——/——/
0% 20 40 60 80 100%

3. About what percentage of your company's assets is associated with your marine technology operations? Please check below:

/——/——/——/——/——/——/——/——/——/——/——/
0% 20 40 60 80 100%

4. About what percentage of your company's R&D spending is for marine technology operations? Please check below:

/——/——/——/——/——/——/——/——/——/——/——/
0% 20 40 60 80 100%

5. About what percentage of your sales is generated by your marine technology business? Please check below:

/——/——/——/——/——/——/——/——/——/——/——/
0% 20 40 60 80 100%

6. If different from your overall business, what has been the average yearly growth rate of your marine technology sales over the last five years? _____%

7. If different from your overall business, what is the outlook for your marine technology business for the next:

five years? _____

twenty years? _____

IV. THE NATURE OF YOUR MARKETS

1. About what percentage of your marine technolgy sales is for civilian applications (i.e. non-defense)? Please check along the line below:

/——/——/——/——/——/——/——/——/——/——/——/
0% 20 40 60 80 100%

2. About what percentage of your civilian marine technology sales is to foreign customers? Please check below:

/——/——/——/——/——/——/——/——/——/——/——/
0% 20 40 60 80 100%

3. What nations, if any, are your principal foreign civilian customers?

_____

4. About what percentage of your foreign marine technology sales is to developing (or so-called "3rd world") nations? Please check below:

/——/——/——/——/——/——/——/——/——/——/——/
0% 20 40 60 80 100%

5. About what percentage of these sales to developing nations is for civilian applications? Please check below:

/——/——/——/——/——/——/——/——/——/——/——/
0% 20 40 60 80 100%

6. About what percentage of your defense marine technology sales is to foreign customers? Please check below:

/——/——/——/——/——/——/——/——/——/——/——/
0% 20 40 60 80 100%

7. Approximately what percentage of your domestic sales is to customers located within about 100 miles (150 km) of your location? Please check below:

/——/——/——/——/——/——/——/——/——/——/——/
0% 20 40 60 80 100%

Name of person completing this form: _____

Position in the company: _____

THANK YOU VERY MUCH FOR CONTRIBUTING YOUR TIME TO THIS PROJECT.

I would also greatly appreciate receiving any company literature that you might send to help with this project.

Please feel free to include a separate sheet with any additional comments or questions.

(BLANK)

APPENDIX C

Mailing and Return Statistics

Destination		Number Sent	Useful Number Returned	Useful Return %
US:	California	85	10	11.8
	Massachusetts	37	7	18.9
	Texas	35	4	11.4
	New York	33	2	6.1
	Maryland	20	3	15.0
	Washington	19	9	47.4
	Florida	16	2	12.5
	New Jersey	12	0	0
	Virginia	9	2	22.2
	Louisiana	6	0	0
	Connecticut	5	1	20.0
	New Hampshire	5	3	60.0
	Ohio	5	0	0
	Rhode Island	5	0	0
	Indiana	4	1	25.0
	Illinois	3	0	0
	Pennsylvania	3	0	0
	Utah	3	0	0
	Arizona	2	0	0
	Washington DC	2	0	0
	Michigan	2	0	0
	Missouri	2	0	0
	Oregon	2	0	0
	Alabama	1	0	0
	Colorado	1	0	0
	Hawaii	1	1	100
	Montana	1	0	0
	North Carolina	1	0	0
	Nebraska	1	0	0
	New Mexico	1	0	0
	Tennessee	1	0	0
US Subtotal		328	45	13.7
Canada		29	5	17.2
England		20	7	35.0
Scotland		4	2	50.0
Norway		3	1	33.3
Japan		3	2	66.7
West Germany		2	1	50.0
Australia		1	1	100
Denmark		1	0	0
France		1	0	0
Italy		1	0	0
Netherlands		1	0	0
Sweden		1	0	0
Switzerland		1	0	0
Foreign Subtotal		68	19	27.9
Grand Total		396	64	16.2

APPENDIX D

Survey Raw Data

SURVEY RAW DATA

All responses to each question are listed below. They are not correlated by company for reasons of privacy and anonynity.

I-1: (All are 20th century except the last.) 67,78,71,74,77,70,59,81,67,79, 55,63,79,72,72,59,58,70,68,10,46,78,42,37,68,80,66,78,78,66,72,68,70,75,71, 64,48,74,65,72,81,82,75,75,83,46,83,78,73,70,71,75,54,81,72,81,45,1590.

I-2: Yes: 17, No: 41.

I-3: 3,50,60,8,30,10,5,2,17,1300,75,15,1500,5,65,500,173,60,9200,220,13,2150, 1000,15,8,72,6,18,36,16,80,53,53,15,1,45,140,350,200,9,85,24,10,125,3248,30, 72,965,25,100,45,40,4000,100,200,150.

I-4: (In $MM.) 2.75,2.8,0.142,0.6,0.5,0.01,40,2,0.5,1,3,30,7,400,0.3,50,10, 0.4,1.8,0.2,0.6,0.25,4,2.6,0.2,0.02,1,10,8,19,0.5,7.5,2,0.15,0.65,40,0.124, 3.5,0.5,1.3,1.5,0.15,18.

I-5: (In $MM.) 4.5,5.9,0.36,1.8,1.6,0.4,90,6,1,100,0.3,5,35,15,5,5700,12,1, 160,100,1,1,4,0.35,1.2,1.6,1,12,3,4,1,0.006,1.5,15,25,30,0.25,1,4,2,0.5, 17.9,1.6,2.5,2.5,48,0.035,4.5,2,3.6,250,3.5,18,5.

I-6: (In $MM.) 0.03,0.4,0.5,0.04,0.35,0.025,0,2.5,0.04,25,0.012,0.2,6,0.5, 0.7,0.12,5,6,1,0.2,0.2,0.04,0.12,0.15,0.01,0.3,0.3,0.411,0.05,0.002,0.03,5, 1.4,2.5,0.05,0.05,1,0.3,0.15,1,0.4,2,0.1,0.175,25,0.09,3.5,0.26.

I-7: (In %/year.) 0,20,12,10,17,15,10,15,17,15,10,30,17,3,25,25,23,15,15,20, 18,10,10,12,70,22,4.5,-20,10,20,21.2,0,15,45,20,11,300,200,10,7,50,12,9.5, 50,60,20,5,5,8,20,10,100,20.

I-8: (In %/year.) Five years: 20,12,10,10,15,10,15,10,20,30,15,3,5,20,17,20, 15,15,20,10,20,12,30,15,20,20,20,15,45,15,100,20,5,15,10,10,50,15,15,6,20, 10,50,9. Twenty Years: 10,5,25,10,20,15,10,5,30,10,10,25,10,10,20.

II-2: A: 27, B: 19, C: 12.

II-3: Yes: 54, No: 3, Not Sure: 1.

II-4: Bachelors: 67,33,12,20,30,40,100,70,50,75,20,50,40,14,60,70,20,67,40, 50,70,20,25,80,20,20,47,0,10,90,35,10,50,50,20,70,25,10,90,0,100,0,35,25. Masters: 0,0,12,10,0,20,20,20,20,20,30,5,11,5,20,33,25,10,33,25,35,20,10, 27,0,0,5,1,70,5,15,20,20,12,1,0,60,0,25,15,10,0,0,0. PhDs: 33,66,0,3,3,5, 30,5,20,1,3,0,10,5,0,5,1,0,5,25,0,0,20,100,0,5,.05,20,0,25,10,10,0,5,40,0, 75,3,2,0,0,0,0,0.

II-6: In domestic sales: 6,5,3,2,1,1,7,2,15,10,10,5,3,3,10,2,5,15,5,5,4,5,3, 0,5,0,15,1,15,3,5,2,15,10,3,0,4,8,0,3,5,3,1,3,0,4,5,10,50,1,2,25,0,0. In foreign sales: 6,2,1,3,1,0,1,5,0,2,20,5,2,3,10,10,3,0,0,0,0,4,3,4,1,3,4,5, 10,5,6,0,4,8,0,4,5,3,1,5,0,2,5,10,20,0,2,5,0,0.

II-7: In domestic sales: 5,4,3,1,0,4,0,5,0,0,2,20,0,1,5,0,3,0,0,0,6,0,4,3,0, 5,3,1,0,2,5,1,3,3,2,15,0,0,2,2,3,5,0,3,20,50,0,1,1,0,4,5. In foreign sales: 5,3,1,1,0,1,5,0,3,20,0,1,3,12,10,3,0,2,0,2,5,2,7,30,2,5,20,2,8,3,12,15,0,2,

5,8,5,10,5,20,40,50,1,6,2,8,10.

II-8: (Each competitor listed once unless otherwise indicated in parentheses.) DATEL, Licor, EPC, EG&G (4), Benthos, Oceano, WHOI, US Navy, Aanderaa (2), Magnavox, Motorola, Raytheon (5), General Dynamics, Sparton, Tetra Tech, GSI, Sea Data Corporation, Rockwell, Westinghouse (2), Honeywell (3), Lockheed, EDO (5), G. I., Hazeltyne, Actran, IKU, Benntech, Hermes Electronics, Ithaco, Neff, SAI (4), Teledyne (2), GECO, Furuno, Koden, Japan Radio Company (2), DISAT-1, Marine Electronics Corporation, ITMorrow, SIMRAD, Kongsberg, GE, IBM, ICOM, Hull Engineering, Hydro Products (3), Sub Sea (3), Osprey (2), Perry (2), Ametek-Straza (2), ISE, Slingsby, Kraft, Atlas, International Transducer, Bendix Oceanics, FEL, Gould, AT&T, Mar, Tracor (2), Western Instruments, OTC, DORD, AMR, Mesotech, UDI, Britsh Marine Technology, DuV, Global Marine, Vitro, Potomac Research (2), Ferranti ORE, OSI, SSL, Praklaseismos.

III-2: 20,90,80,95,10,100,80,100,40,65,10,100,75,100,80,30,100,5,95,100,100, 100,100,100,100,100,15,0,50,100,90,100,100,20,100,15,85,75,10,5,40,95,25,70, 30,60,10,100,100,100,10.

III-3: 20,70,80,45,10,20,100,20,100,30,65,10,100,75,100,80,20,100,15,95,100, 100,100,75,100,100,100,15,0,50,100,80,100,100,40,100,100,15,85,75,5,95,40, 80,40,70,10,100,100,100.

III-4: 5,50,60,25,15,10,100,0,100,65,0,100,65,100,80,20,100,10,95,100,100,100, 100,100,100,95,15,0,50,100,60,100,100,10,20,100,15,55,75,20,10,95,40,80,10, 50,60,100,100,100,25.

III-5: 15,60,15,80,65,10,20,100,40,100,40,65,5,100,75,100,80,30,100,20,95,100, 100,100,100,100,100,85,5,10,50,100,85,100,100,60,100,100,35,85,75,5,5,70,85, 40,90,30,90,10,100,100,100,20.

III-6: (In %/year.) 0,20,-5,10,5,15,5,15,10,20,3,25,23,10,20,15,10,10,12,70, 22,4.5,-20,0,25,0,45,20,11,200,7,50,30,80,20,5,15,4,20,10,100.

III-7: (In %/year.) Five Years: 0,20,-5,5,10,10,5,10,10,3,5,20,20,10,20,10, 20,12,30,15,20,25,45,15,100,20,5,15,50,50,15,15,20,10,50,15. Twenty Years: 5,15,10,20,10,5,30,25,10,50,25,10,10,20.

IV-1: 35,80,100,100,35,10,80,100,80,100,20,5,80,15,20,75,75,20,80,0,5,90,45, 75,60,85,100,7,80,25,80,100,80,80,25,100,10,25,85,95,65,80,100,95,75,100,90, 90,100,5,10,7,90,90.

IV-2: 5,20,35,5,15,10,20,65,10,20,40,0,10,55,20,5,75,10,0,0,20,20,55,55,20,85, 0,7,50,25,10,20,80,90,75,10,10,25,85,15,5,3,50,92,25,60,10,30,10,0,50,5,60, 85.

IV-3: (Number of listings indicated in parentheses.) Britain (11), Canada (12), Singapore (2), Brazil (3), West Germany (5), Japan (5), Mexico (2), France (6), Australia (6), Italy (5), Norway (5), India (1), USA (7), South East Asia (2), Saudi Arabia (2), Korea (1), China (5), Ireland (1), North Sea Oil Producers (1), Europe (3), Argentina (1), Spain (1).

IV-4: 0,10,15,5,5,10,0,0,10,0,10,40,0,0,20,0,0,0,17,0,10,5,7,7,0,7,0,0,0,0,40, 0,0,0,0,5,25,5,0,0,60,15,0,20,10,0,50,0,50,0,5,20.

IV-5: 0,100,100,100,5,80,100,0,95,0,0,55,0,0,85,0,0,0,3,0,30,95,100,5,0,7,0,0,
0,100,0,0,0,0,5,95,95,0,0,100,100,0,100,70,0,100,0,10,0,100,100.

IV-6: 0,0,0,0,0,20,0,0,15,0,0,15,20,85,20,0,30,25,0,10,50,0,5,0,7,100,20,0,0,
20,50,0,0,0,5,5,0,0,0,0,0,2,0,5,0,0,0,20,5,80.

IV-7: 65,5,20,10,25,5,15,60,75,10,50,70,75,5,15,10,10,20,0,3,40,10,15,50,0,5,
7,20,10,80,70,20,0,0,60,60,25,0,15,45,10,50,90,7,50,40,80,15,100,100,2,10.

APPENDIX E

Sales Destination Calculation

SALES DESTINATION CALCULATION

For the purposes of Figure 6, a company's total sales were broken down into the following seven mutually exclusive categories:

A = military foreign sales to developing nations
B = military foreign sales to developed nations
C = civilian foreign sales to developing nations
D = civilian foreign sales to developed nations
E = military domestic sales
F = civilian domestic sales within 100 miles
G = civilian domestic sales beyond 100 miles.

Although each of these quantities was not asked for explicitly in the survey (besides making it longer, some of these questions would likely have reduced the response rate), it is possible to reconstruct all of these values from the survey data (so long as it was filled out fairly completely). In the algebraic expressions that follow, the numbers 1 through 7 refer to the values given for the corresponding questions in section IV of the questionnaire. As determined by these calculations, A through G are percentages of the company's total sales volume.

C = ((1 * 2) + (100 - 1) * 6) * 4 * 5
A = ((1 * 2) + (100 - 1) * 6) * 4 * (100 - 5)
B = (100 - 1) * 6 - A
D = (1 * 2) - C
E = (100 - 1) * (100 - 6)
F = (100 - 2) * 1 * 7
G = (100 - 2) * 1 * (100 - 7)

APPENDIX F

Some Unsuccessful Avenues of Research

SOME UNSUCCESSFUL AVENUES OF RESEARCH

Two unsuccessful research directions should be mentioned here. Both were intended to yield further information about the marine high technology industry, and both failed to do so.

The first direction involved financial investment firms. Regional and national offices of Kidder Peabody, Merrill Lynch, E.F. Hutton, and Frost and Sullivan were contacted about the availability of in-house reports on any sectors of the marine technology industry that might relate to the proposed marine high technology industry. In all cases except Kidder Peabody, the response was that no such reports were in existence or even being planned, and the implication seemed to be that even if they did exist, it was unlikely that they would be made available for this work. Kidder Peabody had done some work on the offshore supply industry, and provided some samples of their reports, but this sector of the marine industry can by no means be considered to be high technology.

The second unsuccessful avenue involved patents. The argument was that a properly circumscribed patent search of national and international patent data bases could provide useful information on the nature and extent of invention (and perhaps innovation) in the marine high technology industry. Much like the SIC codes, however, the patent classification system proved far too clumsy to allow an appropriately focused search without numerous timeconsuming and expensive iterations. It might have been possible to search the data base for selected company names, but this would not have resulted in the kind of inclusive search that would provide a

good check on the scope of the survey. A second alternative along this line was a service offered in the past by the Office of Technology Assessment and Forecast in the U.S. Patent and Trademark Office, Department of Commerce. For a fee, this office would produce a patent activity report for any specified industry sector. Unfortunately, no such reports had been prepared in any marine technology field before the office was "zeroed" in a recent round of budget cuts.

(BLANK)

BIBLIOGRAPHY

BIBLIOGRAPHY

Frank R.Carmichael. Offshore Drilling Technology. NoyesData Corporation, New Jersey, 1975.

Zvi Griliches, ed. R&D, Patents, and Productivity. The University of Chicago Press, Chicago, 1984.

Felicity Henwood. Science, Technology, and Innovation, A Research Bibliography. St. Martin's Press, New York, 1984.

Porter Hoagland III. Patent Activity in the Seabed Mining Industry. Woods Hole Oceanographic Institution Technical Report WHOI- 85-20, May 1985.

Marine Technology Society and IEEE. Oceans '84 Conference Record. 1984.

National Research Council. Marine Technical Assistance to Developing Countries: The U.S. Role. National Academy Press, Washington, 1982.

Richard R. Nelson and Richard N. Langlois. "Industrial Innovation Policy: Lessons from American History." Science 219:814-818, February 1983.

Office of Technology Assessment. An Assessment of Maritime Trade and Technology. Washington, October 1983.

OTA. Oil and Gas Technologies for the Arctic and Deepwater. Washington, May 1985.

OTA. Review of Ocean Thermal Energy Systems. Washington, January 1984.

OTA. Technology and Oceanography -- An Assessment of Federal Technologies for Oceanographic Research and Monitoring. Washington, June 1981.

Pontecorvo et al. "The Contribution of the Ocean Sector to the U.S. Economy." Science 208:1001-1006, May 1980.

Roland W. Schmitt. "Building R&D Policy from Strength." Science 220:1013-1016, June 1983.

U.S. Department of Justice. Competition in the Coal Industry. May 1978.

---."Abstracts on International Developments in Marine Technology." IEEE Journal of Oceanic Engineering, Vol. OE-10, No. 2. April 1985.

---. French Offshore Yearbook 1983. Editions Olivier Lesourd. Paris, 1983.

---. High Technology Magazine, October 1984. Boston.

---. "In Massachusetts, State Sows Seeds of New Tech Centers..." Boston Globe July 16, 1985.

---. Jane's Ocean Technology, 1979-80.

---. Sea Technology Magazine, various issues 1985. Compass Publications, Virginia.

---. Sea Technology Buyers Guide/Directory, 1982/83 and 1984/85. Compass Publications, Virginia.

---. Various Company Literature.

DOCUMENT LIBRARY

August 21, 1987

Distribution List for Technical Report Exchange

Attn: Stella Sanchez-Wade
Documents Section
Scripps Institution of Oceanography
Library, Mail Code C-075C
La Jolla, CA 92093

Hancock Library of Biology &
Oceanography
Alan Hancock Laboratory
University of Southern California
University Park
Los Angeles, CA 90089-0371

Gifts & Exchanges
Library
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, NS, B2Y 4A2, CANADA

Office of the International
Ice Patrol
c/o Coast Guard R & D Center
Avery Point
Groton, CT 06340

Library
Physical Oceanographic Laboratory
Nova University
8000 N. Ocean Drive
Dania, FL 33304

NOAA/EDIS Miami Library Center
4301 Rickenbacker Causeway
Miami, FL 33149

Library
Skidaway Institute of Oceanography
P.O. Box 13687
Savannah, GA 31416

Institute of Geophysics
University of Hawaii
Library Room 252
2525 Correa Road
Honolulu, HI 96822

Library
Chesapeake Bay Institute
4800 Atwell Road
Shady Side, MD 20876

MIT Libraries
Serial Journal Room 14E-210
Cambridge, MA 02139

Director, Ralph M. Parsons Laboratory
Room 48-311
MIT
Cambridge, MA 02139

Marine Resources Information Center
Building E38-320
MIT
Cambridge, MA 02139

Library
Lamont-Doherty Geological
Observatory
Colombia University
Palisades, NY 10964

Library
Serials Department
Oregon State University
Corvallis, OR 97331

Pell Marine Science Library
University of Rhode Island
Narragansett Bay Campus
Narragansett, RI 02882

Working Collection
Texas A&M University
Dept. of Oceanography
College Station, TX 77843

Library
Virginia Institute of Marine Science
Gloucester Point, VA 23062

Fisheries-Oceanography Library
151 Oceanography Teaching Bldg.
University of Washington
Seattle, WA 98195

Library
R.S.M.A.S.
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149

Maury Oceanographic Library
Naval Oceanographic Office
Bay St. Louis
NSTL, MS 39522-5001

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. WHOI-88-6	2.	3. Recipient's Accession No.

4. Title and Subtitle

A Broad-Scale Profile of the Marine Advanced Technology Industry

5. Report Date March1988

6.

7. Author(s)

Hauke Kite-Powell

8. Performing Organization Rept. No. WHOI-88-6

9. Performing Organization Name and Address

The Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.

(C)

(G)

12. Sponsoring Organization Name and Address

The Massachusetts Centers of Excellence Corporation

13. Type of Report & Period Covered

Technical Report

14.

15. Supplementary Notes

This report should be cited as: Woods Hole Oceanog. Inst. Tech. Rept., WHOI-88-6.

16. Abstract (Limit: 200 words)

A descriptive definition of marine high technology products and companies is proposed, and results of a mail survey of companies comprising this proposed marine high technology group are reported. A profile of the marine high technology industry emerges from information about company background, assets, sales, research and development activity, growth, and employment, as well as data on industry competition, geographic distribution, and the company social structure of the industry. The data suggest that a fairly distinct subgroup of advanced technology companies does exist within the marine technology industry, and that the companies comprising this subgroup display characteristics typically associated with high technology companies.

17. Document Analysis **a. Descriptors**

1. marine high technology
2. marine technology industry survey
3. marine technology industry profile

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Approved for publication; distribution unlimited.	UNCLASSIFIED	77
	20. Security Class (This Page)	22. Price

(See ANSI-Z39.18) *See Instructions on Reverse*

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce