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United States Coast Guard

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COMDTINST 16577.2
AUG 16 1995

COMMANDANT INSTRUCTION 16577.2

Subj: DIFFERENTIAL GLOBAL POSITIONING SYSTEM (DGPS) NAVIGATION SERVICE CONCEPT OF OPERATIONS

A. PURPOSE. To distribute the DGPS Navigation Service Concept of Operations.

B. ACTION. Area and district commanders, commanders of maintenance and logistics commands, and unit commanding officers shall ensure that the DGPS Navigation Services Concept of Operations receives appropriate distribution.

C. BACKGROUND. DGPS is an enhancement of the U.S. Department of Defense's Global Positioning System (GPS). A network of ground based reference stations provides corrections to the GPS satellite ranging measurements, to provide a navigation accuracy of 8-20 meters in real time. The three specific objectives of this Concept of Operations are: (1) to provide a framework to include operations, logistics, and maintenance of the DGPS service, (2) to identify changes that must be made to the existing radiobeacon support infrastructure, and (3) to be the U.S. Coast Guard organizational document that identifies internal support responsibility assignments. The Concept of Operations, coupled with electronic equipment support plans will begin the recurring budget process to provide future funds for the DGPS service life-cycle maintenance costs.

D. DISCUSSION. Upon receipt of the DGPS Navigation Service Concept of Operations, please review the concept. Send any comments and/or suggestions to Commandant (G-NRN). Your opinions and input are important and will be used when revising the DGPS Navigation Service Concept of Operations.

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Encl: DGPS Navigation Service Concept of Operations.

Encl. (1) to COMDTINST 15577.2

U. S. Coast Guard

Differential Global Positioning System
Navigation Service
Concept of Operations

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FOREWORD

This is a Concept of Operations for the U.S. Coast Guard Differential Global Positioning System (DGPS) Navigation Service. It places emphasis on meeting current and future performance requirements for both internal and external Service customers. Significant realignment of existing organizational responsibilities and priorities for radiobeacons are required for Service implementation. This concept provides the common vision to plan, coordinate, and integrate these infrastructure changes across organizational boundaries.

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1. INTRODUCTION

1.1 Purpose

This Document is to ensure that all members of the Coast Guard's radionavigation and logistic support community share a common vision on how the DGPS Navigation Service will be implemented. The three specific objectives of this Concept of Operations (CONOP) are: (1) to provide a framework to include operations, logistics, and maintenance of the DGPS service, (2) to identify changes that must be made to the existing radiobeacon support infrastructure, and (3) to be the U.S. Coast Guard organizational document that identifies internal support responsibility assignments. This document, coupled with electronic equipment support plans will begin the recurring budget process to provide future funds for the DGPS service life-cycle maintenance costs. The key element which must be understood is that the level of effort devoted to the marine radiobeacon must be increased. DGPS radiobeacons will be a top priority on the National level as the critical segment in the newest public navigation service. Current radiobeacon policy, from equipment failure response to preventive maintenance, must be revised as the majority of beacons will be much more than individual navigation aids. The DGPS service availability and reliability requirements are achievable ONLY with long-term organizational support commitment.

1.2 Background

DGPS is an enhancement of the U.S. Department of Defense's Global Positioning System (GPS). A network of ground based reference stations provides corrections to the GPS satellite ranging measurements. Each reference station monitors all satellites in view, comparing the measured ranges with expected measurements based on the reference stations surveyed location. Separate corrections are calculated for each satellite, allowing the user maximum flexibility in the choice of satellites for navigation. These differential corrections are then transmitted from the reference station to GPS users who apply the corrections to their received GPS signals.
Marine radiobeacons located at each reference station broadcast corrections to users. The corrections are modulated on the radiobeacon carrier. (285-325 kHz band) in the form of Minimum Shift Keying (MSK) modulation. The modulation data rate for any beacon can be 50, 100, or 200 bits per second (bps).

The accuracy of the Coast Guard's DGPS Navigation Service is expected to be better than 10 meters (2 drms) in all approaches to major U.S. harbors. The system will also be capable of warning the user when it is not performing within specified tolerances, and can prevent the DGPS user from using unhealthy satellites. Warning times for the DGPS system are less than ten seconds.

Additional subject background on the Service architecture, definitions, and DGPS development history is provided in the appendices.

2. OPERATIONAL REQUIREMENTS

2.1 Customer Needs
The DGPS Tentative Operational Requirements (TOR) document, G-NRN memorandum dated 5 Dec 1990, identified four missions to be supported by DGPS:

- Harbor and Harbor Approach (HHA) .navigation
- Vessel Traffic Service (VTS)
- Aids To Navigation (ATONE) positioning.
- Exclusive Economic Zone (EEZ) surveying

HHA is the only listed mission that requires a navigation capability for both government and public users. The other three are government missions requiring a positioning service. HHA, being considered the highest risk mission, was therefore chosen for concentrated analysis. The goal was to accurately model the HHA mission; then utilize the model to derive measurable performance values for the DGPS service.

In addition to the four missions listed above, the Coast Guard is cooperating with the U.S. Army Corps of Engineers (USACE) to implement DGPS service along inland rivers. As a result, USACE surveying, positioning, dredging, revetment maintenance, and other navigation related activities will be more efficient. A memorandum of agreement between the USCG and US Army was signed in February 1994.

The Coast Guard will use the DGPS service for its own missions, and will make it available to both the general public and other government agencies. Some applications that have been identifidd by G-N include VTS (dependent surveillance), low visibility search and rescue operations, Q-route survey support, and Automated Aid Positioning System (AAPS) aboard ATON servicing units. Most importantly, a DGPS service will ensure that a harbor and harbor approach (HHA) radionavigation service will be provided to meet the accuracy, reliability and integrity requirements outlined in the Federal Radionavigation Plan (FRP).

2.2 Performance Measurements
Traditionally, radionavigation system critical performance is defined In terms of accuracy, integrity, availability, reliability, and coverage. Appendix B gives definitions for these five performance measures from the 1992 FRP. The U.S. Coast Guard has extensive experience in specifying navigation service alarm thresholds to ensure safe oceanic (OMEGA) and coastal (LORAN) radionavigation. However, in the transition from coastal to harbor navigation the probability of vessel collision or grounding clearly increases. The DGPS service is intended to improve HHA navigation safety under all weether conditions. Therefore, integrity and reliability parameters had to be established to levels that would significantly reduce the risk of any navigation casualty while traversing harbor areas. Values for accuracy and availability set by the 1992 FRP are summarized in Table 2-1. The positioning user values come from the requirement statement provided by G-NSR, G-NVT, NOAA, and USACE. HHA accuracy value is set within the 8-20

meter range based on individual harbor constraints within each DGPS broadcast coverage area.

Table 2-1

Usage	Accuracy (2drme)	Availability
Harbor/Harbor Approach	8-20 meters	99.7%
ATON Positioning	10 meters	95.0%
Vessel Traffic Services	10 meters	99.9%
NOAH Near Shore Surveying	15 meters	95.0%
Army Corps of Engineering	6 meters	98.0%

Integrity is provided by continuously monitoring critical performance parameters and automatically alarming the user when these parameters are not being met. Each DGPS broadcast will be monitored at the point of transmission and an alarm is automatically sent to the user within ten seconds of a fault detection. Site monitor alarm thresholds can be set to ensure user accuracy performance is available throughout the site's assigned coverage area. The Service goal is ZERO false alarms and ZERO missed alarms.

Reliability is a function of both the Service failure rate plus that of the user's equipment. To maximize DGPS service reliability the operational goal is that there will be NO unforecast Service outages. In other words, during mission planning a user can rely on having the Service available if a broadcast outage has not been advertised.

The Broadcast Standard for the USCG DGPS Navigation Service, COMDTINST M16577.1 provides detailed specification and description of broadcast signal parameters and content. The document's appendices include site listings and assigned coverage areas.

2.3 Service Validation
Each site's integrity monitor will collect and forward data to the Control Station. The Control Station database will be used to calculate each broadcast's performance. This evaluation will be done on a monthly basis. Coverage in critical waterways will be validated by analyzing data collected from far-field monitors. Any coverage "holes" will be investigated, documented, and solutions sought.

2.4 Customer Feedback
The Control Station will log service outages reported from users. Users with new service requirements will be directed to contact the Program Manager within the office of Commandant (G-N).

3. ORGANIZATIONAL RESPONSIBILITIES

3.1 Radiobeacon Management

The Aids to Navigation Manual, Radionavigation, COMDTINST M16500.13 series describes the present marine radiobeacbn system. Using radiobeacons to generate marine radionavigation signals under the concept of DGPS will create considerable changes to the present system of controlling and maintaining radiobeacons. The operation of DGPS requires a more centralized approach to radiobeacon management (Figure 3-1). The following changes to operations, maintenance, logistics, training, and system life cycle management are required.

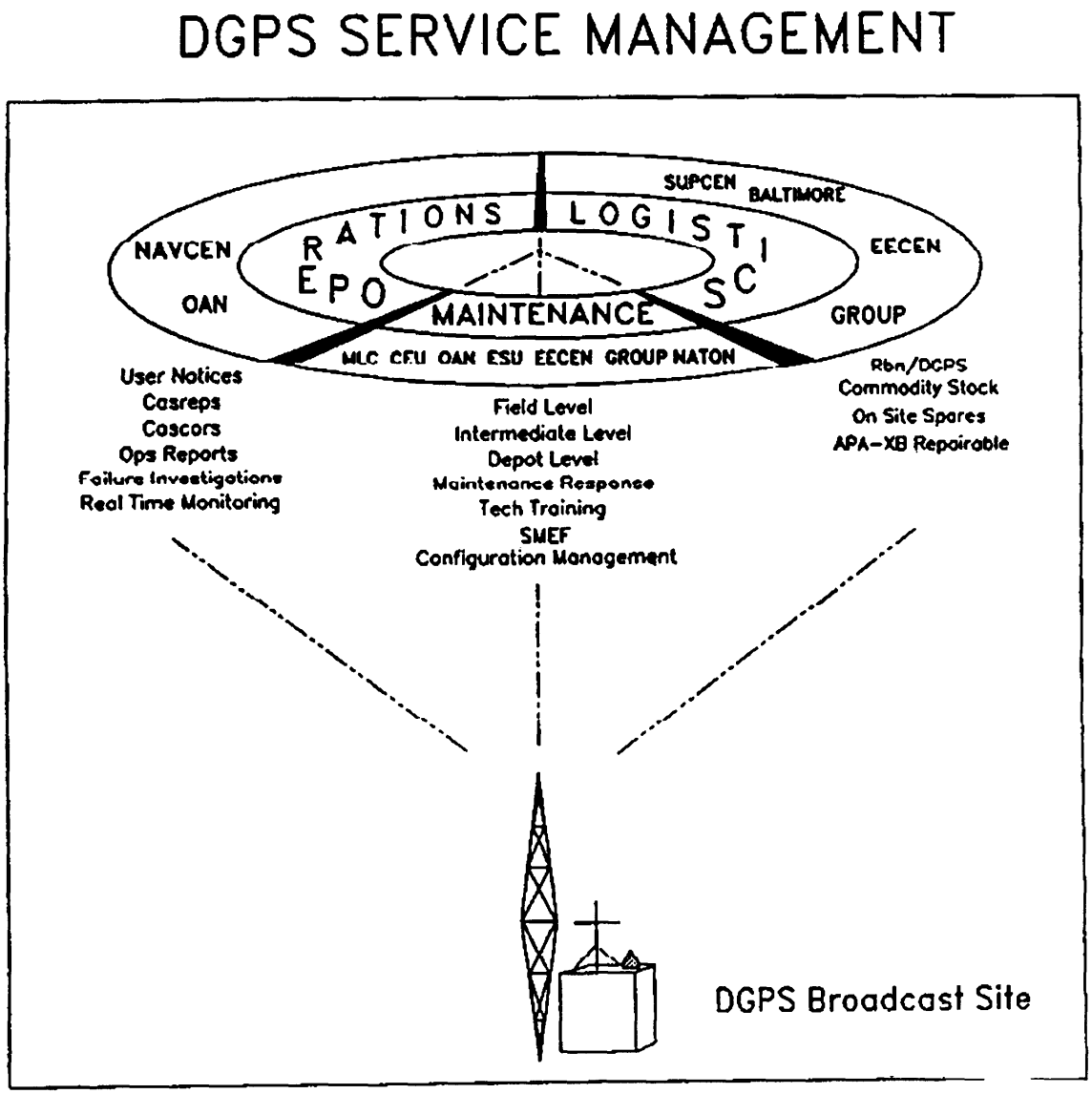

Figure 3-1

3.2 Operations

1) NAVCEN is responsible for Operational Control (OPCON) for the DGPS Navigation Service.
2) NAVCEN is responsible for development and promulgation of a DGPS Operations Manual for G-N approval. The Operations Manual establishes policies and procedures for the DGPS system day-to-day operations, record keeping, report requirements, logistics, training and communications.
3) NAVCEN will issue and maintain an OPORDER for each broadcast site that defines operating parameters.
4) District commanders have responsibility for Administrative Control (ADCON) of the DGPS Broadcast Sites within their District.
5) The centralized approach to management of DGPS radiobeacons places the requirement on NAVCEN to operationally monitor and control each DGPS site. This results in a reduction of District responsibilities as follows:
    a) DGPS Broadcast Site monitoring is no longer required by each District.
    b) Notices to Mariners advising users of unforecast system outages as well as proposed and scheduled service off-air time will be initiated by NAVCEN by notifying appropriate District oans. District oans will then issue them through normal channels.
    c) NAVCEN will be responsible fot authorizing all requests for off-air.
6) Only Continuous Radiobeacons will be used for DGPS. Sequenced and Calibration Radiobeacons are not required.
7) The transmission of Morse Code characters by DGPS radiobeacons is no longer required. DGPS Broadcast Site identifying information is included in the RTCM SC-104 format. Refer to the Broadcast Standard for the USCG DGPS Navigation Service, COMDTINST M 16577.1, for a detailed explanation of broadcast signal characteristics.

3.3 Maintenance

1) Commandant G-TES will provide MLCs with general guidance. Maintenance procedures will be issued using the Coast Guard Planned Maintenance System (CGPMS) which is the responsibility of G-TES. Overall broadcast site condition will be validated monthly at the organizational level. MLCs will perform an annual engineering inspection and report the results to NAVCEN. Twelve new Electronic Teohnioian billets, five to MLCPAC and seven to MLCLANT, are provided to meet additional DGPS organizational and intermediate level maintenance requirements.
2) DGPS Broadcast Sites are exempt from discrepancy response factor calculations as defined in COMDTINST M16500.7, Aids To Navigation Manual. Discrepancy Response criteria are as follows:

a) When a site's primary equipment fails and the site is operating with secondary equipment, servicing unit shall respond within 24 hours or as soon thereafter as weather and resource constraints permit.

b) When a site is off-air, servicing unit shall respond immediately after notification as weather and resource constraints permit.

3) The Electronics Enginoering Center (EECEN), Wildwood NJ, is designated the Support Maintenance Engineering Facility (SMEF) for the DGPS system.

3.4 System Life Cycle Managerneht

1) Configuration Management is the responsibility of SMEF.

3.5 Logistics

1) G-TES-3 is the logistics support manager and will provide the Equipment Integrated Logistic Support Plan (EILSP) for DGPS. The EILSP defines support and maintenance responsibilities, in detail, for the organizational, intermediate, and depot level inventory control point. The EILSP also describes requirements for funding, personnel and training.

2) Support Center Baltimore will maintain a commodity stock of DGPS Broadcast Site parts. G-TES-3 is designated the commodity stock manager and will establish a centralized point for depot-level repairs.

3.6 Training

1) Training requirements in support of DGPS equipment are being established at the National Aids To Navigation School (NATON), RTC Yorktown VA. Per the DGPS Acquisition Plan, one ET1 0E instructor billet was provided at RTC Yorktown. This billet has been filled. The existing radiobeacon course curriculum is being modified (keying card segment for Morse Code identifier is replaced with DGPS functionality) and the class length will not change. The present schedule of four classes per year with eight students per class will remain. No additional resources are planned.

2) NAVCEN has developed and conducts on-the-job DGPS Control Station watchstander training. No resident training or additional resources are required.

4. SUMMARY

The fact that the level of awareness and effort devoted to marine DGPS radiobeacons must increase cannot be overstated. The resources needed to maintain DGPS are in place. District funding requirements in support of radiobeacons are not expected to increase. Actually, the number of radiobeacons requiring support have been reduced. Technicians from the Groups will continue to respond to radiobeacon casualties as required, however, this level of support will decrease. The reasons for this are that DGPS makes use of the latest technology at the organizational and intermediate level. The preventive maintenance work load is minimized due to black-box technology. Redundant systems are in place so that the failure of one side of a transmitter will not have an immediate adverse effect on the DGPS service. And, integrity monitoring and control of each site will be done electronically by the East and West Control Stations. The U.S. Coast Guard will continue to fully cooperate on international fronts with the International Association of Lighthouse Authorities (IALA) and the International Maritime Organization (IMO) to achieve global DGPS commonality. Nationally, the U.S. Coast Guard is consulting with other agencies to adapt the DGPS service to meet their needs. U.S. Coast Guard representatives are participating within a RTCM Special Committee 104 working group. This group is developing commercial standards for Reference Station, Integrity Monitor, and user equipment specifications. Through significant enhancement of maritime safety and the inherent water transport efficiency increase, the DGPS service will be a high value navigational asset.

APPENDIX A: SERVICE ARCHITECTURE

The U.S. Coast Guard DGPS Navigation Service architecture is shown in Figure 1. The functional elements of the Service include:

Reference Station - Precisely located GPS receiving equipment with computer to calculate range corrections based on comparison of satellite navigation messages and the known location of the receiver.

Broadcast Site - A marine radiobeacon transmitting the GPS corrections to DGPS service users.

Integrity Monitor - Precisely located MSK radiobeacon receiver and GPS receiver capable of applying, differential corrections. The corrected GPS position is compared to the known position to determine if the correction broadcast is in tolerance.

Control Station - Centralized control of DGPS service elements. Location is staffed by a watchstander 24 hrs/day. DGPS service performance data archiving and processing is accomplished here:

Communication Network - Provides connectivity between sites for passing performance data and control commands using an X.25 Packet Switched Service.

DGPS User Equipment - Consists of two interfaced receivers with a display; a radiobeacon receiver capable of MSK demodulation, and GPS receiver capable of applying differential corrections from the radiobeacon receiver.

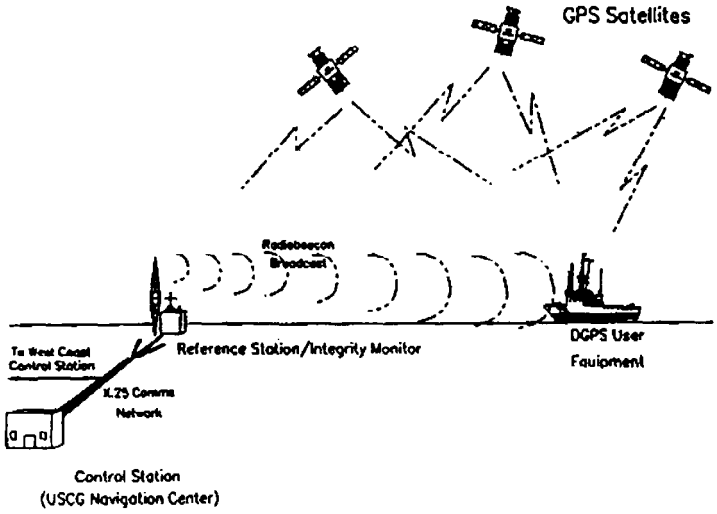

Figure 1. SERVICE ARCHITECTURE

Two identical Control Stations will be employed to monitor and control all DGPS sites. The East Coast Control Station is located at Alexandria, VA. The West Coast Control Station with be located at Petaluma CA. Each Control Station will have the capability of assuming the other's responsibility in the event one becomes inoperable. Additional site redundancy is provided by a complete spare set of equipment installed at both the East and West Control Stations.

Each broadcast site will have a standard configuration that includes two complete reference station and integrity monitor equipment sets for redundancy. Locations of existing and planned broadcast sites are shown in Figure 2.

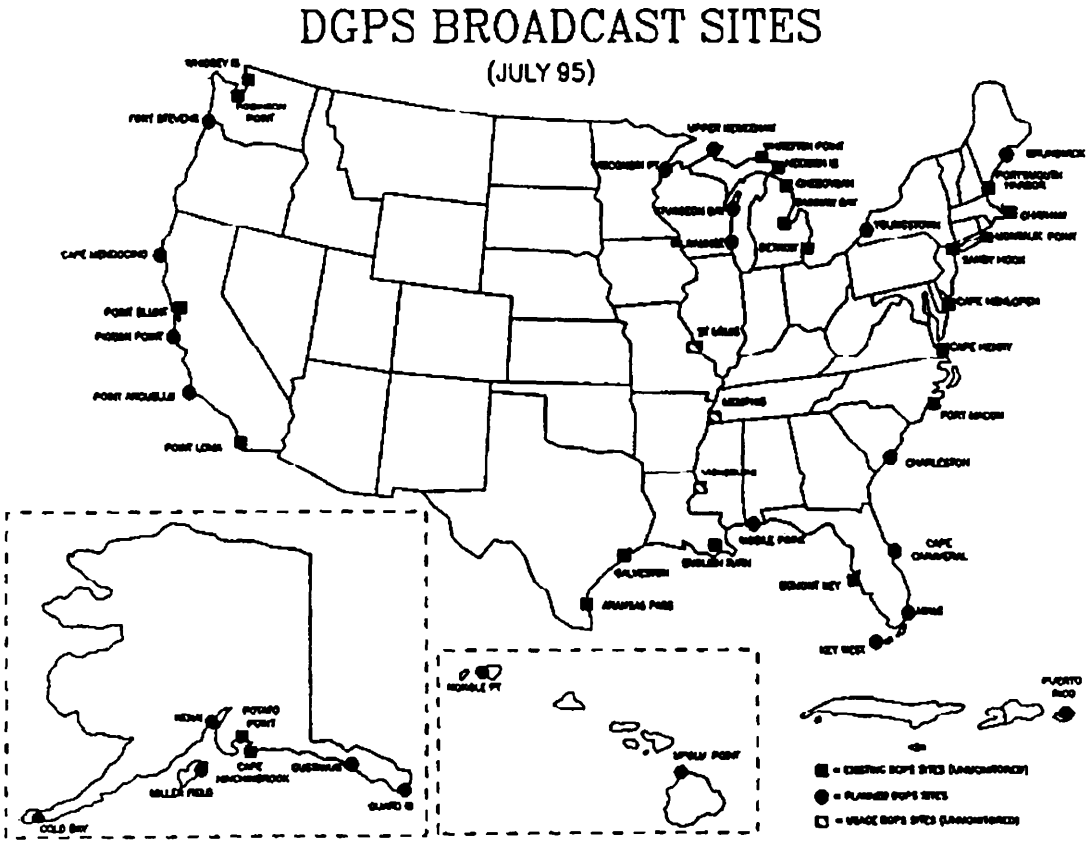

Figure 2. DGPS SITE LOCATIONS

APPENDIX B: GLOSSARY OF TERMS

Accuracy - the degree of conformance between the estimated or measured position of a platform at a given time and its true position.

Availability - the percentage of time service is usable by navigator.

Bits per second (bps) - unit of measure for speed of transmission of serial digital data to the user across the radiobeecon datalink. For example, if broadcast rate is 100 bps it takes 2.1 seconds to send the correction information for three satellites (210 bits).

Coverage - the surface area or space volume in which signals are adequate to permit the user to determine position to a specified level of accuracy.

Integrity - the ability of a system to provide timely warning to users when it should not be used for navigation.

Minimum Shift Keying (MSK) - MSK is a special form of frequency modulation. MSK involves utilizing the smallest possible frequency shift of the carrier frequency to relay digital information. A shift up in frequency from the carrier relays a digital "1" and down a "0".

Reliability - the probability of performing a specified function without failure under given conditions for a specified period of time.

2 drms - Horizontal accuracies listed in the CONOP are all 2 drms values. "2 drms" means twice the distance of the root mean square error. In practice, any position fix obtained using the given system has a 95% probability of having a radial error equal to or less than the 2 drms value expressed.

APPENDIX C: DGPS DEVELOPMENT HISTORY

In the last three decades, the U.S. Department of Defense (DOD) has led technology from terrestrial to space-based radionavigation systems, first with TRANSIT, and then the prototype NAVSTAR Global Positioning System (GPS). GPS, as with previous DOD radionavigation systems, was designed to meet military mission requirements with little consideration for civilian applications. However, as prototype GPS satellites were placed in orbit, innovative civil users found economical applications for the available GPS signals. Perceiving the growing demand, industry developed and produced GPS receivers tailored to emerging civil market applications. DOD requested the U.S. Department of Transportation (DOT) assume the lead in civil GPS matters. In February 1989, DOT assigned the U.S. Coast Guard as the lead agency in providing a civil GPS interface. The U.S. Coast Guard's assignment to the civil interface role followed the natural evolution of past U.S. radionavigation systems. The U.S. Coast Guard had been involved in the investigation of potential GPS civil use since the late 1970s and was therefore well prepared for this interface initiative.

During this same period, the U.S. Coast Guard Research and Development (R & D) Center in Groton, Connecticut, had been conducting research and testing of differential techniques to enhance Loran-C and Omega accuracy. The differential effort was driven by the search for a system with the capability to meet the accuracy requirement for Harbor/Harbor Approach (HHA) navigation as had been defined in the Federal Radionavigation Plan (FRP). The FRP identifies an accuracy of 8 to 20 meters (2 drms) is required for the HHA phase of navigation.

As the DOD development of GPS evolved, and the U.S. Coast Guard gained knowledge from civil application research, GPS appeared as the natural progression of differential technology application. The GPS Standard Positioning Service (SPS) that DOD makes available for civil users provides predictable accuracy to 100 meters (2 drms). Military GPS user's Precise Positioning Service (PPS) provides an accuracy of 22 meters (2 drms). Both SPS and PPS service falls short of the Federal Radionavigation Plan's HHA requirement. However, the application of differential technology to GPS does promise to provide the required accuracy improvement. As early as 1983, GPS receiver manufacturers and the U.S. Department of Transportation, with the U.S. Coast Guard as a participant, began work to develop a standard differential GPS correction message format. This effort was coordinated through the Special Committee (SC) 104 created by the Radio Technical Commission for Maritime Services (RTCM). In 1987 the U.S. Coast Guard R & D Center demonstrated that differential corrections received by user equipment inside the coverage area of the correction broadcast improved GPS SPS to a predictable accuracy of 10 meters (2 drms). The R & D Center used a VHF data link to broadcast corrections conforming to a draft RTCM SC-104 format at a 50 bits per second data rate. With the promising capability of DGPS, the HHA accuracy level requirement was verified by a U.S. DOT study of the navigation of vessels over 30,000 dead weight tons in the restricted waters of the Great Lakes/St. Lawrence Seaway.

In 1989, the U.S. Coast Guard modified the existing marine radiobeacon located at Montauk Point, New York to broadcast differential corrections in the RTCM SC-104 format. The Montauk Point field tests demonstrated that MSK modulation of an existing radiobeacon signal was effective in the transmission of RTCM SC-104 format corrections. Also, MSK modulation could be used with no adverse effect on the automatic direction finding receivers of traditional maritime radiobeacon users. Important to both the U.S. Coast Guard and the public; MSK technology is economical to implement at existing radiobeacons and within user receivers. By January 1990, the RTCM published the SC-104 format version 2.0 document establishing a formal U.S. industry differential GPS (DGPS) correction format. With the RTCM SC-104 standards and the initial radiobeacon broadcast success, Montauk Point began the first continuous public U.S. DGPS broadcast on August 15, 1990. This transmission marks the beginning of the U.S. Coast Guard's transition from DGPS research and development to implementation of a U.S. maritime DGPS service.