NAVAL POSTGRADUATE SCHOOL
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THESIS

REVIEW AND EVALUATION OF PLANS TO INCORPORATE NAVSTAR GLOBAL POSITIONING SYSTEM USER EQUIPMENT ON MILITARY SEALIFT COMMAND SHIPS

by

Ariane R. Foureman

December 1984

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The NAVSTAR Global Positioning System (GPS) is a spaced-based navigation system scheduled to be fully operational by 1990. GPS User Equipment (UE) is scheduled for installation on Navy ships commencing 1987. This thesis examines plans to incorporate GPS UE on Military Sealift Command (MSC) ships. The Naval Auxiliary Force and Special Mission Support ships have been funded and scheduled for military GPS UE. Plans for

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(1) equip Strategic Sealift ships with military GPS UE,

(2) include GPS navigation equipment in ship enhancement programs, and

(3) require GPS UE in MSC time and voyage charters.

Review and Evaluation of Plans to Incorporate NAVSTAR Global Positioning System User Equipment on Military Sealift Command Ships

by

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The NAVSTAR Global Positioning System (GPS) is a space-based navigation system scheduled to be fully operational by 1990. GPS User Equipment (UE) is scheduled for installation on Navy ships commencing 1987. This thesis examines plans to incorporate GPS UE on Military Sealift Command (MSC) ships. The Naval Fleet Auxiliary Force and Special Mission Support ships have been funded and scheduled for military GPS UE. Plans for Strategic Sealift and Miscellaneous Service Support ships have not yet been made. Alternatives for equipping these ships with either commercial or military GPS UE are examined. Primary recommendations for MSC ships when GPS is operational with two-dimensional coverage (by the end of 1987) are:

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I. INTRODUCTION

A. OBJECTIVE AND SCOPE

This thesis reviews and evaluates plans to incorporate NAVSTAR Global Positioning System (GPS) User Equipment (UE) on Military Sealift Command (MSC) ships in the MSC Fleet Inventory and in the New Ship Construction/Conversion Program. The scope is:

a. to identify MSC ships currently funded and scheduled for military GPS UE installation considering the GPS UE Installation Schedule (POM-86 Decision Package [Ref. 1], the MSC Fleet Inventory [Ref. 2], and the New Ship Construction/Conversion Program [Ref. 3].

b. to determine and evaluate alternatives for equipping currently unfunded MSC ships with military or commercial GPS UE in terms of mission requirements taking into account technology required, equipment characteristics and availability, schedules of the GPS program, and Department of Defense (DOD) navigation system phase-outs.

c. to present major considerations and implications of choice in alternatives (military or commercial) of GPS UE considered for all MSC ship groups.

Information in this thesis is applicable only to the user equipment (UE) segment of GPS and its application to MSC ships. However, the discussion and evaluation of alternatives can also be applied to other services which charter commercial platforms and service support craft.

This thesis does not provide a conclusive cost benefit analysis comparing the alternatives of procuring and installing GPS UE. Currently, commercial GPS UE for general marine navigation has not been produced nor is it available. More important, two competing companies have submitted bids in response to the request for proposal (RFP) released on 17 August 1984 by the Joint Program Office (JPO) for the production and integration of military GPS. Because the contract has not yet been awarded, specific information and costs are proprietary information for military GPS UE, and are extremely competition-sensitive. As data is not yet publicly available, an indepth cost benefit analysis could not be conducted.

B. METHODOLOGY

Research methods used were personal interviews and a review and study of pertinent literature and publications. The majority of technical information concerning GPS and GPS UE was provided by the GPS Joint Program Office in Los Angeles, California; the ARINC Research Corporation in Santa Ana, California; Magnavox in Torrence, California; Rockwell-Collins in Cedar Rapids, Iowa; and Texas Instruments in Lewisville, Texas. Information concerning the MSC was provided by OPNAV-42 and MSC Headquarters in Washington, DC; the MSC Pacific Area Command (MSCPAC) in Oakland, California; and the MSC Office (MSCO) in Long Beach, California.

Two basic assumptions are made: first, GPS will be operational and will replace currently existing navigation systems; and second, MSC's mission will continue as currently defined.

Discussions and conclusions are based on the author's understanding of statements and comments gathered during personal interviews and telephone conversations. Conclusions and recommendations are drawn from the interpretation of information available within the research time frame (July to December 1984). Additionally, they reflect the author's personal experience, which included operational tours at the Navy Space Surveillance System (NAVSPASUR), MSC Europe Area Command (MSCEUR), and Near Term Prepositioning Force (NTPF).

C. BACKGROUND

Compared to star fixes, the quantum jump in navigation on the high seas occurred with the operational use of the TRANSIT system in 1964. By 1973, the wide variety of 120 navigation and positioning systems operated by DOD in terms of both cost effectiveness and operational enhancement was the driving force that resulted in a need for replacement of these systems by developing the NAVSTAR Global Positioning System (GPS).

GPS is a space-based radionavigation system under tri-service/agency and North Atlantic Treaty Organization (NATO) development. GPS is applicable to both military and civil communities. It is designed to provide continuous, all-weather positioning information at any time of day to an unlimited number of suitably equipped users located anywhere on or out to 500 miles from the earth's surface. GPS provides highly accurate three-dimensional (latitude, longitude, and altitude) positioning (to within 16 meters spherical error of probability (SEP)), velocity (to within 0.05 meters/second), and system time (to within 55 nanoseconds) [Ref. 4:p. 2].

Currently GPS is in Phase II, full scale development. DSARC III decision milestone for Phase III production, is scheduled for the fourth quarter (QTR) calendar year (CY) 1985 [Ref. 5]. Full approval is anticipated [Ref. 6].

GPS is to become the primary DOD radionavigation system. Committed to GPS, DOD plans to phase-out the use and operation of existing radionavigation systems. As of November 1984, these phase-out plans[1] are as follows:[2]

SYSTEM	PHASE-OUT STARTS	PHASE-OUT COMPLETE[3]
LORAN-C	1987	1993
OMEGA	1987	1992
TRANSIT	1987	1994

The DOD policy for TRANSIT is to terminate TRANSIT operations as GPS becomes operational. The transition is scheduled to start in 1987 and by the end of 1994 [Ref. 7], "TRANSIT will be off the air as far as the Department of Defense is concerned. ...We have indicated that as GPS comes on line, we in the DOD will no longer have a need for TRANSIT and we plan on getting out of the TRANSIT business. We intend, in fact, to shut down TRANSIT." [Ref. 8:p. 107]

As a fallout of the GPS development, and because the GPS is expected to eventually replace existing navigation systems, anyone who uses navigation is a potential user. This is true for the mainstream Navy fleet as well as for logistic support and special mission ships.

Implicit in the funded military GPS UE installation schedule (POM-86 Decision Package), the Chief of Naval Operations (CNO) has determined and identified the need for military GPS UE funding and installation on Navy aircraft, ship and vehicle platforms. The mainstream high priority platforms (e.g., U.S. Navy carrier) are already scheduled for funding and installation of GPS UE. Military GPS UE is to be installed on U.S. Navy ships beginning in 1987 and continuing until the mid-1990's. [Ref. 1]

The Military Sealift Command (MSC) is a fleet command and the Navy Operating Agency for Ocean Transportation. Recently MSC's role as the nation's strategic arm of defense has been formally recognized. The U.S. Navy now has three major functions: sealift, sea control, and power projection. Until recently the U.S. Navy had two major functions: sea control and sea power. On 13 March 1984, the Secretary of the Navy, John Lehman, formally declared sealift as being the Navy's third major function. [Ref. 11:p. 2]

During the several years leading up to this formal recognition, MSC's mission of contingency-related strategic sealift was increasingly emphasized vis-a-vis its traditional peacetime role [Ref. 12:p. 38]. Additionally, contingency preparedness, sealift readiness, and strategic sealift have been given a surge of attention. In March 1981, CNO Admiral Thomas Hayward warned a House Armed Services Committee sub-committee that "without adequate and reliable sealift, literally none of our military plans is executable." [Ref. 12:p. 40]

By 1984, the Strategic Sealift Division (OP-42) was established as part of the Office of the Deputy Chief of

Naval Operations (DCNO) for Logistics (OP-04). Vice Admiral T.J. Hughes, Jr., OP-04, stated "Logistics half way is no good," and added, "...$6 billion over the next five years is going to OP-42." [Ref. 13]

As of 19 October 1984, the MSC Fleet Inventory consisted of 187 ships. The ships are grouped into one of four functional ship groups:

SHIP GROUP	ACTIVE AND RESERVE SHIPS
Strategic Sealift (STRAT)	111
Naval Fleet Auxiliary Force (NFAF)	28
Special Mission Support (SMS)	23
Miscellaneous Service Support (MSS)	25
	------
	187 TOTAL

Additionally, 56 ships are in the New Ship Construction/ Conversion Program. Eight ships are planned as replacements for existing ships and 48 ships will be added to the MSC fleet.[5]

Most of the NFAF and SMS ships have been funded and are scheduled for military GPS UE installation under the POM-86 Decision Package (hereafter referred to as POM-86) [Ref. 1]. The STRAT and MSS ship groups, particularly the STRAT ship group, have not been considered for military GPS UE to date [Refs. 14;15].

MSC ships use TRANSIT and OMEGA for primary ocean navigation, and LORAN-C (where available) for primary coastal navigation [Ref. 9:pp. 18-19], all of which are scheduled for DOD phase-out in the 1990's. This makes MSC ships candidates for either military or commercial GPS UE. In view of the identified need for military GPS UE aboard naval platforms (as well as on multi-service platforms), and the emphasis being placed on strategic sealift, there is a need for insuring that all MSC ships are considered for GPS UE and that a decision is made as to whether to provide them with military or commercial GPS UE. For military GPS UE, it is recognized that the required number of GPS UE sets will not be appreciable (approximately 8 to 111) in terms of the total number of sets the Navy will procure (7453) [Ref. 1]. However, the role of MSC in defense of the nation dictates that its ships be given adequate consideration in the implementation plans for procurement of GPS UE.

FOOTNOTES FOR CHAPTER I

[1]The Federal Radionavigation Plan (FRP), the official source of navigation policy and planning for DOD and Department of Transportation (DOT), states that by 1986 a national decision is to be made for navigation systems [Ref. 9:p. 55]. The effective FRP is dated 1982. the revised version, already signed by DOT, is expected to be signed by the Secretary of Defense (SECDEF) by the end of 1984 [Ref. 10].

[2]Sources: [Refs. 7;8:pp. 107-108;9:pp. 28-42].

[3]All DOD service plans call for phase-out of LORAN-C requirements and overseas LORAN-C funding. DOT expects to continue LORAN-C operation for continental coastal areas until the year 2000. [Refs. 7;9:p. 28] The Army and Air Force will phase-out military use of OMEGA by 1992. The Navy has possible limited use of OMEGA beyond 1992, and intends to re-evaluate use of OMEGA as a backup to GPS for selected platforms when GPS is fully operational [Ref. 9:p. 32].

[4]MSC Fleet Inventory dated 19 October 1984 [Ref. 2]. Includes 140 active and reserve ships and 24 inactive ships in the MSC controlled fleet plus 47 ships (Maritime Administration (MARAD) assets) which are operated by MSC when activated). See Chapter II and Appendix A for additional information.

[5]Reference 3 of October 1984 is used as basic information. The author has used 56 ships to reflect delivery of the third T-AGOS and second MPS as per Reference 2. Also, two new construction T-AGS ships are assumed throughout thesis (Chapter II), as replacements for USNS Bowditch and USNS Dutton.

II. GPS PROGRAM AND MSC ORGANIZATION

A. GPS PROGRAM

The Global Positioning System (GPS) is a joint program as directed by DOD. The Air Force is designated as the executive (lead) service. Major participants include the Navy, Army, Marine Corps, Coast Guard, Department of Transportation (DOT), Defense Mapping Agency (DMA), and North Atlantic Treaty Organization (NATO).

GPS has been under development since 1973. The impetus for GPS was the potential for a universal positioning and navigation system which could meet the needs of a broad spectrum of users. Additionally, definite cost savings would accrue by reducing the proliferation of specialized equipment responsive only to particular mission requirements. [Ref. 16]

1. GPS Program Organization

The GPS program is managed by the GPS Program Manager (PM),[6] at the Office of Primary Responsibility (OPR). The PM is assigned to plan, organize, coordinate, control, and direct the GPS program. Currently the GPS PM, a USAF colonel, is also head of the Joint Program Office (JPO) at the USAF Space Division. The JPO organization is one PM, an executive office, six directorates, and seven deputy program managers (DPMs). Personnel from each participating service, agency, and NATO are assigned to directorates and DPMs to coordinate extensive program participation and to facilitate integrated program management (Figure 2-1).

Key agencies and organizational players in the GPS program are:

a. Office of Primary Responsibility (OPR): The PM at the OPR has full management responsibilities including operational/support configuration management and final approval authority for the overall GPS program. The OPR during development of the GPS program and during transition (prior and up to the PMRT[7] date) is the JPO. The OPR becomes the Joint Service System Management Office (JSSMO) after Program Management Responsibility Transfer (PMRT). The JPO (JSSMO after PMRT), is the final approval authority for all proposed changes submitted by the respective services or contractors, or initiated by the OPR.

b. Services Involved: The primary GPS users are the USAF, USA, USN, USMC, DOT, DMA, and NATO. Each user has a DPM assigned who reports to the JPO (JSSMO after PRMT) as described above. [Ref. 17:pp. 33-37]

c. Contractors: Two contractors, Magnavox and Rockwell-Collins, are involved in Phase II full scale development of the GPS user equipment (UE). In early 1985 one of the contractors will be awarded the contract for Phase III production of GPS UE. This will result in three contract management teams, with one team for each major development/acquisition contract. The contracts are associated with the three program segments (space, control system, and user equipment) [Ref. 18:p. 20].

d. Executive Services: The Air Force has been designated as the executive service (single manager) for the GPS program and is responsible for the centralized management and configuration control of GPS hardware and software systems. This is in accordance with DOD

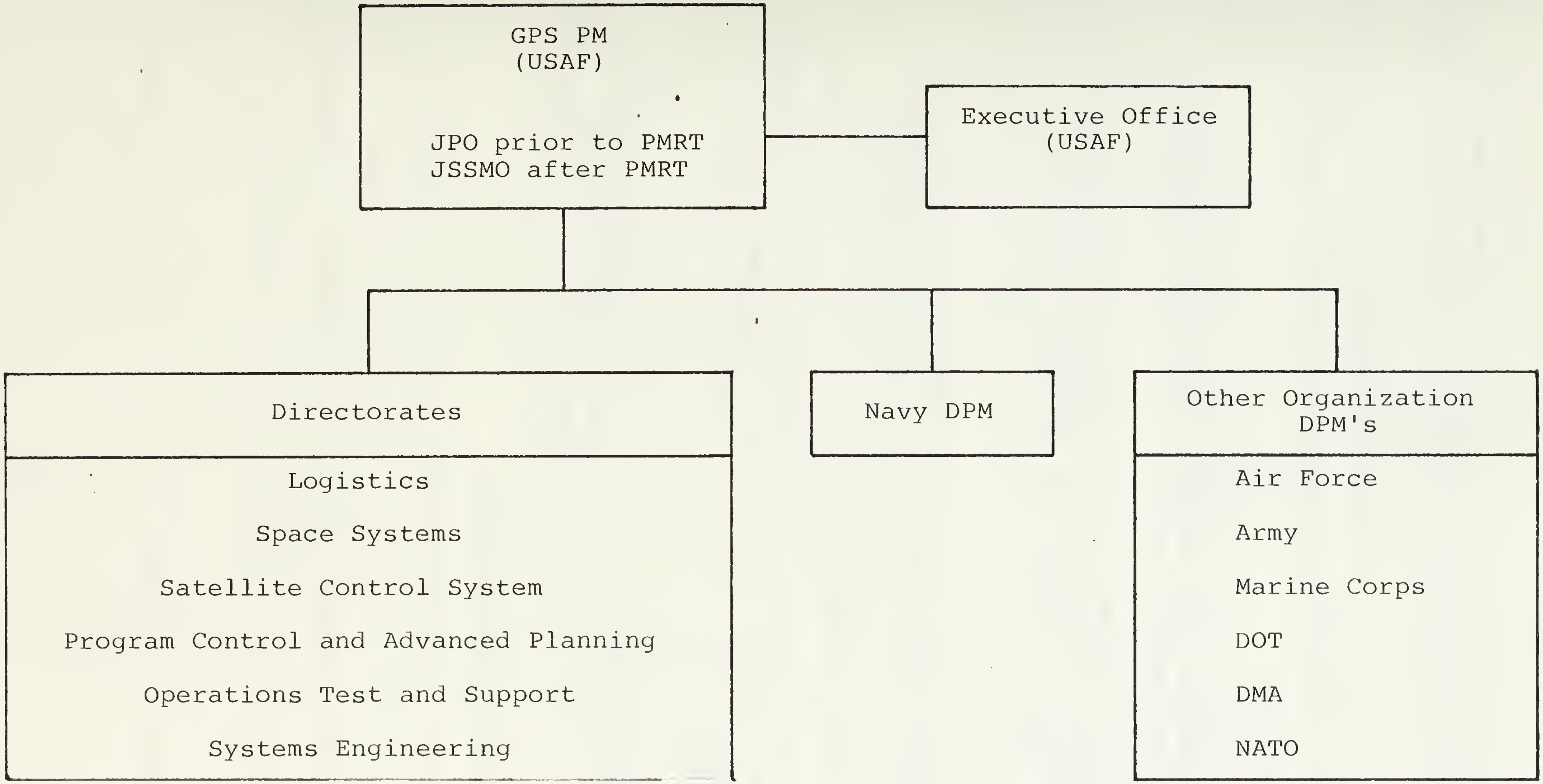


Figure 2-1. GPS Program Organization

single manager policies which direct services to centralize management and configuration control when multi-services are involved.

In addition to the OPR (JPO/JSSMO), major Air Force commands and organizations involved in the GPS program (Figure 2-2) are:

a. Headquarters USAF: Headquarters USAF provides management of GPS computer resources and ensures procedural consistency.

b. Air Force Systems Command (AFSC): AFSC, Andrews Air Force Base, Maryland, is responsible for the development, acquisition, transfer, and turnover of GPS. AFSC has delegated these functions to AFSC/Space Division (SD).

c. AFSC/Space Division (SD): AFSC/SD in Los Angeles, California, was designated as the implementing command. AFSC/SD formed the JPO to manage GPS multi-service involvement and control resources approved for acquisition.

d. Air Force Logistics Command (AFLC): AFLC implements all applicable instructions, regulations, and directives after PMRT (on completion of AFSC turnover).

e. Warner Robbins Air Logistics Center (WRALC): AFLC designated WRALC, located at Robbins AFB in Georgia, as the post-PMRT Systems Manager (SM) of JSSMO. Since GPS is a joint service command, the Navy and Army will have representatives at WRALC. [Ref. 17:pp. 36-37]

2. GPS Program Management

The GPS program management structure (Figure 2-3 depicts a simplified version), provides the framework that allows the PM to effectively run the program with respect to cost, schedule, and performance. Precise information

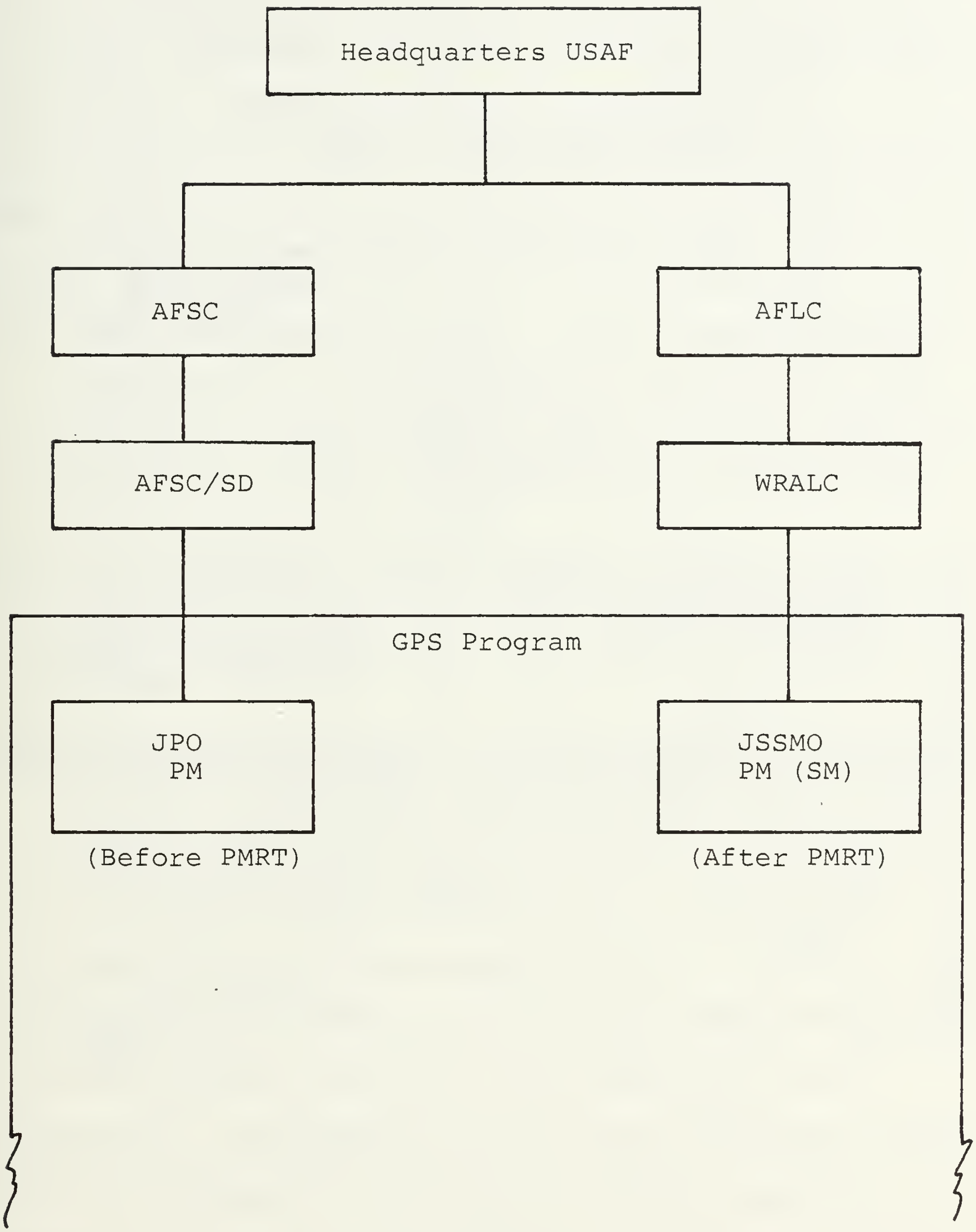


Figure 2-2. Major Air Force Commands and Organizations

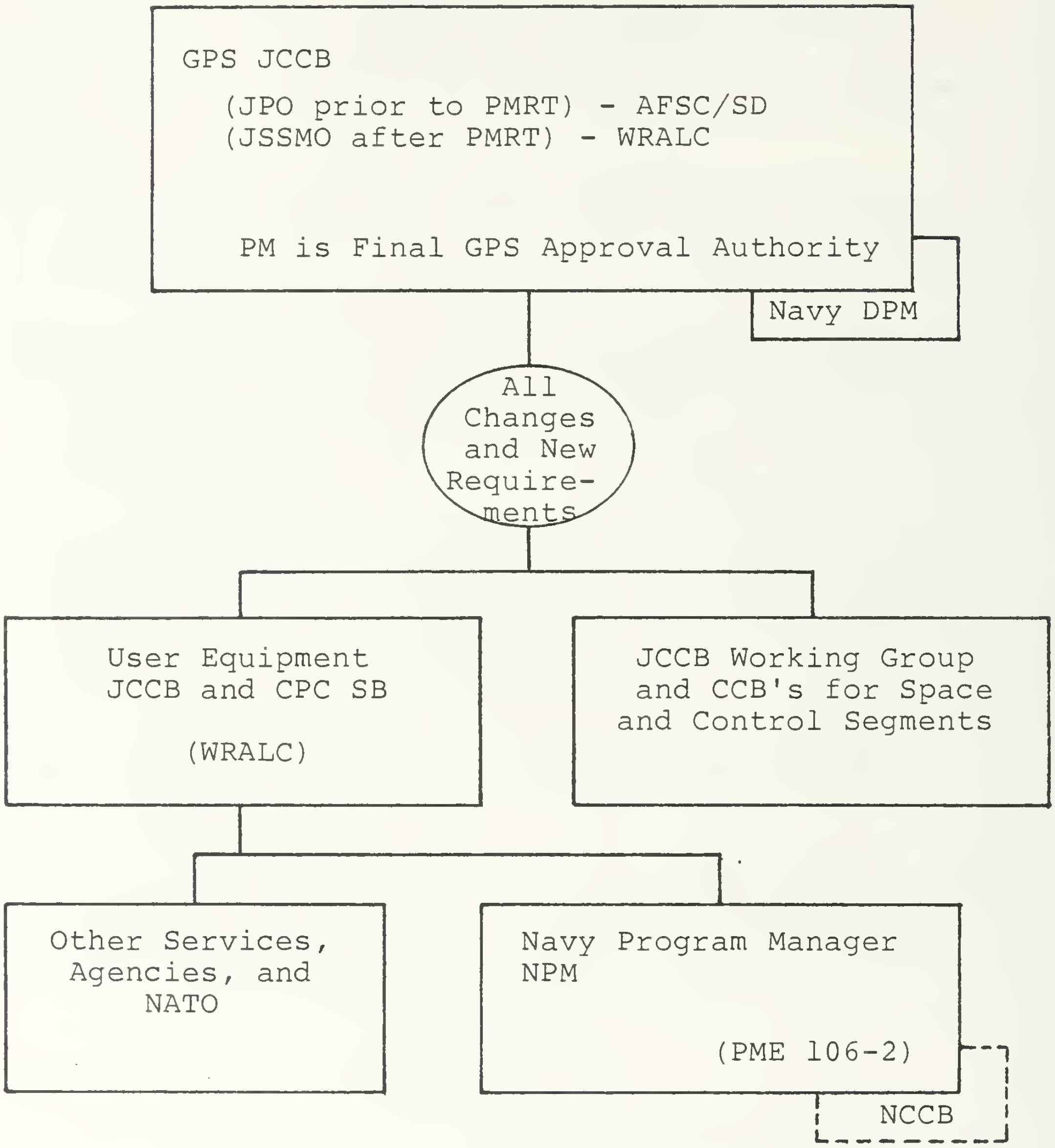


Figure 2-3. GPS Program Management (DOD Common)

related to the interfaces between and within the major system segments is essential to the development process. The overall management of these interfaces, of the system configuration, and of the program life cycle are accomplished through the Joint Configuration Control Board (JCCB), which is composed of members representing all services and agencies.

a. Joint Configuration Control Board: Any changes and any new requirements are presented to the JCCB for consideration. The JCCB, chaired by the PM or his designated representative, is the official agency to act on all changes. Final approval for any change rests with the PM.[8] The JCCB will be located with the PM [Ref. 18:p. 20].

b. User Equipment Joint Configuration Control Board (UE JCCB) and User Equipment Computer Configuration Sub-Board (UE CSSB): These boards approve changes on user equipment which do not impact on the space or the control segments.

c. Navy Program Manager (NPM) (specifically, PME 106-2 for NAVELEX, PME 106): NPM is the single interface between the Navy GPS program management structure and the JPO (specifically, the Navy DPM) prior to PMRT, (JSSMO after PMRT). [Ref. 17:p. 40]

3. Navy GPS Program Relationships

The wide and diverse application of all three types of military GPS UE sets on Navy aircraft, ships, submarines, and ground vehicles involves a wide spectrum of Navy organizations, including the three systems commands (NAVAIR, NAVSEA, and NAVELEX) and the Chief of Naval Material (NAVMAT). The purpose of the Navy GPS program is to ensure commonality and standardization of hardware and software in Navy-unique UE, and to provide support to the Air Force in maintaining commonality and standardization for DOD common UE.

Major Navy GPS program management relations for identifying changes and requirements (Figure 2-4) are:

a. NAVELEX (PME 106): PME 106 has overall responsibility and authority for the Navy GPS program and is responsible for the total Navy acquisition and engineering management of Navy GPS UE.

b. Navy Program Manager (NPM), PME 106-2: PME 106-2 is directly responsible to PME 106 for all GPS matters and interfaces. As described above, PME 106-2 is the interface between the Navy GPS program and the overall DOD GPS program. PME 106-2 is also responsible for Navy technical requirements for Navy GPS UE development and provides Navy technical inputs for GPS UE. After PMRT, PME 106-2 will submit requirements to JSSMO. (Currently, OP-943 submits requirements to the Navy DPM at JPO.) PME 106-2 is assisted technically by the systems commands.

c. Navy Configuration Control Board (NCCB): The NCCB becomes effective at PMRT and will be chaired by PME 106-2. The NCCB will manage Navy requests for changes and new requirements and be responsible for Navy GPS UE configuration management through the life cycle of GPS. [Ref. 17:pp. 37,43,45]

Major Navy GPS program organizational relations to identify funding and installation for military GPS UE on Navy host vehicles are depicted in Figure 2-5 and described below. The example used is for an MSC Maritime Prepositioning Ship (MPS), although currently this ship type is not funded/scheduled in the POM-86 decision package.

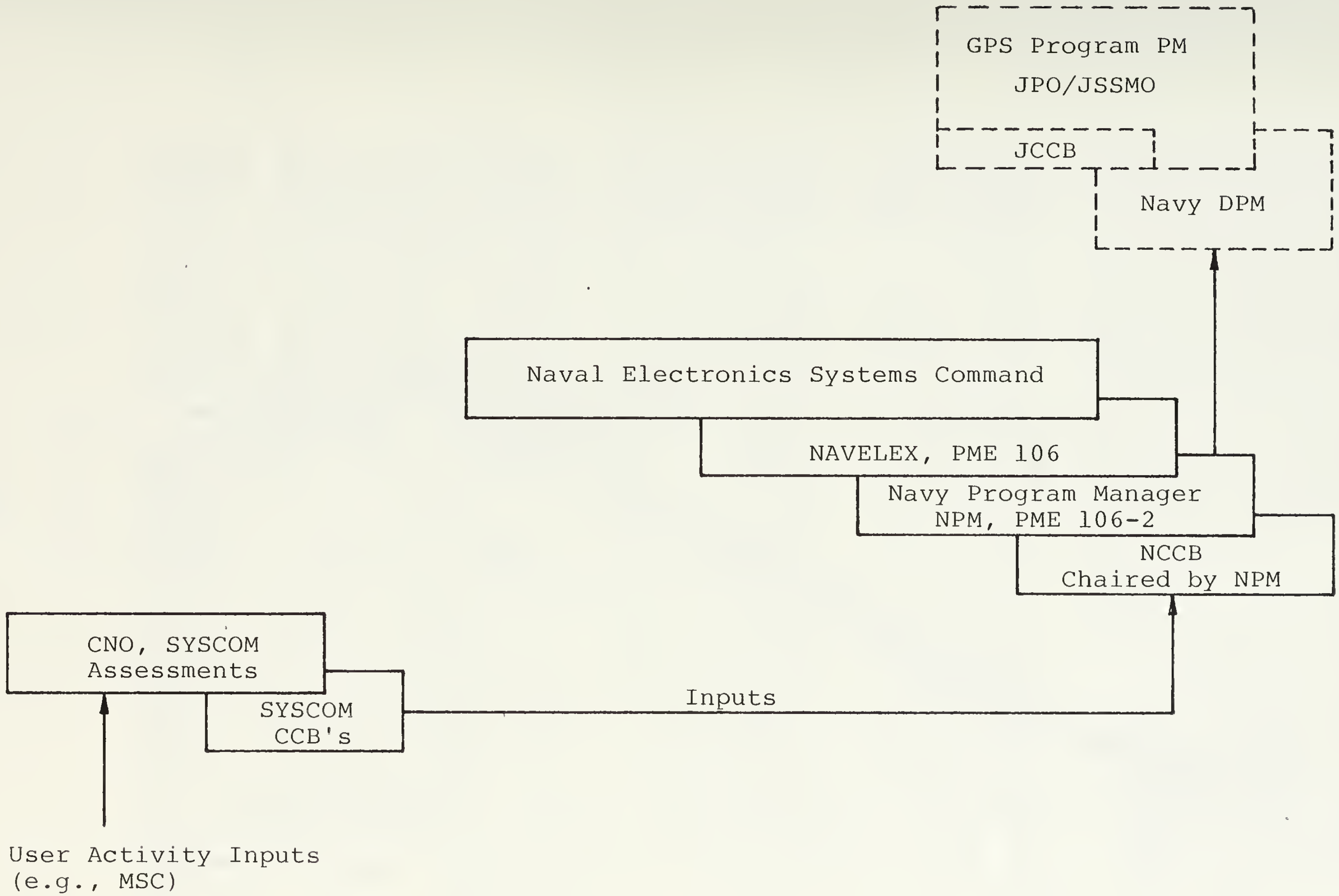


Figure 2-4. Navy GPS Program Management

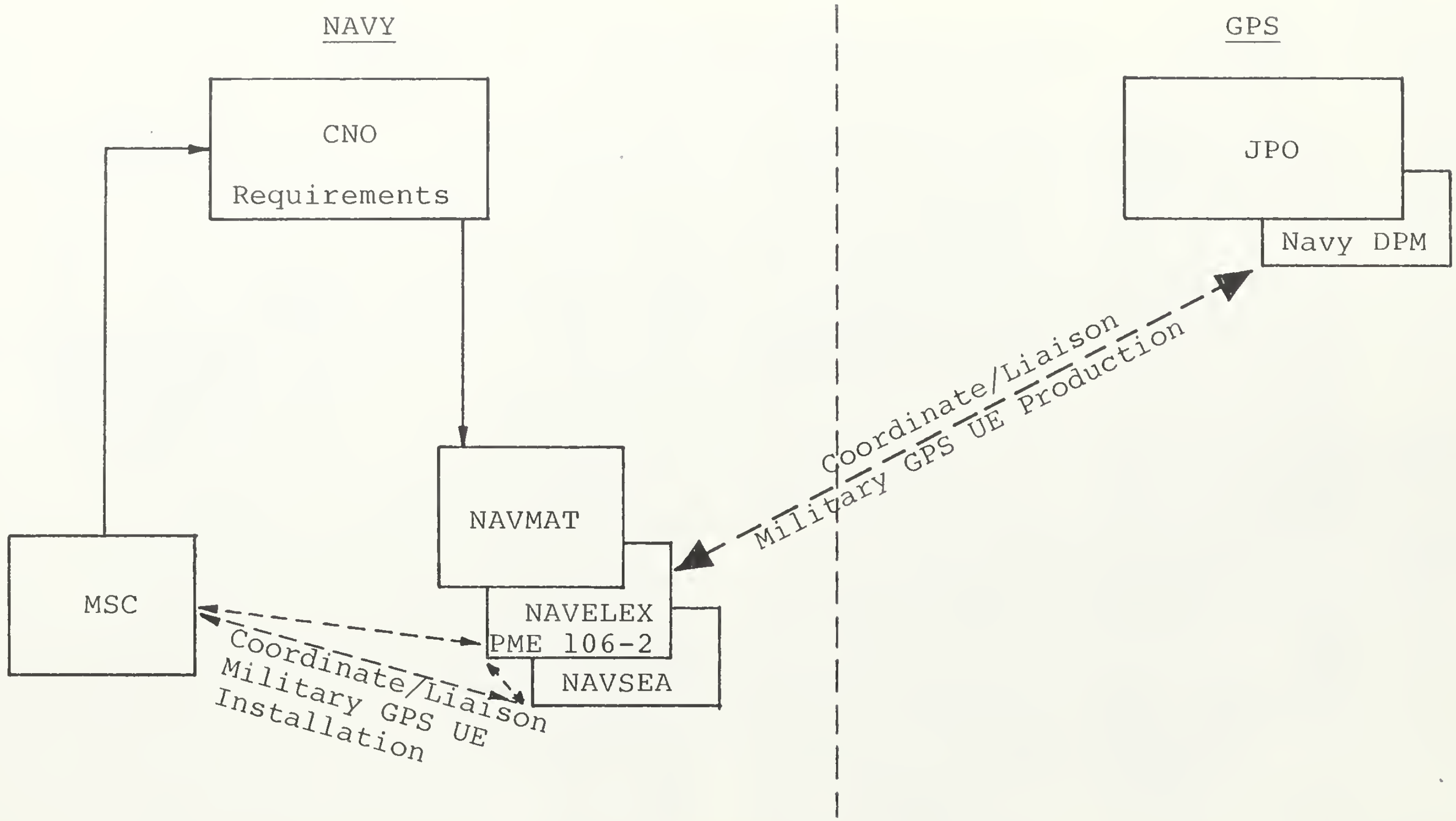


Figure 2-5. Navy GPS Organization Relationships

a. Navy GPS Program Sponsor: The Navy Space Systems Division, OP-943 (under CNO Command and Control, OP-094), is the GPS Program Sponsor for the Navy. Annually, OP-943 requests in writing the program sponsors the number of GPS UE sets needed and the timeframe for UE installation. Current program sponsors include OP-02, OP-03, and OP-05. In this example the program sponsor is OP-04, Deputy Chief of Naval Operations for Logistics).[9] The program sponsors then forward the request to the appropriate platform sponsors. For an MPS the platform sponsor is OP-42, Strategic Sealift Division.

b. Military Sealift Command (MSC) and OP-42: MSC, as a GPS user, and/or Op-42, as the platform sponsor also could initiate the need for military GPS UE. Coordination between CNO and PME 106-2 is needed to identify and determine technical requirements. In any event, the requirements are submitted to the program sponsor (OP-04) who forwards them to OP-95.

c. Office of Naval Warfare, OP-95: OP-95, specifically OP-954 (Strike and Amphibious Warfare Division), approves the need for military GPS UE on the vehicle; validates, consolidates, and prioritizes all requirements; and plans when and how many UE sets should be installed. The information is then forwarded to OP-943. OP-943 plans an initial budget, and forwards requirements and priorities (by ship class) to the Navy DPM at JPO.

d. Navy Deputy Program Manager (Navy DPM): The Navy DPM fits the required number of sets and priorities to the budget constraints. In reality, there is very close liaison between the Navy DPM and PME 106-2, OP-943, and OP-95. The Navy DPM also coordinates requirements with OP-436, the Fleet Modernization Branch of OP-43 (Ships Maintenance and Modernization Division). The end result is the preparation (for PME 106-2) of the POM for military GPS UE funding and installation which is forwarded to and then submitted by CNO in the budget process. The Navy DPM also coordinates Navy production requirements of military GPS UE sets.

e. NAVSEA and PME 106-2: After the POM is approved, funds are provided to NAVSEA and PME 106-2 (via the CNO sponsor and NAVMAT) for installation of equipment onto the MSC ship. NAVSEA is responsible for the installation on ships. The first installation in a class of ships is given final testing by NAVSEA and PME 106-2. PME 106-2 orders, via the contract let by JPO, UE sets from the contractor after the sets have been produced. There is close coordination between NAVSEA, PME 106-2, and MSC for the installation process.

4. GPS Program Schedule and Status

GPS program development is divided into three successive phases. Phase I (concept validation), from 1973 to 1979, validated system performance and feasibility. Emphasis was placed on designing modular hardware and software to reduce development costs, and on using common components in different host vehicle categories [Ref. 4:p. 3]. During Phase I, four U.S. contractors developed and demonstrated GPS UE sets for development, test, and evaluation (DT&E) [Ref. 18:pp. 4,69].

Phase II (full scale development (FSD)), currently underway, is scheduled for completion during the fourth QTR CY 1985 [Ref. 5]. Phase II verifies the operational effectiveness of the GPS concept for both military and civilian users and validates UE design [Ref. 17:p. 146]. At the beginning of Phase II, two contractors (Magnavox and Rockwell-Collins) were selected to competitively develop GPS UE for a group of host vehicles designated by JPO for DT&E and initial operation test and evaluation (IOT&E) activities which began in 1982. The UE sets developed by both contractors were tested in landbased, seaborne, and airborne platforms. [Ref. 18:p. 22]

The Request for Proposal (RFP), released 17 August 1984, is the anticipated production buy for the first five years with a first year contract, and four production options. The contract, estimated at $1 billion, will be a fixed price incentive fee (FPIF) contract. The results of the DT&E/IOT&E testing as well as cost, 'producibility,' and support considerations will lead to the selection of one prime contractor. Source selection is now in progress. JPO expects to award the contract during the first QTR in CY 1985. [Ref. 16]

Full scale production of military GPS UE begins in Phase III. A leader-follower(s) concept of procurement is planned with the leader qualifying a second production source(s) after the first production contract award [Ref. p. 4]. This will provide both contractors the opportunity to develop GPS UE production sets on a cost competitive basis. JPO currently anticipates purchasing approximately 23,400 GPS UE sets [Ref. 5].

Follow-on test and evaluation (FOT&E) will be completed prior to installation of user equipment [Ref. 4:p. 4]. UE sets produced during Phase III will be installed on host vehicles on a prioritized basis

[Ref. 18:p. 18]. Installation of production GPS UE sets on military host vehicles will begin in 1986 and continue through the 1990's [Ref. 18:p. 4]. U.S. Navy ships are scheduled for installation beginning in 1987 [Ref. 1].

During Phase III, production satellites will be launched from the space shuttle starting in 1986 [Ref. 20:p. 1187]. A ten to twelve satellite constellation is planned for late 1987 providing two dimensional coverage. The full eighteen satellite constellation, providing three dimensional coverage, should be operational in 1989. [Ref. 21:p. 74]

In summary, the three phased development and deployment of the GPS is an evolutionary process. Each step provides extensive legacy value for the next step. Throughout this process, system level testing will be accomplished in order to insure optimum system operation [Ref. 4:p. 4].

B. MILITARY SEALIFT COMMAND (MSC)

MSC, a U.S. Navy command with fleet status, provides sealift.[10] Additionally, MSC is the Navy Operating Agency for ocean transportation under the Secretary of the Navy (SECNAV), who is DOD's single manager for ocean transportation [Ref. 22:p. 5]. MSC also sponsors naval control of shipping and convoy commodore staff naval reserve units for the Naval Control of Shipping Organization (NCSORG).[11] MSC operates in direct support of DOD programs. In time of war, MSC shipping will be dictated by world conditions and urgency of transportation requirements. [Ref. 23:p. 1, para 5]

1. Organization

The MSC commander reports to the Chief of Naval Operations (CNO) through the Strategic Sealift Division (OP-42), recently established in 1984. OP-42, as part of the Office of the Deputy Chief of Naval Operations (DCNO) for Logistics (OP-04), develops policy and provides planning support on matters concerning strategic mobility, sealift, and maritime affairs. OP-42 is the primary focal point for MSC on the CNO staff and within the Navy concerning sealift matters. [Ref. 11:p. 7] Additionally, OP-42 is the primary interface with the Maritime Administration (MARAD) and the merchant marine industry [Ref. 24].

Dual-hatted as Assistant to Chief of Naval Operations for Naval Control of Shipping (OP-06N), the MSC commander reports to DCNO of Plans, Policy and Operations (OP-06). In matters concerning procurement policy or contracting for ships and transportation systems, and in financial matters, the MSC commander reports to the

Assistant Secretary of the Navy for Manpower, Installation, and Logistics (ASN MI&L), and to the Assistant Secretary of the Navy for Financial Management (ASN FM) (see Figure 2-6).

MSC is a world-wide organization with command headquarters in Washington, DC. There are four area commands: Yokohama, Japan; Oakland, California; Bayonne, New Jersey; and Bremerhaven, Germany (Bremerhaven will relocate to London (Eastcote), England in 1985 [Ref. 26:p. 2]); and three smaller sub-area commands (Naples, Italy; Subic Bay, Republic of the Philippines; and New Orleans, Louisiana). Additionally, offices, small units, and representatives are located wherever sealift traffic requires (over 50 other ports in 1982) [Ref. 27:p. 2]. Command manpower strength in 1984 is approximately 9100 (1600 personnel ashore, 7500 personnel afloat) [Ref. 28:p. 2].

2. Sealift and Mission

Strategic sealift is the fastest growing segment of the Navy budget, reflecting its importance to national defense. The 1984 Navy budget for sealift (other than for cargo shipment) was twice as much as in 1981 and 1982 combined [Ref. 22:p. 5]. The current sealift budget is $1 billion [Ref. 24].

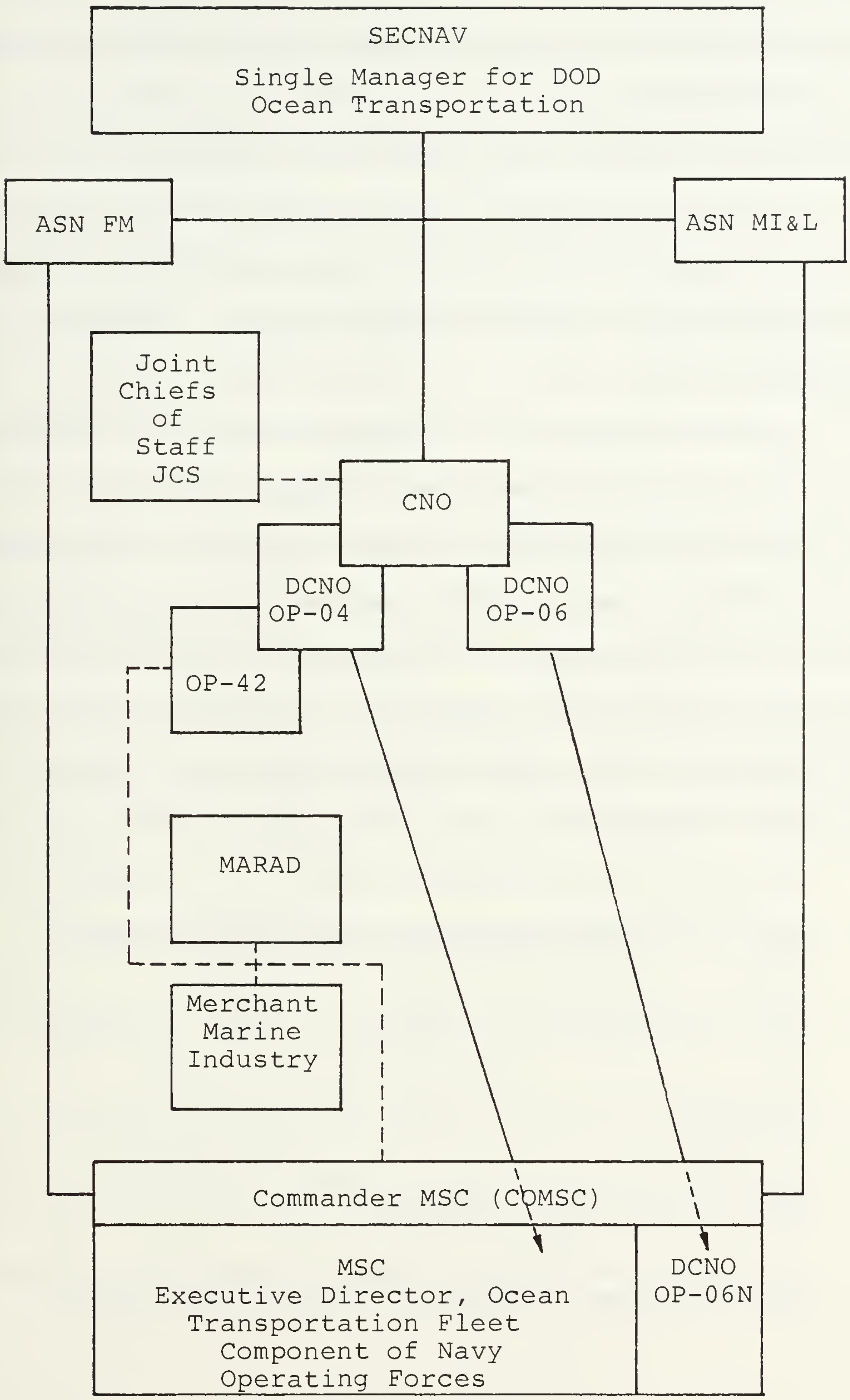


Figure 2-6. MSC Organizational Relationships

Until 1979, MSC had been considered a peacetime ocean transportation command which carried cargo primarily for peacetime DOD logistic support.[13] If needed in a contingency, sealift was assumed to be available [Ref. 12:p. 37]. However, several events[14,15] in the 1970's demonstrated the need for more adequate strategic lift capabilities. Today, the emphasis is clearly on strategic sealift.

As a result of the increased emphasis on sealift, MSC's mission is "to provide the sealift capability to deploy and sustain military forces anywhere in the world as rapidly, and as long as operation requirements dictate, in support of national security objectives" [Ref. 28:p. 1]. Basically, this mission emphasizes strategic mobility and contingency sealift as MSC's primary mission, whereas formerly, the emphasis was on peacetime sealift.

MSC has five responsibilities:

a. to provide contingency and mobilization sealift support to military forces world-wide.

b. to provide peacetime logistical sealift support to military forces world-wide.

c. to develop plans and capabilities for emergency expansion.

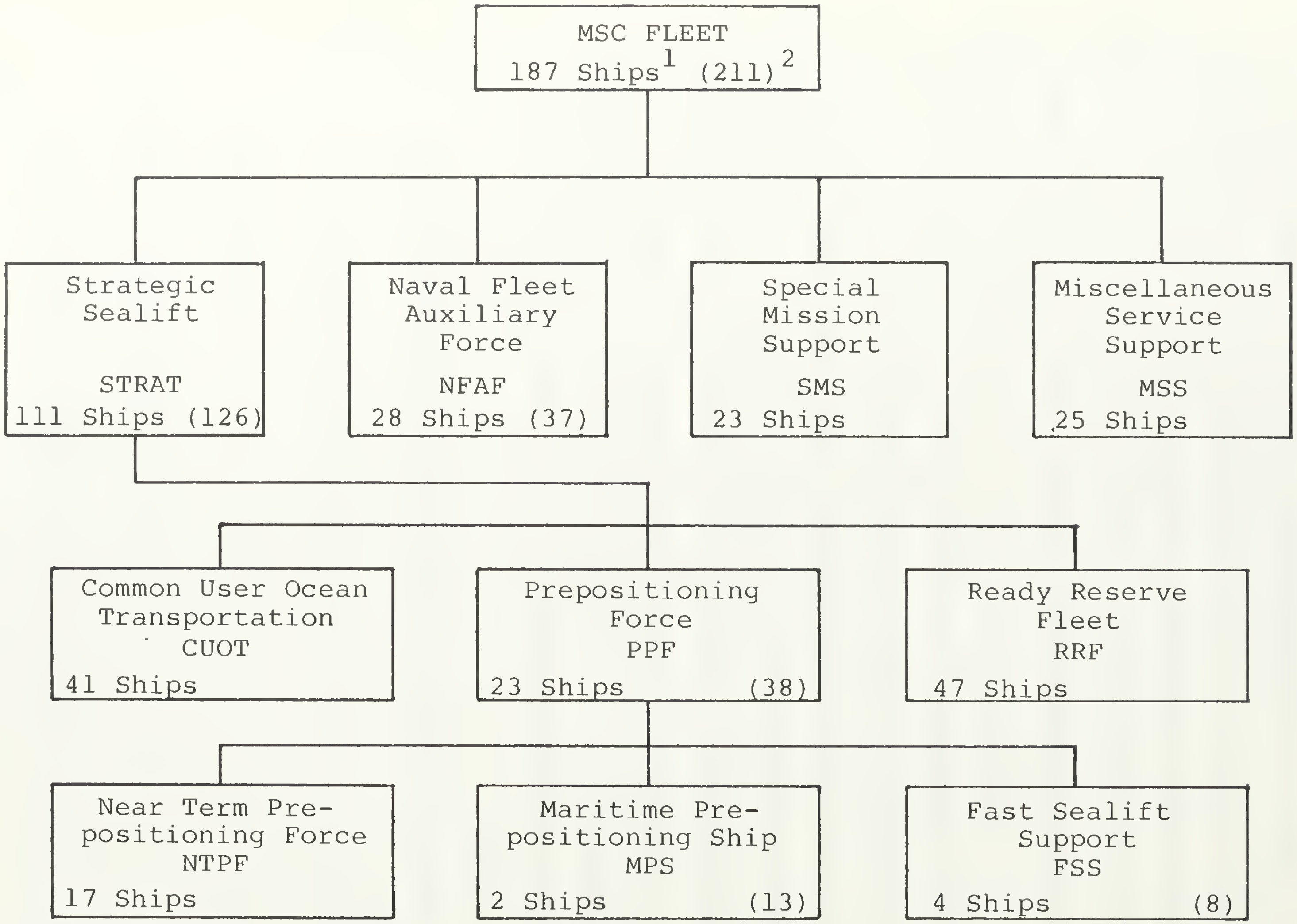
d. to operate fleet auxiliary force ships for the U.S. Navy in both peace and war.

e. to provide and operate ships for special transportation purposes (primarily scientific support).

These responsibilities demand a capability and capacity to deploy and sustain military forces whenever and wherever needed, as rapidly and as long as operational requirements dictate. MSC ship groups (described in the following section) carrying out the strategic sealift mission are the Strategic Sealift (STRAT) ships, Naval Fleet Auxiliary Force (NFAF), and Special Mission Support (SMS) ships. MSC peacetime operations include the movement of DOD cargo, providing direct support to the Navy combatant fleet or special mission support, maintaining afloat prepositioning forces on station, and participating in strategic mobility exercises. All of these operations contribute directly to maintain readiness for the primary mission. In addition to the three ship groups above, a fourth ship group, the Miscellaneous Service Support (MSS) ships carry out the peacetime role. [Ref. 11:pp. 1-3]

3. Ships

The MSC Fleet[16] is organized (Figure 2-7) as follows:



Note: 1. Number of active and reserve ships.
2. Numbers in parentheses indicate total number of ships carried in MSC Fleet Inventory as of 19 October 1984. Includes active, reserve, and selected ships under new construction/conversion program.

Figure 2-7. MSC Fleet Organization [Ref. 2]

Strategic Sealift (STRAT)

Common User Ocean Transportation (CUOT)

Prepositioning Force (PPF)
Near Term Prepositioning Force (NTPF)
Maritime Prepositioning Ship (MPS)
Fast Sealift Support (FSS)

Ready Reserve Force (RRF)[17]

Naval Fleet Auxiliary Force (NFAF)

Special Mission Support (SMS)

Miscellaneous Service Support (MSS)

As seen above and in Figures 2-7 and 2-8, ships in the MSC Fleet fall into one of four functional ship groups: STRATT, NFAF, SMS, or MSS. The STRAT ship group is composed of three sub-groups: CUOT, PPF, and RRF. In turn, the PPF is further divided into: NTPF, MPS, FSS, and RRF. [Ref. 2]

Each of the four ship groups (and sub-groups) is described below. The order of discussion follows the order of the ships given above.

a. Strategic Sealift (STRAT) Ships

STRAT ships are sponsored by OP-42. Almost all are manned with contract-operated civil (commercial) merchant marine crews and, except where indicated, have no military contingent on board. STRAT ships are composed of (see Figure 2-9):

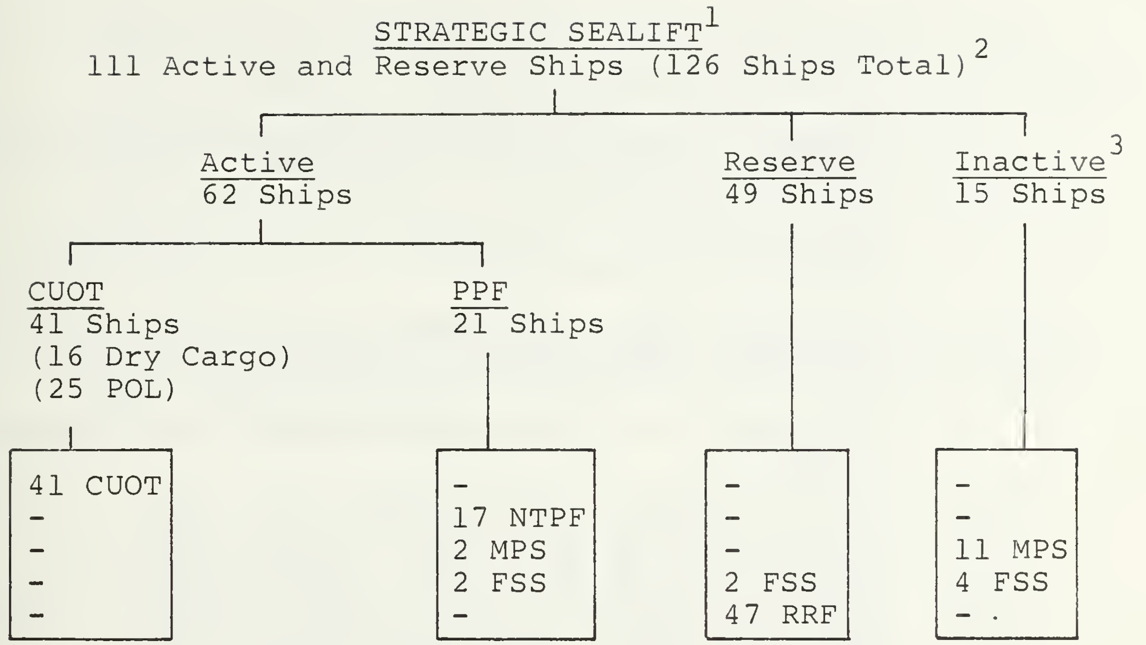
• FUNCTIONAL SHIP GROUPS	Active and Reserve Ships	Inactive Under Construction/ Conversion	Grand Total
1. Strategic Sealift (STRAT)			
Common User Ocean Transportation:			
Dry Cargo	16	-	16
POL[1]	25	-	25
Prepositioning Force (PPF):			
Near Term Prepositioning Force (NTPF)	17	-	17
Maritime Prepositioning Ship (MPS)	2	11	13
Fast Sealift Support (FSS)	4	4	8
Ready Reserve Force (RRF)	47	-	47
TOTAL STRAT	111	15	126
2. Naval Fleet Auxiliary Force (NFAF)	28	9 (T-AGOS)	37
3. Special Mission Support (SMS)	23	-	23
4. Miscellaneous Service Support (MSS)	25	-	25
TOTALS	187	24	211

• MSC FLEET[2] (Summary)

Active and Reserve Ships:	187 ships
Inactive (Under Construction/Conversion):	24 ships
Total MSC Fleet Inventory:[2]	211 ships

NOTES: 1. All are tankers except for one: Barge Hanna.
2. As of 19 October 1984.

Figure 2-8. MSC Fleet Inventory (Functional Ship Groups) [Ref. 2]



Ships by Assignment:	USNS[4]	Chartered[5]	MARAD Custody
41 CUOT	17 CUOT	24 CUOT	-
17 NTPF	3 NTPF	14 NTPF	-
(13) MPS	-	(13) MPS	-
(8) FSS	(8) FSS	-	-
47 RRF	-	-	47 RRF[6]

Active and Reserve USNS: 24 Ships
Total USNS (28 Ships)

Active and Reserve Charters: 40 Ships
Total Charters (51 Ships)

Reserve Ships MARAD Asset (Commercially Operated) 47 Ships

TOTAL non-USNS Ships 83 Ships (94 Ships)

MSC Controlled Ships[7] 64 Ships (79 Ships)

<u>Active and Reserve Strategic Sealift</u> 111 Ships
<u>TOTAL STRATEGIC SEALIFT</u> (126 Ships)

Figure 2-9. MSC Strategic Sealift Ship Group [Ref. 2]

NOTES:

1. As of 19 October 1984.
2. Numbers in parentheses include active, reserve, and inactive ships.
3. Inactive ships are currently undergoing new construction/conversion.
4. Includes government owned ships and bare boat charters. See Appendix A.
5. Chartered less bare boat charters. See Appendices A and B.
6. Ships are MARAD owned except for four ships which are Navy owned, MSC assets in MARAD custody. When activated (and under MSC's control), ships are commercially operated except for seven ships which are operated under the General Agency Agreement (GAA). See Appendix A.
7. Plus activated RRF ships.

Figure 2-9 (Continued)

a. Common User Ocean Transportation (CUOT): CUOT consists of 16 common user dry cargo ships and 25 tankers. Normally providing point-to-point service for DOD logistic requirements, these ships are assigned to strategic sealift requirements when needed. Ships are either under time charter to MSC, bareboat chartered,[18] or government owned. CUOT ships are under operational and administrative control of MSC.

b. Prepositioning Force (PPF): The PPF provides afloat maritime prepositioning and fast sealift. The PPF is under operational and administrative control of MSC. PPF is composed of:

   (1) Near Term Prepositioning Force (NTPF). Since 1980, the NTPF has been deployed in the Indian Ocean (Diego Garcia) to provide maritime prepositioning. Essentially, 17 ships are mobile storage depots with a 12-hour underway requirement. Loaded with equipment, munitions, fuel, and water for the Rapid Deployment Force, their location is near potential trouble areas. The NTPF fills the short-term need for maritime prepositioning. In the 1985-1986 timeframe, the NTPF will be replaced by MPS ships [Ref. 30:p. 739]. All ships in the NTPF are chartered or bareboat chartered ships. A small military staff is aboard the flag ship. Additionally, three ships carry Navy communications vans.

   (2) Maritime Prepositioning Ship (MPS). Thirteen MPS ships will be divided into three squadrons of four, four, and five ships to provide the permanent maritime prepositioning afloat in different locations around the world. Each squadron will have a flag ship with a small Navy staff and detachment, and secure communication capability. A second ship will be designated and equipped as the alternate flag ship [Ref. 31]. Two ships have been delivered; 11 are being built or converted to roll-on/roll-off (RORO) capability. After delivery, the MPS ships will be under long-term charter to MSC. With a stern loading ramp and lighterage for over-the-beach operations, an MPS can unload cargo across the shore in up to 50-knot winds and 3-knot currents. In this way, all cargo can be discharged within

five days. Using a pier, all vehicles can be unloaded within 12 hours, and all cargo within 72 hours. [Ref. 29:p. 38]

(3) Fast Sealift Support (FSS) ships. The FSS ships provide rapid-response sealift capability. At 33-knots, they are the fastest ships in the U.S. Merchant Marine. Sailing time is approximately five days to Europe or two weeks to the Persian Gulf via the Suez Canal. Of eight ships, four have been delivered, and four are undergoing conversion to combination RORO/container ships. The majority of cargo to support one Army mechanized or armored division can be loaded or offloaded in a single day. [Ref. 11:p. 5] The FSS ships will be anchored in a reduced operating status (ROS) in coastal ports near the equipment they will lift. FSS ships will be underway fully loaded in five days (ROS 5) when directed. [Ref. 27:p. 9] FSS's are government owned and charter operated. FSS ships do not have secure communications capability. However, a military detachment is on board during deployment to accompany super-cargo. [Ref. 32]

c. Ready Reserve Force (RRF): The RRF consists of 47 ships which are owned by the Maritime Administration (MARAD).[19] In three locations, they are a reserve status with a reduced operational status (ROS) of either ROS 5 days or ROS 5 to 10 days. When activated, an RRF ship is under operational control of MSC. A program is underway to upgrade the capabilities of the RRF [Ref. 33].

b. Naval Fleet Auxiliary Force (NFAF)

NFAF ships provide direct logistic support to Navy fleet ships at sea. They are Navy owned and are registered naval vessels. The NFAF ships are part of the Navy's total Mobile Logistics Support Force (MLSF). They are assigned to either the Atlantic Fleet or Pacific Fleet for operational control, and are sponsored by OP-03.

Administrative control is by MSC. The ships are manned and operated by MSC Civil Service (Government) Merchant Mariners (MSC/CIVMAR). Additionally, NFAF ships have a small military contingent on board. Currently, 28 NFAF ships (plus nine ships being constructed) are carried in the MSC fleet inventory.

c. Special Mission Support (SMS)

Twenty-three SMS ships provide special transportation for their sponsors.[20] In support of special needs (primarily scientific research, cable laying and repair, missile tracking, and surveillance) of DOD agencies. They are like NFAF ships in terms of ownership, manning, and naval registration. Operational and administrative control is by MSC. Most ships have a small military contingent on board. If SMS assets were required, for example, in a contingency or strategic sealift requirement, for all practical purposes the SMS ships' normal operations would cease, and the crews would be reassigned to perform the required strategic sealift mission [Ref. 11:p. 3].

d. Miscellaneous Service Support (MSS) ships

The 25 ships and service craft in the MSS provide various types of support (such as fuel and coal delivery, downrange support, scuba diving platforms, tug boat, target towing, and boat services) to various DOD sponsors.[21] Except for four Navy owned pusher boats which provide boat service to the NTPF in Diego Garcia, all MSS ships are either time or voyage[22] chartered. Operational and administrative control is by MSC. Manning is by civil (commercial) merchant mariners and no military contingents are on board. Vessels and boats in the MSS are not considered suitable for strategic sealift [Ref. 34].

FOOTNOTES FOR CHAPTER II

[6]Program Manager (PM) is also referred to as System Manager (SM).

[7]PMRT, Program Management Responsibility Transfer, is the transition of overall program management responsibilities from the implementating office, AFSC/JPO, to the operational office, AFLC/JSSMO. The objective of PRMT is to accomplish an orderly, timely, and efficient transfer of program and functional responsibility. At PMRT, certain inter-relationships and functional responsibilities of the executive and supporting services change or become effective. For the Navy, the major effect by PMRT is the change for final approval authority from JPO to JSSMO. PMRT occurs during Phase III. PMRT is scheduled to occur in 1987. [Ref. 17:pp. 33,38,44]

[8]Changes beyond the scope of the JCCB's authority require approval from the Office of the Secretary of Defense (OSD) (for example, for changes to the program's mission element or program cost) or approval from the DOD component (for example, changes to the flexible modular interface (FMI) unit) [Ref. 17:p. 38].

[9]It should be noted that OP-04 is not currently on distribution for OP-943's letter [Ref. 15]. To be included on distribution OP-04, identifies the need for military GPS UE to OP-943 via the Office of Naval Warfare OP-95, specifically, the Force Level Plans Division, OP-950 [Ref. 5].

[10]In accordance with national security objectives, MSC provides sealift capability to support the Unites States' forward military strategy. This strategy uses oceans as avenues to engage an enemy as far forward (away from U.S. borders) as possible. It is heavily dependent on the capability to project U.S. combat power overseas. Successful deployment and sustainment of power, in turn, are transportation dependent. Over 90 per cent of all combat cargo to be moved must go by sea. [Ref. 25:p. 1]

[11]NSCORG is a reserve-manned organization responsible world-wide to fleet commanders for the routing and control of allied merchant ships during mobilizations and military contingencies [Ref. 11:p. 6].

[12]Strategic sealift is afloat prepositioning and sea movement of cargo in response to DOD strategic mobility and logistic support requirements. Cargo includes material, POL (petroleum, oil, and lubricants), and when requested, passengers. [Ref. 11:p. 2]

[13]Actually, the value of prepositioning cargo and of rapid deployment capability was realized prior to and during the Vietnam War [Ref. 29:p. 37]. However, no organization was willing to shoulder responsibility. Also, differing perceptions prevailed. The end result was that MSC remained a peacetime operation. For example, the Joint Chiefs of Staff (JCS), CNO, MSC commanders, and elements of Congress had been advocating readiness aspects of sealift, but opposing views were held by DOD's Office of Manpower, Reserve Affairs, and Logistics (MRA&L), and the House Appropriations Committee who focused on peacetime needs, economy, and efficiency. By 1981, the Navy finally accepted its responsibility for sealift rather than viewing the mission and MSC as competitors for Navy funds. [Ref. 12:pp. 36-38]

[14]Specifically, the 1973 Arab-Israeli War required a U.S. airlift. The 1974 Arab oil embargo, 1979 Soviet invasion of Afghanistan, and Soviet military buildup along the Iranian border emphasized the vital importance of the Persian Gulf. [Ref. 29:p. 37]

[15]The August 1979 Defense Guidance proposed prepositioning supplies to increase responsiveness of forces in rapid deployment. By January 1980, the Maritime Prepositioning Ship (MPS) concept had been developed. Meanwhile, the Soviet invasion of Afghanistan dictated an immediate need for an MPS-like capability in the Indian Ocean. As a result, the first near term prepositioning ships deployed for the Indian Ocean in July 1980. Expanding a year later, the program became known as the Near Term Prepositioning Force (NTPF). [Ref. 29:p. 38] By August 1982, the program had grown from the original seven ships to seventeen ships.

[16]Ships in the MSC Fleet are categorized and discussed either by: (a) functional group (which is used in the MSC fleet inventory [Ref. 2] and in this thesis), or (b) ship designation and ownership (information is provided in Appendix A).

[17]The RRF is a Maritime Administration (MARAD) asset. When activated, a ship is under control of MSC.

[18]See Appendix B for types of charters.

[19]A few (e.g., two to four) ships, ex-USNS ships, are Navy owned (MSC asset) in MARAD's custody [Ref. 2].

[20]Sponsors include NAVOCEANCOM, NAVELEXSYSCOM, NAVSEA, ESMC, LANTFLT, and DIRSSP [Ref. 2].

[21]Various DOD components which are sponsors include NAVSUP, Pacific Missile Test Center, Naval Civil Engineering Lab, NOSC, NORDA, DOD, DOE, NAVLOGPAC, TRALANT, the David Taylor Naval Ship Research and Development Center (DTNSRDC), and MSC [Ref. 2].

[22]See Appendix B for types of charters.

III. GPS SYSTEM DESCRIPTION AND USER EQUIPMENT (UE)

Like LORAN and TRANSIT, GPS is being developed as a military navigation system. However, unlike earlier systems such as TRANSIT which was kept highly classified until well after the system became operational, Global Positioning System (GPS) aspects and applications are being openly and actively discussed by civil as well as military communities. [Ref. 35:p. 2][23] The operational GPS will provide two navigation services: the precise positioning service (PPS) and the standard positioning service (SPS).[24] Horizontal predictable and repeatable accuracy is approximately 18.1 meters (2 drms[25]), currently 100 meters (2 drms) for PPS and SPS respectively. Horizontal relative accuracy is 10 meters (2 drms) for both PPS and SPS. [Refs. 9:p. 34;36:p. 22]

A. GPS SEGMENTS

GPS consists of three major segments: the space segment, control segment, and user equipment segment. The space segment is used by both military and civilian users. Each community uses its own user equipment.

The space segment includes a navigation package and an integrated operational nuclear detonation detection system.

When fully operational, this segment consists of eighteen satellites[26] (plus spares) in six circular orbits 10,898 nautical miles above earth. The high altitude and precise satellite spacing is such that a minimum of four satellites will always be in view to the user, thereby ensuring continuous world-wide coverage without distortion. During Phase III, production satellites will be launched from the space shuttle. The projected launch schedule will produce a twelve satellite constellation by the end of 1987. Full GPS operation, with an eighteen satellite constellation, is scheduled for 1989 [Ref. 37:p. 45].

The control segment consists of a master control station, ground control and antenna stations, monitor stations, and an alternate control center. The control segment maintains control and accuracy of the satellite network. While passively tracking satellites in view, the control segment collects orbit and ranging data. The information is then processed, updated, and uploaded back to the satellites. [Ref. 39:p. 2] Initial availability of the operational control segment is scheduled for January 1985. Full operation is scheduled in 1987. [Ref. 5]

The user segment consists of user equipment (UE). GPS UE is designed to first acquire satellites, and then receive and process data from four satellites either sequentially or simultaneously. After acquiring the satellites, the UE measures the relative delays between two frequencies transmitted from each satellite. This allows computation of signal delay. Then, using navigation signals from each of four satellites, the UE (specifically the RPU) measures four independent pseudorange rates with respect to the satellites. The UE then converts this information, which is the user's velocity and range with respect to each satellite, into three-dimensional position, velocity, and system time.

Because the position solution is referenced to a common grid, the World Geodetic System 1972 (WGS-72), civil and military position data can be standardized on a world-wide basis. UE can transform navigation information into other commonly used datums as well. [Ref. 40:p. 4] Military and commercial GPS UE are described below.

B. MILITARY GPS UE

The capability feature of military GPS UE is accessibility to both levels of accuracy, PPS and SPS, provided by the operational GPS satellites.

Military GPS UE is designed for maximum commonality and interchangeability at the module level. The use of common modules or components is consistent with the overall GPS program strategy to reduce life cycle cost while satisfying a large range of host vehicles having various navigation requirements and operating dynamics. A military user equipment set is an appropriate combination of four major components: the antenna, receiver processor unit (RPU), flexible modular interface (FMI) unit, and control display unit (CDU). (Appendix C describes military GPS UE set components.) While not part of the UE set per se, hardware such as racks and cabling complete the items which would be installed. Each component or line replaceable unit (LRU) is designed for use on multiple host platforms. The integration of military GPS UE on Navy platforms will be achieved by selecting the appropriate combination of LRUs necessary to meet individual platform requirements. [Ref. 39:p. 8]

UE sets are designed for usage in a wide variety of host vehicles. Three types of UE sets, distinguished by the type of RPU used, have been developed and can be classified as Low Dynamic (LD), Medium Dynamic (MD), and High Dynamic (HD) sets. While the RPU is the same for each set type (e.g., the same RPU is used in all two-channel MD sets), other LRU elements can be substituted to meet specific host requirements.

The one-channel LD set is intended for men (e.g., foot soldiers) and vehicles (e.g., jeeps, tanks, riverine vehicles). The two-channel MD set is intended for surface ships, helicopters, and medium performance aircraft (e.g., reconnaissance, transport and tanker aircraft). The five-channel HD set is intended for submarine (SSN/SSBN) and high performance aircraft (e.g., attack, fighter, and strategic aircraft). This set will normally be used in a vehicle operating in a high dynamic and/or high jamming environment, or in a vehicle where fast acquisition of GPS signals is required. While the GPS UE set types are intended for the vehicles just described, specific host requirements and utilization dictate the GPS UE set and design to be provided. [Ref. 18:pp. 26,27] UE set performance and physical characteristics, navigation modes, operating states, and design features are summarized concisely in Reference 18 on pages 32-43 and 52-53. UE set environmental design, maintenance support concept, reliability and maintainability, and UE set interface are discussed in Reference 18 on pages 54-63.

In addition to component part commonality, military GPS UE is designed to provide worst-case capability in terms of use, environment and exposure to threat. Primary hostile environment threats include jamming, spoofing, electromagnetic pulse (EMP) bursts, and nuclear events. While some degree of hardening and shielding is incorporated in all military GPS UE, the degree to which the host vehicle is likely to require protection determines how much protection is provided.

C. COMMERCIAL GPS UE

While development of commercial GPS UE is outside the scope of DOD joint program development for GPS space, control, and military UE segments, DOD does determine the accuracy capability which will be available to civil users of GPS. Four DOD policy issues are applicable and important to navigators using commercial GPS UE. The policy issues are PPS access, SPS accuracy, SPS availability, and user charges.

DOD plans to restrict access to PPS by encrypting the P-code signal, which provides PPS accuracy, transmitted by the production satellites. PPS, intended primarily for military application, will be available to civil users only on an approved case-by-case basis and only if the user can provide security. Current plans are for a cryptographic device to control access to PPS. [Ref. 8:p. 103] However, what is to be protected, and how much security is to be provided, have yet to be determined at this writing [Ref. 16].

The second policy is that SPS will be continuously available at the highest level of accuracy consistent with U.S. national security interests [Ref. 9:p. 62]. To date DOD has established this level at a degraded SPS accuracy of 100 meters (2 drms) for civil users when GPS is operational. However, it is envisioned that the permitted SPS accuracy of

100 meters is likely to improve, eventually providing accuracies approaching 20-40 meters (2 drms). [Ref. 41:p. 187]

The third issue is the availability of SPS accuracy. If required, DOD can selectively degrade SPS accuracy to worse than 100 meters.

And finally, the fourth issue is that of user charges. The U.S. Congress has directed that GPS be made available on a user charge basis. Tentative annual charges are $375 for SPS and $3700 for PPS. However, there has been strong opposition from the Federal Aviation Administration (FAA). Also, DOD would like to avoid the administrative and technical complication of user charges. Therefore, most observers predict that user charges will never be implemented. [Ref. 42:p. 4]

In view of the above, commercial GPS UE will be developed to receive and/or process either only the SPS accuracy level, or both the PPS and SPS accuracy levels [Ref. 42:p. 3]. Although specific commercial GPS UE configuration is not now available for general purpose GPS use, it will be comparable to military GPS UE. That is, generically, commercial and military GPS UE will be the same and consist of an antenna, RPU, CDU, etc., plus cables and rack mounts. What will be available in terms of design characteristics for commercial GPS UE can be described generally in terms of navigation equipment currently available.

Currently, commercial satellite navigation UE is designed to meet the needs and desires of the commercial market. A key feature is that technology improvements are quickly incorporated. Consequently, periodic product improvements result in equipment which is technologically current. With costs dictating inexpensive design and production when possible, and competition forcing production of reliable and effective equipment, commercial GPS UE, which will become available, is anticipated to be highly competitive, inexpensively produced, and varied to meet a wide use of applications in the civil sector. Additionally, to attract a broad spectrum of civil users, GPS UE will need to be priced low enough to compete with existing satellite navigation systems until the latter are phased-out. Unless a company is producing equipment for DOD use, meeting full DOD mil-specs for DOD commonality and hardening will not be design features of commercial GPS UE.[27] [Ref. 43]

D. MARKET STATUS

Commercial GPS UE for general purpose marine navigation is not currently a marketable product because the full production satellite constellation is not yet available.

Further, general purpose GPS UE is not available to this type of user (e.g., a cargo ship, whose operation is point-to-point navigation, as opposed to the user requiring precision positioning, such as in geodetic survey) because the return on investment is not yet adequate for companies to produce and then sell commercial GPS UE. [Ref. 45]

While there is a market of potential users, the key reason is that the current GPS prototype satellite constellation, while allowing access to full accuracy[28] of both PPS and SPS, is limited to only a few hours a day of full GPS coverage in most parts of the world. When compared to TRANSIT, today's limited availability (but superior accuracy) of GPS is similar to OMEGA's often degraded and error-prone accuracy (but continuous availability). The shipping world prefers TRANSIT, and has almost forgotten OMEGA unless it is used with TRANSIT. Even though TRANSIT is periodic and its accuracy is less than OMEGA's potential accuracy, TRANSIT is more reliable than OMEGA, and it is better than celestial navigation. [Ref. 45]

Another reason is that DOD policy is still being developed such as the capability to be allowed to commercial users in terms of GPS accuracy and availability. For instance, SPS accuracy had been stated at 500 meters; however, it is now 100 meters [Ref. 36:p. 22]. Further, while approval for DSARC III is fully expected, the final mix of navigation systems still needs to be determined regarding what systems will be available and until how long. For example, until 1984 completion of TRANSIT phase-out was scheduled for 1992 [Refs. 9:p. 44;8]; now it is scheduled for 1994 [Ref. 7]. One company, for the purposes of market planning, expects TRANSIT to be available until the year 2000. Nevertheless, participation on the part of the civilian communities is having an impact on government planning. The National Ocean Industries Association (NOIA), for instance, strongly advocates that PPS accuracy is required for vital commercial industries. [Ref. 46] And as a result of the South Korean commercial airline which was shot down in 1983, a Congressional concurrent resolution was passed for government planning to expedite use of GPS for civil aviation [Ref. 47:p. 4].

It is apparent that commercial GPS UE producers will take advantage of military GPS UE developments. Commercial companies are conducting market research. Those that have been or are involved with government GPS, such as Magnavox, Rockwell-Collins, and Texas Instruments, are competitively developing their own commercial GPS UE. These companies already have made a substantially large investment in research, development, and resources (equipment, time and personnel). They are already in a position to produce their own commercial GPS UE, dependent on U.S. government GPS developments [Ref. 43], and will have an advantage over newcomers.

Also, even in its current state, GPS has near-term use in fields such as hydrographic research and geodetic survey, where immediate cost savings can be realized with the present research and development (R&D) satellite constellation [Ref. 42:p. 4]. Texas Instruments has produced and made available the first commercial GPS UE set, the TI-4100. The TI-4100 is for precise marine positioning as opposed, for example, to transocean general marine navigation. The four TI-4100 models and associated antenna cable range from $139,800 to $145,550, with a cassette transporter at $17,800 and accessories (rack mounts or carrying case) from $875 to $1660 [Ref. 48]. This equipment enables the use of current R&D satellite structure; however, its use is primarily for hydrographic and specialized applications such as offshore oil rig positioning. In this use precise positioning is required as opposed to positioning requirements needed for general marine navigation. It should be noted that for geophysical marine work, such as in positioning an offshore oil rig, the time and fuel saved is more obvious. Texas Instruments, in marketing their currently commercially available GPS UE, makes this specific point: if the customer has an offshore oil rig that needs to be positioned at exactly the same coordinates the explorers have noted, hitting the correct position "is so critical that missing it by as little as ten meters might mean failure...[the customer would]...spend as much time measuring and maneuvering as necessary -- even if it meant spending four days at sea getting it right." [Ref. 49:p. 3] While necessary, that amount of time would cost the customer "...the price of several TI GPS units any of which could pinpoint the location in minutes." [Ref. 49:p. 3]

In another application, a cost study completed by the U.S. Naval Oceanographic Office (NAVOCEANO) showed that $3,000,000 in annual operating costs[29] could be saved for two hydrographic ships and their associated survey launches, by purchasing fourteen geodetic receivers called GEOSTAR. GEOSTAR's are modified Texas Instruments TI-4100 GPS receivers being developed under a government research contract [Ref. 50:pp. 81-82].

However, other companies, such as Navidyne (which is not involved in government GPS UE R&D), plan to observe GPS and government developments before investing to produce GPS UE. Navidyne feels that widespread commercial GPS UE will be available about one year after the entire GPS constellation is in place and fully operating. Then companies having the ability to produce low priced equipment should be able to provide commercial GPS UE. "It will be a fine product in the 1990's," said one Navidyne official, "the market place will take off on its own." [Ref. 45]

On the other hand, companies which have had or are working on government contracts can be expected to provide commercial GPS UE somewhat earlier. Since they have already made a substantial investment in research, development, and resources, these companies will be in a position to get a jump on newcomers.

While specific information is not available,[30] Magnavox is developing a variety of commercial GPS UE sets as well as a modification unit to retrofit currently existing MZ-1100 series navigation receivers [Ref. 43]. Rockwell-Collins, on the other hand, plans to produce GPS products to be combined with components produced by other companies (such as Navidyne) as opposed to directly supplying end users [Refs. 46;51].

The primary feature for the commercial GPS UE market will be in product differentiation, with low price being the most important factor to assure widespread commercial use of GPS UE.

Even though it is too early to make commitments for production schedules and prices for commercial GPS UE which will be available when the satellite system is operational, Magnavox predicts that prices will be very reasonable. Competent commercial GPS UE will be available at prices of

$500 or less before the year 2000 [Ref. 42:p. 5]. It is too early to predict prices, but the trend is obvious. Due to technological improvements and competition, the price of sophisticated electronic devices continues to decline. This trend exists in mature products such as color TV sets built in large volume and in calculators. For example, the author experienced that a hand-held calculator (Texas Instruments) that sold for $69 in 1974 dropped to under $10 by 1983. The trend is even more dramatic for less mature, more sophisticated instruments such as satellite navigation equipment. For example, the price trend for Magnavox equipment from mid-1976 until 1982 was downward at 28 per cent per year. A model produced in 1982 fell below that curve. [Ref. 20:p. 1188] There is no reason to believe that the price trend for civil GPS UE products will be any different [Ref. 42:p. 6].

In order to attract a large number of civil users, the price of GPS UE which does become available when GPS becomes operational will need to be low enough so that many users will be able to purchase the equipment. Additionally, GPS UE must be competitive with radionavigation systems currently in use, particularly with TRANSIT user equipment. A key determinant in prices is the quantity that manufacturers will produce. [Ref. 52:p. 15]

Simplicity of operation is a second factor in assuring wide civil use of GPS UE. Simple GPS UE operation, however, is solved by GPS itself for the civil as well as military communities. The awkward and unfriendly characteristics of the existing radionavigation systems will not be problems with the GPS. For instance, GPS will eliminate problems of periodic fixes and proper initialization (both TRANSIT disadvantages), calibration requirements and adjustment of notch filters (both LORAN-C disadvantages), and fear of erroneous data (OMEGA). [Ref. 20:p. 1188]

Finally the third factor is competition. Every indication is that a very large number of companies world-wide are planning to enter the GPS UE market in the short run. Intense international competition will result in lower prices and improved performance for the users. Then, when the competitive pressure becomes too intense and profit margins shrink or disappear, many companies will leave the market, leaving a more stabilized group of producers. [Ref. 42:p. 6]

As time passes, commercial GPS UE can be expected to become more flexible, lightweight, compact, easy to use, reliable, and technologically current. To the extent that mil-specs do not force use of obsolete components, these features can also be expected in military GPS UE. The commonality design for military GPS UE should help toward this end. Additionally, prices are expected to continue dropping, allowing better government buys, and even better government lot buys. This is certainly true for commercial GPS UE. It is also true for military GPS UE; however, it is constrained by the additional cost of mil-specs, and by the probability of these specifications forcing the use of obsolete LRUs.

FOOTNOTES FOR CHAPTER III

[23]For example, the Institute of Navigation is sponsoring a seminar, "National Technical Meeting" in January 1985. And, the International Association of Geodesy jointly with the International Union of Geodesy and Geophysics, DOD, DMA, U.S. Department of Commerce, and National Oceanic and Atmospheric Administration (NOAA) are sponsoring the "First International Symposium on Precise Positioning with the Global Positioning System, Positioning with GPS - 1985" in April 1985.

[24]PPS and SPS are from satellite signals P-code and C/A code respectively. See footnote 26.

[25]"drms" is deviation (distance) root mean square (radial error).

[26]Each satellite broadcasts a composite signal on two L-band frequencies to correct for ionospheric refraction effects. The two frequencies are called L_1 (1575.42 MHZ) and L_2 (1277.6 MHZ). Two types of signals will be carried: a precise (P) signal, also called P-code, is a "pseudorandom" sequence of ones and zeros with a switching rate of 10.23 MHZ (the P-codes are so long they repeat every seven days), and a clear acquisition C/A signal, also called C/A code, with a switch rate of 1.023 MHZ (the C/A code repeats every millisecond, e.g., the codes are 1023 bits long) [Ref. 38:p. 5]. L_1 will carry both the (P) and (C/A) signal. L_2 will carry either the (P) or (C/A) signal. Superimposed on these signals will be navigational and system data including satellite ephemeris, atmospheric propagation correction data, and satellite clock bias information [Ref. 18:p. 2].

[27]However, when designing their commercial equipment, some companies will meet some of the mil-specs [Ref. 44].

[28]It should be noted that currently both PPS and SPS are available. As stated earlier in this chapter, DOD plans for limiting access are applicable to the operational GPS using production satellites.

[29]Annual cost savings were in support unit costs, helicopter support, equipment, and geodetic teams. More efficient use of ships, reduction of minor costs due to a smaller military personnel complement, and vehicle/small boat support are not included in the $3,000,000 figure [Ref. 50:p. 82].

[30]Because source selection for the government contract to produce military GPS UE is currently in progress, specific information and costs are extremely competition sensitive and are proprietary information. The contract is scheduled to be awarded in early CY 1985. Magnavox and Rockwell-Collins are the competing companies.

IV. CURRENT STATUS OF MSC AS A USER

A. CURRENT RADIONAVIGATION SYSTEMS USED

Above all, the Master is responsible for the safety of his ship. Military Sealift Command (MSC) policy is that the meeting of schedules are to be considered desirable targets; they are not to "...be met by accepting undue risks of collision with other ships, heavy weather or ice damage, or otherwise violating the principle that the safety of the ship is paramount to all other considerations." [Ref. 53:Section 1-5-8 p. 1-39d] A key part of this policy is that the Master is responsible for the safe navigation of his ship.[31] This is fundamentally a straightforward task, which a few years ago was effectively accomplished by celestial navigation and prudence.[32] Successful navigation then as now, is the direct result of the accuracy of the fix. [Ref. 54:p. 137]

Of the radionavigation systems used currently, MSC ships use LORAN-C, TRANSIT, and OMEGA. MSC's need for good navigation equipment is reflected in the proforma portion of both tanker and dry cargo charters. Currently, LORAN-C and a satellite navigation (SATNAV) system are required; however, MSC charters do not specify a particular SATNAV system. [Ref. 55] However, today the two systems available and in use by the civilian sector for ocean navigation are

TRANSIT and OMEGA [Ref. 9:pp. 18,19]. Of the two, TRANSIT is the standard SATNAV used for sea-going vessels [Ref. 56:p. 24].

While each system has advantages, each also has major limitations. The following are brief comments on major limitations of the systems used in MSC ships:

a. LORAN-C: Coverage is limited to U.S. coast, Continental U.S., and selected overseas areas (approximately 10 per cent of earth) [Ref. 40:p. 1]. Useful range is 1000 nautical miles because the stations are land-based. LORAN-C is limited by skywave interference. While good for coastal navigation, the major constraint is that coverage is limited to localized areas [Ref. 9:p. 25].

b. OMEGA: System is subject to multipath errors [Ref. 40:p. 1]. While coverage is continuous and the range of operation is nearly world-wide (essentially 88 per cent global coverage by day and 98 per cent by night [Ref. 57:p. 13]), OMEGA is limited in accuracy due to propagation effects and restrictions on using signals when close to a station. For these reasons, the system does not meet the accuracy requirements (when used alone) for maritime navigation in U.S. coastal areas [Ref. 9:p. 30].

c. TRANSIT: Coverage is periodic versus continuous. The interval between fixes is about 90 minutes (30 minutes at 80° latitude, 110 minutes at the Equator). While the system provides world-wide coverage (except at the poles), and accurate positions for fixed and low dynamic (slow moving) vehicles, the primary user limitation is that positional fixes are not continuous. Dead reckoning (DR) is required between fixes.[33,34] [Ref. 9:pp. 44-45]

For additional information concerning navigation systems, readers may refer to Reference 58, pages 6-11, 18-26, and 32-37.

Currently, approximately 70 per cent to 75 per cent of the TRANSIT receivers that MSC purchases commercially are Navidyne receivers, and 25 per cent to 30 per cent are Magnavox receivers [Refs. 59;60]. "Both are good," said one MSC staff member, "...but I can get you four Navidynes for the price of one Magnavox.[35] With Magnavox, you pay a lot for quality, reliability, and high MTBM[36] -- 3500 hours [MTBM] for the [Magnavox model] 1157, ... We just bought a Magnavox system for about $50,000, ... We don't have maintenance problems. Occasionally, we'll replace the antenna. It takes about 45 minutes." [Ref. 61] The price of another system recently purchased by MSC, the Mark II from INTECH, was $12,000 for the SATNAV and $22,000[37] for the system. INTECH products were estimated to be approximately 40 to 45 per cent of the cost of Magnavox products [Ref. 62]. Since the MSC ship which is to receive the INTECH navigation system already has the hardware (e.g., cabling) and foundations in place, an estimated worst-case installation cost would be approximately $2,000. [Ref. 62]

B. COMPARISON OF MSC AND THE MILITARY GPS UE INSTALLATION SCHEDULE

Three primary sources were used in determining MSC ship installation schedules for military GPS UE: (1) the MSC Fleet Inventory [Ref. 2]; (2) the MSC new ship construction/ conversion program [Ref. 3]; and (3) the GPS UE Installation

Schedule, POM-86 Decision Package [Ref. 1], hereafter called POM-86.

POM-86 identifies Navy platforms to receive military GPS UE, and provides a schedule for UE procurement and installation. The Joint Program Office (JPO) has approved funding and installation of military GPS UE on vehicles listed in POM-86. Currently in the planning, programming, budgeting (PPBS) process, POM-86 should receive Congressional obligational authority in October 1985. Assuming this is forthcoming, and that funding and the schedule are approved, JPO will procure military GPS UE starting in 1986. The first installations in POM-86 are scheduled in 1987.

References 2 and 3 were used to construct a summary[38] of MSC ships against which POM-86 was compared. As described in Chapter II, each ship belongs to one of four functional categories:

a. Strategic Sealift (STRAT)

b. Naval Fleet Auxiliary Force (NFAF)

c. Special Mission Support (SMS)

d. Miscellaneous Service Support (MSS)

Fifty-six ships undergoing (or projected to undergo) construction or conversion [Ref. 3][39,40] were also considered since they too affect the total number of GPS UE sets required. Ships planned for conversion originate either from resources outside the MSC Fleet (e.g., private industry), or from within the MSC Fleet (e.g., conversion of USNS Hayes to another class type). Ultimately, newly constructed or converted ships, when added to the MSC Fleet Inventory, will either be outright additions to the MSC fleet or replace existing vessels. The constructed summary allowed direct comparison between MSC ships and the POM-86 schedule.

For the purpose of this thesis, ships scheduled to be replaced or retired were not included in the constructed summary of MSC ships used for comparison with POM-86. However, it should be noted that if replaced vessels remain in service after 1994 (TRANSIT phase-out period end in 1994), then they should also be considered for GPS UE.

1. Ships Scheduled for Military GPS UE (Included in POM-86)

POM-86 provides 58 military GPS UE sets for MSC ships with 41 units for Naval Fleet Auxiliary Force (NFAF) ships and 17 units for Special Mission Support (SMS) ships. For MSC ships included in POM-86, procurement of military GPS UE will be made from 1988 through 1992. A two year period for production and delivery is anticipated. Following delivery, two years are allowed to install the equipment. MSC ship installations are scheduled from 1990 through 1994. Some NFAF ships under construction may not meet the installation time period as discussed below.

a. NFAF Ships

Figure 4-1 is a comparison between the constructed summary of MSC NFAF ships and general POM-86 information. Ship requirements are for 44 GPS UE sets. Forty-one military GPS UE sets are scheduled, leaving a shortfall of three GPS UE sets. An update to POM-86 for one ship has been submitted [Ref. 66]. Approval to the update will result in new shortfalls (two T-AK/FBM's, fleet ballistic missile resupply ships) for military GPS UE. Except for the T-AK/FBM's, NFAF ships were considered as platform candidates for military GPS UE early in 1982 [Ref. 39:p. 7].

The installation schedule, allowing for the year assigned in POM-86 plus two years for installation, will enable the nine new construction T-AGOS's (T-AGOS #4 through #12), and thirteen new construction T-AO's (T-AO #187 through #199), to be built before GPS UE is scheduled for installation in POM-86. Whether the POM-86 installation schedule enables GPS UE installation on six additional new construction T-AGOS's (T-AGOS #13 through T-AGOS #18), depends on the progress of ship construction and delivery of the ship. If the ships are delivered as planned, or are far enough into construction that GPS UE can be installed prior to the end of 1992 (the end of the required two-year installation period), the POM-86 will allow for GPS UE

Ship Type	# Active Ships MSC Inventory	New Construction/ Conversion Program	Total	Required GPS UE Sets	POM-86 Schedule	POM-86 Host (Class)	POM-86 Shortfall	POM Update Requested by Sponsor	Revised Shortfall
T-AE	1	-	1	1	1	AE-26	-	-	-
T-AF	1	-	1	-	-	-	-	-	-
T-AFS	3	-	3	3	2	T-AFS 8	1	1	-
T-AGOS	3	15	18	18	18	T-AGOS	-	-	-
T-AK/FBM	2	-	2	2	-	-	2	-	2
T-AO	11	-	11	-	-	-	-	-	-
T-AO 187 Class	-	13	13	13	13	T-AO 187	-	-	-
T-ATF	7	-	7	7	7	T-ATF 166	-	-	-
TOTALS	28	-	56	44	41		3	1	2

Note: The T-AF 58, T-AO 105 class, and T-AO 143 class (12 ships) are not listed above as they are expected to be retired from the fleet. [Ref. 66]

Figure 4-1. Comparison Between NFAF Constructed Summary and POM-86 for Military GPS UE [Refs. 2;3;63;66] installation. On the other hand, if the T-AGOS construction schedule slips, the last ship may not be available until after the required installation time period. However, with a delivery schedule for T-AGOS #13 through T-AGOS #18 similar to that for the earlier T-AGOS's (deliveries at 2.5 month intervals [Ref. 67]), the POM-86 schedule will meet the delivery schedule. (The delivery schedule calls for delivery of the eighteenth T-AGOS in 1991 [Ref. 3].)

POM-86 calls for installation of all eighteen GPS UE sets onto T-AGOS's during the same interval, which is approximately one ship installation per 1.3 months over a two-year installation period. Unless operational commitments indicate otherwise, this should not present a problem.

NFAF ships, as noted in Chapter II, are Navy-owned and are registered naval vessels. They are assigned to either the Atlantic Fleet or Pacific Fleet for operational control, and to MSC for administrative control. NFAF ships provide direct support to the Navy fleet.

b. SMS Ships

Figure 4-2 is a comparison between the constructed summary of MSC SMS ships and general POM-86 information. Ship requirements are for twenty GPS UE sets. POM-86 schedules seventeen military GPS UE sets, leaving a shortfall of three GPS UE sets. Of the three ships, one is

Ship Type	# Active Ships MSC Inventory	New Construction/ Conversion Program	Total	Required GPS UE Sets	POM-86 Schedule	POM-86 Host (Class)	POM-86 Shortfall	POM Update Requested by Sponsor	Revised Shortfall
T-AG	1	-	1	1	1	T-AG 194	-	-	-
T-AG 195	-	1[a]	1	1	-	-	1	-	-
T-AGM	3	-	3	-[d]	-	-	-	-	-
T-AGOR	4[b]	-	4	4	3	T-AGOR	1	-	-
T-AGS	7[c]	2	9	9	9	T-AGS	-	-	-
T-AK	1	-	1	1	-	-	1	-	-
T-ARC	4	-	4	4	4	T-ARC	-	-	-
TOTALS			23	20	17		3		

Notes: a - Reflects conversion of USNS Hayes from T-AGOR 16 to T-AG 195.

b - Reflects USNS Lynch (T-AGOR 7), USNS De Steiguer (T-AGOR 12), USNS Bartlett (T-AGOR 13), and USNS Mizar (T-AGOR 11).

c - Does not include USNS Bowditch (T-AGS 21) and USNS Dutton (T-AGS 22), which are to be replaced by new construction T-AGS 39 and T-AGS 40.

d - Two T-AGM's are scheduled to receive military GPS UE in 1985. Third T-AGM is to be replaced.

Figure 4-2. Comparison Between SMS Constructed Summary and POM-86 for Military GPS UE [Refs. 2;3;63;64;65] the USNS Hayes, which is to be converted to T-AG 195, one is USNS Mizar (T-AGOR) involved in oceanographic research, and the third is USNS Furman (T-AK), an undersea cable transporter. The author did not determine whether sponsors had submitted requests for military GPS UE. Except for the T-AK, SMS ships were also considered as platform candidates for military GPS UE in 1982 [Refs. 4:p. 7;39:p. 7].

The installation schedule, allowing for the year assigned in POM-86 plus two years for installation, enables completion of new construction/conversion ships before GPS UE is installed.

SMS ships are like NFAF ships for ownership and naval registration. Operation and administrative control is by MSC (see Chapter II). SMS ships require precise positioning service (PPS) information due to the missions they support.

c. Summary

Both NFAF and SMS ships were funded/scheduled in POM-86. NFAF ships need military GPS UE because they operate with battle forces. The need is taken care of through the Fleet Modernization Program. SMS ships need military GPS UE because of the missions they support. [Ref. 66] Most SMS ships are involved in activities such as ocean surveillance and surveying whose sponsors require PPS information [Ref. 62].

In summary, of sixty-four NFAF and SMS ships in the constructed summary, fifty-eight ships (approximately 91 per cent) are currently scheduled for military GPS UE. Of six existing shortfalls, one NFAF (T-AFS) has been submitted as an update to POM-86 for military GPS UE. The five remaining shortfalls, if determined not to need military GPS UE, will require commercial GPS UE by the end of the TRANSIT phase-out period.

2. Ships Not Scheduled for Military GPS UE (Not Included in POM-86)

Strategic Sealift (STRAT) ships and Miscellaneous Service Support (MSS) ships comprise the bulk of the MSC Fleet. As shown below, over half of the MSC Fleet is made up of STRAT ships. Together the STRAT and MSS ships make up over 72 per cent of the MSC Fleet:

	Active and Reserve Ships		Inactive	Grand
	# of Ships	%	Ships	Total
STRAT	111	59.36	15	126
NFAF	28	14.97	9	37
SMS	23	12.30	-	23
MSS	25	13.37	-	25
TOTAL	187	100.0%	24	211

In terms of funding and planning for installation of either military or commercial GPS UE for STRAT and MSS ships, the author finds no special plans being made to date for STRAT or MSS ships. They were not included for military GPS UE.

Although an interest for GPS has been expressed at MSC commands, MSC personnel stated that no advanced planning for MSC to be a candidate for GPS UE was known [Refs. 59;68], as of July 1984, and that definitive planning was not yet needed [Ref. 61] as of August 1984. Although MSC could be a potential user, there are several reasons why MSC is not currently involved [Ref. 68]: first, the GPS operational satellite system does not function yet; second, commercial equipment is not yet available; and third, DOD policy issues (discussed in Chapter III) need to be finalized. Additionally, one staff member [Ref. 61] felt that TRANSIT would be available for another fifty years.

Several considerations make the STRAT and MSS ships markedly different from NFAF and SMS ships. The first difference is in ownership and manning. All NFAF and SMS ships are government owned and government civil service manned with DOD/MSC merchant mariners (MSC/CIVMARS). In the STRAT ships, 86 per cent of the CUOT and PPF ships (64 ships) are manned by civilian merchant mariners [Ref. 2:pp. 4-8].[41] Also, approximately 62 per cent of the 64 ships are commercially owned and under charter to MSC [Ref. 2:pp.4-8].[42] In the MSS ship group, 84 per cent of the ships are under charter (commercially owned) and also operated (manned) by civilian merchant mariners [Ref. 2:p. 12].[43] Finally, almost all NFAF and SMS ships have a small military detachment embarked (usually a communications detachment), whereas only a very few STRAT ships have military personnel aboard (e.g., the NTPF flagship and planned MPS flagships have/will have a military contingent on board to provide secure communications capability and to function as the flag staff).

The second difference between STRAT/MSS ships and NFAF/SMS ships is that the emphasis on strategic sealift (since late 1979's) [Ref. 12:p. 38], and the establishment of overall MSC sponsorship at the OPNAV level (1984) [Ref. 13] are recent developments as described in Chapters I and II. An important concern is to insure that the MSC Fleet is adequately prepared and equipped to meet the primary mission. As a result, more ships are being added to the MSC Fleet and ship enhancement programs have been initiated.

The third difference is the 'visibility' and employment of the ships (author's opinion). STRAT and MSS ships traditionally were not too 'visible'. Even today, during peacetime operations, they do not usually function directly with operating forces (e.g., a point-to-point tanker (CUOT) along the West Coast as compared to a fleet oiler (NFAF)). However, as explained in Chapter I, there has been a tremendous effort and emphasis on sealift support, strategic sealift, and maritime prepositioning.

a. STRAT Ships

Ships are assigned (see Chapter II) as either Common User Ocean Transportation (CUOT) ships, Prepositioning Force (PPF) ships, or as Ready Reserve Force (RRF) ships. The PPF group is further divided into the Near Term Positioned Force (NTPF), the Maritime Prepositioning Ship (MPS) ships, and the Fast Sealift Support (FSS) ships.[44] The RRF, a Maritime Administration (MARAD) asset, is in a reserve status with an Reduced Operational Status (ROS) of either ROS 5 days or ROS 5 to 10 days. As explained earlier, when activated, RRF ships are under operational control of MSC.

In considering STRAT ships for future planning, the NTPF will be replaced by the MPS ships [Ref. 29:p. 38]. Unless their charters are renewed, NTPF ships will be returned to their owners (e.g., by the end of 1986). The proposed force structure of the Maritime Prepositioning Program and support for the force, is to have thirteen T-AKR's (MPS ships) deployed afloat in three task forces plus the following support ships in ROS: eleven T-ACS's, two T-AH's, eight T-AKR's (FSS), and two T-AVB's. [Ref. 30:p. 739]

b. MSS Ships

The 25 ships and service craft in the MSS are under various charters and DOD component sponsorship. These ships are not suitable for strategic sealift [Ref. 34]. The services vary from carrying break bulk coal to providing ferryboat service.

Some craft may not require any/any additional navigation aid. For instance, the four pusher boats (the only MSS ships and craft owned by the Navy and sponsored by MSC), are boats used for personnel and cargo transfer between the NTPF ships and the shore. When not in use, the pusher boats are stowed aboard NTPF ships. However, all the vessels in this group should have their required navigation needs considered.

c. Summary

Because of the emphasis on sealift support, anticipated phase-out of TRANSIT, improvements which will be available with the GPS method of navigation as opposed to current methods of navigation, and the potential need of good navigational aids on board the ships, STRAT and MSS ships also need to be considered for GPS UE. The basic decision required is whether they should receive military or commercial GPS UE.

FOOTNOTES FOR CHAPTER IV

[31]The only time the Master can legally transfer his navigational responsibility (to the Pilot) is when transiting the Panama Canal. [Ref. 53:Section 1-5-9, page 1-39d]

[32]It is recognized that navigation aids (such as satellite navigation, gyroscopes, and radar) are not and cannot substitute for good judgement, basic seamanship, strict compliance with the International Navigation Rules, and an alert lookout. While they are extensions of the navigator's vision and boons to navigation, they are only aids. [Ref. 53:Section 1-5-8, page 1-39c]

[33]Civil TRANSIT users far exceed DOD users. For example, by the end of 1981 and 1982, the numbers of civil users were 34,000 and 38,000 respectively, as compared to the numbers of DOD users which were 405 and 460, respectively. [Ref. 9:pp. 44-45]

[34]Approximately 90 per cent of all commercial receivers sold are single channel receivers [Ref. 58: pp. 44-45].

[35]For example, government purchase price is $4462.50 and $21,241.00 for a Navidyne ESE-4000 and Magnavox MX-1102, respectively [Refs. 44;51]. Here, the factor is approximately 4.8.

[36]MTBM is mean time between maintenance.

[37]System included TRANSIT, SATNAV, and components, plus OMEGA, two satellite frequencies, printer, and 100 per cent spare parts [Ref. 62].

[38]Additionally, constructed summaries for NFAF and SMS ships were modified by References 63, 64, 65, and 66.

[39] Reference 3 lists 58 ships in the construction/conversion program. Author is using 56 to reflect the delivery and active status of T-AGOS #3 and one T-AKR (MPS) in Reference 2. (This MPS ship is the second one delivered.)

[40] Of the 56 ships, 24 ships are carried in an inactive status in Reference 2. They are T-AGOS #4 through #9, and 15 T-AKR's (4-FSS's: T-AKR #289 through #292, and 11-MPS's) (see Figure 2-8). The remaining 32 new construction/conversion ships will be added to the inventory as follows:

a. Twenty-two ships will be simply added. Included are six T-AGOS #13 through #18, two T-AH's #19 and #20, thirteen T-AO 187 class, and one T-AVB which is currently not in the inventory as an RRF because it is in the yards.

b. Eight ships will be added as replacements for other existing ships. Included are two T-AGS #30 and #40 for USNS Bowditch and USNS Dutton (T-AGS 21 and 22), T-AGM 24 for USNS Sentinel Ranger (T-AGM 22), and five T-AOT 1121 class for five T-5 tankers.

c. Two ships are being converted to another class. One will become a T-AG 195 and the other will become the second T-AVB.

[41] (55 ships commercially manned) ÷ (64 total active and reserve ships less RRF) = 85.9 per cent.

[42] Excludes bareboat charters. (40 ships under charter, excluding sealift tankers and two USNS RORO's) ÷ (64 total active and reserve ships less RRF) = 62.5 per cent.

[43] (21 vessels commercially owned and operated) ÷ (25 total MSS ships) = 84 per cent.

[44] Two of the thirteen MPS ships and four of eight FSS ships have been delivered. The remainder of the ships are under construction/conversion as of 19 October 1984 [Ref. 2].

V. EVALUATION OF GPS UE FOR MSC USE

A. REQUIREMENT

Inclusion of the NAVSTAR GPS program in POM-86 reflects the stated need for military GPS UE on surface ships. In the missions of the U.S. Navy, the Military Sealift Command (MSC) provides sealift capability. As a result of the emphasis placed on strategic sealift, the primary role of MSC is to provide contingency support and strategic mobility in terms of sealift, as discussed in Chapter I. Peacetime logistics is secondary. Strategic sealift is a key factor in deciding whether to provide military or commercial GPS UE to MSC ships. The other key factor is that TRANSIT is expected to be phased out by the end of 1994.

Currently, the Naval Fleet Auxiliary Force (NFAF and Special Mission Support (SMS) ships are funded for military GPS UE [Ref. 1]. The NFAF ships are funded because they directly support the fleet. SMS ships are funded because of the special missions they support (e.g., surveying).

At this time, no plans have been made for Strategic Sealift (STRAT) and Miscellaneous Service Support (MSS) ships. STRAT and MSS ships can benefit from the improvements which will be available with GPS. STRAT and MSS ships need GPS UE because they use TRANSIT and OMEGA for primary ocean navigation, and LORAN-C (where available) for primary coastal navigation. As discussed in Chapter I, all these radionavigation systems are scheduled for DOD phase-out in the 1990's. In view of the emphasis currently placed on strategic sealift, together with the phase-out plans for existing navigation systems these ships will need GPS UE. The question becomes whether to provide MSC STRAT and MSS ships with military or commercial GPS UE.

In the author's judgement a decision must be made regarding whether military or commercial GPS UE is to be used on MSC ships, particularly on those in the Strategic Sealift (STRAT) group. This decision needs to be made bearing in mind that the primary mission is to provide sealift in contingency situations. The STRAT ships are considered to be a major support element for the military in a contingency. Considering this, it is important to examine the alternatives of providing military or commercial GPS UE. Equipment characteristics and/or capabilities, security, and other factors impact on the decision of which alternatives to select. These factors include cost, equipment availability, and scheduling. Cost includes the purchase price and installation cost of GPS UE. Figures provided in this thesis indicate only rough estimates, but are where military and commercial GPS UE vary significantly.

B. EXAMINATION OF CONSIDERATIONS IN MSC USE OF GPS UE

The following presents an examination of considerations regarding the use of GPS UE to fulfill MSC's operational need. Major items are equipment capability (equipment characteristics and technology), security, and other factors (cost, equipment availability, and schedule).

1. Equipment Capability

This section examines several statements concerning use of GPS UE on MSC ships. The format in this section provides information on the equipment capability under consideration, presents a statement on the subject, and provides points of agreement and disagreement with the statement.

a. Equipment Characteristics Include Military Design, Commonality, and the Latest Technology

(1) Military Design. The primary equipment characteristic is the design of military GPS UE for a military environment. While military [Refs. 6;61;63;68] and commercial [Refs. 43;69] sources agree that military design features (such as hardening) would not be required during peacetime, viewpoints differed as to whether or not they would be useful to MSC ships during a contingency.

a. Statement. MSC ships should be equipped with GPS UE which is designed for a military environment (military GPS UE).

b. Disagree.

1. Koberger [Ref. 70:p. 310] states that the merchant marine, usually involved in commercial shipping, does not normally consider providing ships with hardened equipment.

2. Magnavox [Ref. 43] stated that hardening and anti-jamming features should not be needed on MSC ships.

3. Steward [Ref. 29:p. 40] explains that the concept behind the Maritime Prepositioning Ship (MPS) ships is that they should be in safe passage (unopposed during transit) to the objective area, and that a Naval escort would be provided if needed. What "unopposed" meant was not defined.

c. Agree.

1. Koberger in Reference 70 agrees with JPO [Ref. 18:p. 30] that electromagnetic pulse (EMP) bursts are unpredictable in terms of time of occurance, duration, and magnitude. He also states that twenty years ago, tests over Johnson Island tended to indicate that high altitude thermonuclear blasts can send out an EMP which burns out unhardened or unprotected transistorized and computerized electronics for thousands of miles. [Ref. 70:p. 309].

2. The Navy DPM [Ref. 6] stated that the military GPS UE, being designed to protect the equipment, will provide at least some measure of survivability.

3. Even if MSC ships are not expected to be in dangerous or opposition areas, MSC ships, such as STRAT, NFAF, and SMS ships need to reach their destination. MSC currently requires a certain amount of minimum protective standards. For instance, washdown drills are held quarterly [Ref. 71: p. 1-90, para. 1-16-3]. Equipment is issued and procedures are established for chemical, biological, and radiation (CBR) training in USNS ships [Ref. 72:p. 2-1-6, para 2-1-6]. Additionally, the crew receives extra pay when entering hazardous or war-zone areas.

d. Summary. The contingency environment, for which MSC ships (STRAT, NFAF, and SMS ships - those that provide strategic sealift) are to be prepared, has no guarantee of being peaceful. Plans for contingencies are made to respond effectively, if and when needed. Preparation to accomplish this includes planning for equipment requirements as well as for operations. For this reason, equipment which is militarily designed must be considered for those MSC ships intended for use in a contingency situation. Nothing guarantees safe passage, or the availability of a Naval escort, for example, for the MPS ships. At the minimum, a certain amount of hardening is desirable. This, as well as the equipment (e.g., NBC gear) currently on board, will provide some protection and survivability.

(1) Commonality. Commonality and design to meet rigid military specifications are key features of military GPS UE. One argument heard is that military GPS UE will have older technology built in because of mil-specs, whereas while commercial versions will quickly incorporate the latest technology quickly.

a. Statement. Commonality of military GPS UE is desirable for MSC ships as well as for the Naval fleet.

b. Disagree.

1. One MSCPAC staff member [Ref. 61] said that purchasing and servicing TRANSIT navigation equipment is not currently a problem, that follow-on maintenance is minimal, and that the largest costs are up-front.

2. A statement from Navidyne [Ref. 45] was that for the extra cost in purchasing military GPS UE, an entire set(s) of parts and spares could probably be provided to each ship.

3. Magnavox [Ref. 43] stated that they and other commercial companies provide world-wide service facilities for their navigation products.

c. Agree. The Navy DPM said [Ref. 6] that mil-spec and commonality features are required for sound configuration management and effective logistic support for GPS UE because so many military platforms will have the equipment.

d. Summary. The author feels that commonality is useful for the military system, MSC government-owned and bareboat chartered ships, and ships under long-term charters (e.g., fifteen to twenty years) to MSC, but that it would not be useful for ships under short-term charters.

(2) <u>Latest Technology</u>

a. Statement. Commercial GPS UE featuring the latest technology is an advantage for MSC ships.

b. Disagree.

1. MSC personnel [Refs. 60;62;83] stated that the navigation equipment provided is the one that can do the job. Once installed, it is not replaced only to provide the most recent technological features. Therefore, the new construction/conversion ships benefit the most from new technologies.

2. A military statement from JPO [Ref. 6] was that commonality and design of replaceable components can allow updating military GPS UE.

c. Agree. Commercial sources [Refs. 43;46] and MSC personnel [Refs. 62;83] agree that the availability of the latest technology in commercial GPS UE is an advantage, for example, in equipping new construction/conversion ships with navigation equipment.

d. Summary. The availability of the latest technology in commercial GPS UE is a trade-off with the military design and commonality features of military GPS.

b. Technological Capabilities Include the 100 Meter (2 drms) Accuracy Level of SPS, Degradation and PPS Accuracy, and Two-Channel Equipment.

(1) SPS Accuracy. SPS accuracy is to be provided at 100 meters (2 drms).

a. Statement. Accuracy at 100 meters (2 drms) is sufficient for general marine navigation (oceanic).

b. Disagree. None.

c. Agree. Commercial sources [Refs. 43;45] and MSC personnel [Refs. 59;61;76] agreed.

d. Summary. The 100 meter (2 drms) accuracy is sufficient for most MSC ships.

(2) Degradation and PPS Accuracy. Current policy is that the government can degrade accuracy to worse than 100 meters (2 drms).

a. Statement. This policy may drive the need for access to PPS accuracy by MSC ships which can be used for strategic sealift (STRAT, NFAF, and SMS ships).

b. Disagree.

1. Although the government has the right to control and degrade any of the radionavigation systems it operates [Ref. 8:p. 105], this right has not been exercised. Accuracy is not likely to be degraded by the government because even during a contingency, navigation is required by both military participants and civil non-participants. For instance, navigation systems were not degraded during the Falkland Island Crisis.

2. An interagency agreement between the Department of Defense (DOD) and the Department of Transportation (DOT) recognizes that the two agencies have joint responsibility to ensure that both military and civil needs are met. Implicit in this joint effort is the assurance of civil sector radio-navigation readiness for mobilization in national emergencies. [Ref. 9:p. 14]

c. Agree. Koberger [Ref. 70:p. 309] states that time is a critical factor in contingencies. This is true whether supplies are being delivered or if a ship is to rendezvous with an escort or at a remote area lacking port facilities for beach offloading. If commercial GPS UE were installed on MSC ships (e.g., Prepositioning Force (PPF) ships), it could later be determined that a ship requires access to PPS, hardening features, and/or military GPS UE for navigation. Depending on what kind of commercial GPS UE has been installed, time could be saved or lost. For example, if non-hardened commercial GPS UE with only C/A capability for SPS accuracy had been installed, then valuable time could be lost, if the navigation equipment and particularly the cabling needs to be replaced. This is particularly true if the ship has already deployed (either the ship needs to return to port or proceed as it is equipped). For example, for ships in port, even if communications equipment has to be installed and cargo has to be loaded, there is no guarantee that there would be enough time to install or modify additional equipment; nor is there any guarantee that parts or resources will be available.

d. Summary. If commercial equipment were decided to be used, at the very least, the cabling should meet military specifications for military GPS UE in order to save time by eliminating the need to replace cabling. Cabling installed depends on the antenna to be used, and generally speaking, commercial quality grade cabling is not the same as military cabling. Regarding installation, using military cabling (even for commercial equipment) would improve impedence and reduce signal loss. [Ref. 73] More important, it would then allow changing the cable ends and adding equipment capable of PPS accuracy.

(3) Two-Channel Equipment. Medium dynamic (MD) two-channel military GPS UE was designed for use on surface ships. Most commercial equipment being designed for general marine navigation will be one-channel GPS UE.

a. Statement. MSC ships require one- channel GPS UE for general marine navigation.

b. Disagree. There was no disagreement to this statement.

c. Agree.

1. Military and commercial sources, [Refs. 43;45;46; 60;61;69;74:p. 268;75:pp. 71,83;76] all agree that one-channel GPS UE is sufficient for MSC ships involved in general marine navigation. Specifically, a Navidyne official [Ref. 45] stated that unless a ship required two-channel equipment (for instance, for shore bombardment from a moving vehicle or for survey operations), single-channel equipment is sufficient. Magnavox [Ref. 43] concurred, adding that even many fleet ships could use single-channel commercial GPS UE and not be degraded in mission capability in terms of navigation accuracy.

2. Additionally, MSC personnel [Refs. 61;76] stated that two-channel capability would not be required for the following NFAF and SMS ships: T-AE, T-AF, T-AFS, T-AK/FBM, T-AO, and T-ATF.

d. Summary. Unless MSC ships are involved in special operations, they require one-channel GPS UE. Ideally, military GPS UE would provide one-channel versus two-channel GPS UE sets for general marine navigation.

2. Security

Current DOD policy is that civil users who desire access to PPS will need to provide adequate security protection to the crypto (secure) device that will allow access to PPS. The GPS UE set itself is unclassified; the key code device is classified. With the exception of the NFAF and SMS ships, most of the other ships cannot currently provide security protection for classified material. Masters of these ships have a safe to hold confidential material if required, but this is avoided when possible.

Material of higher classification is not stored aboard the ship.

It is also important to consider physical security aboard MSC ships. Piracy exists, and sabotage can be a concern. For example, when loaded, a tanker rides low in the water, with approximately 15 feet of freeboard at the main deck. Recently an MSC tanker was boarded by seven pirates while transiting the Singapore Straits at a slow speed [Ref. 77:pp. 1-2]. There are, however, certain accommodations that can be made. Specifically, those ships lacking secure facilities could have GPS UE installed; then, when needed, the added keying device or access card could be provided to the ship, with a seagoing guard if necessary. Upon rendezvous the device could be turned over to military personnel. [Ref. 78] Military GPS UE could be installed with the key being issued when needed [Ref. 73]; commercial GPS UE capable of access to PPS could be also installed in the same way. Because commercial GPS UE with PPS capability will increase in price, it is envisioned that many commercial GPS UE sets for general marine navigation will not provide this feature. In any event, when needed, the key code would be provided and the equipment could then be restored to full capability. While this may work for units ashore, extra logistic efforts may be necessary to provide the device to deployed ships. Advanced planning is necessary to minimize the loss of time which could be critical in a contingency.

The author's judgement is that GPS UE installed on STRAT, NFAF, and SMS ships must have the capability for PPS access so that the primary mission can be met. The key code should not be kept aboard except on units deployed with military personnel who do have secure facilities (e.g., communications detachment, or communications mil-van). For example, MPS flagships and alternate flagships should be provided with GPS UE that has PPS. Other PPF ships (e.g., T-AKR (FFS's), T-ACS's, and T-AVB's) should use the suitcase method when deployed in a contingency, in that the key code is carried aboard for the voyage. All STRAT ships in the PPF should have military GPS UE installed, or at least commercial GPS UE with the capability for PPS accuracy service. If it were decided that CUOT and RRF ships are to use commercial GPS UE, then it is the author's judgement that cabling meeting military specifications should be used. Besides the improvements mentioned earlier, this would allow easier change-overs to military GPS UE end units such as the antenna and user set components (plus terminal and connectors) in the event military GPS UE were used later. Again, if commercial GPS UE were procured, it should have PPS capability.

The author feels that no special equipment or cabling is required for each MSS ship determined to be unsuitable for use in strategic sealift.

The concept in equipping RRF ships is to use off-the-shelf equipment. While this may be the policy, the author feels that the cabling used in the installation should meet the specifications for PPS access and, preferably, the use of military GPS UE. This not only enables access to PPS if and when required, and use of military GPS UE if this should be decided on later, but also slowly builds the contingency capability in the U.S. flag fleet. Further, a requirement for GPS UE for navigation in the RRF ships should be added to the RRF ship-enhancement requirements.

3. Other Factors

a. Cost

Unit-for-unit, the military can expect to pay more because military equipment meets rigid specifications and is designed for military contingency use. This costs; the military pays for it. (As discussed in Chapter III, although prices of commercial GPS UE are unknown at this time, they can be expected to be competitive with prices of equipment currently used in navigation systems (e.g., TRANSIT)).

Both military and commercial per unit prices for GPS UE are expected to decrease over time. However, the military will pay more for military GPS UE because of the rigid specification requirements, than if commercial GPS UE were purchased.

One aspect to consider is the overall cost to DOD versus the cost to MSC alone or JPO alone. In terms of both the purchase of equipment and installation, several considerations can be addressed even though costs and prices are not yet known. For instance, military GPS UE requires Program Objective Memorandum (POM) funding, and therefore plans need to be made well ahead of time. If military GPS UE were purchased for MSC ships, NAVSEA would be responsible for the installation. Military GPS UE could be installed in one of two ways: pierside by an Augment Installation Team (AIT), or in a shipyard. The team concept, preferred by JPO because it is less expensive than a shipyard installation, would be handled by NAVSEA; the shipyard installation by NAVSEA or MSC (as assigned by NAVSEA) and would occur normally in a commercial shipyard (naval shipyards are occasionally used). One difference between MSC ships and the U.S. Naval fleet is that MSC ship availability periods are shorter. If military GPS UE were to be installed, MSC ship operational schedules might impact on installation scheduling.

If commercial GPS UE were purchased, Navy Industrial Fund (NIF) funding would be used. Since NIF funding is a revolving account, POM planning would not be required by MSC, but would be required by the commands receiving shipping services from MSC.

Even though MSC has several ways to purchase commercial GPS UE under NIF funding (for example, large-lot buy -- 20 units instead of a single unit, or letting ship owners buy their own equipment), the cost still comes back to DOD. This is because MSC charges those to whom shipping service is provided, and these customers receive funding from POM submissions. Installation of commercial GPS UE would be handled by MSC. Again, several methods are available: MSC could purchase and arrange for installation in a commercial shipyard, purchase the equipment and have the shipowner install it, or (as would usually be the case), simply have the shipowner purchase and install his own equipment.

In any event, in addition to determining whether military or commercial GPS UE should be provided, the costs of procurring and installing GPS UE need to be considered.

As an example, the estimated total of the military GPS UE purchase price plus AIT installation cost can be less than the estimated total of purchasing commercial GPS UE plus a shipyard installation cost, as depicted in Figure 5-1. Costs, derived from Reference 79, are the best estimates available at this writing. The following comments should be noted (Figure 5-1 applies):

(1) Military GPS UE (FY 79 Dollars). $68,713 reflects the estimated average cost per one two-channel MD set for one T-AO 187 class ship. (The author estimated per set costs for one T-AO 187 class ship by dividing the estimated total number of sets to be purchased into the total estimated equipment procurement cost provided in Reference 79.) The cost of $68,713 is the estimated other procurement Navy (OPN) cost [Ref. 79:p. 75]. It includes the user set components plus spares, installation kit cost, cables, and government production support [Ref. 5]. The cost of the receiver RPU and other components was estimated at $54,534. [Ref. 79:p. 256] The higher cost of purchasing military GPS UE reflected in Figure 5-1 is the result of rigid specifications and design requirements which must be met in producing military equipment [Ref. 6]. For instance, requirements for military design include the Navy hammer blow test (impact test), hardening, anti-jamming, temperature cycling tests, fungus tests, and space/weight specifications [Ref. 80].

(2) Commercial GPS UE. Magnavox estimates that commercial GPS UE purchase prices will be approximately 30 per cent to 50 per cent of military GPS UE [Ref. 80].

	MILITARY GPS UE WITH AIT INSTALLATION	COMMERCIAL GPS UE WITH SHIPYARD INSTALLATION	
		30%	50%
Estimated Equipment Cost	$68,713	$20,614	$34,357
Estimated Installation Cost			
AIT (Team Concept)	75,000	-	-
Shipyard Installation	-	181,299	181,299
TOTAL	$143,713	$201,913	$215,655
±20% Range	$114,970 to $172,456	$161,530 to $242,296	$172,524 to $258,786

Note: 1. Costs are in FY 79 dollars.

2. An AIT installation (the preferred installation at the JPO), is assumed for military GPS UE. It should be noted however, that the purchase of military GPS UE with a shipyard installation exceeds all total cost and range estimates above.

3. Commercial GPS UE is not installed by AIT.

Figure 5-1. Estimated Total GPS UE Procurement and Installation Cost for One T-AO 187 Class Ship (FY 79 Dollars)

The lower cost of 30 per cent and the more expensive cost of 50 per cent, and ranges of ± 20 per cent are shown in Figures 5-1 and 5-2. Because navigation equipment is mature (although electronic/digital improvements could still occur), and because major technical changes to GPS UE are not expected, ±20 was selected to provide ranges for the estimated costs.

(3) Installation Costs. The GPS program office determined that a shipyard installation was three to five times more expensive than a pierside installation [Ref. 81:p. 4] depending on the location of the installation. Another estimation for the cost of installing GPS UE during Phase II of GPS testing was approximately $70,000 for a team installation as opposed to $169,000 for a shipyard installation [Ref. 82:pp. 34,39]. This study showed that the estimated shipyard installation (no overtime involved) was more than the estimated cost for the team installation by a factor of 2.4 (approximately). Using the conservative 2.4 factor with an estimated cost of $75,000 (FY 79 dollars) [Ref. 79:p. 256] for a team installation of military GPS UE on a T-AO 187 class MSC ship, results in an estimated shipyard installation cost of $181,299 (FY 79 dollars). Estimated installation costs and ranges are summarized in Figure 5-2.

GPS UE PURCHASE COST	ESTIMATED COST	ESTIMATE COST WITH A ±20 PERCENT RANGE
Military Set and OPN Support	$68,713	$54,970 to $82,456
Commercial Equipment (at 30% of military equipment)	$20,614	$16,491 to $24,737
Commercial Equipment (at 50% of military equipment)	$34,357	$27,485 to $41,228
GPS UE PURCHASE COST		
Military Receiver RPU and Components	$54,534	$43,627 to $65,441
Commercial Equipment (at 30% of military equipment)	$16,360	$13,088 to $19,032
Commercial Equipment (at 50% of military equipment)	$27,267	$21,814 to $32,721
INSTALLATION COST		
AIT Installation	$75,000	$60,000 to $90,000
Shipyard Installation	$181,299	$145,039 to $217,559

Figure 5-2. Estimated GPS UE Purchase and Installation Costs and ±20% Ranges of Cost for One T-AO 187 Class Ship (FY 79 Dollars)

As depicted in Figure 5-1, the lower price of commercial GPS UE can be offset by the higher cost of a shipyard installation. In the example used, the total estimated cost of the military GPS UE set with an AIT installation was $37,586 less than the estimated shipyard cost alone. The team installation concept, the preferred method of installation at the JPO [Ref. 6], can only be used when military GPS UE is procured. AIT installations would be handled by NAVSEA. If commercial GPS UE were procured, the installation would be done in a shipyard under the Master Ship Repair Agreement. MSC or the ship owner, as directed by MSC, would handle the installation. [Ref. 83]

Even if the military GPS UE/AIT installation is underestimated, the 20 per cent higher cost of $172,456 is still lower than the commercial equipment purchase at both 30 and 50 per cent plus a shipyard installation. Comparing the high range for the military GPS UE/AIT combination with optimistic lower costs for the two (30 per cent and 50 per cent) commercial equipment/shipyard combinations, the high estimate of military GPS UE/AIT at $172,456 is higher than the commercial GPS UE (30 per cent)/ shipyard combination by $10,926, but slightly lower than the commercial GPS UE (50 per cent)/shipyard combination (by $68). Therefore, the average combination cost of military GPS UE/AIT installation is lower than the average combinations of commercial equipment (at both 30 and 50 per cent) with a shipyard installation. Furthermore, the military GPS UE/AIT installation combination at its worst case ($172,456) is still lower than the best case commercial GPS UE at 50 per cent/shipyard installation combination ($172,524). The worst case military combination ($172,456) is slightly higher however, than the best case combination of commercial GPS UE at 30 per cent/shipyard installation. Therefore, the best combination in terms of GPS UE procurement plus installation cost appears to be the purchase of military GPS UE with AIT installation.

An additional consideration is that the cost of failing to meet the mission in a contingency or war is difficult to estimate. However, in any kind of contingency (for instance, in the Falklands), time is a crucial factor. If war erupts in Europe, an estimated ten million tons of military supplies and fifteen million tons of fuel will need to be delivered to NATO in the first three months. Furthermore, almost all will have to go by sea [Ref. 70:p. 309]. As described earlier, while an argument can be presented that the ships can be equipped with required gear as they are loaded, there is no guarantee that time, equipment, and resources will be available to carry out this additional requirement. However, if commercial GPS UE with the capability for PPS accuracy were installed, it would be faster to provide the required key card.

The same is true if commercial equipment were installed (e.g., by shipowner or government) and if it were later determined that military GPS UE should have been used. Having installed military-specified cabling in the first place, (for the commercial GPS UE), it would be faster to simply replace the system components (e.g., antenna, RPU, CDU, and FMI) and cable termination ends than to also have to rip out the old cabling and replace it with new cabling suitable for military GPS UE or PPS access with commercial GPS UE.

b. Equipment Availability

MSC ships will need to be equipped with either military GPS UE, which will be available during GPS Phase III production, or with commercial GPS UE which is expected to be available from a wide range of manufacturers when GPS is fully operational (as described in Chapter III). Commercial GPS UE from companies formerly or currently involved with government GPS UE can be expected to be available earlier [Ref. 45]. For instance, Magnavox [Ref. 44] and Rockwell- Collins [Ref. 46] both plan to have products available in mid-1985.

c. Schedule

Chapter I provided the planned phase-out schedule[45] of existing radionavigation systems that MSC ships currently use. Phase-out periods end in 1992, 1993, and 1994 for OMEGA, LORAN-C, and TRANSIT, respectively. However, LORAN-C is expected to continue to be available until year 2000, and there is limited Navy use of OMEGA possible after 1993. The POM-86 lists the year in which the equipment is to be installed, then two years are allowed to complete the installation. Of the NFAF and SMS ships scheduled for military GPS UE, 39 per cent (16 ships; T-AE, T-AFS, T-AO 187 class) will not meet the 1994 TRANSIT phase-out completion unless the UE can be procured and installed all within 1994. The remaining NFAF and SMS ships (25 ships, 61 per cent) scheduled for military GPS UE will meet the planned phase-out schedule. Of course, should the radionavigation phase-out schedule slip, then more time would be available for installation.

All other MSC ships will need to have had plans made for either military or commercial GPS UE. Because LORAN-C, OMEGA, and TRANSIT are used, planning should be in terms of the earliest system scheduled for phase-out, which is OMEGA in 1992. However, OMEGA is used in conjunction with TRANSIT satellite navigators and these navigators would be able to continue using TRANSIT information. Therefore, the year in which GPS UE installations must be completed is 1994 to meet the end of TRANSIT phase-out.

Whether military or commercial GPS UE is to be used in MSC ships determines how far in advance planning needs to be done or action taken. In order for JPO to plan, coordinate, and provide military GPS UE for MSC ships not already included in POM-86, additional ships must be identified now. To be included in the Five-Year Defense Plan (FYDP), the ship requirements should be included in POM-88; to meet the TRANSIT phase-out schedule, the latest POM submission would be POM-92. The two schedules are shown below:

ACTION SCHEDULE	FOR FYDP (POM-88)	LATEST POM FOR INSTALLATION (POM-92)
Requirements identified by sponsor/user. Plans for requirements and any Navy unique features are made. JPO makes final approval for military GPS UE.	1984-85	1985-88
POM requirements for all service/agency users prepared at JPO level for PME 106-2. POM input submitted to SECDEF.	1985	1989
POM inputs processed at SECDEF level.	1986	1990
POM submitted into President's budget. Funds appropriated.	1987	1991
POM funds available for action/installation begins.	1988	1992
FYDP: Budget year plus four years.	1988-92	- -
Installation period.	- -	1992-94

However, it should be noted that the POM-92 schedule assumes that installations can all be done in the two-year installation period. It does not consider the impact on the schedule for other service installations, nor does it consider the impact on schedules prepared at the JPO level. This is a worst case schedule. It is the author's judgement that requirements for additional military GPS UE be made earlier then POM-92 to allow more flexibility at the end of the 1986-1994 period.

If commercial GPS UE is to be used on MSC ships, installation will need to be scheduled prior to 1994. Additionally, requirements for GPS UE should be specified in charter contracts first, so that phased-out navigation systems are not relied on to meet the SATNAV requirement of the charter and second, so that the benefits of GPS are used.

The decision as to whether military or commercial GPS UE is to be provided to ships in the MSC Fleet needs to be made in the near term. This is particularly true if military GPS UE is used because the additional requirement will impact on the GPS program schedules, planning, and priorities, and requires POM funding.

C. EVALUATION OF MILITARY GPS UE FOR CURRENTLY SCHEDULED SHIPS

NFAF and SMS ships are currently scheduled for military GPS UE as discussed in Chapter IV. The following are the advantages and disadvantages of providing military GPS UE to NFAF and SMS ships.

1. Advantages

a. Military GPS UE fully meets MSC's mission, particularly the primary mission of strategic sealift.

b. The equipment provides full range of GPS accuracies (both PPS and SPS) to the ships to a degree of accuracy not obtainable from any other navigation system available today or in the foreseeable future [Ref.: 40:p. 1].

c. Continuous twenty-four hour coverage in any weather will be available to a ship located anywhere on earth when GPS is fully operational.

d. Military GPS UE meets the GPS commonality objective which is important for logistics supply and configuration management of GPS. The equipment has modular components for maximum interchangeability of parts.

e. Military GPS UE is a long term solution for MSC as well as for U.S. Navy fleet ships and other Navy platforms.

f. Such a provision equips NFAF and SMS ships with comparable or the same GPS UE that the Navy operating fleet has. For NFAF ships, and in a contingency for SMS ships, this means that rendezvous and other operations with the fleet can be conducted with the same equipment (hence capabilities) being available to both parties.

g. Military GPS UE is designed for the harsh environment of military operations. (Equipment is militarily prepared.)

h. This provision takes advantage of GPS program development and resources spent to date. Additionally, the government can take advantage of large lot buys, and AIT team installation (cheaper installation than at a shipyard). Also, combining the purchase of military GPS UE with AIT installation is less expensive than purchasing commercial GPS UE and using shipyard installation.

2. Disadvantages

a. The use of more expensive military specifications for the equipment may not be required operationally. If this is the case, unnecessary expenditures will be incurred.

b. Military GPS UE will have obsolete technology built in. However, the UE was designed with modular components for maximum interchangeability which will maximize this problem.

c. Two-channel equipment is scheduled where one-channel equipment is sufficient [Refs. 43;45;63;78]. Two-channel equipment is more expensive unit-for-unit than is one-channel equipment, therefore extra costs are incurred.

3. Options

The Medium Dynamic (MD) GPS UE set was designed for surface ships. The Low Dynamic (LD) GPS UE was also tested for use in surface ships. Advantages and disadvantages are as follows.

a. Medium Dynamic (MD) Two-Channel GPS UE

(1) Advantages. The MD GPS UE set is designed expressly for use on surface ships. The second channel, while not needed, unless required by a special mission, (e.g., fine control which is not applicable to NFAF or SMS

ships) is an added benefit. Specifically, user set response times are reduced by 1.5 minutes [Ref. 18:pp. 32-33].[46]

(2) Disadvantages. None, except that the MD set has a higher price tag.

b. Low Dynamic (LD) One-Channel Manpack GPS UE

(1) Advantages. One-channel capability is less expensive than the MD GPS UE sets, is easily and quickly installed, and fully meets military requirements.

(2) Disadvantages. For most surface ships, ship dynamics in rough waters preclude use of the LD set. Specifically, the antenna mounted on the mast can result in lever arm motion exceeding the 40 knot upper range for which the LD set is designed. For example, at sea state four, the antenna lever arm velocity can be greater than ship forward velocity. [Ref. 84]

4. Recommendation

Use military GPS UE in NFAF and SMS ships as scheduled.

D. EVALUATION OF MILITARY GPS UE ALTERNATIVE FOR NON-SCHEDULED SHIPS

The following are advantages and disadvantages of providing military GPS UE to the STRAT and MSS ships.

1. Advantages for STRAT Ships

In addition to advantages listed for NFAF and SMS ships, advantages for STRAT ships (CUOT, PPF, and RRF ships) are:

a. Military GPS UE provides the same capabilities on the same equipment as NFAF, SMS and Navy Fleet ships. This helps logistically if parts are needed and increases the commonality base. It is particularly applicable for long-term charters and government-owned ships.

b. In the event PPF ships proceed along (without escort) during contingencies, they are provided with militarily designed equipment. If it is then needed (e.g., long range EMP burst), protection is available. The ships are prepared. This is no different than providing protection to an NFAF or SMS ship which could make a solo transit.

c. SPS accuracy can be provided on a full time basis, with PPS accessibility provided by using the key code. In the event there is a possibility of degradation to worse than 100 meters for SPS accuracy, PPS can be made available.

d. Such provision will enhance the capabilities of the U.S. flag fleet. For instance, the time charters, when returned to owners, will have had militarily specified cables installed. At the end of the charter period the military GPS UE (antenna, RPU, CDU, and FMI) could be removed (government furnished equipment) or possibly sold to the owner. However, if it were removed the cabling could remain, thereby increasing the usefulness of the ship for later contingency use or time chartering. RRF ships (MARAD assets) are also enhanced.

e. Military GPS UE would allow the use of AIT installation (because military equipment is being provided) on CUOT, PPF and RRF ships. An AIT installation is considerably less expensive than a shipyard installation.

2. Disadvantages for STRAT Ships

a. Most ships lack secure spaces for classified material (keycode allowing access to PPS will be classified). Moreover, physical security is vulnerable on ships with low freeboard. However, by providing the key/code for PPS access, on a basis as needed, and by initially installing GPS UE and cabling which allow use of PPS, the ships are fully equipped like the operating Navy fleet ships (with the exception that the key code for PPS access is not carried on board). An escort may be required with the use of the PPS key card. Using the device requires additional planning (e.g., storage ashore) and time provided by personnel. [Ref. 78]

b. The rest of the ship is not hardened or militarily prepared. This would be a start. Enhancement programs such as the one to upgrade RRF ships are meant to equip ships so they can meet mission requirements [Ref. 33].

c. Military GPS UE is not user friendly. Because military GPS UE will be capable to do more (e.g., fire control), the equipment will have more user features (e.g., knobs) and can be more complicated than commercial GPS UE for this reason. (The civil merchant mariner is used to simple equipment.) [Ref. 61] However, advantages from GPS navigation itself, as discussed in Chapter III, provide user friendliness.

d. Some ships are foreign built and so are not in the COSAL system. This problem can be dealt with on a case-by-case basis.

e. Flexibility of MSC in arranging for equipment is reduced. The commercial purchase of commercial GPS UE results in a shipyard installation, which is more expensive than an AIT team installation of military GPS UE.

3. Advantages for MSS Ships

Same as advantages listed above.

4. Disadvantages for MSS Ships

a. Ships are not suitable for strategic sealift operations [Ref. 34] therefore they do not need equipment to meet contingencies.

b. Some ships are on the shorter time charters, or are voyage charters. For this, the normal method of doing business can be used; that is, operate and work with the ship owners as if MSC were a commercial enterprise. [Ref. 61] The ship owner would provide a commercially equipped ship. However, this may result in a higher cost to DOD overall. (DOD customers to whom MSC provides shipping service eventually pay the bill for the equipment and installation.)

5. Options

The same options (MD or LD) exist for STRAT and MSS as for NFAF and SMS ships. The advantages and disadvantages of MD and LD military GPS UE are the same as for NFAF and SMS ships, except for small vessels in the MSS ship group as follows:

a. Advantages of using LD sets on small MSS vessels are that the one-channel LD manpack is suitable for small vessels and boats which operate in calm waters. For example, the tugboats could use manpacks [Ref. 84]. This reduces the cost of procurement. Installation is easy and fast, and the equipment fully meets military requirements.

b. There are no disadvantages of using LD sets on small MSS vessels unless the vessels are prohibited to have lithium batteries on board as are Naval vessels. (Modifications are being made to manpacks (battery replacement) to allow use of manpacks on board small Navy vessels.) [Ref. 84]

6. Recommendations

Provide military GPS UE to the STRAT ships and keycode for access to PPS when need is anticipated. Do not provide military GPS UE to the MSS ships, except when manpacks can be used.

E. EVALUATION OF COMMERCIAL GPS UE ALTERNATIVE FOR NON-SCHEDULED SHIPS

The alternative to providing STRAT and MSS ships with military GPS UE is to equip them with commercial GPS UE. The following are advantages and disadvantages of doing so for both STRAT and MSS ships, except as noted.

1. Advantages

a. DOD Federal Navigation Policy implies that radionavigation methods will be provided to civilian users so that they can meet mobilization requirements, should they be needed (see the discussion earlier in this chapter).

b. With commercial equipment capable of PPS accuracy, the key code could be provided as would be done with the military GPS UE. The full range of GPS accuracy would then be available.

c. Commercial GPS UE fully meets requirement for a peacetime navigation system.

d. Equipping MSC ships with commercial equipment is the standard way of doing business at MSC. Allowing ship owners to do so takes the worry out of MSC's hands. [Ref. 62]

e. Commercial GPS UE provides flexibility as to the different ways to accomplish the job of outfitting ships with commercial GPS UE. For example, MSC could purchase and install equipment; MSC could purchase, but the owner would install the equipment; or the owner could purchase and install the equipment. MSC is not bound to military channels and installation schedules.

f. MSC could arrange for a multiple unit buy. This would result in a lower overall cost to the government as opposed to paying each ship owner to equip his ship(s). [Ref. 78]

g. MSC ships could be provided with equipment which is technically current and updated with the commercial market. Obsolescence problem of military GPS UE would not be applicable.

h. A lot of money is saved on a system by not purchasing capabilities (e.g., hardening) that are never used.

i. A large number and variety of UE manufacturers are expected when GPS is operational. The market will be wide and competition keen. Prices are expected to be low and competitive with equipment available today.

j. The price of commercial GPS UE is estimated to be 30 per cent to 50 per cent lower than that of military GPS UE because of less stringent design requirements [Ref. 80]. (However, as described earlier, the installation cost in a yard for commercial equipment is higher than that of an AIT for military equipment.)

k. Most commercial GPS UE will be one-channel UE sets, with SPS access capability only.

2. Disadvantages

a. Commercial GPS UE is a peacetime system for the STRAT ships. The ships are not fully prepared to meet their primary mission (STRAT only).

b. Since most commercial GPS UE will be only for SPS access, MSC ships will still have degraded accuracy with a possibility of degradation to worse than the normal 100 meter (2 drms) SPS accuracy. Equipment is not hardened or militarily prepared in the event of contingency (STRAT only).

c. Commercial GPS UE will not provide commonality between ships, unless MSC purchases the equipment. There would be no commonality with the Navy. Lack of commonality may make a difference in supplying parts or spare components, depending on the commercial company providing the equipment and on the location of MSC ships.

d. The installation for commercial GPS UE is more expensive than is the installation for military GPS UE by an AIT.

e. There is no need to change over if TRANSIT will still be available. However, the benefits gained from GPS's continuous coverage, plus those disadvantages that GPS eliminates as compared to other navigation systems (see Chapters I and IV), outweigh not having GPS UE. Also, reliability of TRANSIT data which may be available after the end of the phase-out, will not be guaranteed.

f. With the provision of commercial GPS UE, ships which are overseas or located in remote areas may be dependent on the manufacturer's providing or having service available.

3. Options

Two options exist with commercial GPS UE. One is to retrofit existing (Magnavox) equipment for GPS usage. The other is to purchase new commercial GPS UE.

a. Option #1 - Purchase New Commercial GPS UE. The advantages and disadvantages of option one are the same as those listed above for commercial GPS UE. The primary disadvantage is the cost of a shipyard installation.

b. Option #2 - Retrofit Existing Magnavox Equipment. Magnavox, in addition to producing commercial GPS UE, plans to produce modification kits so that present Magnavox receivers (MX-1100 series) can be retrofitted for current GPS use. Use of MX-1100 series receivers can then be extended after GPS is operational. Advantages are that the current GPS, in spite of a limited satellite constellation can be used sooner. Also, installation costs are minimal when compared to complete replacement of a navigation system.

Foundations and ship structure changes are not required. [Ref. 43]

Twenty-five to thirty per cent of MSC ships use Magnavox receivers for TRANSIT. This makes retrofitting of current Magnavox receivers an attractive alternative to purchasing new commercial GPS UE. If the decision is made to equip MSC ships with commercial GPS UE, whether current Magnavox equipment is replaced with new GPS UE or is retrofitted with modification kits will depend on the condition of the current equipment [Ref. 62] and the price of retrofit kits.

The argument against retrofitting current Magnavox receivers is that retrofitting is a short term solution, a stop gap measure [Ref. 6].

Having GPS capability sooner by using the current GPS satellite constellation provides only a few hours of continuous data per day. Also many more companies are expected to join the market place when GPS is operational. But, by waiting, MSC would have a larger base of companies from which to choose commercial GPS UE.

More important, the primary mission (for STRAT ships) is ignored for what is perceived to be less up front costs because the retrofit will still result in equipment with SPS accuracy only [Ref. 6]. However, Magnavox feels that retrofitting is a viable solution, particularly since it is also felt that many ships do not require military capabilities such as anti-jamming [Ref. 43].

The retrofit, however, because of costs, may be a suitable solution to chartered ship's owners who are primarily concerned with the return on investment. But, because the cost of the retrofit or replacement will be billed eventually to MSC, the ship owners will go along with MSC's preference. The costs of purchasing a commercial kit to modify existing commercial GPS equipment and/or purchasing new commercial GPS UE are not fully known; however, retrofitting current equipment has lower initial outlays.

In summary, the advantages of option two, Magnavox retrofitting, are:

a. Early use of GPS with current satellite constellation.

b. Retrofit kits provided by a reputable company (Magnavox) for current MX-1100 series navigation systems currently used aboard 25 to 30 per cent of the MSC ships.

c. Cheaper installation done quickly involving a board addition or replacement and, in some cases, an antenna change to currently used Magnavox 1100 series models.

The disadvantages of retrofitting are:

a. A stop gap measure for the STRAT ships; and not a long-term solution.

b. Greater overall cost if retrofitting occurs and subsequently GPS UE is purchased.

c. Higher early costs if retrofitting is immediate. With competition among producers expected to be large, it may be less expensive to wait and see what will be available on the commercial market.

4. Recommendations

The author recommends first, that MSC purchase commercial GPS UE in multiple unit buys; second, that the equipment allow access to PPS; and third, that cabling used in the installation meet military specifications for the military MD GPS UE.

Second, the author suggests purchasing commercial GPS UE for MSS ships, in those cases where military one-channel LD GPS UE (manpacks) cannot be used. Retrofits are recommended only when the retrofit would make more sense than replacing the entire navigation system. For example, a retrofit is called for if a ship had just had a new non-GPS system installed and has a short time period left (e.g., eight months) in its charter with MSC, and if TRANSIT phase-out ends in two weeks. In this case, MSC would gain the benefit of GPS data for the remaining eight months in the charter period.

F. IMPLICATIONS OF GPS UE SELECTION

The implications of selecting military equipment instead of commercial equipment are the following:

a. If military GPS UE is provided to MSC ships, then the most current technology available in commercial GPS UE is sacrificed. This assumes that military GPS UE will be obsolete by the time it is installed on host vehicles and/or that new technology will not be incorporated into military user equipment in a timely manner. Besides, unit-for-unit, the opportunity to purchase lower priced commercial equipment is lost.

b. If commercial GPS UE is provided, then MSC ships (less the MSS ships) are not fully prepared to meet their primary mission. There is still a chance to lose the ability to meet the primary mission (e.g., a long range EMP blast could reach a ship transiting alone). Further, in terms of installation, the opportunity to use AIT and realize savings in installation cost is lost.

In summary, it is better to provide militarily designed equipment to MSC ships which are to fulfill the role of strategic sealift. This includes the STRAT (CUOT, PPF, and RRF), NFAF, and SMS ships.

As stated before, the NFAF and SMS ships are already funded and scheduled to receive military GPS UE. The STRAT ships are not. The bottom line is whether a peacetime or military navigation system will be provided, and whether DOD willing to pay for militarily designed navigation equipment for these ships.

In the author's judgement, as long as the primary mission is strategic sealift, then the STRAT ships, as well as the NFAF and SMS ships, must be equipped with military GPS UE to fulfill the mission. There is still the chance that, during a contingency, a long range EMP burst could knock out the navigation electronics. This means that military GPS UE must be provided to STRAT ships, especially to the PPF ships: MPS's, FSS's, and later to T-ACS's, T-AVB's and T-AH's. Military GPS UE should also be provided to CUOT and RRF ships. Should it be decided that commercial GPS UE is to be used, then, as stated above, cabling should be installed which can be used for military GPS UE and/or the commercial PPS capability, and the equipment should be hardened to some minimum degree. The MSS ships, which provide peacetime mission support and are not involved in the strategic sealift mission, should be equipped with commercial UE, except when military manpacks could be used.

FOOTNOTES FOR CHAPTER V

[45]The term phase-out is used to describe a transition time period. From beginning to completion of the phase-out, the government will fully operate and maintain the existing radionavigation system (for instance TRANSIT). However, new developments and improvements will not be made to the system. At the end of the phase-out period the government will no longer attempt to keep the system fully operational [Ref. 10]. Therefore, those who use TRANSIT as a principal source of navigation can do so throughout the phase-out time period, but will need to be equipped with GPS UE at the end of phase-out [Ref. 6].

[46]User set response times are measured in two parameters: reaction time (REAC) and time-to-first-fix (TTFF). REAC is defined as the elapsed time from UE set turn-on until the first full accuracy data output. TTFF is defined as the elapsed time from the initial demand on a UE set that has been turned on for a minimum of seven minutes to a subsequent data output and display. Specific response times [Ref. 18:pp. 32-33] are shown below:

Military GPS UE Type	REAC	TTF
LD Set	10.5 min	5.5 min
MD Set	9.0 min	4.0 min
	---------	-------
Minutes saved in response times using an MD UE set	1.5 minutes	1.5 minutes

VI. CONCLUSION AND RECOMMENDATIONS

The purpose of this thesis was to study plans to incorporate NAVSTAR Global Positioning System (GPS) User Equipment (UE) on Military Sealift Command (MSC) ships. MSC functional ship groups which are funded and scheduled, and those not funded nor scheduled for military GPS UE were identified. Alternatives for equipping unfunded/unscheduled MSC ships were examined emphasizing major considerations and implications in the alternatives selected for all ships in the MSC fleet.

GPS, a world-wide all-weather navigation system which determines position, velocity, and time with greater accuracy than any current system, is applicable to the needs of both military and civilian communities. Further, it has been selected by the U.S. Government as the candidate radionavigation system to replace and/or supplement all other radionavigation systems currently in use.

The need for military GPS UE in Navy platforms is implicitly identified in the military GPS UE installation schedule (POM-86 Decision Package). MSC functional ship groups included for military GPS UE are the Naval Fleet Auxiliary Force (NFAF) and Special Mission Support (SMS) ships. MSC ship groups which are not funded or scheduled are the Strategic Sealift (STRAT) ships and Miscellaneous

Service Support (MSS) ships. The STRAT ships include the Common User Ocean Transportation (CUOT) ships, the Prepositioning Force (PPF) and the Ready Reserve Force (RRF).[47] The PPF, in turn, is composed of the Maritime Prepositioning Ships (MPS's), Fast Sealift Support (FSS) ships, and Near Term Prepositioning Force (NTPF) ships.

A. CONCLUSION

Because of the identified need and plans of GPS UE on Naval platforms, the status of the GPS program in its anticipated continuation into Phase III production, and the phase-out plans of navigation systems currently in use, MSC ships also must be considered for GPS UE. While military GPS UE is identified for NFAF and SMS ships (approximately 50 ships), the STRAT and MSS ships (approximately 125 ships) need a viable alternative if military GPS UE is not provided. A decision is required regarding whether STRAT and MSS ships should be equipped with military or commercial GPS UE.

Important in considering whether to provide military or commercial GPS UE to MSC ships, particularly to STRAT ships, is MSC's role in providing sealift as one of three major functions of the Navy. Developments in the Middle East during the mid to latter 1970's resulted in a surge of interest in strategic sealift and in mobilization planning. As a result, the emphasis today is clearly on strategic sealift, strategic mobilization, and contingency planning. Because of the increased focus on sealift, MSC's primary mission is to provide sealift for strategic mobility in support of national security objectives.

The basic question in deciding to provide MSC ships with military or with commercial GPS UE is whether to equip them with a GPS navigation system that is militarily designed and prepared for contingencies or to provide strictly peacetime (commercial) GPS UE. In the author's judgement military or commercial GPS UE must be selected on the basis of being able to fulfill the strategic sealift mission. Primary criteria for selection are equipment characteristics and technological capabilities. Security is an issue which must be addressed aboard MSC ships. Cost, equipment availability, and GPS program and DOD radionavigation systems phase-out schedules are additional factors to weigh.

In the author's judgement, because the primary mission is strategic sealift and because in the fulfillment of that mission MSC ships could be vulnerable, (even though it is recognized that the idea is to use, for instance, MPS ships in safe passage), there is a need to provide militarily designed GPS UE. Further, as long as the possibility exists that the government can degrade Standard Positioning Service (SPS) accuracy to worse than 100 meters, MSC ships involved in strategic sealift (STRAT, NFAF, and SMS ships) must have access to Precise Positioning Service (PPS).

Military GPS UE fully meets mission requirements. The equipment is militarily prepared and is part of the commonality objective set by the Department of Defense (DOD). Also, if the equipment is installed allowing SPS accuracy only, it can be adapted quickly for PPS accuracy by providing the key/access code. Moreover, AIT pierside installation offers the advantage of substantial savings when compared to shipyard installation. This can defray the cost of purchasing military GPS UE. Commercial GPS UE offers the advantages of PPS accessability (if equipment purchased has this capability), the opportunity to purchase equipment with the most current features and technology available, and the traditional way of conducting business between MSC and commercial ship owners. Because MSC's primary mission is strategic sealift and because of the advantages of military GPS UE, equipping MSC STRAT ships with the latter (particularly the PPF ships and also ships which could be involved with strategic sealift which have long-term time charters), will fully provide these ships with GPS navigation equipment to meet MSC's primary mission.

B. RECOMMENDATIONS

The following recommendations are made.

Military GPS UE should be provided to MSC ships involved in strategic sealift. This includes the STRAT ships (with particular emphasis on the PPF ships and those ships under long-term charter), NFAF ships, and SMS ships.

If commercial GPS UE is selected, the following should be furnished: military-type cabling, capability for PPS accuracy access, and equipment hardening to at least some minimum degree. Besides being prepared in terms of navigation equipment to fully meet MSC's primary mission, an additional advantage of these provisions is that the preparedness of the U.S. flag ships will be enhanced to meet contingency and mobilization requirements.

Commercial GPS UE, and where possible, military (or commercial equivalent) low dynamic (LD) manpacks should be provided on MSS vessels. Whenever possible, multiple-unit purchases should be made for commercial equipment by MSC.

A cost benefit analysis comparing military versus commercial GPS UE in terms of use, procurement, and installation would avail information and should be conducted. When conducted, it should determine the costs and benefits to DOD as a whole, as opposed to only MSC or to only the GPS program. Such an analysis probably could be made after the award of the military GPS UE production contract and successful Phase III approval, and when commercial producers have GPS UE available for general marine navigation.

Specific ship requirements for military GPS UE in the the MSC STRAT ships should be identified and submitted in the Five Year Defense Plan (FYDP). Requirements for the POM should be presented in sufficient time to allow funding and installation prior to the end of the phase-out of TRANSIT.

MSC ship charters should specify a requirement for GPS UE when GPS is operational with two-dimensional capability (scheduled for 1987).

Finally, GPS navigation should be included in the enhancement programs for PPF and RRF ships.

FOOTNOTES FOR CHAPTER VI

[47]As described in Chapter I, ships in the RRF, a Maritime Administration (MARAD) asset, are under control of MSC when activated.

APPENDIX A

MSC FLEET (MSC CONTROLLED FLEET)

Chapter I stated that ships in the MSC Fleet are categorized and discussed in either one of two ways. The thesis refers to ships differentiated by the four functional groups [Refs. 2;11]. This section describes the alternative and more traditional way to categorize MSC ships.

Here, the MSC Fleet is called the MSC Controlled Fleet.[48,49] It consists of (see Figure A-1):[50]

1. MSC Nucleus Ships (also called the MSC Nucleus Fleet): These are United States Naval Ships (designated USNS) which are owned by the U.S. Government or under bareboat charter to MSC (the United States). They are in the custody of the Navy, and permanently assigned to MSC for administration and operation. The ships are active status in-service ships, which are either MSC government civil service manned (MSC/CIVMARS) with DOD/MSC merchant mariners, or contract-operated with commercial merchant marine crews. MSC is the agent for these ships and provides or arranges all husbanding.

2. MSC Chartered[51]-Ships (also called the MSC Controlled (Chartered) Fleet): These are commercial privately-owned ships of the U.S. Merchant Marine (U.S. flag ships from the Maritime Industry) under charter to MSC.

CONTROLLED SHIP GROUPS	ACTIVE AND RESERVE SHIPS (LESS RRF)	INACTIVE SHIPS UNDER CONSTRUCTION/CONVERSION	RESERVE RRF
1. Nucleus (USNS) Ships			
STRAT	24	4 (FSS)	-
NFAF	28	9 (T-AGOS)	-
SMS	23	-	-
TOTAL USNS:	75		
2. Chartered Ships			
STRAT	40	11 (MPS)	-
MSS	21	-	-
TOTAL CHARTERED:	61		
3. General Agency Agreement (GAA)			
STRAT	-	-	47
4. Other: MSS[1]	4	-	-
TOTALS:	140	24	47

MSC CONTROLLED FLEET[2] (SUMMARY)

Current Controlled Fleet:	140 Ships
Controlled fleet with delivery of new construction/conversion of FFS, MPS, and T-AGOS:	164 Ships

MSC FLEET[3] (SUMMARY)

Active and Reserve Ships (140 + 47):	187 Ships
Total MSC Fleet Inventory[3] (140 + 24 + 47):	211 Ships

Notes: 1 - Government owned, not USNS designated (pusher boats).
2 - RRF ships are only part of the controlled fleet when activated.
3 - As of 19 October 1984. [Ref. 2]

Figure A-1. Controlled Ship Groups

Occasionally, they are foreign flag ships chartered by MSC. Ship designation is usually SS (steamship), MV (motor vessel) or (a few) RV (research vessel). The ships are manned with contract-operated, commercial merchant mariners. MSC conducts liaison with the ships' agents who husband them.

3. General Agency Agreement (GAA) Ships: These are ships in the custody of the Maritime Administration (MARAD) which have been activated.

FOOTNOTES FOR APPENDIX A

[48]Sources: [Refs. 53:para 1-1-1, p. 1-1;72:para 4, p. 1;85:para 5, pp. 1-2]

[49]Unless activated, a Ready Reserve Force (RRF) ship (47 ships as of 19 October 1984) is not part of the MSC Controlled Fleet. This is slightly different from what is listed in the inventory and from the categorization of MSC ships by functional groups where RRF ships are included, but in a reserve status. [Ref. 2]

[50]A fourth category consists of in-commission ships (USS) of the U.S. Navy temporarily assigned to MSC for operations. If so assigned, although they are MSC-controlled ships, they are not MSC nucleus ships.

[51]Appendix B describes types of charters.

APPENDIX B

MSC CHARTER TYPES

1. Bareboat Charter. Basically MSC rents an empty ship. The ship owner relinquishes control and management of the vessel to the chartering agency (MSC) for a number of years (often for the ship's entire expected service life). MSC is responsible for all costs of operating and for equipping the ship, as well as for maintenance and repairs. MSC pays "hire" which is expressed in terms of dollars per deadweight ton per month, or dollars per day.

2. Time Charter. In a time charter, MSC hires a fully equipped and manned ship for a specific period of time. The charter term varies from a few weeks to years. Unlike bareboat charters, the ship owner is responsible for hiring the crew, managing the ship, and paying all operating costs except fuel, port charges, and canal tolls. MSC, as the charterer, directs utilization of the ship. MSC schedules services of the ship in any location and for any cargo it chooses, except as prohibited in the charter agreement. "Hire" is the same as in bareboat, except when the ship is not available for service ("off-hire"). If the charter period is for more than a year, there is usually a provision

for increases in payment for crew wages, stores, and subsistence.

3. Consecutive Voyage Charter. In a voyage charter, MSC basically rents "space" onboard the ship for carriage of cargo. The ship owner remains completely responsible for the operation and cost of the ship (including fuel and port charges). The charter allows for the ship to make as many consecutive voyages as it can in a specified period of time. Payment is in terms of "freight," which is expressed in dollars per ton of cargo carried. It is normally payable only on the successful discharge of cargo at the end of a voyage. If MSC, as the charterer, does not supply a full cargo, MSC pays freight on unused space. There is usually a provision for payment of escalation of crew wages, bunkers, stores, and subsistence.

4. Single Voyage Charter. Also called a spot charter, this charter is like the consecutive voyage charter except that it involves one shipment or one voyage instead of several.

Sources: [Refs. 71:para 1-1-4, p. 1-3;86]

APPENDIX C

MILITARY GPS UE SET COMPONENTS

The following identifies and describes major components in military GPS UE sets. As stated in Chapter II, the primary component LRUs for a nominal military GPS UE set are the antenna, RPU, CDU and FMI [Ref. 4:pp. 8-11].

1. Antenna/Antenna Electronics

The antenna and antenna electronics are separate LRU's. The antenna receives signals transmitted from the GPS satellites and transfers them to a preamplifier or Antenna Control Unit (ACU). For the purpose of definition, the antenna is defined as a combination of receptor elements, radomes, and supporting structure(s) for the elements, as well as internal cables and antenna signal connectors. Two generic antenna types are available for use in UE. The fixed reception pattern antenna (FRPA) is an antenna that is fixed with respect to the antenna structure. It does not have the capability of modifying its reception pattern and is a simple omni-directional antenna with a deep null at the horizon. The controlled reception pattern antenna (CPRA), also called an adaptive array antenna, is a multiple element array antenna. In conjunction with the associated ACU, it has the ability to modify the reception pattern in order to reject interference signals and/or emphasize GPS navigation signals. The CPRA can detect the direction of the jamming source under jamming conditions, and quickly alter receiving patterns to place nulls in the jam direction. The type of antenna for ships discussed in this thesis is the FRPA, which will be mounted on the mast.

The preamplifier or ACU processes RF signals and outputs them in the proper form to be accepted and utilized by the Receiver Processor Unit (RPU). The basic functions are to increase the signal level from the antenna, reject interference by filtering, and provide input burnout protection and self-test functions. Additionally, the ACU combines the signals from the various antenna elements and negates jamming signals.

2. Receiver Processor Unit (RPU)

The RPU, a micro-computer consisting of approximately 80 per cent software, performs signal and data processing [Ref. 17:p. 13]. Three RPU variations are available:

a. Low dynamic (LD) (one channel), manpack vehicular: The LD set tracks and monitors four satellites sequentially.

b. Medium dynamic (MD) (two channels): The MD set channels sequentially track and monitors two satellites each.

c. High dynamic (HD) (five channels): The HD set tracks and monitors four satellites simultaneously.

Each variation of the RPU's will perform the following functions:

a. Receive and amplify signals from the preamplifier or ACU and four desired satellites.

b. Select and acquire signals from four desired satellites.

c. Track acquired navigation signals (four simultaneously for the five-channel set, four sequentially for the one- and two-channel sets).

d. Extract navigation data from the GPS satellite data received.

e. Measure signal propagation error.

f. Compute position, velocity, and time.

g. Output necessary data to the host vehicle integrated system through the Flexible Modular Interface Unit (FMI).

h. Accept navigation sensor aiding data from the FMI.

i. Provide resistance to jamming.

j. Generate self-test signals for UE fault isolation.

k. Provide additional functions as required by platform configurations and mission.

3. Flexible Modular Interface Unit (FMI)

The FMI will perform the interfacing function between the RPU and the platform. This includes all vehicle-unique interfaces and all mission-unique or vehicle-unique functions not performed by the RPU. The FMI will provide the GPS UE with the capability of interfacing with both analog and digital platform equipment, and may contain a micro-processor for data manipulation where required. The

FMI for each platform will be designed to meet the unique requirements of that platform. These unique designs will be based on the requirement to use replaceable components common to all FMIs. This function partitioning approach will allow for commonality in the use of the other LRU's across many Navy and tri-service applications, while supporting platform-unique requirements in the platform unique FMIs.

The complexity of design of a unique FMI is heavily dependent upon the resident navigation system configuration, the quality and types of navigation instruments (displays and controls) to be used, and the electrical interface characteristics of the host vehicle. Since the LD set is not integrated with other host vehicle navigation systems, it does not require an FMI.

4. Test Flexible Modular Interface (Test FMI)

The Test FMI allows the inherent fault isolation capabilities of the GPS UE to be extended from the LRU level to the intermediate level of maintenance to be performed aboard the platform. Shipboard applications will include a Test FMI.

5. Control Display Unit (CDU)

The CDU provides the operator with the capability to control the UE, input data, and observe UE-generated outputs. The GPS CDU contains operating controls, a data entry keyboard, and alpha numeric displays. The CDU is functionally partitioned from the RPU to permit operation of the sets without the CDU in platforms designed to control the GPS UE via an existing platform control system. For shipboard applications, the GPS CDU will be either located with the RPU or mounted in some other location (e.g., bridge). Additionally, a remote CDU will be provided where required.

6. Data Loader Unit (DLU)

The DLU may be used to enter mission-dependent data (e.g., way points) into the UE set to alleviate operator workload. It will be composed of a data loader receptable that will be installed into the host vehicle and a data memory unit cartridge which will be used to enter mission data into the receptacle. A DLU cannot be used with the LD set. Since its primary purpose is to reduce operator workload, it is not absolutely essential for the MD and HD sets.

7. Master Control Unit (MCU)

Each of the GPS UE LRU's will be capable of being mounted individually or as part of a group of LRU's. The MCU provides the physical mounting and connector interface between the GPS UE and the platform. For most shipboard applications, all of the LRU's (with the exception of the antenna/antenna electronics, remote CDU if applicable, and possibly the local GPS CDU), will be contained in one enclosure. [Ref. 4:pp. 8-11]

APPENDIX D

GLOSSARY

ACU	Antenna Control Unit
AFB	Air Force Base
AFLC	Air Force Logistics Command
AFSC	Air Force Systems Command
AIT	Augment Installation Team
ASN	Assistant Secretary of the Navy
ASN/FM	Assistant Secretary of the Navy for Financial Management
ASN/MI&L	Assistant Secretary of the Navy for Manpower, Installations, and Logistics
C/A Code	Course Acquisition Code
CBR	Chemical, Biological, and Radiation
CCSB	Computer Configuration Sub-Board
CDU	Control Display Unit
CIVMAR	Civil Service (Government) Merchant Mariner
CNO	Chief of Naval Operations
COSAL	Consolidated Shipboard Allowance List
CPRA	Controlled Reception Pattern Antenna
CUOT	Common User Ocean Transportation
CY	Calendar Year
DCNO	Deputy Chief of Naval Operations
DIRSSP	Director Strategic Systems Program
DOD	Department of Defense

DOE	Department of Energy
DOT	Department of Transportation
DLU	Data Loader Unit
DMA	Defense Mapping Agency
DPM	Deputy Program Manager
DR	Dead Reckoning
drms	Deviations (Distance) Root Mean Square
DSARC	Defense Systems Acquisition Review Council
DT&E	Development, Test, and Evaluation
DTNSRDC	David Taylor Naval Ship Research and Development Center
EMP	Electromagnetic Pulse
ESMC	Air Force Eastern Space Missile Command
FAA	Federal Aviation Administration
FM	See ASN/FM
FMI	Flexible Modular Interface
FOT&E	Follow-on Test and Evaluation
FPIF	Fixed Price Incentive Fee
FRP	Federal Radionavigation Plan
FRPA	Fixed Reception Pattern Antenna
FSD	Full Scale Development
FSS	Fast Sealift Support
FYDP	Five Year Defense Plan
GAA	General Agency Agreement
GPS	Global Positioning System

GPS UE	Global Positioning System User Equipment
HD	High Dynamic
JCS	Joint Chiefs of Staff
JCCB	Joint Configuration Control Board
JPO	Joint Program Office
JSSMO	Joint Service System Management Office
IOT&E	Initial Operation Test and Evaluation
LANTFLT	Atlantic Fleet
LD	Low Dynamic
LRU	Line Replacement Unit
MARAD	Maritime Administration
MCU	Master Control Unit
MD	Medium Dynamic
MI&L	Manpower, Installations, and Logistics
mil-specs	Military Specifications
mil-van	Military Van
MLSF	Mobile Logistics Support Force
MPS	Maritime Prepositioning Ship
MRA&L	Manpower, Reserve Affairs, and Logistics
MSC	Military Sealift Command
MSC/CIVMAR	MSC Civil Service (Government) Merchant Mariner
MSCEUR	Military Sealift Command Europe
MSCO	Military Sealift Command Office
MSCPAC	Military Sealift Command Pacific
MSS	Miscellaneous Service Support

MTBM	Mean Time Between Maintenance
MV	Motor Vessel
NATO	North Atlantic Treaty Organization
NAVAIR	(NAVAIRSYSCOM) Naval Air Systems Command
NAVELEX	(NAVELEXSYSCOM) Naval Electronics Systems Command
NAVLOGPAC	Naval Logistics Command Pacific
NAVMAT	Chief of Naval Material
NAVOCEANCOM	Naval Oceanographic Command
NAVOCEANO	Naval Oceanographic Office
NAVSEA	(NAVSEASYSCOM) Naval Sea Systems Command
NAVSPASUR	Navy Space Surveillance System
NAVSUP	Naval Supply Systems Command
NBC	Nuclear, Biological, and Chemical
NCCB	Navy Configuration Control Board
NSCORG	Naval Control of Shipping Organization
NFAF	Naval Fleet Auxillary Force
NIF	Navy Industrial Fund
NOAA	National Oceanic and Atmospheric Association
NOIA	National Oceanic Industries Association
NORDA	Naval Ocean Research and Development Analysis
NOSC	Naval Ocean System Center
NPM	Navy Program Manager
NTPF	Near Term Prepositioning Force
OPN	Other Procurement Navy Appropriation

OPR	Office of Primary Responsibility
OSD	Office of the Secretary of Defense
P-Code	Precise Code
PM	Program Manager
PMRT	Program Management Responsibility Transfer
POM	Program Objectives Memorandum
PPF	Prepositioning Force
PPS	Precise Positioning Service
QTR	Quarter
R&D	Research and Development
RF	Radio Frequency
REAC	Reaction Time
RFP	Request for Proposal
ROFLO	Roll-on, Float-off
RORO	Roll-on, Roll-off
ROS	Reduced Operational Status
RRF	Ready Reserve Fleet
RV	Research Vessel
SD	Space Division
SECDEF	Secretary of Defense
SEP	Spherical Error of Probability
SECNAV	Secretary of the Navy
SM	System Manager
SMS	Special Mission Support (ship group)
SPS	Standard Positioning Service

SS	Steamship
STRAT	Strategic Sealift (ship group)
T-ACS	Auxiliary Crane Ship (STRAT)
T-AE	Ammunition Ship (NFAF)
T-AF	Fleet Stores Ship (NFAF)
T-AFS	Combat Stores Ship (NFAF)
T-AG	Navigation Test Support (SMS)
T-AGM	Missile Range Instrumentation Ship (SMS)
T-AGOR	Oceanographic Research Ship (SMS)
T-AGOS	Ocean Surveillance Ship (NFAF)
T-AGS	Surveying Ship (SMS)
T-AH	Hospital Ship (STRAT)
T-AK	Freighter (Cargo Ship) (STRAT), Undersea Cable Transporter Cargo Ship (SMS)
T-AK/FBM	Fleet Ballistic Resupply Ship (NFAF)
T-AKR	RORO (Vehicle Cargo Ship) (STRAT)
T-AO	Fleet Oiler (NFAF)
T-AOG	Gasoline Tanker (STRAT)
T-AOT	Transport Tanker (STRAT)
T-ARC	Cable Repair Ship (SMS)
T-ATF	Fleet Ocean Tug (NFAF)
T-AVB	Aviation Intermediate Maintenance and Supply Ship (ROFLO Cargo/Container Ship, also called Maintenance Aviation/Supply Ship) (STRAT)
Test FMI	Test Flexible Modular Interface
TI	Texas Instruments

TRALANT	(COMTRALANT) Training Command U.S. Atlantic Fleet
TTFF	Time-to-First-Fix
UE	User Equipment
U.S.	United States
USA	United States Army
USAF	United States Air Force
USMC	United States Marine Corps
USNS	United States Naval Ship
WGS	World Geodetic System
WRALC	Warner Robbins Air Logistics Center

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