AD-A110 445 WILLIAMS (CHARLES W) INC ALEXANDRIA VA F/G 5/1
TECHNOLOGY SCENARIO FOR THE YEAR 2005. VOLUME I. BASIC REPORT.(U)
OCT 81 K W SIMMONS, W J BURTON, A R OLSON DTCG23-80-C-20030
UNCLASSIFIED USCG-D-70-81-VOL-1 NL

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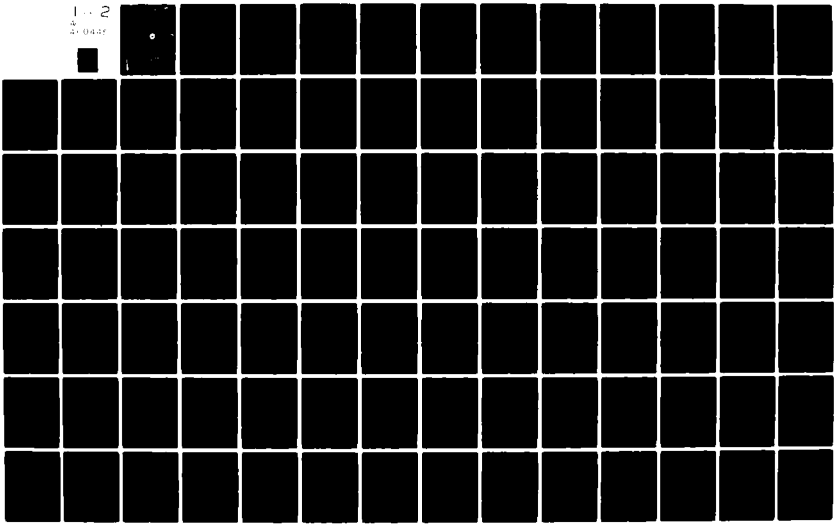

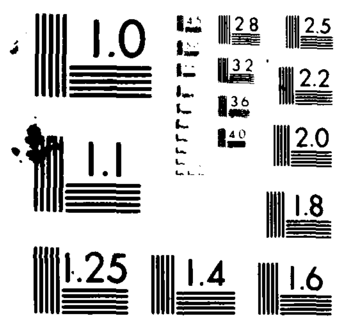

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NATIONAL BUREAU OF STANDARDS-1963-A

Report No. CG-D-70-81

TECHNOLOGY SCENARIO FOR THE YEAR 2005

VOLUME I:

BASIC REPORT

by

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FINAL REPORT

October, 1981

Document is available to the public through the
National Technical Information Service,
Springfield, Virginia 22151

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
United States Coast Guard
Office of Research and Development
Washington, D.C. 20590

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CG-D-[illegible]	AD-A110 445	

4. Title and Subtitle SCIENCE AND TECHNOLOGY SCENARIOS FOR THE YEAR 2005
VOLUME I: Basic Report

5. Report Date October, 1981

6. Performing Organization Code

7. Author(s) Simmons, K. W.; Burton, W.J.; Olson, A.R.; Williams, C.W., Jr.

8. Performing Organization Report No. PO 56

9. Performing Organization Name and Address
CHARLES W. WILLIAMS, INC.
801 North Pitt Street
Alexandria, Virginia 22314

10. Work Unit No. (TRAIS)

11. Contract or Grant No. DTCG23-80-C-20030

12. Sponsoring Agency Name and Address
COMMANDANT
U.S. COAST GUARD
Washington, D.C. 20593

13. Type of Report and Period Covered
Final Report
September 17, 1980 to
October 15, 1981

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract: This two-volume study forecasts advances in science and technology and their implications to the Coast Guard to the year 2005. Implications include increasing demands for Coast Guard services, and expanding opportunities for the Coast Guard. Volume I describes the forces acting to promote or inhibit growth of science and technology; identifies potential areas in which the Coast Guard could make use of these advances; and describes a set of four "scenarios" for the year 2005 depicting the potential operational uses of these advances. The central themes of these four scenarios are respectively: command and control, environmental protection, the effects of the impending water shortage in the U.S., and use of an advanced marine vehicle by the Coast Guard. Volume II presents detailed scenes in amplication of the scenarios of Volume I and includes an appendix with a list of references and bibliography. Conclusions:

- By the year 2005 offshore economic activities will have increased significantly with a concomitant increase in demand for Coast Guard services, particularly service as a law enforcement agency; frequently there will be a requirement for Coast Guard services well beyond 200 miles from the coast.
- The increase in demand for Coast Guard service can be met only with a quantum increase in Coast Guard capability--an increase which will be difficult to achieve in any foreseeable budget climate.
- U.S. national interest demands that Coast Guard capabilities be devoted to operational rather than regulatory functions, and that the center of gravity of Coast Guard operations be moved seaward, leaving state and local authorities responsible for the closer inshore activities.
- The Coast Guard can increase its operational effectiveness in the face of these new demands through exploitation of new technologies in command and control, environmental protection, and advanced marine vehicles.

17. Key Words
forecast
science
marine environment
Coast Guard

18. Distribution Statement
DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclass.	Unclass.	(Vol I) 191	$52,384.00

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

410926

PREFACE

This report responds to Coast Guard contract No. DTCG23-80-C-20030 "To develop a series of scenarios representing the technologies for the year 2005 in order that the Coast Guard can evaluate the potential utility and effectiveness of different technologies in a future environment". This study is one of several Coast Guard studies addressing the 25-year future.

The context of the study is the "crunch" in which the Coast Guard is caught between inadequate resources and expanding demand for services.

The scope of the study includes the effects of any technological developments likely to emerge within the latter part of the 20th and early 21st centuries.

Chapters 1 and 2 of Volume I are introductory. Chapter 1 is an introduction and summary; Chapter 2 describes the methodology.

Chapters 3 and 4 of Volume I present an overview forecast of influences operating upon the two domains of principal interest--the Coast Guard on the one hand, science and technology on the other.

Chapters 5 through 9 of Volume I and all four chapters of Volume II present material on the four scenarios: Command and Control, Environmental Protection, Water Shortage, and Advanced Ma[illegible]hicle. As one moves through these chapters the depth of detail increases. Chapter 5 is the most general. Volume II is the most detailed; it provides operational "scenes" for each of the scenarios. Volume II also contains the Appendix, "List of References/Bibliography".

Chapters 10 and 11 of Volume I present the outcome of the study. Chapter 10 presents implications to the Coast Guard, and Chapter 11 sets forth conclusions.

TABLE OF CONTENTS: VOLUME I

Chapter

TABLE OF CONTENTS: VOLUME II

TABLE OF CONTENTS: VOLUME II (cont'd)

CHAPTER 1: INTRODUCTION AND SUMMARY

As resources of the land are depleted, and as the resources of the seas become more visible, U.S. economic activity is moving seaward. Increasing demand for Coast Guard services are keeping pace with that movement. This increasing demand comes at a time when ecological concerns are at an all-time high, when the Coast Guard and other government agencies are being particularly pressed by budgetary constraints, and when science and technology appear to be offering new opportunities. Exploitation of technological opportunities may close the gap between requirements for Coast Guard service and Coast Guard capability, but the inability to exploit these opportunities may widen it.

The purpose of this study is to present a panoramic view of the state of science and technology through the year 2005, and to evaluate its potential to serve Coast Guard needs. A somewhat more specific purpose of the study is to develop "scenarios" through which particular aspects of this panoramic view of science and technology may be perceived with clarity.

The scenarios were developed against two criteria:

- o Address scientific and technological developments which are likely to occur over the next 25 years.
- o Depict technologies likely to be relevant to the Coast Guard.

STATEMENT OF THE PROBLEM

A brief statement of the problem is:

- o The Coast Guard operates in a rapidly changing environment.
- o The demands placed on the Coast Guard originate in this environment; these demands also are changing rapidly in form and increasing in intensity.
- o Technology is a major source of change in the environment; technology also represents a major opportunity for enhancing Coast Guard capability to meet new demands.
- o Technology thus represents both challenge and opportunity to the Coast Guard.

- o In order to meet the challenge of technological change and to exploit its opportunities, the Coast Guard requires a view of technological evolution in the long term future; to be most useful this view should be a spectrum of possibilities rather than a simple forecast.

CONTEXT OF THE PROBLEM

For most of its life the Coast Guard has pursued an operational policy to accept the challenge of new assignments without expanded resources to meet the new assignments. This "can-do" spirit pervades the professional corps of the Coast Guard and is admired greatly by the Coast Guard's constituency--especially in Congress. This conservatism has been in contrast to many other federal agencies, where an adversary relationship has persisted between less conservative agencies and resource allocation agents--the Congress and OMB in particular. Resource allocators have developed built-in mechanisms to constrain expansion through resource acquisition. Unfortunately such mechanisms do not discriminate well between bona fide requirements for increased resources on the one hand, and bureaucratic aggression on the other. In periods of expanding budgets the intensity of interagency competition for resources is muted; although the more aggressive agencies win more than others, everyone wins something. But in periods of budget cutbacks the competition for funding moves toward a zero-sum game in which the less aggressive lose at least as much as the more aggressive win.

A pattern of budgetary restraint is likely to extend into the future. It will place the Coast Guard in a position of double jeopardy. All agencies will exaggerate needs. Hence any legitimate need for increase will be masked, and only exaggerated demands will stand much chance. Concurrently Coast Guard policy inhibits strident, even though cogent, demands for increased resources.

In the face of this double jeopardy, Coast Guard capability to meet future demands will depend heavily upon its ability first to perceive and then to exploit technological opportunities. This study relates to the first of these abilities, perception.

SUMMARY OF METHODOLOGY

In the conceptual scheme for pursuit of this study the Coast Guard is perceived as a "Domain of Principal Interest" (DPI) embedded in a universe from which certain driving forces and barriers interact with the DPI. The universe in which the DPI operates is conceived as a set of three concentric spheres. The DPI is at the center, subject to the impact of forces originating in the spheres around it. The three concentric spheres enclosing the DPI are: a "Macro" environment--the totality of the external world containing the forces that set dynamic patterns in all institutions; a "Governmental" environment--the administrative/legislative/judicial environment in which the Coast Guard is embedded; and a "Science and Technology" environment--which will ultimately determine the technological opportunities open to the Coast Guard. In the study terminology each sphere is described as a "Framework"--a conceptual device for analysis of the interaction of forces within, between, and among the three environments.

Related to these frameworks are two detailed "Models"--a "Relevant Technology Model" and a "Coast Guard Model". In the lexicon of the study, "models" are analytic devices through which to depict and describe, in more detail than the frameworks, the DPI and its immediate technological environment. The Relevant Technology Model is a component of the Science and Technology Framework, but in considerably more detail than the rest of that framework. The Coast Guard Model is a structured description of the Coast Guard, its operations and missions. The heart of the study methodology was to develop the structure of these frameworks and models, acquire the data/information with which to load them, and then analyze the dynamic interactions among these frameworks and models.

The steps of the process are presented here in an oversimplified summary. The first step was to develop the structure of frameworks and models. Using these frameworks and models as the fundamental conceptual structure, data/information was then loaded into them. Data and information sources were:

- o Coast Guard interviews
- o Interviews in other government agencies
- o The Charles W. Williams, Inc. "Corporate Memory"--a compilation of data and information from previously completed and related studies
- o Public, governmental, and university libraries
- o Technical periodicals and books

From the data-enriched frameworks emerged trends in the macro environment, government, and science & technology. These trends formed the basis for the identification of a set of candidate scenario themes, and then later for the development of scenarios around four of these themes. Themes were chosen as illustrative of technological advances, or of basic non-technological trends most relevant to the Coast Guard. A series of technological forecasts was then developed centered around each of these themes. From these forecasts, or "scenarios", highly specific and imaginary "scenes" were developed to portray, in as graphic a manner as possible, the kind of events in which the Coast Guard could become involved, should the forecasts materialize.

SUMMARY OF CONCLUSIONS

The results emerging from the analysis of the frameworks and models fell into three groups: developments external to the Coast Guard which impact on the Coast Guard's work load--usually increasing it; opportunities offered by science and technology which promise to enhance Coast Guard mission efficiency or effectiveness; and implications to the Coast Guard from these developments and opportunities.

External Developments

Resource depletion on land coupled with resource availability in the oceans, especially energy resources, are leading toward offshore buildup of economic activities. These activities are occuring with increased density and over larger geographic regions. Symptomatic of this expanding activity offshore is the Fisheries Conservation Zone established in March of 1977. With this one act alone, the Coast Guard's geographic area of responsibility increased by several fold. As economic activity continues to move offshore, Coast Guard responsibility will continue to increase, both from increased area of coverage and from increased density of operations within the area.

Climatic changes coupled with increased industrial uses are expected to create a severe water shortage in the U.S. by the end of the century. Such a shortage could further increase offshore traffic. This could occur as an indirect effect, through seaward movement of industry to reduce the effects of the shortage.

A major factor likely to delay build-up of economic activity in the marine environment is absence of effective governance structure and process. The North-South, rich-poor gap is leading to an expanding demand for ocean resources among the less developed nations and to international conflict over "rights" to these resources. Exploitation of these resources is being delayed momentarily because of lack of effective governing structure or process through which to resolve conflict, and to administer agreed-upon operating rules. Only a fragmented system of governance exists in the offshore regions. Neither national nor international governing processes are in effect, and the prospects for change in the short term are low. This is the major factor inhibiting rapid growth of economic activity in the offshore regions. The stalemate is likely to be resolved within the next decade. Once it is resolved, developed nations with access to the oceans' resources, including the U.S., will move quickly to exploit them.

When the logjam of ineffective governance is broken, economic activities offshore will accelerate markedly. This increase will bring with it a major increase in demand on the Coast Guard, particularly for environmental protection and law enforcement. The longer term increases in law enforcement demands will derive from increases in smuggling of drugs and illegal aliens. Next most pressing demands for services will be for search and rescue, ice operations, and military operations. The latter includes countering antisocial action, which may be difficult to distinguish from bona fide military action.

By the end of the century, the management of the vast offshore regions, even with the increased density of activities, will be sufficiently similar to suggest a single managing agency in the federal government. The task will also be sufficiently identified to be easily separated from that of managing the inshore regions--i.e. the coastal waters, ports, inland waterway traffic and equipage, bridges, etc. At issue will be the identity of the agency or combination of agencies to assume responsibility for this offshore management.

Competition between agencies of the federal government will be a factor in determining the outcome of this issue. By virtue of its unique operational capability, the Coast Guard is the best equipped agency to perform this task and fulfill this responsibility.

Coast Guard Opportunities

Information technology will advance through developments in computer science so that automatic information processing will be available at low cost to all operating units. Information flow will substitute for people flow. To some extent information flow will also substitute for equipment and instrumentation flow--e.g. surveillance equipment and instrumentation.

Artificial intelligence emerges from advances in computer science. As a component of information science, it will be particularly useful in management of operations, such as vehicular or communications traffic. It will augment or even replace the human component of teams with operational responsibilities, and will assist decision makers on these teams. It will provide problem-solving in real-time for a variety of optimization problems relating to traffic management and resource allocation problems.

Applications of these advances will be feasible for the Coast Guard in Command and Control systems, including intelligence and surveillance components of these systems.

Toward the end of the 1980s, developments in artificial intelligence will promote the maturing of robotics as a new technology. Robotics promises to answer a century-old problem for men at sea--personnel transfer between craft in adverse weather, or where crews of boarding craft face physical violence from craft under investigation. By the year 2005 robotics will be well advanced.

The technology of environmental protection will shift from clean-up toward prevention; techniques of both prevention and clean-up will shift away from present "scoop-it-up-and-dispose-of-it" techniques toward chemical treatment, administered on a large scale from centralized environmental protection "command posts".

After its auspicious start in the International Geophysical Year, "Big Science" will continue to be applied to the oceans. This activity will continue to promote development of total systems concepts of the ocean environment, and will promote significant increases in understanding ocean phenomena. One of the forecast results will be a revised and more optimistic estimate of the resuscitative powers of the oceans. Another will be understanding of the effect of world climate changes on the ocean environment. The concept of "environmental control" will undergo changes in the direction of improved control and fine tuning of environmental conditions.

A number of vehicular technologies are already in use and available to the Coast Guard. Application would render Coast Guard operations significantly more mission-effective. These include technologies of the air cushion vehicle, hydrofoil, ram-wing, lighter-than-air, and SWATH. Application of these newer vehicle technologies would reduce Coast Guard requirements for lengthy searches and patrols by ships and aircraft. Used in conjunction with advanced command and control systems, these new vehicle types could detect a target with confidence, move directly to it at high speed, interact with it, and return to base.

Advances in materials science will offer opportunities for greatly improved hull structures, propulsion, material bonding, sealing and preservation.

Construction of offshore oil rigs and other structures before the end of the century, especially in the Gulf of Mexico and off the East Coast, will offer the Coast Guard basing opportunities for advanced marine vehicles which may further reduce the time between start and intercept in a law enforcement, rescue, or military mission.

Implications to Coast Guard

An expanded area of Coast Guard responsibility, increased density of operations, and budgetary constraints together make the next 25 years a critical juncture in Coast Guard history. Without improbable budgetary increases--large enough to support a dramatic expansion of Coast Guard in size--the Coast Guard is unlikely to retain the capability to accomplish all of its expanding missions. If shortfalls in mission accomplishment are unavoidable, it would be in the best interest of the U.S. if these did not occur in the areas in which the Coast Guard's unique operational capability can be exercised; rather, these shortfalls should occur in those areas which could be filled by other government or private entities--regulatory action, for example. Two major avenues of change are open to the Coast Guard, both of which may be gradual, and neither of which will be easy or inexpensive. The first is the application of advances in two technology areas:

- Information technology to develop a sophisticated command and control system, including intelligence and surveillance components; and

- o Vehicular technology to acquire new surface craft with high speed capability, without necessarily the long endurance required for lengthy search and patrols.

The other suggested avenue of change is a gradual but strong shift of emphasis in the Coast Guard's role, toward operational missions offshore, away from inshore or near-shore missions, and particularly away from non-operational missions. In order to give sufficient priority to offshore functions, the Coast Guard may find it necessary to deemphasize and defer selected functions to other federal, state or local authorities, or to private industry. This will apply especially to regulatory functions, but may also include all aspects of Port Safety and Security, Commercial Vessel Safety, and Bridge Administration.

Installation of a sophisticated Coast Guard intelligence net (including surveillance) and Command and Control system, would be a major step toward developing a Coast Guard capability to match requirements. It would permit the Coast Guard to shift from search and patrol functions with high endurance but low speed conventional craft, to a wait-and-act operation with high speed craft retained at base until a target for action has been detected, located, and identified, and the operational commander has decided on action.

Acquistion of advanced vehicles with high speed capability will complement the acquisition of advanced intelligence, surveillance, and command and control systems in providing the Coast Guard with capability to operate effectively in law enforcement, rescue, and military roles in extended offshore regions, and in ice bound waters.

Further, the Coast Guard will be able to perform a leading role as a manager of the marine environment through its adoption of new environmental protection methods, using the latest chemical and biogenetic advances.

Coast Guard and Navy capabilities are diverging. This means that by virtue of their different weapon capabilities, Coast Guard and Navy roles will be different, one from the other, in any military action. Coast Guard and Navy will complement each other, but will not substitute for each other. The Navy's capability will be to counter sophisticated weapons of USSR, the Coast Guard's to counter less sophisticated weapons of law violators, antisocial, or terrorist groups.

Another important conclusion is that shift of costs from the Coast Guard to beneficiaries through imposition of user charges will be required if the Coast Guard capability is to be maintained at peak performance.

MAJOR STUDY CONCLUSION

The major conclusion of this study is that by the year 2005 the technologies of information science and marine vehicles will offer opportunities for the Coast Guard to increase its operational mission effectiveness, especially in the more distant offshore regions. Effective application of these two technologies would be consistent with an institutional change in the best interest of the U.S. Such a change would take advantage of the Coast Guard's unique operational capability, and would involve programmatic alterations in which:

- The Enforcement of Laws and Treaties mission is greatly expanded.
- Environmental Protection, Rescue, Military Readiness and Ice Operations missions are also expanded.
- Other missions, particularly regulatory missions, are deemphasized or even eliminated.

Intuitively, implementation of these changes would have far reaching consequences on the institutional structure of the Coast Guard. However, analysis of this type of change is beyond the scope of this study.

CHAPTER 2: METHODOLOGY

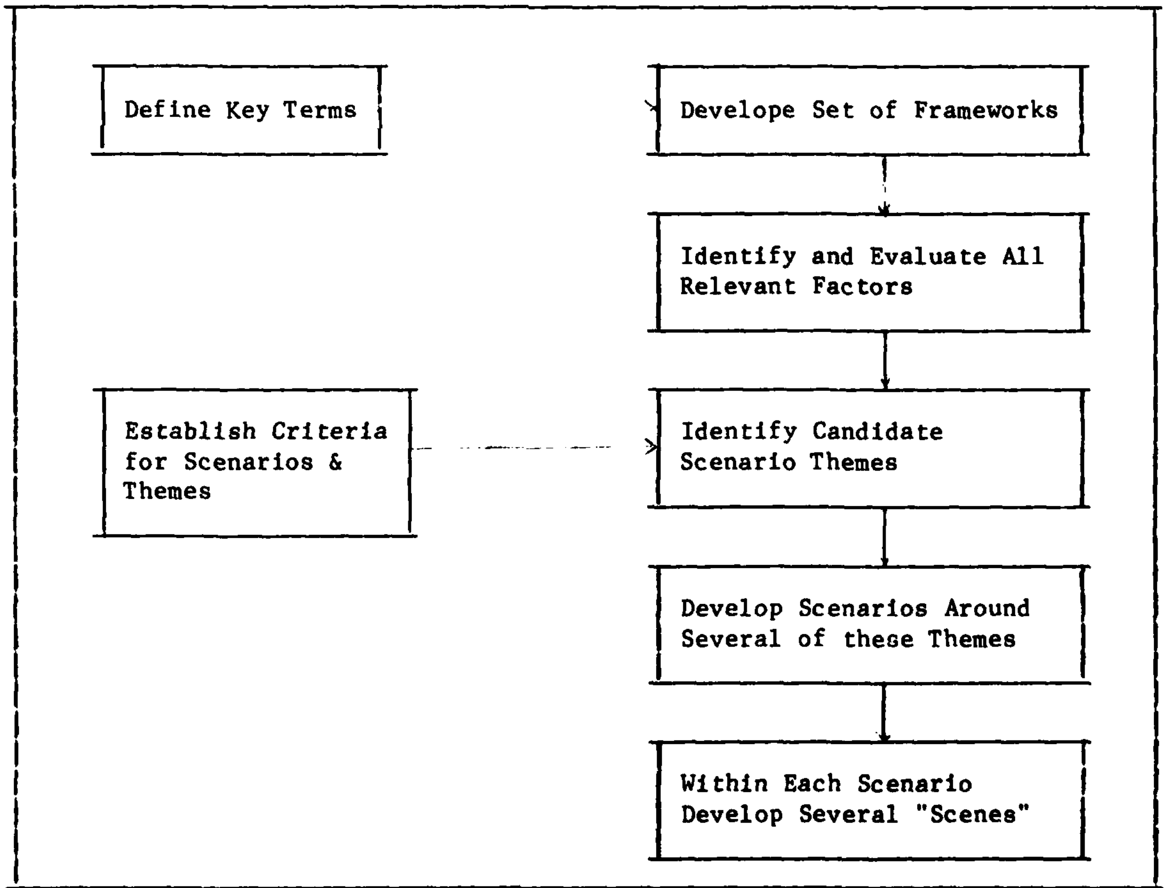
In order that the approach may be tracked from data to conclusion, this chapter describes the study's methodology.

The overall approach is summarized in Figure 2-1. The concept depicted by this figure is summarized in the following steps:

- Define key terms. Futures literature is not so mature that ambiguity in terminology has vanished; different students of the future use divergent terms to mean the same thing and the same terms to mean different things. For example, the basic term "scenario" has a wide variety of meanings in the futures studies community. We considered it prudent to define our terms for mutual understanding.

- Develop a set of "frameworks". These are logical constructs within which to collect and synthesize the relevant information. The five

Figure 2-1: GENERAL LOGIC FLOW



structures were developed in such a way as to depict the most relevant aspects of the world external to the domain of principal interest--the Coast Guard and its future use of technology.

- Macro Framework: the universe at large
- Government Framework: a structure of government functions
- Science & Technology Framework: the basic structure of today's science and technology
- Relevant Technology Model: those aspects of the basic structure of science and technology that appear likely to relate most directly to the Coast Guard through the end of the century and beyond.
- Coast Guard Model: the basic functions performed by the Coast Guard

o <u>Identify and evaluate all "relevant factors"</u>. These are the environmental driving forces and barriers which could influence future technological developments of relevance to the Coast Guard. These factors include political, economic, military, social, and science/technology components which promote or inhibit technological application for the Coast Guard.

o <u>Identify candidate scenario themes</u>. These are identified as those "factors" most likely to be central thrusts of development relevant to Coast Guard operations through the end of the century and into the next.

o <u>Develop "scenarios" around several of these themes</u>. In coordination with the COTR, four scenario themes were selected for expansion. Each scenario depicts a plausible future, assuming that the central thrusts represented by the factors do in fact materialize.

o <u>Within each "Scenario" develop sets of individual "Scenes"</u>. These scenes represent alternative scenarios, or possible operational events that could take place in the year 2005, should the forecast of factor development come to fruition.

In the following paragraphs each of these steps is amplified in some detail.

DEFINITION OF TERMS

The following definitions form the basis for understanding the methodology and content of this report.

<u>Scenario</u>: Depicts a hypothetical situation which could occur at some future time, given that certain variables are projected in selective ways into that future. The scenario is based on forecasts, but is not itself a forecast; rather, it is a hypothetical but very detailed picture of what could take place given a set of forecasts. Its utility derives from its richness of detail and not its accuracy of prediction.

Its fineness of detail is far too great to permit its interpretion as a prediction, and such interpretation is a misuse; rather, this fineness of detail is a graphic way to demonstrate the full meaning of the forecasts that undergird the scenario. Scenarios serve forecasting as historical novels serve the study of history; each describes a time period in the richest possible context. Thus the scenario is an integrating, synthesizing interpretive device.

Scenario theme: The direction and magnitude of a single central variable that forms the core around which a scenario is constructed. A forecast is appropriately used as a scenario theme. The relationship between scenario and scenario theme may be illustrated by: "If (theme..) occurs, then (scenario..) could occur." The scenario detail is developed from forecasts of variables other than the themes, and the interaction among these other variables and between them and the theme is assessed, but the theme is dominant.

Most Probable Scenario: The scenario whose central theme is judged to be more likely to occur than any other theme. The term "most probable" does not mean that the situation described by the scenario itself is likely to occur in all its detail; it simply means that the theme and the associated variable forecasts are judged to be more likely than any other combination. In some instances even this probability may be low. For example, in a distribution of ten possible events, the probability of the most probable may be well below 50%.

The term "most probable" also does not mean that other themes are improbable. It simply means that the "most probable" theme is somewhat more likely than the others.

Alternative Scenarios: A set of related scenarios whose respective themes are closely related and cover a distribution of possibilities including those of both high and low probability. Each theme may permit the creation of a series of separate scenarios--or, as we have called them, "Scenes"--which depict different aspects of the possible futures deriving from the same basic theme.

Relevant Factor: An exogenous variable, parameter, or constant; any factor external to the scenario theme which has potential to impact on the theme--either in driving it, inhibiting it, or rendering it irrelevant. The theme of one scenario may be a relevant factor in another.

THE CONCEPTUAL FRAMEWORKS

The frameworks are defined in some detail as follows:

- Macro Framework

- Government Framework

- Science & Technology Framework

- Relevant Technology Model

- Coast Guard Model

The basic structures of these frameworks are as shown in figure 2-2 on pages 2-6 and 2-7.

- Macro Framework: The entire universe external to the focus of study effort. It is the combination of scientific, technological, economic, political, and societal developments that set the overall patterns within which all institutions will operate. These patterns become the fundamental source of all driving forces for change.

  The Macro Framework provides the structure on which the forecast of global, regional, and national events is constructed. It identifies those variables in the macro environment that either drive or oppose changes in the Science & Technology universe or in the Coast Guard.

  Current literature contains a plethora of information and speculations on the future. Much of it is valid. But in order to make it useful to any particular future-oriented project the information must be translated through a set of intervening structures, constants, parameters and variables into a form that has meaning to the focus of analysis. The function of the macro environmental framework is to provide that translation. In a sense it acts as a funnel through which to pour information about the world at large and acquire a focus on the problem at hand. The most fundamental driving forces toward and barriers against change relevant to the Coast Guard reside in this framework.

  The results of the work in this step of the study are reflected in Chapter 3 of Volume I.

- Governmental Environmental Framework: The administrative environment in which the Coast Guard is embedded. This framework depicts the roles, purposes, and general organizational relationships of world, international, national and subnational governmental structures. In many senses the Coast Guard is a competitor/adversary in the conflict for resources within this structure. The governmental forces and inhibitors acting to influence both the Coast Guard and the technological environment of the Coast Guard are highly relevant but often difficult to bring into balanced focus. The Government framework brings these elements into sharp focus. It depicts the key elements of goverment that impact on science and technology and on the Coast Guard. This framework provides a description of the various actors and their functions that are most relevant to the focus of study. The Coast Guard functions as an integral unit within this framework.

  The results of this step are contained in Chapter 3 of Volume I.

o <u>Science and Technology Framework</u>: The developments in science and technology which ultimately will determine the technological environment in which the Coast Guard will operate. This framework partitions the domain of science and technology into its various components. It derived from comprehensive integration of the various areas of scientific and technological develment gleaned from the Scientific Thesauras, the NSF listing of scientific specialities, a number of technical information search services and a variety of other scientific and technological forecasts performed by us in previous work.

  The results of this step are summarized in Chapter 4 of Volume I, and are also contained in many portions of the remainder of the report.

o <u>Relevant Technology Model</u>: A focussing and restructuring growing out of the Science and Technology Framework to bring out clearly those aspects of technology that are most relevant to the Coast Guard--either from the point of view of direct use by the Coast Guard or from the point of view of applications in opposition to the Coast Guard. This structure is labeled a "model" in order to emphasize its comprehensive detail. The model is the foundation and cornerstone of the forecasts of the project. It interacts with the macro framework, the governmental framework and the science and technology framework.

  The results of this step are summarized in detail in Chapter 4 in Volume I, are also contained in Volume II, and serve as the foundation for Chapters 6 through 9 of Volume I.

o <u>Coast Guard Model</u>: A delineation of the roles and responsibilities of the Coast Guard from the perspective of operational functions, independent of present and prospective program structure.

RELEVANT FACTORS

After framework and model building, those driving forces and barriers were identified which were considered likely to impact heavily on the Coast Guard either in terms of the agency's own use of science and technology, or in posing challenges to the Coast Guard.

SCENARIO DEVELOPMENT

The flow of influence in determining the characteristics of a scenario is depicted in Figure 2-3.

<u>Factor Grouping</u>

This step identified factors--i.e., the driving forces and barriers--likely

Figure 2-2: FRAMEWORKS AND MODELS

A. FRAMEWORKS

MACRO FRAMEWORK

Human Universe

Political
Economic
Social
Population
Science/technology
- Biology
- Chemical
- Physical
- Engineering
- Architecture

Physical Universe

Land, water, atmospheric resources

- Energy
- Metals/materials
- Agriculture/food
- Climatological/weather
- Geographic/geological

Protection/conservation

GOVERNMENT FRAMEWORK

Legislative

Laws
Regulation (including certification & licensing)

Executive

Enforcement (including investigations, apprehensions, hearings, penalties)
Research (into areas of potential exploitation)
Services (direct to the public or industry)
Operations
Defense
Foreign relations

Judicial Process

SCIENCE & TECHNOLOGY FRAMEWORK

Aeronautics

Agriculture

Astronomy

Astrophysics

Biology

Chemistry

Earth Science

Electronics

Energy Conservation

Engineering

Materials

Methods & Equipment

Military Science

Missile Technology

Nuclear Science

Ocean Science

Physics

Propulsion

Space Technology

(Continued on next page)

Figure 2-2 (cont'd) : FRAMEWORKS AND MODELS

B. MODELS

COAST GUARD MODEL

Navigational Systems Component

Taffic Managment Systems Component

Marine Surveillance

Emergency Assistance and Rescue System

Marine Environment Maintenance and Repair Component

Applied Marine Research/ Logistics

Military Readiness Component

Adminsitrative Law Component

Legal Administrative Component

Marine Law Enforcement

Judicial Component

Transportation/Modal Management System

Marine Management System

Miscellaneous, Special Assignments

RELEVANT TECHNOLOGY MODEL

COAST GUARD OPPORTUNITIES

Ship/hull Design
(Propulsion, hull, airframe)

- Surface
- Subsurface
- Amphibious
- Air

Systems Design

- Communications
- Surveillance
- Detection
- Data processing
- Navigation
- Weapons
- Ecological control
- Forensic analysis
- Automation
- Electronics

Funding

- Direct
- Sharing
  - States
  - Users

OTHER

Contraband Concealment

Energy Exploration, Discovery, Exploitation, Development, Production, Storage, Transmission

Resource Exploration

Deep Sea Operation

Weather Modification

Space

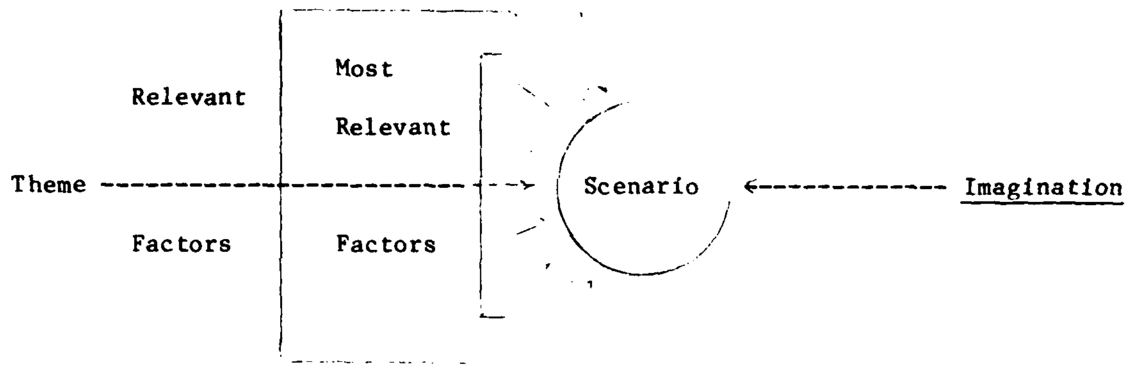
Transportation

Medicine

Neurobiology

Sociobiology

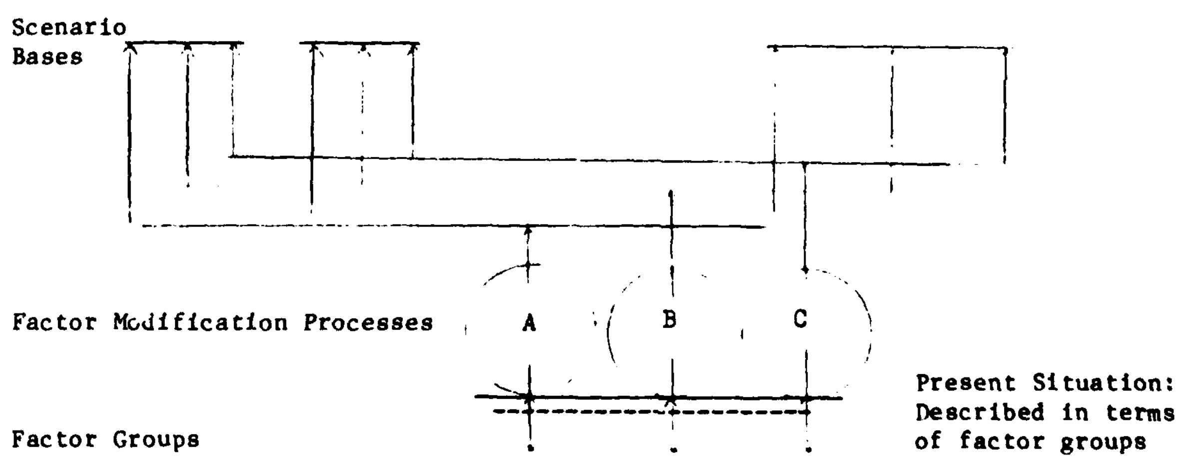
Figure 2-3: DETERMINANTS OF A SCENARIO



in the potential/candidate scenario themes. The operation performed in this stage is depicted in Figure 2-4.

The objective was to develop a set of factor groupings to serve as a basis for describing the emerging scenarios. The end result was the first candidate sets of themes and associated factor groups. Many factors were incorporated into more than one theme, but with different weights and values; each factor grouping depended upon the compatibility among factors in the context of the science and technology forecast. The heart of this task was to get factors and themes in each group to be mutually consistent and plausible. The foundation for this work was the Relevant Technology Model developed earlier.

Figure 2-4: RELATIONSHIP: SCENARIOS/FACTOR GROUPS



Criteria for Development of Scenarios and Scenario Themes

The fundamental criterion against which to design scenarios and their respective themes was whether they "represent the technologies for the year 2005". They need to do that in such a way that both the future utility and the effectiveness of the different technologies may be evaluated by the Coast Guard. Certain additional criteria were found to be useful as guidelines.

Theme Criteria:

- In order to insure a broad menu for selection, the initial compilation contained a large number of candidates.
- Each theme represented a reasonably likely thrust into the future--not necessarily highly likely, but not implausible.
- A preference was to make the theme technological. This was done in three of the four scenarios; the global water shortage was chosen as the theme for the fourth scenario.
- Several high probability themes were selected to be candidates at the outset, and a number of lower probability but high impact themes were also included.

Scenario Criteria:

- Each scenario was internally consistent with respect to its theme and relevant factors.
- Given the theme and associated relevant factors, each scenario was required to be plausible.
- Each scenario was oriented toward Coast Guard-relevant detail. That is, each scenario depicted an operational situation in which the Coast Guard role is clearly evident.
- Each scenario represented a situation in which demand on the Coast Guard and opportunity for the Coast Guard is emphasized.
- A sufficient number of candidate scenarios were developed to represent an across-the-board sampling of operational opportunities confronting the Coast Guard.

Most Probable Scenario Development

This scenario was to be a hypothetical situation in the year 2005 at some geographical point in the marine environment. This situation, although hypothetical, should depict the most salient features of an advanced technology environment in which the Coast Guard is likely to find itself.

The Command and Control Scenario is the most probable scenario. Of the four scenario themes selected, it is judged that the most probable is advance of information technology and its integration into the Coast Guard. The Advanced Marine Vehicle theme is the most probable from the point of view of technology development itself; however, it is judged that its adaptation by the Coast Guard is somewhat less likely than the adaptation of the advances in information technology. The other two themes--Water Shortage, and Environmental Protection--represent probable developments, but not quite as probable as the first two.

DEVELOPMENT OF INDIVIDUAL SCENES

After a series of basic scenarios had been developed, it became evident that the breadth of each was so great as to permit expansion along several different lines. This expansion was accomplished through the use of "Scenes" within each of the Scenarios. Each scene depicted a quite different operational circumstance, but each was based upon the same central theme as its parent scenario, upon the same technological base, and the same relevant factor group. The complex of scenes in a given scenario was designed to provide the Coast Guard with a broad view of the challenges and opportunities likely to emerge from a given set of theme/factor group projections.

FINAL REPORT PREPARATION

The material in Volume I, as one moves successively from Chapter 3 through Chapter 9, is increasingly focussed on the domains of principal interest, science and technology and the Coast Guard. Chapters 6 through 9 of Volume I contain the heart of the technological forecasts in each of the four themes, respectively. The material in Volume II, the "Scenes", provides illustrations of the technological forecasts of Chapters 6 through 9 of Volume I.

CHAPTER 3: FORECAST OF THE MACRO ENVIRONMENT

This chapter presents the "Macro Environmental" forecast. "Macro environmental" means a comprehensive global array of driving forces toward change and barriers inhibiting change in the two domains of primary interest: science and technology on the one hand, and Coast Guard on the other. The chapter includes analysis of both Macro and Governmental Frameworks, extracting from these frameworks the most relevant factors affecting both science/technology and the Coast Guard. Such factors operate at a most fundamental level: they create the context in which Coast Guard problems and opportunities will emerge through the year 2005, and they constitute the major forces operating on the domain of science and technology. The structure of the detailed factor analysis is shown in figure 2-2 on page 2-6.

The chapter is divided into four sections: Political, Economic, Military, and Four Relevant Considerations. The last section reflects a view of the unfolding of four highly influential factors operating in the macro environment. First is the inexorable degradation of the ecology; second is the related imminent global water shortage; third is the emerging transformation in the process of governance, both national and international; and finally a forecast of changes in management problems and practices.

POLITICAL

"Ownership" of ocean resources will become an even more important national and international issue. Individual U.S. states will claim near shore resources for internal use, but will attempt to avoid a corresponding sharing of costs. Those nations having access to the ocean's resources through contiguous shore lines or technological capability, will align first against those with less access, and second against each other. Within the U.S. the role of private enterprise for ocean development will remain ambiguous through the end of the century. This may impede resource exploitation during the next two or three decades, but developmental progress is likely to resume sporadically as the need for resources becomes alternately more and less acute. As issues concerning ocean use and ownership emerge, the federal government will be required to exercise "managerial" control further and further from shore.

The USSR will have firmly established itself as a global maritime power. It will have acquired the world's largest attack submarine, nuclear powered ballistic missiles with 4,000 mi. range, a huge guided missile ship, large-deck nuclear-powered aircraft carriers, and sophisticated intelligence collection capabilities based on electromagnetic intelligence. These advances will dominate some aspects of the power struggle.

The U.S. will direct major effort toward reestablishing itself as a major seapower--strong Navy, Coast Guard, Merchant Marine, fishing and research fleets. This effort will include integration of U.S. maritime functions to eliminate waste and duplication with a strengthened Coast Guard, merchant marine, and fishing fleet adding some military capability. The effort will also result in recovery of U.S. ability to conduct ocean research from the decline of the 60s and 70s.

International cooperation will promote "big" science projects in areas of major concern to many countries. For example, ocean science, particle accelerators, space exploration, fusion research, and coal liquefaction process development will produce multinational cooperative funding.

U.S. national security will depend even more than at present on our ability to meet present and future technological challenges. The USSR, with heavy investment in unproductive hardware, may have an obsolete war machine and a restless population because of massive military expenditure's priority over civilian needs. While the sheer numbers of U.S. forces will not match that of the Warsaw Pact Nations, U.S. technology will be sufficiently advanced to insure security.

There will be a distinction between the states' political and judicial jurisdiction as activities move into the marine environment.

ECONOMIC

By 2005 the population in the Lesser Developed Countries (LDCs) will have increased both in numbers and in proportion of world population, but food and other essentials will not have kept pace. This food crisis will not be an effect of inadequate technology, but will rather be an effect of cultural inhibitions against new types of food, and inadequate distribution systems. In addition, the cost of energy to the LDCs will continue to rise, inhibiting their already weak growth potential. One result will be continued growth in the gap between the Advanced Industrialized Countries (AICs) and the LDCs--to the point of eventually becoming a major source of world instability. The LDC/AIC gap will increase pressure on the U.S. to "share the wealth", including admission of more aliens. Conflict and illegal immigration will result, requiring Coast Guard response. Interdiction of illegal aliens may compete with drug suppression for Coast Guard priority. In addition, transportation of illegal aliens and drugs will shift to larger ships and aircraft.

The U.S. will be increasingly competitive with other high-technology countries. As countries evolve from older technology, trade reflects the changing balance between suppliers of raw materials to suppliers of finished goods. Since WW II the U.S. has switched from a net exporter of manufactured goods to exporting more raw materials. Industries such as textiles and steel have shifted to the LDCs, partly because of wage differentials and partly because of lag in innovative technology in the industrialized countries. With improved technology, by 2005 some manufacturing may return to the mature industrialized economies. The world will be more economically interdependent, with manufacturing migrating to the most efficient location, and with trade increasing.

The gap between economic theory and economic reality will continue in the U.S. and other AICs. The behavior of western economies will continue to baffle the economic theorists with its violation of the "rules" of conventional economics. Continued "tinkering" with the western economies will result in their continued malaise.

With government cooperation, U.S. shipbuilding will undergo a resurgence and maintain a leading position in ship-building technology. The time lag between design and construction of advanced-technology ships will be minimized. Advanced shipbuilding techniques will impact on all phases of the advanced marine vehicle, as well as the design and manufacture of conventional ships and craft. U.S. shipbuilding will be aided by U.S. advances in computer technology. This technology will be applied in a number of ways, including Computer Aided Design (CAD) to improve design, Computer Aided Manufacture (CAM) to aid production, and simulation models which make testing of new designs more efficient.

The full economic value of the ocean's resources will become apparent to the general population of the U.S. as well as to people in other countries; however, no full agreement will be reached with respect to international rights in and beneath the oceans. International conflict over ocean resources will continue. The present U.S. 200 mile economic zone will be established with some degree of credibility in general international legal theory, and will be claimed by other nations as well. In actual practice, the Fisheries Conservation Zone (FCZ) and economic zones will be frequently violated. Conflict over ocean rights will lead to frequent ambiguities with respect to military versus law enforcement action. That is, foreign power aggression will often be masked as antisocial action or law violation from undetermined sources. The Coast Guard and the Navy will become partners in countering antisocial action in the ocean environment, but without clear definition of their respective roles; the issue will continue to be clouded.

MILITARY

A deep level of ambiguity will develop between law enforcement action on the one hand, and defense against antisocial action by a foreign power on the other hand. This ambiguity will lend pressure to close the responsibility gap between law enforcement agents and military agents--i.e. between the Coast Guard and the Navy.

The number of supercarriers in the Navy will decrease, as they become more vulnerable to antiship missiles. As this increased vulnerability is acknowledged by the Navy, large carriers will be restricted to operations distant from the antiship missile threat. Such restriction will emphasize the utility of smaller, faster craft with modern weapons. U.S. offensive striking power will be dispersed among submarines and a large number of surface ships in order to mitigate a Soviet first strike.

As weapons technology advances, the weapons installations in U.S. Navy ships will become increasingly specialized to counter advanced technology weapons of the U.S.S.R., and thereby less suitable for use in the lower level conflict likely to confront the Coast Guard. Thus a gulf is widening between Navy and Coast Guard capabilities to counter hostile action. The gap is not leading to incompatibility, but to a circumstance in which Navy and Coast Guard ships will complement each other, but will not be substitutes for each other, and in which the respective roles for which each is best suited do not overlap.

FOUR SPECIAL CONSIDERATIONS

In the context of the foregoing, four particular aspects of the macro environment warrant special consideration. First are those relating to the ecology, second are those relating to the rapidly approaching world-wide water shortage, third are those relating to certain trends and issues emerging in the process of governance as it may be expected to relate to the Coast Guard, and fourth are those relating to the problems and practices of management. Two of the Themes relate directly to these aspects of the macro environment; hence the intensity of interest.

1. Ecological Considerations

Concern for the environment will weigh increasingly in economic and political decisions in the U.S.

- One effect of this concern will be continued pressure against growth--both growth of profits (i.e. future productive capacity), and growth in production of goods and services, including energy-related goods and services.

- This concern for the environment will be exercised more through governmental action than through private action--thus fostering governmental intrusion into private enterprise; toward the end of the century, as performance-oriented regulatory systems become common, this governmental action will diminish in magnitude.

- The objects of concern will include elements external to as well as within the marine environment.

  - Land: desert encroachment, effects of mining, water supplies, soil depletion and erosion, scenic beauty.

  - Air: climate, air quality, ozone layer, global temperature stability.

  - Sea: water, seabed, living resources and other organic substances, dynamic stability.

- Since different nations have widely different values and standards with respect to the environment, and since the geographic envelope of the effects of many offshore operations are extremely broad, international conflict over environmental protection policies and practices is highly likely; economic extensions into the marine environment by one nation are likely to conform to a totally different set of specifications with respect to environmental protection than are those of an adjacent nation. These types of conflict may be resolved by the UN or regional bodies, but are likely to involve long and tedious processes of negotiation.

- The environmental and conservationist concerns of the '70's led to an operational policy by which decisions are delayed pending impact assessment. If oceanic resource development is to proceed to its limit, that trend must slow. As environmental protection technologies are put in place, significant resource development will be possible with accurate, predictive models of environmental impact, and without an increase in environmental risk.

- Safe but initially expensive ways will be found to dump chemically modified waste products into the marine environment; after time, as economies of scale are reached, these systems will be less expensive than present techniques.

- Interest in environmental protection will support technical advances in surveillance capabilities.

If the forecast of the movement of the U.S. economy seaward is correct, there will be a most significant effect on the environment. Industrial activities in the ocean environment will have enormous effects, both direct and indirect. (See Volume II for detail.) The direct effects will include changes in physical characteristics of the region brought about by the physical developments offshore. The indirect effects, which will include changes in living systems, may take longer to become visible, but may be even more important than the direct effects.

Of the major geographical regions, the coastal zone is the most sensitive to ecological disturbance. The deep ocean and land regions tend to be surprisingly adaptable to changes. Coastal zones, on the other hand, are not. They contain very large, interdependent, and fragile living systems. The impacts of external events on the coastal zones are more likely to be catastrophic than those in either land or open sea environments. This is particularly true with respect to the food chain. As the federal government assumes responsibility for these regions, sea use management policy will be founded on discrete environmental characteristics.

The principal direct effects of economic movement seaward include:

- o Extensive build-up of offshore activities will bring about significant changes in regional geography.
- o Hydrocarbon exploration and production will introduce unprecedented quantities of polluting substances into vulnerable oceanic ecosystems.
- o Traffic patterns will spread and their density will increase.
- o Fishing grounds will often be altered in location and in their fundamental nature; new and different species will be fostered, while other species will find the new environment less supportive than previously and will diminish in population.
- o Construction will cause at least a temporary disruption to natural systems:
  - Some species of fish will be driven away.
  - Some scavengers will be attracted.
  - Some plant life will be temporarily destroyed, while other forms of plant life will be stimulated.

The principal indirect effects of the seaward movement of the U.S. economy will include:

- o The maintenance and hygiene of the marine environment, which will become a major activity in itself.
- o Developments and extensions in marine science and engineering will stimulate the development of new business activities.

2. Water Shortage Considerations

The background of a potential global water shortage includes several key factors of world-wide significance.

- o Population: A 45-65 percent increase in population will lead to a substantial increase in the amount of water consumed for all purposes. That consumption will contribute to already ominous trends.
- o Water Technology: New techniques of water reuse and desalination will be used as fresh water supplies become less plentiful. Irrigation techniques will be improved (drip method) to use less water. Cloud seeding will be practical in some cases. With greater need to save water, provide hydropower, and reduce flooding, there will be more and improved dams and aqueducts. This hydraulic engineering of freshwater systems may alter the salinity and cyclic flows in estuaries, and

interfer with the life cycles of organisms that spend part of their lives in the ocean and part in fresh water. Because nutrients will be trapped behind new dams, the quantity and quality of estuarine and coastal productivity will be adversely affected.

- Energy: Energy use will continue to increase, with demand persisting.

  - Petroleum products: Petroleum production capacity is not increasing as rapidly as demand. The rate at which petroleum reserves are being added per unit of exploratory effort is falling. World petroleum production will peak before the end of the century. Political and economic decisions in the OPEC countries could cause oil production to level off even before technological constraints come into play. A world transition away from petroleum dependence may take place.

  - Coal: Coal will be the biggest gainer in energy use, with increased demand for deepwater ports. Nuclear and hydroelectricity production will continue to increase, as will natural gas usage. There will be more offshore drilling for oil to sustain the projected 3.3 to 4.4 percent annual increase in the demand for oil. The oil increase, and a projected doubling or tripling of world demand for coal, with the U.S. a major supplier, will produce more marine transport of oil and coal, with consequent shortages of port and processing facilities. More petroleum pollutants will enter the oceans. Proliferation of onshore and offshore power plants will result in extensive use of oxidants and other biocides (especially chlorine) to prevent biological fouling in cooling towers, entrainment, and thermal pollution, altering the habitat of marine organisms. The increased use of nuclear energy may lead to accidental release or to deliberate disposal of radioactive materials into the oceans. U.S. coal production will be required to meet a major part of world energy needs, even after allowance for a vigorous conservation program, development of solar and other renewable sources, continued nuclear growth, and the expected availability of oil and gas. The U.S.'s useable coal supply is expected to be 28 percent of the world's total in 2005. The combination of environmental assaults on clean water caused by the large increase of coal production and use within the U.S. will include pollution of ground water from surface mine runoff, acid rain, and CO_2 in the atmosphere.

- OTEC: With increased energy needs, Ocean Thermal Energy Conversion will be in early growth stages by 2005. It may have significant impact on the quality of water in the ocean. The OTEC technology utilizes the temperature difference between the warm surface water and the cold deep water to generate electricity. OTEC plants are likely to be anchored in deep waters close to subtropical and tropical islands. Each plant may take in and discharge as much water as the flow of a large river. OTEC environmental effects could include killing of plankton and larvae of coastal and oceanic fishes by drawing them through heat exhangers, by chemicals used for antifouling treatments, or thermal shock. OTEC will add to the number of structures offshore and generate electricity and fresh water for Coast Guard and Navy ships.

- Nonfuel minerals: More mining wastes will be produced and more mineral products will be in circulation, due in part to increased production of various minerals from lower grade ores. As a result, more of these wastes will enter the earth's air and freshwater systems and, eventually, the oceans. Of particular concern are toxic wastes resulting from increased production of several heavy metals. Chromium production is projected to increase annually by 3.3 percent, copper by 2.9 percent, lead by 3.1 percent, mercury by 0.5 percent, and zinc by 3.1 percent. Increased industrial dredging for gravel and coral sands will also have significant local impacts. If initiated, deep-sea mining operations will produce locally disruptive effects on open-ocean ecosystems.

- Weather Modification: Weather prediction and weather modification technology will be developed to provide more accurate forecasting, and a small degree of control over extreme weather conditions--e.g. control over the development and tracks of violent storms. World-wide weather monitoring and prediction capabilities will improve. These will include installation of systems of data collection buoys to be coordinated with satellite operations for oceanographic and meteorological observation and monitoring.

- Desertification: Encroachment of desert regions into formerly arable regions will become at least theoretically tractable.

3. Governance Considerations: Changes in the Governance Processes

This section discusses some of the key issues which are perceived as likely to impact on the Coast Guard and its use of advances in science and technology from now through the end of the century. The salient ways in which the process of governance is likely to impact changes in the marine evironment is presented.

International Aspects

The evolution of the international law of the sea will determine the umbrella of governance under which economic activities in the marine environment will operate. The size of that umbrella will, in turn, determine the environmental problems and policies to be addressed. The issue will not constrain the U.S. in close-in waters, but as activities move seaward governance will become more important. The basic question is which of two concepts will dominate UNCLOS III: The "common heritage of mankind" or "free enterprise". At one extreme, forces are in motion to insure countries with no access to ocean resources a "fair share" of those resources, independent of their capability to extract them; at the other extreme are the forces that seek to guarantee private enterprise protection of their property rights--a protection analogous to that of property rights within the U.S.

The probability of the different outcomes along this spectrum varies from one UNCLOS III session to the next, and even from time to time during each session. At the moment, there appears to be an impasse. One proposal favors protection for developed countries' entrepreneurial investments in offshore development; another guarantees a percentage of profits to a common sea authority. A possible development in the present negotiations is prolonged and fruitless debate until U.S. urgency to proceed leads to a unilaterial decision providing development through a government or quasi-government corporation, or by offering safeguards to private industry in the form of guaranteed protection of assets and profits.

It is forecast that the U.S. will decide upon an aggressive policy. Once that decision is clearly made, the lack of UN decision will neither delay nor inhibit U.S. investment. Further, since significant increases in the offshore industrial complex are likely to emerge nearer shore, it is forecast that any impediment created by UN delay will have its major effect only late in the time period of this study. U.S. official concern for resource shortages will result in development, regardless of the governance issue, for ocean areas where U.S. de facto or de jure jurisdiction has been reasonably established. Such jurisdiction currently extends over the OCS and to some extent out to 200 miles. Legislative and executive action continues to gradually expand de facto jurisdiction.

Beyond the OCS and 200 miles, however, the absence of institutionalized governance is likely to inhibit U.S. exploration and exploitation of resources--primarily impacting deep sea mining. Further, toward the end of the time period of this study, the potentiality for new forms of energy extraction/exploitation will reveal opportunities farther out to sea than are now in the planning stage. Such development is likely to raise additional jurisdictional issues.

The foregoing description focusses on several key questions regarding the management of the marine environment in the long term future:

- How to manage a "Commons"--possibly an intractable problem. There may be no way to "manage" the oceans as long as there exists no autoritative governing body. See figure 3-1 for "The Commons" rationale.

Figure 3-1

THE TRAGEDY OF THE COMMONS

The "Commons"--the village grazing ground--are full. One farmer puts one additional cow in to graze. The result is more benefit for him, less for each cow in the pasture--and therefore less for each other farmer with cows grazing.

The farmer will add cows until the incremental gain to him equals the incremental cost. In other words, the farmer will add one cow until the gain from that cow equals the loss from all the cows he owns grazing in the commons.

If he owns only a few, as a percent of the total, he will reach an equilibrium point later than if he owns many; thus the smallness of his minority gives him added power. If the added cow was his first cow, he may go on adding cows until he destroys the commons; that is, a newcomer may enter and destroy the commons with least loss to himself.

Trap: To each farmer it appears that he will gain by adding a cow while the others share the loss. But if each villager adds a cow, everyone is worse off.

Trap Springs Shut: No one can gain by removing a cow! Therefore no one will remove one unless he is sure that everyone else will also.

Conclusion:

Freedom in a commons leads inevitably to tragedy. Each seeking gain leads to injury to all, including self; if one is of high morality and seeks the good of all, he will suffer. Therefore for efficiency of commons operation:

COMMUNITY-IMPOSED COERCION--I.E. GOVERNANCE--IS NEEDED.

- How to control the chemical content of discharges from all industry--i.e. how to (1) set standards; (2) measure against these standards; (3) evaluate the results of this measurement; and (4) take appropriate action.

- How to reorient regulatory activities toward effective management. New forms of regulatory processes will be needed which place the burden of proof of regulatory need on the regulating body, and the burden of effective mitigation action on the marine operator.

- How to assess and regulate standards for each region of the hydrosphere into which discharge flows--given the ecological differences among hydrospheric region.

- How to integrate the political, technological, economic, and social judgements required to adjudicate the myriad emerging issues.

Based on this discussion several forecasts are presented:

- Realization of the increasing importance of the oceans' resources to the economic and military security of the U.S. and other nations will draw the concentrated attention of the highest levels of the U.S. and other governments.

- In certain regions--e.g., the Caribbean--the ambiguity of governance may lead to international conflict over resources well within the 200 mile limit.

- The Coast Guard or some other agency will be named Lead Agency for oceanic affairs, and will be assigned added functions, despite the austere budgetary restrictions forecast to dominate the federal government environment through the end of the century. More coordination between ocean agencies will be needed and will be effected. Agencies will include, in addition to the Coast Guard, NOAA, DOI, DOJ, DOD, and DOS, or their equivalents.

- A comprehensive ocean policy will gradually emerge, but probably not in complete form until well after the end of the century.

- Efforts will be made to improve managerial efficiency and effectiveness, with some degree of success.

National Aspects

The ocean policy formulation process of the U.S. is fragmented. A large number of federal agencies contribute to it, but no single agency is in any sense a lead authoriy. Bureaucratic competition for leadership is active.

The problem of governance over the marine environment is complicated by having no subordinate structure--e.g. state and local governments. Any governing process that becomes institutionalized beyond the 3-mile limit will be composed essentially of national and supranational elements. Regional bodies exist, but these are created and operated from the national level.

From the point of view of the Coast Guard the key issues at the national level will be centered around the effectiveness of U.S. regulatory policies and regulatory competence. Can the U.S. develop effective policies, and having done so is there the competence to institutionalize them? Here we address two issues--regulatory policies and regulatory competence. Both, independently and in concert, will be highly important factors.

Regulatory policies will set the foundation for effective management of the sea regions. The issues to be encountered will include:

- During the last two decades, the technology-forcing regulatory activity of the federal government has virtually exploded. The result has been strident claims by industry that it is being smothered out of existence by regulations. The evidence supports at least portions of these claims.

- On the other hand certain environmental protection regulations have undoubtedly been of great benefit, resulting in bona fide protection of the environment. In addition, we expect that the advent of regulatory authority over management of the oceans--"sea use management"--will have a favorable effect by reducing some of the uncertainties associated with a "commons".

- Improvements in regulatory management/administration may be expected in certain dimensions. Some rather drastic reforms in the legislative/regulatory process are likely to take place within the next decade, significantly impacting on operations in the marine environment through the end of the time period. A systematic method needs to insure that new regulations are consistent with each other and with previously enacted regulations. Some form of "performance regulation" which provides firm, reasonable guidelines for ocean operations while imposing stiff, enforced penalties on violators, and while minimizing procedural requirements, is likely. This would have the further implication that financial resources, analogous to auto liability insurance, would be required through which violators would be protected from financial disaster. Insurance companies then themselves become part of the regulation-enforcement network.

- Most of the regulations currently under attack are procedural rather than substantive. By "procedural" is meant regulation requiring excessive attention to minute detail forcing operational requirements to meet often amorphous environmental standards. When a regulation is "procedurally oriented", it masks its purpose behind detailed instructions for implementation. While the purpose may be perfectly clear to operator and regulator alike, cumbersome techniques are spelled out for implementation and enforcement. Such a burden on operators and enforcers can be reduced if regulatory bodies shift away from procedural and move toward substantive regulations. Substantive regulations impose significant penalties on violators, but base those penalties on actual results of the operation rather than on procedural violations. Contemporary opinion is showing movement in that direction. However, performance-oriented regulations will be extremely difficult to insist upon; regulatory personnel have a vested interest in massive amounts of detail which mean job expansion and security, while providing comfort through a sense of "This is the way things have always been done, so why change anything?"

- One result of technological advances in environmental protection may be an improved regulatory process gradually moving away from procedural regulations toward performance standards. That shift will be built upon, defined from, and enhanced by the more complete understanding of marine communities and other advances outlined below. A result could be improvements in both the effectiveness and efficiency of regulatory activities. Should this occur, it would tend to promote both healthy expansion of offshore economic activities and environmental enhancement. Effective institutionalization of "sea use management" concepts will further promote effective and safe extensions of economic activity into the marine environment while encouraging responsible exploitation of marine resources.

Given that effective regulatory policies have been established, then the next crucial element in successful regulatory action will be regulatory competence. Some of the more important considerations in this area include:

- The science/art of regulation is still in its infancy. If the free enterprise system is to be preserved, this art/science will require modification toward balance between effectiveness in achieving regulatory objectives on the one hand, and efficiency in permitting enforcement without inordinate disruption of operations on the other hand. This balance must start with policy, but can be implemented only with professional personnel of high and specialized competence. For example, regulations imposing penalties only if an operation fails to meet prescribed water quality standards, but allowing the operators to determine how best to accomplish this level, may be substituted for regulations that impose procedural requirements to prevent pollution. The achievement of this sort of balance requires balanced judgement and environmental knowledge more than procedural competence on the part of the regulators.

- Expanding demand for regulatory competence will increase the strain on the Coast Guard to maintain continued mission competence in new operational environments as it keeps up with surging federal regulatory activities. Argument that only operationally competent personnel can develop adequate regulations will not be challenged in the abstract, but will in the world of action. Regulatory competence will be demanded which is both effective in terms of addressing its objective, and susceptible to practical implementation by operating units whose reason for existing is not compliance with regulations but some other useful purpose. That call will lead toward development of "performance" regulation--analogous to performance specifications in engineering contracts--to replace "procedural" regulation which specifies the "how" to comply with the standard sought, rather than the "what" is to be accomplished.

- A major challenge in regulatory competence will be open to the Coast Guard in facing the need for balance between standards of personal safety and environmental protection on the one hand, and their freedom to operate on the other. A difficulty in accomplishing this end will be resolution of the conflict in the values "justice" and "fairness" to violators vs. resolute refusal to become enmeshed in procedural standards.

- A number of innovative regulatory processes have emerged in recent years that promise to enhance regulatory competence in reducing overhead costs on the economy. Some of these have already been touched upon and are outlined here in summary form.

  - Performance standards. Replacement of regulations that require specific compliance methods with regulations that stipulate the end to be achieved. Private enterprise is thus left free to find the most effective and efficient means of compliance.

  - Economic incentives. Reward of compliance with tax benefits, government procurement preferences and constraints, or government contract fees.

  - Enforcement reform. Use of private enterprise itself to provide the inspection services--e.g. government licensed auditors, consumer agents, verifiable self-reporting systems, compliance checks on a sampling basis, and penalties.

  - Competition enhancement. Use of subsidies and other means to promote entry of firms who otherwise would have difficulty meeting capital requirements.

  - Marketable rights. Establishment of criteria for exchange of government offshore lease rights.

  - Protection of the public from catastrophic failure. Establishment of federal programs to insure private interests against penalty from the catastrophic failure of an enterprise which culpably violates regulations. This would be accompanied by resolution to impose catastrophic penalties when warranted.

  - Publication of consumer satisfaction indicators. A proposal of questionable feasibility--at least questionable at this stage of its development--is to identify how well a firm's product or service is being received by that sector of the public with opportunity to evaluate it. In this example the "product" would be environmental quality.

- Initiative sharing. Granting to the regulated industry the right to develop its own proposal for meeting the objectives of the regulating agency. This has been inititated by the EPA with insufficient time yet to determine its efficacy.

4. Management Considerations

Forecast changes are in three broad areas: first in the area of general management, then in personnel management, and finally in the area of long term institutional changes of far reaching significance.

General Management

The information society will be decentralized physically and geographically, but more centralized managerially--because of the visibility of all activities.

The increasing and changing interaction of every unit of management with every other unit will magnify the complexity of management processes, making supervision more difficult. Coupled with that change will be an increased ability for every manager to perceive the world around him more clearly, to communicate with his colleagues more completely and rapidly, and to distinguish the judgemental from the programmable aspects of his decision making.

More specific changes that may be expected in the management process include:

- o The demographic characteristics of the U.S., particularly the baby boom of the period 1945-1965, will bring about a change in the availability of personnel at the various conventional levels of management--i.e. a plethora at the middle and top levels, and paucity at the entry level.
- o This change in population characteristics will lead to a flattening out of many management structures, and to restructuring of some of the jobs of managers; it will also lead to increasing incentives to substitute capital for labor wherever possible--particularly in the information-based industries.
- o Pressures have already begun on managers to increase productivity--their own as well as that of the workers under their supervision; these pressures will mount as the century nears its close.

- o There will be an increase in the share of the economy operated by the small firms as opposed to the large. This will derive several factors:
  - Increasing resource costs
  - The information explosion
  - Increased efficiency and effectiveness in the regulatory process
  - Declining dominance of regulatory process
  - Changing mix of the production processes in many industries
  - Change in the relative efficiencies of the factors of production
  - Change in the size of firms that reflect optimum economies of scale; i.e. economies of scale will occur at lower stages in the growth of firms than has occurred in the past.
- o International competition will tolerate protectionism only to a certain point at which U.S. firms will come to grips with the need to further increase productivity in order to survive.
- o The information explosion will redefine the nature of many if not most jobs; computer-assisted management will permit the physical location and the time of work to be more flexible. Teleconferencing, videoconferencing etc. will supplant the face-to-face contact that has been perceived to be so necessary up to now.

Interpersonal communications between all levels of organizational authority will increase, with a decrease in the protocol whereby one level of management speaks to another, several levels removed. All personnel will become accustomed to operating under the fairly close scrutiny of others from all levels. Whereas some opposition to this will occur, on net it may increase motivation when the scrutiny is seen to be objective and fair, because it will entail increased participation of all members of the organization in its decision making process.

Competitive advantage will accrue to the managers with competence in the judgmental, qualitative aspects of management, coupled with an appreciation for the capabilities of quantitative methods.

Personnel

The personnel function in particular is likely to undergo several changes.

First there is likely to be a revolution in the labor force as a result of the information revolution--a revolution in skills and competencies required. Personnel will generally be highly literate in the language of computer science, especially in contrast to the 1980's. The "average person" will become knowledgable in computer programming concepts and ways of thinking.

The population hump born of the post WWII "baby boom" will be passed and the availability of personnel, especially highly qualified personnel, will be low. A compensating factor is the gradually increasing level of education, including graduate level experience for a larger portion of the population. So although the numbers of qualified personnel may be down, the proportion of qualified personnel in the population will be up. This will have an affect on Coast Guard personnel functions, especially recruitment and retention of the most qualified technical personnel.

Within the military services one of the distinctions between officer and enlisted status has been education level. Increasing numbers of today's enlisted personnel are acquiring not only the baccalaureate degree, but also advanced degrees. The effect of the reduction of numbers of qualified personnel in the general population, accompanied by an increase in proportion of qualified personnel may lead to an alteration in the officer/enlisted structure—a blurring of today's distinction.

With this distinction becoming blurred, the basic character of the military personnel structure may change, with the officer/enlisted distinction having considerably less significance. While education will decline as a factor in establishment of status, visible accomplishment through skills or competence will rise. This will be so even though the education may be "earned" through attendance at a university for four years. The effect within military services will be that the status accruing to "officers" will decline, while the status accruing to highly skilled enlisted will rise.

This will complicate recruitment in two ways: first the attractiveness of a career in the Coast Guard will increase, but the pay requirements will also increase, placing a heavier load on the personnel budget; second, there will be increasing differences in the levels of sophistication among jobs, and recruitment and retention problems will be aggravated.

Competition for information-trained personnel will lead the military services to require equipment adapted for less qualified personnel; thus facilities and equipment must be designed to adapt to the type of personnel who uses it--personnel not in high demand by the "knowledge industry". This trend is also likely to lead to further emphasis on the modular equipment concept under which equipment maintainance in ships and aircraft is performed by personnel in special repair facilities, not directly assigned to the ship or squadron.

Training of officers for C^3 billets will be done in simulation equipment in which correspondence to reality is extremely high; thus training costs will drop.

Value and life-style differences will be more readily tolerated, but family life will be highly valued, adding to the burden of Coast Guard recruiters.

Fundamental Institutional Changes

Social status in the U.S. has accrued from at least four sources: birth; "earned" professional position (e.g. physician, judge, brick layer, etc.); acquired wealth; and visible accomplishment through skill or competence.

For many years the structure of social class resting on birth in the U.S. has been eroding. "High society" is gradually fading away. U.S. class structure is moving away from elitism and toward equality of status.

Work values will find expression in the "right" to interesting--if not challenging--work. This value will complement the trend toward equality of status. In order to maintain motivation, work must be closely matched in quality and in complexity to the capabilities of personnel; this will pose problems for recruiters in competition with other labor users.

The changing social and work structure in the U.S. economy is likely to alter the traditional personnel structure in the military services, including the Coast Guard. The rise in status of enlisted expertise coupled with the trend in society toward "first name basis" relationships between seniors and juniors will lead to a shift in the basis of respect away from authority and toward competence. Eventually this shift will stimulate a change in the personnel structure of the military services. A vertical division of the present structure in some form is likely, based upon technological competence, especially information technology.

The present system is so deeply embedded in tradition that it will take a long time to change, but the beginnings of such change will be seen clearly before the year 2005. Any new system may, at least for a time, carry the traditional terminology, "officer" and "enlisted", but since this will no longer be adequately descriptive, it will give way to new more accurate terminology.

This trend in the military services will be opposed by several counter trends.

- "Credentialism" is a trend in the U.S. The trend is manifest in the military services by an increasing value placed upon advanced degrees as a basis for promotion, especially within the officer corps. There is a parallel trend toward earning baccalaureate and higher degrees by an increasing proportion of enlisted--in expectation of increased potential for advancement.

- The value attributed to quality of work in the U.S. has declined, especially in large bureaucratic organizations. In only a few of these large organizations has this trend been somewhat successfully resisted. The Coast Guard is one of these.

- The value attributed to "taking care of one's self" has risen and is manifest in the work place. It is interpreted in a variety of ways--from healthy concern for one's own physical and psychological health to narcissistic concern with self to the exclusion of others.

CHAPTER 4: FORECAST OF SCIENCE AND TECHNOLOGY

This chapter presents forecasts of key trends in science and technology. The subject areas and contents have been tailored to Coast Guard applications. The material is presented in two major sections: the first is a section on the general environment in which science and technology is expected to operate through the year 2005; and the second is a general overview of science and technology through the next 25 years.

GENERAL ENVIRONMENT OF SCIENCE AND TECHNOLOGY

Beginning with World War II and continuing through the 1950s and 1960s, the federal government committed ever increasing funds in support of science and technology. Since the mid-to-late 1960s the federal government's support of science and technology has leveled off to about a constant rate. A major question for U.S. science and technology in the 1980s and 1990s will be to what degree this apparent shift in federal support is permanent or merely a cyclical adjustment; can the science and technology community expect even less federal support between now and the end of the century?

Complicating this question is a relatively new concern with U.S. productivity and declining capital investment. The effect of productivity and investment problems on federal science and technology policies is expected to be adverse, but not crippling.

Even further complicating the question is a change in the complexion of research institutions in the U.S. Traditionally basic research has taken place in universities and has been applied through industrial R&D. University research has been in the public domain, industrial research has been proprietary. As universities suffer declining endowments, they will attempt to compensate through patent estates and industrial applications of "pure" breakthroughs. Federal subsidies will thus be perceived as unfair support to competition with private industry.

A separate trend is being established among the other advanced industrialized countries. In Japan, Germany and France the governments have become partners with private industry in the research and development process. Should the U.S. follow these examples, the U.S. government would become increasingly a partner with industry in research designed to stimulate innovation.

Another uncertainty in the science/technology future is the dependence of industrial chemistry on the price of hydrocarbons. A large share of the promise in science/technology's future rests upon the emergence of new products from industrial chemistry. A significant proportion of these products require hydrocarbon bases in some form. Thus commercialization of these products is highly price-sensitive.

Finally is the question of the degree to which procedural regulations will impede innovation. At the moment a trend is developing against such regulations, but how long this inhibition will last, or how effective it will be, is an open question.

These are but a few major contemporary policy questions. Because of the nature of policy making, outcomes to these questions are far less susceptible to accurate forecasting than are some of the other issues presented in this chapter--for example, issues of advance in science or technology.

SCIENCE AND TECHNOLOGY FORECAST

Scientific and technological advances will depend upon: the marriage of science with technology; advances in computer speeds and versatility; brain research; refined materials; successful development of energy sources beyond the "conventional"; availability of feedstocks for materials; and energy research and production. In addition a public awareness coupled with a sense of urgency and sacrifice will be required.

Energy

Up to 2005, petroleum will still dominate fuels, but its availability will have declined, and be critical. Today's marginal sources of oil will have been exploited. The countries that move ahead in synfuels and renewable energy sources will have an extremely advantageous position.

The balance of power will shift from the monofuel producing countries to those with a diversified base. The U.S., USSR and China can be in a relatively good position with their large coal resources, depending on their development of synfuel technology. Technologies such as controlled fusion, improved nuclear power, OTEC, and biomass will be developed and in use, gradually replacing petroleum in the areas where each is most efficient. Priority will be established for the use of the most advantageous fuel for the most pressing national needs.

Several energy producing processes, presently neither fully developed nor completely accepted, will be refined and developed by the end of the century. These include:

- Refinement of nuclear power technology to assure cleaner use of the breeder reactor;
- Development of photovoltaic cells for a second generation application of solar power;
- Proof of feasibility of fusion power by the end of the century, although commercial application will not occur before about 2020;
- Development of fuel cell technology for widespread application with increase in efficiency, energy conservation, and environmental protection.

Coal, a great hope for U.S. balance of trade prospects, will produce a need for 60% increased port capacity, and concomitant congestion.

Catalytic agents and other techniques will be developed for economic use of thick and tarry crude oil not now being processed.

Synfuels from coal, shale, peat, and biomass are technologically feasible, but cost inhibits their use. Cost reduction will be the focus of technological effort in the next two or three decades, with alternative starts and stops as the natural petro fuels are thought to be first less and then more available.

A second problem with synfuel application is institutionalization, with its long lead times and social inertia. By the year 2005, however, synfuels will be a major element in the economies of the advanced industrial countries (AICs).

Rapid progress will be made in developing and commercializing energy storage techniques. These techniques will augment the more conventional storage techniques, such as compressed gas and a head of water, in a variety of ways:

- Electrical. The theoretical limits of electrical storage have not been reached. Progress in this area will come from advances in materials--particularly electrolyte and electrode materials.

- Mechanical. Although this potential is not as great as that of electrical storage, three forms of mechanical storage will be further developed: the flywheel, water pumped to a height, and compressed gas. Of the three the compressed gas and the flywheel offer the most promise, and one or the other is likely to find application by the year 2005.

- Chemical. One of the most promising opportunities for chemical storage of energy is in hydrogen. Production of hydrogen from water will advance and become economically feasible by the year 2005 to the point that use of hydrogen as storage of energy will be in wide use.

- Electromagnetic fields. This form of storage is principally in capacitors and magnets. It may become commercialized, but has lower probability than the other forms described.

- Thermal. Hot water is used currently to store energy, and with improved materials of insulation will become more useful. With increased costs of energy, it may be commercialized to a large extent by the year 2005.

- Hybrid forms. Almost any combination of the above forms of energy storage could come into use, depending upon which ancillary areas of technology are advanced--for example, a breakthrough in insulation materials could advance hot water storage capacity, or combinations of battery and flywheel storage are possible, though neither is foreseen as the present time.

Transportation

With transportation the major user of liquid fuel in the U.S. and other AICs, major effort will be devoted toward increasing system efficiency, component efficiency, and energy storage. By the year 2005 automotive vehicles will be moving with average fuel efficiencies of 50-60 miles per gallon, mass transit systems will enable fast and convenient travel from virtually any urban or suburban point to any other. None of these advances will take place with quantum leaps, but rather with gradual and persistent effort applied with institutional resolve and cooperation, including the squabbles and intergroup delays inherent in our interest-group political system.

Medicine

One of the major advances in medical technology will be the use of microcomputers and imaging of the operations of the human body, and the accompanying diagnostic capabilities that this provides.

Health and medicine will benefit from these biotechnological advances. Benefits will include, for example, nerve fiber substitutes and disease prevention as well as cures for many of the presently perceived "incurable" diseases.

There will be greatly improved skin, nerve, and bone replacement techniques. Genetic research will lead to:

- o Overcoming the self-generated immunity of bacteria and viruses to antibiotics;
- o Healing of hereditary diseases including those mental illnesses related to heredity
- o Development of monoclonal antibodies and other products of genetic engineering and improvement in health of the wealthier nations.
- o Production of interferon by fusing DNA taken from two sources, leading to a powerful weapon against cancer and viral infection.
- o Hybridomas, man-made hybrid cells that can be introduced into the body to produce swarms of disease-fighting antibodies

Biotechnology

Gene cloning and rapid DNA sequencing will help provide solutions to energy problems. This process may convert sunlight (photosynthesis) to carbon molecules. Many tools are already at hand. Advances in chemistry will be applied to agricultural improvement, enhancing America's global position.

New technologies will lead to the production of food from available resources--i.e., without the need for new and exotic sources. Plants will be developed which thrive in a harsh environment; waste conversion will be efficient in recovery of nutrients; plants resistant to herbicides as well as to disease will be developed; "selective" herbicides which can distinguish between desired and undesired targets will be developed; plant and livestock yields will be increased without requirement for more expensive inputs.

Plant disease and its prevention will be a major target of science through the end of the century. Seeds will be developed to suppress pathogens, and soils will be innoculated with nitrogen-fixing bacteria or algae, reducing the need for fertilizer.

Advances in recombinant DNA will permit the production of any desired protein in a variety of hosts. Production will be either directly of the product desired or of enzymes which then contribute to its production. The first products will be pharmaceuticals, followed by foods and other organic products.

The technology for producing synthetic enzymes will continue to advance. Synthetic enzymes will be tailored to a variety of applications, including acceleration of the natural processes of recovery from environmental damage.

Materials

With the source of many strategic materials located within the boundaries of adversary or unstable governments, the U.S. will have incentives to develop new sources of materials as well as improved methods of production and substitute materials. Innovative techniques will exploit low grade ores. In addition the U.S. will accelerate its interest in exploiting marine nodules.

Macromolecular chemistry--the chemistry of the basic ingredients of living matter, such as wood, fibers of all types, leather, etc.--will become a major field of research and application. These areas of research will include polymers and other kinds of chemical structuring in which molecular architecture as well as chemical content will be highly important in determining properties. The objects of this research will include proteins and carbohydrates (cellulose), globular proteins (enzymes), and polynucleotides (DNA and RNA--the repositories for all essential information in biosynthesis and replication). Knowledge to date in these fields is largely descriptive/empirical rather than theoretical; however, we are on the threshold of further theoretical advances.

The chemistry of materials will permit the composition of useful materials from a diversity of more abundant and more easily combined sources than are available in the 1980s. For example, as ceramic technology advances in terms of increasing versatility, including electrical conductivity, ceramic materials will be developed as substitutes for other materials. Ceramics are made from metal oxides which form about 90% of the earth's crust.

The advances described in the preceding paragraph are based upon advances in knowledge of basic mechanisms of the chemical synthesis--the catalytic agents and reagents. A limitation of this knowledge is likely to persist into the future. This is that the chemical composition of the new synthetics will be more predictable than their properties. Despite that uncertainty, forecasts from technological "experts" do express a consensus along broad dimensions of likely properties to be found in materials by the end of the century and beyond. Examples are offered in several technical areas.

- o Many of the advances will relate to general properties of utility either at the user end of the process or at the production/distribution end. For example:

  - Optical fibers of a fraction the diameters of present fibers will become available.

  - Synthetic polymers will be developed that find application in fibers and plastics.

- Non-brittle, light-weight ceramics will be developed with capability to operate in high temperature engines--leading to increasingly efficient, fuel-conserving engines.

- Improved strength and fatigue resistant ceramics will be developed.

- Synmetals from ceramics and other materials will be developed which are resistant to corosion and abrasion.

- Materials will be developed with sharply discrete boundary conditions across which their characteristics change. For example, materials with certain hardness characteristics at one temperature range will have a quite different hardness characteristic at a different temperature range, and the boundary between the two ranges will be only a few degrees. This will permit modifying a material's characteristics with relative ease depending upon the circumstance and desired use.

- Adhesives and cohesives will be developed with easy-to-apply characteristics.

- Anisotropic materials will be further developed. These are materials with different characteristics depending upon direction of the molecule-e.g., higher tensile strength in one direction of stress than in another.

- More easily formed, strong, light-weight materials will be developed--e.g. materials that are formed by stamping and molding.

- The science of materials will facilitate the manufacture of materials with characteristics on demand--high strength, light weight, conducting, insulating, etc.

- Synthetic fuels will be derived from the easy-to-effect reaction between hydrogen and carbon monoxide.

- A "composite material" that negates radar pulses may come into use (made notorious through the media's exposure of the DOD "stealth" aircraft). Plastics with fiber-reinforced strength characteristics will be developed.

o Significant advances in producing desired electrical properties will be made, including the following:

  - "Synmetals" are already feasible which induce electrical conductivity in normally nonconducting materials by "doping" polymer techniques. These materials can be varied in their properties from insulator to conductor, and conductivity can be combined with many useful properties not found in metals. They combine conductivity with low cost, light weight, flexibility, and strength. They can be chemically tailored for: conduction only in the presence of light, heat, or pressure; switch between conducting and nonconducting on command, conduct in one dimension only. They are likely to revolutionize the production of electric motors, making them much more efficient and smaller, and they are also likely to find uses in "superbatteries" with the capability to store large amounts of electrical energy for long periods. Low-cost photovoltaic cells will also be developed.

- Ceramics will be developed with increasing versatility, including electrical conductivity. Polymers will also be developed with electrical conductivity. Organic electrical conductors, some of them polymers, will be developed.

- Polyacetylene--made from common welding gas--is a promising materials which can convert light to electrical energy and has the potential to be made into solar cells. A 0.1 millimeter thick rechargeable battery has been made from polyacetylene which produces 2.8 volts. Higher voltages and currents are possible by layering. This material also has potential to revolutionize the technology of electrical storage.

- Macro superconductor devices that operate at significantly above absolute zero will be available. These will derive from the extremely fast circuit operations permitted with superconducting materials--even today the Josephson switch operates at 6 pico seconds (1 picosecond = 10^{-12} second). By the year 2005 generators, motors, and transmission lines will use these superconductors and improve many times the efficiency of production and transmission.

- Synthetic magnetic materials will be developed.

o Chemical and biogenetic processes will substitute in many ways for what has traditionally been machining of parts and surfaces. "Growth" of organic structures, parts and possibly even machines will become feasible. Molecular engineering will become applicable to many manufacturing processes.

  Two examples are:

  - Parts that grow their own strength fibers will be developed.

  - A "mineral accretion" technology will permit the "growth" of structures beneath the sea surface.

Resource Exploration

A major effort to discover "unconventional" fuel deposits will pay off in the discovery of new sources of nonfossil hydrocarbon fuels, such as methane, in such locations as beneath the earth's crust, at the ocean margins and spreading centers, volcanic formations, etc. Advances in ascertaining the indicators of these deposits will bring many of them into full use by the year 2005. Geological indicators will be found to identify from satellites as well as from surface positions the locations of new oil and gas deposits as well as deposits of other resources. New sources of submarine hydrothermal energy will be found in ocean spreading centers, hot springs, and convergence zones.

Space Technology

This technology will dominate many aspects of communication, weather forecasting, navigation, resource evaluation, environmental monitoring, and national security and arms control. The space shuttle will become a much used vehicle. Manned operations in space will be routine; larger spacecraft will reduce costs by permitting repair in orbit. The U.S. will be the only nation with this capacity until the end of the century. The space shuttle will spearhead advances in space technology with new developments in the properties of materials, heat resistant methods, instrumentation, computer technology and remote control of activities, astronomy, and use of laser technology. There will be new generations of satellite communications. Landsat remote sensing satellites will be operational. The National Ocean Satellite System will analyze sea and ice conditions, marine weather, and marine pollution and provide oceanographic observations.

The technologies of 3D seismology, artificial intelligence, exploration from satellites, and high speed digital computation will lead to orders of magnitude increases in our capability for geological and meteorological data collection and for the use of correlated observations to make geological and climatological inferences. The earth's magnetic fields, gravity fields, heat radiation, and the electromagnetic radiation from vegetation and other surface features of the earth will also provide indications of geological and climatological conditions.

Mineral and energy deposits beneath the earth's crust in the vicinity of the ocean margins will be discovered, inventoried, and made accessible.

Ocean Science and Technology

New types of underwater construction processes will utilize the natural organic activities of the oceans. These involve "real life" growth of lightweight structures--e.g., the use of low voltage electrolytic techniques to fill in structures, once the basic network of the structure has been deposited. These construction processes will be not only less expensive than conventional processes, but can be accomplished with minimum disturbance to living systems.

Advances in information processing will enhance the visibility and communications of the surface and subsurface regions of the oceans. Led by computer technology, understanding of the physics, chemistry, and biology of the oceans will increase manifold. The scientific investigation and knowledge of microscopic flow, interactions, vibrations, etc. at the sea/air and sea/seabed interfaces will advance; frequency anomalies have been found that will permit transmission of information through these interfaces with an order of magnitude higher effectiveness and efficiency than in the 1980s. These flows/fluxes consist of acoustic radiation, electromagnetic radiation, organic and inorganic matter, and gaseous, liquid and semisolid matter. Investigations will advance across boundaries, and within the water column. Technological capabilities in communications, surveillance, and navigation will improve very significantly. This includes satellite technology and photographic technology.

The following exemplifies some of these areas of prospective advance:

- o Detection of substances in sea water from satellite or airborne laser detectors
- o Chemical oceanography

- o Radionuclides and radioisotopic sediments
- o River/ocean interfaces
- o Atmospheric ionization

Instrumentation for the following will be available:

- o Automated data acquisition systems
- o Ocean conductivity measurement
- o Trace metal detection
- o Forces on offshore structures
- o Seabed measurements in mud
- o Acoustic measurements for such items as:
  - High data rate acoustic telemetry systems and hydrophone arrays
  - Split-beam towed sonar for acoustic measurements
  - Precision television presentations for echo-ranging sonar
  - Assessing the condition of oil pipelines on the ocean floor
  - Measuring the transverse movement of sea floor gas pipelines
  - Measuring the properties of the oceans
  - Ocean current measuring devices

Improved understanding of all the forces that act upon weather will enable advanced computerized weather models to be constructed, and produce predictions of increased reliability. This will aid navigation and planning for the efficient routing of ships, especially lighter-than-air craft and advanced technology sailing craft. Satellite observation of currents will also be an aid to navigation.

Automation/Information

Information will be increasingly more available and organized. Improved information technology will help the U.S. regain its lead in advanced technology; International competition will be an important stimulant to U.S. innovation.

Microprocessors will become integrated parts of most appliances and vehicles used in the advanced industrialized countries (AIC's); this will mean that virtually all vehicles--autos, boats, buses, trains, aircraft, ships, etc.--will make use of minicomputers for maneuvering safety and efficiency.

Decentralization capability will permit use of computers by virtually every business and every household. Information services will become public utility services, with centralized information sources producing information in a variety of forms to be sent to small business and home terminals.

Artificial Intelligence (AI) and Robotics

Of the new technologies described to this point, the linked disciplines of AI and robotics appear to be least advanced. However the technology push of computer science and the demand pull of safety in nuclear power plants is likely to foster much more rapid advances in the latter part of the century. Development in these fields is likely to have significant impact on the Coast Guard especially in command and control and in the important area of interaction between seaborne units and adverse weather.

Robotics and other forms of automation will explode into use in industry and in society. All manufacturing will be susceptible to use of robots, especially in circumstances where human error or safety to workers are major factors. Consumer application of automation technology will extend to extensive use of computer-operated devices for control of household and automotive appliances.

CHAPTER 5: RELEVANT TECHNOLOGIES

This chapter amplifies the science and technology forecasts outlined in Chapter 4 and presents detailed technological forecasts which provide the background and analytical foundation for the scenarios. (These forecasts may be correlated with the scenarios presented in Chapters 6 through 9 and with the "Scenes" presented in Chapters 1 through 4 in Volume II.)

1. FORECASTS: TECHNOLOGIES RELATED TO COMMAND AND CONTROL

Electronics

A 20-25 year forecast for electronics is even more uncertain than a similar forecast in other areas. The uncertainty occurs because the infrastructure involved in production and distribution of many of the industry's products is small and flexible. Thus the low costs, small size, and flexibility of many electronics products leads to fairly rapid institutionalization in most of the value-added stages of these products. As a result, the risk, time, and expense involved in exploiting a new idea is reasonably small.

The production structures of advanced industrial societies will be organized around electronics. Development of the silicon chip as the key element of computer memory was a tremendous stimulant to innovation. A million-bit chip will be in operation by the end of the century; today's large main frame computers will be reduced to the size of a basketball. Advanced computer technology will continue to reduce costs and increase speed of processing. When combined with computer assisted design and manufacture, this will result in a reduced number of manufacturing workers and increased manfacturing efficiency. These factors could also stimulate a return of manufacturing to the more technologically advanced countries. Assembly and testing can be done more accurately with computer aid than by people alone. Quality control will be improved in the U.S. Robot technology will be used for assembly lines and handling hazardous substances. Automated operations, including robotics, will advance with almost universal applications.

Information will flow freely and reliably between operating units in air and sea modes. The reliability problems that have beset communications over large distances will rapidly diminish as the technology of the 1980s matures and becomes institutionalized. The capacity of individual operating units to process clear and encrypted information in multiple channels will permit virtually unlimited coverage. Advanced modulation techniques will permit use of multiple broadcast channels with minimum mutual interference.

Some of the specific advances will be:

- "Photonic" circuits which use light rather than electrical pulses will become operational. "Electro-optical" chips will form the basis for these circuits.
- Interaction between human and computer will be through voice, enabling the educated lay person to program and operate a complex computer net.
- Computers will be adaptable to program modification on-line; personnel will be sufficiently knowledgeable to make use of this common feature in a limited degree.

Artificial Intelligence and Robotics

As the century nears its end the field of Artificial Intelligence will become the cornerstone of computer science. Artificial Intelligence (AI) is the science of programming intellectual functions and behavior. The discipline began about 25 years ago. In 1977 the Defense Science Board identified artificial intelligence as one of ten fields of science with greatest potential for the next several decades. Another was microelectronics. Still another was distributed computing, a process through which electonic computation occurs throughout a network of computers; this has particular application to command and control systems. AI promises techniques with broad applications for qualitative problem-solving. The techniques include heuristic programming, automated reasoning, symbolic information processing, and knowledge-based judgmental choices. Existing applications of AI include: medical diagnosis, judgmental reasoning (knowledge-based), chemical structure identification, signal interpretation, mathematics, system control, language development, and both visual and audio inputs to robot operations.

The rise of AI coincides with emerging limitations of current command and control systems. Today's systems are slow, poorly integrated, and lack capacity to address many of the conflicts of operational situations. The systems are also excessively centralized, and therefore highly vulnerable to damage in communications networks.

AI is particularly relevant to problems of military operations--ocean surveillance, for example. Many of these problems require heuristic methods which produce acceptable rather than optimal solutions. The Navy has established an AI center at the Naval Research Laboratory to pursue the subject. One of the most attractive features of AI is that its "problem solving" components can incorporate new data at any time, can accept guidance about priorities, and can interact with other human or machine problem solvers.

Associated with the development of AI is development of robotics. The nuclear power industry is likely to promote development of robotics from the necessity to maintain and repair power plants quickly, with least cost, and at minimum risk to repair personnel. By the year 2005, technology will permit production of robots controlled by remote operators. Operators will wear jackets lined with sensors and motors to simulate human muscle and nerve performance, as well as 3D helmets for viewing. The operation may be thousands of miles distant, yet the operator will feel the environment of his work place as if he were there--with the exception that he will be physically comfortable and feel perfectly safe. Pressure, temperature, and motion will be transmitted to the operator, but within tolerable limits of discomfort.

Information Technology

There will be a trend away from centralized computers systems toward autonomous but linked systems. Degree of centralization will be less a function of computer design and more a function of the manner in which computers are networked together.

Global communication networks will multiply by linking space technology with computer technology. These networks will employ satellite systems based on advanced generations of the "supercomputer". Advances in information processing technologies will enable operating units to communicate with each other securely in every kind of operation at sea or over land. Satellite-augmented communications/surveillance networks will insure reliable intelligence, command, communications, and control processes. Global video conferences will be highly reliable and useful routine events.

Satellite involvement will be accompanied by telephone integration, use of optical fibers, electronic mail, text editing and distribution systems, and EFTS. Some basic problems in security and privacy will emerge, as well as legal problems such as ownership of software.

The era of the "supercomputer" will be in full swing, with computer speed and scope enormously enhanced. This will enable operators to have on-line computer service almost any time and place, with 3D information presentation and decision-assisting modules as aids. Advances in microminiaturization--more than 1-million-bit chips--will permit decentralization of operational control in tactical situations; each operating unit will have the capability to take in virtually as much information as do entire command and control centers in the 1980s. Switching networks to control information traffic flow will have been developed so that any of a number of micro-processors in a net will have the capability to assume total net control. Algorithm development will match developments in computer hardware.

Computer-aided design and computer-aided manufacture (CAD/CAM) will burgeon compared to the 1980s; self-diagnosing and self-repairing systems will be in use.

The information processing industry will continue to benefit from more efficient materials and components concurrent with reduced costs. The materials involved will be key elements in computers, lasers, solar cells, infrared detectors, and fiber optics.

The decline in the cost of chips will continue, enabling manufacturers to place increasing computer capability at the disposal of the consumer at minimum cost. Bubble memories and Josephson junctions will foster fast recall from dense memory, and even greater increase in computational speed. Microprocessors will be in operation in almost every conceivable piece of equipment as "fine tuning" control devices to improve performance and to render performance at least semi-automatic. Examples include: automotive equipment, home appliances, retail store operations, and all aspects of production. In the Coast Guard these features will appear in virtually every piece of equipment in ships and aircraft.

Certain innovative benefits will accrue to users of the advanced technology:

- o Software engineering will lead to self-checking of highly complex programs.
- o Voice-data bank interaction will be feasible in communicating both to and from computers.
- o Knowledge of genetic behavior will lead to its use as a model for computer programming and allow programming by the generally educated person without specific training in computers.

Intelligence Technology

The technical capability to gather and interpret intelligence data will grow with advances in information technology, although progress will still be very slow in assessing intent. Mathematical pattern recognition and image analysis from satellite stations will become feasible and operational. These and other techniques of intelligence will permit advance warnings of impending law violation, antisocial, or terrorist activity. The balance between encryption and decryption techniques will continue to oscillate, favoring first one then the other; security of intelligence/information in computer networks will become somewhat enhanced over the 1980s, but not close to 100%.

Intelligence gathering processes in the soft areas--e.g. political and social intelligence--will advance but at a slower pace than the corresponding processes to gather "hard" intelligence.

Surveillance Technology

Geographically huge regions will be viewed in 3D from a single location, with the capacity to reduce or enlarge the regions under observation to gain perspective or greater detail. Infrared technology will augment all aspects of this capability.

The full electromagnetic spectrum will be available for sensing instrumentation: ultraviolet (0.4 micron region), through the visible spectrum, both short wave and long wave IR, and microwave (50 cm region). Tunable IR lasers will add to the capability.

Microwave technology will permit development of radar surveillance systems an order of magnitude improved over 1981 systems for surveillance of the atmosphere and the sea surface.

Surveillance capability will improve to the point that a large number of fish species will be identifiable by satellite surveillance methods--particularly the methods of high resolution photography.

Advances will also be made in the following:

- Telemetering from data buoys
- Programmed surveys of preselected regions
- Sound propagation in shallow water
- Acoustic properties of the bottom-to-sea boundary

- o Assessment of seismic radiation from sea bottom
- o Monitoring gravity waves in the deep ocean
- o Interface of laser technology with acoustic measurements
- o Detection of geomagnetic and small scale density fluctuations in sea water
- o Acoustic surveillance of fisheries
- o VHF and UHF communications for submersibles
- o Fiber optics communications between subsurface units
- o Subsurface television for subsurface surveillance
- o Development of advanced cables, connecting devices, and towing coupling devices for subsurface towing, tethering, and mooring
- o SeaSat technology
- o Satellite measurement of surface winds through radiometry
- o Safety, security, and efficiency of offshore installations

Microwave technology will permit almost complete identification of foreign objects detected by radar or laser--through ability to pick up both reflected and radiated characteristics of the object. This includes the ability to identify the nature of a spilled substance, as well as the identity of the spiller.

The capability to track over long distances and periods of time by means of both passive and active electromagnetic radiation will permit continued targeted surveillance of objects suspected of antisocial intent, or objects whose safety is in question.

Command Control & Communications Technology

Display techniques and technology will lead to the capability of presenting statistical data in a variety of forms to suit the capability and even the taste and preference of operators and observers. Curves, histograms, probability functions, Venn diagrams, matrices, and other presentation forms will be readily available for information display. Judgmental information/data will be presented in curvilinear and other forms, and amenable to modification by the operator/user. 3D displays will be available for viewing through "synthetic aperture" techniques such that a large cubic region is visible through binocular instruments from a single seated position.

Unique combinations of light and other electromagnetic radiation--including lasers--through interferometry, spectroscopy, and holography will present displays on CRTs that illuminate increasingly useful aspects of objects being represented--such as ship and aircraft configurations, human movements about a vehicle at some distance, and cargo storage arrangements.

Stereoscopic imagery and multipolarized radar systems will be in use to provide added variety and versatility to displays for efficient operations.

Acoustic/mechanical and subsurface electromagnetic radiation phenomena will be exploited, permitting both passive and active detection of surbmerged objects at many times the present distances.

Low cost radio communications equipment will be available to virtually all participants in emergency situations; this will facilitate coordination of operations in environmental protection, search and rescue, and law enforcement operations.

Air space and sea space will be virtually collision-proof. CRTs will be used in restricted waters. The displays will depict accurate charts as well as moving surface and air targets. Equipment will be highly redundant and reliable, will use solid state materials, and reflect truly "modular" characteristics. There will be a shift in balance between complexity and sophistication, leading toward highly sophisticated but not inordinately complex equipment which is both reliable and maintainable.

The computers in use for C^3 will also be highly integrated components of the general purpose equipage of ships and aircraft. Such data processing systems will include a highly developed system for ranking uses to suit operational circumstances. Robotics will augment the C^3 equipment in management of all aspects of logistics support for operations at sea.

Navigation Technology

Navigation systems for the early 21st century are to some extent already operational in the form of Omega, Transit, and NavStar Global Positioning System (GPS). By the early 2000s NavStar will be the principal system with Omega and Transit as overlapping backup.

Inspection and Concealment Technology

Chemical, electromagnetic, laser, visual, acoustic, mechanical and nuclear means of examining ship cargos will aid law enforcement officials in detecting contraband and illegal personnel in transit. Robotics will constitute a major advance in investigative capability. It will permit safe boarding of vessels despite adverse weather and despite hostile receptions by ships' companies.

Highly effective intelligence systems will permit advanced knowledge of probable violations before boarding or arms-length investigation is commenced.

Technology will in many ways favor violators more than law enforcers. Techniques of concealing contraband and illegal persons will encourage law violators to atttempt smuggling operations. New terrorist and other antisocial technologies will also encourage law violators. The technology of masking identity will keep pace with that of identification, placing a pressure on the Coast Guard to invest in the most advanced identification techniques and equipment. Techniques of concealment of both ships and aircraft from radar detection will also advance, favoring Coast Guard adversaries more than its allies.

2. FORECAST: TECHNOLOGIES REATED TO ENVIRONMENTAL PROTECTION

The science and technology of the ocean is likely to be much more intensely studied and therefore much more effectively applied. Rather than being an extension of the science and technology of the land environment, the oceans will begin to be viewed as systems in themselves. This viewpoint will lead to new and unforeseen ways of making use of and protecting the oceans and their resources. Major thrusts of environmental science and technology will include biochemical functions of "natural" marine systems, the assimilative capacity of the oceans, their capability to clean themselves after environmental damage, and methods to convert potential pollutants into substances to improve water quality by acting "naturally".

Improvements in our knowledge of the environment will lead to the capability to expand economic activity into the marine environment with ever-decreasing risk to the environment and at lower incremental costs than present costs of environmental protection.

Currently studies are starting to focus on ecosystems as interdependent rather than isolated. By the end of the century this will lead to concentration on marine ecological zones, their adaptation to natural and mechanical changes, and the normal evolution of the systems. Environmental impacts will be more predictable.

The flows of nutrients, energy, information, and strength of life-preserving tendencies as separate subsystems in the oceans will be studied. Models will be developed, patterned after some of the concepts of general systems theory, which will identify common elements and characteristics among living systems of apparent great diversity. These studies will lead to better understanding of the biology and chemistry of the oceans from a total-system point of view.

For the next few years the issue of water quality will take precedence over water quantity. However, toward the end of the century the reverse will take place as the problems of water availability and distribution become acute. Research on water quality and the sources of its contamination will lead to greater understanding of a number of sources of water pollution, including:

- o Contamination of ground water--the source of about 40% of drinking water in the U.S.

- o Nonpoint sources of water contamination--as opposed to the research done to date which has concentrated on point sources of contamination. Land disposal of waste is believed to be a major contributor in this category, but the mechanisms are not well understood. Almost all the effort in the U.S.to this point has been directed toward point sources of pollution. Some of the sources believed to be pertinent include:

  - Agricultural run-off

  - Erosion from construction sites

  - Storm water run-off from urban areas

  - Land disposal of waste

  - Atmospheric deposits

  There may be a need for institutional changes in the manner in which these sources are managed.

- o Deterioration of aquatic ecosystems--much of which is believed to be closely related to the nonpoint source contamination of water quality.

The deep ocean deposit of radioactive waste is an issue unlikely to become dominant before the end of the century, but may very well become a "hot issue" by that time, particularly as attention begins to divert from high level waste products to low level products.

Marine Environmental Problems

Foreign substances are injected into the marine environment from a variety of sources and have a variety of effects. The primary sources are from accidental spillage, deliberate dumping, and injection of industrial effluents, seepage from shore, run-off, and air/water transfer--acid rain, sulfur, coke, toxic chemicals and particulates. These sources may be converted into a beneficial form in the future; but at the present state of our knowledge, most appear to be harmful.

Some technological problems are:

- o Toxic substances introduced into the marine environment are spread over enormous distances through atmospheric and ocean convection;
- o These substances are also spread through secondary flows--i.e. the migratory patterns of ingesters and their predators;
- o The time required to identify these patterns and networks may be several decades, and the time and expense of necessary remedial action may be even greater;
- o The kinds of products of greatest concern include:
  - Thermal pollution
  - Industrial chemical waste products, including contaminated cooling water from offshore industrial operations
  - Synthetic organic chemicals--DDT and other insecticides/herbicides
  - Radioactive waste products
  - Accidental discharges--e.g. oil spills, other toxic material spills
  - Sewage sludge and litter
  - Dredged materials, which may hold large volumes of any of the above.

The marine environment appears to have remarkable recuperative powers. Marine science is still in its rudimentary stages, and may offer opportunities not now clearly evident. The current base of knowledge may well form the foundation for determination that the assimilative capacity of the oceans and coastal waters is very great. For example, the ability of organisms to enrich themselves with the materials in sea water may be far greater than we now imagine; the ability of organisms to adapt favorably to levels of contamination now thought to be toxic may be higher than expected. Current methods of establishing minimum acceptable levels of concentration may be leading to more conservative standards than are necessary. Moreover, the emergence of biochemical technology may allow the conversion of such materials into positive injections so that they will become a part of the normal ecosystem, not contaminants. (See Chapter 7.)

Huge areas of ignorance exist with respect to marine pollution. The following represent some of the areas where understanding is lacking:

- Clear distinction between causes of beneficial effects and adverse effects
- Mechanisms and networks through which these foreign substances are distributed through the environment
- Nature of the chemical and physical interactions between these substances and the natural elements of the environment
- Differences between long term and short term effects
- Line between acceptable and unacceptable levels of concentration; nature of "minimum acceptable risk"
- How to address the geographical/physical transformations caused by massive alteration of the environment from either injection of foreign substances or by building of structures in the environment--i.e. the loss of habitats for entire populations of shellfish in a region

Pollution impacts on the marine environment may be ranked in five levels

FIGURE 5-1: LEVELS OF MARINE LIFE AT WHICH POLLUTION IMPACTS

Level	Effect	Time to Assess
Biochemistry & single cell	Toxify, detoxify, or simply carry	Minutes-hours
Organism	Physiological and behavioral changes--e.g. feeding habits, shelter building,	Hours-months
Community	Behavior of schools--local movement patterns, etc.	Days-years
Population	Behavior of entire species-migration patterns, caring for young, territoriality, etc.	Months-decades
Communities of populations	Behavior of entire populations of different species in a region	Years-decades

of marine life. The effect at each level is somewhat different and the time required to ascertain impacts is longer as one moves up the hierarchy. These levels are depicted in the tabulation of Figure 5-1.

The problem of radioactive injections into the marine environment presents special difficulties. Some of its important components include:

- The amount of natural radionuclides is significant--from natural substances in seawater and from cosmic radiation.
- Fall-out from the atmosphere is the largest single contributor to human-produced radioactivity in the oceans, but the concentration is sufficiently low to constitute a minor problem at the present time.
- Nuclear effluents constitute the second largest contributor, and here the concentrations are higher, so this may become a problem at some time in the future--perhaps one of the most important problems in management of radioactivity in the marine environment.
- Deep-sea dumping of nuclear fuel rods is likely to be concentrated in closely controlled regions, and although radiation intensity may be high, the control is likely to be sufficient to contain the pollution.
- The major problem is that paths back to humans and the subsequent effects are not understood.

Promising Research

Areas where our capability to monitor, model, protect, and control the total environment will be expanded by extensive research include:

- Computer models of the environment will be developed which focus more precisely our present knowledge of cause-effect relationships in the air, water, sea and land environments.
- Our knowledge of natural resuscitating mechanisms of the environment will be expanded; as a result, our ability to catalyze such natural action will be increased.
- Techniques and technologies for remedying environmental damage--particularly oil spills--will be developed.
- The problem of coastal erosion will become somewhat more manageable.
- Determination/definition will be made as to acceptable levels of concentration of various foreign substances in air and water and how to convert or control such substances before toxic levels are reached.

Research into the basic engineering of marine environmental protection is likely to include such items as the following:

- Systems for prevention and recovery of oil spills—through collection of spilled oil, combustion of oil before spreading, barriers, and other oil containment devices.

- Development of blow-out protection systems

- Environmental recuperation studies and biochemical understanding of natural marine ecosystems

- Improved methods of assessing the environmental impact of new oil and other resource extraction installations in specific geographical areas

- Improved methods of assessing the impact of the introduction of other industrial activities into the marine environment—such as paper production, energy production, nuclear power plants, production of other industrial products

- Development of shipboard systems with minimum environmental risk

- Advanced design for offshore-onshore interface in production/transportation facilities--for both nonliving and living resource processing

- Ship systems designed for accommodation of environmental requirements; construction regulations institutionalized to the point of causing far less contention than they did in the first few years of environmental consciousness

- Similar advances in the design and construction of offshore installations, both from the point of view of protecting the environment and for safety and security of personnel and equipment

- Understanding and control of the atmospheric/oceanic transfer mechanisms

Probable Research Outcomes

The outcomes of this technological research will include knowledge about the following:

- How to effect positive changes in discharges so that they not only do not contaminate, but actually contribute to creation of beneficial, well functioning marine ecosystems

- Identification of control devices and their long term and short term effects

- Acceptable levels of contamination for each species for each contaminant

- Optimum level of nutrient enrichment or oxygen for species so that favorable habitats may be designed

- Indices for aggregate assessment of the condition of a body of water in terms of contaminants or natural functioning

- Synergistic and antagonistic effects of aggregates/combinations/collectives of contaminants--or of contaminants interacting catalytically with what would otherwise be non-contaminants

- Global flow patterns of contaminants/nutrients, especially along coasts

- Exact nature of degradation/immobilization process for each contaminant--i.e. its half-life

- When dispersal, when contaminant, or when biochemical modification is the best solution to a pollution problem

- Long term effects of low levels of contamination

- Assessment of overall state of pollution in the U.S. marine environment

- Closer definition of pollution standards

- Nationwide information systems to disseminate the science and technology of environmental protection, as knowledge in this discipline grows

- Knowledge of the long term effects of relatively low levels of pollution in the environment, especially in coastal waters

- Establishement of a coastal network of environmental quality monitoring

3. FORECAST: TECHNOLOGIES FOR COPING WITH THE WATER SHORTAGE

The U.S. faces a future with increasing problems of droughts and inadequate water supplies. Many locations are overdrawing surface and ground supplies, and water depletion is expected to increase. Water shortages aggravated by either inadequate storage capacity or lack of transportation capability are likely to entail high economic and social costs. When shortages of water occur or are expected, a number of steps can be taken which involve varying degrees of technological sophistication.

Augmentation

Augmentation involves either storage of water for later use, transporting it for immediate use, or making use of weather modification to increase local supplies. The first two of these actions have the potential to permanently alter natural landscapes and to create ecological disruptions. Storage is accomplished through building impoundments on existing streams.

This is expensive, and may increase evaporation, reducing the total water supply. Because of the large quantities involved, transportation of water over long distances is expensive and energy intensive.

Weather modification has been the object of extensive applied research and development to modify precipitation by seeding clouds with silver iodide, frozen carbon monoxide, and other chemicals. Seeding of winter storms in local areas of the West has increased total precipitation from 5 to 25 percent. Cloud seeding has increased snowpack on the slopes of the western mountain ranges and also added to spring runoff and snowmelt in downstream storage reservoirs.

Seeding of summer clouds to produce additional rainfall is considerably more complex than seeding of winter clouds. Experiments on single cumulus clouds have had mixed results. Some experiments have decreased rainfall; the causes for this are not fully understood. However seeding of multi-cloud formations has had positive results. For example, experiments in the Dakotas increased total seasonal rainfall by 10 to 20 percent. In Florida results ranged from a plus 18 percent to a minus 67 percent. Whether the same results can be obtained in other parts of the country is not yet known.

Conservation

The goal of water conservation is to avert critical water shortages and to get the greatest use from existing supplies.

Several processes to reduce water consumption are applicable, some of which involve application of technologies, and others less so. One of the most important water conservation measures is the application of resources to the maintenance and repair of major urban water transportation systems--the sources of major leaks and waste in water supplies. Other measures include:

- Irrigation: A prime candidate for water conservation because of the large quantities of water used and its concentration in the relatively water-short Western states. Irrigation accounts for 47 percent of total national water withdrawals and 81 percent of consumptive use.

Recent reports indicate that the potential for saving in irrigation withdrawals is from 20 to 45 billion gallons per day.

- Delivery Systems Improvements: such as lined and covered canals. This type of improvement can reduce withdrawals by as much as 10 percent. Better on-farm water management practices, such as closer scheduling of water applications to meet crop needs without over irrigating; irrigating at night instead of during the day; improved irrigation systems such as sprinkler and drip systems and well designed surface systems; and better land preparation, can reduce withdrawals an additional 10 to 40 percent.

- Domestic Use Curtailment: only 6 percent of total national withdrawals. This use seems an unlikely candidate for conservation, but ways to reduce water use substantially at little cost do exist. Savings of one third can be achieved within the home by retrofitting showers and toilets with more efficient fixtures.

- Dry Cooling Towers for Electricity Generation: could reduce water consumption by 25 to 30 percent. These towers use no water but require more energy to operate and are more expensive than other methods.

- Inplant Treatment and Recycling in Manufacturing Processes: measures already in use and effective, but expensive.

- Evaporation reduction: federal funding of evaporation reduction is only a few thousand dollars a year, yet recent studies have ranked an evaporation reduction technique as having more potential than the other alternatives, including cloud seeding.

Water Reuse

Limitations of supply, increased delivery costs, and water pollution control laws for higher quality waste-water discharges have increased the national interest in water reuse and waste-water reclamation. Sewage is 99 percent water. Some ways of reusing water are:

- Use of treated waste water for manufacturing, steam-powered electric generation, and irrigation

- Routing storm water to recharge basins to augment aquifer recharge

- Use of treated waste water to augment water supply either by aquifer recharge or by blending in surface-water reservoirs

- Use of treated waste water to create a pressure barrier to protect fresh-water aquifers from salt-water intrusion

- Use of reverse osmosis (filtration with membranes or hollow fibers under pressure) to cleanse waste water

Feasibility of reusing waste water depends on the ease with which quality can be improved to meet requirements of intended users. Further research, including development and operation of prototype facilities to determine acceptable practices, is needed.

Recycling is the fastest and simplest way to deal with water problems. Over the short run, recyling will increase. New chemicals for use in treating or purifying water, and new types of hardware will be developed, e.g. boilers, valves, pipes, compressors, pumps, heat exchange instruments and controls. More filters or fluid control equipment that turn dirty water into drinking water will be manufactured. Electro-chemical, solar powered systems are already used in many parts of the world to make brackish water potable.

Increased use of waste water and return flows may require rearranging the sequence of uses so that those requiring the highest use come first, followed by users who are increasingly tolerant of lower-quality water. More often reuse may be increased by the installation of improved treatment facilities, either at the first user's effluent or at the second user's intake. Genetically engineered micro-organisms may be developed for use in water cleansing, especially for oil spills; but extensive research will be necessary to insure against potential effects on human health and the environment before their large scale release into the environment. Such measures are costly, and they may consume significant quantities of energy as well as chemicals. Some high risk low profit areas may be of interest to society, but may need government promotion if they are to be developed. Changes in the quality of the environment may occur directly, or as the result of decreased stream flows below the region of more intensive water use.

Desalination

Water desalination, or desalting, is the process by which potable water is produced from saline or brackish waters. It is one method that can be developed to meet threatening water shortages and pressures caused by increasing requirements in water-short areas.

Since 1955, the number of desalination plants has increased from about a dozen, producing 2 million gallons per day, to more than 330 producing almost 100 million gallons per day--about 0.1 percent of the nation's total fresh water withdrawals for domestic and manufacturing use. Although most desalination is for industrial purposes, its use for domestic purposes has inceased in recent years. In 1975 it was over 30 million gallons per day.

Fifty-four percent of the desalination plants are in California, Texas and Florida. However about 61 percent of the installed capacity is east of the Mississippi River and a significant number of the plants are in the industrialized northeast. Desalination operations are still expensive and they also use significant quantities of energy; therefore desalination facilities are constructed only if alternative sources of water are unavailable or more costly.

Desalination can be done efficiently in conjunction with OTEC energy production. Where water is already lifted to take advantage of the temperature gradient, it can be forced through tubules or membranes for reverse osmosis.

Improved Management

Water supplies can be improved by better management of water storage and distribution facilities. Water research and development activities are fragmented among 28 federal organizations. It is difficult to assure that conservation and augmentation technologies with the most potential receive the highest level of federal funding. An important part of surface water management is the allocation of water for artificially recharging ground-water when a temporary surplus of surface water occurs. Much of future water needs will be satisfied by better and more comprehensive planning. Adverse water-quality conditions will receive additional attention, ground-water overdraft conditions will be better defined, and flood-plain management procedures will be further developed.

Careful planning and consultation between biologists, hydrologists, and mine engineers can reduce toxic waste injection into aquifers and help effective restoration of these underground reservoirs. Newly developed computer simulations can add to planning strategies.

Water projects generally support a dominant single purpose such as urban water supply, irrigation, flood control, or navigation. Additional purposes are sometimes incorporated as justification, such as hydroelectric generation, to provide revenue. As a result of this single-purpose approach, adverse environmental effects sometimes occur and water is not available for other purposes.

Since deficits can be overcome either by adding storage to increase dependable flow, provided flow is not already at a maximum, or by raising the level of waste treatment in order to reduce required dilution flows, there is a choice among the three types of programs: one that holds new storage to a minimum, one that minimizes treatment, and one that aims at a least-cost combination of treatment and storage.

As projected requirements increase, the range of choice among programs narrows. When the requirement for waste treatment is carried to above 95 per cent, the flow is restricted, and curtailment of water use is the only solution. When this occurs, the water deficit will have to be dealt with by such remedies as changes in the distribution of population, land use or economic activity.

By 2005 total in-plant manufacturing water requirements are projected to increase 500 percent. However because of pollution control limitations on waste discharge, the technology of water management within plants is expected to change. The result of innovative water management technology will be a tenfold in-plant recycling increase. Fresh-water withdrawals are thus projected to decline by one-third.

Although advances in cooling technology by the year 2005 will result in a decrease of 11 percent in freshwater withdrawals for steam-powered generation of electricity, that process will still account for 94 percent of withdrawals for energy production. Unless new technology is developed for return of less hot cooling water, consumption (water not returned to use) will increase from 2 percent of freshwater withdrawals to 13 percent for electric production. This is due largely to greater evaporation resulting from higher temperatures in the recycling process.

Another step taken in the case of water shortage involves reducing rates of water use. This may be through economic incentive, as increasing scarcity drives up the cost of water, or administratively, with regulation. Water use may also be reduced by new, less water-intensive technology (cooling towers for power plants, or drip irrigation).

When all means of augmentation and water-use reduction have been exhausted, and withdrawals still threaten to exceed available supply, water must be allocated among several uses, so that the damages resulting from shortages will be minimized, or the water supply will fail entirely. Supply failure creates a potential for public health problems, industrial shutdowns, and massive crop failures (which also have human health implications).

Some supply measures can be implemented only after relatively long-term planning and construction (water transmission and storage facilities); others are available on an immediate and short-term basis (water-use reduction techniques not involving new technology). The options which require construction have the additional potential of creating adverse environmental impacts, and may require large increases in the use of energy. The least disruptive option may lie in still longer-term planning, to place future water-using activities in areas better able to provide the necessary water. This has implications for increased concentration of industry and population near oceans.

To prevent decline of ground-water levels to where pumping is uneconomical, several things can be done:

- o Alternative sources of water found
- o Artificial recharge developed
- o Water-using activities relocated
- o Water use reduced through improved management

In the absence of appropriate water-conserving measures, the increasing energy costs related to greater pumping lifts could force abandonment of irrigated cropping (which withdraws more ground-water than any other use) if no other source of water at reasonable cost is available.

A mix of increased storage and other alternatives seems to offer the most effective solution. To sustain desired withdrawals, considerable additional storage would be needed, but in many areas neither the reservoir sites nor the uncommitted flow are available. If projected water requirements are to be satisfied, there is a strong need for water conservation to save water, weather modification to increase precipitation, and improved methods to reduce evaporation.

The problem of water supply and control will be more manageable in the future with use of services such as the National Water Data Exchange (NAWDEX) of the U.S. Geological Survey. This data base now has available a large collection of data dealing with water resources and it will become more comprehensive. It deals with the primary areas of surface waters, ground waters, and water quality, and includes reports of the geology, hydrology, recoverability, and utilization of water resources. The Master Water Data Index, a computerized data base implemented by NAWDEX, includes information about more than 375,000 hydrologic sites operated by over 400 organizations. Meteorological data (rainfall, temperature, and wind velocity), the indexing of streamflow, river stage and rainfall data measured at 15-minute intervals, 60-minute intervals, etc., and the primary use of water at each site, are among the data available. Use of such data in the future will lead to improved managemnt of the available resources.

Research is likely to reveal correlation between the sun's activities and climatological changes on earth--i.e., sun spots, luminosity, magnetic storms, etc. It is estimated that a change of less than 0.1% in the sun's luminosity could have a most significant effect on the climate of earth. Means of detecting these solar changes will also be refined and further developed--such as identifying spectral details and correlating them with environmental/climatological changes on earth, and coupling components of change in one medium to those in the other.

4. FORECAST: TECHNOLOGIES RELATED TO THE ADVANCED MARINE VEHICLE

In this section is a brief description of some of the key technological areas of change. Following this is a description of some of the specific types of vehicles which appear to define the spectrum of possibilities for the advanced marine vehicle in the year 2005.

Vehicle Technologies

Improved seagoing vehicle technology is driven both by expectation of future conditions in the marine environment and by direct technological opportunities. Both sources of change are addressed.

The costs of conventional resource extraction will continue to rise, leading to the economic feasibility of platforms which are now infeasible. Massive and highly cumbersome offshore platform/vehicles will be developed and placed into operation. They will be mobile, weather-proof, and move about the ocean floor to explore and extract resources. Manned and unmanned diving vehicles, submersibles, and other deep-water apparatus will come into common use, enabling work at great depth to inspect, maintain, and repair the massive offshore structures and associated equipment.

Technology will enhance the reliability and maintainability of vehicles, structures and equipment. Nuclear propulsion will be revived as a primary means of moving heavier sea-going vehicles. Advanced vehicle designs will come into use, e.g. air cushion vehicles, and all sea-going air and surface vehicles will be improved with respect to ability to operate under adverse weather conditions.

The following paragraphs identify likely advances in specific categories of vehicle or vehicle-related technologies.

Shipbuilding technology

In the 1980s, shipbuilding will continue to move dramatically from the more developed to lesser developed countries. Western Europe halved its orders from 1970 to 1980, with workforce falling 46%. Third-world countries led by South Korea, Taiwan and Brazil increased ship construction by 30%. Japanese ship-building workforce has fallen by almost 35%. By 2005, that trend will be reversing, with the more developed countries' improved technology, (downsizing and automation) diversification and specialization. Primarily motivated by strategic need, the U.S. will have improved its own shipbuilding capabilities. Building yards will have been forced to expand and to use advanced technology in design and construction.

Ship building will be increasingly automated, from the design phase, shortened by three-dimensional computer displays, through the production phase with computers operating hundreds of machine tools simultaneously, and greatly enhanced quality control. Modular construction will predominate. There will be new options in structural materials used in shipbuilding.

Propulsion Systems

Technological advances will occur in several areas. Advances in fuel cells, diesel-driven systems, gas-turbine systems, and nuclear systems will lengthen the reach of vessels without refueling. Aircraft with greater endurance and higher speeds will also be available. Submersibles will be available with long endurance and quiet operation. To conserve fuel, conversion will be necessary to new and more efficient types of ship and aircraft propulsion.

Two esoteric forms of propulsion are the object of serious research. Neither of these forms is likely to come to fruition before the end of the century, but may show promise soon after that.

- <u>Electromagnetic Propulsion:</u> Electromagnetic propulsion has been envisioned since at least 1950, when Stewart Wey, a consultant for Westinghouse Corp. developed the idea for use for submarines. At the higher speed promised by electromagnetic propulsion, subs would have less drag than wave-hindered surface vehicles. The drawback has been massive weight, high cost, or both.

  The development of highly efficient niobium-titanium superconductors, cooled by liquid helium to a temperature of -550° F., may prove the feasibility of electromagnetic propulsion. A full scale, 10,000-ton submarine tanker may achieve a top speed of 115 miles per hour. The sub's demand for fuel would be less than the fuel needs of a traditional tanker.

  Another use of electromagnetic propulsion would be for propelling ships by means of a network of submerged cables in a port.

- <u>Marine Electric Drive System Ships:</u> The U.S. Navy has produced an operational acrylic superconducting marine electric drive system that may lead the way to smaller, more efficient naval ships. The system performed "almost flawlessly" during sea trials. It makes use of the superconductivity phenomenon at very low temperatures (-450° F.), in which intense magnetic fields can be generated using small amounts of material. Liquid helium is used to cool the superconductor magnetic system to produce a small, lightweight and quiet DC motor/generator.

  Navy ships with as much as 14% reduction in size but no change in performance and payload could be produced with savings in construction and operating costs.

  The advantages of electrical over mechanical drive systems include freedom of machinery arrangement, variable prime mover to propeller speed ratio, and cross-connect capability in multi-screw ships.

Hulls and Airframes

New forms of hull design, such as hydrofoil, air-cushion vehicles, etc., constitute the most important direction of change. In addition, new forms of helicopter and VSTOL aircraft will facilitate inter-craft transfer in heavy seas.

Combinations of advances in both propulsion and hull/airframe design will have a synergistic effect in two relatively new forms of propulsion:

- "Super-cavitation" designs will increase the efficiency and speed of hydrofoil boats and ships. Water is separated from the upper surface of the leading edge of the foil surface, leaving the whole surface unwetted, and the cavities do not collapse until well behind the foil; this prevents the buffeting and erosion of the surface, and promotes increased efficiency in energy transmission from the propulsion system to vehicular motion.

- "Jetfoil" techniques to augment delivery to the wat r of the energy of propulsion will become operationally feasible. These are configurations of propeller, hull, and propeller guards to enhance energy transfer from propeller to water.

Vehicular Materials

Advances in vehicular materials appear to offer desirable characteristics in a number of dimensions:

- Radar Invisibility: Through the use of "composite" materials the Defense Department has demonstrated that it is possible to negate a radar pulse through microantennas and circuits tuned to the radar frequency, absorbing most of the energy, thus resulting in little reflection. A new family of composite materials of carbon fiber and silicon fiber-wound structures, stronger than aluminum and almost as strong as steel, but lighter than both, exists that is almost transparent to radar pulses. Du Pont's strong and light Kevlar™ can be fabricated in strands or extruded, cast or forged. Naval architects, naval engineers and ocean engineers could use these materials for surface craft that are "invisible" to radar and submarines that are "invisible" to sonar. Surface craft such as air cushion, surface effect, hydrofoil and other high-speed vehicles are candidates for this technology.

- Weight Reduction; The Air Force has developed fiber-reinforced composite materials that reduce structural weight by 30%, and in 1982 will begin advanced development programs that will show these materials as suitable for the primary structure of large combat aircraft and will extend their allowable operating temperature range to equal or exceed aluminum.

The AF program in metal matrix composites has demonstrated their strength and stiffness. Their durability and damage-tolerant properties are less understood. They are already being used in secondary structures, for unique uses, such as radar absorption.

- Lubricants: The science of materials will develop new lubricants with several very useful properties:

  - Capacity to operate at extremely low temperatures without thickening and freezing
  - Capacity to operate at extremely high temperatures without decomposition, vaporization, or oxidation
  - Capacity to withstand long periods in storage without deteriorating absorption of dirt and debri, or separation of additives
  - Capacity to withstand long and heavy loads between bearing surface without degradation
  - Reduction in amount required for a given area of lubrication

The application to marine operations are many. It appears possible, for example, to use conductive graphite for transmission lines and lightweight wiring in aircraft, which would lead to enormous savings in weight, and therefore energy. Solar cells and light, rechargeable batteries essential to conversion and transportation of solar electricity may have applicati·n to submersibles, ships, and aircraft.

The Soviets may be using titanium for their new huge attack submarine. If so, because of the strength and light weight of titanium, the Soviet sub may go faster and deeper than any U.S. sub.

New Vehicle Types

Because of the long lead times associated with the building and introduction into operational use of sea vehicles, any vehicles in operation by 2005 must of necessity be already operational, in development, or a combination of both. This section describes a spectrum of these types.

Some combination of three specific features will make the marine vehicles of the year 2005 different from contemporary units. One is automated control. Consistent with advances in microprocessing and with C^3 technology, this feature will be acquired at only a slight increase in cost. A second feature is the capability to move rapidly over the sea surface. The third feature is the capability to maintain a stable platform in heavy seas, which facilitates interaction among craft at sea in heavy weather. In contrast to the first feature, the second and third can be acquired only at significant increase in cost. Further, the requirement for the third may be overtaken by introduction of robotics.

These advanced vehicles all have advantages in one or more of three characteristics where change in technology promises to offer the greatest operational benefits. These are: lift, speed (i.e. propulsion), and stability. The following tabulation indicates the possibilities in each of these three dimensions, and the general areas that research and development in vehicular technology is emphasizing today:

1. Three high-speed "surface" vehicles--air cushion, hydrofoil, and wing-in-ground (and ram-wing)
2. An ultra-stable vehicle of moderate speed--SWATH
3. Lighter-than-air vehicles
4. Remotely piloted vehicles

1. High-Speed "Surface" Vehicles

Three basic types constitute this class. The first is the air cushion vehicle which rides on a cushion of air propelled downward from the body of the craft. Propulsion is by a combination of screw, water jet, and/or directional characteristics of the supporting stream forming the cushion. These craft are called "hovercraft" since they have the capability to hover at zero speed over a given spot. The second class is the hydrofoil. The hydrofoil's weight is supported by foils either deeply submerged or submerged just below the surface. Its hull is clear of the water when it is foilborne, but it rides on the hull at slow speeds. The advantage of both hovercraft and hydrofoil craft is elimination of water resistance, allowing high-speed operation. The third class is the "ram-wing"--a hybrid form of aircraft whose airframe and wing design forms a cushion of weight-supporting air beheath the craft as it flies through the air over land or water surfaces.

Procurement costs, from least to most, are: sidewall hovercraft (SES), catamaran and surface-piercing hydrofoils, amphibious hovercraft, fully-submerged hydrofoil, and ram-wing craft.

For speeds over water below 30 kt the ordinary displacement ship has most of the advantages, though large ships are required for the higher range of these speeds. Between 30 and 60 kt hydrofoil craft offer a smoother and quieter passage than planing boats, and at the expense of slightly less power. They are less expensive to build and operate than helicopters, and less expensive than aircraft over short distances. They are also quieter, cheaper and more seaworthy in rough water than hovercraft, though they lack the advantage of being able to travel over land as well as water. Between 30 and 60 kt, the hydrofoil craft requires less power per ton than any other kind of craft that travels through or above the water. Above 60 kt the choice is between supercavitating hydrofoil craft, helicopters and hovercraft, but at still higher speeds the aircraft comes into its own.

Hydrofoils are useful for missions such as customs launches and police boats, and other law-enforcement roles, where they can patrol at low, economical speeds with foils retracted, yet take off in seconds and overhaul anything that floats--then, with foils retracted again, they can follow a boat into shallows, and beach if necessary.

The ram-wing and wing-in-ground effect craft are essentially aircraft designed to exploit aerodynamic phenomena close to the earth or sea surface. The ram-wing is a craft with a short-span wing with sidewalls at its tips. Its trailing edge and sidewalls remain either in contact with, or almost touching the water surface. At speed, lifting forces are generated both by the wing and the ram-air pressure built up beneath. The wing-in-ground effect machine has an appearance of a flying boat with short-span wings. It is designed to operate low down, at a height equal to half its wing span or less, where it rides on a dynamic air cushion set up between the machine and the surface below.

Flying within the ground-effect cushion, there is a remarkable drop in induced drag, which lowers fuel consumption, and increases the payload/range capability. A heavy sea state imposes limitations on flight because of the interaction between water and vehicle.

2. The Ultra-Stable Vehicle--SWATH

SWATH is a semisubmerged ship design, consisting of two deeply submerged hulls connected to an above-water platform. It has an advantage in stability and greatly increased useable volume for a given displacement. Heavy weapons systems can be carried with more design flexibility and mounting. It is an excellent sonar platform, especially for towing passive sonar arrays, capable of maintaining a stable platform, but maximum speed is about 17 kts. For Coast Guard ELT missions, a maximum speed under 20 kts is unacceptable; however, because of its stability in high seas, SWATH may be the choice for a V/STOL platform. Fitted with hydrofoil capability for fast sprint, the design could be in use by the year 2005 in possible Coast guard uses of law enforcement, SAR, Commercial Vessel Safety, Marine Science, Environmental Protection, or military operations, all to be conducted in a range from inshore to 200 miles offshore.

3. Lighter-Than-Air

Interest in the use of LTA craft appears to be reviving because of their fuel efficiency. Airship enthusiasts agree that "there are no technical problems in building airships that are beyond solution." The Modern Airship Vehicle (MAV) can be built to be safe, fast enough for practical use, and profitable.

Goodyear Aerospace has developed Data Link or Instant Intelligence, the hot-air balloon which enables ejected pilots to be rescued in the air, and the Giant Eye. Under a continuous study of the feasiblity of MAVs under contract with NASA, Goodyear has proposed construction of a space-age ZPG-3W, the largest nonrigid airship ever built, to meet emerging needs for airborn platforms, cargo transport and for military purposes.

Shell Oil has a contract with Airhip Industries LTD. (Britain) to design a giant airship to transport natural gas in a gaseous state. Shell is satisfied with the economics of the airship, concluding that it would save 30 percent over LNG. Substantial savings would be possible for cargo in an airship cruising at 200 miles per hour, because of the large loads, reduced transit time, and lowered fuel costs. The state of the art makes much of this possible today. The new materials would make the airship less vulnerable to weather, and sophisticated electronics are available to avoid the worst weather.

4. Remotely Operated Vehicles

Several of the vehicles listed above would be suitable for remote operations. A small, remotely piloted seaplane would make use of the new command, control, and communications technology expected to make substantial progress within the next decade. A small ELT task force could be developed consisting of pilotless vehicles on full-scale combat, reconnaissance, or other types of missions under the radio control of a ground station, "mother" aircraft, or satellite. A Navy study indicates that such planes, fully loaded with electronic eavesdropping

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TECHNOLOGY SCENARIO FOR THE YEAR 2005. VOLUME I. BASIC REPORT.(U)
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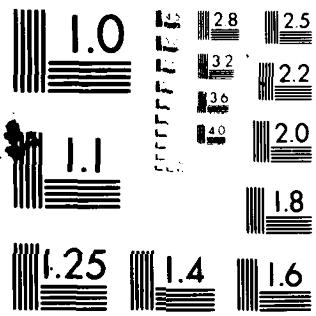

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

gear, could be operated in waves as high as 16 feet. By spending time loitering on the water's surface during deployment, a force of five such craft could probably accomplish a week's antisubmarine mission at a third the cost of deploying a similar number of land-based ASW aircraft, and one-eighth the cost of an ASW mission conducted by surface vessels.

Although robots are usually not considered to be remotely operated vehicles, we include them here because our forecast is that robotics is an emerging technology of great importance to the Coast Guard. The technology is expected to grow dramatically by the end of the century. By this time the U.S. may have caught up with some of the other nations, notably Japan, who have invested more in the technology. The robot may make a crucially important contribution to Coast Guard capability for surface vessel intership interaction in adverse weather conditions--either in rescue or law enforcement missions.

CHAPTER 6: TECHNOLOGICAL FORECAST: COMMAND AND CONTROL CAPABILITIES

This chapter is the first of four focussing on the respective scenario themes. This chapter is first, a forecast of the general capabilities that a command control and communications (C^3) system could have in the year 2005, and second a more specific description of a hypothetical C^3 system that could be operating in the year 2005.

FORECAST: COMMAND AND CONTROL SYSTEM CAPABILITIES

The technology of automation will become sufficiently sophisticated by the year 2005 to permit the automation of many tactical operations performed by the military services. This will be programmed into the C^3 computers, and operational commanders will rely upon them for a significant number of operational situations. Manual override will always be possible.

In fact, the C^3 technology will advance so rapidly that senior operational commanders will find themselves doubting that a system can perform as specified. This incredulity will lead to slower adoption of the systems than could otherwise occur.

One feature of these future systems that will be taken advantage of, however, is the capability to present overviews of tactical situations to all echelons in an operational chain. In this way each level will have a far more complete picture of any tactical and strategic situation than has been possible before. This advance will stem from the cost and size reduction of equipment so that each operating ship or aircraft can be equipped with sufficient instrumentation to provide an overview of each operational situation almost equivalent to the breadth and scope of the view provided to the operational commander. That is, the difference in the viewpoint of the senior operating personnel from that of the most junior unit will be significantly reduced from that of the 1980's. This will permit the exercise of increased freedom of judgment on the part of the on-scene officers, with concurrent overview and override opportunity by the senior.

Some of the specific capabilities which will support this degree of automation include developments in the areas of decision making, decision guidance, information availability, rapid computation, and communications. Brief descriptions of some of the developments in each of these areas follow.

In addition to applications in the C^3 systems, computer technologies will result in the automation of most of the functions in ships and aircraft. Mini-computers will be incorporated into the designs of most equipment to monitor and control its operation, and to insure the early detection, diagnosis and often automatic repair of faults.

DECISION MAKING

Operational commanders in all of the services will continue to guard their operational decision-making freedom and are not expected to subordinate their own judgement to a computer print-out. However, as they become accustomed to the capabilities of advanced computer technology they will make increasing use of computer solutions in their own tactical decisions.

- Programmed options

  A series of preprogrammed operational solutions will be made to suit a large number of possible situations. Decision criteria will be programmed into the C^3 system, and sensor entries to the system will establish the fact base against which to assess conformity to the decision criteria. As operational situations develop and change, the system will display the decision criteria, the movement of variable[illegible]d or away from these criteria, and the fact that a decision is [illegible]nt. Override at any time by the commander will be possible, and he w[illegible] be able to select either "Go with preprogrammed decision unless told otherwise" or "Go to the point of decision and no further" leaving the actual implementation to the commander.

- Presentation of judgmental aspects for selection

  Each operational decision involves judgmental aspects, not susceptible to quantification or preprogramming through algorithms. Computer programs and displays will be developed which permit injection of the commander's judgment choices into the decision in a variety of ways.

- "Judgmental" probability assessment

  In the context of the above, the C^3 commander will have available the means to inject into the program his own judgment with respect to several variables whose values may not be reflected by the C^3 system in conformance with his judgment; this injection then will change the computer outputs accordingly. The display in the C^3 center presents to the commander a visual indication that a variable has been assigned a probability of having a certain value by the computer, but that the commander may wish to alter that value to suit his own judgment of the actual situation. Examples: probability that a rain squall will interfere with an operation; likelihood that commercial traffic in the vicinity will converge to embarrass an operational commander.

- "Judgmental" expected value assessment

  The computer programs described above will also present to the C^3 commander "expected values" of certain variables; these are variables whose values the commander may wish to change to be more in accord with his own judgment. An example might be a computer-estimated point of nearest approach by a suspected law violator, or a value attibuted by the system to the time of confluence of a mass of fishing boats entering a particular zone. The commander may wish to change one of the input variables in a "What if.....?" type question, thereby bringing about a change in the expected value of the time of convergence.

o Preprogrammed operational decision criteria

Associated with the foregoing capability of the C^3 system to preprogram objectives, is its capability to receive decision criteria against which to test algorithmically the degree to which individual operational decisions appear to be contributing to meeting these criteria, or the degree to which any decision may violate one or more criteria.

GUIDANCE FOR MAKING DECISIONS

The computer-based systems will also be capable of providing operating commanders with policy or doctrinal guidance to assist them in their tactical decision making. For example the following capabilities are foreseen.

o Preprogrammed operational objectives

Many operational objects can be analysed in terms of a hierarchical structure -- primary objective, supported by subsidiary objectives in several tiers. To the degree that an operational commander is willing or capable of structuring his objectives in such a manner, the C^3 system will be capable of keeping track of them, and also capable of keeping track of the progress the operation is making toward them. In the tension of operational exigencies, feedback from the system to the commander then provides information useful to check the soundness of individual decisions, i.e. whether these decisions are logical in the context of the structure of preprogrammed objectives.

Example: An objective might be to interdict a flow of smuggling operations over a specific region of the ocean. Designed subordinate objectives could be to deploy own forces in a certain predetermined array; establish surveillance coverage in a specified manner; insure that subordinate commanders have been briefed against certain requirements; etc. As the operation proceeds the C^3 system is capable of feeding back to the commander the state of progress toward each of these subordinate objectives without his queries. This enables him to become enmeshed in concentrating on the operation, without danger of himself or his staff suffering from mental lapses that permit catastrophic or near-catastrophic errors.

- Preprogrammed tactical guidelines

  This is a special case of the immediately foregoing. Tactical guidelines or doctrine may be one category of criteria fed into the system.

- Preprogrammed priorities

  The commander will be alerted if his decision does not conform to the programmed priorities of objectives.

- Preprogrammed consistency rules

  The commander will be able to check his decision against programmed consistency rules for both the original criteria and his own earlier objectives and decisions.

- "Do you really mean it?" display

  Consistent with the above, displays will offer signals to commanders to indicate that the decision maker may do well to pause and reflect upon impending irrevocable decisions.

- Prioritization in terms of variance from a standard

  Automatic monitoring of key variables--the "vital signs" of the operation--will permit the commander to monitor complex operations with confidence. He will be assured that even with a very large number of variables under his surveillance, any deviation by more than a specified amount from a standard will be detected and reported by the system.

- Cybernetic Systems

  Human-created "cybernetic" systems are extremely complex and integrated electronic, mechanical, biological, systems with automated feed-back and control. They have appeared on the science horizon as potentially adaptable to the service of the operational CG commander. This means that overall mission objectives, and the strategies for their attainment, can be built in to the system in such a way as to minimize human injections into the decision process at the scene of action. This in turn will minimize the number of personnel required in the C^3 centers, and will increase the probability of mission accomplishment. Game theoretic systems will become competitive with one another, and programming competence will pay off at least as much as on-site action competence.

VIDEO DISPLAYS

A variety of visual and audio-visual display techniques will be available to operational commanders, two of which are exemplified as follows.

- Graphic Displays for Decision Making

  A wide variety of displays will be available for presentation to the commander and his operational staff to depict geographical variables, geographical scenes, solutions to optimization problems in the operation, projected positions of selected operating units, etc. These displays include statistical presentations of distribution functions, probability functions, decision trees, etc.

- 3D Video Telephone and Radio Telephone

  Widespread use of 3D video and voice radio/telephone communications equipment permits reduction in the number and frequency of conferences required in establishing operational policies, and in commander-to-commander discussion of operational issues.

  Probes will be capable of moving objects about in 3D space, ranging on them, and making assessments of their relative positions and velocities.

COMPUTATIONAL CAPABILITIES

In addition to the foregoing we forecast that the computer systems of the year 2005 will be capable of performing on-line computations.

- Ability to respond to "What if..." Questions

  This is the capability to respond to queries from the commander or his staff as to what is the likely outcome of certain changes in variables -- e.g. assumptions upon which the operational situation may be based, or criteria inserted into the system for decision-assisting roles. An example, might be a question such as "What will be the closest point of approach to a specified target if I change the course and speed of one of my units to a different value?"

- Testing of tactics with on-line simulation

  On-line simulation of operations will be possible and will permit on-scene commanders to check out different operational strategies/tactics in a simulation mode before commitment to action; this can be accomplished in a relatively short time.

o Statistical computations and feed-out on-line

The tactical data systems will provide to commanders the probability distributions, histograms, and standard statistics of distributions of most of the variables associated with his operation--both ongoing and historical.

o Probability and expected value answers

The commander will be able to ask questions of the system such as: "What is the probability of target A passing within x miles of unit B?"; "What is the expected value of the time of intercept?"; etc.

INFORMATION AVAILABILITY

One of the key attributes of these advanced systems will be their capability to acquire, manipulate, and present a variety of types of information in forms to suit the needs of the operational commander. Some of these characteristics may include the following.

o Information acquisition

Preprogrammed into the system is the constant search for information of specified types. In other words, the system is constantly alert to acquire specified types of information by radar or other means, without further direction from the operational commander.

o EW display of selective sources -- "What do you see with the following characteristics out there?"

The data systems will be capable of answering queries such as "Search the region under surveillance for targets with the following characteristics and report all that you find".

o Jamming and anti-jamming advances

Jamming/anti-jamming technology will advance evenly so that jam-proofing is just about as feasible as it has been for several decades--that is, feasible only to a degree.

o Play-back features

All tactical data systems in ships and aircraft and in C^3 centers will have the capability to play back selected portions of what has gone on in the system--not only what has been displayed, but also what has gone through the system. This means that an event that occurred but did not appear on any display can be recalled for viewing, even though it has not been observed to that point.

o Warning signals: "Watch it; you may have a problem!"

As part of the foregoing feature, the system will provide the commander with special alerts to deviations of more than average significance--such as an unidentified target that has not been acknowledged by the operators.

COMMUNICATIONS

Communications between operating units will be enhanced by orders of magnitude over the capabilities of the 1980s.

o Communications channels

The managability of frequency spectra will improve to the point that the number of communications channels available within a given frequency band will increase. "Spread spectrum" communications will be in wide use.

o Communications denial systems--EM absorption by materials

New materials will be available with highly electromagnetic absorptive characteristics; radar invisibility will not be fully possible, but near-invisibility will be in line with the "Stealth" research of the 1980s.

o Cryptography--Voice coding/decoding/analysis

Cryptological advances have made voice coding and decoding highly feasible. This means that transmission/reception can be adapted to a single--or selected multiple-voice characteristics, i.e. transmit that voice and no other, and receive that voice and no other. The voice to machine interface is also easily crossed--with automatic dictation feasible, and voice play-back interchangable with video play-back.

DESCRIPTION: THE COMMAND, CONTROL, COMMUNICATIONS SYSTEM

This section describes a hypothetical system that could exist in the year 2005 and be in use by the Coast Guard if advantage is taken of capabilities forecast in the previous section. We present this description in terms of three components of the system--the command, control and communications center itself--which we have labeled the "C^4"; the information sources for the system in general and for this center in particular; and the "on-scene" situation from the point of view of C^3 capabilities.

THE COMMAND COMMUNICATIONS AND CONTROL CENTER (C^4)

The cost of automation equipment will be sufficiently low, and the size sufficiently small to permit C^4's in virtually all Coast Guard ships and aircraft. Each C^4 will be capable of handling essentially all the data/information required by all the levels of command, from Commandant down. Thus command may be exercised from virtually any ship or station where the operational commander is, or may be assumed by the commander nearest the scene. All C^4's have essentially the same capability.

Each C^4 will have both general and special facilities. The general display screens will be 3D and will present views of the regions under the cognizance of the commander, adjusted to suit the circumstance in terms of large regions covered comprehensively, or smaller regions covered in more detail, but less comprehensively. Passive electromagnetic sensors will introduce intelligence/information/data into the displays automatically to add corroboration to the active radar/IR/laser products on the display.

Separate display screens in the C^4 will be devoted to summary plots for each of the types of operation for which the commander is responsible--fisheries, SAR, environmental protection, enforcement of laws and treaties, safety and security of offshore installations, and military operations. These displays will be dynamic; e.g. they will move with the migration of the fish, fed automatically from the data sources in the intelligence system, which in turn is fed by satellite. In addition, each screen can show additional data about fishing activity in progress, and fishing craft approaching. When suspicious craft are active in the region, they will be monitored by remote sensing devices, both satellite and earth surface mounted. When Coast Guard action is demanded, the screen will present complete information on all Coast Guard craft, including surface, air, and subsurface. Direct communications with all operating units will permit the commander to exercise complete operational control over the situation.

Common Characteristics of the C^4

Almost all of the craft in an operation will have the capability to operate a C^4, and we forecast that most of them will be equipped with such a center. In these centers audio and visual displays will be coordinated in terms of "human engineering"--adaptable within broad limits to personal preferences of individual Commanders. They will be highly "automated" in the sense that almost all operations are in some way controlled or monitored by a small computer, built into the system. This automation is not necessarily unique to the C^3 system, but is ubiquitous; virtually all equipment and machinery will have this attribute--to control operations, to identify and locate faults as they occur, and in many cases to correct these faults. In addition, we forecast that these centers will have certain common characteristics, summarized as follows.

- The human-machine interface in each C^4 will be highly sophisticated to optimize the capabilities of the human and the machine elements over time and circumstance. All information on one or more targets will be available to operational commanders, but the information/intelligence will be tailored to the particular needs of each member of the C^4 team--electronic intelligence, weapons, material readiness, communications, detection, tactics, support forces, logistics situation, etc. The "fog of operations" often will be significantly diminished because the distinction between certainties and uncertainties is made clear.

- Human interjection into the system can be made at the discretion of commanders and their staffs at "judgment points" in the system--not necessarily only at command/decision points, but at points where human judgment of varying degrees of expertise is required. Options to by-pass "judgment points" or to inject new ones will be available where needed. Each C^4 will maintain a record of judgmental inputs for post-mortem purposes. In addition to the options to inject judgment, each commander will have multiple options for injecting "what if......" questions, both in ongoing operations and in post mortems.

- Fault-tolerance will exist at low, intermediate and high levels--to test decisions against <u>all</u> information intelligence available and against policy decisions already made. "Did you really mean it?" questions emerge from this feature of the system. In addition, on-line simulation opportunities will exist at all stations for commanders to check out tentative decisions. Each C^4 has the on-line capability for commanders and others to alter programs as the need arises.

- The overload burden that was common in earlier systems will be relieved. The C^3 systems will be generally adequate for most loads, and the confidence of peronnel in equipment reliability will be high.

- A high degree of computational sophistication will provide for the use of statistical distribution and probability functions with confidence levels and limits. Personnel will be required to be educated to use these techniques.

INFORMATION SOURCES FOR THE C^4

By the year 2005, the sources of information to the C^4 will have become as sophisticated as the instrumentation within each center. These sources will have a common base in a National Intelligence System as backup to the C^3 System. Intelligence will be integrated with surveillance information for presentation.

National surveillance of all surface, air, and subsurface activities is maintained out to about 1500 miles through devices such as: satellite (including radar, laser, photo, infra red (IR), passive electromagnetic (EM)), acoustic (passive & active), ship and airborne radar, over-the-horizon (OTH) radar, electromagnetic reception, infra red, laser, and extremely low frequency (ELF) communications. Even EM/IR/olfactory/chemical detection of substance in ELT investigations will be presented. Forecasts of ship and aircraft movements will be made and presented to the C^4 in real time, and all levels of command will be able to see the same picture.

Additional features will include such items as:

- Electromagnetic detection and decryption of virtually all radio traffic in the region will be available to commanders. This will provide advance information on movements of almost all craft in the region.

- Historical data will be used to compute probabilities of changes; pattern recognition techniques will be used to identify similar situations and thereby to identify likely changes in present situations. Direct reading of radar and other sensor scopes will be reduced, and replaced by scope information manufactured by the computer to offer improved clarity.

ON-SCENE CHARACTERISTICS

In addition to the information and intelligence available through the intelligence and surveillance systems already described, each surface vessel and aircraft at the scene of action will have certain capabilities and equipment. The forecast of these capabilities, equipment and techniques available to the on-scene commander, beyond the capabilities described in the previous section include the following:

All Coast Guard ships and aircraft will have capabilities such as the following:

- o Capability to detect substances from outside ship and aircraft hulls/airframes at some distance through chemical, EM radiation, laser, holographic, acoustic, cosmic, and possibly even extrasensory means.
- o Capability to analyze voice patterns on-scene to detect various states of tension.
- o Capability to analyze both personnel and vehicular behavior patterns in terms of consistency with previous patterns -- with a view to detect abnormal patterns, and lead to sources of abnormalities; the "something's fishy" detector.
- o Surface-current sensing radar integrated into inertial navigation system.
- o CASP (computer assisted search plan) for visual searches in SAR and ELT visual detection. Parameters of search include:

Visibility	Cloud cover
Wind speed	Target shape, color, signatures
Swell height	Sun elevation

- o Display and communications equipment adaptable to personal preferences of on-scene Commanders--options of aggregating information to suit individual preferences.
- o Capability to acquire information on:
  - All vehicles as to location and movement.
  - Projected movements determined both by calculation, and by weighting of intelligence.
  - Weather and climate--both present and impending
  - Ocean conditions--temperature differentials, salinity, current effects, impurities effects

- Fish schools--location, movements, density, type, habit patterns

These capabilities will be acquired by a variety of equipment. Most Coast Guard surface and air craft operating at the scenes of SAR, ELT or military operations will be equipped with instruments/equipment in all of the following categories: sonar and other acoustic-related, optical, chemical, electromagnetic, electric field, magnetic, and weapons. The forecast of the types of equipment likely to be available in each of these categories follows.

o <u>Sonar</u>

A variety of sonar types, both active and passive, will be available with frequency analysis and discrimination capabilites to discern with almost visual acuity the immediate environment--out to a few hundred yards for high frequency sonar and out to several miles for lower frequency sonar. The technology of frequency analysis will permit identification of the acoustic signatures of virtually all the noise sources in the oceans. This will lead to an increase in the use of passive sonar over that of the 1980's.

- <u>Obstacle avoidance</u>

  Extremely high frequency sonar devices will enable surface and subsurface craft to detect and navigate around submerged obstacles of very small size. This same type sonar may also be used to detect other objects which are the target of search--either in SAR missions, or law enforcement missions.

- <u>Mapping (multi-beam)</u>

  Multi-beam sonars will be part of the capability of virtually all Coast Guard ships. These will have the capability to radiate simultaneously in several different directions at different frequencies in order to acquire a panoramic view of a region, and to map the region in 3D in real time.

- <u>Portable (hand-held)</u>

  Divers operating from certain surface craft will be equipped with hand-held sonar of high frequency which provides them with visibility of their environments equivalent to that provided by by flashlights.

- <u>Synthetic aperture</u>

  The small size possible with synthetic aperture technology will permit ships and helicopters of low weight-carrying capability to be equipped with versatile sonars.

- ASW sonar--passive and active

  The use for which sonar was originally developed, ASW, will continue to be one of its primary applications in the Navy. The Coast Guard military role will be somewhat more specialized, so the application to the Coast Guard is somewhat limited. However, the Coast Guard will maintain proficiency in ASW capability simply through its sonar applications in other uses.

- Parametric

  Special-purpose sonar will be available for particular missions in which the sonar function is not to make geographic searches over a range of distances and directions, but to direct search for targets of particular characteristics--principally acoustic characteristics. This type sonar will have application to law enforcement operations or military operations in which a particularly troublesome adversary's operation or device has existed for some time.

- Side-scan

  Complementary to the multi-beam sonar for map making is the side-scan sonar for search from a fast moving ship. This function will permit the ship to survey a far larger geographical region than would be possible through the more conventional sonar which directs its beam forward.

o Other acoustics-related equipment

Although any acoustic echo ranging or listening device in the ocean may be labeled "sonar", the following functions apply combinations of technologies including, but not confined to acoustics. Such technologies include magnetic, electrical, chemical, and mechanical.

- Imagery holography

  Acoustic/laser/mechanical holography will permit the thorough analysis of objects beneath the sea surface at relatively short range. These instruments will provide a highly sophisticated analysis of the acoustic and mechanical signatures of objects being examined.

- Bottom-profiling

  Acoustic/chemical/mechanical/laser devices will provide the capability to map in extremely great detail the bottom profiles in small area regions where interest in detail is intense.

- Positioning/navigation

  The same analysis/synthesis capability provided by this technology will also permit extremely accurate navigation through the use of a combination acoustic/magnetic navigation aids in ships and submarines.

- Sub-bottom profiling

  Advanced acoustics will provide the capability to make detailed surveys of the volume of seabed immediately beneath the water.

- Communications

  Underwater telephonic technology will permit communications between stations separated by several miles; it will include encryption and decryption functions.

- Environmental sensing

  Acoustic/magnetic/mechanical/electrical equipment will enable operational commanders to perceive the dynamics of environmental changes as they occur--changes such as movement of bottom silt, ocean currents, salinity and other mineral concentrations, temperature gradients, etc.

- Buoys

  Inexpensive information gathering devices may be placed in buoys and monitored, especially by ships and aircraft close by. These devices will enable commanders in operating units to identify the traffic of recent passage, and some of the activities of that traffic.

- Arrays

  Passive arrays of acoustic/optical/laser/magnetic/electromagnetic devices will be placed on or near the sea bottom and monitored for surveillance purposes.

o Optical equipment

The technology of wave form analysis will permit use of optical equipment to augment the other surveillance/detection equipment described above. This equipment will be particularly useful for short range surveillance where a degree of precision is warranted that cannot be obtained with lower frequency devices. In addition, other optical devices and techniques will include:

- Lidar detection

  Light in the low frequency end of the visible spectrum can be used for echo-ranging functions. These devices may be expensive, but for special high priority work requiring great precision of measurement at some distance they may serve a most important function.

- Imaging - aerial

  Photographic/holographic/television imagery in real-time from aircraft and satellite platforms will be available to on-scene operational peronnel.

- Imaging - range gating

  This imaging can be selective to particular range gates and frequencies in order to conduct search for specific targets of known characteristics.

- Imaging - scanning

  The imaging can also be made to scan wide geographic regions for less intense but more comprehensive coverage.

- Communications

  The use of microcircuitry using fiber optics and optical circuit microprocessors will permit reliable communications between stations from remote distances and over many channels. Security of communications by encryption will be high, although cryptographic technologies will render the balance between encryption and decryption uncertain most of the time.

- Environmental sensing

  Based upon satellite photograhic sensors, environmental surveillance from optical sensing will offer commanders complete knowledge of the current and immediate future state of the environment, plus a reasonable estimate of forthcoming changes.

- Foreward Looking Infrared (FLIR)

  FLIR devices will enhance the commanders view of the details of his tactical situation, especially at night and in low visibility weather.

- Use of Animals

  Pigeons will assist in detecting orange and yellow colored objects in SAR operations.

o Magnetic

The technology of magnetic detection from air and surface platforms will permit detection and identification of magnetic anomalies beneath the sea surface from several hundred yards. These instruments will provide the following information/intelligence to the operational commander on the scene: (1) initial detection of subsurface activity; (2) corroborative indication of activity detected by other means; and (3) identification through magnetic signatures of the nationalities and characteristics of the source of the activity.

o Electric Field

Electrostatic technology will augment magnetic detection technology in its surveillance role, especially for activities near the sea surface.

- o Electromagnetic

Extremely low frequency radiation may become the means of communcations between units just below the sea surface--down to a few hundred feet--and between these units and shore and sea bases at some distance. The technology of low frequency transmission beneath the sea surface promises even greater communications capability in the future.

- o Chemical

The capability to detect chemical characteristics through electromagnetic means and vice versa will permit on-scene commanders to acquire intelligence/ information on the nature of cargoes and the identity of personnel.

- o Weapons Likely to be Encountered

On-scene commanders may confront a variety of weapons, mostly in their law enforcement role. These weapons have approached the sophistication of military weapons as the forces of law violation have become more affluent.

  - Flare and chaff dispensing equipment to inject confusion into the operational commanders' view of the situation
  - Sophisticated C_3 equipment in law violation ships and aircraft
  - Terrain-following/terrain-avoidance systems in law violation craft
  - All-weather navigation capability in adversaries
  - Stand-off delivery capability in adversaries
  - Non-lethal incapacitating weaponry in use by law violation forces as well as by the law enforcment forces
  - Laser weapons of precision power also in use by law violation forces

CHAPTER 7: TECHNOLOGICAL FORECAST: ENVIRONMENTAL PROTECTION CAPABILITIES

The second scenario theme is "Environmental Protection", and this chapter presents a technological forecast in support of that scenario. A more detailed description of the scenario and related "Scenes" is presented in Chapter 2 of Volume II. This current chapter is presented in three parts. First is a discussion of the changing nature of environmental issues. Next is a description of the effects of the offshore build-up just now beginning and forecast to continue for several decades or more. Then is a description of the technology likely to be available in support of environmental protection efforts in the year 2005.

THE CHANGING FOCUS OF ENVIRONMENTAL ISSUES

Environmental protection will continue to represent a core of controversy through the end of the century. The intensity of the debate between environmentalists and developmentalists is unlikely to decrease in this study's forecast period. An impact of the technologies avaliable to protect the environment in 2005, however, will be to shift the debate considerably toward more general issues of growth versus a stable "zero sum" economy and the socioeconomic consequenses of development. That will be so because the ecological impact of development will not only be predictable, but systems will be available to mitigate undesirable effects, eliminate certain types of pollution, and convert other types into desirable injections into the water.

The more important characteristics of this changing focus of the environmental controversy are as follows:

- Research will have developed a new component of environmental management: the capability to manage the ecosystem in part by insuring that injections into the environment approximate "normal", healthy, and "natural" materials. The chemical and biological effects of materials injected into the ocean environment, or occuring there naturally, will be better understood. Linked with the research on the behavior and interaction of various injected materials will be sophisticated models of the natural variation in unpolluted marine ecosystems. Such models will demonstrate what types of changes are normal, and how ecosystems can be managed by introducing modified "natural" injections.

- The capability to exploit specific discharges to their limits will be developed. Coastal zone "protectors", regulators, and marine operators will have sophisticated techniques, knowledge and understanding of discharge. The result will be a revolution in marine management. Ocean science will go beyond merely understanding the assimulative or cleaning/biodegradition capability of marine ecosystems, to understanding how those processes work and to understanding the physiological, biochemical and geological interactions that make up a "healthy", "normal" system. The present debate will be shifted from how much material can be assimilated and how much development is safe, to how the material can be made or converted to something "natural". This will, to a large degree, obviate the traditional environmentalist argument that potential marine and coastal zone development is unsafe.

- The ability to allow for positive management rather than merely protection will lead to heavy pressures against the contemporary environmentalist position. It will no longer be logical. The issue in the marine environment will thus shift to mirror the wider social debate about the wisdom of further growth. As the technology of environmental protection improves, the slowing effect of the environmentalists will diminish, without jeopardy to the environment.

- A major concern will be to reach a broad social concensus toward growth in general and ocean resource development in particular. Effective, environmentally responsible sea zoning, aided by the technologies discussed below, will have an important role to play in the reaching of that consensus.

- A general balance will be reached as to the actual damage done to the ocean environment by a modest amount of waste dumping; the immensity of ocean water volume will become appreciated in terms of its capability to absorb foreign materials without unacceptable damage. This appreciation then will lead to acceptance of moderate amounts of dumping.

PHYSICAL/GEOGRAPHICAL EFFECTS OF OFFSHORE BUILD-UP

As the resources of the land environment become depleted and less accessible, the economies of the advanced industrial nations, including the U.S. will move seaward. This move will center for the next decades on oil extraction, but will eventually extend well beyond oil extraction. The physical and geographical effects of this offshore build-up will be both direct and indirect, or primary and secondary. The direct effects will be the changes in the physical characteristics of the region brought about by the physical developments offshore. The indirect or secondary effects may be even more important than the primary effects, but will not be as evident and will take longer to manifest their significance.

Before addressing the distinction between these primary and secondary effects, a word is in order concerning the very significant distinction between environmental considerations in a land vs a sea environment. While the ocean is more forgiving of many types of environmental uses than land-oriented ecosystems, the coastal zone is not. Catastrophic impacts are often more likely in that region than in either the land or the open sea environments. This is particularly true as it concerns the food chain. Much of the present discussion on environmental regulation, by both environmental groups and operators, is as applicable to one environmental zone as another; yet, there is a qualitative and quantitative difference in the range of outcome. Such differences, based upon actual effects, will be the foundation of sea use management regulatory systems.

Some of the more important characteristics of the primary and secondary effects are summarized as follows:

Primary Effects

- Extensive build-up of offshore activities will bring about significant changes in regional geography. The operating structures themselves will be only a part of this change; ancillary structures will be constructed, traffic-bearing conduits will be built, and support facilities of a variety of types will emerge including breakwaters and artificial harbors, etc.

- Traffic patterns will change both from the effects of the activities on in-transit traffic, and from the build-up of local traffic associated with the offshore complexes.

- Industries involved in extraction of living resources will also be affected. These will include fishing, crabbing, and all the other types of living resource extraction activities. Fishing grounds will be altered in location and often in their fundamental nature; new and different species will be fostered, while other species will find the new environment less supportive than before and will diminish in population. Environmentalists, fishermen and other special interest groups will raise strident objections, and will predict extreme and adverse effects from the new installations, most of which will not be born out in subsequent experience. On the contrary, a number of new and potentially exploitable types of living resources will be found to thrive, giving rise to new and unpredicted business opportunities.

- The natural environment will be changed, but not necessarily adversely. The extensive intrusion of human activities into the environment will be damaging to some elements of the environment, but stimulating to others.

- Construction activity and its debris will cause a temporary disruption to balance in nature:

  Some species of fish will be driven away, and their predators with them;

  Some scavengers will be attracted, and their predators with them;

  Some plant life will be temporarily destroyed, while other forms of plant life will be stimulated by the the absence of some of the fish life that has previously kept it in balance; As time approaches the end of the century, pollution is likely to be reduced; this will result from increased pressures from environmentalists, from advances in environmental technology duplicating and enhancing marine ecosystems as integrated systems, and from increased understanding of the mechanisms of the oceans' self-healing and self-restoration characteristcs.

- New types of underwater construction processes will be developed that make use of the natural organic activities of the oceans to contribute to the construction process itself--e.g., the use of low voltage electrolytic techniques to fill in structure frameworks, once the basic network of the structure has been deposited.

- Operational activity and its debris will make necessary a readjustment in nature's balance in most of the dimensions described above; this readjustment will involve transient changes at first, followed by gradual adjustment to steady-state conditions.

- The presence of foreign bodies in the oceans will also be a source of alteration in the balance of nature. Marine growth has always been a problem for ships and harbor facilities and it will continue to be so. However, it is likely to become susceptible to control and redirection in constructive ways by the end of the century.

o The changes just over the horizon and described here will lead to vociferous objections from a variety of special interest groups, including but by no means dominated by the environmentalists, as these changes emerge and appear to give advantage first to one then to another of these groups. These conflicts will present a demand for attention and resolution by whatever body of governance may be emerging for the marine environment.

Secondary effects

o The maintenance and hygiene of the marine environment will become a major activity in itself, involving heavy concentration of attention from both governing bodies and private enterprise.

o Developments and extensions in marine science and engineering will emerge that yield opportunities to exploit the ocean as a balanced community; these developments will have by-products in other applications and are likely to stimulate the development of new business activities.

FORECAST OF TECHNOLOGICAL CAPABILITY AVAILABLE TO PROTECT THE ENVIRONMENT

At the present time Coast Guard operational missions concerning the environment consist primarily of responding to oil spills, mostly close to shore, by applying the best local technique to counter them. By the end of the century it is forecast that the problem will be far more sophisticated, and will encompass a far wider scope of operational activity.

Missions of operating environmental control systems may be divided into three activities: monitoring, protection, and clean-up. All three will impact on CG roles/missions, and all three will provide data bases for an integrated national system of sea use management.

ENVIRONMENTAL MONITORING

The advancing technology will lead toward "environmental management" in place of the generic terms "environmental protection". Whereas some potential pollutants were recognized in the past only by catastrophic events, these types of problems will be anticipated with the new technology.

Sophisticated models will be available to depict the natural behavior of ocean regions. They will be predictive and capable of answering "What if....?" questions. These models will be designed to show what types of changes are natural and how ecosystems can be manipulated by introducing "pollutants". In this manner entire ecosystems can be managed, and environmental managers will have available accurate predictive models of marine ecosystems based upon studies of single organisms, food chains, and communities of organisms as well as entire climatic and environmental zones. These zones may be physiological, behavioral, biochemical and ecological. The models will fully integrate not only the complexity of the potential polluting materials themselves, but the complexity of a marine community. As the monitoring systems sense and record large amounts of data from the marine environment, the models will be applied to track how the organisms or material are interacting as well as what sort of synergistic or antagonistic effects may take place. It will also be possible to "protect" certain areas from negative effects by depositing or injecting potentially dangerous waters or materials into other areas where their effect could be positive. An example of such a concept would be nutrient enrichment of estuarine waters from sanitary wastes under suitably monitored and controlled conditions.

Some of the more important factors in the future of environmental monitoring include the following:

- Remote sensing technology will advance significantly. This technology includes: satellite, subsurface, surface and platform-mounted sensors, all dependent on ocean science and technology.
- Advanced sensors will be deployed in U.S. waters. These will include: photographic, acoustic, laser, radar, passive electromagnetic,etc. They will be deployed on buoys, subsea installations, and on offshore structures.
- Each monitoring station will use a variety of technical systems--barometric, temperature, laser/acoustic, salinity, trace metal, chemical, and wind speed.
- Microprocessors will be used on monitoring stations to integrate functions.
- Satellite-borne sytems will use combinations of photographic, laser, IR, and radar sensing.
- Surface systems will use acoustic tracking, multi-beam mapping, conventional and side-scan radar and IR techniques, sub-bottom profiling, underwater telephone, passive sensing arrays, optical equipment.
- Science and technology will lead to effective programs to neutralize the effects of the most damaging pollutants, such as:
  - Synthetic Organics (DDT, Kepone)
  - Chlorination Products
  - Dredging and Large Volume Waste Disposal
  - Litter (any solid man-made or natural material that is out of place in the environment)
  - Artificial Radionuclides
  - Microorganisms
  - Trace Metals
  - Sedimentation by River Plumes
  - Fossil Fuel Compounds
  - Heat
  - Airborne pollutants, Air/Water transfer

ENVIRONMENTAL PROTECTION

Environmental protection means "preventive" and implies a move toward performance versus procedural standards. By environmental protection is meant those measures that may be termed "preventive" in the sense that they are designed to prevent materials being injected into the marine environment in a location where their presence would be undesirable. It is expected that during the time period of this study standards of environmental protection will gradually move away from technology forcing standards, such as smokestack scrubbers, toward performance standards. That shift will be enhanced by the more complete understanding and ability to track and monitor marine ecosystems outlined in the section on Environmental Monitoring.

"Total systems" environmental management is forecast. This will mean that entire ecosystems will be susceptible to managing as entities in themselves, with the monitoring just described as a fundamental feature of this management. This sophisticated ocean monitoring, linked to improved biochemical science and technology will have profound implications for protective measures. Not only will exact performance parameters be available for marine operations, but those standards will be amenable to continuous monitoring and will differ according to location, daily climatic conditions or wave patterns.

Coastal zone regulators and operators will have almost total engineering understanding of discharges--that is, how to exploit them in an optimum manner. Linked with marine ecosystem models and sophisticated monitoring, this capability will be a powerful instrument of ocean management.

- Nutrient standards will be set in addition to standards for such things as turbidity or biostimulants--substances with properties that stimulate biological growth and health. Performance will be designed to "protect" but also enhance. For instance, effluents may be chemically modified in a holding tank to provide an attractant/nutrient for flounder at one time of the year, and striped bass at another, depending on migration patterns, water temperature, or vessel installation location.

- The performance of the discharge will be monitored continually to balance or modify the ecosystem. Is the discharge encouraging the growth of animals that attract predators? Are worms being encouraged and, in turn, bringing in urchins which are destroying kelp?

The capability for broad "total systems" ocean environmental management will rest upon a foundation of advances in the basic chemistry and biology of oceanic substances. These advances will lead to improved capability in managing the oceans' ecological balance.

- In the future instead of regulating the levels of substances that may be injected into the environment during operation, it will be possible to establish the chemical modification for balancing the ecosystem of a large geographical area. As the reactions occurring in cells are better understood, as synthetic enzymes are evolved, and as understanding and modification of organic processes is fostered, in relation to the ecosystem as a whole, biochemical processing should be more practical for a number of hazardous or toxic substances and discharges. This means that it will be possible to set performance standards in a positive rather than strictly negative manner.

- Research will continue to develop systems for biochemical treatment or modification of potentially polluting materials before they enter the environment. Biochemical treatment/modification systems derive from a sophisticated understanding of the components of the marine environment, and will have profound implications for designing preventive measures. Systems falling under this category, while largely theoretical and speculative, are potentially important components of ocean management and sea zoning systems as well as devices for environmental protection.

    - Such systems will be independent pollution control devices, work as adjuncts to existing mechanical systems, and will be incorporated into design of operating equipment. They will provide operators and planners with a wide spectrum of options for materials now defined as wastes, toxic materials or contaminants.

    - Biochemistry will use microorganisms, enzymes or other proteins to catalyze reactions which occur in living cells, and to create hybrid cell lines to convert material from one form to another, or to consume an undesirable substance. Such technologies will have important direct application for environmental protection. Research experimenting with these systems of biochemical modification is progressing in facilities as different as those of the food and petroleum industry.

Mechanical cleaning or prevention devices have been the most important technology for environmental protection in the past. Advances relate to ability to prevent catastrophic failure and include: faster response, ability to recognize and act upon incipient problems, ship tank design, scrubbers, and sensing instrumentation (particularly X-ray fluorescent units operating with miocroprocessors and acoustic devices).

- o Mechanical cleaning or prevention systems will still have an important role to play. Although the advances in chemical and biological systems will deemphasize technology-forcing regulations, improved understanding of the marine environment will result in implementation of performance standards.

- o The purpose of mechanical cleaning and protection systems will still be protection against catastrophic failures, typified by blow-out preventors for offshore drilling operations and vapor collectors for tankers, LNG carriers or offshore transhipment points. Among the advances that can be expected are:

  - Design improvement for more efficient, quicker response time in spills: i.e., Kelly valves or other shut off points that are easier to use or designed for better human interface.

  - Automated back-up systems linked to sensing equipment to register seismatic data or air quality data before problem is evident to human operator and begin shut-down or mitigation procedures.

  - Bilge and loading tank separators especially designed for water conditions that will include:

    - x Improved gravity separators

    - x Cartridge filter/coalescers capable of allowing nutrients to pass through system

    - x Regenerative filter/coalescers to lower maintenance costs

    - x Practically-sized oil/water separator for operational units

  - Continued use of existing "scrubber" technology

  - Sensing instrumentation designed to function with prevention equipment and monitor how well the equipment is working. Systems under development include:

    - x X-ray fluorescence unit and sodium iodide crystal detectors for detecting trace metals, elevated levels of radiation and monitoring such chemical signs as pH. Microprocessors to reduce and analyze the data to determine if the waste stream is approaching established environmental limits. Should the levels be exceeded an alarm will sound alerting operating personnel.

x X-ray florescence units and passive sonar systems to monitor underwater pipelines and structures and to give advanced warning of potential toxic spills or breaks.

The major contaminant today and for the next many years is petroleum. At present, for example, much potentially toxic material enters the marine environment because of oil spills, petroleum seepage or emptying of bilge tanks. Developments in this area will have several implications.

o The long term build-up of petroleum residues may be as damaging to marine ecological systems as is the better publicized catastrophic results of a major spill from a well blow-out or tanker collision. Petroleum is a highly complex mixture of mostly hydrocarbons, but with significant amounts of other elements as well, including oxygen, sulfur, nitrogen and vanadium.

o In the future chemical systems will be able to effect almost complete biodegradation of petroleum through a two step processing system. This system would be a part of any preventive device for tanks or bilges but could also be utilized in the ocean should a catastrophic spill take place. The processes:

  - Pretreatment--Flow of gaseous nitrogen at 70°C removes volatile components. The oil could then burn in a safer manner.

  - Microbial Action--bacteria and microorganisms are put into the petroleum, causing breakdown of the hydrocarbons into resins and alkanes. Microorganisms then consume the alkanes, and the resins remain harmlessly.

o Thus the potential will exist to almost totally eliminate petroleum from entering the marine environment from bilge tanks or holding tanks. A chemical system could be linked to existing separator technology, isolating petroleum residues from water. The water could be recycled and the petroleum undergo pretreatment and treatment. Since it is estimated that about 85% of all oil entering the marine environment comes from routine discharges, such systems could dramatically improve environmental quality. Chemical treatment could also be applied to drilling muds, greatly cutting the cost of maintaining environmental standards for the offshore oil industry.

There is a potential for sophisticated waste "processing"--rather than disposal--that will be linked to the accurate models and monitoring systems already discussed. Already most water treatment facilities utilize biochemical treatment or modification. Although such systems are usually very simple, say adding lime, alum and activated carbon to the effluents, they will become fairly complex. The basis of these systems will be advances in biochemistry, organic chemistry and cellular biology. Also important will be technology transfer from biomass fermentation. Such systems will not only pretreat waste or toxins, but will mitigate potentially catastrophic toxic spills.

ENVIRONMENTAL CLEAN-UP

This mission and its associated technology currently comprises the most important Coast Guard environmental program. It is institutionalized in the Coast Guard by the National Strike Force to counter oil spills. The Coast Guard is charged with recovering spilled oil or other hazardous chemicals in U.S. waters when the operator responsible is unable or fails to take proper action. Because of this mandate, oil spill technology is directly relevant to the Coast Guard and has been an important research priority within the agency. A special Interagency Test Group supported by the Coast Guard, EPA, Navy, Geological Survey, Department of Energy, and the Canadian Department of Environment was established for this purpose.

Progress has been significant. In 1970 the Coast Guard virtually had no pollution control capability, and today has more than $16 million invested in equipment inventory. This must be balanced against the fact that to date no offshore oil spill has been completely cleaned-up. Therefore, development of spill clean-up capability can be expected to have a continued high priority, particularly since the pace of development of offshore petroleum reserves is expected to increase. The Coast Guard is investing heavy R&D resources into development of technology for this mission. Development of the Coast Guard's pollution response capability has occurred in three phases, two of which have been completed. Phase three is of vital importance to this scenario.

o Phase One:

Focused on prevention through enforcement of anti-spill regulations and development of pumps to mitigate accidental spills.

o Phase Two:

Consisted of containment of spilled oil near the source to prevent, mitigate, or minimize damage to areas which are environmentally sensitive. The Coast Guard developed an open water barrier.

o Phase Three:

Recovery of spilled oil is not yet operational. While such recovery can be effected from confined areas, with slow moving water, recovery remains beyond the state-of-the-art during severe weather, from inaccessible locations, and from fast moving waters.

Technology for the mission to be developed during Phase Three may be grouped into three categories:

o Chemical containment or recovery systems

At the present time, those chemical systems under experimental development are used as adjuncts to mechanical containment and recovery operations. As the biochemical nature and interaction of petroleum and other chemicals in the marine environment are understood more completely, we expect chemical systems to be able to play a more direct role. Microbial biodegradation could be used to neutralize catastrophic spills and mitigate damage.

Recovery and control of spilled oil presently is very difficult. One of the largest problems is the inability of current technology to effect total recovery of the spill. That problem is due mainly to the unharvested material migrating back over the track just cleaned by the equipment. For that reason, continued passage of the recovery unit over the spill area serves, at some point, only to reduce the film thickness of the oil. Chemical systems will be deployed with more conventional mechanical containment and recovery systems to help alleviate that problem.

Amino Carbamate, or other gelling agents, will convert the liquid oil into a solid gel. The gel then could be recovered efficiently, helping to effect near total recovery. Efficient recovery, linked with biodegradation capability of any residue, will greatly reduce the chance of a catastrophic spill. Such chemical techniques will become increasingly efficient as research continues, and will be developed for other potential spill materials as well.

o Mechanical containment systems

The Coast Guard open water containment barrier has been used successfully since the mid-1970s. Containment barrier design and deployment should continue to develop and show improved efficiency. Efforts presently are directed toward:

- Containment systems for deployment in harsh weather or sea conditions.

- Self-propelled barriers with built-in storage capability, perhaps utilizing membrane technology so that oil could be absorbed into the walls of the barrier.

- Improved pump floats for deployment with barriers, linked with built-in "herders" to effect efficient recovery. In development are herders consisting of jets of water or air that will force the spill against booms and so direct it toward the recovery unit.

- Anticipatory rather than reactive containment response as a result of advances in the accuracy of models for oil and chemical spill behavior, capability of real time predictive capability of spill movement, and improved detection capability for early response.

o Mechanical Recovery Systems

Developments in recovery state of the art will overcome the three major deficiencies of current systems: the inability to recover spills during severe weather, from remote places, and from fast moving waters or during high sea states. The two most important developments are (1) procurement of dracone barges, and (2) development of the zero relative velocity (ZRV) skimmer.

- Dracone barges are flexible, portable, towable containers which will be used to store pollutants temporarily. They can be used with pumps in conjunction with containment systems, or pollutants may be pumped directly into the barge from a damaged vessel or structure. Orders have been placed by the Coast Guard to acquire five 240,000 gallon, eleven 40,000 gallon, and three 10,000 gallon barges.

- ZRV skimmers currently are under development. They are designed for recovery of oil from moving water. The recovery unit will be a 46 foot diesel-powered catamaran with a large absorbent belt that is driven at "zero relative velocity" in relationship to the water, although there will be in the first generation ZRV skimmers a six knot limitation to water speed. The ZRV under development will have the capacity to pick up 600 to 1000 gallons of oil per minute, transferring the harvested oil either to a conventional or dracone barge. The skimmer will break down into three sections small enough for the unit to be transported by truck or by C-5A aircraft.

  Continued development and improvement of design should add greatly to the efficiency and capability of ZRV skimmers. Used in conjunction with the other systems already described, formidable technology to prevent, control, mitigate and clean up ocean pollution will be in place by the end of the study period.

CHAPTER 8: TECHNOLOGICAL FORECAST: CAPABILITY TO HANDLE WATER SHORTAGE

This chapter presents detailed information on three aspects of the water shortage problem in support of the Water Shortage Scenario presented in Chapter 3 of Volume II. The chapter begins with a discussion of water uses and how they are increasing. This is followed with a description of the present state and forecast future of our water supply, and the chapter concludes with a description of the effect of climate on the water supply.

PRINCIPAL WATER USES

Agriculture

Irrigation accounts for 99 percent of water used for agriculture and offers the greatest opportunity for conservation of water. There are about 45 million acres of irrigated farmland in the U.S. Withdrawals are projected to decline somewhat as a result of ground-water overdraft in the Southwest and some increase in irrigation efficiency. There has recently been a significant increase in irrigated cropland in the South Atlantic-Gulf Region.

Since 1950, the Nation's agricultural crop production has increased 50 percent. This increase resulted from significant improvements in productivity--not from major increases in the total cropland harvested. The most significant improvemements were more productive varieties of crops; increased use of chemical fertilizers, pesticides and herbicides; larger and more efficient machinery; and improved management. By the year 2005 domestic consumption of agricultural products will have increased about 25 percent. Productivity is expected to increase, but at a slower rate.

Irrigation is playing an increasingly important role in augmenting agricultural production and reducing production instability. The total irrigated area of the world is expected to increase by at least 10 percent by the year 2005. The major irrigation problems arise from water losses due to ineffective or badly managed systems, and from salinity and waterlogging associated with inadequate drainage. About 50 percent of the water used in irrigation is not utilized by the crop, but is lost in run-off, evaporation and percolation. Even under optimum conditions of efficiency, 25 to 30 percent of the water used is lost.

Increasing salinity of water with irrigation use is a growing problem. Water used for irrigation is drawn from rivers and streams where salt and other minerals have been dissolved in it. In contrast, rain water is almost free of salt and other minerals, and is therefore ideal for irrigation. It is estimated that half of all irrigated lands are damaged by salinization, alkanization and water logging. Large areas of irrigated land have been abandoned as a result of soil salinization.

Although irrigated land presently comprises only 13% of the world's total arable area, it accounts for by far the largest proportion of the total water use by man and will continue to be the greatest water user in the future. The total irrigated area of the world is expected to increase from 223 million hectares in 1975 to 275 million hectares by 1990.

While there is considerable scope for change in input of water per acre, the main determinant of water use in the foreseeable future will be the number of acres under irrigation. To estimate this number, exports, national demands, crop mix, prices paid for irrigation water, and direct allocation of water for competing use will be among the major considerations.

Energy Production

Steam-powered generation of electricity accounted for 95 percent of the fresh-water withdrawals for all energy production in 1975.

Advances in cooling technology by the year 2005 will result in a decrease of 11 percent in freshwater withdrawals for steam-powered generation of electricity, but steam generation will still account for 94 percent of withdrawals for energy production. In contrast to withdrawals, consumption (not returned to use) will increase from 2 percent of freshwater withdrawals to 13 percent for electric production. This is due largely to greater evaporation resulting from higher temperatures in the recycling process.

The relationship between energy production/use and water consumption is important. Water is used for energy production, and energy is used for augmentation of water supplies. For example, coal-produced energy requires significant amounts of water; as use of coal as a source of energy increases, so will water used in its production. New energy systems, such as production of synthetic fuels from coal and shale, are also large water consumers. On the other hand, increased energy costs will cause problems in many water development projects, (e.g., pumping of water for irrigation) and may reduce the amount of water available for a variety of uses.

As increased amounts of fossil fuels, especially coal, are burned, problems of water pollution are expected to worsen. Emissions of sulfur and nitrogen oxides combine with water vapor in the atmosphere to form acid rain or produce other acid deposition. Already, in large areas of Norway, Sweden, southern Canada, and the eastern United States, the pH value of rainfall has dropped from 5.7 to below 4.5, well into the acidic range. Rainfall has become more acid in parts of Germany, Eastern Europe, and USSR.

Damage has already been observed in lakes, forests, soils, crops, nitrogen-fixing plants, and building materials. Of 1,500 lakes in southern Norway with a pH below 4.3, 70 percent have no fish. Similar damage has been observed in the Adirondack Mountains of New York and parts of Canada. River fish are also severely affected. In the last 20 years, first salmon and then trout disappeared in many Norwegian rivers as acidity increased.

Another problem related to the combustion of fossil fuels (and the global loss of forests and soil humus) is the increasing concentration of carbon dioxide in the earth's atmosphere. By the year 2005, the CO_2 level is expected to be nearly a third higher than preindustrial levels. Agriculture and other human endeavors would have great difficulty in adapting to such large and rapid changes in the climate. Highly disruptive effects on world agriculture and water supply could occur before the middle of the twentyfirst century. Eventually, it could lead to the melting of the Greenland and Antarctic ice caps and a gradual rise in sea level, forcing abandonment of many coastal cities.

Minerals Industry

The minerals industry had 2.1 percent of fresh-water withdrawals in 1975. Water withdrawals for the minerals industry will grow with increased use of minerals (as the U.S. attempts to become less dependent on imported minerals) unless there are improvements in water-use efficiency or recycling. By 2005, consumption is expected to increase 64 percent, though remaining at a constant 2 to 3 percent of total consumption. Water used in fuels mining is important in the Missouri and Upper Colorado Regions where coal and oil-shale mining and processing are developing.

WATER SUPPLY

The single most significant cause of increased future water demand will be population growth (45 to 65 percent increase by 2005). By the year 2005, population growth alone will cause at least a doubling in the demand for water in nearly half of the countries of the world. Any improvment in standard of living would cause still greater increases.

Increases of 200-300 percent in world water withdrawals are expected over the 1980-2005 period. By far the largest part of the increase is for irrigation, which will double.

Advancing technology and increasing development further increase man's dependence upon water. Water is used for human consumption; transport of wastes and sanitation; energy, industrial, and agricultural production; transportation; and recreation.

More than 99% of the water on the globe is unavailable or unsuitable for beneficial use, because of salinity (seawater) or location (polar ice cap). Water available for human use is, for practical purposes, fresh water from streams, lakes, and aquifers (ground water).

By the year 2005, half of the earth's annually renewed water will be in use by man. Nearly 60 percent of all water withdrawn is returned to the environment. Assuming no substantial climatic change, the world supply estimate should remain relatively constant in the near future, while water withdrawals climb steadily with population and rising agricultural and industrial output. Any significant increase in the rate of water withdrawal, even doubling by the year 2000, is virtually certain to cause major water supply problems. The use of energy and other resources by the water supply sector will increase dramatically. Water shortages will become more frequent, and their effect will be more widespread and more severe. This is a result of the intensely local nature of a water resource. Most water economies exist within smaller hydrologic provinces, in single river basins, or adjoining basins connected by water transmission facilities. When the supply in such a limited area falls short of the attempted withdrawals, water shortages occur, regardless of the quantity of water available in neighboring basins. Nonuniform distribution in water, both in space and time, is the fundamental cause of the uniquely local nature of water supply problems. The availability of water will become an even more binding restraint upon the location of industry.

In the industrialized countries competition among different uses of water--for increasing food production, new energy systems (such a production of synthetic fuels from coal and shale) increasing power generation, and increasing needs of other industry--will aggravate water shortages in many areas.

The United States has an ample supply of water from both surface and underground sources, but water shortages occur because of the uneven distribution of precipitation. Usually associated with the arid West, water shortages also periodically occur in the humid East. Inadequate water supplies can be caused by poor quality of water or by economic, social and environmental constraints.

In 1975, the U.S. consumed (withdrew without return) 107 billion gallons per day of fresh water (surface and ground). By the year 2005, this amount is projected to increase to 135 billion gallons per day, an increase of almost 27 percent. The increase is a result of growth in manufacturing and mineral industries, steam electric generation, and agriculture, and also as a result of evaporation due to higher water temperatures from increased recycling. Agriculture is, and will continue to be, the major consumptive user of water, with this water unavailable for downstream uses.

Water flowing through a natural stream channel is needed to sustain an acceptable level for navigation, fish and wildlife population maintenance, outdoor recreation, hydroelectric generation, waste assimilation, downstream diversion, and ecosystem maintenance.

Approximately 50 interstate compacts and international treaties affecting water resources have been approved by the Congress to allocate the amounts of water among political subdivisions for existing or potential uses downstream.

THE EFFECT OF CLIMATIC TRENDS ON WATER SUPPLY

Analysts warn that water supply problems are long term. Underground water tables have been receding for generations as new farming techniques, industrial developments and a steadily rising population expand water demand.

A National Defense University study, "Climate Change to the Year 2000", based on a survey of 24 climatologists from seven countries, showed uncertainty about future trends, but in average, showed:

- A change of about +0.5°C in the mean sea level temperature in the Northern Hemisphere
- Hemispheric warming or cooling will probably be most pronounced in high latitudes (effect on poles)
- Hemispheric temperature changes will be accompanied by changes in the intensity and pattern of atmospheric circulation and probably changes in the variability of climate (more extremes)
- These atmospheric circulation changes will probably result in important variations in the east-west movement of weather and will affect the distribution of precipitation

For four months (10/80 - 1/81) a single weather pattern gripped almost the entire U.S., causing a coast-to-coast drought unique in weather history. The weather system causing the drought is also unusual. Many meteorologists feel it marks the end of a 40-year cycle--the end of good weather which had continued since the dust bowl. They believe the U.S. will have severe and erratic weather conditions, as evidenced by record snow, cold, and drought in three of the past four years.

Two unusual weather patterns caused the conditions. First, there were two very large and very persistent high-pressure systems over the West Coast and Rocky Mountains which remained there for four months. In the U.S. such weather conditions were almost never seen until 1977, when a similar high pressure blocked the West Coast for months. In summer 1980, another on the Midwest and part of the East caused record high temperatures and continued the water deficit that began the previous winter.

Second, the "jetstream", a bundle of powerful steering currents that move at speeds of up to 300 miles per hour at 30,000 feet above the earth, is not where it normally is. Generally the jetstream would wander straight through the middle of the country from west to east, pushing storms into a position where they could pick up moisture from the Gulf of Mexico, and, spinning clockwise, deposit it on the Midwest and East.

In 1977, the jetstream skipped up and crossed Canada instead of the U.S., dipping south only at the Great Lakes. This left the West extremely dry, while the Midwest and East were severly cold, with Arctic air mixed with snow.

In 1980, the jetstream jumped again up into Canada, but did not turn south at the Great Lakes.

Weather systems are so complex that long range forecasts are not now possible. The patterns of climate result from complex interactions between the atmosphere, oceans, land masses, ice pack and glaciers, and vegetation. Investigators are also studying causal factors external to the climatic system, such as solar activity, planetary tides, changes in the earth's orbit and rotation, volcanic emissions, and man-induced (anthropogenic) alterations of our environment. Anthropogenic factors include carbon dioxide, flurocarbons, particles in the air, changes due to land use, and heat generated by use of energy. Not enough is now known to make a realistic quantitative model relating cause and effect, but valid linkages of the interaction of subsystems have allowed simple global models which have had small but statistically significant degrees of accuracy. It is known that the climate of the 1950s and 1960s was exceptionally favorable and that, on the basis of past experience, the earth can expect both more variable and less favorable climate in the future. Some human activities, especially those resulting in releases of CO_2 into the atmosphere, are known to have the potential to affect the world's climate.

The benign climate of the 1950s and the 1960s was by no means typical of the interglacial (or postglacial) period the earth has been experiencing for approximately the last 10,000 years. This 20-year period was most favorable for agriculture and food production over much of the cultivated areas of the industrialized high-technology nations.

Warming of the climate will occur if the warming effect of atmospheric carbon dioxide predominates over all other effects. Many meteorologists consider that carbon dioxide from the unrestrained combustion of fossil fuels is potentially the most important environmental issue facing mankind. CO_2 is a basic product of the combustion of all hydrocarbons, including fossil fuels and wood. The burning of wood, coal, natural gas and oil spews several billion tons of carbon dioxide into the atmosphere each year. Only about half can be assimilated by nature. A rapid increase will occur in part because of the continuation of growth of fossil fuel combustion and in part because of the shift to coal and synthetic fuels produced from coal, both of which produce more CO_2 per unit of heat than do oil and gas. Coal releases 25 percent more CO_2 than oil and 75 percent more than natural gas per unit of heat produced.

Clearing of forests for food production aggravates the CO_2 problem by eliminating one natural use of CO_2 and may contribute approximately as much to the increase of atmospheric CO_2 as the combustion of fossil fuels. CO_2 is not subject to economically practical control by any pollution control technology. The CO_2 content of the atmosphere has been increasing since routine observations began. The average concentration increased by about 5 percent in the 20-year period 1958-78. Brookhaven National Laboratory estimates that annual emmissions of CO_2 will increase by 35-90 percent by the vear 1990.

As carbon dioxide builds up in the atmosphere it creates a "greenhouse effect," trapping heat. For even a doubling of carbon dioxide in the atmosphere, there will be a 2° to 3°C rise in the average temperature at middle latitudes and a 7 percent increase in global average precipitation. The temperature rise will be 3 or 4 times greater in polar regions. These hot spots would shift precipitation and other global weather patterns, with potentially disastrous effects on native vegetation, wildlife and crops. Polar hot spots could begin to melt the ice caps. If this happened, sea levels would rise, forcing evacuation of coastal regions, changing ocean currents and life-supporting nutrient upwelling zones, and wrecking havoc in marine, estuarine and coastal wetland ecosystems.

Such large global warming could cause a significant increase in the length of the growing season in the higher middle latitudes, and a substantial decrease in the variability from year to year in the length of the growing season. Precipitation levels would generally increase, especially in the subtropical and higher middle latitudes. In the lower middle latitudes (30° to 45°--most of the U.S.) drought conditions similar to the mid-1930s and early-to-mid-50s would prevail.

At the present state of the art, predictions depend as much on history as on meteorology. Since weather records have not been kept for long enough for accurate trend analysis, science goes to records in nature such as the rings on long-lived conifers. Each ring reflects the climate of the year it was added. These studies show that since the year 1600, large areas of the western U.S. have undergone a period of drought approximately every 22 years. This corresponds to the 11-year cycle of maximum sunspots, when, with every other outburst (every 22 years) the magnetic field of the sun changes directions. This would predict the next major drought as for the year 2002. The magnitude of sunspots is not predictable (last year's maximum, predicted as 60 sunspots, was 150), and there are other variables. Another theory from long-term studies of weather patterns shows that the 20th century has had exceptionally high levels of rainfall, higher than at any other time since record-keeping began in 1602. The longer records indicate that we are most likely to return to the mean. The probability is that there will be less water in the West. Computer models based on these records and sunspot behavior predict that until the year 2003 the north central and northeastern portions of the United States will have drier and colder weather than normal. The implications are grim for America's midwestern breadbasket.

If the "warming" trend continues, fewer extremely cold winters might be expected, but the chance that the interior of the U.S. would experience hot summers and widespread drought conditions resembling those of the mid-1930s is likely to increase. The warming would be substatially beneficial to Canadian and Soviet wheat production; it would be moderately detrimental to wheat in Argentina, Australia, and India and marginally unfavorable to corn in Argentina and the U.S.

Recent work of two scientists at NOAA has tightened the link between climate and solar activity. There is evidence that the thickness of the atmosphere relates to sunspots. The height of the tropopause (the top of the troposphere, the lowest region of the atmosphere) fluctuates with changes in sunspot activity. Large-scale weather changes are intimately related to the height of the troposphere. This affects the flow of global winds, hence the climate, enough to cause a drought.

Almost all of the predictions, from warming trends to cooling trends call for more frequent droughts in the U.S. for the next 25 years. One thing that almost all climatologists agree upon is the profound effect of increased CO_2 in the atmosphere.

In sum, the consensus of many "top climatic experts" is that there will be a warming trend in the next 25 years, with increased danger of drought in the West and Midwest.

CHAPTER 9: TECHNOLOGICAL FORECAST: ADVANCED MARINE VEHICLE CAPABILITIES

This chapter describes the forecast capabilities of the advanced marine vehicle in the year 2005. This vehicle will have three features to distinguish it from the vehicles of the early 1980's. One is automated control consistent with advances in microprocessing and with C^3 technology; this feature will be acquired at relatively small increase in costs. A second feature will be the capability to move rapidly over the sea surface. This feature involves significant change in hull and hydrodynamic characteristics and will involve correspondingly greater cost. The third feature is the capability to effect transfer of personnel between craft in heavy seas. This will come about through robotics and through use of more stable platforms; it will also be relatively expensive.

This chapter first describes the principal areas of technological advances relevant to marine vehicles--those in which high promise of increased capability lie. Second there is a brief description of some of the other directions that technology is taking that have relevance to marine vehicles, but which do not promise quite the revolutionary advances that the developments in the first section do. Finally there is a description of the specific vehicles now under evaluation by governmental and commercial users that constitute the application of the key areas of advance described in the first two sections.

PRINCIPAL AREAS OF ADVANCE IN MARINE VEHICLE TECHNOLOGY

The three dimensions where changes in vehicle technology promise to offer the greatest operational benefits are: lift; speed (i.e. propulsion); and stability in a seaway. The following tabulation indicates the possibilities in each of these three dimensions, and the general areas that research and development in vehicular technology is emphasizing today.

Lift

There are several ways in which a vehicle can acquire air lift capability:

- Air buoyancy--a bag filled with a gas lighter than its supporting atmosphere.

- Airfoil lift--the lifting power of a "wing" designed so that as it moves through the air a lifting power is created on is upper surface.

- Airstream lift--the lifting power of a propeller or jet, resulting in the imparting of momentum to an air stream flowing downward.

- Air cushion--the creation of a cushion of air between a vehicle and the sea surface, a cushion on which the vehicle is supported. Such a cushion can be created in either of two ways:

  - By a stream of air directed downward from the vehicle, or

  - By the forward motion of the vehicle at a low altitude.

There are also several ways in which a vehicle can acquire water lift capability:

- Hull buoyancy--the result of the vehicle displacing less than its weight in water.

- Pontoon buoyancy--addition of pontoons to bring total vehicle displaced water weight down to a buoyant level.

- Foil lift--the lifting power of a "wing" form which creates lift as it moves through the water.

- Ski lift--the effect of a plane surface moving over the surface of the water This effect can be created either by actual skis or by the hull itself.

Propulsion

There are several ways in which a vehicle may be propelled through either air or water:

- Propeller driving air

- Jet imparting momentum to air--and hence to the vehicle

- Propeller driving water--i.e. a "screw"

- Water jet

- Water paddle

- Water fishtail motion--not yet engineered efficiently

Stability

And there are several ways in which a surface vessel can acquire increased stability in heavy seas:

- Support by foils which transmit the weight of the vehicle to the sea at a depth sufficiently below the surface to reduce or avoid the effect of surface wave motion. These foils may be either near the surface (the so-called "surface piercing" foils), or they may be submerged well below the depth at which action of the sea surface has any effect.

- Hull-mounted fins analogous to ailerons in an aircraft.

- Rudder-roll under the control of a feedback loop such that the rudder is moved in synchrony with the roll of the vessel to reduce this roll. In order for any of these methods to be effective the vessel must have considerable headway.

- Extremely low center of gravity--well below the sea surface--so that a significant portion of the weight of the vehicle is below the surface and therefore less susceptible to wave motion, coupled with a vertical fin-effect such that vertical motion of the vehicle is impeded by the water resistance of the submerged fins. (Only one vehicle relying on this phenomenon has been under consideration--the SWATH.)

- Catamaran structure--an "outrigger" or a dual hull construction to give the vessel extensive width compared with its draft and height. (The SWATH vehicle also uses this effect.)

- Extremely large displacement--achievable only through actual displacement, not susceptible to synthetic production in any known manner.

Traditionally only a small number of these processes has been put to use in the three functions discussed. Since the middle 1950s an awareness has grown that most of the others, singly and in combination, can be exploited beneficially. Several other nations--notably the USSR, Canada, the UK--have devoted considerably more effort to investigating and exploiting this fact than has the U.S. However, U.S. technology-push and demand-pull forces are finally beginning to operate toward significant advance in over-the-water vehicle design.

OTHER ADVANCES IN MARINE VEHICLE TECHNOLOGY

In addition to the foregoing central thrusts of advance in marine vehicle technology, there are a number of other subsidiary areas in which advances have been in progress, and are summarized as follows:

Vehicles, Equipment, and Machinery.

Advances will be made in equipment, machinery, and vehicles so that by the end of the century both manned and unmanned submersibles will be operating at great depths. Mobility will be markedly enhanced between offshore structures and within and among the complexes through use of vehicles with technologically advanced characteristics. Such vehicles exist in a variety of forms, and are labeled in this report "Advanced Marine Vehicle", a generic term to indicate any vehicle with technologically advanced characteristics. By the end of the century there will be a significant increase in capability to install and operate offshore units in the polar regions.

Specific advances will be made in the following: manned and unmanned submersibles, advanced navigation and collision avoidance systems, and automated and sophisticated machinery in such areas as: Vessel Traffic Service systems; navigation and control systems for unmanned submersibles; seafloor surveys; collision avoidance systems; propulsion for submersibles; and metallurgy of heat exchangers.

Rudder-roll techniques/technologies will contribute toward ship stability when engaged in operations in heavy seas involving helos or boats.

Helicopter operations in polar waters will become even more commonplace than they are today. The Boeing Vertol 234 helicopter has been introduced into use in the North Seas. It can carry 44 people up to 600 nautical miles, and the British Airways has had 7 million passengers without a casualty.

Propulsion Systems

Advances in fuel cells, diesel driven systems, gas-turbine systems, and nuclear systems will lengthen the reach of vessels without refueling. Aircraft with improved endurance and speed characteristics will also be available. Submersibles will be available with long endurance and quiet operation. New forms of fuel for ships and aircraft will necessitate conversion by any owner of ships and craft desiring to conserve on energy/fuel. Two esoteric forms of propulsion are the object of serious research. Neither of these forms is likely to come to fruition before the end of the century, but may show promise soon after that.

- o Electromagnetic Propulsion

  Electromagnetic propulsion has been envisioned since at least 1950, when Stewart Wey, a consultant for Westinghouse Corp. developed the idea for use for submarines. At the higher speeds promised by electromagnetic propulsion, subs would have less drag than wave-hindered surface vehicles. The draw-back has been massive weight, high cost, or both.

  The development of highly efficient niobium-titanium superconductors, cooled by liquid helium to a temperature of -550° F., may prove the feasibility of electromagnetic propulsion. A full-scale, 10,000-ton submarine tanker may achieve a top speed of 115 miles per hour. The sub's demand for fuel would be less than the fuel needs of a traditional tanker.

  Another technique of electromagnetic propulsion would be the propelling of ships by means of a network of submerged cables in a port.

- o Marine Electric Drive System Ships.

  The U.S. Navy has produced an operational acrylic superconducting marine electric drive system that may lead the way to smaller, more efficient naval ships. The system performed "almost flaw-lessly" during sea trials. It makes use of the superconductivity phenomenon at very low temperatures (-450° F), in which intense magnetic fields can be generated using small amounts of material. Liquid helium is used to cool the superconductor magnetic system to produce a small, lightweight and quiet DC motor/generator.

  Navy ships with as much as 14% reduction in size with no change in performance and payload could be produced, with savings in construction and operating costs.

  The advantages of electrical over mechanical drive systems include freedom of machinery arrangement, variable prime mover to propeller speed ratio, and cross-connect capability in multi-screw ships.

Hulls

New forms of hull design--hydrofoil, air-cushion vehicles, etc.--have already been described as the most important direction of change underway. New forms of helicopter and VSTOL aircraft will facilitate inter-craft transfer in heavy seas.

Ship and Aircraft Speed

The high cost of increasing vehicle speed, coupled with adversaries' more ample resources, may favor law violators in opposition to law enforcement agencies. On the other hand, this same advance in vehicle speed will offer advantage to the law enforcement agencies in dealing with the less sophisticated adversaries and with the many units who are not intentionally violating the law or threatening national security.

Two developments in particular are likely to enhance speeds of ships and boats. These will find application in hydrofoils, but they are not confined to hydrofoils.

- "Super-cavitation" propeller designs will increase the efficiency and effectiveness of ship and boat propulsion. Water is separated from the upper surface of the leading edge of the propeller surface, leaving the whole surface unwetted. The cavities do not collapse until well behind the foil; this prevents erosion of the surface, and increases efficiency in energy transmission from propeller to vehicular motion.
- "Jetfoil" techniques to augment delivery to the water of the energy of propulsion will become operationally feasible. These are configurations of propeller, propeller guards, and hull to enhance energy transfer from propeller to water.

Vehicular Materials

Composites - It is possible to negate a radar pulse through micro antennas and circuits tuned to the radar frequency, absorbing most of the energy, thus resulting in little reflection. A new family of composite materials of carbon fiber and silicon fiber wound structures, stronger than aluminum and almost as strong as steel, but lighter than both, exists that is almost transparent to radar pulses. DuPont's strong and light Kevlar™ can be fabricated in strands or extruded, cast or forged. Naval architects, naval engineers and ocean engineers could use these materials for surface craft that are "invisible" to radar and submarines that are "invisible" to sonar. Surface craft such as air cushion, surface effect, hydrofoil and other high speed vehicles are candidates for this technology.

The Air Force has developed fiber-reinforced composite materials that reduce structural weight by 30%, and in 1982 will begin advanced development programs that will show these materials are suitable for the primary structure of large combat aircraft. This will extend the aircraft's operating temperature range to equal or exceed that of aircraft constructed of aluminum. The USAF program in metal matrix composites has demonstrated their strength and stiffness. The durability and damage-tolerant properties of these composites are less understood, but they are already being used in secondary structures, for unique uses, such as radar absorption.

For applications in marine operations, conductive graphite can be used for transmission lines and lightweight wiring in aircraft with enormous savings in weight, and therefore in energy. Solar cells and light rechargeable batteries essential to conversion and transportation of solar electricity are being developed, and may have application to submersibles, ships, and aircraft.

SPECIFIC NEW VEHICLE TYPES

The types of vehicles described below are applications of the key areas of advance summarized above. This section is an amplification of the material in Chapter 5 (beginning on page 5-29) and describes the present state of the art in several of these specific applications:

- o Three high-speed "surface" vehicles--air cushion, hydrofoil, and hybrid aircraft (wing-in-ground and ram-wing)
- o An ultra-stable vehicle of moderate speed--SWATH
- o Lighter-than-air applications
- o Remotely piloted vehicles

High-Speed "Surface" Vehicles

Because of their great speed, efficiency, and reduced crew requirements, high-speed surface vehicles will be the Advanced Marine Vehicle of the year 2005. Three types are of principal interest and are described in some detail.

1. Air Cushion Vehicles

Aerostatic-type air-cushion vehicles are divided into two categories--plenum chamber craft and peripheral or annular jet craft. Plenum chamber craft employ the simplest concept of surface effect. Air is forced from the lift fan(s) directly into a recessed base, where it forms a cushion of pressurized air and causes the craft to rise to its designed hoverheight. Flexible fabric extensions give increased obstacle and overwave clearance. Variances include the sidewall (SES) where the air cushion is contained between solid sidewalls and transverse skirts fore and aft.

The cushion of the peripheral or annular jet craft is generated and sustained by a continuous jet of air expelled through ducts around the outer periphery of the base of the craft hardstructure. The flexible skirts fitted to this type can take the form either of an extension fitted to the outer wall of the air duct only, or an extension to both inner and outer walls.

Because of their versatility and lack of restrictions, air cushion vehicles have many applications. Many if not most of these applications depend in some manner on the capability of all air cushion vehicles to hover. They are also capable of setting down safely on the sea surface, and lifting off.

Their uses have ranged from Coast Guard duties to survey tasks, to airport crash/rescue, to highly successful Canadian Coast Guard operations in search and rescue missions on the West coast. They have also been very successful in icebreaking missions, and as fireboats. In military amphibious use, they can be dispersed amid dunes for concealment. They are extremely effective for contraband control, night and day. Inflatable craft are evolutions from inflatable life rafts, and have the configuration of small boats. They can be air dropped to the sea.

The optimum use of air cushion vehicles is for larger loads at greater speeds. They also have special applicability to use in amphibious tasks. Hovercraft provide lower operating costs and increased reliability. In 1978 1.88 million passengers and 300,000 vehicles were carried across the English Channel without a single casualty. It is extremely reliable mechanically and very maneuverable. The role and pitch and the heave problems are now essentially solved with computerized control.

An important relationship from a decision-maker's point of view is that between speed and size. The larger vehicles require more airlift and are therefore increasingly more expensive; in order to justify this added expense for most applications, speed advantage must also increase with size. The typical hovercraft requires up to about 50% of its power in lift and consequently it must be operated at higher speeds in order to realize benefit commensurate with its added cost.

The ease of installation of new superstructure configurations on ACV bases increasingly facilitates "platforms" on which an array of different equipment can be installed. The principal military uses of hovercraft are broadly: Amphibious Assault and Logistics (AAL); Mine Countermeasures (MCM); Antisubmarine Warfare (ASW); and Coastal Patrol (CP). All of these roles are compatible with Coast Guard missions.

Small and medium-sized hovercraft can replace aging patrol boats and cutters. They can be armed with antiship missiles which will enable them to face very much larger displacement vessels on equal terms. They can also operate over surf and over the terrain irregularities of a coast line or beach.

One use of the SES for the Coast Guard may be for pollution control, with an open water oil recovery operation capability once it arrives on the scene.

It will be capable of low speed towing of oil recovery devices at low speeds in coastal waters 10 to 100 NM offshore and in high seas. It will have fire fighting and dewatering capacity.

U.S. Navy Air Cushion Vehicles

Prototype 150-ton air cushion amphibious assault landing craft, called JEFF, have been in operation since 1977 as test models for the follow-on air cushion landing craft program.

The Navy has tested its advanced development models of JEFF in two versions, JEFF-A and JEFF-B, one from each of two contractors. They have a capacity to carry 60 tons of deck cargo, with design gross weight of 345,000 pounds, and have achieved over-water speed of 62 knots with a range of 200 nautical miles. JEFF B achieved a speed of 55 knots overland and crossed 10-foot-high sand dunes while carrying a 60-ton payload, close to its designed full load capacity of 75 tons. They can be launched from the well decks of amphibious ships, transition the surf zone and beach to offload cargo--men, vehicles and equipment--on hard ground. The demonstrations showed that the technology is ready to be incorporated into a low-risk design of a landing craft for fleet use. The next step is the acquisition of the LCAC (Landing Craft, Air Cushion).

With JEFF, U.S. amphibious forces will be able to operate at safe standoff distance from hostile shoreline. Because of high speed and long range, JEFF will be able to lie offshore over the horizon and dart in for landings with minimum danger to craft, crew, and cargo. It can venture far inland, riding over sand dunes, marshes, rocks, light vegetation, to join with personnel and light equipment delivered by helicopters. It can haul 75 tons, has three lanes for vehicles, roll on/roll off capability, system redundancy, and exceptional stability--with uninterrupted operations in sea state 3. It opens 4 to 5 times the coastal area sites available today.

Late this year (1981) a contract is to be awarded for detail design and pilot production of six LCACs of 79 planned for eventual construction. The first craft should be in operation by 1985.

For some time the U.S. Navy has had plans for building rigid sidewall hovercraft SESs between 2,000 and 5,000 tons. The first stage was construction of two 1/20th scale model 100-ton test craft--the SES-100A built by Aerojet General, and the SES-100B built by Bell Aerospace Textron. The 100B set a world speed record for hovercraft of 90.3 knots (100 mph) during a 1977 test run. The prototype is capable of speeds of 70 knots or more in 2-foot waves. Waterjet propulsion is employed on the Aerojet-General craft, and partially-submerged, supercavitating propellers are used on the Bell design, which has been tested in wave heights in excess of 8 feet. The projected vessel, designated 2KSES, would be eleven times the displacement of the 200-ton SR.N4, the biggest hovercraft in the Navy today. The Navy believes that a 2,200-ton SES is the smallest size craft suitable for transocean operations. If it proved effective, the Navy planned to introduce an operational class of 2000-3000 ton SESs for use as escorts, small helicopter and V/STOL aircraft platforms and missile-armed surface combatants. The Navy was also contemplating craft of 6-10,000 tons.

Funding for additional RDT&E and construction of the larger test platform was recinded almost immediately by the Carter administration and the continuation of design and engineering work on the 3,000-ton 3KSES was jeopardized. It has since been canceled out of the program by the Reagan administration. The hundred-knot SES program is a key element in the Navy's long term planning to improve fleet effectiveness. It was designed principally as a sea going research platform, which would enable the SES concept to be tested in a number of military configurations, one of which was that of an anti-submarine-warfare frigate for convoy duties. The speed of the SES would lend itself also for short take-off and landing aircraft and remotely-piloted vehicles, which could be recovered at an essentially zero speed differential.

By the year 2005, the Navy can regain lost ground by introducing large numbers of SESs. A ship of from 1500 to 2200 tons appears likely to be capable of transoceanic transit without refueling. They will be capable of ASW, amphibious assault, early warning, aircraft strikes and logistic supply, including troop carriers, sea-control ships and high-value cargo carriers. As fast troop carriers, they will lower expenditures by allowing more troops to be retained at U.S. bases.

A 600 ton "skirted" SES* may be used for a long-range military platform to serve as a early warning system in the Arctic. It will be the only vehicle capable of roaming the rugged wastes of pack ice under all weather and temperature conditions on a 24-hour basis, making the transition from sea to ice without reduced speeds. These large vehicles could permit much faster transit between the North Atlantic and the North Pacific, enhancing our defense.

The surface-effect warships will carry missiles, helicopters or V/STOL attack aircraft like the Harrier, and will have a substantial tactical advantage over the fastest displacement ships. Equipped with ASW weapons and fire control for sustained operations, it would also prove ideal for countering the potentially critical submarine menace. Apart from its high speed, the SES has minimal water contact, provides a low noise signature and is a difficult target for torpedoes. As an aircraft carrier, its speed can reduce the relative approach velocity of aircraft, simplifying landings. As a logistics transport, the SES

*The term "skirted" refers to one of two methods of guiding the air flow from the lift fan; the skirt is soft material susceptible to accomodation to movement over rough surfaces, such as surf or sand dunes; the "hard" sidewall is not so capable. The principal design is with hard side walls and skirts fore and aft. An SES designed for use in the Arctic would be skirted on four sides.

can complete the trans-Atlantic crossing in 30 hours with multi-thousand-ton payloads, permitting the U.S. armed services to reduce the number of personnel based overseas, without compromising the ability to respond immediately in an emergency. As a result of the reduction in motion and the quicker service, travel fatigue is greatly reduced. It is an all-weather, high performance, long-range military platform.

A hope for continued U.S. advancement in high-speed ocean vehicle technology is the fact that Bell Aerospace Textron, which lost the 3000-ton SES competition, didn't break up its team when the Navy SES program lagged, but joined with Halter Marine to form Bell-Halter and is now building high-speed support vessels to serve the burgeoning offshore oil and gas industry. The first Bell-Halter SES (also the nation's first commercial SES) was 110 feet in length, and capable of speeds up to 85 mph in calm water. One advanced version will be 157 feet long, displace 320 tons, have a speed of 50 knots, a range of 2,000 nautical miles, and be designed to carry "a wide variety of military payloads."

Faster, more stable ships will be available in 2005, with a quantum leap in capabilities.

USSR Air Cushion Vehicles

Soviet ACVs include the 220-ton, 65 knot "Aist", an amphibious logistic supply craft built to carry a mixed load including troops, tanks, and missiles, and the 90-ton, 55-60 knot Lebed, for deployment with such amphibious ships as a new 13,000 ton LSD, which is capable of carrying three amphibious assault ACVs. Each of the ACVs can carry a fully armed platoon onto a landing beach. It is thought that 30 to 35 are in service. About 15 Aists were in service in 1978, and were capable of crossing sea areas, bogs, rivers and canals previously considered natural defenses. The Soviet Navy has also started a long-term SES development program.

The Soviet Navy also has a growing interest in SES as a particular form of the air cushion vehicle; Soviet SESs are replacing many midsized patrol boats. Of 264 commercial hovercraft worldwide in 1978, the USSR had more than 200.

2. Hydrofoil

The hydrofoil represents a combination of the high-speed boat with the airplane. Unlike the air-cushion vehicle, which is raised above the water or other supporting surface by a cushion of pressurized air, the hydrofoil is raised above the water surface by small wing-like foils, designed to generate lift. The foils are connected to the hull by struts and at a given speed the lift generated by the foils raises the hull out of the water. In 1975, hydrofoils had logged three billion passenger miles without a single fatal accident.

There are two basic foil systems: the "surface-piercing" type, and the "fully-submerged" type. Submerged foil craft have small foils, and the total weight of the vessel above them makes them top heavy; their attitude and depth below the water must be controlled continually, which is practical with computers coupled with some form of mechanical, electrical or other controlling devices. When effectively stabilized, the fully submerged hydrofoil is far more effective and efficient than the surface piercing type for use in a wide range of circumstances. The surface-piercing type is easy to construct, operationally reliable, and simple to maintain, and is ideal for inland waterways. The fully submerged, autostabilized hydrofoil vessels are the only ones capable of sustaining water speeds higher than those of fast nuclear submarines in high seas. They lose relatively little speed with sea state. They are also effective against fast missile-craft and destroyers which shadow the aircraft carriers and combat ships. Their smoother ride make them better for personnel and subject to less maintenance.

The ability of hydrofoils to cruise at economical speeds and sprint at great speeds makes them useful for many Coast Guard missions, such as SAR and Law Enforcement. Military uses include deployment as fast hit and run raiders, submarine chasers, and landing craft. A ship on foils cannot be reached even by a homing torpedo, and although such a craft could not be kept foil-borne all the time (because of heavy fuel consumption) it could take off in a few seconds as soon as the presence of a torpedo was detected--and would be out of range in a very short time.

"Super-cavitating"* craft are limited to about 67 kt, and speed in super-cavitating craft is at the expense of fuel consumption. Speeds of 100 kt or more may be feasible only for limited (especially military) purposes. Nuclear fuel, though higher in original cost and greater in weight, with its minimal fuel consumption might be feasible for very high speed craft.

Optimum size depends on function. Size spells comfort and seaworthiness, but dictates more and more speed, which eventually means expense of operation and loss of payload. Seaworthiness, comfort, and safety all go to some extent with size, but they also depend on the method of stabilization.

Some of the advantages of hydrofoils over aircraft include the airplane's requirement of complex ground installations and a minimum flight distance to make the operation viable. Helicopters are very costly to build and maintain and are limited in capacity. Hydrofoils are especially good in groups of small rocky islands and coastal strips and for use in ASW, minelaying, minesweeping. They are a very successful first ship for use in "narrow seas".

U.S. Navy Hydrofoil Vessels

PHM (Patrol Hydrofoil, Missile): 5 ships of the "Pegasus" class were constructed in the 1980s. They are a virtually unstoppable threat to enemy shipping.

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*See page 9-6 for discussion of super-cavitation.

They are small, (235 tons) swift (50 knots) and lethal (76mm rapid fire gun and 8 Harpoon missiles).

One of PHM's greatest advantages is its ability to operate year-round, in all weather, climates, and sea environments. Fully submerged foils and a sensitive automatic control system allows 40 knot speeds in seas in which conventional ships are quite limited. Stability adds to crew efficiency and equipment survivability. It is a poor radar target, is difficult to track and classify, has good maneuverability, and has the ability to attack over the horizon. It can substitute for many missions of Spruance-class destroyers and guided missile frigates, freeing them for other duties, or requiring fewer of them.

By the 1990s there will be a 1,500-ton destroyer escort hydrofoil which will cross the Atlantic without refueling.

"Jetfoil"* fast patrol hydrofoils will be applicable for fishery protection, and other law enforcement activities. Their reliability of close to 100% will make them desirable. Catamaran hull configuration, waterjet-propelled, and retractable tandem foil systems will make them stable, fast platforms. An 890-ton Naval hydrofoil frigate will have been perfected and adapted for the Coast Guard. It is the smallest practical size for a vessel capable of undertaking all the tasks required for sea patrol.

A triple-mode operational capability is available; hullborne, sub-cavitating mode with a speed of 16 knots and a range of 1,450 nautical miles; foilborne, sub-cavitating mode with a speed in excess of 45 knots and a range of 1,400 miles; and foilborne, supercavitating mode, with a speed of 75 knots and a range of 850n miles. Payload would be between 110 and 150 tons.

Increasingly, the "more and smaller" policy for sea defenses makes sense. Restricted funds, inflation and general manpower shortage makes the hydrofoil

*See page 9-6 for discussion of "jetfoil".

attractive from a cost/effectiveness viewpoint. Fifty knot missile-armed hydrofoils cost less than the frigates and destroyers they replace and, in addition to being much faster, second generation craft, because of their auto-stabliization systems, reduce their speed only slightly in the higher sea states. It has greater manueverability, and its maintenance and crew requirements are lower. Armed with missiles, even a 60-ton craft can take on a much larger displacement ship, and its retractible foils mean that, unlike the larger craft, it can operate totally independently of deepwater anchorage. Crew comfort in these mini-super-warships should reach a new peak. Seasickness in rough weather in the larger and more sophisticated hydrofoils should all but disappear. The computerized control systems make the accelerations compare favorably with a medium-range jet airliner.

The development of the naval hydrofoil has been far more successful than expected and is now regarded as an attractive investment. Their high speed simplifies patrolling long coastlines and the availability of greater numbers provides additional firing points in the event of conflict. Cost effectiveness studies by the U.S. Navy show the PHM, e.g., to be superior to P3C aircraft, carrier aircraft and surface ships in performing close-surveillance and quick-reaction/counter-strike missions. Also, because of its all-weather, high-speed capability, it can perform anti-submarine missions that no conventional surface ships can execute.

Baron von Schertel, who designed and built the world's first military hydrofoils, stated that one of the reasons why Western navies failed to adopt foilborne craft earlier is that many senior officers had the idea that they were highly specialized and needed to be supported by highly skilled personnel. As a result it was assumed that exceptional costs would be involved, and higher technical risks. But when the operational and maintenance requirements of a fast patrol boat (FPB) are compared with those of a naval hydrofoil, it is soon evident that the problems involved are practically identical. Data on conventional FPBs will be used by hydrofoil designers who will then plan a foilborne variant, employing existing, proven components. The craft will then be designed to meet a specification like that of the conventional FPB, but with advantages of high speed, improved range, and superior sea-state performance.

The hydrofoil will be used in many different roles, from assault craft and minelayer to convoy escort. It offers a performance unprecedented in warship design.

USSR Hydrofoil Vessels

The USSR had 330-ton Sarancha hydrofoils (speed in excess of 50 knots) and the 440-ton 55-knot Babochka, a fast patrol boat designed specifically for anti-submarine warfare, with an overall length of 164 feet. Its power for foilborne operation is supplied by three gas-turbines. It is almost certainly intended for operation on the open seas. It appears that the foils are of the surface-piercing design. The main armament appears to be anti-submarine torpedoes in two triple mounts forward of the superstructure and two 30mm L/65 fully-automatic twin mounts for antiaircraft defense. More advanced vessels, including the 1,000-ton foil-borne warship which could be operational in 1990, are on the drawing board, and the USSR is exporting hydrofoils to her satellites, including three 230-ton torpedo boats to Cuba. She will have a foilborne warship by 1990, equipped with satellite torpedo boats. By 2005, her SESs will include one with a loaded weight of more than 2,000 tons.

Unlike the NATO nations, the USSR and later the Warsaw Pact countries, recognized the suitability of hydrofoils for military use soon after WW II.

3. Ram-wing and Wing-in-Ground Effect Craft

Aerodynamic craft include ram-wing and wing-in-ground effect machines. The ram-wing is a craft with a short-span wing with sidewalls at its tips. Its trailing edge and sidewalls remain either in contact with, or almost touching the water surface. At speed, lifting forces are generated both by the wing and the ram-air pressure built up beneath. The wing-in-ground-effect machine has an appearance of a flying-boat with short-span wings. It is designed to operate low down, at a height equal to half its wing span or less, where it rides on a dynamic air cushion set up between the machine and the surface below.

Flying within the ground-effect cushion, there is a remarkable drop in induced drag, which lowers fuel consumption, and increases the payload, or the range, by at least half again as much. An inverted delta-wing overcomes pitch instability, one of the major problems encountered when flying close to the surface in a craft equipped with conventional wings. It is inherently stable in ground effect, automatically maintaining a fixed height above the surface. It can fly in and out of ground effect to clear obstacles, manuevering in the same way as slow-flying aircraft, but when out of ground effect the economic advantages are lost.

In 1980, an "airfoil boat", using the ram-wing ground effect principle, with a range of 1,336 miles, with retractable wheels, for both land and sea use was manufactured in Germany. Through use of an airfoil, this configuration uses the air lift capability of a craft moving rapidly, in conjunction with the air cushion effect. It operates in moderate seas in the 90-180 knot range.

The USSR has a giant 10-jet wing-in-ground, which operates above the water at speeds of 300 kts.

The use of this new aerodynamic technology could permit the return of the seaplane as a very viable option. The power-augmented-ram/wing-in-ground effect vessel would fill the need for a rapid long-range heavy-lift aircraft not dependent upon foreign bases or overflight rights. Another concept would have very large airships or aircraft lift themselves from the surface on an air cushion, then fly conventionally. They, too, could utilize the wing-in-ground effect, reducing the wing's induced drag when it is close to the ground or water. In both concepts, a power-augmented ram propulsion system would be used to raise the transport vertically. Navy studies show that it should be feasible to develop a 1,000-ton transport capable of carrying the payload of three C-5 transports twice as far with greater fuel efficiency. It would fly across oceans close to the water's surface, clearing waves up to 12 ft. It could loiter for an extended time in the water or be flown to altitude to conduct tactical missions or avoid bad weather. It would offer greater operating efficiency because it would do away with either a sturdy seaplane hull or landing gear. Very large water-landing cargo ships would eliminate the need for extra-well reinforced runways. New lighter and less corrosive materials like titanium and composites will make them even more practical.

By the year 2005 there will be a need for an aircraft of 1,000 tons gross weight that will be able to compete fully with ships in carrying international cargo. It could be operated from ports served now by containerships.

The economy of the wing-in-ground-effect aircraft depends on close-to-surface operation, which limits its surveillance use. However, it would be very fast for the rescue stage of SAR, and would be able to hover (with power-augmented takeoff), land beside the distressed ship, and take aboard large numbers of people.

The Air-Cushion Landing Aircraft is also a new concept. The Lockheed Spanloader aircraft, a heavy-lift ACLS (air cushion landing system) freighter, can carry a payload of 560,000 pounds non-stop from the U.S. to the Middle

East. It combines the functions of wheels, skis or floats in a single system. This minimizes airstrip requirements and enables aircraft to take off and land from any flat unprepared surface--open fields, water, ice, marsh, sand. It also permits the aircraft to make safe and controlled crosswind landings and takeoffs with far heavier loads than can be borne by conventional multiwheel undercarriages. It is therefore useful in the Arctic. For parking on land or water, a lightweight bladder seals the airjets, thus supporting the aircraft at rest on land or providing it with buoyancy to keep it afloat. By employing a surface-effect, take-off and landing system (SETOL) a single naval aircraft will have the capability of performing a variety of roles formerly requiring a land-based aircraft, a carrier-based aircraft and a seaplane. The roles include close support, search and rescue, logistics support, amphibious assault cover, reconnaissance, and the transfer of equipment and personnel between ships on the move. Development of ACLS systems is being encouraged in the USSR, and they are expected to replace conventional wheeled undercarriages on a great number of aircraft by the end of the century.

The Ultra-Stable Vehicle--SWATH

SWATH is a semisubmerged ship design, consisting of two deeply submerged hulls connected to an above-water platform. It is extremely stable, has a high useable volume for a given displacement, can mount heavy weapons systems, and can serve with high effectiveness as a sonar platform, expecially for towing passive sonar arrays. Its maximum speed is not as high as the other vehilces described to this point, but because of its stability in high seas, SWATH may be the choice for a V/STOL platform. Fitted with hydrofoil capability for fast sprint, the design could be in use by the year 2005 in Coast Guard law enforcement, SAR, Commercial Vessel Safety, Marine Science, Environmental Protection, or military operations.

Lighter-than-air craft (LTA)

Recent Interest

Renewed interest in LTA craft is being expressed. A consensus is growing among policy makers as well as airship enthusiasts that there are no technical problems beyond solution in building airships, that the Modern Airship Vehicle (MAV) can be built to be safe, fast, and profitable, and that the potential fuel economies render a large scale effort in the best interest of the U.S.

One of the most pressing problem with airplanes and helicopters today is the rising cost of fuel. Lighter-than-air craft are much more fuel efficient than other aircraft. Airships are estimated to be three times as fuel efficient as airplanes. They depend on aerodynamic forces to some extent for flight control, but derive their lift principally from gases; thus fuel consumption is minimum. In addition, airships have several other advantages which have stimulated revival of interest in LTA vehicles. They are far less damaging to the environment than conventional aircraft, and they are almost silent. At their home bases, they probably will require hangars and ground-handling systems, but at intermediate stopping points the base requirements may be less extensive than those required for modern jet aircraft.

Airships can be constructed to carry large and very heavy payloads over long distances. For many missions they strike an optimum balance among the variables weight, delivery-time, and cost. Large cargo-carrying aircraft, like the C-5, carry reasonably heavy loads for long distances in minimum time, but are very expensive per ton-mile. Ships carry heavier loads over long distances, and are less expensive, but they require much more time. The airship falls in between; it can carry heavy loads over long distances in less time than ships and at only moderately higher cost. So for certain missions it promises to be ideal. The airship also has the capability to operate for long periods without replenishment of supplies or fuel. The limiting factor is crew fatigue. Even here, however, adequate space is available for relief cre .

Contrary to popular belief, the airship is not susceptible to catastrophic deflation from a slight puncture; the differential gas pressure between lifting gas and atmosphere is minimal. Leaks or small holes allow seepage of the lifting gas, and the size of hole required to bring the airship down is measured in square yards, not square inches. Even with a fairly large hole, the airship would descend gradually and under aerodynamic control.

One limitation of lighter-than-air craft derives from their large wind cross-section which requires large power expenditure in high winds to maintain position and aerodynamic control. This limitation is far less than is believed by many skeptics, and has been reduced through advances in airship technology. Important improvments in weather prediction also permit navigation to avoid weather which is potentially damaging. Many advocates claim that airships are no more vulnerable to adverse weather than other modern aircraft, and point out that historically airships have been able to maintain station in extremely adverse weather.

Physical Characteristics of Airships

There are three types of airship: the rigid, semirigid, and nonrigid (called blimp). The rigid airship is a rigid frame with fabric stretched over the frame, in which individual gas cells are placed. The airship's engines are mounted on the frame. The nonrigid consists of a large envelope divided into cells; each cell contains a lighter-than-air gas. The envelope attains its shape when the gas pressure slightly exceeds the pressure of the external atmospheric air. The "control car" is the station constructed for the craft's personnel and cargo, and serves as the foundation for the propulsion system of the craft. It is suspended from the envelope with lines attached to catenary curtains at the envelope's upper surface. The semirigid is similar to the nonrigid, except that it has a rigid keel attached to the envelope, with the control car and engines suspended from this keel.

In the past, rigid airships have been built larger than blimps. The largest nonrigid (a U.S. Navy ship) was 403.4 feet in length, with a capacity of 1,516,300 cubic feet. This is in contrast to the largest rigid (Hindenberg) which was 803.8 feet in length and had a 7,062,940 cubic feet capacity. Large size has the advantage of more volume per unit area of envelope surface. This advantage is somewhat countered by the increased weight of the rigid frame and additional equipmemt, but nevertheless gives the large rigid construction an advantage in lift in some instances. In addition, the larger ships do not require a proportionately larger crew--although for the longer endurance flights of which the rigid airship is capable, the larger crew would be required to avoid crew fatigue.

Nonrigids are generally preferred for small sizes while rigids are preferred for large sizes. If a new material called "Kevlar™" is developed as an envelope material, nonrigid construction could be superior for all sizes.

Three gases have been used to provide lift for airships; hydrogen, helium and hot air. Hydrogen has more lift capacity than helium, there are inexhaustible quantities, and it is inexpensive to produce. A disadvantage is that it is highly flammable, and would be a hazard in the face of hostile military or law violation forces. However, for use in non-violent circumstances, today's technological advances could render hydrogen-filled airships as safe as other vehicles using gasoline or jet fuel.

Helium is noncombustible, nonpoisonous, odorless and tasteless. It is present in extractable quantities only in some natural gases. Until recently, large quantities of these gases had been found only in the U.S. and Canada, but helium sources have now been discovered in USSR and Poland, destroying the

U.S.'s virtual monopoly. There are reports of airship construction, including heavy-lift vehicles, in the USSR which exploit the newly discovered supplies of helium.

There is an almost inexhaustible supply of helium stockpiled in the U.S. and waiting for airship development. In 1960 the U.S. began stockpiling helium, and, at heavy cost, a 4.2×10^{10} cubic feet supply has been accumulated and stored in underground wells at Amarillo, Texas. At the present rate of consumption these reserves will last for 200 years. It costs $8 million annually to maintain the stockpile.

History

The development of lighter-than-air craft, especially the rigid-frame type, suffered a damaging blow with the Hindenburg disaster (May 6, 1937). Its burning would not have happened if the dirigible had had access to helium rather than hydrogen. The U.S. at that time had a monopoly on the natural gas source of useable helium and would not supply it to Nazi Germany.

Although in World War II blimps for protection of shipping and barrage balloons for bombing protection in Britain were invaluable, their development has been neglected. Since blimps were last used by the U.S. Navy in 1960-61, certain new developments have significantly increased the probability that lighter-than-air craft can be very valuable additions to the Coast Guard. These have been in the areas of materials for airship shell and frame, improved instrumentation for navigation, communication, and weather prediction, and improved computer capabilities.

As early as 1931, rigid airships were being used by the Navy for reconnaissance and aircraft carriers. They had a hangar in the belly of the airship holding five high-speed fighter planes, which were launched and retrieved in mid-air by means of a trapeze arrangement lowered through a trap door in the bottom of the hull. On a single airship flight six pilots made 104 takeoffs and hook-ons in three hours. More than 3,000 such launchings and hook-ons were made during one airship's 54 flights.

Although large-scale development of rigid airships stopped in the 1930s, the U.S. Navy continued its interest in blimps, and in the 1950s the ZPG-2W and ZPG-3W were built for use as surveillance craft as part of an early warning net. In addition, the technology needed to improve the airship has been developing in other fields. Advances in materials, structures, propulsion and operations would permit a craft far superior to those of the past.

The safety record of LTA craft has been remarkably good. For example, Goodyear Aerospace has operated a fleet of blimps over about 50 years and has carried over a million people without a single injury.

Some of the interesting safety considerations include:

- One of the most important limitations to LTA craft, as pointed out in previous paragraphs, is susceptibility to wind hazards. The Goodyear safety record was accomplished through a combination of cautious use of the LTA craft in other than optimum weather, and effective use of available navigation technology. Thus weather adversely affected reliability of flights during bad weather, but not safety. The Goodyear blimp has all the navigational equipment necessary to operate in bad weather, but caution dictated flight curtailment under adverse weather conditions.

- Use of non-flammable helium, improved navigational equipment, and improved ground handling technologies, all promise to improve the safety of airships. The development of new, strong and lightweight materials and computer designed analysis of stress and strength will eliminate many of the structural weaknesses of the earlier ships.

- The low landing speed of airships means that should an accident occur on landing, the effects will be much less adverse than with heavier-than-air vehicles. The multiple engines of the airship permit normal landing in the event of engine failure.

New Developments and Potential Uses

Several characteristics projected to future lighter-than-air craft make them attractive for Coast Guard uses and include:

- Hover capability.

- o Capability to tether to a buoy or surface craft
- o Towing capability
- o Range in speed from zero to more than 100 knots.
- o Vertical takeoff and landing
- o Capability to operate in adverse weather
- o High fuel efficiency over long distances and long periods of time

These characteristics will give the LTA vehicle a unique advantage over both ships and aircraft in certain missions requiring long endurance, high speed, transportation of medium size and weight payloads, fuel economy, long radar horizon, boarding capability, and stable low vibration platform.

New materials such as Kevlar™ offer greater strength, durability, and impermeablility with less weight. Kevlar™ is alleged to have five times the strength of steel, weigh 50% less than nylon, and require less than one half the storage space of nylon. It is also resistant to acids and sea water corrosion. Its only major disadvantage is a high sensitivity to ultra violet light, which deteriorates its permeability and renders it useless as a gas envelope. The frames of airships could be made of new aluminum alloys, titanium, stainless steel, Kevlar™, graphite or fiberglass, offering greater strength for the weight. Today's turboprop engines deliver 17 times more horsepower, require fewer repairs, and consume less fuel than a 1930 engine of the same weight. Improvements in communications and navigational equipment will aid in accurately controlling the craft, allowing a smaller crew.

With current technology, ground handling can be technically much less complex than it was in the early 1930s when the last rigid airship was operational. A later Navy pioneering effort in portable masts and ground-handling tractors was successful in reducing the need for large ground crews. Loading and unloading containerized cargo from an airborne airship is technically feasible and will be particularly useful in areas where airfield space is limited.

Examples of recent new LTA developments are Data Link, a hot-air balloon which rescues ejected pilots in the air, and Giant Eye, a space-age nonrigid airship, the largest ever built. Giant Eye could serve as an airborne platform, in cargo transport, and in military functions. A study of the feasibilty of a giant airship to transport natural gas in a gaseous state has also been sponsored by Shell Oil Company. Shell is satisfied that this design will meet several highly desirable criteria. Lower fuel costs will make the airship economical for cargo, and it will have acceptable speed capability. New materials will make this airship less vulnerable to weather, and sophisticated electronics will help avoid the worst weather.

The future use of airships is highly likely to enhance the Coast Guard missions of Enforcement of Laws and Treaties, Search and Rescue, Environmental Protection, and Military Readiness. Even with the technology that exists today, the capabilities of the LTA craft appear attractive in a number of useful roles.

The following paragraphs suggest some additional characteristics and capabilities forecast for LTA vehicles by the year 2005.

- Nuclear powered large airships would have virtually unlimited range with large payloads.
- The easy interchange of cargo containers and passenger gondolas will make the airship more economical by cutting the time needed to load and unload freight, and allowing a switch from passengers to freight.
- Engine suspension systems for blimps will be designed to rotate 360°, allowing extra lifting power when needed for VTOL operations. Heating the helium for takeoff would also give the airship extra lift.
- Small blimps for law enforcement missions could be built which could fly at low altitudes (e.g. 500 feet), require a one-man ground crew, and operate at extremely low costs.
- Since the airship requires minimal fuel to stay aloft, it will be possible to establish sky stations capable of remaining aloft for long periods, ready to respond quickly to emergencies. It can provide a platform in the sky for surveillance for military, criminal or search

and rescue missions. A giant airship within the capability of current technology could serve as a flying hospital, bringing the finest medical facilities to disaster victims with unprecedented speed. It will also be possible to build unmanned nonrigids to operate at extremely high altitudes and conduct over-the-horizon surveillance.

Remotely Operated Vehicles

Several of the vehicles listed above would be amenable to remote operation. For example, a small remotely piloted seaplane would make use of the new command, control, and communications technology expected to be perfected within the next one or two decades. The "stealth" techniques which received publicity in the late 1980s depend upon materials with radiation absorbing characteristics which could be "painted" on the fusilage of remotely operated vehicles, thus resulting in low reflectivity and near invisibility to radar.

These remotely piloted craft could also take advantage of a new light weight composite material. This composite material (epoxy imbedded with carbon fiber) has been used in a plane (The Lear Fan) that is almost as fast as a jet, and uses one-fourth the energy. The material has four times the strength of aluminum and half its density. (These new composites weigh significantly less than metal, require much less machining and drilling, and produce less waste; but they are still very expensive compared with more conventional materials.) Use of these composite materials will increase speed and reduce energy requirements for aircraft, helicopters, surface effect vessels, and would be particularly applicable for remotely operated craft.

It is conceivable that the Coast Guard could, by the year 2005, have in use pilotless vehicles on full-scale combat, reconnaissance, or other types of missions under the radio control of a ground station, "mother" aircraft, or satellite. A Navy study indicates that such planes, fully loaded with electronic eavesdropping gear, could be operated in waves as high as 16 feet. By spending time loitering on the water's surface during deployment, a force of five such craft could probably accomplish a week's antisubmarine mission at a third the cost of deploying a similar number of land-based ASW aircraft, and one-eighth the cost of an ASW mission conducted by surface vessels.

Cost and safety concerns make remotely operated undersea vehicles attractive as potential replacements for human divers for inspecting offshore oil and gas fields. Untethered, unmanned underwater vehicles have a major problem of communication for command and control. Research has shown that microprocessors can assist in the solution, but the radiation-absorbing characteristic of sea water promises to remain a key obstacle to underwater communications.

A prototype of a small surveillance blimp which employs radio control gear has been flown. It could patrol large areas with minimum manpower by using television cameras and transmitters. The flight controls are so simple that one man could keep several blimps flying simultaneously.

CHAPTER 10: IMPLICATIONS TO THE COAST GUARD

The major impacts on the Coast Guard from forecast conditions stem from two sources. One is the macro environment, which sets the conditions under which science and technology will interact with the Coast Guard in the year 2005. The second is science/technology itself, whose dynamics present both opportunities for improved effectiveness and efficiency, and problems that could inhibit Coast Guard mission accomplishment.

"Implications" are any or a combination of the following:

- Issues--situations demanding decision
- Opportunities--circumstances offering potential for the Coast Guard to improve mission efficiency or effectiveness
- Problems--circumstances making mission accomplishment more difficult or expensive
- Change in constraints--change in the limits within which the Coast Guard is permitted to operate. Changes may be either tightening or loosening; limits are usually defined either as rules and modes of operating, or as resource availability.

GENERAL IMPLICATIONS

Several developments appear to be crucial in determination of the environment in which the Coast Guard's adoption of new technologies will occur.

The Advanced Industrialized Countries (AICs) will continue to experience economic growth. This means that the density of economic activity in all its aspects, including the oceans, will increase. Increased density of ocean operations means increased demand for Coast Guard services. In addition, the U.S. and other AICs are also extending their respective national sovereignties seaward, commensurate with economic interests farther out. This extension automatically increases the area of responsibility for operating federal forces at sea. Other aspects which may affect the Coast Guard include:

- Economic activity is precariously unstable unless it takes place under the protection of some form of governance in the ocean environment beyond a short distance from shore.

- In order to promote coordination and reduce interference among these economic and political competitors, a U.S. federal agency is likely to be empowered to exercise leadership in the process of governing. The Coast Guard is better equipped than any other federal agency for this role, and should be prepared to assume major portions of this role if called upon.

- Supranational governance will also occur as the various nations with interest in the resources of the oceans cooperate in exploiting these resources. The Coast Guard will play an important role in this supranational governance.

As economic activities in the marine environment increase, the complexity of relationships among the competitors will also increase. This means more accidents, damage claims, tort claims, traffic congestion, law violations, and other demands for service from governing agents. An increased burden of administration and operation will then rest on the ocean-managing agent of the U.S. federal government. The precise nature of the Coast Guard role in this managerial function may be uncertain, but it is clear that the Coast Guard will have an important role. The following factors will affect this role.

- The size of the geographical regions to be covered by ocean managing agencies has undergone a quantum increase. This poses a problem in the law enforcement and the search and rescue functions which is different from the past not only in degree but in kind; "more of the same" will not suffice. The capability to identify and locate quickly the source of trouble, to move action units directly to the scene, and to act once there, will increase in importance. This places a premium on high quality intelligence and surveillance capability: the capability to move surface and air units expeditiously and reliably to the scene, without reconnaissance along the way; and the capability for physical interaction, under adverse weather conditions, with other ocean craft at the scene.

- The role of federal lead agency for management of the marine environment is likely to fall to the "winner(s?)" of bureaucratic competition. The roles of other agencies will be to some extent fall-out from this competition. In this circumstance the administrative system established for this function will derive from a political rather than a managerial process. It will not necessarily be managerially sound, but may continue to be fragmented and unwieldy.

- One of the most important requirements likely to emerge from this expansion of activities in the ocean environment is for systematic management of sea use--the allocation of space and priorities for all the various uses to which the ocean and its resources can be put.

- As the activities in the marine environment increase and move seaward, the roles of the individual states in the regions inshore will also increase, to the relief of federal agencies such as the Coast Guard. But this shift of resonsibility to the states will come only from pressure on them to accept it; it will be expensive and resisted by many of the states.

- Also as the activities move seaward, increased responsibility will be placed on the industrial actors in the marine environment for functions relating to their own activities--particularly with respect to environmental protection.

- Movement seaward of economic activity will include a major component in ice-blocked waters. The Coast Guard is unique among federal agencies in capability to free seaways from ice.

SPECIFIC IMPLICATIONS

Deployment of Forces

By the year 2005 oil platforms on the OCS may be available as Coast Guard bases, especially in the Atlantic and Gulf of Mexico. The probability of this availability may not be high, but it is sufficient to warrant consideration in this report. Some of the considerations would be as follows:

- By 2005 the oil and gas supply offshore will have peaked, leaving surplus platforms. Clusters of these platforms or artificial islands will ring the U.S. These platforms will extend our "shores" to the edge of the continental shelf or about 200 miles into the Atlantic and over most of the Gulf of Mexico. They will be present off the Pacific Coast, but will not extend as far seaward. Thus in the busiest sea lanes and in the areas of most smuggling, illegal aliens entry, enemy infiltration, and heavy traffic, the Coast Guard could have outlying platform bases.

- These platforms could be bases for permanent monitoring devices and deployment of aircraft. They could greatly facilitate the use of many more fast surface-effect, hydrofoil, and air cushion vehicles. Coast Guard vessels could be refueled, recharged, supplied, and repaired. Personnel could be refreshed or replaced. Ships and aircraft will be modular, with many interchangeable parts; with a store of modular parts, the platforms could be capable of fast repair operations.

- Like the present-day platforms in the North Sea, they will be hotel-like in capacity. They will be largely self-sufficient and multipurpose, with facilities for production of electricity and fresh water. OTEC, wind mills, fuel cells, and eventually fusion power will be involved in this production.

- Some of the larger clusters of platforms will have facilities for recreation, education (for advanced degrees or technical training), and medical care. They may have quarters for family members, including civilian jobs for family members (i.e., schools, etc.)

- Depending on location, the platforms may be in clusters with offshore oil and gas platforms, ocean mining facilities, OTEC, kelp/seaweed farms, fresh water production, fertilizer factories, fish farming, biomass production, or floating vegetable farms.

- A new energy-saving technique for cooling industrial or commerical buildings is production of ice with snow-making machines. This could be efficiently used offshore. It would also produce fresh water, salt, and other useable by-products.

- The primary advantage of using platforms as bases will be shortened response time to events such as law violation, threat or damage to the environment (especially oil platforms), rescue operations, or antisocial infiltration. But other advantages will also accrue: less patrolling by cutters will save fuel; trained ELT, MEP and SAR crews will be available and ready; communications links will be shortened; modular parts will be available on platforms for ships and aircraft, pollution clean-up equipment, tankage for excessive pollutants, fire fighting and dewatering equipment, and support for diving operations.

- With the greatly increased traffic in the year 2005, in the busier locations and the need for safer traffic lanes out into the 200 mile zone could require Coast Guard Vessel Traffic Service (VTS) with control centers on offshore platforms.

Command and Control

By taking advantage of advances in information technology in application to a Coast Guard command and control system, the Coast Guard's operational mission capability--ELT, SAR and military readiness--will be enormously enhanced.

The cost of Coast Guard acquisition of this technology is likely to be relatively low, especially compared with the cost of a bold move into use of the advanced marine vehicle. It would also be possible to move incrementally into the command and control technology by acquiring a select number of components.

Advanced Marine Vehicle

To meet the challenge of more activities over a larger region, new Coast Guard ship designs will emphasize speed, with many versatile but relatively small ships rather than a smaller number of larger ships. Based in part on offshore platforms, these high speed craft will complement sophisticated surveillance and intelligence systems shared by the Coast Guard with ıer agencies. The need will be reduced for high endurance surface craft whose characteristics reflect patrol and surveillance missions. A seaworthy hydrofoil or air cushion vehicle will satisfy the new requirements in a cost effective manner. Lighter-than-air craft may also find utility for surveillance. Technology will provide improved means of remote control of these vehicle which will further increase their utility.

The Ecology and Water Shortage

The comprehensive systems of environmental management which were forecast are discussed at length in Chapters 7 and 8 of this volume and Chapters 2 and 3 of Volume II. They include systems to produce tailored environmental data, information, analyses and assessments--including weather, geological and geophysical analyses for use in marine operations. The final outcome is a system representing a virtual "revolution" in the concept of environmental protection, and movement toward positive environmental management. The scenarios reflect these considerations, and the explicit implications to the Coast Guard are summarized.

Several effects of general enviromental developments are relevant:

- The Coast Guard responsibility to prevent damage to the environment from the growth of the offshore economic activities will be severely challenged through the next two or more decades. The components of the challenge include regulation, inspection, law enforcement, follow-up of spills to assess responsibility, and clean-up after spills. One of the most important aspects of this challenge will be to develop regulations that provide protection, but do not inhibit investment. In some areas reduction of Coast Guard responsibilty will begin to occur. For example, individual states will be forced to accept increasing shares of the responsibility for maintaining a clean environment within the three mile limit, but the rate of increase of state responsibility will not match the rate of increase in Coast Guard responsibility at greater distances.

- The Coast Guard will participate in environmental adjudication between various parties, both foreign and domestic.

- Advances in technology will enhance the Coast Guard's capability to contain or neutralize oil spills and other environmentally damaging events. But while acknowledging the extreme need for clean-up capability mandated by current mission requirments, the Coast Guard may be investing significent resources in clean-up and containment equipment that will be made obsolete by advances in biochemical "processing" of potential polluting material.

- Pipeline monitoring, transshipment facilities, all-weather recovery, and more distant operations will be some of the specific new responsibilities imposed on the Coast Guard. Other substances will be added to the list of common pollutants as the century nears its end, such as LNG, the products of OTEC ship-plants, and the products of other offshore energy-intensive production plants. Development of an offshore mineral extraction industry will have a heavy impact on the environmental protection role of the Coast Guard. The effects of recovery of minerals from the sea floor, especially in the shallower waters, will require extensive monitoring by the Coast Guard. The other possible extraction methods are likely to raise considerable concern among the environmentalists, and require time to settle before mineral extraction on a large scale is developed. Antisocial action will mount as a likely cause of environmental damage. This means the Coast Guard will combine an operational capability to combat hostile action with the capability to contain environmental damage.

- The Coast Guard administration of pollution compensation funds will increase in complexity and scope. "Super" funds will become common and more effective as deterrents to potential oil spillers. As these responsibilities mount it will become clear that some federal agency should be designated to manage them; it will also become clear that, politics notwithstanding, the Coast Guard is one of the logical governmental bodies to be given the additional responsibility of centralized marine manager.

The specific effects on the Coast Guard of the forecast water shortage can be categorized as either direct or indirect. The direct effects derive principally from two sources: drought and direct use of water. The indirect effects derive from six sources: shipping, growth of U.S. commerce, movement of economic activity offshore, export growth, environmental protection, and international conflict.

Direct Effects

Water shortages induced by droughts will raise serious navigation problems for the Coast Guard. Programs for Port Safety and Security, Short Range Aids to Navigation, Bridge Administration, Boating Safety, and Radio Navigation Aids will be adversely impacted.

As a user of fresh water the Coast Guard will suffer the same operational limitations as all other other marine vehicles. That difficulty will enlist support from the Coast Guard in promoting offshore production of water--OTEC plants and desalination plants--as well as in promoting propulsion systems that conserve water.

Indirect Effects

Decreased and erratic water supplies will make the U.S. waterways undependable, at the same time that they are more in demand as the most economical means of bulk shipment. The only lessening of demand will be because of an occasional cutback of grain production due to drought. Increased need for waterborne shipping will produce pressure for more canals, improved waterways and extention of the shipping season in the Great Lakes and St. Lawrence Seaway. The effect on the Coast Guard will be acquisition of additional responsibility, but under increasingly adverse circumstances.

Water shortages will have an extremely heavy impact on the waterborne commerce of the U.S. With the exception of petroleum products, virtually all major commodities will experience a significant increase in pressures for growth over the next few decades*. Depending upon estimates of coal export, growth for all waterborne commodities moving in domestic and foreign trade range from 24 percent under a low coal export scenario to 51 percent under

* Some of the estimates on changes in commodity trade volumes are of interest: Crude oil and petroleum products decline under all forecasts; this decline ranges from -24% to -36%. Coal shows the highest rates of increase, from 125 percent under low use to 280 percent under high coal export. Farm products rank second to coal in growth rates; the 25 year increase ranges between 115% under low use to 146% under high. Metallic ores is the third highest growth commodity with increases ranging from 76% under low use to 114% under high. Chemicals and fertilizer growth increases from 70 to 84 percent. Domestic water borne shipping is projected to increase 48%; foreign, 21%.

high coal export in the year 2005. The effect of a water shortage will be twofold: first it will curtail this growth in commerce, and second it will tend to move much of the related traffic away from U.S. ports and inland waterways, and to offshore routes.

The water shortage will equate to further pressure to develop offshore food production, which in turn will add to Coast Guard offshore responsibilities.

U.S. coal production and export will grow to compensate for the reduced and more expensive oil supply. The energy ports of the U.S. will be increasingly vital, with the Coast Guard bearing the brunt of traffic regulation. The U.S. will develop deep draft ports capable of moving coal efficiently. With decreased water levels, the Mississippi and St. Lawrence Seaway will carry less rather than more of the traffic required to maintain this flow of coal.

Federal standards in environmental protection will wax and wane during the period of this report. During the relaxation periods, the loosening of environmental controls will cause a hastening of water shortages.

PROGRAMMATIC IMPLICATIONS

A very brief assessment of the implications of the forecasts to the major Coast Guard programs is presented.

Short Range Aids to Navigation and Radio Aids to Navigation

Better technology and reduced costs of automation, sensing, and radiation devices will improve Coast Guard capability to meet requirements in both of these mission areas. Information technology and more easily formed types of durable materials will constitute the basis for more effective and efficient aids to navigation of all types. Applications will extend from inland waterways to open ocean operations, and will include buoys, beacons, satellite systems, and inertial navigation systems.

Enforcement of Laws and Treaties

This is the area in which the Command and Control scenario will have its greatest impact. Of the four operational missions of the Coast Guard--ELT, SAR, military readiness, and ice operations--it is forecast that ELT will increasingly dominate demand for Coast Guard services through the end of the century and into the next. This demand will grow at a much faster rate than the demand for military services, at a slightly faster rate than demand for SAR services, and at about the same rate as demand for counter action against antisocial technology. As the activities in the marine environment increase and move seaward, the need for operational units to perform the law enforcement and SAR roles will be emphasized.

- One aspect of the increasing complexity of the law enforcment function of governance in the marine environment will be the interface between policing action and judiciary action. It is troublesome enough when only the Coast Guard and U.S. federal courts are involved; it becomes more complex when state courts become involved, and even more complex when international law is involved.

- Applications of new technology are as likely to be made by law violators as by law enforcement agents. By the year 2005 the Coast Guard's adversaries in the marine environment may have acquired a more sophisticated technology than the Coast Guard--in terms of performance of seagoing/airborne units.

- The application of antisocial technologies to law violation, coupled with an increase in terrorism, will constitute yet another factor increasing the burden on law enforcing agents in the marine environment; in addition, the use of advanced technologies by the antisocial forces will be successfully countered only by law enforcement forces with equally advanced technologies.

- U.S. law enforcement functions are already extremely fragmented, and becoming more so. Within the federal government the Coast Guard is in partnership with several other agencies: the DEA, FBI, INS, OSHA, as well as the White House. Certain UN bodies are also involved, and as the international aspects of marine environment operations increase, the involvement of international bodies may be expected to increase.

- The complexity of law violation operations will increase the need for multiple unit operations--i.e., more than one ship/aircraft combination converging on a law violator in a particular scenario.

Marine Environmental Protection

New technologies will completely alter the basic concepts of environmental protection. There will be a shift from clean-up to preventive measures. The environmental preservation systems of the future will provide prescriptions for environmental enhancement as well as protection. They will offer tailored, interdisciplinary information, analyses and assessments on the ecological system as a whole, through which environmental managers may take decisive action. Centralized control centers, linked through advanced command and control systems, will provide the means for execution and coordination of ocean uses, activities, and environmental protection measures. Exploitation of this potential for enhanced environmental management in the future will require a centralized authority. The Coast Guard with its existing operational capability and experience/expertise, is the leading candidate among federal agencies to assume this role as centralized authority for environmental mangagement.

Commercial Vessel Safety

The advances in information and computer technology will have a heavy impact on increasing the Coast Guard's capability to insure commercial vessel safety. The technology of new materials will also permit regulation improvements in this area through improved hull strengths, joining techniques, preservative characteristics, etc.

The Coast Guard's increased burden of operating will tend to reduce its capability to assign resources to this function. More reliance will be placed upon the ship operators for their own safety; insurance will be required and user charges will be imposed.

Port Safety and Security

The increases in command and control capability can be extended to port safety and security. Vessel traffic services, detection of potential hazards to ships or port facilities, and information systems on port activities can all be improved. As in the case of Commercial Vessel Safety, this function will suffer from the increased operating load on the Coast Guard. It is recommended that the Coast Guard attempt to shift responsibility for this function insofar as possible to state and local authorities in order to maximize its contribution in the area of greatest competence, as an operational asset of the federal government.

Search and Rescue

This function will be more efficiently and effectively accomplished by the Coast Guard by virtue of its increased capability in information technology in general, and its command and control capability specifically. Faster ships and more versatile aircraft will foster successful missions.

The assessment supports the concept that the interests of the U.S. are served by the Coast Guard shedding SAR responsibility close to shore and transferring this function to states and local authorities. This would mean relieving the Coast Guard of a major portion of its present SAR work load, since 75-80% of SAR cases are within one mile of shore.

Recreational Boating Safety

New communications sensing devices will aid in this function; however, it is considered that this function cannot be performed by the Coast Guard without jeopardy to its other missions which national interest places at higher operational priority--the missions farther out to sea. Again, more responsibility will be placed upon operators.

Bridge Administration

Comments with regard to dilution of Coast Guard resources apply particularly to this area. This mission is likely to be reassigned to another agency, perhaps a state agency.

Military Preparedness

The historic "war time" partnership between Coast Guard and Navy is rapidly changing. This is mainly because of the differences in technology of weapons for defense against Soviet weaponry on the one hand, and weapons for countering terrorism and lower level antisocial action on the other hand. The Navy will concentrate on the former. The Coast Guard will acquire a strong capability in the latter, if the Coast Guard takes advantage of technological opportunities to meet the challenge of rising terrorism and other antisocial action. This means that the Coast Guard is likely to have an exclusive role in some future "war", a role that involves countering extensive lower level hostile action at sea. Thus the Coast Guard military capability will become a more integral part of the U.S. military readiness posture by becoming complementary to the Navy, rather than adjunct to the Navy. The Coast Guard will have capabilities for types of conflict for which the Navy is ill equipped, such as the lower level antisocial activities likely to arise in conjunction with terrorism, and the ambiguities of enforcement of laws and treaties in circumstances where the source of disruption is unknown.

Ice Operations

Expanded operations in the northern waters, including Great Lakes and Arctic operations, will further increase Coast Guard work load. These operations will be especially aided through use of air cushion vehicles. If these ice operations increase significantly, the Coast Guard may find air cushion vehicles preferred over hydrofoil as a major acquisition policy; their use as ice breakers has already been demonstrated. Application of information technology to navigation aids will also improve efficiency and safety of operations in ice-bound waters.

CHAPTER 11: CONCLUSIONS

Technology impacts upon the Coast Guard in three ways.

- Coast Guard exploitation of emerging technologies in information and in marine vehicles offers some relief from the most severe problem confronting the Coast Guard--a squeeze between expanding demand for services and tight resources.
- As advanced economies move seaward, a need for ecological conservation/protection will increase. Technologies of environmental conservation/protection are advancing with sufficient speed to offer the Coast Guard opportunity to stay abreast of increasing needs.
- Coast Guard initiatives to exploit new technologies in information, marine vehicles, and environmental management will require major institutional change within the Coast Guard, new ways of operating and new processes of administration.

This chapter offers background for this conclusion.

The U.S. marine environment stands at the threshold of a new historic era. A complex set of historical, technological, sociocultural, physical, and political factors are combining and the early stages of a discrete marine "system" is emerging. We are now in the early stages of this new period. Shifting onshore activities offshore is changing them, forcing adaptations to different technical, economic, employment, regulatory and governance problems. Traditional sector distinctions are breaking down and gradually being replaced by a separate marine system, functioning as a component of the broader national and international economy, but with its own logic, structure, economics and institutions. Within the marine environment this change will be analogous to many of mankind's major historic shifts--hunting-and-gathering to agriculture, agriculture to industry, industrial society to information society. It will result in a number of discontinuities with profound effects upon U.S. and international economies.

Depletion of land resources coupled with perceived abundance in the oceans is stimulating seaward movement of the economies of the Advanced Industrial Countries (AICs). At the same time the ocean policy formulation process at the international, national and subnational levels is fragmented. At the international level the controversy between "common heritage of mankind" and "free enterprise" continues to inhibit policy decisions. At the national level, a large number of federal agencies contribute to policy making, but no single agency has the lead. Competition for leadership is active. At the state and local levels the contribution to this policy formulation process is ad hoc within three miles of the shore line, and beyond three miles no underpinning of state and local governance exists at all. Without both the structure and processes of governance economic activity is inhibited by risks.

Science and technology will constitute a major driving force behind the changes in the marine environment through the year 2005. Energy and resource extraction will constitute a second major driving force. Political controversy and indecision will continue to constitute the most important inhibiter.

The management of the marine environment will place a major administrative demand on some federal government agency(ies) by the year 2005. The objects of this management will include such matters as:

- o Law enforcement
- o Safety/security of people and property
- o Sea use and space allocation
- o Traffic management
- o Resource extraction/development/conservation
- o Environmental protection

The realization that the Coast Guard is entering a completely new era is gradually becoming clear to executive and legislative bodies. In addition to its military role, the Coast Guard will be caught in the confluence of two trends whose effect on the Coast Guard will be that of multiplication, one by the other. These two trends are:

- o Increased geographical domain of responsibility
- o Increased density of activity within that domain

This activity will increase demands on the Coast Guard, particularly in law enforcement: fishing rights, drugs, illegal aliens, and terrorism.

The marine environment's discontinuity places the Coast Guard at a critical juncture, caught between expanding obligations placed upon it, and static or diminishing resources. Without some change in this imbalance between demand and resources, the Coast Guard's future mission effectivness and efficiency will be in jeopardy.

TECHNOLOGICAL OPPORTUNITIES FOR THE COAST GUARD

Several types of opportunity are available to the Coast Guard to redress this imbalance. Application of technological innovation is one of these. Such application is limited to the extent that by policy decision the Coast Guard is more a user of "off-the-shelf" technology than a generator of new technological applications. There are exceptions to this, notably in the areas of environmental cleanup and ship stabilization technology.

Technological applications which offer a means of aiding the Coast Guard in its effort to accommodate to the new environment require drastically new ways of addressing the Coast Guard missions. These new ways include, for example, the use of a nation-wide intelligence net, an ocean-wide surveillance net, and relinquishing of inshore responsibilities which are deeply embedded traditions, and whose loss may adversely affect morale. This morale effect could occur from changing the Coast Guard image from benevolent rescuer to tough law enforcement officer.

Technologies which offer important opportunities for the Coast Guard include: information, vehicles, ecology, and materials. Other technologies offering opportunities of perhaps slightly lower level of importance include: biogenetics, synthetic materials (including metals, plastics, ceramics, fuels), energy storage, and biophysics.

Advances in information technology will provide capability for highly centralized direction of operations from remote locations; the same advances will permit effective acquisition of information at the scene so that the "big picture" will be available to virtually all elements of an organization conducting an operation. This will give the commander the option to observe operations without taking charge himself, and without relinquishing the right to take over if necessary. A by-product of information technology, electronic surveillance, will replace patrol surveillance by the year 2005.

A major opportunity for the Coast Guard is application of information technology to its Command and Control system. Success of such application depends upon concomitant application to intelligence and surveillance. The Coast Guard application of information technology will depend heavily on the information industry at large, including that in foreign countries like Japan.

A second opportunity is the application of advanced marine vehicle technology to the Coast Guard's fleet of surface and near-surface craft. Determination of the most cost-effective combination of vehicles depends on an in-depth study, which would address the reduction in costs for surface patrols, realized through acquisition of the more advanced vehicles. High speed intercept action will replace economical cruising speed patroling by the year 2005. With these advanced marine vehicles, fuel costs per mile traveled may increase over the 1980s, but fuel costs per successful mission accomplished will decrease.

The most likely candidates for this combination are:

- Air cushion vehicle
- Hydrofoil
- Ram-wing vehicle
- SWATH
- Lighter than air vehicle

The choice among these opportunities presents the Coast Guard with the need for early decision with respect to a major conversion opportunity--i.e. an opportunity to begin now to convert capital resources into those needed for the future, with some risk to current capability. Some of the more important aspects of this choice include the following.

- In order to make decisions on these issues, the Coast Guard needs a means of evaluating the degree to which its law enforcement mission has been accomplished. Judgmental evaluations of accomplishment of SAR and military missions may be adequate; but the uncertainty of the number of law violators that elude apprehension renders assessment of law enforcement effectiveness problematical. Thoroughly modern intelligence systems, command and control systems, and surveillance systems are likely to reduce this uncertainty.

- Under today's budget constraints the Coast Guard may have to choose a balance between present and future capability. Opting for replacement of cutters with conventional craft rather than with advanced vehicles would probably cost less in initial outlays, and could be accomplished faster. But this may only further delay Coast Guard readiness to meet the requirements of the year 2005 and after.

- In addressing this choice, a further dilemma is how to render the benefits of advanced vehicles commensurable with a dollar cost figure, in order to make comparisons against conventional craft. In terms of cost per unit weight of hull, the cost of advanced technological means of mission accomplishment may be excessive; however, in terms of degree of mission accomplishment per operating unit, the cost may be very low.

The technology of intervehicular transfer in heavy weather will be a major benefit to the Coast Guard and will have a marked impact on its ability to accomplish its extended search and rescue and law enforcement missions in the year 2005. A major ingredient of this new capability will be robots. Robots will permit personnel in a Coast Guard air or surface craft to interact effectively with the personnel in a storm-damaged craft, or in hostile smuggling crews, under adverse weather conditions and in the face of physical violence. Another major ingredient will be stabilized ship platforms--e.g. rudder-roll stabilization and SWATH.

ECOLOGICAL CHANGE AND THE COAST GUARD

The impending U.S. water shortage will aggravate rather than relieve the Coast Guard's dilemma by fostering even further increase in density of offshore operations. Direct application of technology by the Coast Guard is unlikely to offer relief.

The environmental protection issue is likely to have both aggravating and ameliorating effects on the Coast Guard. Aggravation may accrue from increased priority on environmental conservation/protection. Relief may accrue through large-scale government and industry efforts in environmental preservation, damage prevention, and cleanup. Some relief may also accrue through direct Coast Guard application of technology to the cleanup process; however, this is likely to be short term, as opposed to the longer term preservation and prevention technological applications.

OPTIMUM ROLE FOR COAST GUARD

The interests of the U.S. would be served from exploitation of the Coast Guard's operational capability--if necessary at the expense of its regulatory capability. U.S. interests would also be served from legislation and executive decision to place responsibility on the individual states for the management of the near-shore regions of the marine environment. The Coast Guard would be relieved of myriad functions which it does well and which enhance the Coast Guard's image as benefactor, but which overburden its capabilities.

The Coast Guard burden could also be affected by a change in the law permitting the Navy to assist in law enforcement functions. This action would be less desirable than the others suggested here, because it would divert defense forces from their primary missions.

The Coast Guard financial burden could be lightened through imposition of user charges to direct beneficiaries of Coast Guard services. This action would be disadvantageous in that it would involve considerable additional administrative load for the Coast Guard. Additional financial relief could derive from laws requiring industrial users of the marine environment to insure themselves fully against damages to the environment--either through a "super fund", self insurance, or otherwise.

INSTITUTIONAL CHANGES

A changing social and economic structure is taking place in the U.S. A large component of this change is in the work place, and is likely to alter the traditional personnel structure in the military services, including the Coast Guard. The officer/enlisted dichotomy is likely to give way to a different structure based upon a mix of education with skill and competence. Education per se will decline as a factor, while skill/competence will rise. The present system is so deeply embedded in tradition that it will take a long time to change, but the beginnings of such change will be seen clearly before the year 2005. Any new system may carry the traditional terminology, "officer" and "enlisted", but this will no longer be adequately descriptive, and it will give way to more descriptive terminology.

A problem accompanying such a personnel transition will be to maintain the strong sense of institutional "professionalism" that the Coast Guard has maintained throughout its history.

The present fragmented nature of the governance of the marine environment demands institutional innovation in three respects:

- Establishment of comprehensive policy objectives for this governance
- Development of the structure and process to achieve these objectives
- Evaluation of the continuing outcomes of the new governing process

The Coast Guard's role in the policy formulation process will be influenced by the Coast Guard's own policy decisions. As an agency with at least as much institutional experience as any other, and as the agency with perhaps the highest image in terms of motivation to serve the public interest, the Coast Guard is in a position to take a leadership role in development of policy positions. Over the past several years the U.S. position has been uncertainly split between "common heritage of mankind" and "free enterprise". The ultimate position of the U.S. on this issue may be crucially important to the U.S. and its future access to the ocean's resources. Coast Guard experience should be reflected in the ultimate policy decision.

Similarly, the Coast Guard has the opportunity to create to some extent its own position in the structure of governance that ultimately emerges. Obviously the Coast Guard's own internal structure will need to adapt to the new environment; this in itself will require institutionally innovative measures within the Coast Guard. But in addition, the Coast Guard is in a position to influence favorably the overall federal structure for marine governance.

By the very act of participating in the policy-making and structure-creating decisions, the Coast Guard would be participating in the evaluation process, and would be establishing itself as a major factor in overall marine environment policy matters. Such a role would be fully consistent with the interests of the U.S. to maintain a continuing appraisal of its policy as the marine economy emerges.

If the shortfall in U.S. oceans policy persists, it will place the Coast Guard in an institutional atmosphere of "policy uncertainty" for many years. The drive of Coast Guard professionals to innovate--either technologically or institutionally--may be mitigated in such an atmosphere.

The dynamic interaction between technological change and cultural change renders highly uncertain a forecast of either without the other; further, the nature of this relationship is such that forecasting outcomes is itself highly uncertain. The best that can be done is to identify some of the variables that need to be monitored in order to perceive emerging trends at the earliest possible time. Some of these variables are:

- Personnel requirements--including educational issues
- Transferability of current technological skills to new technologies

- Changing work-place values
- Trends in management processes and techniques
- Shift to increasingly capital-intensive operations
- Shifts in the roles of skilled versus unskilled labor
- Role of government in fostering science and technology
- Productivity of U.S. work force
- Science education in U.S. schools and universities

In addition, the following major issues will require monitoring, as the relative importance of these issues undergo continuing change through the next several decades.

- Internal organizational implications of the changing technologies
- External relationship implications to the Coast Guard of continuing technological change
- Effect of advancing military technology on Coast Guard relationship to the Navy

*U.S. GOVERNMENT PRINTING OFFICE: 1981 524-194/299 1-3

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