Federal Radionavigation Plan

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Radionavigation Plans and Policy

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LETTER OF PROMULGATION

This letter promulgates the first edition of the Federal Radionavigation Plan jointly prepared by the Departments of Defense and Transportation. It supersedes the Department of Transportation National Plan for Navigation dated November 1977. A052269

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, maritime, and terrestrial navigation systems to meet validated requirements. 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 Department of Commerce (Maritime Administration) and the National Aeronautics and Space Administration and has their concurrence.

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

Harold Brown
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Secretary of Defense

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Secretary of Transportation

(19) DOD

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16. Abstract

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 of 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 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 coordinate 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 [illegible] volumes: Volume II, Requirements, has 50 pages; Volume III, Radionavigation Characteristics, has 46 pages; and Volume IV, Radionavigation Research, Engineering and Development, has 124 pages.

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PREFACE

The Departments of Defense and Transportation developed this 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 responsibilities 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.

V2-

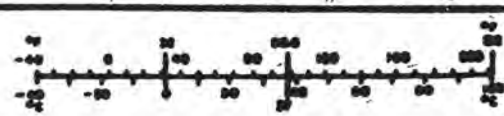
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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FEDERAL RADIONAVIGATION PLAN

VOLUME I

RADIONAVIGATION POLICY AND PLANS

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EXECUTIVE SUMMARY

Radionavigation is required to support movement of resources, raw materials, manufactured goods and people in the processes of the domestic and international economy and trade to assure national defense and security, and to ensure safety of life and property in commercial land, sea, and air transportation systems.

The Federal Radionavigation Plan delineates policies and plans for Government-provided radionavigation services. The document describes respective areas of 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 those sections of the DOD Joint Chiefs of Staff (JCS) Master Navigation Plan dealing with common-user systems.

The document describes the various phases of navigation and indicates the current and anticipated future requirements for each phase. Present systems are described with their utilization and acceptance. The potential of future systems is addressed.

The Plan covers Federally operated systems having a high degree of common use (either military/civil or between the various transportation modes). The systems considered are:

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

The goal is to select a suitable mix of these 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 is a secondary consideration.

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. Some civil user requirements are highly specialized.

Thus, 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 methodology for DOT and DOD 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 NAVSTAR GPS has the potential to replace many existing station-referenced systems. Certain military applications, nevertheless, require covertness and redundancy, or multiple, independent navigation systems. Technically and operationally NAVSTAR GPS is more complex than existing systems and represents a significant challenge in the development of low-cost user equipment. The Plan delineates the issues that must be resolved if NAVSTAR GPS is to find wide use.

This document, which will be updated annually, is composed of four volumes:

Volume I: 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 coordinate research, development and implementation of radionavigation systems is provided in this volume.

Volume II: User requirements (civil and military) 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 discussed. Present and future anticipated needs are both addressed.

Volume III: 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: A summary of Federal radionavigation R,E&D plan together with individual R,E&D plans for military and civil air, land, and marine applications is presented in this volume. Open issues and means for their resolution are addressed. A key feature is a discussion on how the individual agency R,E&D plans will be coordinated to help assure that all aspects of each system are thoroughly evaluated while avoiding duplication of activities.

VOLUME I

CHAPTER 1

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

This document is the first edition of the FRP. It represents the combined planning for government-provided radionavigation services by Federal agencies. It also incorporates the most recent changes to the two following planning documents:

A. The Department of Transportation (DOT) National Plan for Navigation (NPN), dated November 1977.

B. The Department of Defense (DOD) Joint Chiefs of Staff - Master Navigation Plan (MNP), 1978 edition.

Prior to the time work was started on this 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 DOT, DOD, 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 between DOT and DOD 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 civil governmental agencies such as NASA and DOC, and State and municipal agencies. The DOD Positioning/Navigation Executive Committee (Pos/Nav Committee) addresses uses of navigation by the military services.

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

1.2 PURPOSE

The purpose of this FRP is to:

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

B. Provide a document for comparing civil and 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 summary system planning schedule through the Year 2000.

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

1.3 SCOPE

This Plan covers civilian and military radionavigation systems with primary navigational application to civil and military needs. 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-A
- 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 Approach/Landing and en route/terminal phases of aviation operation by aeronautical users.

- o Ocean, coastal, harbor approach, harbor, and inland waterway navigation by marine users.

- o Automatic Vehicle Monitoring (AVM), Automatic Vehicle Location (AVL) and Site Registration operations currently under consideration by land users for vehicle monitoring and location identification.

- o Launch, In-Flight/Orbit and re-entry phases of space navigation.

Navigational and positional location requirements for each major system, user class, and phase of operation are established in Volume II.

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 performance 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

RADIONAVIGATION 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 BACKGROUND

Primary source documents for Navigation Policy are:

The DOT National Plan for Navigation (NPN), originally published in 1970, established policy based on existing statutes, executive orders, directives and use. Later editions of the NPN, issued in April 1972 and November 1977, included some policy revisions.

The DOD Radionavigation Policy is contained in the 1978 edition of the Joint Chiefs of Staff - Master Navigation Plan (MNP).

2.2 NATIONAL RADIONAVIGATION POLICY

The following statements specify United States radionavigation policy to:

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 unnecessary 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 environmental 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 social 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 Federal systems.

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

J. Establish, maintain, and disseminate signal characteristics for common-user (civil and military) systems.

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

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

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 NAVSTAR GPS continuously available on an international basis for civil and commercial use at the highest level of accuracy consistent with national security interests. It is presently projected that an accuracy of 200M Circular Error Probable (CEP) (500M 2 drms) will be made available during the first year of full NAVSTAR GPS operation with accuracy available to civil users improving as time passes. (See Volume III, Chapter 2, Paragraph 2.2.1.)

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 with emphasis on the highest level of standardization.)

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 management 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 vehicle, 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 performance requirements are met in a cost-effective manner.

C. Maintain liaison with 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.

The Defense Mapping Agency (DMA) is responsible for military mapping, charting, and geodesy aspects of navigation, including geodetic surveys, accuracy determination, and positioning. DMA also serves as a focal point within the DOD for civil and other government agencies' interests in NAVSTAR GPS for geodesy purposes. 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 administrative 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 Master Navigation Plan (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.

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 Military Departments/Service Staffs; the Positioning/Navigation Executive Committee; and the Positioning/Navigation (POS/NAV) Working Group. Brief descriptions are provided below.

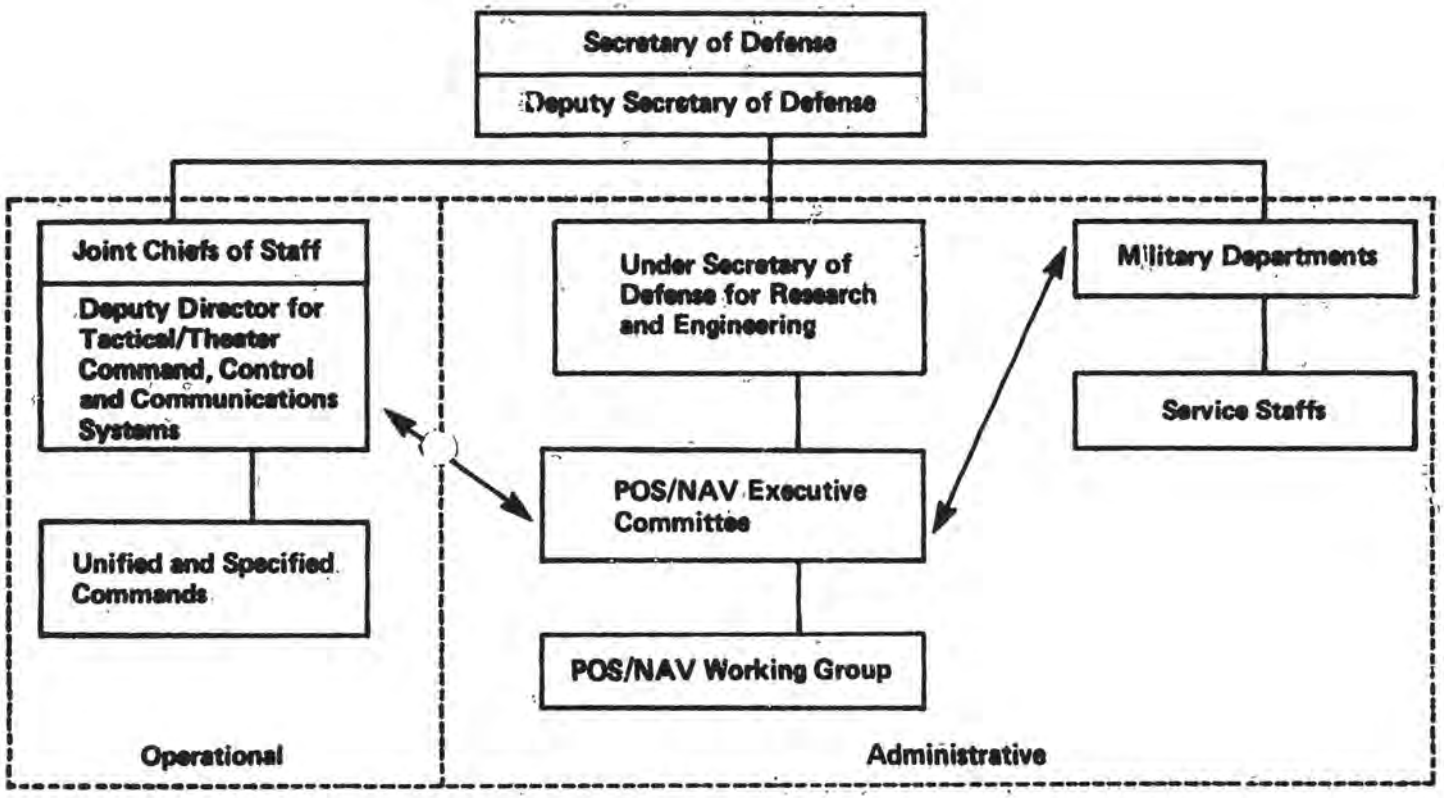


FIGURE I-3.1 DOD Navigation Structure

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 economics 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 phaseout of systems of questionable need.

The Positioning/Navigation (POS/NAV) Working Group provides a forum for the identification and resolution of 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.

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 Department of Commerce (DOC) and the National Aeronautics and Space Administration (NASA) participate in the development of DOT radionavigation plans. The roles of the participating agencies are described below.

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 responsibilities regarding the provision of aids to navigation: the U.S. Coast Guard, the Federal Aviation Administration (FAA) and the Saint 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 or of 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; or (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 St. Lawrence Seaway Development Corp. (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.

The Department of Commerce, through its jurisdiction over the National Oceanic and Atmospheric Administration, provides charts and related information for the safe navigation of marine and air commerce. The DOC is authorized to conduct hydrographic and topographical surveys, tide and current observations, and field surveys for aeronautical charts. The DOC is also authorized under 15 U.S.C. 272 to undertake research on the propagation of radio waves. This includes the study of propagation factors affecting the accuracy of radionavigation systems. The DOC through its jurisdiction over the United States Maritime Administration (MARAD),

is charged with promotion of the interests of a U.S. merchant marine composed of the best-equipped, safest, and most suitable types of vessels, constructed in the U.S., and manned with a trained and efficient citizen personnel. As part of this effort, MARAD investigates position determination using existing and planned communications satellites, 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 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 the DOT, and help to assure the most efficient implementation of those policies and plans without decreasing the responsibility or usurping the authority of the individual operating elements.

B. Provide a body which can, on a continuing basis, facilitate coordinated navigational planning on a multimodal basis within the 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 decisionmaking 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.

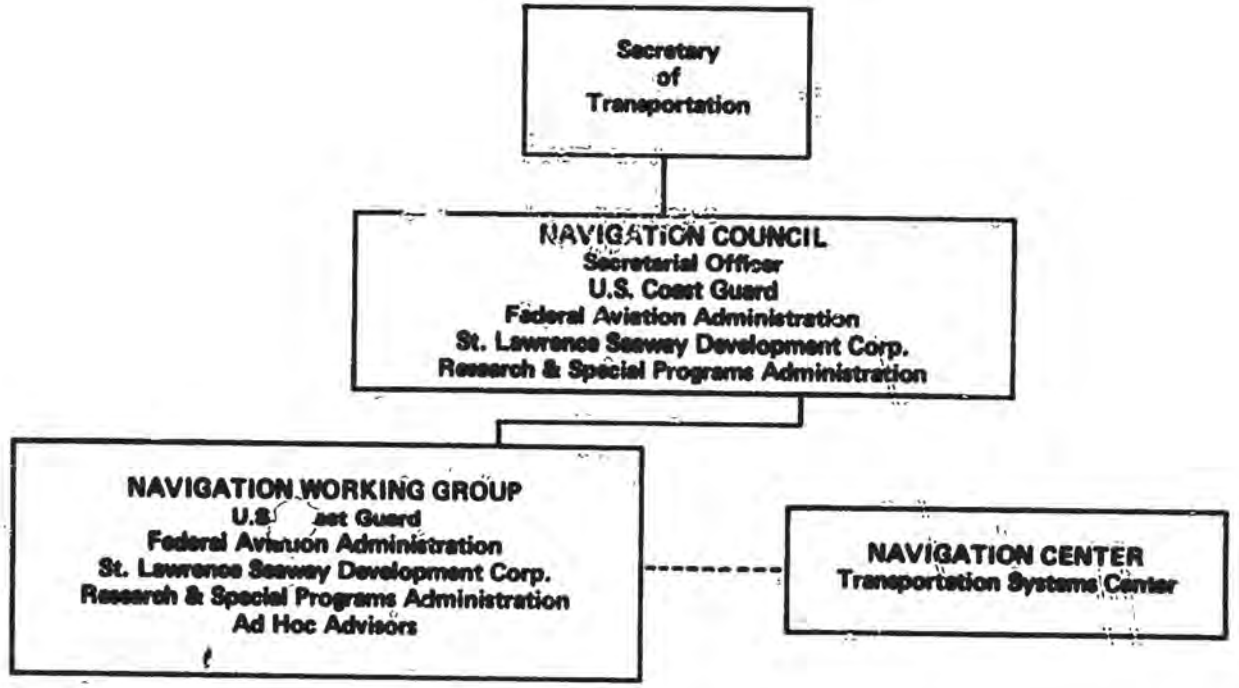


FIGURE I-3.2 DOT Navigation Structure

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, 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:

- o Serves as the focal point to formulate coordinated policy recommendations to the Secretary;
- 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, 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 the DOD, the DOC, the NASA, and other Federal Agencies, as required; and
- o Multimodal navigational issues with other governmental agencies, industry, and user groups, as directed by the Navigation Council.

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 (described in 3.1 and 3.2). 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 the 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 insure 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. Pursue the preparation of 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 action plans. These plans will be reviewed and updated annually as part of the agencies' normal budget process.

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: the efforts needed to maintain existing systems in a satisfactory operational configuration, the development needed to improve their present performance or to satisfy existing unsatisfied requirements in the near term, and 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 satisfies completely all the needs of military missions nor provides highly accurate, three-dimensional, worldwide navigation capability. NAVSTAR GPS is being developed to satisfy 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 the present systems do not satisfy. Thus, it could ultimately become the primary worldwide system for military and civil navigation and position location.

4.1 EXISTING NAVIGATION REQUIREMENTS

It is accepted generally 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. Because 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. Table I-4.1 also shows 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 Table I-4.1 as primary system (P), secondary or supplementary systems (S), or a system under development or evaluation (E). These classifications are:

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

***All US LORAN-A service is being terminated no later than December 31, 1980

TABLE I-4.1 Radionavigation System Applications

A. "P" indicates a system 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 are directed toward improving an existing service or enhancing system performance.

B. "S" indicates sytems 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 combinations 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. LORAN-A has been the most widely used system, but is now being phased out. The system which has been certified to replace LORAN-A at this time is OMEGA. It is expected that at least three lines of position should be available throughout the North Atlantic and Pacific. Although the FAA has approved the use of OMEGA on the North Atlantic oceanic route, at present, the International Civil Aviation Organization (ICAO) does not plan to adopt OMEGA as an international standard. ICAO has, however, provided users desiring to use 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 route and terminal navigation for flights conducted under Instrument

MISSION	SYSTEM							
	GPS	LORAN-C	OMEGA	TACAN	TRANSIT	VOR	RADIOBEACONS	MLS/ILS
ENROUTE								
Strategic Attack	E							
Strategic Defense	E							
Counter Air	E							
Defense Suppression	E							
Close Air Support	E	P						
Interdiction	E	P						
Special Operations	E	P		P		S		
Collateral Missions	E		P					
Airlift	E	P		P		S	P	
Space Transportation	E							
Aerial Refueling	E			P		S		
Reconnaissance, Intelligence Assets	E	P						
TERMINAL								
Strategic Attack	E					S		P
Strategic Defense	E			P		S		P
Counter Air	E			P		S		P
Defense Suppression	E			P		S		P
Close Air Support	E			P		S		P
Interdiction	E			P		S		P
Special Operations	E			P		S		P
Collateral Missions	E			P		S		P
Airlift	E			P		S		P
Space Transportation	E							
Aerial Refueling	E			P		S		P
Reconnaissance, Intelligence Assets	E			P		S		P
Command, Control and Communication Assets	E			P		S		P

LEGEND

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

*Special purpose systems are not reflected in this table.

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

MISSION	SYSTEM							
	GPS	LORAN-C	OMEGA	TACAN	TRANSIT	VOR/DME	RADIO-BEACONS	MLS/ILS
General Aerial Navigation	E			P		P	P	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							
Aircraft Approach	E			S		S	S	P
Position Location of Aerial/Ground Sensors	E			S		P	S	E
Position Location of SIGINT/COMINT/DF Systems	E			P				
Position Location of COMINT Collection Systems	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*

MISSION	SYSTEM							
	GPS	LORAN-C	OMEGA	TACAN	TRANSIT	VOR/DME	RADIOBEACONS	MLS/ILS
Enroute, General Purpose								
Ship	E		S		P			
Submarine	E	P	S		P			
Air (MPA/TAC)	E	S	P	P		S	S	S
Search & Rescue								
Ship	E		S		S			
Air				P				
Mine Countermeasures								
Ship	E		S		S	S		
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

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*

MISSION	SYSTEM							
	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*

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. In consequence, it is expected that the ICAO will vote to extend service to 1995. The U.S. Government is expected to support this action, because of the widespread, long, and satisfactory use of this system, the investment in avionics and ground equipment of about $700 million, and technical expertise and the recent substantial investment of other nations, particularly third world nations.

General use area navigational routes (RNAV) have been implemented throughout the high altitude en route and for non-precision approaches. In addition, RNAV routes have been established to meet special user requirements. Area navigation 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), non-directional beacons (NDB), and RNAV procedures. The requirement for a common civil/military system is not yet met. The Microwave Landing System (MLS) now under development could meet the need for a common user system. The MLS can provide lateral and vertical guidance over wide sectors and precise distance information.

4.2.3 Ocean Phase of Marine Navigation

Navigation on the high seas is now done by the use of celestial fixes, LORAN-A, LORAN-C, and OMEGA. TRANSIT is available for use, but user equipment costs and fix interval limitations have deterred widespread use of the system.

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

4.2.4 Coastal Phase of Marine Navigation

Requirements for operation within the coastal area are not 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 will be fully implemented in 1980. LORAN-A is being phased out on a regional basis according to the schedule described in Volume III.

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 (RDFs) 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 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 research, development, and demonstration projects have been sponsored. Also, there is nothing to prevent a prospective user from taking advantage of an operating navigational system.

The practicability of using radiolocation systems for land operations is being evaluated by a number of State and municipal governments and by municipal transportation entities. Demonstrations of automatic vehicle monitoring (AVM), automatic vehicle location (AVL), location identification, emergency services coordination (dispatch), personnel protection, environmental situation monitoring, and resources protection are planned.

State and local governments supply most of the raw geographic, demographic, agricultural, and industrial data required by the Federal government for planning and management purposes. In some instances these data are only roughly correlated as to geographic location. Some Federal agencies have related problems in determining political boundaries, particularly in rural areas. Efforts are underway to systematize and correlate geographic data base files with respect to a common coordinate frame of reference. This includes use of the Department of Commerce, Bureau of the Census Geographic Base File/Dual Independent Map Encoding (GBF/DIME) file.

Land location has tentatively been broken down into two phases:

1) Site Registration: Recording the location of a place or event for record purposes or to return to it at a later time.

2) Automatic Vehicle Monitoring (AVM) or Location (AVL): The tracking of land vehicles by measuring radionavigation or location signals in the vehicle and transmitting the results of that measurement to a central facility for display.

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. All U.S.-operated LORAN-A stations are scheduled to cease operations by the end of 1980. The plan for LORAN-A is shown in Figure I-4.1.

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 is nearly complete. The planned coverage by 1980 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-4.2.

When the Great Lakes chain reaches full operational status in early 1980, it will, for the first time, provide a high accuracy navigational capability for the open waters of the Great Lakes.

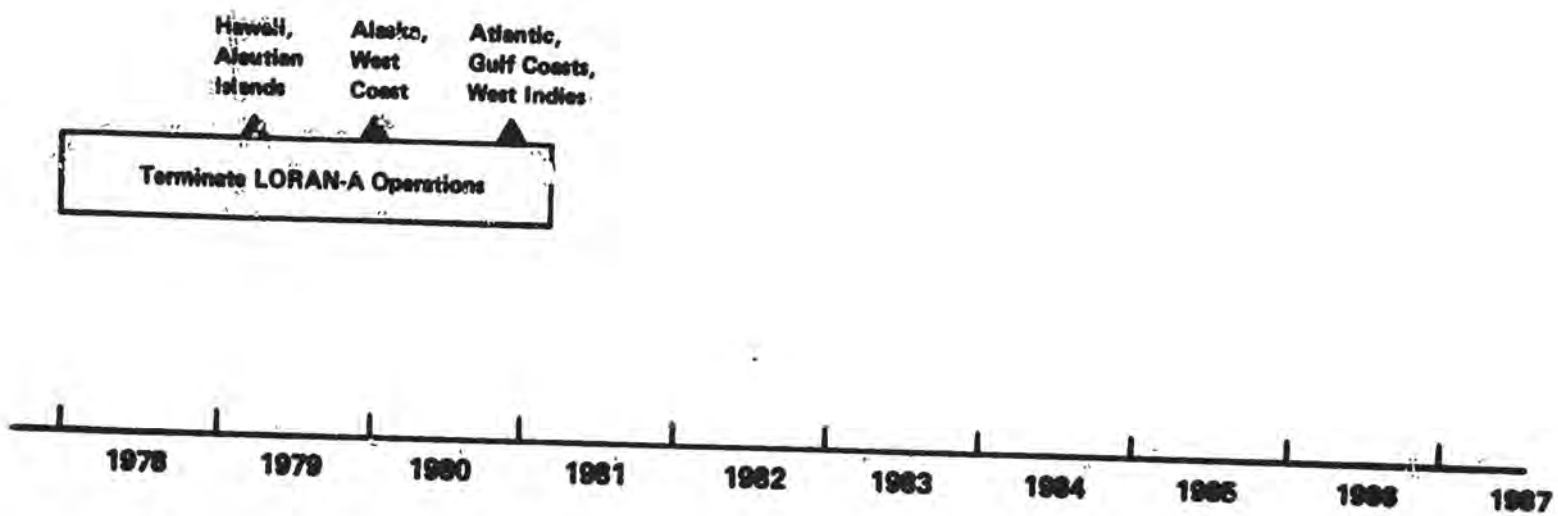


FIGURE I-4.1 Operating Plan for LORAN-A System

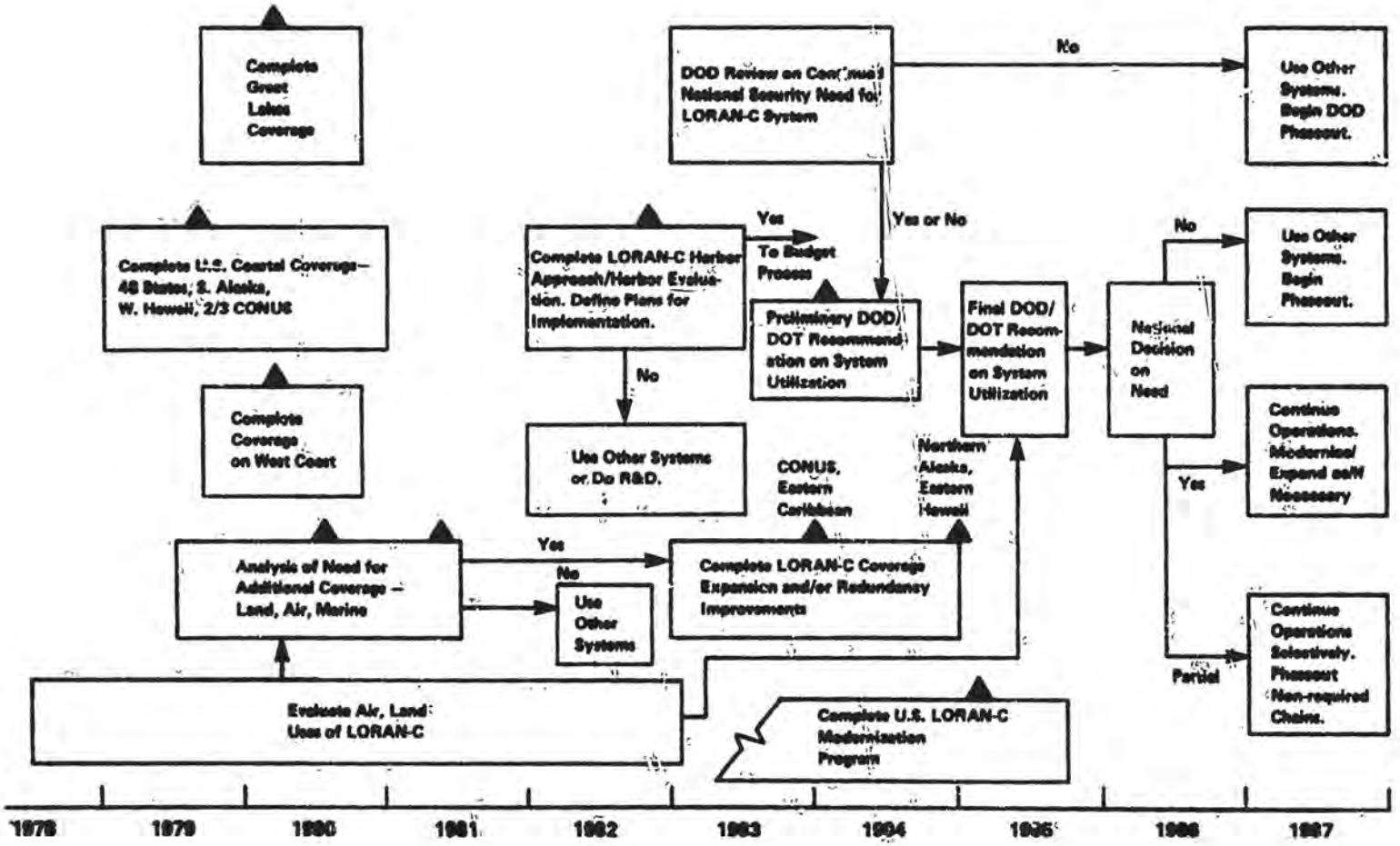


FIGURE I-4.2 Operating Plan for LORAN-C System

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. User expansion could be accelerated further by new classes of users, especially for land applications, and the decreasing cost of user equipment. 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 will be 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 will close coverage gaps in the areas of Dixon Entrance and Puget Sound. In the U.S.S.R. there two LORAN-C chains operating; one in the southwestern part of Russia, the 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, Puerto Rico, the U.S. Virgin Islands and the North Slope of Alaska is under study. Depending on the results of this study, LORAN-C service may be expanded in these areas.

When the LORAN-C system becomes fully operational in early 1980, its signals will cover not only U.S. coastal areas and other waterways, but also about two-thirds of the land area of the coterminous 48 states. As a consequence, it is anticipated that LORAN-C will be used increasingly to provide position location information on land. To extend the coverage for this purpose to the entire coterminous 48 states will require three to five additional stations in the midcontinent.

SYSTEM: LORAN-C; (DOD Total)

DESCRIPTION: LORAN-C is a LF hyperbolic radionavigation system. The receiver computes lines of position based on time of arrival differences between two transmitters of a chain. The first chain was located along the U.S. coast in 1960. The Coast Guard will operate 12 chains throughout the world by 1980.

CHARACTERISTICS:

ACCURACY[1]			AVAILABILITY	COVERAGE	REL	FIX RATE	FIX DIM	CAPACITY	AMBIGUITY POTENTIAL
PREDICTABLE	REPEATABLE	RELATIVE							
450m	18-90m	18-90m	99+%	US Coastal, 2/3 CONUS, Selected Overseas Areas	99+%	25 Fixes per Second	2D	Unlimited	Easily Resolved

SCHEDULE:

	1980					1985				1990				1995							2000
PHASE IN/OUT:																					
DECISION PTS:						Reconsider Use															
NUMBER OF USERS:	1,008	1,028	1,120	1,127	1,136	1,136	1,122	1,004	880	752	699	336	176	67	67	67	67	67	67	67	67
EQUIP PURCH: USER SETS:																					
EQUIP PURCH: GND STA:																					

1. 2 drms

TABLE I-4.6 - LORAN-C System Characteristics and User Schedule

SYSTEM: LORAN-C (Civil User Totals)

DESCRIPTION: LORAN-C is a LF hyperbolic radionavigation system. The receiver computes lines of position based on time of arrival differences between two transmitters of a chain. The first chain was located along the U.S. coast in 1960. The Coast Guard will operate 12 chains throughout the world by 1980.

CHARACTERISTICS:

ACCURACY[1]			AVAILABILITY	COVERAGE	REL	FIX RATE	FIX DIM	CAPACITY	AMBIGUITY POTENTIAL
PREDICTABLE	REPEATABLE	RELATIVE							
460m	18-90m	18-90m	99+%	US Coastal, 2/3 CONUS Selected Overseas Areas	99+%	25 Fixes per Second	2D	Unlimited	Easily Resolved

		79	80	81	82	83	84	85
CIVIL USERS	AIR[2]	300	450	525	600	700	850	1000
	MARINE	32,600	44,900	54,000	57,900	62,000	66,500	71,500

(1) 2 drms
(2) Only CG Planes and Offshore Users

TABLE I-4.6 (Cont.) LORAN-C System Characteristics and User Schedule

The number of stations may have to be further 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. When NAVSTAR GPS becomes operational, military use of LORAN-C is expected to phase down. Army phaseout of LORAN-C will be completed by 1991, and Air Force phaseout will be completed by 1992. Navy users will continue to operate LORAN-C receivers as long as the system is available; however, Navy use of LORAN-C will be re-evaluated at the time of NAVSTAR GPS phasein.

4.3.3 OMEGA

The OMEGA system has been developed and is being 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. The purpose of OMEGA is to provide an all-weather, nearly 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. A temporary station is located in Trinidad. 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 (Trinidad transmits at 1 kw). Figure I-4.3 outlines the operating plan for the OMEGA system.

The Coast Guard operates the two stations located in the U.S., and contracts the operation of the stations in Liberia and Trinidad, subject to reimbursement by the U.S. Navy. The remaining stations are operated by the partner nations with varying degrees of technical and logistic support from the U.S. Coast Guard.

The temporary station located at Trinidad in the West Indies is planned to continue operation until the Australian station becomes available in late 1980.

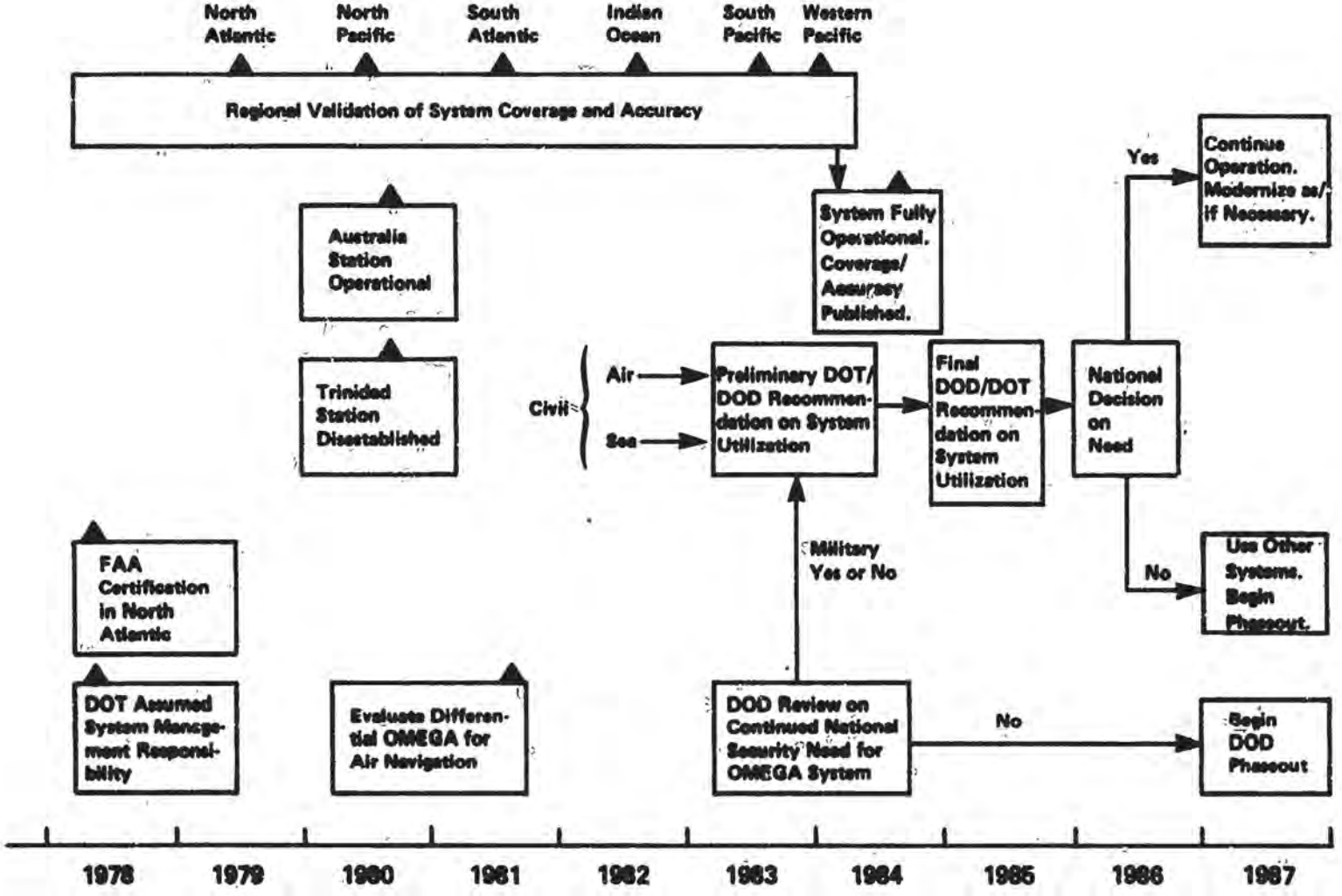


FIGURE I-4.3 Operating Plan for OMEGA System

B. User Community

In addition to the DOD air and marine users, some 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 oceanic 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 some aircraft operating in oceanic 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 late 1980. 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 until the eighth station is in operation and accuracy and coverage can be measured and validated. This is expected to take place sometime in 1983. 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.

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 ambiguity, and provide positive station identification, has been implemented.

Differential OMEGA, which is still in the developmental stage, 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.

SYSTEM: OMEGA (DOD Total)

DESCRIPTION: The OMEGA Navigation System is a VLF hyperbolic radionavigation system capable of use by ships, submarines, aircraft and units on land. The system has eight transmitting stations ~ 5000 miles apart. Position information is obtained by measuring relative phase of received signals.

CHARACTERISTICS:

ACCURACY[1]			AVAILABILITY	COVERAGE	REL	FIX RATE	FIX DIM	CAPACITY	AMBIGUITY POTENTIAL
PREDICTABLE	REPEATABLE	RELATIVE							
3.7-7.4km	3.7-7.4km	1.85-3.7km	99%	Near Global (over 99%)	99%	One FIX in 10 Seconds	2D	Unlimited	Requires Position Knowledge within 36NM[2]

SCHEDULE:

	1980						1985					1990					1995					2000
PHASE IN/OUT:																						
DECISION PTS:							Review															
NUMBER OF USERS:	1,434	1,823	1,830	1,864	1,877	1,883	1,881	1,575	1,466	1,300	1,200	1,140	1,038	894	879	860	860	860	860	860	860	860
BOMP AIR	28	28	28	28	34	32	0															
PURCH SHIP/SUBS	4	4	4	4	4	4	4	0														

1. 2 drms
2. Assumes a three frequency receiver

TABLE I-4.7 OMEGA System Characteristics and User Schedule

SYSTEM: OMEGA (Civil User Totals)

DESCRIPTION: The OMEGA Navigation System is a VLF hyperbolic radionavigation system capable of use by ships, submarines, aircraft and units on land. The system has eight transmitting stations ~ 5000 miles apart. Position information is obtained by measuring relative phase of received signals.

CHARACTERISTICS:

ACCURACY[1]			AVAILABILITY	COVERAGE	REL	FIX RATE	FIX DIM	CAPACITY	AMBIGUITY POTENTIAL
PREDICTABLE	REPEATABLE	RELATIVE							
3.7-7.4km	3.7-7.4km	1.85-3.7km	99%	Near Global (over 90%)	99%	One FIX in 10 Seconds	2D	Unlimited	Requires Position Knowledge within 36 NM[2]

		79	80	81	82	83	84	85
CIVIL USER	(AIR)[3]	730	740	760	780	790	800	820
	MARINE (X000)	3.3	4	4.4	4.9	5	5.2	5.5

1. 2 drms
2. Assumes a three frequency receiver
3. Only oceanic users

TABLE I-4.7 (Cont.) OMEGA System Characteristics and User Schedule

The DOD has adopted OMEGA as an en route navigational system for aircraft and ships, replacing LORAN-A. The development of low-cost, combined LORAN-C/OMEGA receivers should also enhance use of the system.

The FAA plans to investigate the use of Differential OMEGA as a potential navigation system for aircraft operating in remote areas, primarily in Alaska. Some countries are also considering the use of 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 in 1991 and by the Air Force in 1992. The Navy will use OMEGA as a backup to NAVSTAR GPS for certain of its vessels and aircraft, but plans to re-evaluate its use at the time of the NAVSTAR GPS phasein.

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 Federal Aviation Administration operates approximately 770 VOR/DME and VORTAC stations and 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. These are available to all users. The operating plan for VOR/DME/VORTAC is shown in Figure I-4.4.

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 started a replacement program during Fiscal Year 1978.

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 aircraft and military aircraft operating in U.S. airspace. The projected civil and military user population is shown in Table I-4.8.

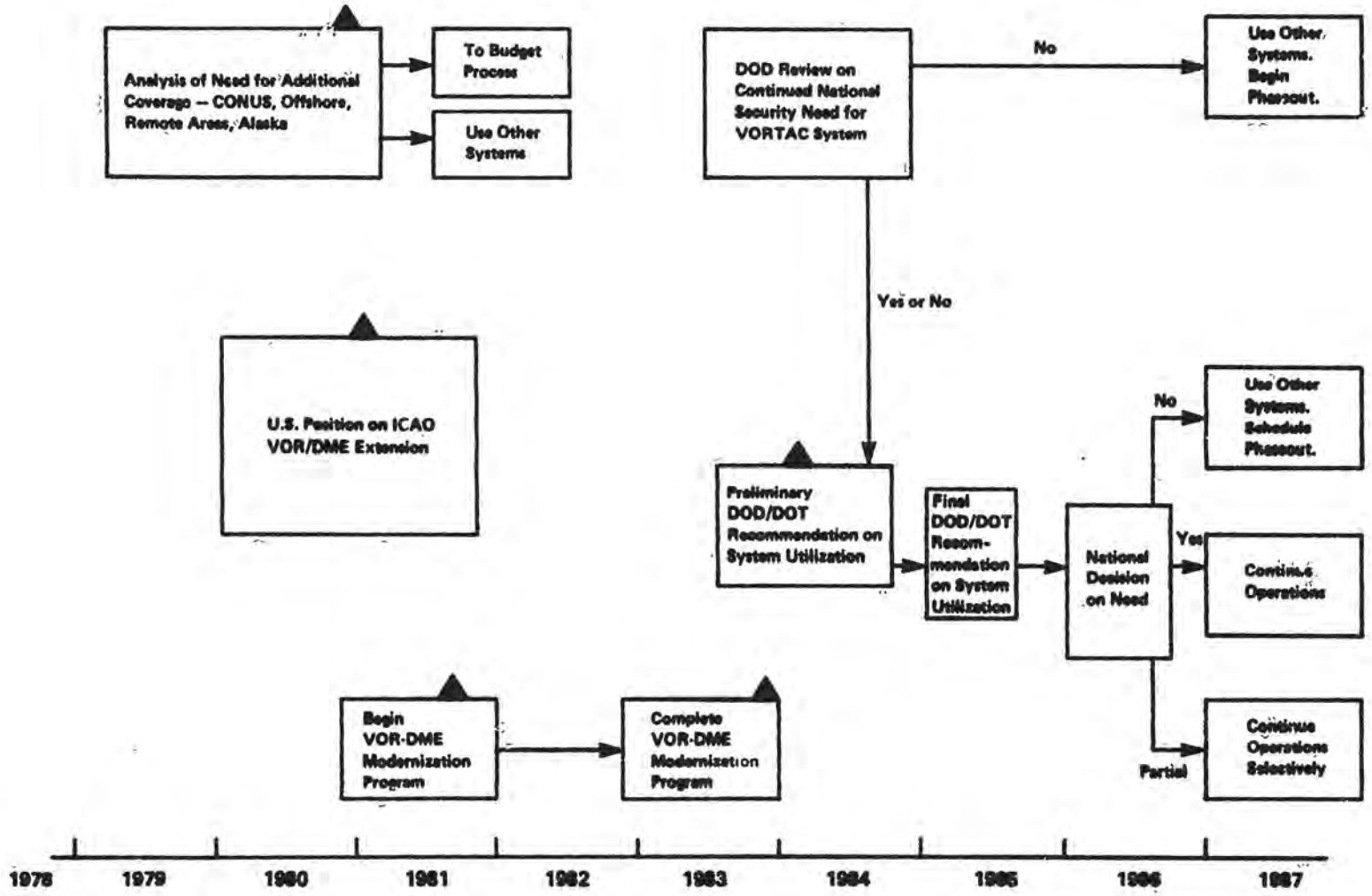


FIGURE I-4.4 Operating Plan for VOR, VOR/DME, VORTAC System

SYSTEM: VOR, VOR/DME (DOD Total)

DESCRIPTION: VOR provides aircraft with bearing information relative to the VOR signal and magnetic north. Used for landing, terminal and enroute guidance. VOR transmitter operates in the VHF. DME provides a measurement of distance from the aircraft to the DME ground station. DME operates in the UHF.

CHARACTERISTICS:

	ACCURACY[1]			AVAILABILITY	COVERAGE	REL	FIX RATE	FIX DIM	CAPACITY	AMBIGUITY POTENTIAL
	PREDICTABLE	REPEATABLE	RELATIVE							
VOR	30m ($\pm 1.4^{o}$)[2]	23-292m ($\pm .35^{o}$)[2]	23-292m ($\pm .35^{o}$)[2]	Approaches 100%	Line of Sight	Approx. 100%	Continuous	Heading or Angle Off Course	Unlimited	None
DME	185m (±0.1nm)	185m (±0.1nm)	185m (±0.1nm)	"	"	"	"	N.M. (slant range)	~100 users per site	"

SCHEDULE:

	1980						1985			1990				1995							2000
PHASE IN/OUT:																					
DECISION PTS:							Review														
NUMBER OF USERS:	11,186	11,636	11,786	11,879	11,983	12,049	11,161	9,451	7,883	6,501	5,306	4,028	3,229	2,636	1,928	1,236	629				
EQUIP / USER SETS:																					
PURCH / GND STA:																					

1. 2 drms
2. 2NM from the transmitter, 2 Sigma

TABLE I-4.8 VOR, VOR/DME System Characteristics and User Schedule

SYSTEM: VOR, VOR/DME (Civil User Totals)

DESCRIPTION: VOR provides aircraft with bearing information relative to the VOR signal and magnetic north. Used for landing, terminal and enroute guidance. VOR transmitter operates in the VHF. DME provides a measurement of distance from the aircraft to the DME ground station. DME operates in the UHF.

CHARACTERISTICS:

	ACCURACY[1]			AVAILABILITY	COVERAGE	REL	FIX RATE	FIX DIM	CAPACITY	AMBIGUITY POTENTIAL
	PREDICTABLE	REPEATABLE	RELATIVE							
VOR	30m ($\pm 1.4°$)[2]	23-300m ($\pm .1°$)[2]	23-300m ($\pm .35°$)[2]	Approaches 100%	Line of Sight	Approx. 100%	Continuous	Heading Angle Off Course	Unlimited	None
DME	185m (± 0.1nm)	185m (± 0.1nm)	185m (± 0.1nm)	"	"	"	"	N.M. (slant range)	~100 users per site	"

		79	80	81	82	83	84	85
CIVIL USER (AIR)	VOR (X850)	168.5	165	176	182	185	189	195
	DME (X880)	54.3	57.3	61	64	65.3	67.5	70.2
	RNAV (X880)	9.6	10.1	10.7	11.3	11.3	11.6	12
TOTAL USER POPULATION		222.4	233	247.7	257.1	261.6	269.1	278.3
NUMBER OF EQUIPMENTS IN SERVICE	VOR (X880)	268.2	278	288	302	312	330.5	338.8
	DME (X880)	59.6	62.9	67	70.1	72	74.5	78
	RNAV (X880)	9.6	10.1	10.7	11.1	11.3	11.6	12
GOVT. STATION	VOR	927	927	927	927	927	927	927
	DME	847	847	847	847	847	847	847

1. 2 sigma
2. 2000 from the transmitter, 2 Sigma

TABLE I-4.8 (Cont.) VOR, VOR/DME System Characteristics and User Schedule

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 well liked by pilots. Because it forms the basis for defining the airways, its use is an integral part of the air traffic control procedures.

VOR/DME is currently protected by international agreements until 1985. The FAA expects that the protection date will be extended to 1995 and is inclined to support that extension for the following reasons:

1) A large international investment for both VOR/DME ground equipment and avionics currently exists. Adequate time must be allowed to amortize that investment.

2) Adequate time must be allowed to develop rules, regulations, procedures and equipment related to any new system. Given that NAVSTAR GPS will not be fully operational until 1987, caution dictates that the existing system be maintained operationally until at least 1995.

Any attempt to replace VOR/DME with an alternate system would require approval by the various international ICAO bodies and by the member states. The process for such approval is estimated to take 2 or 3 years minimum, and most likely at least 5 years for an issue as complex as NAVSTAR GPS. Once a replacement is chosen, an overlap must be provided between the new system and the old system. ICAO, for the reason noted above, is anticipated to favor a reasonably long overlap. In the case of MLS/ILS, for example, ILS is protected to at least 1995.

Given the above considerations, it is realistic to assume that VOR/DME must be operated to at least 1995.

DMEs are also increasingly being used in conjunction with the Instrument Landing System (ILS, paragraph 4.3.6) to furnish continuous ranging information throughout the approach and landing phase. DMEs are also presently being used where marker beacons are not practical. In addition, a compatible precision DME (PDME) is expected to be employed in conjunction with the Microwave Landing System (MLS, paragraph 4.4.1) to aid the flare maneuver associated with CAT III landing. These factors increase the probability that the DME system will be employed domestically and internationally well past 1995.

Since the VOR/DME system operates at frequencies which are limited to line-of-sight coverage, signals are not receivable in areas where terrain such as mountains intervenes between the aircraft and the transmitting sites. As a practical matter the system is not noise-limited and the line-of-sight limitation is ameliorated by overlapping or near-overlapping coverage in many areas.

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 has been certified as a supplement to VOR/DME. LORAN-C certification is expected for coastal, low altitude and remote area navigation.

VOR/DME is expected to be in service at least until 1995. Under international (ICAO) agreement the system is protected through January 1, 1985. There is a strong possibility that the lesser-developed countries which are beginning to implement VOR/DME as part of their Air Traffic Control systems and the countries where VOR/DME is the existing radionavigation system will press for and gain an extension of the ICAO VOR/DME protection date to 1995. Also, even 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 1980s or early 1990s. It would require a substantial period beyond that before economic 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 1986. Phaseout of VOR/DME will be completed by the Navy in 1990 and by the Air Force in 1995 (assuming NAVSTAR GPS or other suitable alternatives are identified). Re-evaluation of the need for Army use of VOR/DME will be accomplished at the time of the NAVSTAR GPS phasein. 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 using military equipment to operate in civil airspace.

A. Operating Plan

The DOD presently operates approximately 140 ground and 200 ship-board TACAN beacons. Present TACAN coverage ashore will be maintained until phased out in favor of NAVSTAR GPS. However, NAVSTAR GPS alone 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-4.5.

B. User Community

There are presently approximately 13,700 aircraft which are equipped to determine bearing and distance to TACAN beacons. These consist primarily of Navy, Air Force, and to a lesser extent, Army aircraft. The prospective civil and military user populations are shown in Table I-4.9. Additionally, NATO military services use TACAN extensively.

C. Acceptance and Utilization

TACAN is used by DOD and NATO aircraft operating under IFR (Instrument Flight Rules) ashore and IFR and VFR (Visual Flight Rules) for tactical and en route navigation afloat. Since TACAN provides good accuracy in range and azimuth and is easy to use, it is generally well accepted by civil and military pilots.

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

All fixed DOD TACAN systems will be phased out commencing in 1985 and will be completed by 1995. 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 function, both ashore and afloat. The decision on afloat replacement of the TACAN function will be made at the time of NAVSTAR GPS phasein.

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.

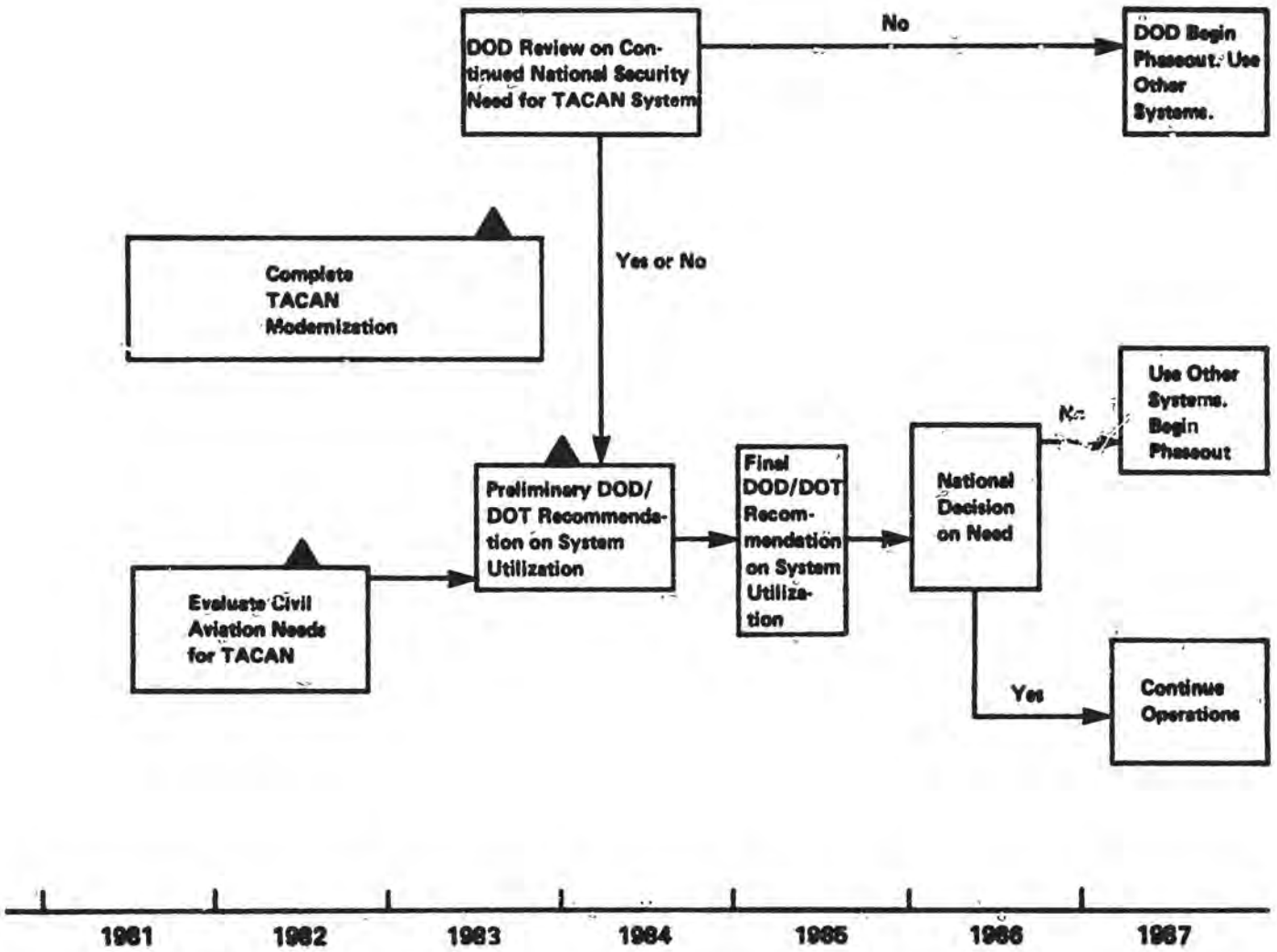


FIGURE I-4.5 Operating Plan for TACAN System

SYSTEM: TACAN (DOD Total)

DESCRIPTION: TACAN is a short range navigation system used primarily by the military. The system provides range, bearing and station identification. TACAN operates in the UHF band. When a TACAN transmitter is colocated with VOR it is denoted VORTAC – 15 such sites exist.

CHARACTERISTICS:

ACCURACY[1]			AVAILABILITY	COVERAGE	REL	FIX RATE	FIX DIM	CAPACITY	AMBIGUITY POTENTIAL
PREDICTABLE	REPEATABLE	RELATIVE							
63m ($\pm 1.0^0$)[2,3]	63m ($\pm 1.0^0$)[2,3]	63m ($\pm 1.0^0$)[2,3]	Approaches 100%	Line of Sight	~100%	Continuous	Heading or Angle Off Course	~300 users per site	Slight
See Table I-4.8 For DME characteristics									

SCHEDULE:

	1980						1985				1990				1995						2000
PHASE IN/OUT:																					
DECISION PTS:							Review														
NUMBER OF USERS:	12,672	12,791	13,043	12,986	12,981	13,031	11,744	9,920	8,086	6,272	5,440	2,834	2,000	1,000	1,000	500	0				
EQUIP USER SETS:	172	986	733	276	280	230	0														
PURCH GND STA.:	83	114	101	88	81	11	12	0													

1. 2 drms
2. 20NM from the transmitter
3. 2 Sigma

TABLE I-4.9 TACAN System Characteristics and User Schedule

A. Operating Plan

The FAA, as of March 1979, operates 581 full ILS facilities, each providing aircraft with vertical and horizontal guidance to the runway. The FAA also operates 54 localizer-only sites. Sixty-one additional civil facilities are non-FAA-operated for a total of 696 commissioned civil systems. By 1982 the number of ILS sites will reach 998. eighty-four of these will be capable of permitting automatic landings under low weather minimums. In addition, there are 93 ILS facilities operated by the DOD in the U.S. The operating plan is shown in Figure 4.6.

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 extensively 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 population is shown in Table I-4.10.

C. Acceptance and Utilization

ILS is the standard civil landing system in the U.S. and internationally for aircraft operating under IFR conditions. Since its introduction in the 1940s, 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. Special systems are used to meet unique military requirements, including ship-board operations.

D. User Base Expansion

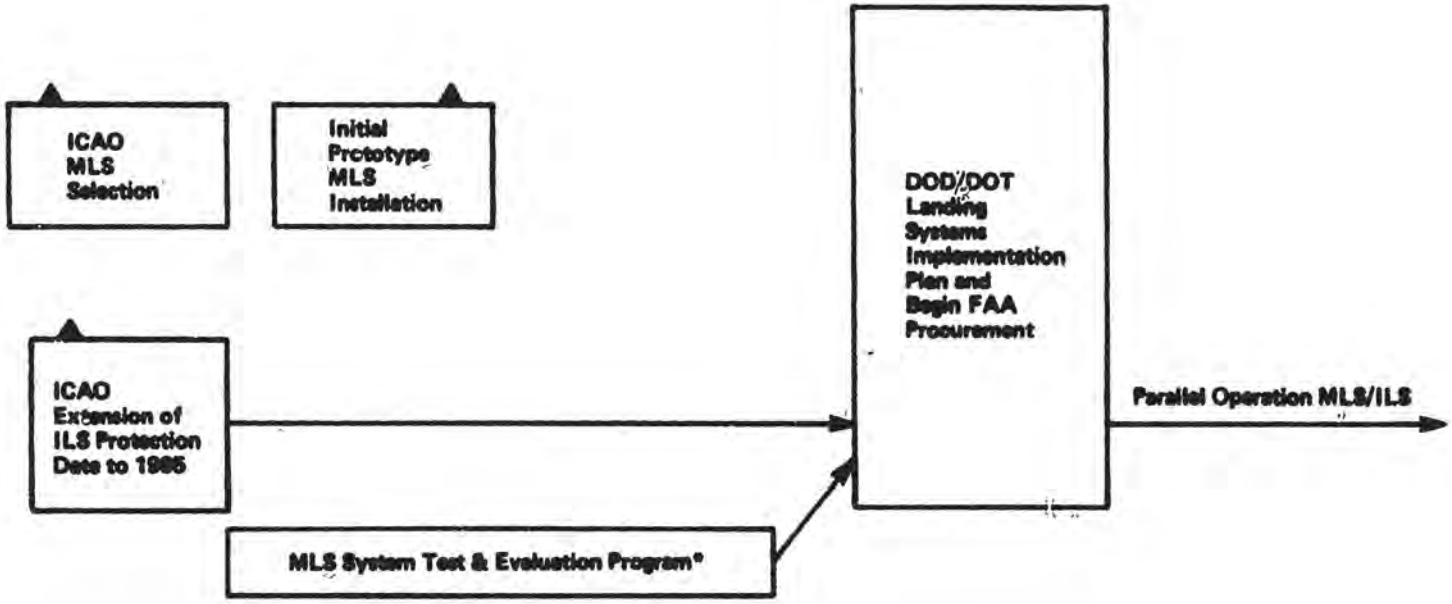
A 1976 estimate is that the ILS user base consists of approxiately 2,600 air carrier and 47,000 general aviation aircraft. While no detailed estimate is available for the user base growth rate, all air carrier aircraft added to the fleet will be ILS equipped and the growth rate for general aviation aircraft is expected to approximate the same as the overall general aviation growth rate of approximately 7% per year.

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:



* Refinement of operational, technical and support concepts which use the unique attributes of MLS to optimize user benefits and minimize costs.

FIGURE I-4.6 Operating Plan for Microwave/Instrument Landing Systems (MLS/ILS)

SYSTEM: ILS (DOD Total)

DESCRIPTION: The Instrument Landing System (ILS) is a precision approach system consisting of a localizer facility, a glide scope facility, and two or three VHF marker beacons. The VHF (108-112 MHz) localizer facility provides accurate, single path horizontal guidance information. The UHF (328.6-335.4 MHz) glide slope provides precise, single path, vertical guidance information to a landing aircraft.

SCHEDULE:	1980			1985					1990					1995						2000	
PHASE IN/OUT:																					
DECISION PTS:																					
NUMBER OF USERS: (GND)	104	112	118	118	118	118	118	118	118	118	118	117	116	100	80	6	6	6	6	6	6	6
EQUIP PURCH USER SETS:																					
EQUIP PURCH XMTR STA:	46	23	20																		

NOTE: ILS user sets have dual VOR capability and have been counted on the VOR chart.

TABLE I-4.10 - Instrument Landing System (ILS) User Schedule - Military

SYSTEM: ILS (Civil User Totals)

DESCRIPTION: The Instrument Landing System (ILS) is a precision approach system consisting of a localizer facility, a glide scope facility, and two or three VHF marker beacons. The VHF (108-112 MHz) localizer facility provides accurate, single path horizontal guidance information. The UHF (328.6-335.4 MHz) glide slope provides precise, single path, vertical guidance information to a landing aircraft.

	79	80	81	82	83	84	85
No. of Civil Users	60.6	63.8	68	70.7	72.4	75	77.5
No. of Equipments in Service	72.7	76.5	81.5	85	87	90	93
Ground Stations	816	816	816	816	816	816	816

TABLE I-4.10 (Cont.) Instrument Landing System (ILS) User Schedule - Civil

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.

2) Since ILS provides only a single straight-line approach path, it constrains airport operations and limits flexibility in relation to provided 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 since ILSs in close proximity can cause mutual interference if adequate frequency separation is not available.

4.3.7 TRANSIT

The Navy Navigation Satellite System (NNSS), also referred to as TRANSIT, is a satellite-based positioning system which provides submarines and surface ships (civil and military) 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. Phaseout by military TRANSIT users in favor of NAVSTAR GPS will begin in 1986 and end in 1992.

There are presently five operational TRANSIT satellites (OSCAR). The Navy will maintain a minimum of four operational satellites on orbit. An improved satellite (NOVA) is under development and it is intended to change to a satellite constellation consisting of a minimum of two NOVA and two OSCAR satellites starting in 1980. The operating plan for TRANSIT is shown in Figure I-4.7.

B. User Community

There are presently about 270 military TRANSIT users. Foreign and domestic commercial vessel use of the TRANSIT system has far outpaced the DOD use. Present estimates are that about 4,000 sets are in commercial use. Determination of precise position (surveying) has recently become an important use of TRANSIT. The projected military user population is shown in Table I-4.11.

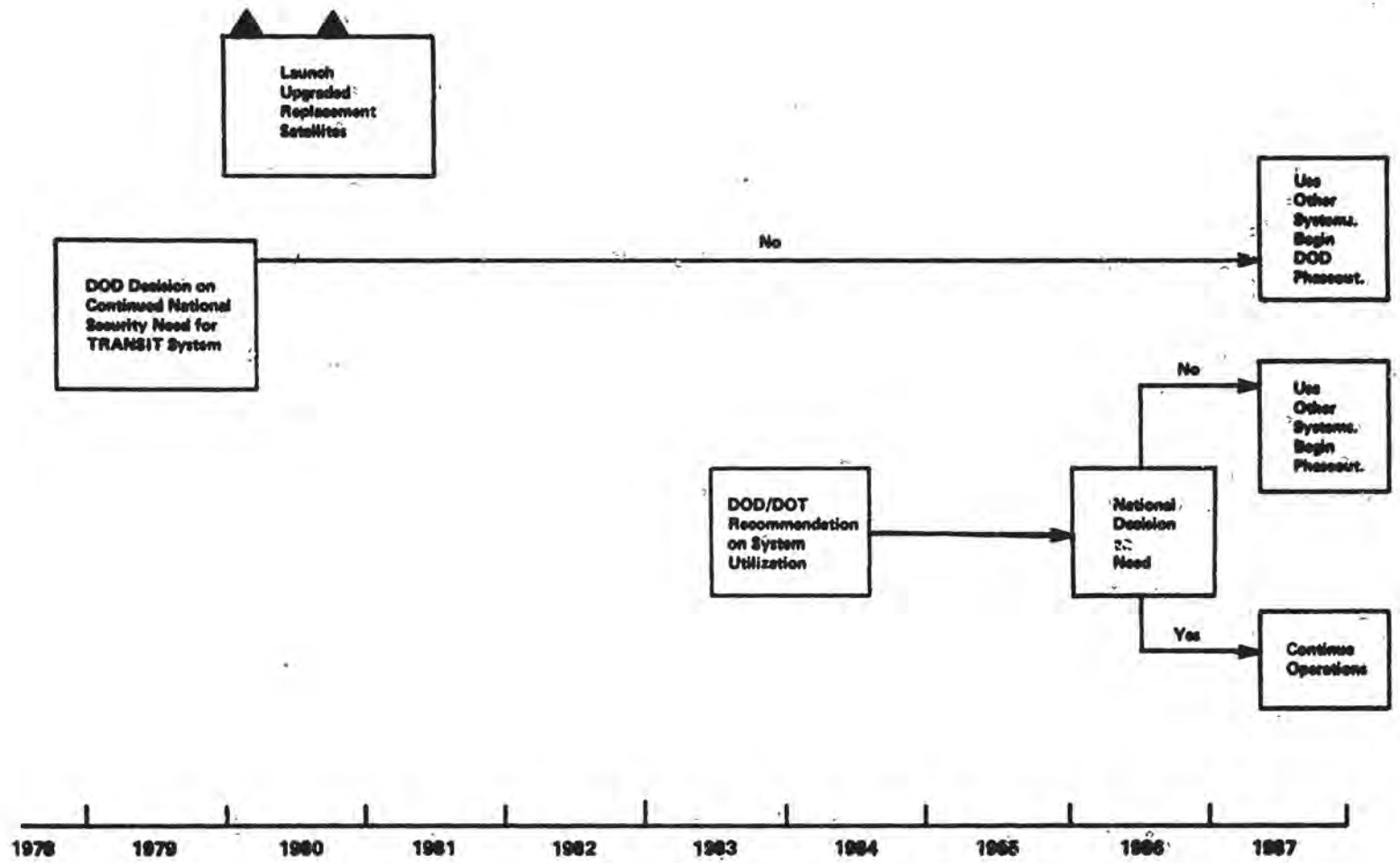


FIGURE I-4.7 TRANSIT System

SYSTEM: TRANSIT (DOD Total)

DESCRIPTION: TRANSIT nominally consists of four satellites in polar orbits. The satellites broadcast continuous information on 150 and 400 MHz. A receiver measures the apparent frequency shifts of the signals (doppler) as the satellite approaches or passes the user. The receiver then calculates the geographic position of the user, based on satellite position knowledge and corrections received from the transmitted signal. Vessel course, speed and time must be known accurately.

CHARACTERISTICS:

ACCURACY[1]			AVAILABILITY	COVERAGE	REL	FIX RATE	FIX DIM	CAPACITY	AMBIGUITY POTENTIAL
PREDICTABLE	REPEATABLE	RELATIVE							
500m	50m	38m	98+% When Satellite is in View	Worldwide, Non-Continuous	–	30 min. at 80° lat. to 110 min at Equator (Average)	2D	Unlimited	None

SCHEDULE:

	1980						1985					1990					1995					2000
PHASE IN/OUT:																						
DECISION PTS:							Review		FOC													
NUMBER OF USERS:																						
SHIPS/SUBS:	232	286	332	382	408	419	423	383	383	343	183	123	63	0								
NO. OF EQUIP. PURCH:	50	52	47	50	26	11	4	0														

1. 2 drms

TABLE I-4.11 - TRANSIT System Characteristics and User Schedule

C. Acceptance and Utilization

TRANSIT provides periodic, worldwide, position-fixing information for Navy ships and submarines and commercial ships, as well as ground users. It is well 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. Special DOD considerations include:

1) The small number of satellites make the likelihood of successful countermeasures very high.

2) Since TRANSIT is a Doppler system, small errors in the user's estimate of their own velocity can cause large errors in user position; thus TRANSIT is impractical for fast-moving vehicles.

3) Due to the frequencies transmitted, use in a submarine demands a receiving antenna be placed above the surface of the water during a portion of a TRANSIT pass.

D) Outlook

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

DOD use and operation of TRANSIT will be phased out in favor of NAVSTAR GPS during the period from 1986 to 1992. NAVSTAR GPS will perform the TRANSIT function with continuous availability, greater accuracy and greater resistance to countermeasures because of the larger number of satellites and their higher orbits.

4.3.8 Radiobeacons

Aeronautical Non-directional Beacons (NDB) are used to supplement VOR/DME in the en route airspace in the state of Alaska. They are also used for transition from en route to airport precision approach facilities and as a nonprecision approach aid at many airports. The beacons also relay transcribed weather broadcasts. 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 radionavigational equipment.

A. Operating Plan

The FAA operates over 600 nondirectional beacons. In addition, there are about 700 non-Federally operated aeronautical beacons. During the next 10 years, expenditures for beacons are planned to be limited to an occasional relocation or establishment of NDB for ILS transition, replacement of deteriorated components, and modernization of selected facilities.

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 installations of some new stations, relocation of others, changes in transmitting procedures for selected beacons, and changes in frequencies. The changes in frequencies will result in more efficient use of the RF spectrum and will provide for future expansions if it should be needed. The operating plan is shown in Figure I-4.8.

B. User Co-User Community

Aeronautical Nondirectional Beacons (NDB): All air carrier, 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 in the order of 3 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. Radio beacons do not provide sufficient accuracy or coverage to be used as a primary aid to navigation for large vessels in U.S. coastal areas.

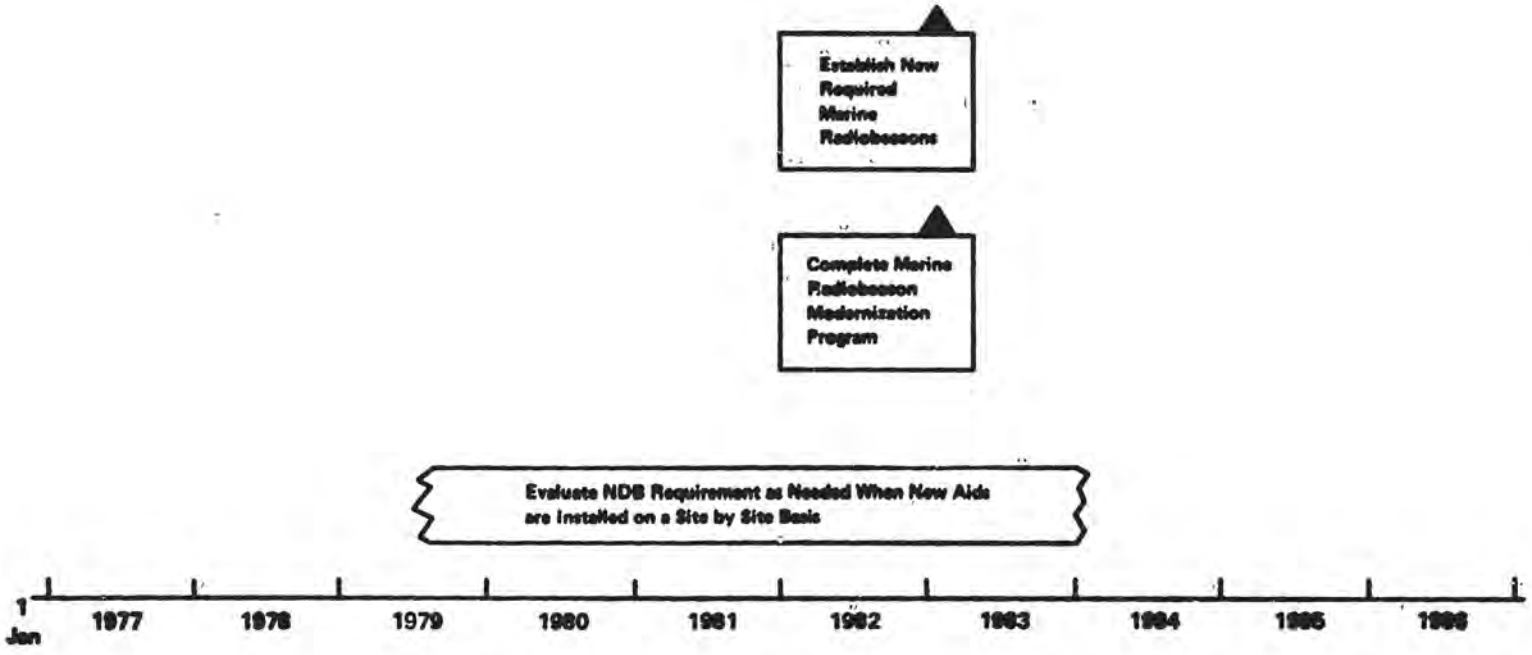


FIGURE I-4.8 Operating Plan for Radiobeacons (Marine/Air)

SYSTEM: RADIOBEACONS (NDB/ADF) (DOD TOTAL)

DESCRIPTION: Aircraft nondirectional beacons (NDB) are used to supplement VOR-DME in the state of Alaska for transition from enroute to airport precision approach facilities and as a nonprecision approach aid at many airports. The beacons also relay transcribed weather broadcasts. Radio beacons are nondirectional radio transmitting stations which operate in the low frequency (LF) and medium frequency (MF) bands to provide ground wave signals to a receiver.

SCHEDULE:	1980					1985					1990					1995					2000
PHASE IN/OUT:																					
DECISION PTS:																					
NUMBER OF USERS A/C RX:	24,499	24,999	24,999	23,841	23,632	24,991	24,949	22,135	20,466	18,926	17,486	16,061	14,336	12,997	12,936	12,222	12,118	12,118	12,118	12,118	12,118
GND/SH TX:	213	213	213	213	213	213	213	213	213	399	393	193	171	149	149	149	149	149	149	149	
SOUP USER SETS:	899	491	436	466	314	399	394	49	199	229	229	232	713	703	763	746	991	991	991	991	
PUNCH GND STA:			33	33	33																

TABLE I-4.12 Radiobeacon User Schedule - Military

SYSTEM: Radiobeacon (NDB/RBN) (Civil User Totals)

DESCRIPTION: Aircraft nondirectional beacons (NDB) are used to supplement VOR-DME in the state of Alaska for transition from enroute to airport precision approach facilities and as a nonprecision approach aid at many airports. The beacons also relay transcribed weather broadcasts. Radio beacons are nondirectional radio transmitting stations which operate in the low frequency (LF) and medium frequency (MF) bands to provide ground wave signals to a receiver.

		79	80	81	82	83	84	85
CIVIL USER	AIR (NDB) (X000)	81.4	85.55	90.9	94.5	98.4	98.3	102.9
	MARINE (RBN) (X000)	370	386	404	423	442	462	484
GOVT GROUND STATION	NDB	629	629	629	629	629	629	629
	RBN	198	199	213	226	226	226	226

Table I-4.12 (Cont.) Radiobeacon User Schedule - Civil

D. Outlook

Only a small expansion is planned for either aeronautical or marine radiobeacon facilities. There is expected to be growth in the number of direction-finder-equipped general aviation aircraft and pleasure boats.

At present, there are no known alternative systems 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 lower-cost alternative.

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 the existing ILS. An MLS transition plan is in coordination. The current operating plan is shown in Figure I-4.6. 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.

D. Outlook

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

SYSTEM: MLS (DOD Total)

DESCRIPTION: The Microwave Landing System (MLS) has been developed by DOT, DOD, and NASA to provide a common civil/military landing system to meet the full range of user operational requirements to the year 2000 and beyond. It is intended as a replacement for the Instrument Landing System (ILS) used by both civil and military aircraft and the Ground Controlled Approach system used primarily by military operators.

SCHEDULE:	1980					1985				1990				1995						2000
PHASE IN/OUT:																				
DECISION PTS:																				
NUMBER OF USERS:																				
A/C RX:								1,000	2,100	3,270	4,350	5,400	6,440	7,620	8,720	9,810	10,000	10,000	10,000	10,000
GND/SHIP TX:							5	20	51	74	97	120	192	169	217	260	260	260	314	321
EQUIP USER SETS:								1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	600	600	600	600
PURCH GND STA:							5	33	34	34	33	33	33	33	33	33	9	9	9	7

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

MLS is expected to operate well beyond the Year 2025. 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 concept 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 worldwide, 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. 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. In 1981 the DOD will make a decision regarding production of operational satellites. A DOD decision regarding production of user equipment will be made in 1983. The system is expected to become operational in 1987. The operating plan is shown in Figure I-4.9.

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 1981-1982 time frame. 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 1987. An operational NAVSTAR GPS Control Center (NCC) will be placed in operation to support the operational system. The NCC 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. They are also the major 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

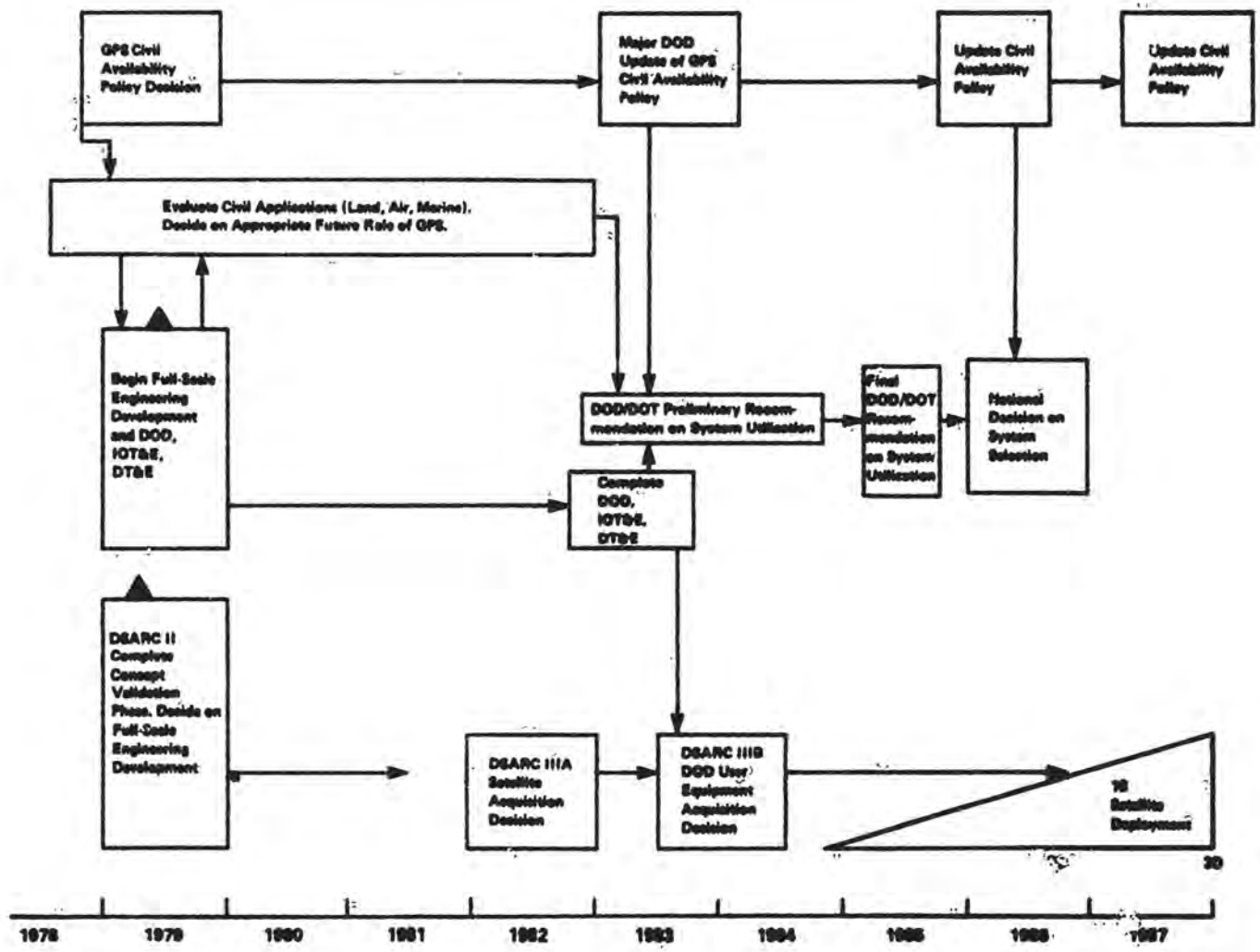


FIGURE I-4.9 NAVSTAR GLOBAL Positioning System

SYSTEM: GPS (DOD Total)

DESCRIPTION: The Global Positioning System is a space-based radio positioning navigation system that will provide extremely accurate three-dimensional position and velocity information together with system universal time to suitably equipped users anywhere on or near the Earth. The space segment will consist of 18 satellites in 12 hour orbits. Each satellite transmits navigation signals at frequencies of 1575.4 MHz and 1227.6 MHz.

CHARACTERISTICS:

ACCURACY[1]			AVAILABILITY	COVERAGE	REL	FIX RATE	FIX DIM	CAPACITY	AMBIGUITY POTENTIAL
PREDICTABLE	REPEATABLE	RELATIVE							
Horiz. 25m Vert. 30m	25m 30m	10m 8m	98%	Global, Continuous	98+%	Essentially Continuous	3D + Time and 3D Velocity	Unlimited	None

18 SATELLITE CONSTELLATION

SCHEDULE:	1990					1995		1990				1995				2000				
PHASE IN/OUT:																				
DECISION PTS:																				
NUMBER OF USERS:							838	2,718	4,398	8,439	11,222	12,889	13,883	14,433	14,885	15,289	15,814	15,814	15,814	15,814	15,814
EQUIP PURCH — USER SETS:						369	1,671	2,129	3,106	3,886	3,389	2,172	1,239	991	992	989	946	427	427	427	427	427
EQUIP PURCH — GND STA:																					

NOTE: Horizontal (2 drms) and vertical (2 sigma) accuracies are available to military and selected civil users. Accuracy available to other users is estimated at: 50-3m (2 drms) horizontal and 430m (2 sigma) vertical.

TABLE I-4.14 - Global Positioning System (GPS) Characteristics and User Schedule

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 NAVSTAR GPS is not accurate enough to replace precision landing systems or meet the marine requirements for harbor approach, harbor, and inland waterway navigation.

D. Outlook

NAVSTAR GPS is a 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 costs 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 well into the next century.

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, economic, 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-4.3 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 interest by 1986.

Work to provide the decision data base is underway. DOT and DOD anticipate completion of technical evaluations of candidate systems (including NAVSTAR GPS) in 1982. At that time, the development of a joint DOD/DOT Economic Planning Model will be completed. It will enable detailed analysis of the costs and benefits of different mixes of existing and developmental navigational 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-4.10) 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 1980-82 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 Radionavigation Plan review.

Three 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, phaseout 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, economic 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 time frame. However, before decisions can be implemented, there may be incremental improvements to existing systems that can be cost-effective for the time period 1980-1995, 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. Other improvements, such as LORAN-C expansion for land and air users, appear attractive but must be weighed individually for relative cost-benefit. 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 recommendation on the future navigation system mix, and the 1986 decision at the national level. This decision becomes the basis for navigational system

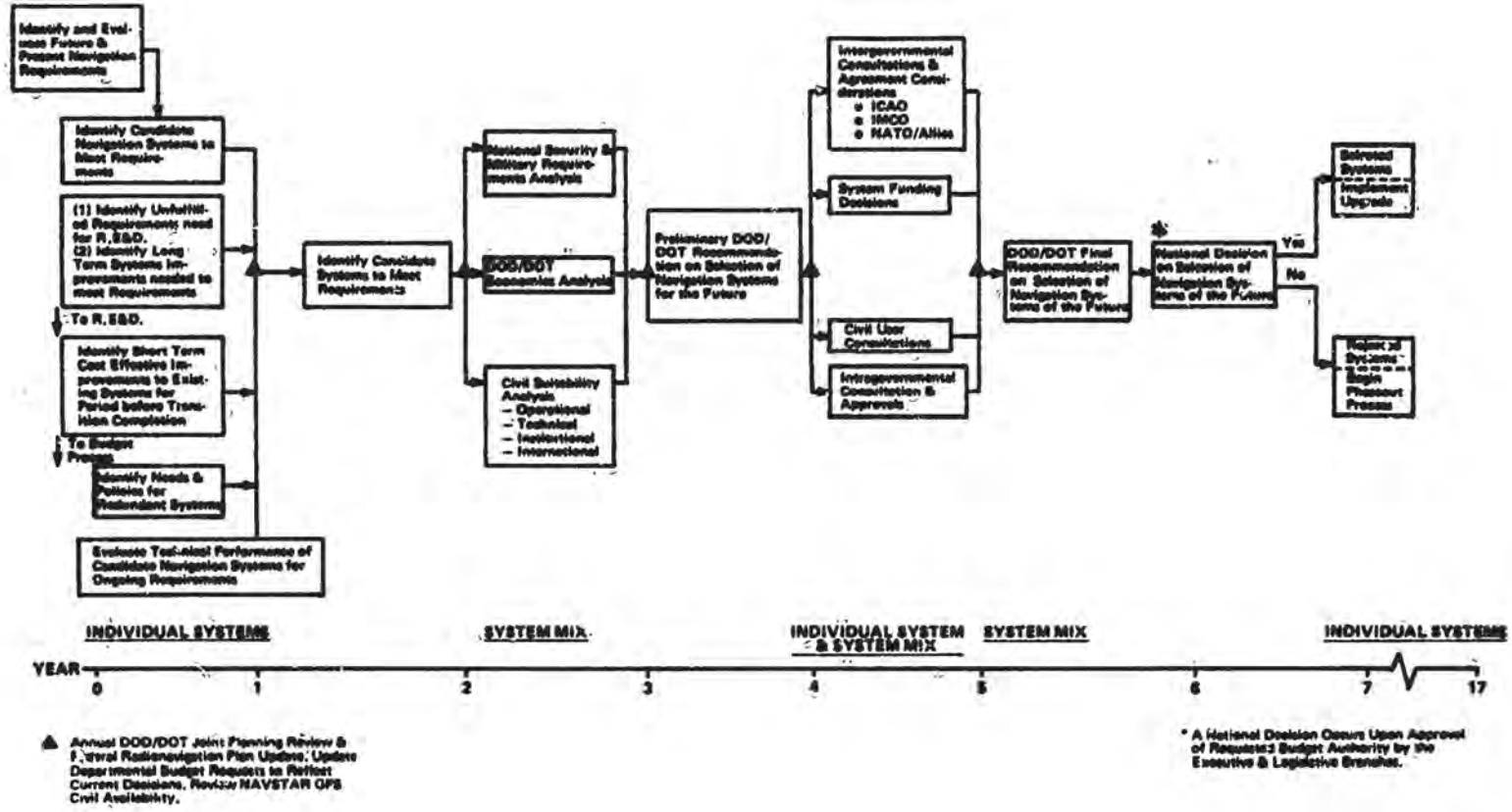


FIGURE I-4.10 Selection of Initial Radionavigation Systems Mix

implementation. Following the 1986 decisions, 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 and military 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 choose 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. The dependence of allied countries on navigation systems which are no longer used by the U.S. Military Services.

d. The need for reliability 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.

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 nonexistent. Consequently, transportable navigational facilities may be needed. DOD navigational systems must operate in extreme environments 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:

- Identifies the unique components of mission requirements
- Identifies technological deficiencies
- 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:

- Received Signal Strength
- Multipath Effects

- o Signal Accuracy
- o Vehicle Dynamic Effects
- o Signal Acquisition and Tracking Continuity
- o Signal Coverage
- o Noise Effects
- o Propagation
- o Interference Effects (Natural, Man-Made)
- o Installation Requirements
- o Environmental Effects.

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 requirements. 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 costs 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; operating, 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.

Although economic issues are often secondary to mission performance in military applications of navigational systems, DOD components are major investors 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.

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/ benefit measure for all classes of systems and users is planned to be attained by 1982.

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 Navigational Services

By the nature of the electromagnetic medium, services provided to meet U. S. requirements can be used by any suitably equipped foreign or domestic operator. At present, there is no charge or cost levied by the United States on foreign users for this "incidental" service.

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 coarse/acquisition 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 coarse/acquisition (C/A) signal will be made continuously available on an international basis for civil and commercial use at the highest level of accuracy consistent with national security interests. It is presently projected that an accuracy of 200m CEP (500m 2 drms) will be available during the first year of full NAVSTAR GPS operation with accuracy available to civil users increasing as time passes. This policy is a key element in determining the non-military navigational services that can be based on use of NAVSTAR GPS signals.

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 its territorial waters. NAVSTAR GPS probably would be accepted at least as a voluntary replacement for another required system. 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 are 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 feasibility of international acceptance of NAVSTAR GPS.

4. Technology Transfer

International sales and manufacture of user and transmitting equipment can help to stimulate international acceptance of a navigational system, by providing a commercial sales promotion of equipment from diverse national sources. Transfers of U. S. technology to other countries, permitting them to manufacture and sell user equipment competitively, would be an important factor in achieving international acceptability of a new radionavigation system such as NAVSTAR GPS.

4.5.3 Criteria for Selection

Criteria are defined to compare the relative attractiveness of alternative navigational systems' configurations. At the minimum, decision 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 environment. (Viability)

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

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

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

1. Service

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

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

c. 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.

2. Viability

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

b. 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.

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

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

3. Standardization

a. 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).

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

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

4. Costs

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

b. 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:

AD	Advanced Development
ADF	Automatic Direction Finder
AFB	Air Force Base
AM	Amplitude Modulation
APL	Applied Physics Laboratory
ARTS	Automated Radar Terminal System
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
ATMSMN	Air Traffic Management System Material Need
AUE	Army User Equipment
AVL	Automatic Vehicle Location
BLM	Bureau of Land Management
C/A	Coarse/Acquisition
CCD	Charged Coupled Devices
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
CNO	Chief of Naval Operations
CONUS	Continental United States
CRT	Cathode Ray Tube
CSC	Computer Sciences Corporation
CSE	Course Selection
CTP	Coordinated Test Program
CW	Continuous Wave
DCP	Decision Coordination Paper
DCS	Data Collection System
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
DR	Dead Reckoning
drms	Distance root mean squared
DSARC	Defense System Acquisition Review Council
DT-1/OT-1	Development Test-1/Operational Test-1

DT&E	Development Test & Evaluation
DTLCC	Design-To-Life-Cycle-Cost
ECCM	Electronic Counter-Countermeasures
ECD	Envelope-to-Cycle Difference
EM	Electromagnetic
EMI	Electromagnetic Interference
EMS	Emergency Medical Service
ERDA	Energy Research & Development Administration (Now Department of Energy)
FAA	Federal Aviation Administration
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
FSED	Full-Scale Engineering Development
FTE	Flight Technical Error
FYDP	Five-Year Defense Program
GA	General Aviation
GBF/DIME	Geographic Base File/Dual Independent Map Encoding
GCA	Ground Control Approach
GDOP	Geometric Dilution of Precision
GOR	General Operating Requirement
GPS	Global Positioning System
GSTDN	Ground Satellite Tracking and Data Network
HHE	Harbor and Harbor Entrance Area
HHS	Health and Human Services
HMS	Harbor Monitoring Systems
Hz	Hertz
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMCO	Inter-Governmental Maritime Consultive Organization
INMARSAT	International Maritime Satellite Organization
INS	Inertial Navigation System
IOT&E	Initial Operational Test & Evaluation
ISMLS	Interim Standard Microwave Landing System
JCS	Joint Chiefs of Staff
JPO	Joint Program Office
JSPS	Joint Strategic Planning System
JTIDS	Joint Tactical Information Distribution System
JTMLS	Joint Tactical Microwave Landing System
kHz	kiloHertz
LCC	Life-Cycle Costs
LF	Low Frequency
LNG	Liquified Natural Gas
LOP	Line of Position
LORAN	Long-Range Navigation
MAORF	Maritime Administration's Operations Research Facility
MAP	Missed Approach Point
MARAD	Maritime Administration

MATCALS	Marine Air Traffic Control and Landing System
MCW	Modulated Continuous Wave
MDA	Minimum Descent Altitude
MENS	Mission Element Need Statement
MF	Medium Frequency
MHz	MegaHertz
MIJI	Meaconing, Interference, Jamming, and Intrusion
MLS	Microwave Landing System
MNP	Master Navigation Plan
MNPS	Minimum Navigation Performance Specification
MRAALS	Marine Remote Area Approach and Landing System
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
NAFEC	National Aviation Facilities Experimental Center
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NAT	North Atlantic Track
NATO	North Atlantic Treaty Organization
NAVSTAR	Navigation System Using Time And Ranging
NBS	National Bureau of Standards
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
NOTAM	Notice to Airmen
NPN	National Plan for Navigation
NSF	National Science Foundation
NSWC	Naval Surface Weapon Center
NTIA	National Telecommunications and Information Administration
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
PDR	Preliminary Design Review
PL	Public Law
POS/NAV	Positioning and Navigation
PRN	Pseudo-Random Noise
R&D	Research & Development
RACON	Radar Transponder Beacon
RAM	Reliability, Availability, and Maintainability
RAYDIST	(Not an acronym)
RBS	Radar Bomb Scoring
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)
ROC	Required Operational Capability
RSI	Rationalization, Standardization and Interoperability
RSPA	Research and Special Programs Administration
RSS	Root Sum Square
RVR	Runway Visual Range
SAFI	Semi-Automatic Flight Inspection
SAM	System Area Monitor
SAR	Selected Acquisition Report
SARPS	Standard And Recommended Practices
SHF	Super High Frequency
SLSDC	St. Lawrence Seaway Development Corporation
SOR	Statement of Requirements
SPO	Systems Program Office
(S)SARC	(Service) System Acquisition Review Council
STOL	Short Take-Off and Landing
STS	Satellite Test System
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
TVOR	Terminal VOR
UHF	Ultra High Frequency
UMTA	Urban Mass Transportation Administration
USDA	United States Department of Agriculture
USGS	United States Geodetic Survey
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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