Federal Radionavigation Plan

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Radionavigation Plans and Policy

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LETTER OF PROMULGATION

This letter promulgates the second edition of the Federal Radionavigation Plan jointly prepared by the Departments of Defense and Transportation. It supersedes the Federal Radionavigation Plan dated July 1980.

The Federal Radionavigation Plan is issued for information on the management of those radionavigation systems which are used by both the military and civil sectors. It supports planning, programming and implementation of air, marine, land and space navigation systems to meet validated requirements as reflected in the President's FY 1983 budget submission to Congress. It is the official source of navigation policy and planning for the Departments of Defense and Transportation. The plan has been prepared with the assistance of the National Aeronautics and Space Administration and has its concurrence.

The Federal Radionavigation Plan will be revised annually. Your suggestions for the improvement of future editions are welcomed.

Caspar W. Weinberger
Secretary of Defense

Drew Lewis
Secretary of Transportation

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16. Abstract

The second edition of the Federal Radionavigation Plan (FRP) has been jointly developed by the U.S. Departments of Defense and Transportation to ensure efficient use of resources and full protection of national interests. The plan sets forth the Federal interagency approach to the implementation and operation of radionavigation systems.

The Federal Radionavigation Plan delineates policies and plans for Government provided radionavigation services. The Document describes respective areas to authority and responsibility, and provides a management structure by which the individual operating agencies will define requirements and meet them in a cost effective manner. It replaces the DOT National Plan for Navigation, and incorporates those sections of the DOD Joint Chiefs of Staff (JCS) Master Navigation Plan dealing with common user systems.

Volume I is a summary document which delineates plans, policies, and authority and responsibility for providing radionavigation services. An integrated management plan describing how DOT and DOD will determine requirements and coordinated research, development, and implementation of radionavigation systems is provided in this volume.

This plan will be updated annually, and is presently made up of a total of four volumes: Volume II, Requirements, has 48 pages; Volume III, Radionavigation System Characteristics, has 47 pages; and Volume IV, Radionavigation Research, Engineering and Development, has 32 pages.

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PREFACE

The Departments of Defense and Transportation have developed the second edition of the Federal Radionavigation Plan (FRP) to ensure efficient use of resources and full protection of national interests. The plan sets forth the Federal interagency approach to the implementation and operation of radionavigation systems.

Various existing and planned radionavigation systems used in air, land, and marine navigation are reviewed in terms of user requirements and current status. The FRP contents reflect a response to a unique combination:

- o DOT responsibilites for public safety and transportation economy.
- o DOD responsibility for national security in normal and stressed situations.

This plan will be updated annually. The established DOD/DOT interagency management approach will enable continuing control and review of U.S. radionavigation systems. For further explanation of navigational terms used in this plan consult The American Practical Navigator, Volume 2, Publication No. 9, Defense Mapping Agency Hydrographic/Topographic Center, 1981.

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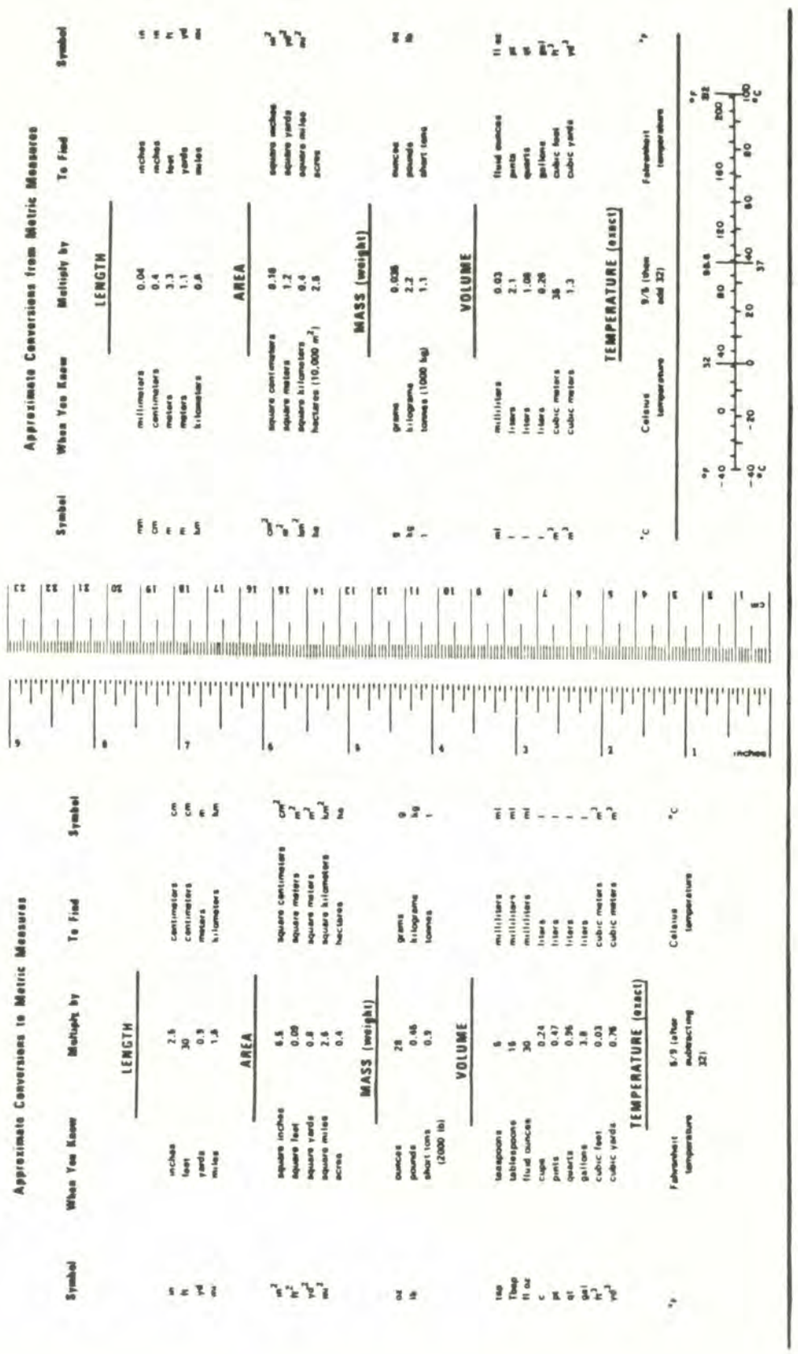

SUMMARY TABLE OF CONTENTS

FEDERAL RADIONAVIGATION PLAN

VOLUME I

RADIONAVIGATION POLICY AND PLANS

TABLE OF CONTENTS

LIST OF FIGURES

VOLUME I

LIST OF TABLES

EXECUTIVE SUMMARY

The Federal Radionavigation Plan (FRP) delineates policies and plans for government-provided radionavigation services. This plan will describe areas of authority and responsibility and provide a management structure by which the individual operating agencies can define and meet radionavigation requirements in a cost effective manner. It is the official source of Navigation policy and planning for the Departments of Defense and Transportation. This edition of the FRP updates and replaces the initial FRP published in July 1980 and incorporates common user (civil/military) radionavigation systems covered in the DOD Joint Chiefs of Staff's Master Navigation Plan (MNP). The MNP has not been replaced by the FRP, since it covers many military only radionavigation systems.

This document describes the various phases of navigation and provides current and anticipated future requirements for each. Additional radionavigation systems may be added or deleted in subsequent revisions to this plan as requirements change. The U.S. LORAN-A system has now been phased out and deleted from the plan.

This plan covers Federally operated systems having a high degree of common use. These systems are sometimes used in combination with each other or with other systems. However, these hybrid systems are not covered in the FRP.

The systems covered in this plan are:

LORAN-C
OMEGA
VOR, VOR/DME, VORTAC
TACAN
ILS
TRANSIT
Radiobeacons
MLS
NAVSTAR GPS.

The goal is to select a suitable mix of these common civil/military systems which can meet diverse user requirements for accuracy, reliability, coverage, operational utility, and cost; provide adequate capability for future growth; and minimize duplication of services.

The process of selecting a system mix is a complex task, since user requirements vary widely and change with time. While all users require safe, expeditious services which are easy to use, military requirements stress unique defense capabilities such as performance under intentional interference, operations in high-performance vehicles, worldwide coverage and operational capability in severe environmental conditions. For the military, cost remains a major consideration but must be balanced with a needed operational capability.

Civil requirements are driven by needs which range from small single engine aircraft, or small vessels, which are highly cost-sensitive and may require only minimal capability, to highly sophisticated users such as airlines or large vessel operators to whom high accuracy, flexibility, and availability may be more important than initial cost. The selection of an optimum mix to satisfy the users,

while holding the number of systems and government and user costs to a minimum, involves complex operational, technical, institutional, international and economic trade-offs. This plan establishes a vehicle for DOD and DOT to address these questions and arrive at an initial optimum mix determination in the mid-80's.

A significant portion of this plan is devoted to NAVSTAR GPS since it has the potential to replace many existing radionavigation systems. Certain military applications, nevertheless, require covertness and redundancy, or multiple independent navigation systems and cannot be replaced by NAVSTAR. Technically and operationally NAVSTAR GPS is more complex than existing systems and represents a significant challenge in the development of low-cost user equipment.

This document is composed of four volumes:

Volume I: A summary document: Delineates plans, policies, and authority and responsibility for providing radionavigation services. An integrated management plan describing how DOD and DOT will determine requirements and coordinate research, development and implementation of radionavigation systems.

Volume II: User requirements: Civil and military requirements and the process for determining them are provided in this volume. Both general requirements and specific requirements related to various applications and phases of navigation are discusssed. Present and future anticipated needs are both discussed.

Volume III: System Characteristics: Describes present and planned navigation systems in terms of nine major parameters: signal characteristics, accuracy, availability, coverage, reliability, fix rate, fix dimension, capacity, and ambiguity.

Volume IV: Research, Engineering and Development Plans: A summary of DOD, DOT, and NASA radionavigation R,E&D plans with primary emphasis on NAVSTAR GPS.

VOLUME I

CHAPTER I

INTRODUCTION TO THE FEDERAL RADIONAVIGATION PLAN

1.0 INTRODUCTION

This chapter describes the background, purpose, and scope of the Federal Radionavigation Plan (FRP). It summarizes the events leading to the preparation of this document and the national objectives for assuring coordinated planning of radionavigation services. The remaining contents of this volume set forth National Policy, Radionavigation Authority and Responsibility, and Radionavigation System Planning. Three supporting volumes (Requirements, Systems Characteristics, and Research, Engineering, and Development) are outlined briefly.

1.1 BACKGROUND

The FRP contains policy and planning for common user (civil and military) radionavigation systems. The Joint Chief of Staff (JCS) Master Navigation Plan (MNP) contains policy and planning for all radionavigation systems used by the DOD, including common user systems.

Prior to the time work started on the first edition of the FRP, the Office of Management and Budget (OMB) and National Telecommunications and Information Administration (NTIA) co-chaired an interagency working group to study planning among various government agencies responsible for providing radionavigation services for both military and civilian users. The working group was composed initially of representatives of DOD, DOT, the National Aeronautics and Space Administration (NASA), and the Department of Commerce (DOC). Later, representatives of the Department of State (DOS) and the Central Intelligence Agency (CIA) were added to the working group.

In April 1979, a DOD/DOT Interagency Agreement strengthened Federal radionavigation planning. Within DOT the Navigation Council and its supporting working group address civil and joint civil/military uses of navigation. This includes radionavigation interests of other federal agencies such as NASA and DOC, and state and municipal agencies. The DOD Positioning/Navigation Executive Committee (POS/NAV Committee) and POS/NAV Working Group address military and Joint Civil/Military radionavigation system planning.

This FRP and subsequent annual revisions serve as the primary planning document for all common-user civil/military Federal radionavigation services.

In the first edition of the FRP reference was made to NAVSTAR GPS P-code and C/A code accuracies to distinguish between the high accuracy of the P-coded signal and the lesser accuracy of the C/A coded signal. In order to separate the means of achieving the two levels of accuracy, P-code and C/A code, from the service provided, future reference to the P-code accuracy will be the "Precise Postioning Service (PPS)" and to the C/A code accuracy the "Standard Positioning Service (SPS)".

1.2 PURPOSE

The purpose of this FRP is to:

A. Present an integrated Federal, military and civil policy and plan for all common civil/military radionavigation systems.

B. Provide a document for comparing civil/military systems and requirements on a common basis.

C. Outline an approach for achieving maximum consolidation of radionavigation systems. Where concrete decisions can be made now, these are presented. Where decisions must be scheduled for a later date, these are identified together with the actions planned to reach such decisions in a timely fashion.

D. Define and clarify new or unresolved issues relating to navigational systems, e.g., operational, technical, economic, and institutional questions.

E. Provide a multi-year system planning schedule.

F. To provide government radionavigation planning information suitable for use by civil users, manufacturers, and non-government operators.

1.3 SCOPE

This plan covers government provided common use radionavigation systems. It does not include systems performing mainly surveillance, surveying, and communication functions.

1.3.1 Systems

The major radionavigation systems subject to the planning process described in this FRP are:

- o LORAN-C
- o OMEGA
- o VOR, VOR/DME, VORTAC
- o TACAN
- o ILS
- o TRANSIT
- o Radiobeacons

- o MLS
- o NAVSTAR GPS

1.3.2 Phases of Navigation and Requirements

Volume II of the plan defines phases of navigation and addresses radionavigation requirements for each phase of aviation, marine, land, and space operations. The phases are:

- o Air - Approach/Landing and en route/terminal.
- o Marine - Ocean, coastal, harbor approach, harbor and inland waterway.
- o Land - Automatic Vehicle Monitoring (AVM), Automatic Vehicle Location (AVL) and Site Registration.
- o Space - Launch, in-flight/orbit and re-entry.

1.3.3 System Characteristics

Descriptions of the salient features of radionavigation systems are summarized in Chapter 4 of this volume. Detailed technical descriptions for each of the radionavigation systems are presented in terms of nine primary system perfomance parameters in Volume III.

1.3.4 Research, Engineering and Development

Federal radionavigation research, engineering, and development activities to improve existing operations or to assess future system alternatives are presented in Volume IV.

VOLUME I

CHAPTER 2

FEDERAL RADIONAVIGATION OBJECTIVES AND POLICY

2.0 INTRODUCTION

The radionavigation policy of the United States has evolved over a number of years through statute, use, and in the interest of national defense and public safety. The policy forms the basis for the development of the Federal Radionavigation Plan.

2.1 RADIONAVIGATION OBJECTIVES AND POLICY

The objectives of United States Government Radionavigation Policy are to:

A. Promote efficient transportation services.

B. Promote national security by providing necessary services.

C. Promote safety of travel.

The following policies and practices implement the above objectives:

A. Provide resources to implement and operate radio aids to navigation. Provide services which contribute to safe, expeditious, and economic air and maritime commerce and which support United States national security interests.

B. Provide for the installation and operation of radionavigation systems in accordance with international agreements.

C. Coordinate national planning for optimal use of the electromagnetic spectrum, achievement of system economies, and avoidance of unnecesary duplication of navigational systems and services. Achieve the highest degree of commonality/interoperability and system utility between military and civil users through early considerations of mutual requirements.

D. Require certain vessels and aircraft to be fitted with navigational equipment as a condition for operating in controlled U.S. airspace or in the navigable waters of the United States, to promote transportation safety and environmental protection.

E. Provide leadership to ensure that navigation services are available to civil users to meet projected demand, performance, safety, and enviromental protection requirements considering conservation and economic constraints on navigation systems providers and users.

F. Promote the scientific and operational evaluation of domestic and foreign aids to navigation and support development of those with potential to:

- o Satisfy unfulfilled operational requirements.
- o Offer major economic advantages over existing systems.
- o Provide significant benefits in the national interest.

G. Encourage and promote international exchange of scientific and technical information concerning aids to navigation.

H. Provide guidance and assistance in siting, testing, evaluating and operating aids to navigation to meet unique requirements not supported by the Federal Government.

I. Promote national and international standardization of civil and military radio aids to navigation.

J. Establish, maintain, and disseminate signal characteristics.

K. Develop, implement, and operate the minimum special navigational aids and services necessary to accomplish military operations.

L. Operate common user (civil/military) radionavigation systems only as long as the United States and its allies accrue greater military benefit than potential adversaries. Cease operations or change the operating characteristics and signal formats of special purpose DOD systems when required. Non-DOD users who choose to use special purpose DOD systems do so at their own risk. Incorporate selective availability techniques into radionavigation systems to deny service to non-allied civil and military users should such denial be in the national interest.

M. In the control of LORAN-C stations, DOT will maximize the utility of service for other than marine users, within the constraints imposed by the need to maximize the quality of service provided to maritime navigation.

N. Make the NAVSTAR GPS Standard Positioning Service (SPS) continuously available worldwide for civil, commercial and other use at the highest level of accuracy consistent with U.S. national security interests. It is presently projected that a predictable and repeatable accuracy of 500 meters (2 drms) horizontally and 820 meters (2 sigma) vertically will be made available during the first year of full NAVSTAR GPS operation with possible accuracy improvements as time passes. During the development phase of the NAVSTAR GPS program, the satellites will be transmitting both the PPS and SPS signals in the clear in support of government sponsored tests. Civil users are cautioned that the system is developmental and signal availability and accuracy are subject to change without advance warning, at the discretion of the Department of Defense. Therefore, until the system is declared operational, any use of the system is at the user's own risk.

O. Equip military vehicles, as appropriate, to satisfy civil aviation and maritime navigation safety requirements. U.S. military vehicles and users will be equipped with navigation systems which best satisfy mission

requirements. In general, a combination of radionavigation and self-contained navigation aids is required. Standardization is a goal, however, this goal may be voided when unique military systems provide the capability to operate safely without reference to civil radionavigation systems.

P. Require, where practical, users of Federally operated navigational aids and services to bear their fair share of the costs for development, procurement, operation, and maintenance of navigational systems insofar as technically and economically feasible.

Q. Provide, through DOD/DOT interagency agreements, comprehensive managment for all government-provided common user radionavigation systems.

R. Insure, in accordance with established national policy, reliance on the private sector to support the design, development, installation, operation, and maintenance of all equipment and systems required to provide common-user radionavigation aids in support of this Federal Radionavigation Plan (within the constraints of national security).

VOLUME I

CHAPTER 3

AUTHORITY AND RESPONSIBILITY

3.0 INTRODUCTION

This chapter describes the DOD authority, responsibilities, and management structure to plan and provide for navigational systems for military missions. The DOT authority and responsibilities are then addressed in the context of its lead role to assure navigation services for the civil sector and to coordinate non-military navigational planning for other Federal agencies. The joint DOD and DOT management structure and actions necessary to reduce costs or to avoid duplication or gaps in combined military and civil navigational services are also presented.

3.1 DEPARTMENT OF DEFENSE

3.1.1 Responsibilities

The DOD is responsible for developing, testing, evaluating, operating, and maintaining aids to navigation and user equipment required for national defense, and ensuring that military vehicles operating in consonance with civil vehicles have the navigational capabilities required to operate in a safe and expeditious manner. Specific DOD responsibilities are to:

A. Define performance requirements applicable to military mission needs.

B. Design, develop, and evaluate systems and equipment to insure that peformance requirements are met in a cost-effective manner.

C. Maintain liaison with other government research and development activities affecting military radionavigation systems.

D. Develop forecasts and analyses as needed to support the requirements for future military mission needs.

E. Develop plans, activities, and goals related to military mission needs.

F. Define and acquire the necessary resources to accomplish mission requirements.

G. Identify special military route and airspace requirements.

H. Foster Rationalization, Standardization and Interoperability (RSI) of systems with NATO and other allied countries.

I. Operate and maintain ground radionavigation aids as part of the civil National Air Space System when such activity is economically beneficial and specifically agreed to by the appropriate DOD and DOT agencies.

The Defense Mapping Agency (DMA) is responsible for military mapping, charting, and geodesy aspects of navigation, including geodetic surveys, accuracy determination, and positioning. Within DOD, DMA acts as the primary point of contact with the civil community on matters relating to geodetic uses of navigation systems. Unclassified data prepared by the DMA are available to the civil sector.

3.1.2 Internal Management

The DOD internal management structure for navigational coordination is shown in Figure I-3.1. The two major parts of the structure represent the adminstrative and the operational chains of command reporting to the Secretary of Defense.

A. Operational Management

The Joint Chiefs of Staff (JCS) are the top level body in the operational chain of command (beneath the Secretary of Defense) and, by authority and direction of the President and the Secretary of Defense, serve as military advisors to the President and the Secretary of Defense. Additionally, the JCS provides guidance for use by Military Departments and the Armed Forces as needed in the preparation of their respective detailed navigational plans. The JCS maintains cognizance over operational navigation requirements and capabilities of the Unified and Specified Commands and the Services. In order to utilize effectively and economically the operational navigational resources serving the military worldwide, the JCS are responsible for the development, approval, and dissemination of the JCS MNP.

The MNP is the official document for JCS guidance for navigational policy and planning. It is the result of a coordinated effort by all operating elements to insure unanimity in navigational system planning to meet identified operational defense requirements. The MNP also facilitates the integration of required military navigational systems and helps to assure the most efficient and cost-effective implementation of JCS policy for radionavigation.

The following organizations also perform navigation management functions:

The Deputy Director for Tactical/Theater Command, Control and Communications Systems, Joint Staff, is responsible for:

- Analysis, evaluation, and monitoring of navigational system planning and operations.
- Navigational matters in general and, specifically, the JCS MNP.

The Commanders of the Unified and Specified Commands perform navigational functions similiar to those of the JCS. They may develop navigational requirements in support of contingency plans and JCS exercises requiring navigational resources external to that command. Additionally, they are responsible for reviewing the JCS Master Navigation Plan.

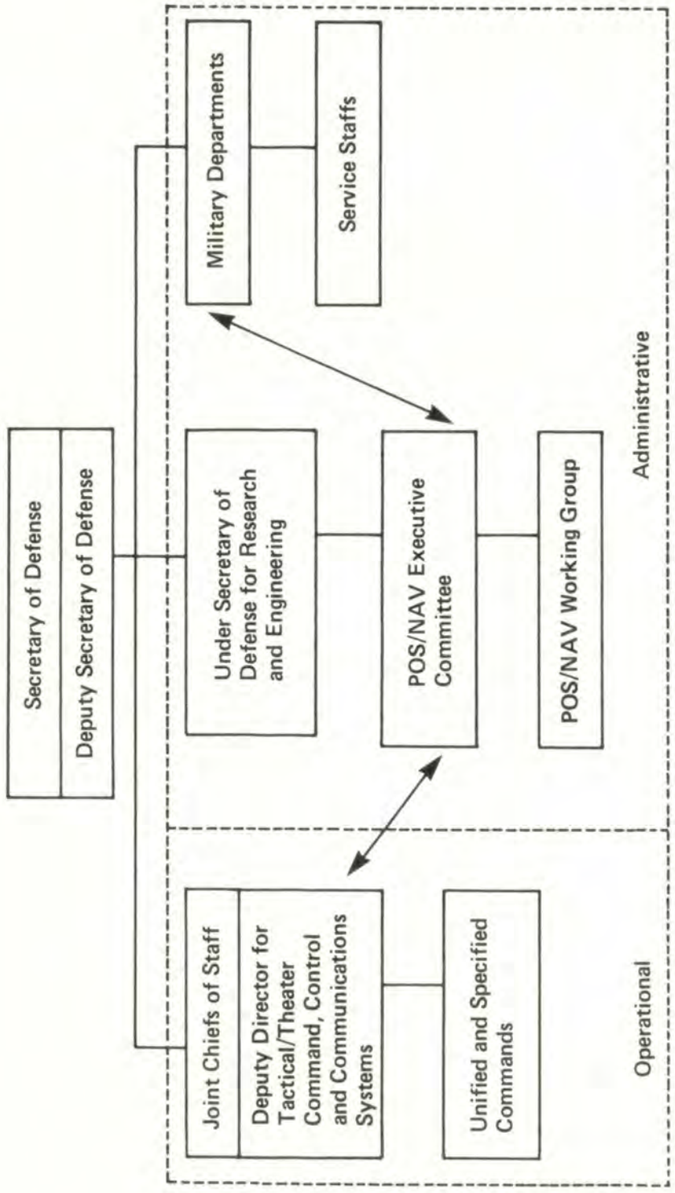

FIGURE I-3.1 DOD Navigation Structure

B. Administrative Management

Three permanent organizations provide radionavigation planning and management support to the Under Secretary of Defense for Research and Engineering. These organizations are the Positioning/Navigation Executive Committee; the Positioning/Navigation (POS/NAV) Working Group; and the Military Departments/Service Staffs. Brief descriptions are provided below.

The DOD Positioning/Navigation (POS/NAV) Executive Committee assists the Under Secretary of Defense for Research and Engineering in review of all DOD programs in the positioning and navigation area. These reviews minimize duplication of effort and effect economies in the area of positioning and navigation. Recommendations are made to the Deputy Secretary of Defense, in coordination with the Organization of the Joint Chiefs of Staff (OJCS), on cost avoidance or phase out of systems of questionable need.

The Positioning/Navigation (POS/NAV) Working Group provides a forum for the identification and resolution of day to day navigational system issues. Working Group membership is composed of representatives from JCS, the Defense Mapping Agency (DMA) and officers from the respective Services. It is chaired by a representative of the Under Secretary of Defense for Research and Engineering.

The Military Departments/Service Staffs are responsible for participating in the development, dissemination and implementation of the JCS Master Navigation Plan and for managing the development, deployment and operation and support of designated navigation systems.

3.2 DEPARTMENT OF TRANSPORTATION

3.2.1 Responsibilities

The DOT is the primary government provider of aids to navigation used by the civil community and of certain systems used by the military. It is responsible for the preparation and promulgation of radionavigation plans in the civilian sector of the United States. The National Aeronautics and Space Administration (NASA) participates in the development of DOT radionavigation plans.

The Secretary of Transportation, as part of his authority under the DOT Act (Public Law 89-670), is responsible for navigational matters within DOT and promulgates radionavigation plans. Three DOT elements have statutory responsbilities regarding the provision of aids to navigation: the U.S. Coast Guard, the Federal Aviation Administration (FAA) and the St. Lawrence Seaway Development Corporation. In addition, several other elements of DOT have responsibilities and interests which may be satisfied by radionavigation or radiolocation systems.

The Coast Guard has the statutory responsibility to define the need for, and to provide, aids to navigation and facilities needed for safe and efficient navigation. Section 81 of Title 14, United States Code provides:

"To aid navigation and to prevent disasters, collisions, and wrecks of vessels and aircraft, the Coast Guard may establish, maintain, and operate:

(1) "aids to maritime navigation required to serve the needs of the armed forces and the commerce of the United States;"

(2) "aids to air navigation required to serve the needs of the armed forces of the United States peculiar to warfare and primarily of military concern as determined by the Secretary of Defense or the Secretary of any department within the Department of Defense and as requested by any of those officials; and"

(3) "electronic aids to navigation systems (a) required to serve the needs of the armed forces of the United States peculiar to warfare and primarily of military concern as determined by the Secretary of Defense or any department within the Department of Defense; or (b) required to serve the needs of the maritime commerce of the United States; (c) required to serve the needs of the air commerce of the United States as requested by the Administrator of the Federal Aviation Agency."

"These aids to navigation, other than electronic aids to navigation systems, shall be established and operated only within the United States, the waters above the Continental Shelf, the territories and possessions of the United States, the Trust territory of the Pacific Islands, and beyond the territorial jurisdiction of the United States at places where naval or military bases of the United States are or may be located."

The Federal Aviation Administration (FAA), under the Federal Aviation Act of 1958 (Public Law 85-726), has responsibility for development and implementation of radionavigation systems to meet the needs for safe and efficient navigation and control of all civil and military aviation, except for those needs of military agencies which are peculiar to air warfare and primarily of military concern. The FAA also has the responsibility to operate aids to air navigation required by international treaties.

The Maritime Administration (MARAD) investigates position determination using existing and planned communications systems, conducts precision radar navigational experiments and investigates the application of radar transponders to navigation and collision avoidance. These efforts are designed to enhance U.S. Merchant Marine efficiency and effectiveness.

The St. Lawrence Seaway Development Corporation (SLSDC) has responsibility for assuring safe navigation along the seaway. The SLSDC operates a Vessel Traffic Control System with the St. Lawrence Seaway Authority of Canada.

The Federal Highway Administration (FHWA), the National Highway Traffic Safety Administration (NHTSA), and the Urban Mass Transportation Administration (UMTA), under their respective statutory authorities, have the responsibility to conduct research, development, and demonstration projects. This could include projects on land uses of radiolocation systems. Also, they assist state and local governments in planning and implementing such systems and issue guidelines concerning their potential use and applications.

NASA supports navigation through the development of technologies for navigating aircraft and spacecraft. In addition to the user equipment, NASA is responsible for development of the ground-based equipment. NASA is also authorized to demonstrate the capability for civil application of military navigational satellite systems to aircraft, ships, and spacecraft navigation and position determination.

3.2.2 Internal Management

The DOT internal management structure for navigational systems planning for civil use is shown in Figure I-3.2. The structure was established by DOT Order 1120.32, dated April 27, 1979, for the following purposes:

A. Coordinate policy recommendations and integrate planning regarding navigation among the operating elements of DOT, and help to assure the most efficient implementation of those policies and plans without decreasing the responsibility or usurping the authority of the indiviual operating elements.

B. Provide a body which can, on a continuing basis, facilitate coordinated navigational planning on a multimodal basis within DOT; and serve as a focal point for recommendations on which DOT navigation policies and plans can be formulated.

C. Assure that the Secretary of Transportation gets consolidated information and provide the means to obtain coordinated high level review of proposed navigational policies and plans.

D. Establish a planning framework within which the DOT operating elements are allowed maximum latitude for navigational system research, development, and implementation consistent with the need to avoid duplication of effort.

E. Provide the technical resources to supplement the navigational planning, implementation, coordination, and decision making of the operating elements.

F. Provide a focal point for obtaining inputs from those elements of DOT which may not have a continuous interest in navigational problems.

G. Provide a DOT focal point for multimodal or interdepartmental navigational issues.

The DOT Navigation Council is the top level body of the structure. It consists of a Secretarial Officer and one policy level representative each from the Coast Guard, FAA, MARAD, the Research and Special Programs Administration (RSPA), and the St. Lawrence Seaway Development Corporation (SLSDC). The designated members may be augmented by representatives of other operating elements to consider specific issues. The Council meets, as required, under the chairmanship of the Secretarial Officer. The DOT Navigation Council:

- Serves as the focal point to formulate coordinated policy recommendations to the Secretary;

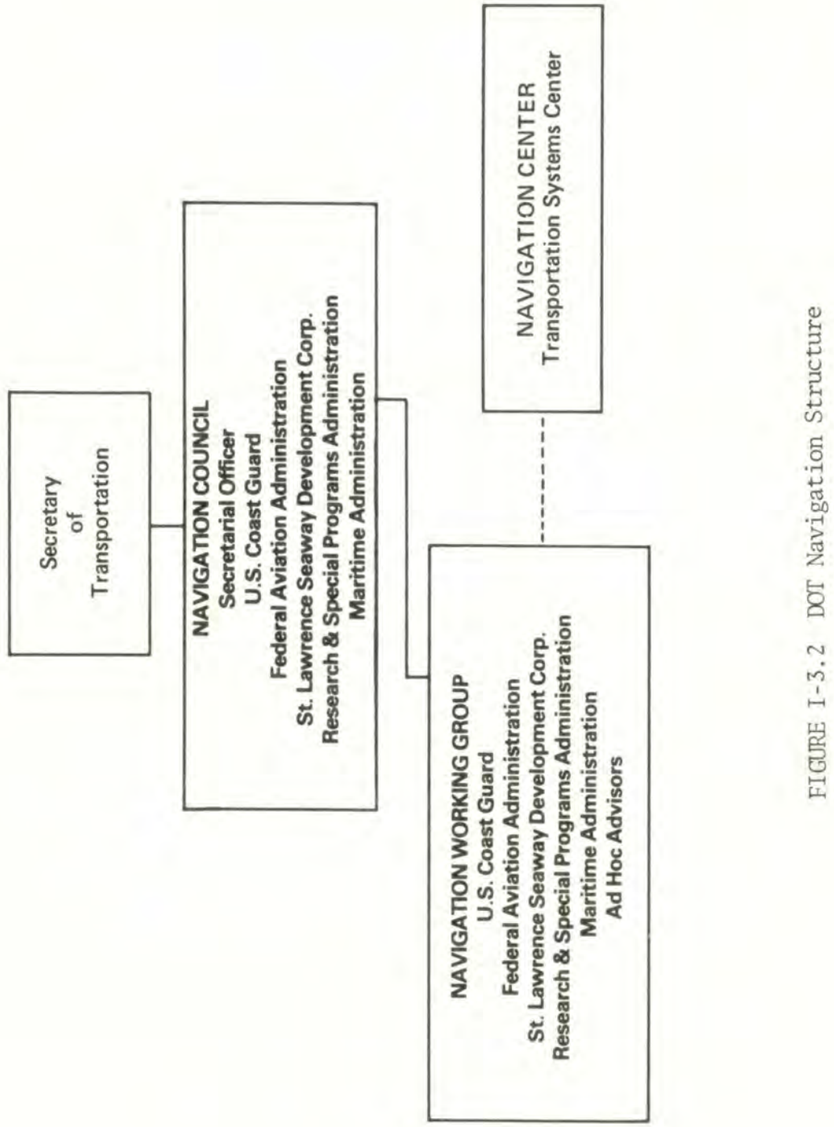

FIGURE I-3.2 DOT Navigation Structure

- o Coordinates with similar committees in other government agencies in accordance with any bilateral or multilateral agreements between DOT and those agencies; and

- o Provides guidance to the subordinate Navigation Working Group.

The Navigation Working Group is the working core of the structure. It consists of one representative each from the Coast Guard, FAA, MARAD, RSPA, and SLSDC. Each representative may be assisted by advisors. Ad hoc advisors from other DOT operating elements which have an interest in navigation are invited to attend meetings as appropriate. These elements are the Federal Highway Administration (FHWA), the Federal Railroad Administration (FRA), the National Highway Traffic Safety Adminstration (NHTSA), and the Urban Mass Transportation Administration (UMTA). The Navigation Center at the DOT Transportation Systems Center (TSC) provides technical assistance to the Navigation Working Group, as requested. The Navigation Working Group facilitates the coordination of:

- o Navigational requirements developed by the DOT operating elements;

- o Navigational plans;

- o Navigational R,E&D and implementation programs;

- o DOT navigation planning with DOD, NASA, and other Federal Agencies, as required;

- o Multimodal navigational issues with other governmental agencies, industry, and user groups, as directed by the Navigation Council, and

- o Coordinates suggestions for the improvement of future editions of the FRP.

3.3 JOINT DOD AND DOT MANAGEMENT

An Interagency Agreement between DOD and DOT for radionavigation planning became effective April 17, 1979. This agreement requires coordination between the DOD and DOT internal management structures for navigational planning. The Interagency Agreement recognizes that DOD and DOT have joint responsibility to avoid unnecessary overlap or gaps between military and civil navigational systems/services. Further, it requires that both military and civil needs be met in a cost-effective manner for the government and civil user community. Implicit in this joint responsibility is assurance of civil sector radionavigation readiness for mobilization in national emergencies.

3.3.1 Specific Responsibilities

The agreement provides that DOD and DOT will jointly:

A. Keep each other informed of the status of development, evaluation, installation, and operation of aids to navigation with existing or potential joint applications.

B. Coordinate all major navigational planning activities to ensure a high level of consistency while still meeting diverse navigational requirements.

C. Attempt, wherever consistent with diverse requirements, to utilize common systems, equipment, and procedures.

D. Undertake joint programs in research, development, design, testing, and operation of radionavigation systems.

E. Prepare a standard definition of requirements and a joint requirements document.

F. Assist in assuring that other government agencies involved in navigation system research, development, operation, or use are aware of and, where necessary, consulted on future plans.

G. Publish a single Federal Radionavigation Plan to be implemented by internal departmental actions. These plans will be reviewed and updated annually as part of the agencies' normal budget process.

3.4 LIAISON WITH THE PRIVATE SECTOR

Interested parties and advisory groups from the private sector are invited to submit their inputs to the Chairman of the DOT Navigation Working Group (Attn: DPB-22), Department of Transportation, Research and Special Programs Adminstration, Washington, DC 20590. This procedure allows for direct interaction between the users of radionavigation aids and the Federal authorities that manage and create policies for radionavigation systems.

VOLUME I

CHAPTER 4

RADIONAVIGATION PLANS

4.0 SCOPE AND THRUST OF THE PLAN

This chapter summarizes the plans of the Federal government to provide general purpose and special purpose radio aids to navigation for use by the civil and military sectors. It focuses on three aspects of planning: (1) the efforts needed to maintain existing systems in a satisfactory operational configuration, (2) the development needed to improve their present performance or to satisfy existing unsatisfied requirements in the near term, and (3) the evaluation of existing and proposed radionavigation systems to meet future requirements. Thus, the plan provides the framework for operation, development and evolution of systems.

The Government operates existing radionavigation systems which meet most of the current and projected civil user requirements for safety of navigation and promotion of reasonable economic efficiency. These systems are adequate for the general navigation of military craft as well, but none completely satifies all the needs of military missions nor provides highly accurate, three-dimensional, worldwide navigation capability. NAVSTAR GPS is being developed to satisfy many of these general and special military requirements. NAVSTAR GPS may have broad potential for satisfying current civil user needs or for responding to new requirements that present systems do not satisfy. Thus, it could ultimately become the primary worldwide system for military and civil navigation and position location. Likewise civil development of the Microwave Landing System promises to provide the technology required to satisfy unfilled military requirements for a highly mobile precision approach system.

4.1 EXISTING NAVIGATION REQUIREMENTS

It is generally accepted that the needs for navigational services derive from the activities in which the users are engaged, the locations in which these activities occur, the relation to other craft and physical hazards, and to some extent the type of craft. As these differences exist, the requirements for navigational services are divided by classes or types of users and the phases of navigation. These divisions are discussed in detail in Volume II and are summarized in Tables I-4.1 through I-4.5. These tables also show the emphasis placed on the existing radionavigation systems in the various phases of navigation. Detailed descriptions of the existing and proposed radionavigation systems are given in Volume III.

4.1.1 Current Systems

Systems are categorized in Tables I-4.1 through I-4.5 as primary system (P), secondary or supplementary systems (S), or a system under development or evaluation (E). These classifications are:

A. "P" indicates a systems which now provides a primary service in one or more phases of the civil and military marine and air environments. Ongoing efforts applied to a given primary system and area of application

SYSTEM	VOR/DME	TACAN	OMEGA	LORAN-C	RADIO-BEACON (NDB/RBN)	ILS/MLS	TRANSIT	NAVSTAR GPS
Phase of Navigation								
AIR								
ENROUTE/TERMINAL								
*Remote Area	E	E	E	S	S	–	–	E
*Helicopter	E	E	E	S	S	–	–	E
Oceanic En route	–	–	P	S	–	–	–	E
Domestic En route	P	P	S	E	S	–	P	E
Terminal	P	P	–	E	–	P	–	E
APPROACH/LANDING								
Non Precision	P	P	–	E	S	–	–	E
Precision	–	–	–	–	–	P	–	E
MARINE								
Oceanic	–	–	P	S	S	–	P	E
Coastal	–	–	–	P	S	–	–	E
*Harbor & Harbor Approaches	–	–	–	E	P	–	–	E
*Inland Waterways	–	–	–	–	–	–	–	–
LAND**								
AVM/AVL	–	–	–	E	–	–	–	E
Site Registration	–	–	–	E	–	–	S	E
SPACE								E

LEGEND
P – Primary System
S – Secondary/Supplemental System
E – System in Evaluation
*New Requirement
**This area is under assessment

TABLE I-4.1 Radionavigation System Civil Applications

are directed toward improving an existing service or enhancing system performance.

B. "S" indicates systems which provide an essential secondary or supplementary service for a primary system in a specified phase of navigation. For these designations, government activities relate to reducing operations and maintenance (O&M) costs of these systems.

C. "E" indicates a system and area of application which is being evaluated as a replacement for an existing primary or secondary system. Such a system may be an existing system which is being evaluated as a candidate for improved service in existing or newly identified phases of operations and applications. LORAN-C is an example of the latter category.

4.2 EXISTING SYSTEMS USED IN THE PHASES OF NAVIGATION

The systems listed in Table I-4.1 are used singly or in combination to support functions of the various phases of navigation. Tables I-4.2 to I-4.5 compare common user systems to mission applications for military use. The following sections describe the approach employed to define the needs, requirements, and degree to which existing systems satisfy these needs.

4.2.1 Oceanic En Route, Domestic En Route, and Terminal Phases of Air Navigation

Federal Aviation Regulations require that aircraft equipped with self-contained navigational systems, except for dual Inertial Navigation Systems (INS), now being used on oceanic air routes, monitor the performance of these systems through use of an externally referenced radio aid to navigation. It is expected that at least three OMEGA lines of position should be available throughout the North Atlantic and Pacific. Although the FAA has approved the use of OMEGA on oceanic routes, at present, the International Civil Aviation Organization (ICAO) does not plan to adopt OMEGA as an international standard. ICAO has, however, provided users of OMEGA with an information publication on OMEGA system operation.

Domestic en route and terminal area air navigation requirements are presently being met except in some remote and offshore areas. The basic short distance aid to navigation in the United States is VHF Omnidirectional Range (VOR) alone or collocated with either Distance Measuring Equipment (DME) or Tactical Air Navigation (TACAN) to form a VOR/DME or a VORTAC facility. This system is used for en route and terminal navigation for flights conducted under Instrument Flight Rules (IFR). It is also used by pilots operating on Visual Flight Rules (VFR). The United States and all other member states of the International Civil Aviation Organization have agreed to provide VOR/DME service to international air carriers up to January 1, 1985. Some of the member states are just initiating VOR/DME service while other states are expanding their coverage. As a consequence, it is expected that the ICAO will vote to extend service to 1995.* The U.S. Government has supported this action, because of the widespread, long, and satisfactory use of this system, the investment in avionics and ground equipment of

*On November 25, 1982 ICAO is expected to vote to extend the protection date to 1995.

about $700 million, and technical expertise and the recent substantial investment of other nations, particularly third world nations.

Area navigation (RNAV) offers potential benefits to users of the National Airspace through direct routing to many destinations, thereby reducing operating costs and conserving fuel.

VOR/DME forms the basis of a safe, adequate, and trusted air navigational system, and there is a large investment in ground equipment and avionics by both the government and users. In view of this, it is intended to maintain the VOR/DME at its present capability at least through 1995.

4.2.2 Approach and Landing Phase of Air Navigation

Requirements for radio approach and landing aids are met by the Instrument Landing System (ILS). Non-precision approaches are based on VOR (with or without DME), TACAN, non-directional beacons (NDB), and RNAV procedures. The requirement for a common civil/military system is not yet met, although the Air Force relies on ILS as a primary precision approach system. The Microwave Landing System (MLS) now under development is planned to meet the need for a common user precision system. The MLS can provide lateral and vertical guidance over wide sectors with precise distance information.

4.2.3 Ocean Phase of Marine Navigation

Navigation on the high seas is now accomplished by the use of celestial fixes, LORAN-C, and OMEGA. TRANSIT is also available for use by the civil maritime community.

Worldwide coverage by most ground-based systems such as LORAN-C, is not practicable. The OMEGA system, when it is fully operational, will provide worldwide coverage.

4.2.4 Coastal Phase of Marine Navigation

Requirements for operation within the coastal area are now fully met. In 1974 LORAN-C was designated as the Government-provided primary radionavigation system for coastal areas of the coterminous 48 states, southern Alaska, and the Great Lakes. LORAN-C was fully implemented in 1980. The phaseout of LORAN-A was completed on December 31, 1980.

The marine radiobeacon system provides primary service in the coastal area and Great Lakes for smaller marine operators, and backup service for all categories of users. Radiodirection finders (RDF) are the only externally referenced radionavigation equipment required in merchant ships by international agreement.

4.2.5 Harbor and Harbor Approach Phases of Marine Navigation

Navigation in the harbor and harbor approach areas is accomplished currently through use of fixed and floating visual aids to navigation, radar, and audible warning signals. The growing concern for means to reduce the incidence of accidents and to expedite movement of traffic during periods of restricted

MISSIONS	SYSTEM								
	GPS	LORAN-C	OMEGA	TACAN	TRANSIT	VOR	RADIOBEACONS	MLS/ILS	OTHER ****
ENROUTE ATOMOSPHERIC									
Foreign Domestic	E	S	S	P*		P	S		S
Domestic	E	S	S	P		S	S		S
Combat Theatre	E	S	S	P			S		S/P
Overwater	E	S**	P**				S		S/P
Remote Area	E	S/P**	S/P**	P*			S		S/P
TERMINAL									
Non-Precision Approach/Landing	E			P*		P	S		S
Precision Landing								P	S
General	E			P*		P	S		S
SPACE									
Launch/Abort	E			S				S	P
Orbital	E								P
Re-Entry									P
Terminal Approach	E			P					S
Terminal Landing								P***	
SITING/SURVEYING	E			S	P				P
TARGET ACQUISITION	E	S	S	S			S		P
AERIAL RENDEZVOUS	E			P*			S		S/P

LEGEND
P - Primary System
S - Secondary System
E - System in Evaluation

* If Available or deployed
** Depending on aircraft configuration
*** Non-Standard MLS
**** Other reflects special purpose military autonomous or cooperative system

TABLE I-4.2 Air Force Missions vs Selected Common-User Radionavigation System

MISSIONS	SYSTEMS*							
	GPS	LORAN-C	OMEGA	TACAN	TRANSIT	VOR/DME	RADIO-BEACONS	MLS/ILS
General Aerial Navigation	E			P		P	P	E/P
General Land Navigation of Wheeled Vehicles	E							
General Land Navigation of Tracked Vehicles	E							
General Navigation of Troop Units	E							
General Navigation of Marine Assault Patrol	E							
General Navigation of Sea Transport Vessels	E		S					
Aircraft Approach	E			S		S	S	E/P
Position Location of Aerial/Ground Sensors	E			P		S	S	E
SURVEYING								
Tube Artillery	E							
Missile Artillery	E							
Air Defense Artillery	E							
Mapping	E							
Mine/Counter mine (LAND)	E							
Special Projects	E							
Position/Navigation System Calibration	E							
Common POS/NAV Calibration	E							

LEGEND

P – Primary System
S – Secondary System
E – System in evaluation

*Special purpose systems are not reflected in this table.

TABLE I-4.3 U.S. Army Missions vs Selected Common-User Radionavigation Systems

MISSIONS	SYSTEMS*							
	GPS	LORAN-C	OMEGA	TACAN	TRANSIT	VOR/DME	RADIOBEACONS	MLS/ILS
Enroute, General Purpose								
Ship	E		S		P			
Submarine	E	S	S		P			
Air (MPA/TAC)	E	S	P	P		S	S	S
Search & Rescue								
Ship	E		S		S			
Air				P				
Mine Countermeasures								
Ship	E	P	S		P			
Air	E			P				
Mine Laying								
Ship								
Submarine	E				P			
Air				P				
Amphibious								
Ship, Boat, Amphibious Vehicle	E							E
Helicopter, Attack Aircraft	E			P		P	S	E
Fighter Aircraft	E			P		P	S	E
Amphibious (USMC)	E							
Anti Air Warfare								
Ship	E	S			S			
Air				P				
Surface Warfare								
Ship	E		S		P			
Submarine	E		S		P			
Air	E			P				
Anti Submarine Warfare								
Ship	E		S		P			
Submarine	E		S		P			
Air	E	S	P	P			S	S
Logistics								
Surface	E		S	P				
Submarine	E		S	P	S			
Air	E		S		S			
Surveying								
Surface	E	P	S		P			
Submarine								
Air	E	P	S	P	P	S		

LEGEND
P – Primary System
S – Secondary System
E – System in evaluation

*Special purpose systems are not reflected in this table.

TABLE I-4.4 U.S. Navy Missions vs Selected Common-User Radionavigation Systems

MISSIONS	SYSTEMS*							
	GPS	LORAN-C	OMEGA	TACAN	TRANSIT	VOR/DME	RADIOBEACON	MLS/ILS
Worldwide Positioning of Satellite Tracking								
Low Altitude	E				P			
Medium Altitude	E				P			
High Altitude	E							
Worldwide Positioning by Satellites	E	X	X		P			
Geodetic Positioning								
By Satellite	E				P			
By Conventional	E	X		X		X	X	X
Deep Ocean Bathymetric Survey	E	P	S		P			
Coastal Hydrographic	E	S			P			

LEGEND
P – Primary System
S – Secondary System
E – System in evaluation
X – Positioning support

*Special purpose systems are not reflected in this table.

TABLE I-4.5 Defense Mapping Agency Missions vs Selected Common-User Radionavigation Systems

visibility and ice cover has resulted in the implementation of Vessel Traffic Services (VTS) and investigation of the use of radio aids to navigation. Specific quantitative requirements for navigation in the Harbor and Harbor Approach phases, which will vary somewhat from one harbor to another, have not been developed and are significantly more demanding than for ocean and coastal navigation. LORAN-C is being investigated as a means to provide improved all-weather position fixing capability in harbor approach channels and harbors. It is anticipated that the use of LORAN-C will be extended progressively into major harbor approaches. Operations on the connecting waters and in harbors on the Great Lakes are similar to those in the Harbor and Harbor Approach phases, and generally have more stringent navigational requirements than the coastal phase of navigation. Short baseline as well as augmented LORAN-C chains are being examined to meet requirements for these areas.

4.2.6 Inland Waterway Phase of Marine Navigation

This phase of navigation is concerned primarily with those vessels which are not ocean-going. Specific quantitative requirements for navigation on rivers and other inland waterways have not yet been developed. Visual and audio aids to navigation, radar, and intership communications are presently used to enable safe navigation in those areas. No change in this practice is expected in the immediate future.

4.2.7 Land Navigation Phases

The government does not have a specific responsibility under law to provide radiolocation systems for civil land use. However, under the general provisions for improving the safety and efficiency of transportation, a number of projects have been sponsored to evaluate the feasibility of using existing and proposed radionavigation systems for land applications.

4.3 EXISTING SYSTEMS - STATUS AND PLANS

4.3.1 LORAN-A

LORAN-A was developed for military use during World War II to provide a long-range radionavigation capability. It was later adopted by civil marine and air users. Although a few foreign governments continue to operate LORAN-A, all U.S.-operated LORAN-A stations have ceased operation with the last two chains terminating on December 31, 1980.

4.3.2 LORAN-C

LORAN-C was developed to provide military users with a radionavigation capability having much greater accuracy than LORAN-A. It was subsequently selected as the U.S. Government provided radionavigation system for civil marine use in the U.S. coastal areas.

A. Operating Plan

In 1974, LORAN-C was designated as the U.S. Government-provided navigational system for the U.S. coastal areas. Implementation of the program authorized at that time has been completed. The coverage is shown in Volume III.

The schedule for implementation of LORAN-C to provide total coverage for U.S. contiguous waters and adjacent land areas is shown in Figure I-4.1.

The Great Lakes chain, which reached full operational status in early 1980, for the first time provides a high accuracy navigational capability for the open waters of the Great Lakes.

B. User Community

Historically, the major user of LORAN-C has been the military. Civil marine use of LORAN-C has been limited until recently by the lack of low-cost receivers and by a lack of coverage in much of the U.S. coastal area. Technological advances are rapidly lowering user equipment costs and coverage limitations are being eliminated by the station expansion and improvement program now under way. The projected numbers of civil and military users are shown in Table I-4.6.

C. Acceptance and Utilization

A high degree of user interest in LORAN-C is in evidence and acceptance is increasing. Because of system reliability as well as accuracy, coverage, and cost factors, a rapid growth in user population is anticipated.

There are a number of LORAN-C chains in operation overseas to serve U.S. military requirements for navigational service. Some of the stations are operated by the U.S. Coast Guard, while others are operated by the host country under bilateral agreement. The service is available to all users, military and civilian, of all nations. Other than the United States, however, Canada is the only country that is committed to the operation of LORAN-C service for general use. One Canadian station has been built in British Columbia, and a second built on Vancouver Island. The former acts as a master to a combined U.S./Canada chain serving the U.S. Northwest, southern Alaska, and west coast of Canada. The second station closes coverage gaps in the areas of Dixon Entrance and Puget Sound. In the U.S.S.R. there are two LORAN-C chains operating; one in the southwestern part of Russia, the other in eastern Siberia. Their coverage is mostly over land. Several other nations are known to be considering LORAN-C for their own requirements. The DOD currently uses LORAN-C; however, this use will phase down as NAVSTAR GPS becomes operational.

Since the LORAN-C stations must be land-based, and they have a useful range of about 1,000 nm, it is not feasible to provide worldwide coverage utilizing this system. The coverage area is fixed by the area where adequate geometry and signal-to-noise ratio are available.

D. Outlook

The adequacy of radionavigation service in island areas such as Hawaii and the North Slope of Alaska is under study. Depending on the results of this study, LORAN-C service may be recommended for expansion in these areas.

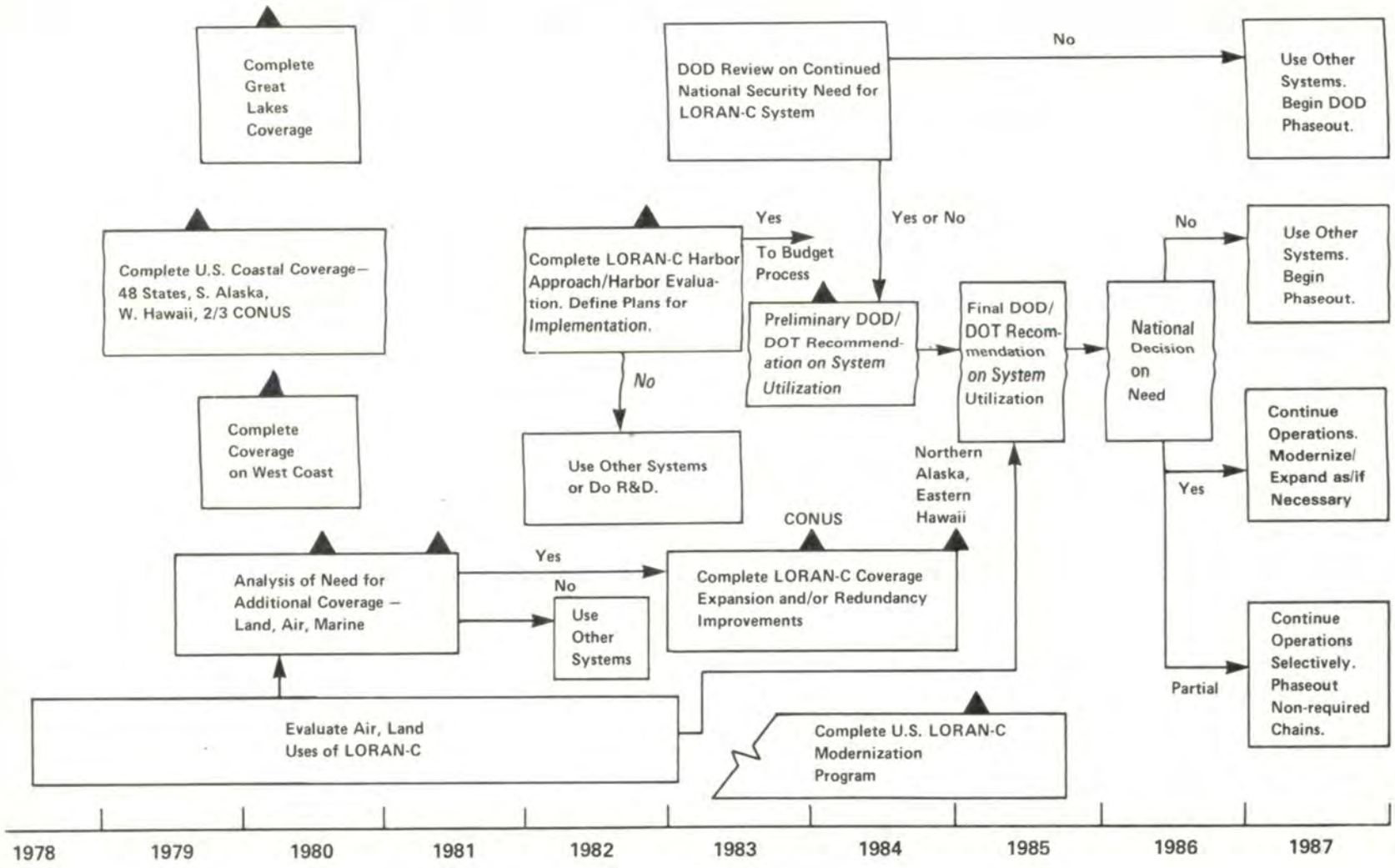

FIGURE I-4.1 Operating Plan for LORAN-C System

FACILITIES/USERS	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
U.S./CANADIAN FACILITIES	25	25	25	27*	27	27	27	27	27	27	27	27	27	27	27
OVERSEAS FACILITIES**	18	18	18	18	18	18	***								
CIVIL USERS (MARITIME) U.S. AND FOREIGN	54,000	57,800	62,000	66,500	71,500	76,500	***								
CIVIL USERS (AVIATION)	500	600	1,000	2,000	3,000	4,000	***								
DOD USERS	410	400	405	380	380	375	325****	265	190	95	65	30	0	0	0

* This increase in the number of Loran-C facilities is projected based on the completion of construction of a facility by the Canadian government at Fox Harbor, Labrador and funding of a U.S. facility at Yakutat, Alaska.

** In addition to the existing oveseas Loran-C facilities the DOD has procured 3 Loran C/D Systems and deployed them overseas.

*** The 1986 national decision on the future radionavigation system mix may affect the number of facilities/users. Therefore, no estimate of facilities are projected for later years.

**** Begin DOD Phase-out.

TABLE 1-4.6 LORAN-C User Schedule

The number of stations would also have to be increased to provide adequate signals over the entire U.S. if LORAN-C is an acceptable common system replacement for aviation. National and international agreements would be required to adopt LORAN-C as the short-distance navigational system standard. If user equipment costs can be reduced to be comparable with those of LORAN-C, then NAVSTAR GPS has the potential of becoming an alternate system.

The LORAN-C system for the coastal areas is expected to continue in operation at least until the Year 2000. This estimate is based on the adoption and use of this system by a very large user population, and the absence of any near-term prospect for its replacement. All current DOD service plans call for phaseout of LORAN-C requirements in favor of NAVSTAR GPS. Assuming the 18-satellite version of NAVSTAR GPS is operational in 1988, the Navy has a continuing requirement for existing overseas LORAN-C coverage through 1992 at current performance levels. The DOD has a continuing need for the joint USCG/USAF LORAN-C chain providing coverage to Korea through 1996 at current performance levels.

4.3.3 OMEGA

The OMEGA system was developed and implemented by the Department of the Navy, with the assistance of the Coast Guard and with the participation of several partner nations. The Coast Guard has the U.S. responsibilities for the operation of the system. In addition, other countries are participating in a signal monitoring effort to assist in verifying system accuracy. Currently there are some 40 OMEGA monitor sites which are in operation. The purpose of OMEGA is to provide an all-weather, worldwide position determination aid to navigation for civil and military air and marine users.

A. Operating Plan

At present seven of the eight permanent stations required for worldwide coverage are operational. The seven stations are located in Norway, Liberia, North Dakota, Hawaii, La Reunion Island, Argentina, and Japan. The eighth and final transmitting station is under construction in Australia, with an expected operational date in 1982. All stations are in normal operation, i.e., they are on air, synchronized, and transmitting at a nominal radiated power of 10 kw at 10.2 kHz. Figure I-4.2 outlines the operating plan for the OMEGA system.

The Coast Guard operates the two stations located in the U.S. The remaining stations are operated by the partner nations with varying degrees of technical and logistic support from the U.S. Coast Guard.

A temporary station which was located at Trinidad in the West Indies ceased operations on December 31, 1980.

B. User Community

In addition to the DOD air and marine users, many commercial and private ships and aircraft are using the OMEGA system. A number of air carriers and private aircraft operators have received approval to use OMEGA either as an update for their self-contained system or as a sole means of navigation when operating on

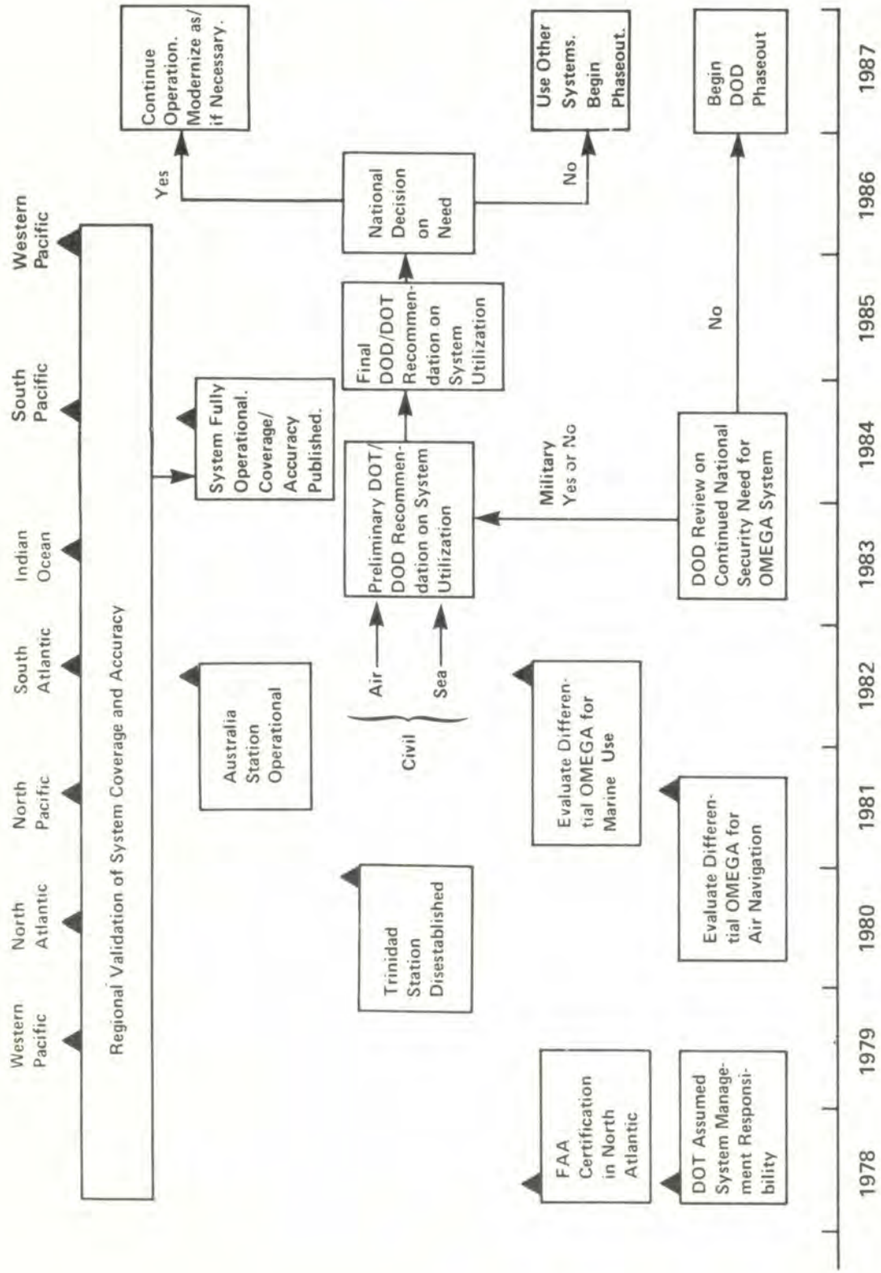

FIGURE 1-4.2 Operating Plan for OMEGA System

oceanic and high altitude domestic routes. The projected numbers of civil and military users are shown in Table I-4.7.

C. Acceptance and Utilization

Because of OMEGA's extensive coverage, it is expected that civil use will involve vessels crossing the high seas and aircraft operating in oceanic airspace and as a supplement for high altitude domestic enroute airspace. Foreign ships and aircraft use this internationally operated system.

Current information indicates that the existing seven permanent stations provide navigational coverage over more than 90 percent of the earth's surface and virtually all of the Northern Hemisphere. The eighth station will be completed by 1982. The existing transmitting stations are usable for navigation. The coverage and accuracy of the system are being verified by a measurement program being conducted on a regional basis. This program includes collecting data from fixed monitor receiver sites to correct and update propagation models and tables, and special calibration tests to confirm propagation parameters affecting coverage and availability. As each given geographic area is validated, the OMEGA system will be declared operational in that area and users will be advised as to operational limitations as appropriate. The OMEGA system per se cannot be declared fully operational worldwide in oceanic regions until the eighth station is in operation and accuracy and coverage can be measured and validated. This is expected to take place sometime in 1985. In addition, several air carriers are collecting data on OMEGA performance on certain oceanic routes in support of the measurement program. Use of OMEGA has been certified by the Federal Aviation Administration (FAA) for use on the North Atlantic by several airlines and as a supplement for high-altitude domestic en route airspace.

The OMEGA system is limited in accuracy due to propagation effects, and restrictions on use of the signals when close to a station. For these reasons, OMEGA cannot meet the requirements for maritime navigation in U.S. coastal areas or for aircraft flying in U.S. terminal airspace.

D. Outlook

No expansion in the number of stations is envisioned. However, an expanded transmission format, involving the addition of a fourth navigation frequency and a unique frequency at each station, which could further resolve lane abiguity, and provide positive station identification, has been implemented.

Differential OMEGA, which is still in the development stage, in the United States, could provide another expansion possibility. Experiments to date, conducted principally in France, Canada, and the U.S., have investigated the degree to which this technique can improve the accuracy of an OMEGA fix, and have explored alternatives for the format of broadcast differential corrections, radio frequency to be used for broadcasts, and techniques for receiving and applying differential corrections automatically.

The DOD has adopted OMEGA as an en route navigational system for aircraft and ships.

FACILITIES/USERS	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
U.S. FACILITIES	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
PARTNER NATION FACILITIES	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6
CIVIL USERS (AVIATION) U.S. AND FOREIGN	8,300	8,600	8,900	9,200	9,500	9,800	*								
CIVIL USERS (MARITIME) U.S. AND FOREIGN	5,000	5,500	6,000	6,500	7,000	7,500	*								
DOD USERS	1,480	1,535	1,660	1,715	1,720	1,715	1,680**	1,475	1,245	1,010	805	630	520	505	475

* The 1986 national decision on the future radionavigation system mix may affect the number of users of this system. Therefore, no estimates of the number of users are projected for later years.
** Begin DOD Phase-out. (Army and Air Force).

TABLE I-4.7 OMEGA User Schedule

The FAA is investigating the use of Differential OMEGA as a potential navigation system for aircraft operating in remote areas, primarily in Alaska. Some countries are already using Differential OMEGA for coastal marine navigation.

Because of the international character of the system and anticipated international user acceptance, operational decisions regarding system life must be coordinated with the partner nations. The military use of OMEGA will be phased out by the Army and by the Air Force by 1992. The Navy intends to reevaluate the use of OMEGA as a backup to NAVSTAR GPS for selected platforms when NAVSTAR GPS becomes fully operational.

4.3.4 VOR, VOR/DME, VORTAC

VHF Omnidirectional Range (VOR) was developed as a replacement for the Low-Frequency Radio Range to provide a bearing from an aircraft to the VOR transmitter. A collocated Distance Measuring Equipment (DME) provides the distance from the aircraft to the DME transmitter. At most sites the DME function is provided by the TACAN system which also provides azimuth guidance to military users. Such combined facilities are called VORTAC stations.

A. Operating Plan

The FAA operates 961 VOR/DME and VORTAC stations including 150 VOR stations. A small increase in the number of stations is planned during the next 5 to 10 years, to meet the requirements in specified areas. The DOD also operates a few stations in the U.S. and overseas. These are available to all users. The operating plan for VOR/DME/VORTAC is shown in Figure I-4.3.

Much of the ground-based equipment is between 15 and 30 years old and reaching the end of its useful life. Cost studies have shown that replacing obsolete vacuum-tube equipment with solid-state equipment will pay for itself in savings on operating and maintenance costs. Based on this, the FAA and DOD started a replacement program. DOD has initiated action to improve reliability and extend the life of its VORTAC equipment until sufficient aircraft are NAVSTAR GPS equipped.

B. User Community

Approximately 80 percent of the general aviation aircraft are equipped with at least one VOR receiver. All air carrier aircraft depend on it for bearing information. DME is used to provide distance information for all U.S. air carrier aircraft and for a large number of general aviation and military aircraft operating in U.S. airspace. The projected civil and miltary user population is shown in Table I-4.8.

C. Acceptance and Utilization

VOR is required for aircraft operating under Instrument Flight Rules (IFR) in U.S. airspace. It is also the internationally accepted standard short distance radionavigation aid for over land and continental approach use in air carrier and general aviation IFR operations. It is easy to use and is generally liked by pilots. Because it forms the basis for defining the airways, its use is an integral part of the air traffic control procedures.

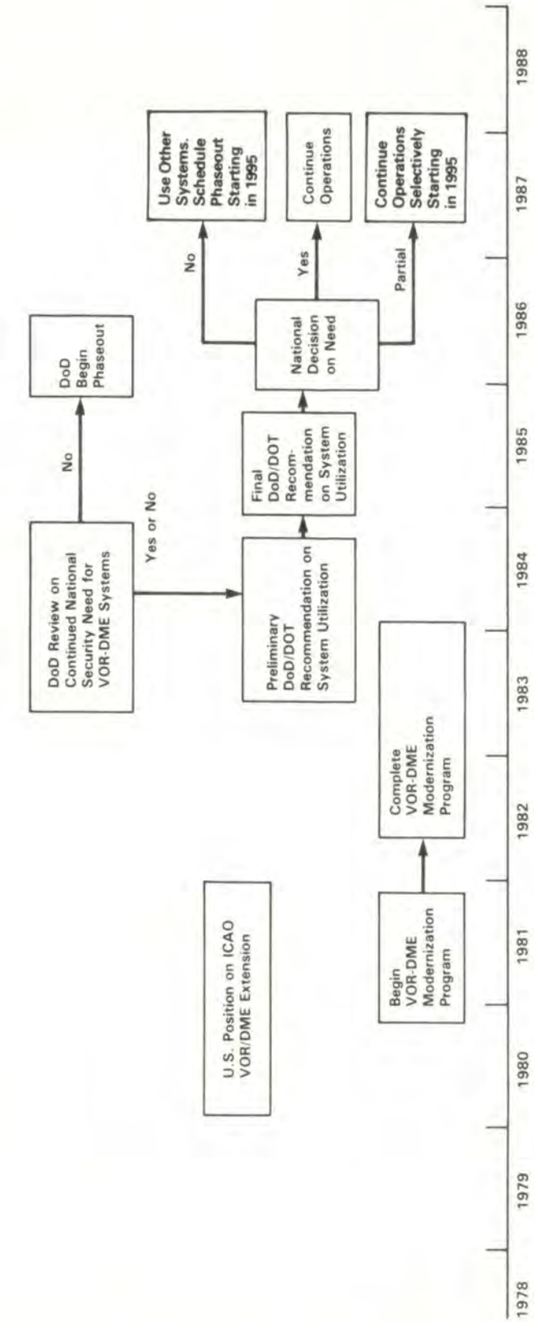

FIGURE I-4.3 Operating Plan for VOR, VOR/DME

FACILITIES/USERS	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
FAA FACILITIES	961	961	961	961	961	961	961	961	961	961	961	961	961	961	961
DOD FACILITIES	80	85	85	85	85	85	85	85	85	85	85	85	85	85	35
CIVIL USERS (VOR)	171,000	179,000	186,000	192,000	199,000	206,000	212,000	219,000	226,000	233,000	239,000	246,000	246,000	246,000	246,000
CIVIL USERS (DME)	47,000	49,000	50,000	52,000	54,000	55,000	57,000	59,000	61,000	63,000	64,000	66,000	66,000	66,000	66,000
DOD USERS**	13,855	13,855	13,830	13,775	13,815	13,690	13,805*	12,025	9,030	6,025	3,480	1,720	810	190	100

* Begin DOD Phase-out.
** Includes integrated VOR/ILS users.

TABLE 1-4.8 VOR, VOR/DME User Schedule

VOR/DME is currently protected by international agreements until 1985. The United States has supported the extension of this protection to 1995 and expects this position to be adopted by ICAO.

D. Outlook

Only a small increase in the number of transmitting stations is projected over the next decade in the U.S. These will meet requirements for new airports, new airways, and special Alaskan requirements.

A substantial increase in the general aviation user category is anticipated with the continuing growth of the number of aircraft being operated in U.S. airspace and the accompanying decreasing equipment cost. There is little or no use of the system expected by non-aviation vehicles. The line-of-sight signal propagation seriously limits coverage at ground level.

VOR/DME supports the current airways structure which is the basis for air traffic control procedures and operations. At present, no system has been identified by the FAA as a replacement. However, OMEGA and LORAN-C have been certified as supplements to VOR/DME in specific areas. DOD will pursue NAVSTAR GPS certification for military aircraft in lieu of VOR/DME/TACAN.

VOR/DME is expected to be in service at least until 1995 and action has been taken to extend the current international protection date from January 1, 1985 to January 1, 1995.* Also, if an alternate system such as LORAN-C or NAVSTAR GPS should prove acceptable to the international aviation community, full implementation would not start until the late 1980's or early 1990's. It would require a substantial period beyond that before phaseout of VOR/DME could be accomplished. At present, VOR/DME, in addition to its flexibility when combined with RNAV, is a highly cost-effective system.

The DOD VOR/DME operational concept is to maintain present system coverage until a suitable replacement is available. Present plans for expansion of the VOR/DME system are limited to site modernization or facility relocation. NAVSTAR GPS is the planned replacement for DOD VOR/DME and VORTAC facilities. This transition will start in 1987. Planned phaseout of VOR/DME will be completed by the DOD in 1997 (assuming NAVSTAR GPS or other suitable alternatives are identified). In the case of a military VORTAC site due for phaseout that has developed an appreciable civilian-use community, transfer of operational responsibility to the DOT will be discussed between DOD and DOT.

4.3.5 TACAN

The Tactical Aid to Navigation (TACAN) is a UHF radionavigation system which provides a pilot with relative bearing and distance to a beacon on the ground, ship, or to specially equipped aircraft. TACAN is the primary tactical air navigation system for the military services ashore and afloat. TACAN is often collocated with the civil VOR stations (VORTAC facilities) to permit military aircraft to operate in civil airspace.

*On November 25, 1982 ICAO is expected to vote to extend the protection date to 1995.

A. Operating Plan

The DOD presently operates 680 and the FAA operates 718 TACAN beacons. Present TACAN coverage ashore will be maintained until phased out in favor of NAVSTAR GPS. However, NAVSTAR GPS in its present state cannot replace the TACAN function afloat (moving platforms).

Civil DME and the distance-measuring functions of TACAN will continue to be the same. The operating plan for TACAN is shown in Figure I-4.4.

B. User Community

There are presently approximately 14,000 aircraft which are equipped to determine bearing and distance to TACAN beacons. These consists primarily of Navy, Air Force, and to a lesser extent, Army aircraft. The projected miltary user populations are shown in Table I-4.9. Additionally, allied and third world military aircraft use TACAN extensively. NATO has standardized on TACAN until 1995.

C. Acceptance and Utilization

TACAN is used by DOD and NATO aircraft operating under Instrument Flight Rules (IFR) ashore and IFR and Visual Flight Rules (VFR) for tactical and enroute navigation afloat. TACAN provides good accuracy in range and azimuth and is easy to use.

Because of propagation characteristics, TACAN is limited to line of sight which approximates 180 miles at higher altitudes. To receive range information an aircraft must radiate, thereby increasing the probability of detection. As with VOR/DME, special consideration must be given to location of ground-based TACAN facilities, especially in areas where mountainous terrain is involved due to its line-of-sight coverage.

D. Outlook

Army and Air Force TACAN systems will be phased out commencing in 1988 and will be completed by 1997. The Navy has plans for TACAN through the year 2000. It should be noted that ground stations will not be phased out until nearly all aircraft are GPS equipped. Several options will be available to replace TACAN on moving platforms. These options include NAVSTAR GPS with a data link, NAVSTAR GPS using the Joint Tactical Information Distribution System (JTIDS) as the data link, and maintaining existing TACAN beacons. The Navy will have a continuing requirement to perform the TACAN type function, both ashore and afloat. The decision on replacement of the shipboard TACAN function will be made at the time of NAVSTAR GPS phase in.

4.3.6 Instrument Landing System

The Instrument Landing System (ILS) provides aircraft with precision vertical and horizontal navigation (guidance) information during approach and landing. Associated marker beacons or DME equipment identify the final approach fix, the point where the final descent to the runway is initiated.

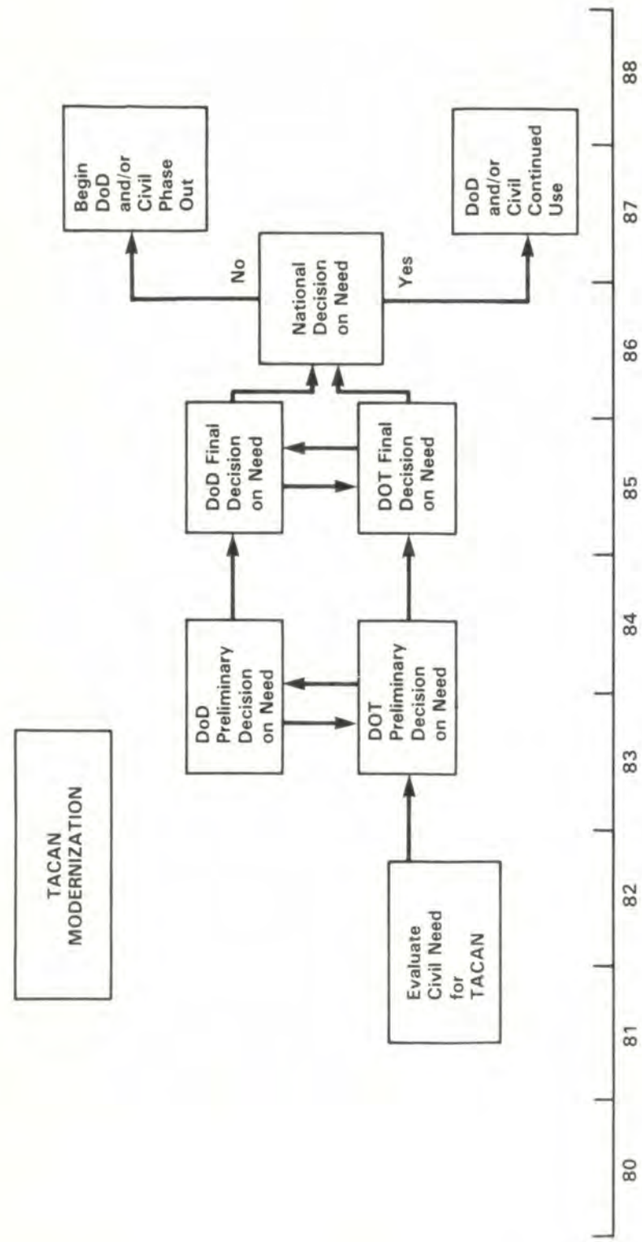

FIGURE I-4.4 Operating Plan for TACAN

TABLE 1-4.9 TACAN User Schedule

FACILITIES/USERS	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
FAA FACILITIES	718	718	718	718	718	718	718	718	718						
DOD FACILITIES	680	685	690	690	685	705	710	710	705	695	680	670	650	475	200
CIVIL USERS	20	30	50	70	100	120	*								
DOD USERS	13,840	14,040	13,940	13,965	13,855	13,900	12,760	10,865**	8,835	6,550	4,775	3,865	2,585	2,130	1,665

* The 1986 national decision on the future radionavigation system mix may affect the number of users of this system. Therefore, no estimates of the number of users are projected for later years.

** Begin DOD Phase-out. (Army and Air Force)

A. Operating Plan

By 1982 the number of ILS sites will reach 727. Eighty-four of these will be capable of permitting automatic landings under low weather minimums. In addition, there are approximately 165 ILS facilities operated by the DOD in the U.S. The operating plan is shown in Figure I-4.5.

Many ILS facilities are of obsolete vacuum-tube design and are being replaced with solid-state equipment.

B. User Community

Federal regulations require U.S. air carrier aircraft to be equipped with ILS avionics. It is also entensively used by general aviation aircraft. Since ILS is the ICAO standard landing system, it is extensively used by air carrier and general aviation aircraft of other countries. The projected civil and military user population is shown in Table I-4.10.

C. Acceptance and Utilization

ILS is the standard civil landing system in the U.S. and the international standard for aircraft operating under IFR conditions. Since its introduction in the 1940's, it has been installed in steadily growing numbers throughout the world. Part of its attractiveness to aircraft owners lies in the economy of avionics costs. Since the ILS localizers and VOR stations operate in the same frequency band, common receivers are used.

Military services use ILS at fixed bases in the U.S. and overseas. Special systems are used to meet unique military requirements, including ship-board operations. Precision Approach Radar (PAR) is the NATO interoperable landing aid.

D. User Base Expansion

The 1981 estimate of civil aircraft equipped with ILS is 84,000 aircraft. This number is expected to increase at a rate of about 3% per year until MLS is fully deployed and then decline to zero at the end of the transition period.

E. Expected System Life

ILS is currently protected by international (ICAO) agreement through at least 1995. Protection past 1995 is a possibility.

F. System Limitations

ILS limitations manifest themselves in three major areas:

(1) Performance of individual systems can be affected by terrain, man-made obstacles; e.g., buildings and surface objects such as taxiing aircraft and snow banks. These items may impose permanent use constraints on individual systems or limit their use at certain times.

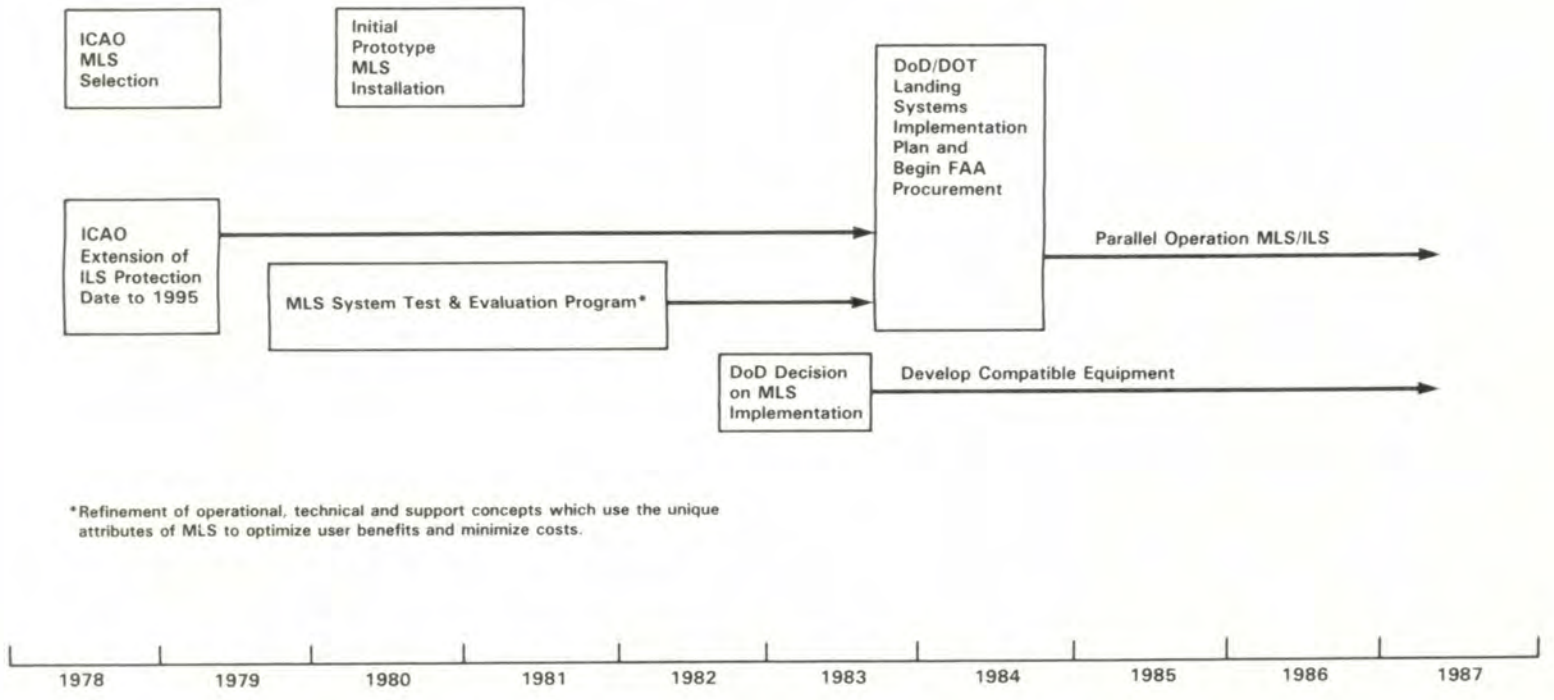

FIGURE I-4.5 Operating Plan for Microwave/Instrument Landing Systems (MLS/ILS)

FACILITIES/USERS	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
FAA FACILITIES	720	727	740	765	793	804	805	805	805	805	805	805	805	805	805
DOD FACILITIES	145	165	195	195	195	195	195	195	195	195	195	195	195	195	90
CIVIL USERS	84,000	87,000	90,000	94,000	97,000	100,000	103,000	107,000	110,000	113,000	117,000	120,000	120,000	120,000	120,000
DOD USERS**	3,350	3,475	3,610	3,645	3,695	3,725	3,745	3,740*	3,160	2,390	1,535	955	430	150	70

* Begin DOD Phase-out.
** ILS only. Integrated VOR/ILS Users are included in the VOR, VOR/DME Table I-4.8.

TABLE 1-4.10 Instrument Landing System (ILS) User Schedule

(2) Since ILS provides only a single straight-line approach path, it constrains airport operations and limits flexibility in relation to providing multiple-approach paths for non-control and optimum aircraft performance for various aircraft types.

(3) Even though the new 50 kHz frequency spacing will eventually double the ILS channel availability, frequency saturation limits the number of systems that can be installed. Frequency saturation occurs when ILS facilities in close proximity, with inadequate frequency separation, produce mutual interference.

4.3.7 TRANSIT

The Navy Navigation Satellite System (NNSS), also referred to as TRANSIT, is a satellite-based positioning system which provides submarines, surface ships, and a few special aircraft with an accurate two-dimensional positioning capability. The TRANSIT system consists of a minimum of four low-altitude satellites in near polar orbits, ground-based monitor stations to track the satellites, and injection facilities to update satellite orbital parameters. Developed mainly to support the Navy Fleet Ballistic Missile Submarines, TRANSIT is now installed on many foreign and commercial vessels in addition to many military surface vessels.

A. Operating Plan

The DOD plans to continue as the operator of TRANSIT until 1992. Specifically, ground-based monitor and injection facilities and replenishment satellites will be funded and operated/supported by the Navy. Phase out by military TRANSIT users in favor of NAVSTAR GPS is planned to begin in 1987 and end in 1992.

There are currently four operational OSCAR satellites (13, 14, 19 and 20) and one NOVA satellite in operation. On May 1, 1981, the Navy ceased operation of Oscar 11, the fifth OSCAR satellite, due to coplanar interference from adjacent satellites OSCAR's 14 and 20. OSCAR's 14 and 20 orbits are precessing toward the OSCAR 11 orbit. OSCAR 11 will not be operated in the navigation mode for approximately 18 months. On May 15, 1981 the Navy launched the first NOVA satellite. The new satellite will fill the large gap between OSCAR's 13 and 14. The NOVA satellite has much greater capability than the OSCAR satellite in that it:

a. Has a 3 db gain in signal strength over the OSCAR Satellite;

b. Maintains a more precise orbit;

c. Provides almost zero precession;

d. Provides more precise time through a computer controlled clock system; and

e. Is capable of operating 10 days without a new data upload.

Launch of a second NOVA satellite is planned for 1982. Plans now call for an operational constellation of two NOVAS and two OSCARS as a minimum. The operating plan is shown in Figure I-4.6.

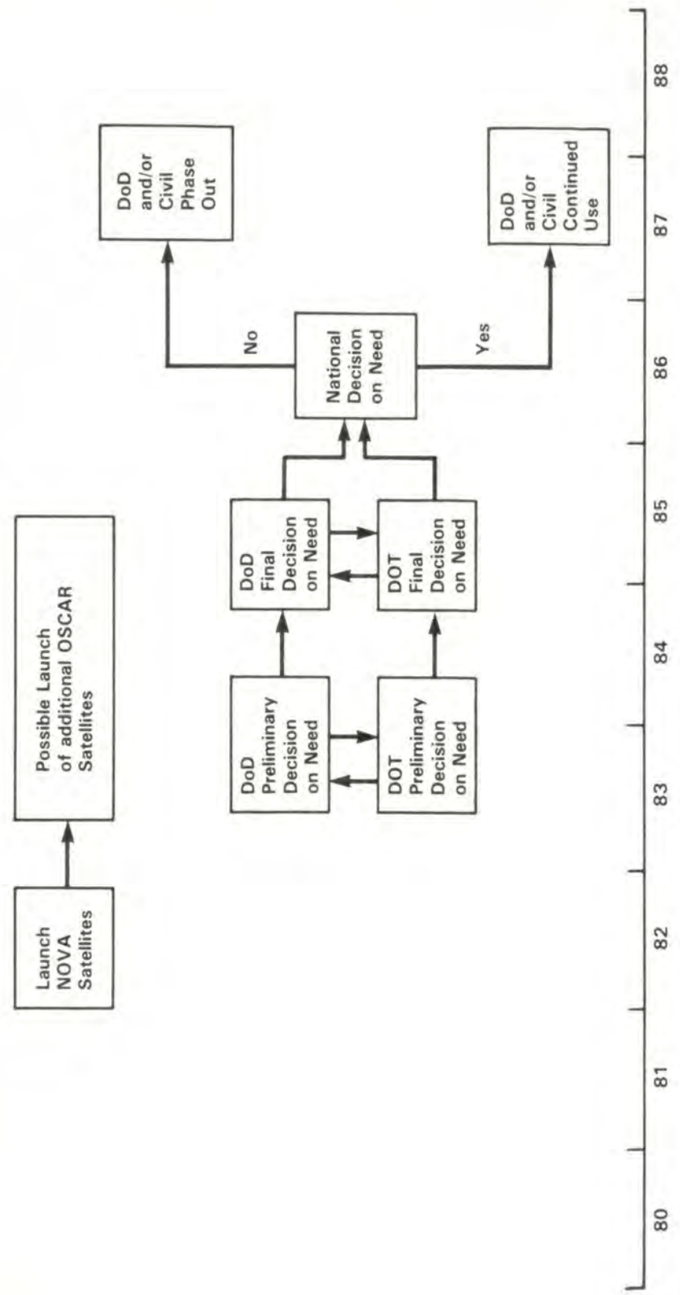

FIGURE I-4.6 Operating Plan for TRANSIT System

B. User Community

There are currently about 400 military TRANSIT users. Foreign and domestic commercial vessel use of the TRANSIT system has far outpaced the DOD use. It is estimated that 34,000 sets were in commercial use at the end of 1981, increasing to 38,000 by the end of 1982. Approximately 90 percent of all commercial TRANSIT receiver sales are for the single channel receivers. Determination of precise position (surveying) has become an important use of TRANSIT. The projected military user population is shown in Table I-4.11.

C. Acceptance and Utilization

TRANSIT provides periodic, worldwide, position-fixing information for Navy ships and submarines and commercial ships, as well as land users. It has been accepted, as indicated by the large increase in commercial sales in recent years. The increased commercial demand for user equipment, and a continuing increase in the number of equipment manufacturers has reduced the user equipment costs.

From a military view point, TRANSIT provides precise positioning for fixed and low dynamic vehicles. In a high dynamic, tactical environment, TRANSIT has little use since it is a Doppler system and small errors in user estimates of platform speed can cause large errors in user position. (One knot of unknown speed can cause a position error of 0.2nm).

D. Outlook

The Scout vehicle, scheduled for phase out by NASA in 1985, is used to launch both OSCAR and NOVA satellites. There are only a small number of these vehicles remaining to launch the satellites. If the Navy deems appropriate, a small number of OSCAR satellites may be launched as orbit spares.

With the exception of the transition to a satellite constellation consisting of a minimum of two improved satellites, there are no plans for expansion of the operational system.

DOD use and operation of TRANSIT is planned to be phased out in favor of NAVSTAR GPS during the period from 1987 to 1992. NAVSTAR GPS will replace the TRANSIT navigation function with continuous availability, greater accuracy, and increased resistance to countermeasures.

4.3.8 Aeronautical and Maritime Radiobeacons

In the contiguous 48 states, Aeronautical Non-directional Beacons (NDB) are used for transition from en route to precision terminal approach facilities and as non-precision approach aids at many airports. In addition, many of the non-directional beacons are used to provide weather information to pilots. In Alaska, NDB's are also used as en route facilities.

TABLE 1-4.11 TRANSIT System User Schedule

FACILITIES/USERS	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
CIVIL USERS (MARITIME)*	34,000	38,000	40,000	42,000	42,000	42,000	**								
DOD TRACKING FACILITIES	4	4	4	4	4	4	4	4	4	4	4	4			
DOD USERS	405	460	500	550	560	545	500***	370	250	135	85	45			

* A substantial number of these users are foreign.
** The 1986 national decision on the future radionavigation system mix may affect the number of users of this system. Therefore, no estimates of the number of users are projected for later years.
*** Begin DOD Phase-out.

Marine radiobeacons provide a backup to more sophisticated radionavigation systems and are the primary low-cost, medium accuracy system for vessels equipped with only minimal radionavigation equipment.

A. Operating Plan

The FAA operates over 600 non-directional beacons. In addition, there are about 200 military aeronautical beacons and 1200 non-federally operated aeronautical beacons. During the next 10 years, FAA expenditures for beacons are planned to be limited to the replacement of deteriorated components, modernization of selected facilities, and an occasional establishment or relocation of an NDB used for ILS transition.

There are approximately 200 marine radiobeacons operated by the Coast Guard. Current plans are to outfit all the stations with new solid-state equipment and to augment and reconfigure the system to provide better service and response to the increasing demand. This effort will include installation of some new stations, relocation of others, changes in the transmitting procedures for selected maritime beacons, and changes in frequencies. The frequency changes will result in more efficient use of the radio spectrum and will provide for future expansion if needed.

The operating plan is shown in Figure I-4.7.

B. User Community

Aeronautical Non-Directional Beacons (NDB): All air carrier, most military, and many general aviation aircraft carry Automatic Direction Finders (ADF).

Marine Radiobeacons: Beacons are utilized by all classes of users within the civil maritime community. They act as a backup for those users having more sophisticated radionavigational capability, and as a primary safety of operation service to the small recreational craft operating in open water. The projected civil and military population is shown in Table I-4.12.

C. Acceptance and Utilization

The large number of general aviation aircraft and pleasure boats which are equipped with radio direction finders attest to the wide acceptance of radiobeacons by the user community. The primary reason for this acceptance is that adequate accuracy can be achieved with low-cost user equipment.

An increasing number of recreational boats will use marine radiobeacons because of the low equipment cost. This use will continue particularly where more costly systems are not justified.

Radiobeacons provide a bearing accuracy relative to vehicle heading on the order of ±3 to ±10 degrees. This might be considered a systemic limitation but, in actual use, it is satisfactory for many navigational purposes. They are not satisfactory for marine navigation within restricted channels or harbors. Radiobeacons do not provide sufficient accuracy or coverage to be used as a primary aid to navigation for large vessels in U.S. coastal areas.

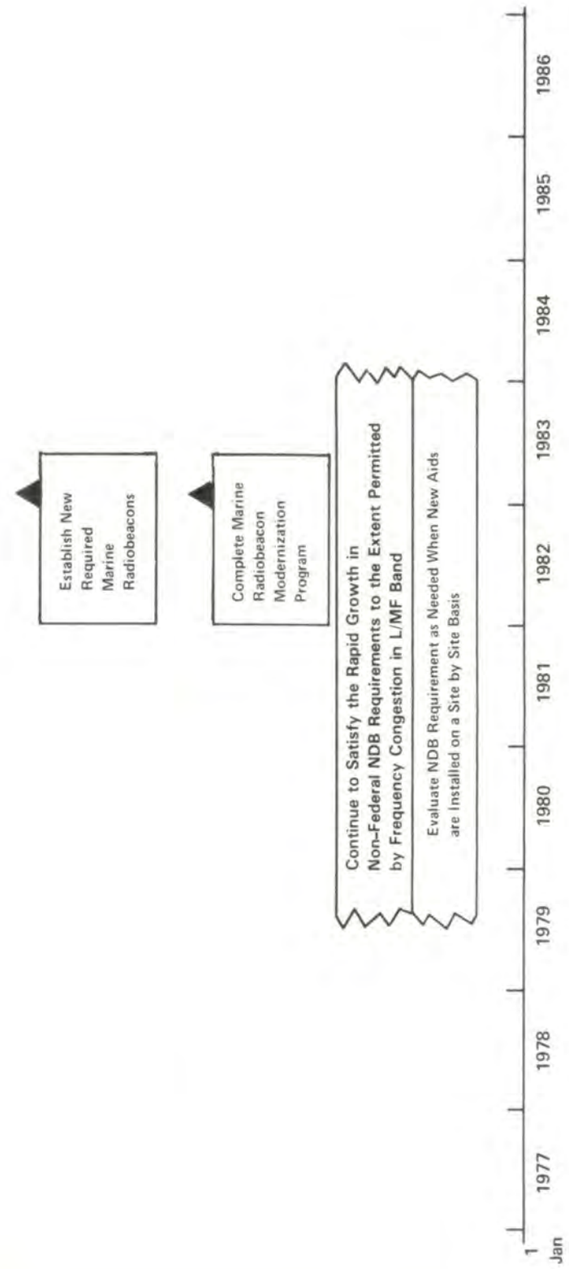

FIGURE I-4.7 Operating Plan for Radiobeacons (Aeronautical and Maritime)

FACILITIES/USERS	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
AVIATION FACILITIES (FEDERAL)	630	640	650	660	670	675	675	675	675	675	675	675	675	675	675
AVIATION FACILITIES (NON-FEDERAL)	1,150	1,220	1,280	1,350	1,410	1,460	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
MARITIME FACILITIES (FEDERAL)	198	206	214	224	224	224	224	224	224	224	224	224	224	224	224
DOD FACILITIES (AVIATION)	185	185	195	195	195	195	195	195	195	195	185	185	185	170	80
CIVIL USERS (AVIATION)	102,000	105,000	109,000	113,000	117,000	121,000	125,000	129,000	133,000	137,000	141,000	145,000	145,000	145,000	145,000
CIVIL USERS (MARITIME)	404,000	423,000	442,000	462,000	484,000	502,000	518,000	532,000	544,000	554,000	564,000	574,000	584,000	594,000	604,000
DOD USERS	12,870	12,810	12,660	12,475	12,460	12,195	12,300*	10,455	7,780	5,155	2,980	865	440	270	120

* Begin DOD Phase-out.

TABLE I-4.12 Radiobeacon User Schedule

D. Outlook

Growth in aeronautical beacon requirements is primarily non-Federal. During the 1975-1980 time period, FAA facilities increased about ten percent. Non-Federal systems, however, grew by forty percent. During the next 10 years, federal expenditures for aeronautical beacons are planned to be limited to the occasional establishment or relocation of NDB for ILS transition, replacement of deteriorated components, and modernization of selected facilities. Growth in the number of FAA beacons will be a function of these factors. It will also be influenced by the assumption of non-Federal facilities. Total growth in the number of FAA ground stations is expected to be somewhat smaller than the ten percent growth experienced in the 1975-1980 time period.

Growth in the total number of non-Federal aeronautical beacons is more diffcult to predict, particularly long-term. In the next five years, however, the total is expected to increase at a slightly slower rate than the forty percent growth experienced in the 1975-1980 time period.

Frequency congestion is one of the principal constraints which limits the expansion of NDB service. At FAA request, this problem is being addressed by the Radio Technical Commission for Aeronautics (RTCA), Special Committee 146 (SC-146). This committee is developing a Minimum Operational Performance Standard (MOPS) for Automatic Direction Finder (ADF) receivers. As existing ADF equipment are amortized, the tighter selectivity of new equipment will permit a greater number of NDB frequency assignments and will result in more efficient use of the radio spectrum.

Only a small expansion is planned for marine radiobeacon facilities. There is expected to be growth in the number of direction-finder-equipped pleasure boats.

At present, there is no known alternative system which would be as cost-effective for the user and the Government. No end of service can be foreseen between now and the year 2000 because of the wide and increasing acceptance by users and the lack of a low-cost alternative. DOD will phase out radiobeacons in favor of NAVSTAR GPS by 1997.

Radar beacons (RACONS) are short-range radio devices used to provide radar reference points in areas of flat coastal terrain and other places where it is important to identify a special fixed or floating aid. The Coast Guard is planning to add a modest number of swept-frequency RACONS in the 1980's to meet critical requirements.

4.4 PROPOSED SYSTEMS - STATUS AND PLANS

4.4.1 Microwave Landing System

The Microwave Landing System (MLS) is a joint development of the DOT, the DOD, and the National Aeronautics and Space Administration (NASA) under FAA management. Its purpose is to provide a civil/military, Federal/non-Federal standardized approach and landing system with improved performance compared with the existing landing systems.

A. Operating Plan

The U.S. Time Reference Scanning Beam (TRSB) MLS technique was selected by ICAO as the international standard in 1978. MLS is expected to replace ILS. An MLS transition plan is in coordination. The current operating plan is shown in Figure I-4.5. Precision DME (PDME) is also expected to be included with this system.

B. User Community

MLS applications are limited to aviation. Widespread use by the U.S. civil and military aviation community is anticipated. Potential users include all segments of international civil and military aviation including NATO. Projected civil and military user population is shown in Table I-4.13.

C. Acceptance and Utilization

Within the U.S. there has been widespread support for a common civil/military MLS. MLS does not have the siting problems of ILS, offers higher accuracy and greater flexibility, permitting precision approach service to be provided at more airports. MLS provides DOD tactical flexibility due to its ease in siting and adaptability to mobile operations. When fully implemented MLS will replace PAR/GCA for the DOD.

D. Outlook

MLS will gradually replace ILS in national and international civil aviation. Military versions, including portable tactical systems and systems for shipboard use, are planned. MLS will replace or limit the deployment of non-standard or interim systems now in use.

MLS is expected to operate beyond the Year 2025. DOD phase in of MLS will begin in 1988 and will be completed by 1997. Inclusion of the L-band DME with MLS would require extension of the DME segment of VOR/DME through the same period.

4.4.2 NAVSTAR GPS

NAVSTAR GPS is a system under development by the DOD. It is a system to provide positioning primarily for weapons delivery systems, as well as a number of other military missions. It will use satellites to provide world wide, continuous, real time, all-weather, precision position location information to equipped users. The DOT is evaluating civil uses of the NAVSTAR GPS system.

A. Operating Plan

NAVSTAR GPS is in development by a DOD joint service program office with representation from NATO allies. It is currently in the full-scale development phase. DOD expects to deploy an operational system based on a demonstrated performance and expected cost merits. DOD plans to award contracts for operational satellites in 1983 and for user equipment in 1984. The operating plan is shown in Figure I-4.8.

TABLE 1-4.13 Microwave Landing System (MLS) User Schedule

FACILITIES/USERS	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
FAA FACILITIES	0	4	4	4	35	95	155	255	355	455	555	655	755	855	955
DOD FACILITIES	0	0	0	0	0	0	0	60	85	150	175	215	255	300	350
CIVIL USERS	0	*	*	*	200	9,00	19,500	28,500	37,800	48,600	58,400	68,000	74,000	80,000	85,000
DOD USERS	0	0	0	0	0	0	0	2,840**	7,640	13,145	18,090	21,765	23,735	24,705	24,745

* Operational Test and Demonstration.
** Begin DOD Phase-in.

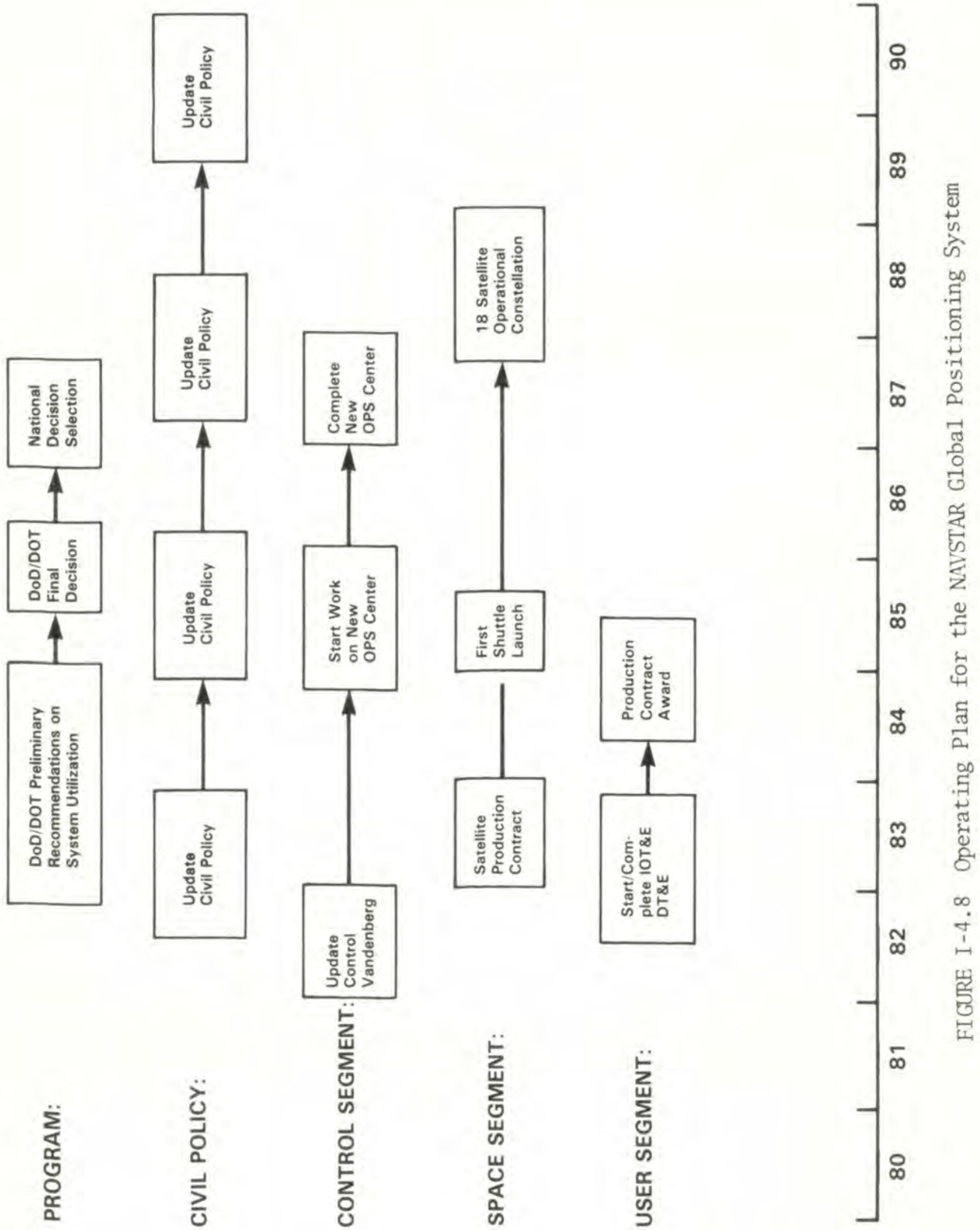

FIGURE I-4.8 Operating Plan for the NAVSTAR Global Positioning System

The NAVSTAR GPS program calls for satellite deployment throughout the full-scale development phase to support the Navy's Fleet Ballistic Missile Improved Accuracy Program and the NAVSTAR GPS user equipment initial operational test and evaluation in the 1982-1983 timeframe. As user equipment enters production and becomes available for operational use, the space segment will be gradually expanded to an initial 18-satellite deployment by 1988. The control system facilities modification at Vandenberg AFB will be completed in June 1982 to support the satellite constellation until the Master Control Station (MCS) is fully operational in 1987. The control segment will perform all system control functions, including ephemeris computation, tracking, telemetry, and command of the satellites.

B. User Community

The DOD expects extensive use of NAVSTAR GPS in almost every military mission area. DOT is evaluating use of NAVSTAR GPS to meet civil navigation requirements. The projected military user population is shown in Table I-4.14.

C. Acceptance and Utilization

NAVSTAR GPS is being developed under the management of a joint service program office with the Air Force as the lead service and largest potential user. The decision to deploy the system will depend upon the demonstrated performance and its expected cost benefit.

If deployed, the degree of its acceptance for civil use will be especially sensitive to the successful design of low-cost user equipment and the navigational services provided. A successful operational evaluation is also necessary before any system can be accepted as a civil radio aid to navigation. The question of use of NAVSTAR GPS by the civil community internationally raises institutional questions on system management which need further examination. Present accuracy predictions indicate that all except for precision landing, civil aviation accuracy requirements can be met by the NAVSTAR GPS undegraded Standard Positioning Service. The marine requirements for harbor approach, harbor, and inland waterway navigation can only be met with the Precise Positioning Service.

D. Outlook

NAVSTAR GPS is a user passive radionavigation system designed to provide high positional accuracy on a global basis. The potential for many users is very high. The accuracy of the signal supplied and the cost of user equipments will be major factors in any expansion. There is no official service life prediction for NAVSTAR GPS at this time. It is expected, however, to provide services into the next century. DOD phase in of NAVSTAR GPS will begin in 1987 and will be completed by 1997.

FACILITIES/USERS	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
DOD USERS	0	0	0	0	0	0	1,455*	6,030	11,630	17,210	21,675	24,915	26,125	26,735	27,020

* Begin DOD Phase-in of Operational Systems.

TABLE I-4.14 NAVSTAR Global Positioning System (GPS) User Schedule (Military)

4.5 SELECTING RADIONAVIGATION SYSTEMS TO BE USED IN THE FUTURE

Many factors determine the choice of systems to meet user requirements. They may be categorized according to operational, technical, economical, institutional and/or international parameters. System accuracy and coverage are foremost among the technical parameters followed closely by systemic availability and reliability. Certain unique parameters, such as anti-jamming performance, apply to military needs. In most cases, current systems were developed to meet distinct and different requirements. They must be retained until suitable single or multi-user systems can be implemented. The current investment in ground and user equipment must also be considered. In some cases, there may be international commitments.

4.5.1 Approach to Selection

Figure I-4.9 shows the sequential process being used to select navigational systems to be used in the future. It represents a coordinated DOD/DOT effort to resolve all outstanding issues and to recommend the optimal choices for the overall national decision by 1986.

Work to provide the decision data base is underway. DOD and DOT anticipate completion of technical evaluations of candidate systems (including NAVSTAR GPS) in 1982. At that time, the development of DOD and DOT Economic Planning Models will be completed. They will enable detailed analysis of the costs and benefits of different mixes of existing and developmental navigation systems for civil and military users. DOD and DOT will then have all tools in place to arrive at informed judgments prior to national decisions. These decisions may be made in 1986 after consultations to ensure consistency in domestic and international operations. DOD/DOT decisions will be reflected in the annual update of the Federal Radionavigation Plan and will be implemented through the budget process.

The flow diagram (Figure I-4.9) illustrates the need to analyze both individual systems and system combinations sequentially. Thus, even though similar analyses of civil suitability and national security objectives are necessary for individual systems in the 1981-83 time frame, a comprehensive overview of all systems must be accomplished later. This will ensure balance, consistency, completeness and equal treatment of all viable alternatives.

The flow diagram describes an ongoing process supporting the annual revision of the Federal Radionavigation Plan. However, the process requires periodic status reviews and assessment of the impact on future decisions. The mechanism for doing this is incorporated into the DOD/DOT Federal Radionavigation Plan review process.

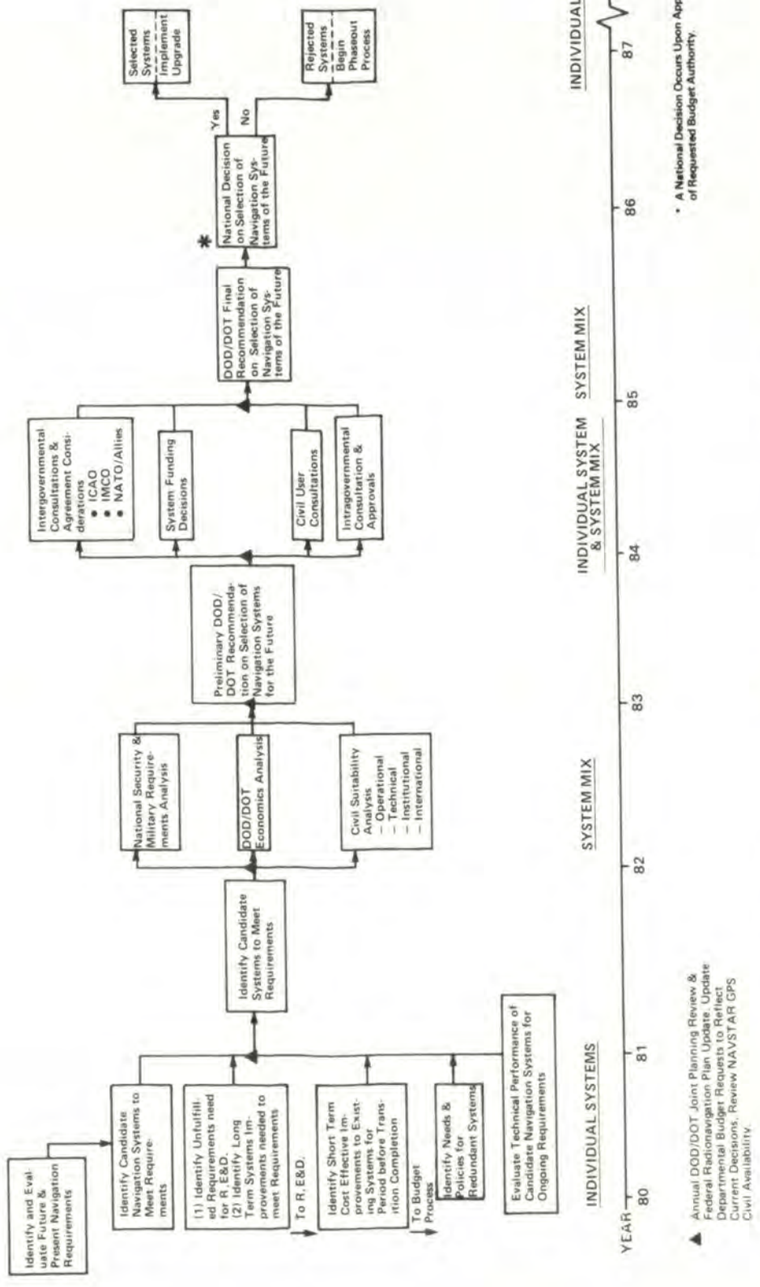

FIGURE I-4.9 Selection of Initial Radionavigation Systems Mix

Four years are scheduled for consultations (1983-1986) with groups that will be affected by the pending national decisions. This includes U.S. allies, including the North Atlantic Treaty Organization (NATO), and both the Inter-governmental Maritime Consultative Organization (IMCO) and the International Civil Aviation Organization (ICAO). An intensive effort is necessary and desirable to establish a stable framework for long-range planning by users and others affected by the transition to a new combination of systems.

A three-step selection process is visualized. First, DOD decisions are made whether a given system is necessary to meet national security requirements or not. If no, phase out of their use of the system can begin. If yes, DOD requirements are incorporated into the decision data base for consideration with other systems. In either case, the second step of consolidated DOD/DOT recommendations follow. These consider fulfillment of civil and military requirements with the minimum number of common user systems. Considerations of operational, technical, economical and institutional issues would dominate the selection process and finally, national decisions reflect the outcome of consultations as well as public policy and budgetary review of the DOD/DOT recommendations.

There are short and long term aspects that need to be addressed in the overall process. The long-term goal is to establish, through an integrated DOD/DOT planning and budgeting process, a cost-effective mix of multi-user systems for the post-1995 timeframe. However, before decisions can be implemented, there may be incremental improvements to existing systems that can be cost-effective for the time period 1982-1995, regardless of the final mix that is selected. Specifically, modernization of the VOR/DME, TACAN and LORAN-C transmitting segments are providing offsetting benefits to the required capital investment. The selection process for the system to be used in the future allows the flexibility to adopt incremental improvements where justified over the short term. Similarly, it permits systemic upgrading and research and development to allow the satisfaction of operational requirements which are not met by existing or planned systems.

Two key events stand out in the process: the 1983 DOD/DOT preliminary recomendation on the future navigation system mix, and the 1986 decision at the national level. The 1986 decision becomes the basis for navigational system implementation. Following the 1986 decision, it is intended that this process will be continued to reflect in the ongoing radionavigation planning such factors as new requirements and advances in technology.

4.5.2 Issues to Be Considered

This section describes radionavigation operational, special military, technical, economic, and institutional (including international) issues.

A. Operational Issues

Volume II defines the operational requirements of civil users of navigational systems. The following paragraphs address the operational issues that define user requirements.

1. The User/Operator Viewpoint

Mobile users/operators want the most direct, economical and safest path to their destinations or, in some cases, the user wants to locate a fixed point or boundary. They must be able to respond correctly and expeditiously to traffic control services. They must have the capability to navigate with accuracy consistent with their environment, the capability of others sharing their space, the performance of their craft, and the rules, regulations, and procedures which govern operations.

Operators can choose from a number of equipments needed to use available aids to navigation. Areas of operation, mission, economics, personal preference and Federal regulations largely determine the aids which they chose to use. In the selection of equipment, operators generally wish to limit or minimize the cost. An aircraft must be equipped so that it may be operated safely and in accordance with a clearance and published regulations even in the event of failure of the surveillance or communications system. A ship must be equipped so that it can navigate safely without assistance other than that provided by established aids to navigation.

B. Special Military Issues

1. Military Selection Factors

Operational need is the principal influence in the DOD selection process. Precise navigation is required for vehicles, anywhere on the earth's surface, on and under the sea and in and above the atmosphere. Other factors that affect the selection process are:

a. The need for flexibility to accommodate new weapon systems and technology.

b. The need for systems that are relatively immune to enemy interference or exploitation.

c. Interoperability with the systems used by allies and civil sector.

d. The need for reliability and survivability in combat.

e. Interruption, loss or degradation of system operation by enemy attack, political action, or natural causes.

f. Development of alternate means of navigation.

g. The need for geodetic accuracy relative to a common reference system to support strategic and tactical operations.

h. Worldwide mobility requirements.

The selection of DOD navigational systems is influenced by the fact that military operations may be conducted in areas where navigational facilities are inadequate or non-existent. Consequently, transportable navigational facilities may be needed. DOD navigational systems must operate in extreme enviroments and, in

some cases, unattended. Moreover, in some applications, navigational systems must be very small and use little power.

2. Civil/Military Compatibility

DOD aircraft and ships operate in, and must be compatible with, civil environments. Thus, there are potential cost advantages in the development of common civil/military systems.

3. Review and Validation

The DOD radionavigation system requirement review and validation process:

a. Identifies the unique components of mission requirements

b. Identifies technological deficiencies

c. Determines, through interaction with DOT, the impact of new military requirements on the civil sector.

The requirement review and validation process will investigate system costs, cost effectiveness, potential cost offsets, user populations, and the relationship of candidate systems to other systems and functions. Validation of operational requirements will establish the necessity of a system to insure successful mission completion.

C. Technical Issues

In evaluating future navigational system candidates, there are a number of technical factors which must be considered:

a. Received Signal Strength

b. Multipath Effects

c. Signal Accuracy

d. Vehicle Dynamic Effects

e. Signal Acquisition and Tracking Continuity

f. Signal Coverage

g. Noise Effects

h. Propagation

i. Interference Effects (Natural, Man-Made)

j. Installation Requirements

k. Environmental Effects

1. Human Factors Engineering.

D. Economic Issues

A number of systems may play major roles in navigation in the future. Some of these systems, such as VOR/DME, are limited to use by a single class of users, e.g., aircraft, in specific areas. Others, such as LORAN-C, have wider coverage areas and application. Still others, such as NAVSTAR GPS, have broad application and global coverage. Without adequate analysis, one could conclude, superficially, that the "optimal" policy would concentrate government investment in a single future radionavigation system to meet all user requirments. Such a conclusion, however, neglects the significant user investment in existing systems and other economic aspects which require a careful analysis of costs and benefits.

Benefits derived from radionavigation systems take many forms, but are summarized frequently in three easily recognized major categories: improved safety of navigation, greater efficiency in transportation and other commercial activity, and more effective protection of national security. Efficiency in commercial enterprise produces economic benefits which are generally obvious, but not so easily quantifiable. Improvements in general safety and security provide additional, significant economic benefits through the prevention of loss of life and limb and protection of capital investment.

Direct cost to the government, as the operator of radionavigational services, and to the user, who must buy the equipment needed to use the services, must be carefully analyzed. The analysis of these costs must consider initial investment, operation, maintenance and replacement costs; and the unamortized capital investment remaining at the time that replacement of the system is contemplated. In the civil sector, the cost of user equipment, more than any other single factor, influences the acceptability of a new system by the majority of civil users. Substantial unamortized investment in user equipment for an older system will cause strong resistance to replacement and demand extended phase in/out period.

DOD is a major investor in navigational systems, subsystems and components. The acquisition of a system which is not cost-effective diverts DOD resources from more productive uses; therefore, affordability from a life-cycle-cost view is a prime concern. As in the civil sector the cost of user equipment for cooperative navigation systems is often the single most important determinant of affordability.

The DOT and the DOD are developing an economic model to evaluate costs and benefits of specific radionavigation scenarios. Such evaluations will be a part of the data supporting future decisions regarding the selection of civil and military navigational systems. Cost comparison for all major classes of systems and users is planned to be attained by 1983.

E. Institutional Issues

Chapter 3 of this volume defines the policy structure governing the development and planning of navigational systems. While all elements need to be addressed in formulation of strategy for system selection, the principal unresolved issues include the following:

1. Cost Recovery for Radionavigation Services

Because of the nature of the electromagnetic medium, radionavigation services presently provided to meet U.S. requirements are available to any suitably equipped user. Further, there is no direct charge or fee levied by the U.S. for the use of any of the Federally provided radionavigation systems. The only cost recovery for radionavigation services from civil users, either domestic or foreign, is obtained from the aviation community as part of the overall process of cost recovery for the DOT provided air transportation services. This cost recovery is achieved through indirect measures such as fuel taxes, registration fees, and/or ticket taxes and at this time covers only part of the DOT's costs. There is no corresponding cost recovery, at this time, from the marine users of DOT provided transportation services.

The DOT has proposed the implementation of fees sufficient in total, to approach full cost recovery from the civil transportation users who directly benefit from Government provided transportation related services. The various fees would be set at an amount so as to generate total revenue from each of the user groups consistent with the cost of the services provided to that group. This proposal is part of the Administration's effort to impose user fees where a service provides benefit to identifiable recipients above and beyond those which accrue to the general public. Under the DOT proposal, the costs of DOT provided services would be recovered through an appropriate and convenient fee system:

- In the case of the U.S Coast Guard, fees for direct services involving a transaction (e.g., licenses and inspection) would be set according to the cost of providing the service. Other services (e.g., maintaining navigation aids and providing search and rescue services) would be financed by an annual fee or other type of charge.

- The cost of the services provided by FAA would be recovered through the following fee system: a passenger ticket tax, aviation gasoline fuel tax, jet fuel tax, freight waybill tax, international departure tax, and a tire and tube tax.

Independent of the DOT effort, the Congress has directed DOD "...to develop a comprehensive plan for recouping from other Federal government and civil users as much of the development, acquisition and operating costs of the GPS system as is deemed feasible." A DOD study is underway concerning the costs to be recovered from the various user groups and an enforceable system of national and international user charges suitable for this major new system. At DOD's request, DOT is participating in parts of the study.

In response to the Congressional guidance, a preliminary status report was submitted by DOD to the Congress on March 1, 1982. The report outlined progress to date and highlighted some of the many additional actions required to formulate a practical user charges program for NAVSTAR GPS. Differences exist in the initial NAVSTAR GPS cost recovery approach proposed in the preliminary status report and the cost recovery approach proposed for the DOT provided transportation related services. However, the NAVSTAR GPS cost recovery approach and user charges program are not yet finalized and remain the subject of the on-going DOD study. Resolution of this user charge/cost recovery issue is an essential part of the process of developing the joint recommendation in 1983.

2. Signal Availability and Accuracy in Times of National Emergency

The availability of navigational signals of adequate accuracy at all times, including times of stress, is essential to reliance on a given system for safety of navigation. A preliminary evaluation of the proposed NAVSTAR GPS signals indicates that many civil requirements probably could be met with the SPS signal. Conversely, guaranteed availability of optimum performance may diminish national security objectives, so that a trade-off or compromise is necessary. Hence, a proposed national policy is being developed on the criteria which will govern availability and accuracy. The Department of Defense proposes that NAVSTAR GPS SPS signal will be made continuously available on a worldwide basis for civil and commercial use at the highest level of accuracy consistent with national security interests. It is presently projected the predicted and repeatable accuracy will be 500 m (2 drms) horizontally and 820 m (2 sigma) vertically and the relative accuracy will be 10 m (2 drms) horizontally and 16.4 (2 sigma) vertically. This level of performance will be reviewed by DOD annually and the level of accuracy modified to accomodate any changes commensurate with our national security posture. It is anticipated that the SPS accuracy will be increased as time passes.

3. International Acceptance of Navigational Systems

The goals of standardization and cost minimization of user equipment drive the search for an international consensus on a selection of navigational systems. For civil aviation, ICAO establishes standards for internationally used navigational systems. In maritime navigation, the trend is toward international recognition of a minimum number of systems from which individual countries could prescribe one or more to be carried by ships in their territorial waters. For aviation, the heavy and growing international investment in VOR/DME is expected to lead to an extension of the ICAO protection date to 1995.* A consideration in the international acceptance of NAVSTAR GPS is the political ramifications resulting from the fact that it is a U.S. military system. Hence, further international consultations will be instituted with NATO allies, IMCO, ICAO, etc., to explore the feasibiity of international acceptance of NAVSTAR GPS.

4.5.3 Criteria for Selection

Criteria are defined to compare the relative attractiveness of alternative navigational systems' configurations. At the minimum, decisions on selection of future systems should meet the following criteria:

A. Provide the necessary service to meet the needs of the military and civil communities. (Service)

B. Be responsive and flexible to the changing operational and technological environments. (Viability)

C. Recognize and accommodate a necessary degree of standardization and interoperability for both domestic and foreign operations. (Standarization)

*On November 25, 1982 ICAO is expected to vote to extend the protection date to 1995.

D. Achieve the required level of service in an economic manner. (Costs)

The major criteria may be further subdivided, as shown below:

A. Service

1. Military Operations: Provide, at a minimum, navigational services to support accomplishment of DOD tactical and strategic missions in an effective and efficient manner.

2. Transportation Safety: Provide, at a minimum, navigational services sufficient to minimize transportation risk to an acceptable level.

3. Economic Efficiency: Provide, to the extent possible and consistent with cost effectiveness, navigational services which benefit the economy. Typically, this will require better performance from the navigational system than imposed by safety of navigation, but less than that needed for military operations.

B. Viability

1. Orderly Transition: Provide for orderly transitional operations and planned obsolescence of equipment as technical improvements evolve and operational requirements are modified or increased.

2. Flexibility: Provide navigational services to a variety of user classes with the minimum number of systems. The intent is to allow the use of special purpose systems only when justified by special circumstances and/or need.

3. Coverage: Provide navigational services in all relevant operating areas, i.e., worldwide, with specialized attention to the United States.

4. Future Systems: Provide for research and introduction of new systems and concepts, particularly where unfulfilled requirements exist or where cost savings appear possible.

C. Standardization

1. International Acceptance: Provide navigational services and systems technically and politically acceptable to diverse groups, including the North Atlantic Treaty Organization (NATO), International Civil Aviation Organization (ICAO), and Inter-governmental Maritime Consultative Organization (IMCO).

2. Civil/Military Interoperability: Provide the basic capabilities to permit common use and common operational procedures by civil and military craft.

3. Equipment Standardization and Compatibility: Provide, to the extent feasible, compatibility between civil and military navigational equipment.

D. Costs

1. Combined User/Government Costs: Provide a mix whose life-cyle costs for government and users are minimum, consistent with adequate service and reasonable benefits.

2. Transition Period Cost: Parallel (new and old) systemic operations will be carried out over a sufficient period to minimize user investment cost penalties and to permit equipment replacement to occur at normal intervals.

GLOSSARY

The following is a listing of abbreviations for organization names and technical terms used in this plan:

ADF	Automatic Direction Finder
AFSCF	Air Force Satellite Control Facility
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
ATMSMN	Air Traffic Management System Material Need
AVL	Automatic Vehicle Location
AVM	Automatic Vehicle Monitoring
C/A	Coarse/Acquisition
CCW	Coded Continuous Wave
CCZ	Coastal and Confluence Zone
CDI	Course Deviation Indicator
CEP	Circular Error Probable
CIA	Central Intelligence Agency
CNI/NAV	Communications, Navigation & Identification/Navigation
CONUS	Continental United States
CS	Control Segment
CSOC	Consolidated Space Operations Center
CSE	Course Selection
CW	Continuous Wave
DH	Decision Height
DMA	Defense Mapping Agency
DME	Distance Measuring Equipment
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOS	Department of State
DOT	Department of Transportation
DPM	Deputy Program Manager
DR	Dead Reckoning
drms	distance root mean squared
DSARC	Defense System Acquisition Review Council
DT&E	Development Test & Evaluation
ECCM	Electronic Counter-Countermeasures
ECD	Envelope-to-Cycle Difference
EHT	Extremely High Frequency
EMI	Electromagnetic Interference
EMS	Emergency Medical Service
ERDA	Energy Research & Development Administration (Now Department of Energy)
F^3	Form, Fit, and Function
FAA	Federal Aviation Administration
FAATC	Federal Aviation Administration Technical Center
FAF	Final Approach Fix
FAR	Federal Aviation Regulation
FCZ	Fishery Conservation Zone

FHWA	Federal Highway Administration
FL	Flight Level
FM	Frequency Modulation
FRA	Federal Railroad Administration
FRP	Federal Radionavigation Plan
FSD	Full-Scale Development
FTE	Flight Technical Error
GA	General Aviation
GBF/DIME	Geographic Base File/Dual Independent Map Encoding
GCA	Ground Control Approach
GDOP	Geometric Dilution of Precision
GPS	Global Positioning System
GRI	Group Repetition Interval (LORAN)
GSTDN	Ground Satellite Tracking and Data Network
HHE	Harbor and Harbor Entrance Area
Hz	Hertz
IAP	Improved Accuracy Program
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMCO	Inter-governmental Maritime Consultive Organization
INS	Inertial Navigation System
IOT&E	Initial Operational Test & Evaluation
JCS	Joint Chiefs of Staff
JPO	Joint Program Office
JTIDS	Joint Tactical Information Distribution System
JTMLS	Joint Tactical Microwave Landing System
kHz	KiloHertz
LF	Low-Frequency
LOFF	LORAN Flight Following
LOP	Line of Position
LORAN	Long-Range Navigation
MAP	Missed Approach Point
MARAD	Maritime Administration
MCS	Master Control Station
MCW	Modulated Carrier Wave
MDA	Minimum Descent Altitude
MF	Medium Frequency
MHz	MegaHertz
MIJI	Meaconing, Interference, Jamming, and Intrusion
MLS	Microwave Landing System
MNP	Master Navigation Plan
MOU	Memorandum of Understanding
MTBF	Mean Time Between Failures
MTTR	Mean Time to Repair
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAVSTAR	Navigation System using Time And Ranging
NCC	NAVSTAR GPS Control Center
NDB	Non-Directional Beacon
NEEDS	NASA End-to-End Data System

NHTSA	National Highway Traffic Safety Administration
nm	nautical miles
NNSS	Navy Navigation Satellite System (TRANSIT)
NOAA	National Oceanic and Atmospheric Administration
NOC	Navstar Operations Center
NOTAM	Notice to Airmen
NPN	National Plan for Navigation
NSF	National Science Foundation
NSWC	Naval Surface Weapon Center
NTIA	National Telecommunications and Information Agency
O&M	Operation & Maintenance
OAST	Office of Aeronautics and Space Technology (NASA)
OCS	Operational Control Segment
OJCS	Office of the Joint Chiefs of Staff
OMB	Office of Management and Budget
OMEGA	(Not an abbreviation)
OPS/QTV	Operations/Qualification Test Vehicle
OSD	Office of the Secretary of Defense
OTP	Office of Telecommunications Policy
PAR	Precision Approach Radar
PDME	Precision Distance Measuring Equipment
PILOT	Precision Intracoastal LORAN Translocation
PLAD	Portable LORAN Assist Device
POS/NAV	Positioning and Navigation
PPS	Precise Positioning Service
PRN	Pseudo-Random Noise
PSE	Peculiar Support Equipment
R&D	Research & Development
RACON	Radar Transponder Beacon
RD&D	Research, Development, & Demonstration
RDF	Radio Direction Finder
R,E&D	Research, Engineering & Development
RF	Radio Frequency
RFI	Radio Frequency Interference
RNAV	Area Navigation (Radio)
RSPA	Research and Special Programs Administration
RSS	Root Sum Square
RTCA	Radio Technical Commission for Aeronautics
RVR	Runway Visual Range
SAFI	Semi-Automatic Flight Inspection
SARPS	Standard and Recommended Practices
SEP	Spherical Error Probable
SHF	Super High Frequency
SLSDC	St. Lawrence Seaway Development Corporation
SPS	Standard Positioning Service
STOL	Short Take-Off and Landing
STS	Satellite Test System
SV	Space Vehicle
TACAN	Tactical Air Navigation
TCV	Terminal Configured Vehicle
TD	Time Difference
TDRSS	Tracking and Data Relay Satellite System

TDSS	Time Difference Survey System
TERPS	Terminal Instrument Procedures
TIP	Transit Improvement Program
TIWG	Test Integration Working Group
TOA	Time of Arrival
TRANSIT	(Not an abbreviation)
TRSB	Time Referenced Scanning Beam
TSC	Transportation Systems Center
TSO	Technical Standard Order
TT&C	Telemetry Tracking and Control
TVOR	Terminal VOR
UE	User Equipment
UHF	Ultra High Frequency
UMTA	Urban Mass Transportation Administration
USDA	United States Department of Agriculture
USGS	United States Geodetic Survey
UTC	Universal Coordinated Time
VFR	Visual Flight Rules
VHF	Very High Frequency
VLF	Very Low Frequency
VNAV	Vertical Navigation
VOR	Very High Frequency Omnidirectional Range
VORTAC	Collocated VOR and TACAN
VTOL	Vertical Take-Off and Landing
VTS	Vessel Traffic Service

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