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CHANGES IN LIGHT AIRBORNE MULTI-PURPOSE SYSTEM (LAMPS) HELICOPTER OPERATIONS WITH THE INCORPORATION OF THE GLOBAL POSITIONING SYSTEM

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

David L. Gay

December, 1992

DEDICATION

To my lovely wife Cindy,

my daughter Amanda,

and my son Jeremy:

Thanks for the support and

understanding when I would not

be pried from the computer screen.

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DISCLAIMER

The information presented in this paper is the sole opinion of the author and in no way reflects the views of the U.S. Government.

ABSTRACT

Until recently, U.S. Naval fleet helicopters have used a Doppler system as the primary means of over-water navigation. Reliable tactical navigation is essential to mission performance, but due to inaccuracies inherent to Doppler navigation systems, an excessive amount of aircrew compensation is required in order to accomplish the mission. With the incorporation of the Global Positioning System (GPS) as the primary navigation source, a significantly improved efficiency in completing the multiple missions of the fleet helicopter may be realized.

Since GPS is a military system, the Department of Defense is aggressively pursuing GPS incorporation into all facets of military tactics and procedures. This paper addresses several methods of applying GPS and GPS related technology to improve the effectiveness of at-sea helicopter operations.

The Thesis concludes that the NAVSTAR GPS is a navigation system that will be a definite force enhancer in military operations. With a minimum of additional monetary investment, the system has the potential to enhance shipboard approaches and improve helicopter operations in the anti-submarine warfare, search and rescue, and naval gunfire support missions.

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GLOSSARY

Almanac: Data transmitted by each satellite which provides coarse orbital information of the other satellites in the constellation.

Coarse Acquisition Code (C/A Code): Also known as the "Civilian Code". The standard GPS binary code which is modulated onto the L1 frequency. It consists of 1023 bits of information with a clock rate of 1.023 MHz. Available to all users.

Cryptographic: A method or device used to encode and decode secret messages.

Delta-Range: The rate of change of the psuedo-ranges.

Ephemeris: The predicted orbital data of an individual satellite which is transmitted along with the various codes.

Hand-Over-Word (HOW): Information transmitted by the satellite which tells a P-code capable receiver where to start searching the P-code in order to expedite a correlation.

Multipath Error: Errors caused by the interference of a signal that has reached the receiver antenna by two or more different paths. Usually caused by one path being bounced or reflected.

Precise Positioning Service (PPS): Provides for increased precision and can be guarded with Selective Availability and Anti Spoofing techniques.

Precision Code (P Code): Also known as the Precise or Protected code. The binary code modulated onto both the L1 and L2 frequencies which is a 267 day long sequence with a clock rate of 10.23 MHz. Not generally available to civilian users.

Psuedo-Range: A distance measurement based on the correlation of a satellite transmitted code and the local receiver reference code, that has not been corrected for errors in synchronization between the transmitter clock and the receiver clock.

Selective Availability (S-A): The capability of the Military to intentionally degrade the positional accuracy of the system by deliberately introducing controlled errors into the satellite ephemeris data.

Semi-Synchronous Orbit: An observer on the ground will observe the same satellite ground track each day; however the satellite will become visible four minutes earlier each day due to a four minute per day difference between the satellite orbit time and the rotation of the earth.

Spoofing: The creation of a false satellite signal that looks to the GPS receiver like the real satellite signal.

Standard Positioning Service (SPS): Specified by the Military to provide 100 meter accuracy at the current Selective Availability setting. Primarily intended for civilian purposes.

Y Code: The encrypted P code. The code can only be accessed by authorized users.

ABBREVIATIONS

ADF.....Automatic Direction Finder
A-S.....Anti Spoofing
ASUW.....Anti Surface Warfare
ASW.....Anti Submarine Warfare
BIT.....Built in Test
C/A.....Coarse Acquisition
DASH.....Drone Anti Submarine Helicopter
DSP.....Digital Signal Processor
DOD.....Department of Defense
EFIS.....Electronic Flight Information System
EMCON.....Emission Control (Electromagnetic)
EOD.....Explosive Ordnance Disposal
FLIR.....Forward Looking Infrared
GEARS.....Geopositioning Aviator Radio System
GPS.....Global Positioning System
HOW.....Hand Over Word
IF.....Intermediate Frequency
JEWC.....Joint Electronic Warfare Center
L1.....Link 1
L2.....Link 2
LAMPS.....Light Airborne Multi-Purpose System
LEO.....Low Earth Orbit
MAGVAR.....Magnetic Variation
MCS.....Mission Control Segment
MHz.....Megahertz (10^6 cycles/second)
MOT.....Mark on Top
NAVSTAR.....Navigation Satellite Timing and Ranging
NGFS.....Naval Gunfire Support
OTHT.....Over the Horizon Targeting
OTPI.....On Top Position Indicator
PPS.....Precise Positioning Service
PRN.....Psuedorandom Noise

RAE.....Royal Aerospace Establishment
RGPS.....Relative Global Positioning System
RTU.....Receiver and Transmitter Unit
S-A.....Selective Availability
SAR.....Search and Rescue
SPS.....Standard Positioning Service
SRS.....Sonobuoy Reference System
TACAN.....Tactical Air Navigation
TACNAV.....Tactical Navigation
UHF.....Ultra High Frequency
UTC.....Coordinated Universal Time
VHF.....Very High Frequency
VOR.....VHF Omnidirectional Receiver

1 HISTORY

It is hard to be sure of the exact beginning of the present day Light Airborne Multi-Purpose System (LAMPS) helicopter since it evolved from a series of events in the mid 1960s to the early 1970s. All U.S. Naval manned helicopter operations were limited to the aircraft carrier until someone noted that the Canadians routinely operated helicopters off of their smaller surface combatant ships, stimulating the inception of the LAMPS program [1].

The main thrust of a ship-based helicopter was to extend the limited eyes, ears and weapons delivery capabilities of the Navy's surface ships. The predecessor to LAMPS was the Drone ASW Helicopter (DASH), introduced to the fleet in 1962[1][2]. DASH was an unmanned platform used to deliver a torpedo to an enemy submarine at extended distances from the ship. Unfortunately, the remotely piloted system was difficult to control and was eventually cancelled.

International events, such as the destruction of an Israeli ship by an Egyptian Styx missile during the 1967 Arab and Israeli War, lead the Navy to quickly establish a successor to the DASH [2]. The Navy responded by taking an off-the-shelf helicopter, the UH-2C, and outfitting it with existing technology borrowed from other platforms such as

the H-3, P-2 and S-2. This new aircraft was designated the SH-2D. The helicopter was stationed aboard Garcia Class and Knox Class frigates which were equipped with some 1950's tactical data link and acoustic analysis technology and the whole marriage was christened LAMPS MKI [2].

The LAMPS MKII was supposed to be a major avionics upgrade built around the existing SH-2D/F. However, a decision was made to cancel the MKII System in favor of pushing forward with the next generation of naval helicopter, the SH-60B [2]. This new aircraft and avionics system was to become LAMPS MKIII.

In the mid 1970s the first truly integrated ship and helicopter union was exploited with the LAMPS MKIII. The Navy, recognizing the degree of avionics integration required between the aircraft and the ship, chose IBM as the prime contractor and Sikorsky as the supplier of the SH-60B. Not only has the ship and helicopter interface met with great success, but the airframe itself has performed so well that another naval H-60 variant, the SH-60F, has begun replacing the current H-3 used for aircraft carrier operations.

Throughout the 30 years that helicopters have been operating on board small ships there have been many technological improvements to ships, airframes and systems. Currently, the typical multi-mission naval helicopter incorporates radar for over-the-horizon targeting, Forward

Looking Infrared (FLIR) for target classification and identification, and the capability for onboard analysis of acoustic data in the prosecution of enemy submarines. All of this capability is basically useless unless the aircrew can relay accurate targeting position information to other combatants. Until recently, fleet helicopters have used a Doppler system as the primary means of over-water navigation. Inaccuracies inherent to Doppler navigation systems require excessive compensation by aircrews which, even when minimized, cause unreliable tactical navigation information. With the inception and incorporation of the Global Positioning System (GPS) as the primary navigation source, a significantly improved efficiency in completing the Anti-Submarine Warfare (ASW) and other LAMPS missions may be realized.

2 GLOBAL POSITIONING SYSTEM

2.1 Overview

Until very recently the questions of airborne navigation have been answered by choosing between the lesser of two evils. Systems, such as Omega, offer a very large coverage capability but demonstrate a relatively low accuracy (2 - 4 miles) [3]. Systems such as VOR and TACAN offer increased accuracy but are limited to line of sight coverage. The advent of the satellite has melded the best of these systems, world wide coverage and increased accuracy, into one system; the NAVSTAR Global Positioning System (GPS).

GPS is a space-based radio positioning system which provides suitably equipped users with highly accurate position, velocity and time data. The NAVSTAR GPS is scheduled to be declared fully operational late in 1993 [4]. When fully operational, this service will provide global, continuous, and all weather navigation capability to users at or near the surface of the earth. GPS receivers operate passively, thereby allowing an unlimited number of simultaneous users. The GPS has features which can deny accurate service to unauthorized users, prevent spoofing and reduce receiver susceptibility to jamming.

2.2 System Description

The GPS is composed of three major subsystems; Control, Space, and User, as depicted in figure 1. The Control Segment is comprised of the Master Control Station (MCS) located in Colorado Springs, Colorado and several monitoring stations located around the world, as shown in figure 2. The Space Segment, when fully functional, will be comprised of 21 operational satellites in semi-synchronous orbits around the earth [4][5]. The satellites will be placed in six orbital planes with three or four operational satellites in each plane. The satellite orbital planes will be at a height of 10,900 miles (20,200 km) and an inclination of 55 degrees relative to the equator [4][5]. To ensure full system availability, three additional satellites will be orbited as spares. Figure 3 shows the six plane, 21 satellite constellation with three spares. Typically there will be five different satellites viewable at any one time from anywhere on earth [5]. The User Segment consists of a variety of receivers designed to receive, decode and process the GPS satellite ranging codes and navigation data messages.

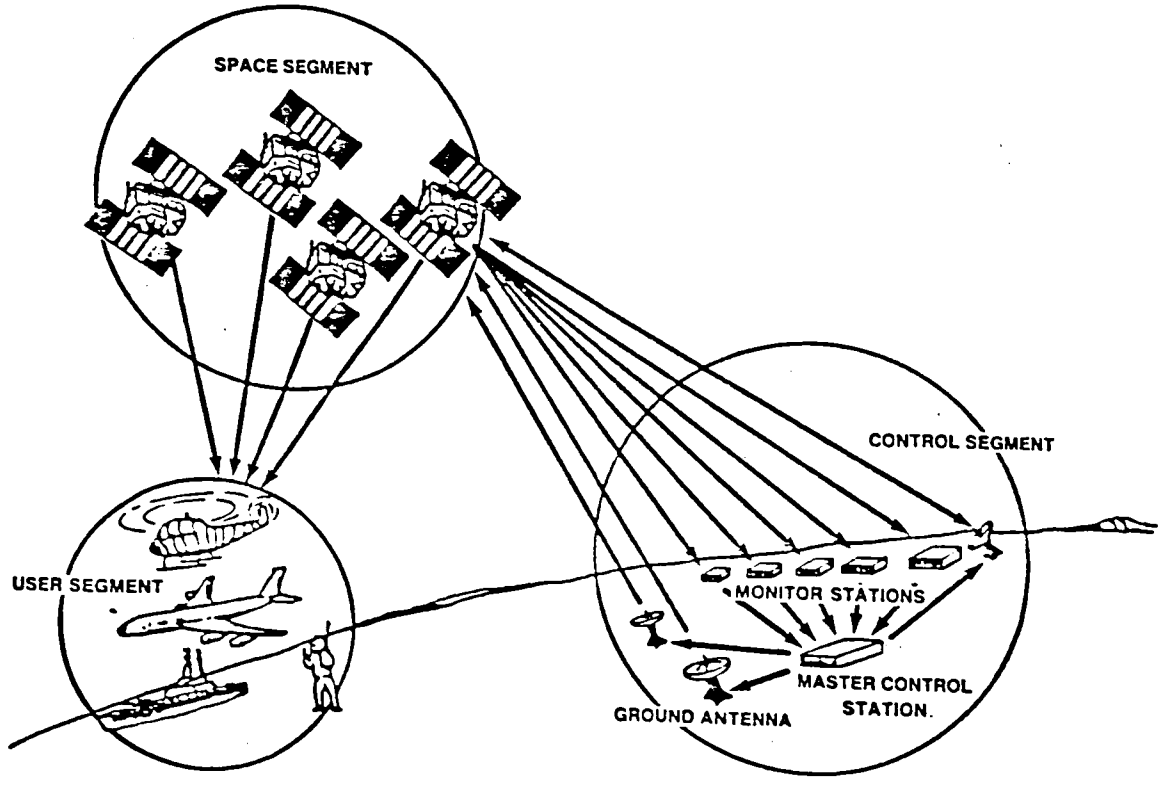


Figure 1 NAVSTAR GPS Subsystems

Source: "NATO-TEAM" at US Air Force Space Systems Division, NAVSTAR-GPS Joint Program Office, Los Angeles, California, NAVSTAR GPS User Equipment - Introduction, 1990.

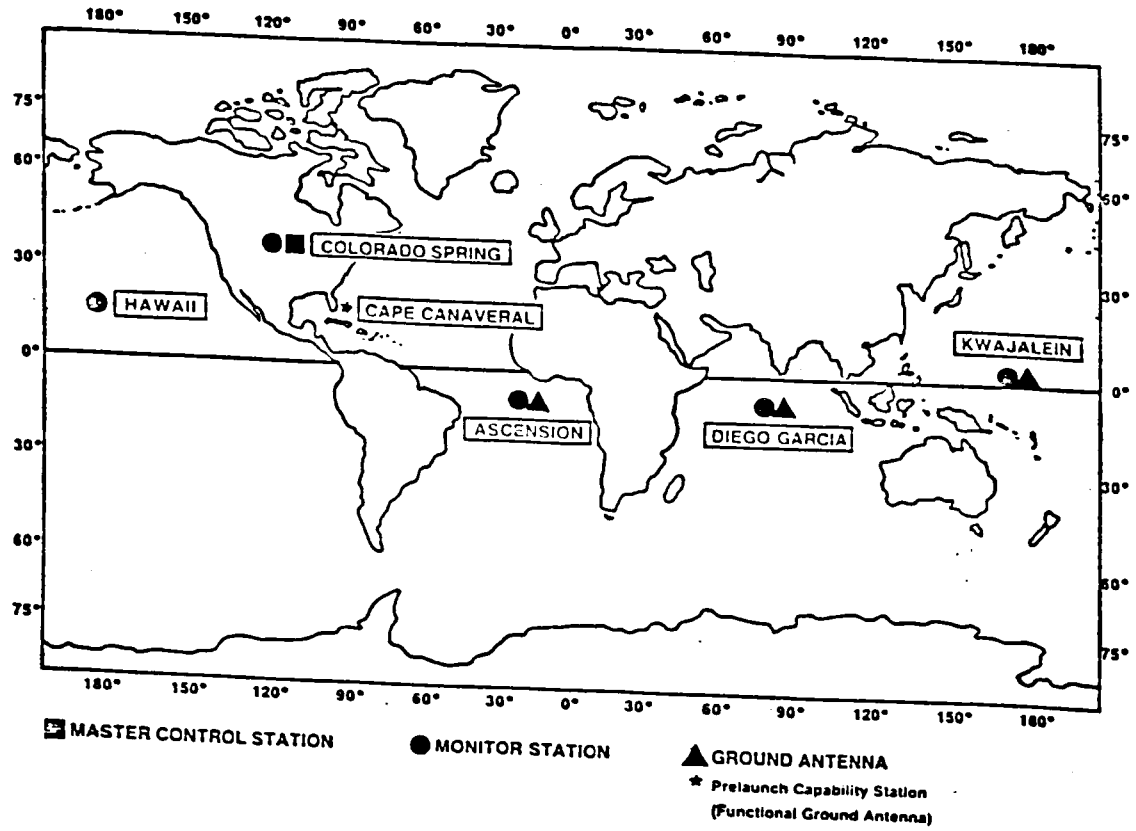


Figure 2 GPS Control Segment Locations

Source: "NATO-TEAM" at US Air Force Space Systems Division, NAVSTAR-GPS Joint Program Office, Los Angeles, California, NAVSTAR GPS User Equipment - Introduction, 1990.

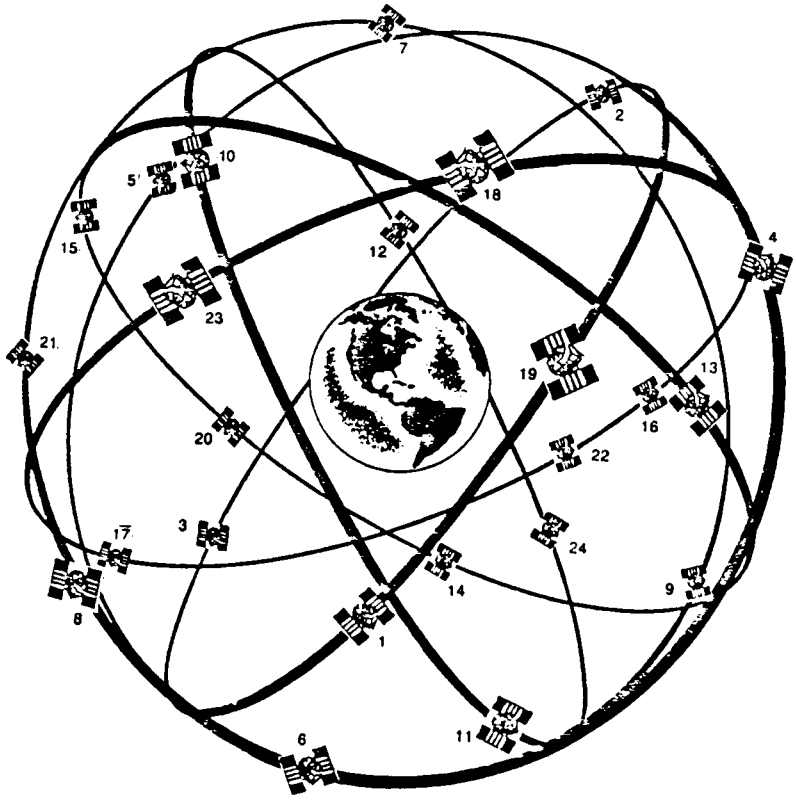


Figure 3 Six-Plane, 21 Satellite Constellation with Three Spares

Source: North Atlantic Treaty Organization (NATO) NAVSTAR GPS Technical Support Group, Technical Characteristics of the NAVSTAR GPS, June 1991.

2.3 System Characteristics

2.3.1 Carrier Frequencies

Each GPS satellite broadcasts signals centered on two microwave frequencies. Link 1 (L1) is centered at 1575.42 MHz and L2 is centered at 1227.60 MHz [5]. These frequencies lie in the band of frequencies known as the L-band which is just above the frequencies used by cellular phones. There are three good reasons for using such high frequencies. One reason is that the L-band is relatively uncluttered with other users. The GPS signal is very complex and contains many components. To transmit this complex information requires a bandwidth of approximately 20 megahertz(MHz) which precludes the use of more crowded broadcast bands. The second reason is to reduce ionospheric interference. The ionosphere affects the propagation speed of the radio signal and causes errors in the perceived ranges to the satellites. This effect is minimized at higher frequencies. The third reason has to do with the Doppler effect. Not only does GPS determine range but it is also capable of determining velocity. Velocities can be determined by measuring the frequency shift of the received signal. To allow for velocity accuracies of less than one inch per second requires the use of signals with centimeter wavelengths (microwaves) [6].

2.3.2 Psuedorandom Codes

GPS signals start out in the satellites as pure sinusoidal waves or carriers. Unfortunately, pure sinusoids cannot be readily used to determine position in real time. To be useful to the user the carrier wave must be modulated in such a fashion that time-delay measurements can be made. This is achieved by modulating the carriers with pseudorandom noise (PRN) codes, as shown in figure 4. A PRN code consists of a series of zeros and ones (binary) which appear to be random in order. By using special devices or algorithms it is possible to cause this apparently random sequence to repeat at a predetermined interval [7]. These sequences are termed pseudorandom.

The same psuedorandom sequence is independently duplicated by the GPS receiver. By matching the duplicated signal to the incoming signal and knowing the instant of time the signal was transmitted by the satellite, the travel time, and hence the range from the satellite, can be determined. Each satellite produces its own set of codes so that the receiver knows which signal is coming in from which satellite, even when the signals from several satellites arrive at the receiving antenna at the same time.

Two different PRN codes are broadcast by the satellites. One is the Precision (P) code and the other is the Coarse Acquisition (C/A) code. The C/A code is a sequence of 1,023 binary digits (chips) which is repeated

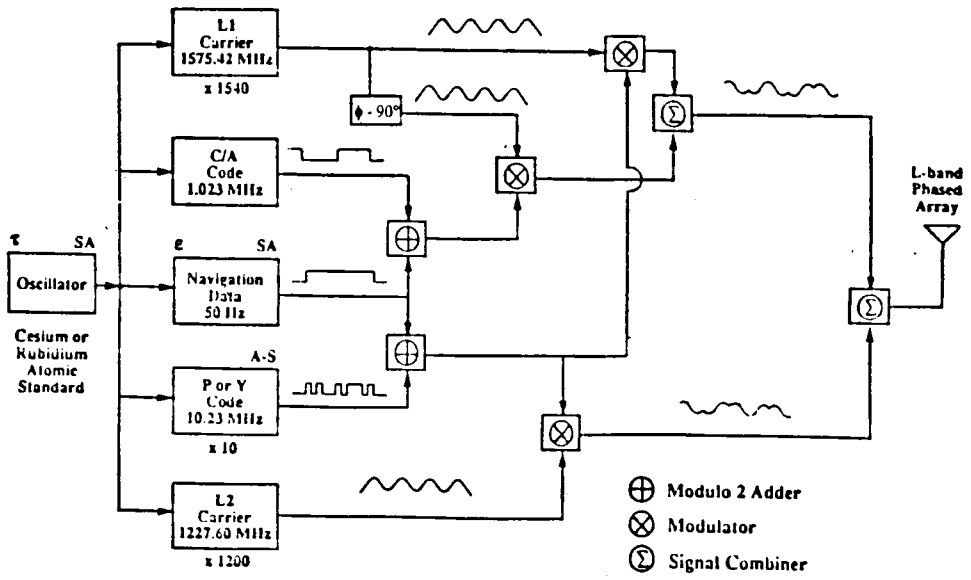


Figure 4 GPS Signal Generation

Source: McDonald, Keith D., "Fundamentals of GPS II", NAVTECH Seminars, 1992.

every millisecond [5][7]. This means that the chips are generated at a rate of 1.023 million per second which means that each chip has a duration of about one microsecond. Since each chip travels through space at the speed of light it is possible to obtain a unit of distance by multiplying the time interval by the speed of light. The "wavelength" of the C/A code is approximately 300 meters since light travels that distance in one microsecond. Since this code is repeated every millisecond, a GPS receiver can quickly lock onto the signal and begin matching the received signal with the one replicated by the receiver.

Higher precision can be obtained in the ranging measurement by decreasing the wavelength of the code [7]. Since the rate at which the chips are generated in the P code is 10 times as fast as compared to the C/A code, it has a wavelength of only 30 meters.

The P code has an extremely long sequence. The pattern of chips only repeats every 267 days [5]. Each satellite is assigned a unique one-week segment of this code which is initialized at Saturday to Sunday midnight each week [5][7].

Currently, the C/A code is modulated onto the L1 carrier and the P code is modulated onto both the L1 and L2 carriers. Users of the single L1 frequency must use a mathematical model to account for ionospheric interference, whereas P code users (military) are afforded the capability

to use both L1 and L2 frequencies which gives a real time correction for the effects of the ionosphere.

2.3.3 Navigation Message

To convert the signal received by the satellite into position the receiver must know where the satellites are. This information is broadcast by the satellites on both L1 and L2. Each satellite sends its own navigation message which consists of orbital information (ephemeris) to be used in position computation, the offset of its clock from GPS system time, information of the health of the satellite and the expected accuracy of the range information. The message also contains almanac data for the other satellites as well as their health status and other information. The receiver uses these data to acquire signals from satellites that are above the horizon but not yet being tracked.

The GPS navigation message is sent out at 50 bits per second, taking 12.5 minutes for all the information to be transmitted [5][7]. To reduce the time it takes for a receiver to obtain an initial position, the ephemeris and satellite clock offset data are repeated every 30 seconds.

Another very important piece of information contained in the broadcast is for P code users. Since the P code is seven days long it would take a long time for an initially unsynchronized receiver to search the whole code to try to match its reference signal. The receiver gets some help

from a special word in the message called the "hand over word"(HOW), which tells the receiver where in the P code to start searching.

2.3.4 System Accuracy

Two levels of navigational accuracy are provided by the GPS, the Precise Positioning Service (PPS) and the Standard Positioning Service (SPS). The PPS is a highly accurate positioning, velocity and timing service which is made available to authorized users, while the SPS is a less accurate positioning and timing service available to all users.

At the present time, the PPS is specified to provide 16 meter positioning accuracy and 100 nanosecond Coordinated Universal Time (UTC) time transfer accuracy to authorized users [5]. If Selective Availability is set to zero then the SPS accuracy is the same as the PPS. With Selective Availability implemented, the SPS is specified to provide 100 meter positioning accuracy to any GPS user during peacetime [6]. SPS receivers can achieve approximately 337 nanosecond UTC time transfer accuracy [5]. A synopsis of positional accuracies is presented in table 1.

2.3.5 Special Features

Access to the PPS is controlled by two features using cryptographic techniques. The S-A feature is used to reduce

Table 1

Positional Accuracies in the S-A and A-S Environment

Operating Mode		Authorized User[3]		Unauthorized User	
S-A[2]	A-S	P Code	C/A Code	P Code	C/A Code
OFF	OFF	16	30	16	30
ON	OFF	16	30	100	100
OFF	ON	16	30	30	30
ON	ON	16	30	100	100

Notes: (1) All accuracies are in meters.
(2) Assumes maximum specified S-A errors.
(3) Authorized implies access to S-A and A-S Algorithms.

Adapted from: van Graas, Dr. Frank, "Coping with Selective Availability and Anti-Spoofing", Unpublished notes, NAVTECH Seminars, September 1992.

the navigational accuracy available to the general user. According to the Department of Defense guidelines, the SPS incorporates an additional degradation to navigational accuracy called selective availability (S-A) which will be set such that 100 meter accuracy is attainable [6]. S-A is accomplished through manipulation of either the navigation message orbital data or the satellite clock signals. System accuracy can be further degraded if it is necessary to do so (i.e. to deny accuracy to an enemy in time of war).

Anti-Spoofing (A-S) can be invoked at random to negate potential spoofing (hostile imitation of the satellite navigation and L-band carrier frequency signals) of PPS signals. The A-S technique alters the P code cryptographically into a code denoted as the Y code [5]. PPS users would have encryption keys and techniques available to allow them to remove the effects of S-A and A-S and obtain the maximum available accuracy. The C/A code signal is totally unaffected by the P code encryption and will remain available for all users [5].

3 SHIPBOARD OPERATIONS

3.1 General

The original concept of stationing a helicopter onboard a ship was predicated on the capability of the aircraft to launch and extend the ship's line of sight limited sensor and weapons delivery capability. Over the years this practice has synergistically enhanced not only individual ship capabilities but has extended its enhancing capabilities to the fleet by providing each Battle Group or Carrier Group with its own organic Anti-Submarine (ASW) and Over the Horizon Targeting (OTHT) assets.

The following discussion will deal primarily with the SH-60B and the SH-60F and assumes a typical Carrier Group employment of the Aircraft Carrier and the accompanying assets. An Aircraft Carrier is typically escorted by several guided missile destroyers and/or cruisers for close-in anti-submarine and anti-aircraft support (within 20 to 30 nm). Also, several frigates with the capability of deploying towed hydrophone arrays guard the outer perimeter against submarine attack (within 100 miles).

The SH-60F is primarily stationed on the Aircraft Carrier and has the responsibility of inner zone ASW and Search and Rescue (SAR). Inner zone is approximately within 30 nm of the carrier. The aircraft is equipped with the

capability of employing expendable, short duration devices known as sonobuoys which can be used to listen or can be made to put sound into the water to determine a target's position. This acoustic information can be processed autonomously aboard the aircraft or data linked to an ASW capable ship for processing. The SH-60F also has the unique capability of coming to a hover and deploying a transducer into the water via a cable (dipping). This transducer can either listen passively for submarine activity or, if the target has been localized and authority for attack has been obtained, the transducer can be commanded to prosecute the target by use of active Sonar.

The SH-60B is primarily stationed on the frigates which have the primary responsibility of patrolling the outer zones of the task force. This aircraft has the capability of deploying sonobuoys in the same manner as the SH-60F. The SH-60B also incorporates a state of the art radar which can be used in a number of missions but is primarily used to extend the ship's sensor range and target unfriendly forces.

The aircraft incorporates a unidirectional, full duplex, encrypted data link which is extremely hard to intercept. The data link allows two-way flow of acoustic, radar, navigation and voice information as depicted in figure 5. Not only is the ship seeing what the aircraft sees but the ship can uplink crucial tactical data and control aircraft sensors.

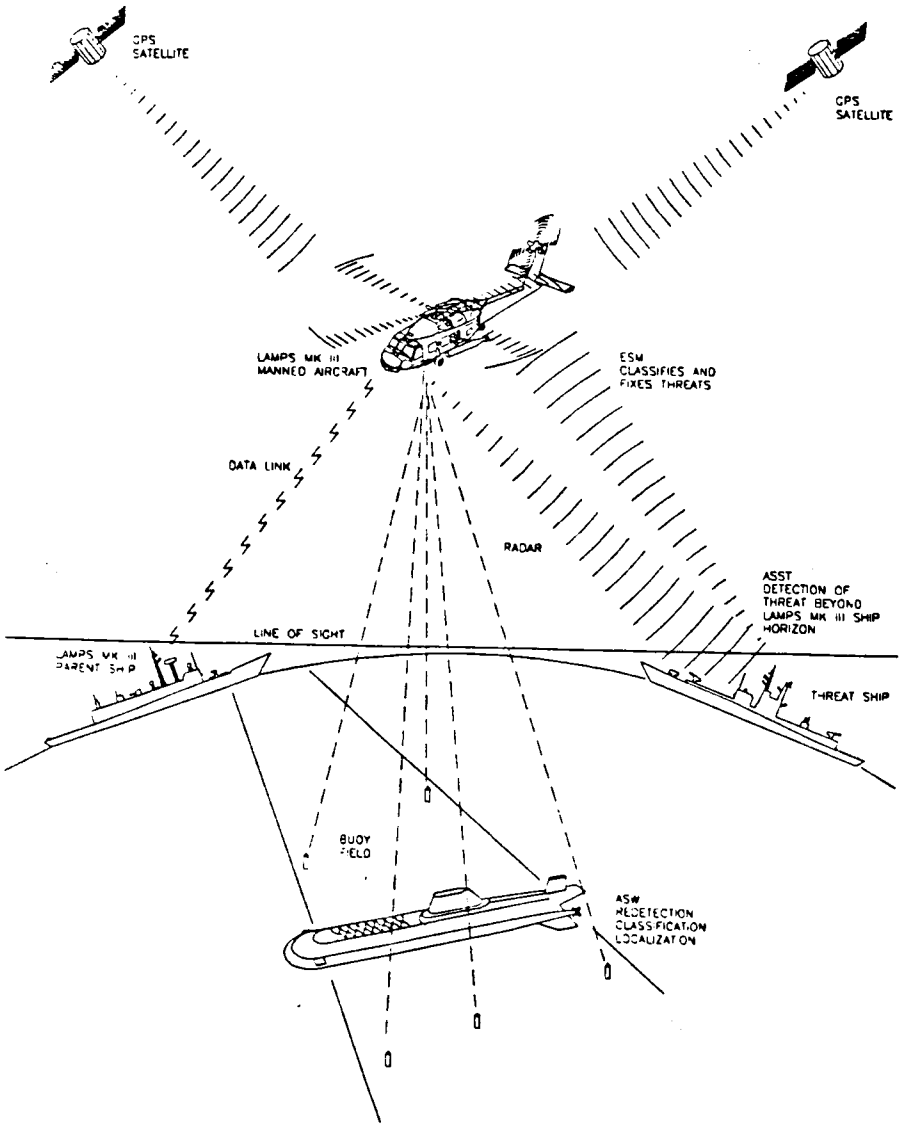


Figure 5 LAMPS MKIII Mission

Source: A1-H60BB-NFM-010, LAMPS MKIII Weapons Systems Manual, 1 March, 1992.

Both the SH-60B and SH-60F use a Doppler based navigation system. The Doppler energy is reflected off the surface of the water and generates velocity and drift information. This information is relayed to the Tactical Navigation Set (TACNAV) in the cockpit and, as long as the crew keeps it updated with new information, will display a "relative world" picture of tactical information.

3.2 Anti-Submarine Warfare

A typical ASW mission begins with the aircrew updating their TACNAV with the latest available information and launching the aircraft toward the latest known location of the enemy submarine. Relying on some other sensor or platform to track a possible target, the helicopter crew's primary mission is to obtain the final localization and attack the submarine. This contact could have been generated by several sources: one or more frigates towing their hydrophones could have triangulated a contact; another helicopter asset could be tracking the submarine and needs to be relieved; or the contact could have been picked up by a fixed wing ASW asset (P-3, S-3).

While enroute to the contact the Doppler system is keeping track of the aircraft speed and drift and is updating the TACNAV. Unfortunately, experience has shown that sea based Doppler systems are susceptible to

appreciable amounts of drift (typically 1-2 knots) due to the movement of the ocean's surface. Doppler signals can be further degraded by the aircraft banking or by pitch excursions which are fairly common to a helicopter in the ASW mission. By the time the aircraft arrives on station, the navigation system can have developed 1000 to 2000 yards of error.

As the aircrew seed the sonobuoy field, each deployed sonobuoy appears on the TACNAV screen at the place where the sonobuoy was deployed relative to where the aircraft "thinks" it is in relation to the "real world". The aircrew now start processing the buoy's acoustic information that is being sent up to the aircraft via a VHF radio frequency. Since the buoys are now in the water they are susceptible to ocean currents and begin to drift.

The submarine position is determined in relation to two or three of the buoys in the water, but, unfortunately, the buoys have drifted substantially when compared to the TACNAV screen. The only recourse that the crew has is to "mark on top" (MOT) of one of the buoys in the water, preferably the buoy that has been in the water the longest. By marking on top of the buoy the crew can update the TACNAV with the new buoy location and generate a velocity bias which can be applied to all of the buoys on the TACNAV screen in relation to the time they have been in the water. This tactic is achieved by use of the On Top Position Indicator (OTPI),

which receives the buoy VHF signal and, acting like an Automatic Direction Finder (ADF), gives the aircrew a steer command to the buoy. Unfortunately, the signal is somewhat unstable and generally gives the pilot an indication that can change by as much as +/- 10 to 15 degrees in one to two seconds. As the aircraft marks on top of the buoy it passes through an area of uncertainty known as the "zone of confusion", which increases in area with altitude. A depiction of these errors is shown in figure 6.

The MOT process is inherently inaccurate and extremely time consuming. The authority to attack a submarine can come very quickly and with great urgency but attack can be delayed significantly by having to update the TACNAV plot to ensure accuracy prior to attacking.

Another error source which must be accounted for is the buoy's bearing inaccuracies. If the buoy's information was absolutely perfect and there were two or more buoys in contact with a target, then the target's location would be given by the intersection of two or more lines of bearing from the buoys. A sonobuoy's performance characteristics are classified but for the sake of this discussion a bearing inaccuracy of +/- 10° will be assumed. With two or more buoys in contact a polygon of uncertainty exists. Subsequent attack on this position of uncertainty may prove unsuccessful if the crew's navigation solution was in error.

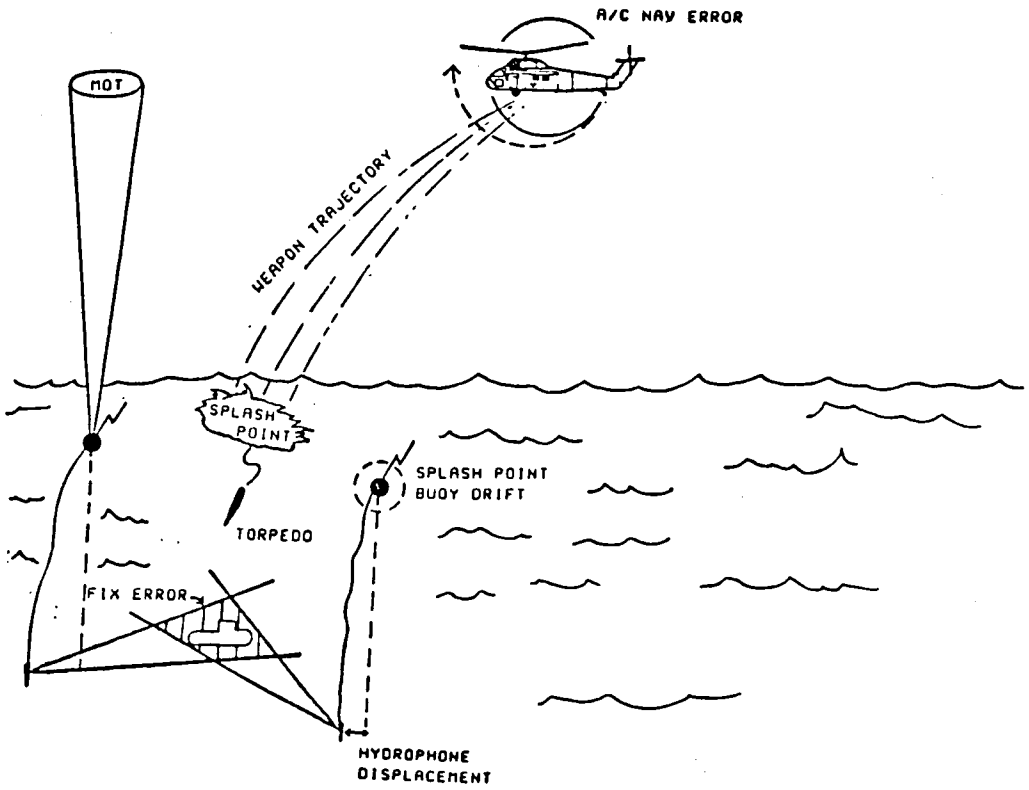


Figure 6 Depiction of Errors Associated with ASW

Source: Shinskie, Robert H., "The Integration of a Global Positioning System to Maintain Sonobuoy Tactical Position for Anti-Submarine Warfare Prosecution", May 1989.

3.3 Over the Horizon Targeting

Over the Horizon Targeting (OTHT) is the "bread and butter" of the LAMPS mission. It is vital to a Task Force's survival to know of any potential threats to the fleet. A ship's sensor range is limited to the horizon or slightly more, depending on atmospheric conditions. Launching a helicopter and relaying the information back to the ship allows for timely dissemination of tactical information and enhances the Task Force's command and control capabilities.

Equipped with a tight beam data link, the SH-60B has the capability to link back to the ship all of the pertinent tactical information, this includes raw Radar and Forward Looking Infrared (FLIR) information. In general, the Task Force would prefer to remain covert. This means that the Task Force Commander will set some form of electromagnetic Emissions Control (EMCON) which will preclude the ships from emitting any radar, TACAN, or even radio communications which might give the enemy a clue to the location of the Task Force. This EMCON may or may not preclude the use of the SH-60B tactical data link.

A typical OTHT mission will begin with the aircrew being tasked by some higher authority to patrol a given sector or to launch with a specific target in mind. Once the aircraft is free of the ship deck, doppler navigation errors once again come into effect. All of the information contained on the data link will be in error by the same

amount as the doppler navigation error up to that point in time. If the ship is unable to radiate its radar to update the aircraft relative bearing from the ship there is no way of knowing how accurate the aircraft position is. Just knowing of an enemy presence and approximate location is of immense help in tactical planning but the positional uncertainty involved by being in EMCON may prove to be too large to be certain of a pre-emptive shipboard missile strike.

Presently there are many tactics which can be used to circumvent the problem of navigation errors. Of course, the one which is most widely used is the tactical data link with which the ship can keep track of the helicopter position and reduce navigation errors by tracking it with radar. As discussed this is not always desirable. Another technique involves using a common geographical feature which can be seen by the ship and the helicopter. All data is then relayed referencing this landmark. Obviously, in open-ocean searches this technique is unworkable. The situation would be much improved if there was a common reference system which could be accessed by all friendly forces and a means existed whereby every player knew their position relative to that reference frame.

3.4 Search and Rescue Mission

The search and rescue mission has many different scenarios but the common requirement is for the rescuing unit to be able to locate the individual in distress. If an aircrew goes down at sea and is able to communicate, they must rely on UHF radio communication. The rescuing aircrew use an Automatic Direction Finder (ADF) to home in on the location of the survivor. This method is inaccurate and gives no other information to the rescuers other than direction.

If the survivor is unable to communicate then it is necessary to initiate an open ocean search. There are many search patterns available for use depending on the scenario. Most of these patterns can be called up on the TACNAV as waypoint information as depicted in figure 7. In an open-ocean search, with no way to update the navigation, the Doppler drift causes large areas of uncertainty in the area to be searched. Due to current navigation uncertainties, it is next to impossible to coordinate several search units at once and guarantee expedient and efficient search coverage. The requirement that the rescuing aircrew have accurate navigation capabilities to preclude from missing any coverage is imperative.

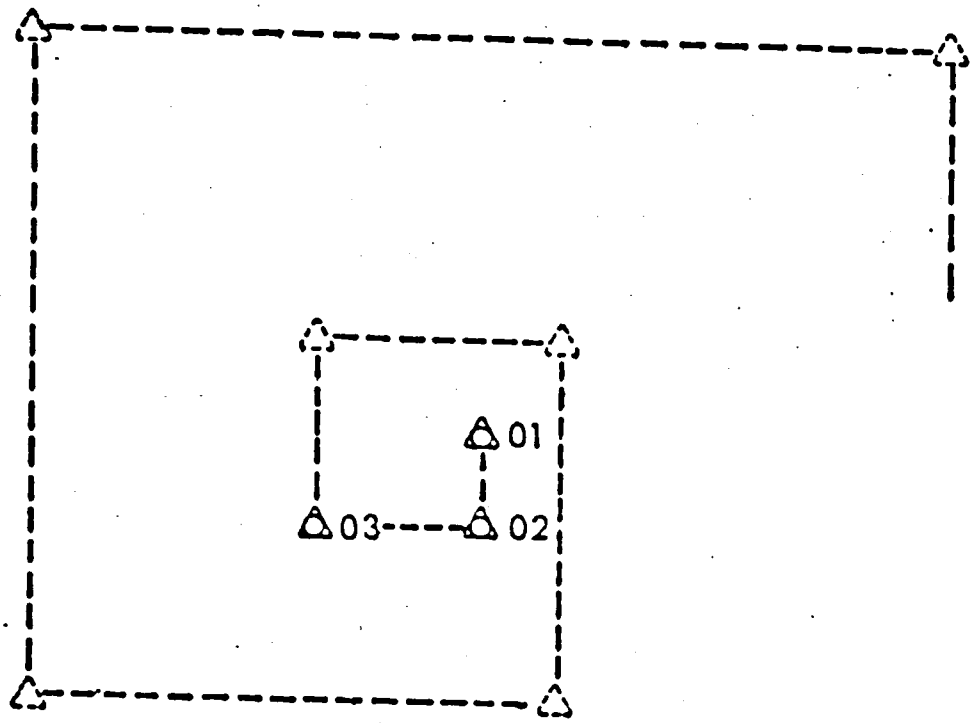


Figure 7 TACNAV Expanding Square SAR Search Pattern

Source: Naval Aviation Depot(NADEP), ENHANCEMENT DESCRIPTION for the REV. A SOFTWARE for the AN/ASN-150 NAVIGATIONAL COMPUTER SET of the SH-2G LAMPS MK-I AIRCRAFT, 22 April 1992.

3.5 Minewarfare Mission

Due to recent world events, countering mine warfare has once again come to the forefront of the U.S. Navy's attention. With the escalation of Desert Shield, Iraq began mining the waters of the Persian Gulf with moored and bottom mines. In February of 1991 the USS Princeton and USS Tripoly became victims of this aggressive act by coming in contact with several moored mines.

Besides random visual sightings of mines, there are generally two ways in which to find mines. First, when a mine breaks its moorings it usually pops to the surface of the water and is an extreme hazard to shipping. Even though the mine presents a very small radar cross section the helicopter still has a limited capability to use its radar to locate it and pass on the mine location to higher authority. The second method makes use of special devices that can be carried aboard the helicopter which can see into the water and detect the sub-surface moored mines. The devices are notorious for having very narrow swath width search capabilities which means that search lanes must be placed very close together, requiring extremely good navigational accuracy.

In both of these cases it is important to be able to find the mine again after the initial detection. Once the mines have been located they must be neutralized which requires that Explosive Ordnance Disposal (EOD) divers must

visually identify the mine and attach explosive devices to it to blow it up. The current state of the art Doppler navigation systems are no where close enough to the accuracy required for this mission.

3.6 Naval Gunfire Support Mission

The Naval Gunfire Support (NGFS) mission uses the helicopter as a forward spotter for the incoming rounds of ammunition fired from some remote location, usually a ship at sea. Accurate positioning and target location is of primary importance to indirect fire systems since it directly affects the probability of hitting the target. Due to navigational errors associated with current systems, the first rounds of ammunition are usually off target by some distance which is directly proportional to the amount of navigational inaccuracies. After the first couple of rounds the aircrew is able to communicate to the ship and adjust each subsequent round by using a vocabulary specifically designed for the NGFS mission. Depending on the tactical situation, this tactic usually puts the helicopter crew at risk due to enemy gunfire or missile attacks.

4 SHIPBOARD OPERATIONS WITH GPS

4.1 General

Currently, integration of GPS into the SH-60B and SH-60F, among many other aircraft, is being tested at the Naval Air Warfare Center Aircraft Division in Patuxent River, Maryland. This testing is a precursor to the fleet receiving these units in mass numbers. Once GPS is introduced to the helicopter community, new capabilities will quickly be realized. This chapter is dedicated to the tip of that iceberg.

4.2 Integration

Currently GPS has been incorporated into many different models of aircraft at the Naval Air Warfare Center Aircraft Division in Patuxent River, Maryland. The LAMPS MK III AN/ARN-151(V)2 GPS User segment consists of an R-2332/AR 5-channel receiver-processor unit (RCVR-3A), an AS-3822/URN Fixed Reception Pattern Antenna (FRPA-3), and associated AM-7314/URN antenna electronics unit (AE-4) [24]. The GPS radio receiver communicates with the SH-60B Standard Airborne Computer (SAC-1) over the MIL-STD-1553B digital data bus. The output data from the GPS radio receiver to SAC-1 is as follows:

a. GPS latitude and longitude

b. GPS status

c. GPS East and North velocities

d. GPS time

e. Estimated horizontal error (ERE)

f. Magnetic variation (MAGVAR)

g. Built in Test (BIT) results

A block diagram showing the basic GPS/aircraft interface is presented in figure 8. The newest software changes allow the GPS to be the primary navigation sensor. The GPS functions are controlled from the Airborne Tactical Officer's (ATO) keyset as shown in figure 9.

4.3 The ASW Mission

The major challenges to performing the anti-submarine warfare mission involve inaccuracies associated with the Doppler system and the inability to precisely pinpoint a sonobuoy position once the buoy is allowed to drift in the ocean currents. With no way to place itself on a geo-positional reference frame, the helicopter must rely on the drifting Doppler system. When the buoys are away from the aircraft for a period of time the aircrew marks on top of a buoy and usually shifts the aircraft symbol on the TACNAV to a position which corresponds to the "master" buoy's position. This way the aircrew develops a drift bias which is then applied to all other buoys according to how long they have been in the water. By performing this maneuver

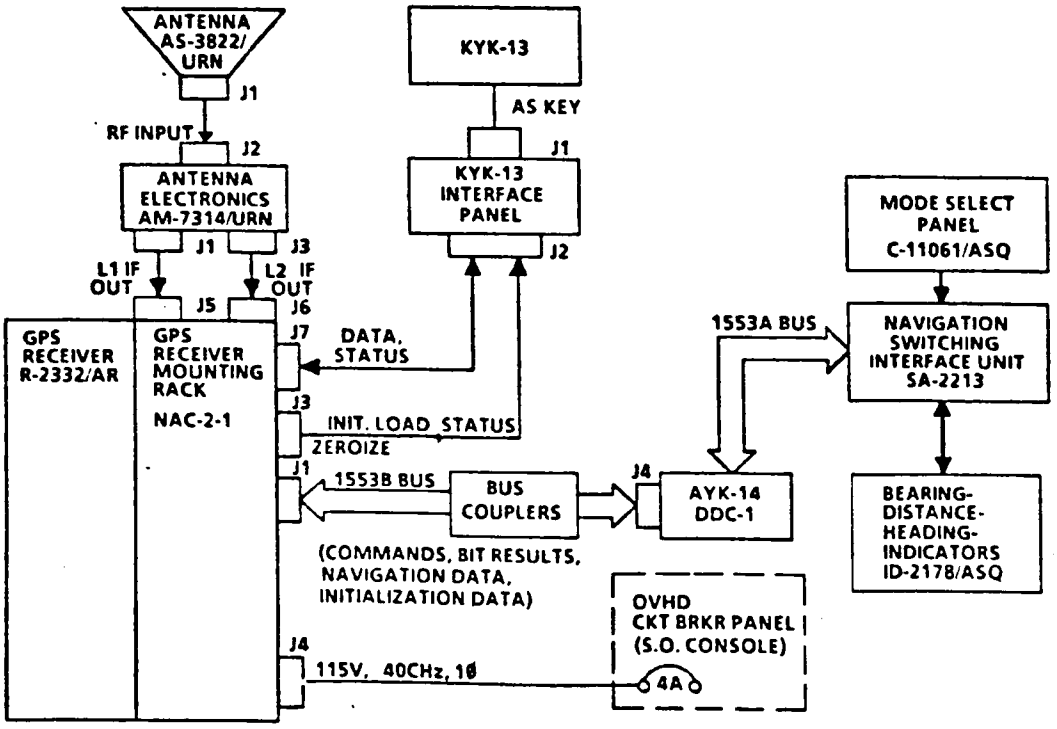


Figure 8 SH-60B and GPS Functional Block Diagram

Source: Smith, P., Fitch, O., Santiago, N., Merritts, R., Dall, M., Test and Evaluation of AN/ARN-151(V)2 Global Positioning System in the SH-60B Helicopter, May 1991.

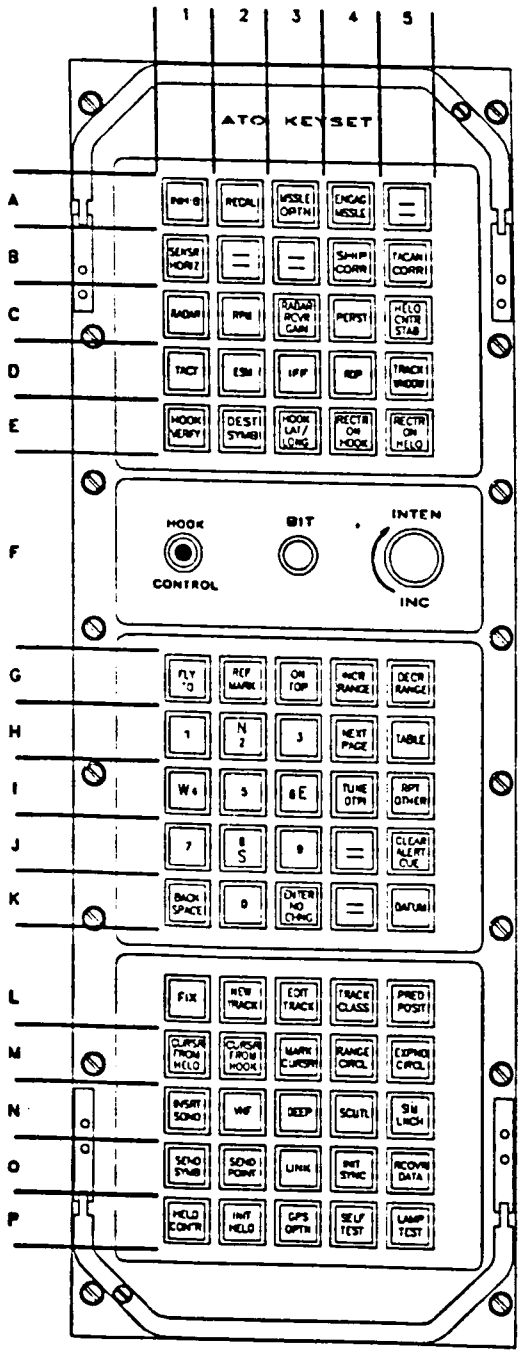


Figure 9 ATO Keyset

Source: A1-H60BB-NFM-010, LAMPS MK III Weapons System Manual, March 1992.

the aircrew has "stabilized" the tactical plot. Unfortunately, this plot is relative to the buoy field and has no geographical reference since it was established by using helicopter position which was generated by the erroneous Doppler navigation system .

By integrating the GPS as the primary navigation sensor and Doppler as the backup sensor, the helicopter can accurately place itself on the face of the earth and can report all positional information according to that reference frame as long as all other combatants are using the same reference system. Unfortunately, the aircrew still has a problem. The buoys in the water are still drifting at an indeterminate rate and direction. When marking on top of the master buoy to stabilize the plot the aircrew can shift the master buoy's position to the aircraft's position. This technique will establish the same bias as before, but now the buoy field will be relative to the aircraft which is established on a common GPS grid. The technique will time shift all buoys in the water according to that drift bias, but all the buoys may not be drifting in the same direction or at the same rate. The process is still very time consuming and maintains the same inaccuracies of the On Top Position Indicator (OTPI).

There are a couple of ways to accurately establish each buoy position automatically, and incorporating one of them would greatly enhance the effectiveness of the anti-

submarine warfare mission. One is the Sonobuoy Reference System and the other uses GPS technology.

4.3.1 Sonobuoy Reference System

The Sonobuoy Reference System (SRS) is currently being used by the P-3 community (fixed wing patrol aircraft) to automatically determine sonobuoy position relative to the aircraft. This is performed by intercepting the VHF radio link from the buoy and triangulating the buoy's position over a period of time. By periodically sampling each buoy, the automated circuitry is able to track all the buoys in the water and update the entire tactical display.

The advantage in incorporating this system in helicopter ASW is that it would automatically track all buoys in the water. There are, however, several significant disadvantages. The system characteristics are such that the air platform must fly a racetrack pattern at a relatively close range to the buoys and accuracy is severely degraded at the altitudes at which a helicopter traditionally operates. The amount of processing time required to position each buoy makes the system relatively slow and the buoy signal is extremely susceptible to jamming in various ways. Finally, if a helicopter is required to join the scenario, the crew must establish its own tactical plot by flying over every buoy in the field which may hold contact on the submarine. This is very time consuming and workload

intensive. Currently this technology is being used on fixed wing patrol aircraft and is not planned for incorporation in the helicopter community.

4.3.2 Global Positioning System

Another way to obtain accurate sonobuoy position automatically would be to incorporate GPS in all sonobuoys. GPS position information could be modulated onto the VHF carrier and sent back to the aircraft along with the acoustic information generated by the buoy. The following paragraphs describe three ways to incorporate GPS into a sonobuoy: (1) an imbedded GPS receiver, (2) a translator, or (3) the TIDGET™ produced by NAVSYS Corporation. Block diagrams of the three sensors are presented in figure 10.

4.3.2.1 Imbedded GPS Receiver Design

In this design the GPS receiver is imbedded in the sonobuoy. The components of a modern GPS receiver include an antenna, a RF subsystem, a frequency synthesizer, a Digital Signal Processing (DSP) chip and a microprocessor. The antenna receives the L1 signal which is mixed in the RF subsystem and then converted to an Intermediate Frequency (IF). The 1.023 MHz C/A code IF signals are generally sampled at a 2 MHz rate and filtered to produce a digitized GPS signal [8]. The digitized code and carrier frequency are processed in the DSP chip to track the code and carrier.

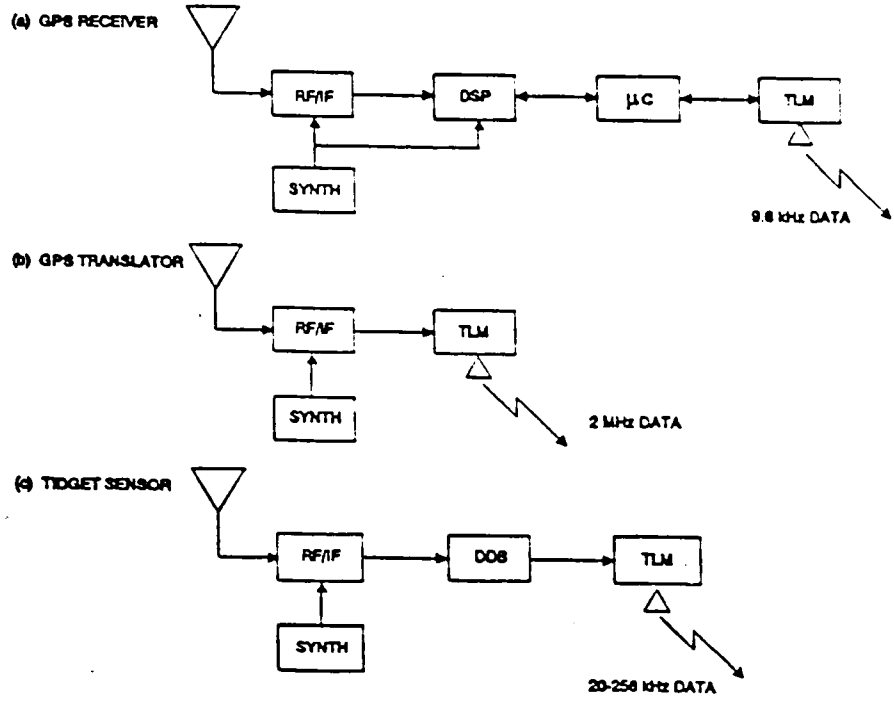


Figure 10 Alternative GPS Sensors

Source: Brown, Dr. Alison, The TIDGET™ a Lowcost GPS Sensor for Tracking Applications, September 1992.

The DSP chip generates the PRN code for each satellite tracked and modulates this code on the received GPS signals. Within the microprocessor the signal is processed and psuedo-range and delta-range measurements are used to derive the position and velocity of the receiver. The receiver provides either psuedo-range and delta-range information or position and velocity fix information from the buoy to the base station onboard the aircraft.

The major advantage to this system is that the amount of additional information modulated onto the VHF carrier is about 150 bits for each fix [8]. The major disadvantage is the cost associated with incorporating these sensors into disposable systems. Several manufacturers have announced a GPS chip design which would cost approximately $250 [6]. The Navy would consider this price prohibitively high considering the large numbers of buoys which would be fitted with this sensor [17].

4.3.2.2 GPS Translator Design

Another option for tracking the sonobuoy using GPS technology is to use a device known as a translator. Currently, the major application of the translator is to track vehicles during highly dynamic maneuvers or where rapid time-to-first-fix is paramount, such as missile tracking. As shown in figure 10, the front end of the translator is the same as that of the GPS receiver and

performs the same function. To allow for the clock frequency to be sent along with the raw data, it is necessary to transmit the information in the S-band [8]. The signal would then be processed aboard the aircraft.

Current estimates of the price of a GPS chip, the RF subsystem and the frequency synthesizer put the price at approximately $100 [6]. Unfortunately, the translator must use a wideband data link which would be very expensive. The current cost of an S-band amplifier alone is over $1000 [6]. Even though this price would come down considerably with mass production it would never be less than that of a GPS receiver.

4.3.2.3 GPS TIDGET™ Design

The third option is the TIDGET sensor [8]. Developed and patented by NAVSYS to reduce the cost of tracking low dynamic vehicles it is thought to be ideally suited for expendable applications such as sonobuoy operations.

The TIDGET utilizes the same RF/IF and frequency synthesizer subsystems as shown in figure 10. However, instead of rebroadcasting the raw GPS information, it is first passed through a data compression algorithm to reduce the required bandwidth of the signal sent back to the aircraft [8].

Periodically, at a predetermined rate, a "snapshot"[8] of the 2MHz sampled GPS data is buffered in memory after

being processed by the compression algorithm. The buffered data is then retransmitted at a substantially reduced data rate. In the aircraft the "snapshot" of data is processed to recover the GPS satellite information which is used to determine sonobuoy position and drift velocity. It would be necessary for the aircraft to have the capability to recover the measurements from all available satellites to aid in computing a precise differential solution in real time.

The TIDGET incorporates the best of both receiver and translator. The cost of the TIDGET, approximately $80 to $100 [18], is less than the receiver since the microprocessor and the digital signal processor would not be incorporated into the sonobuoy. The TIDGET is also much less expensive than the translator due to the translator requirement to incorporate an S-band amplifier. The TIDGET also has the advantage of using the conventional VHF link due to buffering the data and retransmitting it at a slower rate.

4.3.2.4 Security

Due to the sensitive nature of ASW, it is essential to consider the security issues associated with employment of sonobuoys. The two main factors which effect the security of sonobuoy operations are (1) susceptibility to electromagnetic jamming and (2) classification of the receiver. Using a P-code receiver in the buoy, which has

the capability of being encrypted by the military Y-code, renders the sonobuoy practically impervious to jamming or intrusion [5]. However, in the event that the sonobuoys are picked up by unfriendly forces in the operational vicinity, the sonobuoy encryption devices could be compromised.

Placing the major burden of processing the GPS sonobuoy information on the aircraft, as in the translator or TIDGET designs, alleviates the requirement for the buoy itself to carry cryptographic equipment, but still ensures maximum anti-jamming capability.

4.3.2.5 Design Tradeoffs

Since the imbedded GPS receiver design incorporates a microprocessor to determine sonobuoy position, it requires more equipment to be placed in the buoy, increasing size, weight, and cost of the buoy. It would also require that the buoy be encrypted prior to launch to preclude enemy jamming. This would compromise the cryptographic equipment inside the buoy if it were retrieved by unfriendly forces. The one advantage to the receiver design is that it requires only a low bandwidth telemetry data link.

The digital translator has the advantage of small package size and does not require that the buoy be encrypted. The major disadvantage is that translator requires a large bandwidth telemetry data link which will overcome the relatively small cost of the translator.

The TIDGET combines the best of the previous two designs. The system is small, inexpensive and does not require encrypting the sonobuoy. Due to the data compression algorithm, the TIDGET does not require the added expense of a high bandwidth data link .

4.4 Search and Rescue Mission

Any upset of that delicate balance of forces known as flight can lead an aviator into an extremis situation and result in a struggle against the environment or unfriendly forces. The better the initial estimate of location, the higher the probability that the aviator will be located and rescued and the lower the risk to the rescuing unit.

Unfortunately, if the aviator happens to be down in hostile territory, conventional transmissions can also lead to revealing the position to the enemy. For the past 30 to 40 years the basic idea of determining an aviators position was to use a method by which a Search and Rescue (SAR) unit could home on a radio transmission.

Currently, the United States has signed an international treaty which establishes a world wide SAR network for locating emergency beacons [9]. This system requires the pilot to transmit a RF signal to a Search and Rescue Satellite (SARSAT). The satellites are designed to act as repeaters at 121.5 MHz and some will also act as repeaters on 243.0 MHz [9]. The satellite then retransmits

the information to ground stations. There are 18 ground stations in 10 countries which are able to receive the satellite signals [9]. Any of these stations can process the satellite information and determine the location of the downed aviator.

Since any participating country is able to obtain this information, it is possible that an enemy may locate the aviator prior to friendly forces. Activation of either standard military radio (AN/PRC-90 or the AN/PRC-112) within the areas presented in figure 11 will enable the location of that transmitter within approximately 12 miles [9]. This requires that a SAR unit fly to the approximate location to begin the search which, putting that unit at increased risk.

4.4.1 Geopositioning Aviator Radio System

Recently the U. S. Air Force Command in Europe tasked the Joint Electronic Warfare Center (JEWC) to provide a system which could locate a downed aviator with a reduced susceptibility to interception and detection [9]. The system had to have the capability to communicate the position of the aviator to a station beyond the radio horizon, the transmission had to uniquely identify each beacon, the transmission had to be enciphered for privacy and minimize the number of transmissions. The system is known as the Geopositioning Aviator Radio System (GEARS).

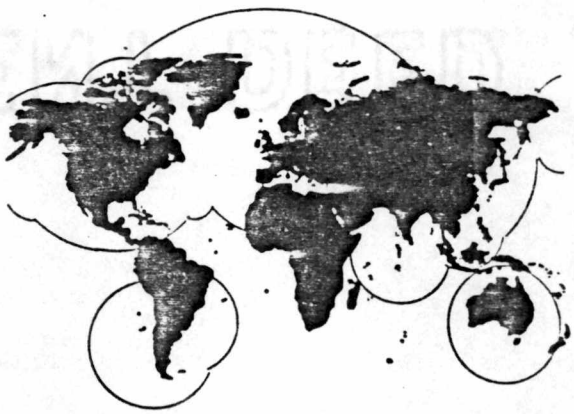


Figure 11 SARSAT RF Coverage

Source: Emery, James W., Jaekle, Thomas H., A Geopositioning Aviator Radio System, September 1992.

The portable Receiver/Transmitter Unit (RTU) weighs approximately 4 pounds [9] and is designed to fit in a jet aircraft seat pan or most survival equipment pouches. The handheld RTU utilizes GPS to determine the aviators location and then transmits this enciphered information to a Low Earth Orbit (LEO) satellite which then downlinks the information to the remote site receiver. Along with position information, a coded message may also be sent. The system is capable of real time data transfer and, since the LEOs are not visible 24 hours a day, the system also has a "store and forward" capability [9].

The system has been demonstrated in the United States and Europe on stationary and moving RTUs [9]. These demonstrations showed that the system has the potential for world-wide coverage. Reception of the RTU signal can also be received directly if the remote receiver is within line-of-sight. Demonstrations showed that any aircraft could be configured to receive the RTU signal [9].

4.5 Naval Gunfire Support Mission

As discussed in Section 3, one of the LAMPS mission is Naval GunFire Support (NGFS). To be done well, NGFS requires two-way communication and the crew of the ship and helicopter must be well trained. The mission is also extremely hazardous due to the aircrew being susceptible to enemy fire.

Although numerous error sources in Naval gunfire can be accounted for, there are still anomalies in flight which can not be corrected. A cooperative effort between three U.S. Army Laboratory Command Labs-the Harry Diamond Laboratories, the Human Engineering Laboratory, and the Ballistic Research Laboratories-is applying GPS translator technology to track a projectile in flight.

The GPS translator uses radio frequency to transmit its location back to the home ship as presented in figure 12. The GPS Artillery Registration Fuse System [10] uses a translator-equipped projectile as a remotely located antenna for the GPS receiver which would be located on the ship. The ship, knowing its precise position using GPS, computes the gun target orders to hit a desired point, prepares and loads a projectile with a GPS fuse, aims and fires the weapon. As the projectile travels down range it receives and retransmits GPS signals to the ship. This allows the ship to observe the actual trajectory, compare it to the computed trajectory, and make corrections for future rounds.

The capability for a ship to track the projectile in real time would provide for the ship to perform the fire support mission in full autonomy. Targets, once identified by prior intelligence, can be acquired and the first round fired for effect much faster. A comparison of GPS versus map positioning showed

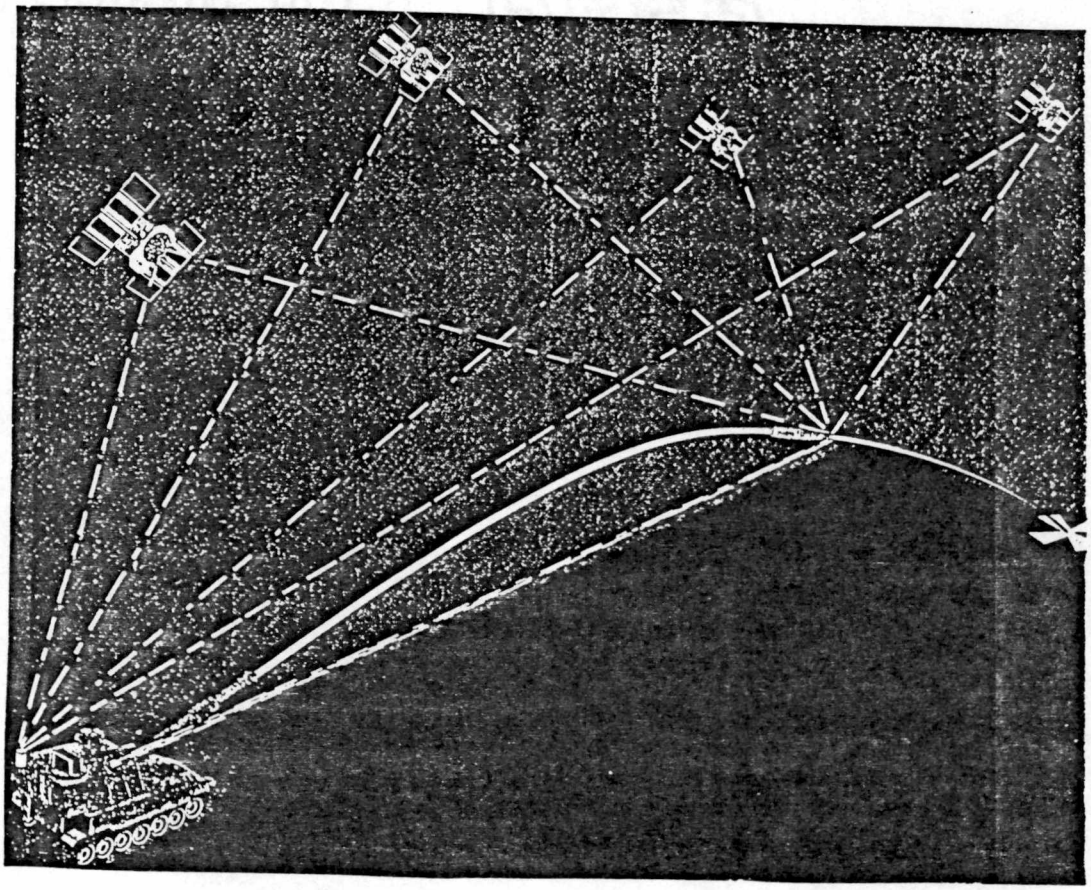


Figure 12 GPS Tracking of Projectile

Source: GPS World, Tracking Projectiles: The GPS Artillery Registration Fuze Program, September 1992.

that GPS enhances artillery effectiveness by a factor of three [5]. This autonomous capability would reduce the requirement to put the helicopter aircrew at risk.

4.6 Shipboard Approaches

In open-ocean operations, an obvious consideration prior to launching an aircraft is its ability to safely return to land aboard the same ship. There will always be requirements for operational commanders to push the edges of the weather envelope and make crucial decisions based on precarious weather conditions. Under the best of circumstances, to maintain covertness, it is desirable for the aircraft to return and land aboard ship with no electronic emissions from the ship. Unfortunately, even with GPS accuracies, this is not possible due to the dynamic operational environment. The best that can be hoped for with today's technology is to minimize electromagnetic emissions, thus ensuring covertness to the maximum extent possible.

Any two GPS receivers will produce their own positional information depending on which satellites are being viewed. Accordingly, each of the receivers will have unique errors associated with it's solution. However, if the two receivers are constrained to view the same satellites and calculate the difference in their positions then most of the errors are effectively cancelled. This is known as Relative

GPS (RGPS) The principles of RGPS are presented in figure 13. The remaining error is largely due to receiver noise and multipath error, both of which can be kept to a minimum by receiver design and antenna location.

The ship's sub-system would consist of a GPS receiver, an interface and processing unit, and a UHF data link. Since the aircraft would not require precise approach information at relatively large distances from the ship, the UHF transmissions would be emitted at a frequency and power which would limit reception range to some predetermined value, thus enhancing covertness. The data which would be required to be transmitted by the ship data link would include ship position, course, speed, wind speed and information concerning the satellites that are being tracked by the ship. In the case of the SH-60B this could be incorporated with the current data link.

The aircraft sub-system would consist of an UHF receiver, a GPS receiver, and a computing system which would interface the data received from the GPS receiver and the cockpit displays. The computer would be required to receive the data link information from the ship and command the aircraft GPS receiver to use the same satellite configuration being used onboard the ship. The displays available to the pilot would be required to present the pilot with information which would lead him to the final approach path, keep him on the glide slope, and present him

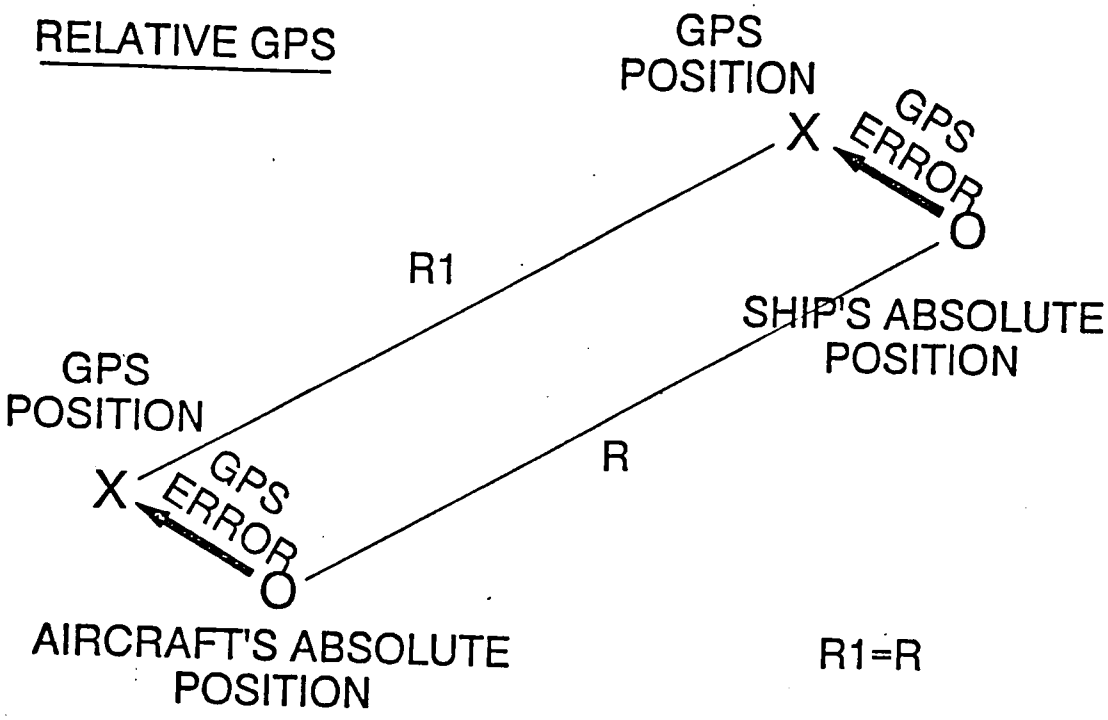


Figure 13 Errors Associated with Relative GPS

Source: Downes, M., Brown, C., Helicopter Approaches in Low Visibility Using RGPS and EFIS, March 1991.

with information which would allow him to slow the approach in the terminal phase prior to landing.

From August 1989 through December 1990 the Royal Aerospace Establishment (RAE) in England tested a GPS shipboard approach system which incorporated the design features previously discussed [11]. The system was aimed specifically at providing precision guidance for the recovery of helicopters to small ships at sea in poor weather conditions using RGPS. The profile flown by the pilots is presented in figure 14. The aircraft cockpit displays were implemented as shown in figure 15. The pilot was given a "map" display which helped to visualize relative positions and was instrumental in expediting the centerline capture. Once established on the centerline, the pilot was presented with cyclic and collective command information. The cyclic information allowed the pilot to maintain line-up and a predetermined speed. The collective information allowed the pilot to maintain the appropriate glide slope in relation to the ship.

The testing met with great success and proved that RGPS can be used for guidance of helicopters to small ship in adverse weather conditions [11]. The results demonstrated a recovery system that was flyable with low pilot workload and

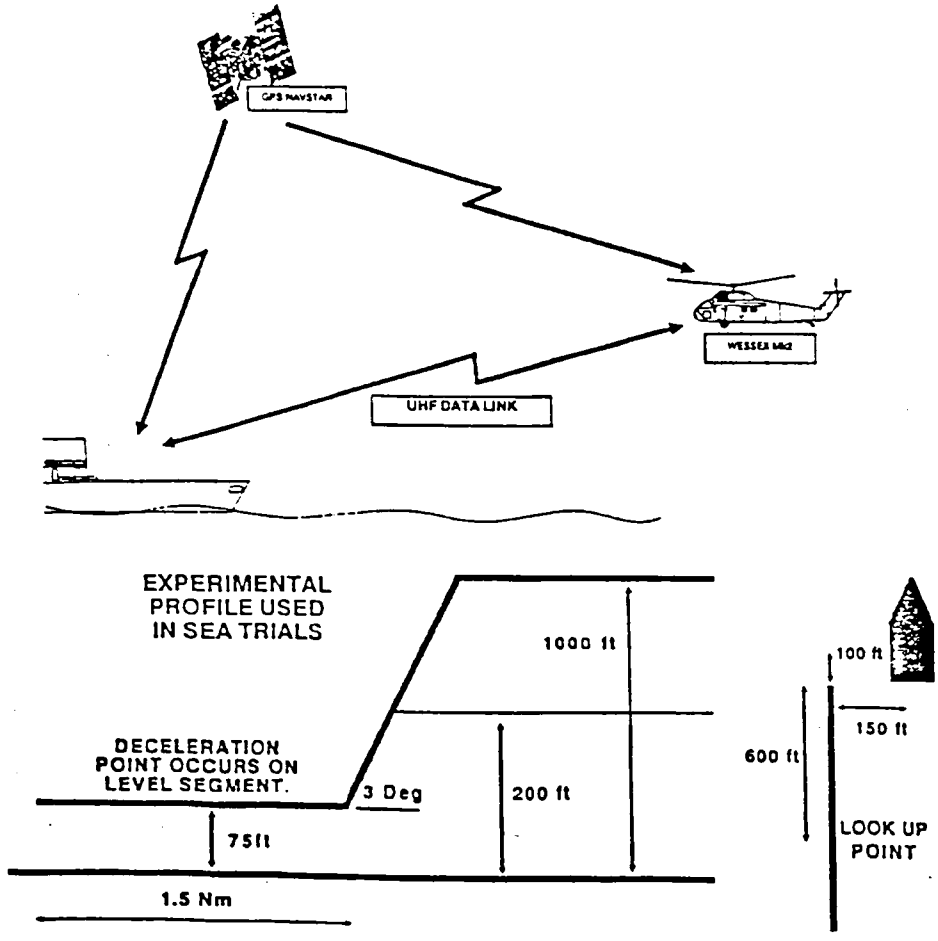


Figure 14 Relative GPS Approach Profile

Source: Downes, M., Brown, C., Helicopter Approaches in Low Visibility Using RGPS and EFIS, March 1991.

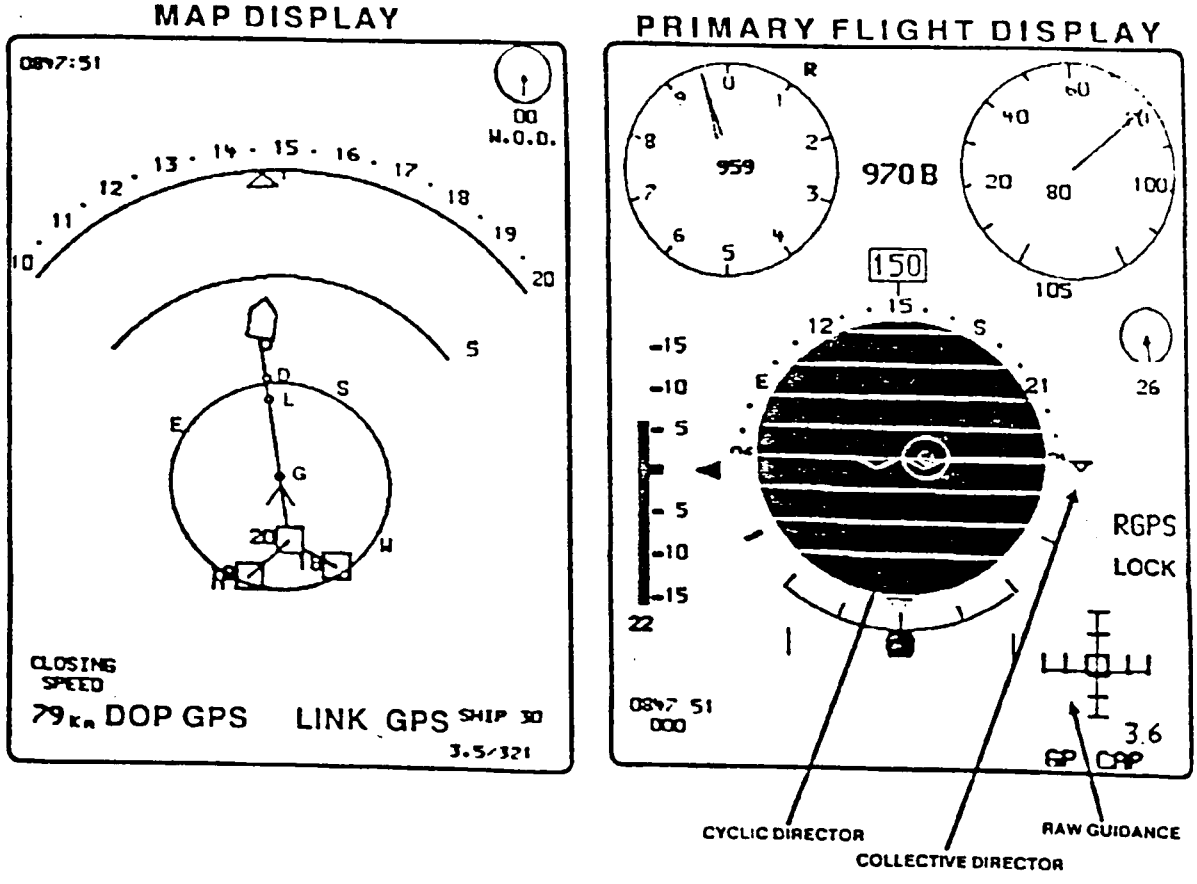


Figure 15 Westland Cockpit Displays

Source: Downes, M., Brown, C., Helicopter Approaches in Low Visibility Using RGPS and EFIS, March 1991.

had an omni-directional capability. RAE is planning follow-on testing to include an airborne computer system that will integrate with the flight control system and allow for fully coupled approaches using RGPS [11].

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 General

Based upon the discussion in the preceding sections, GPS demonstrates excellent potential to increase navigational accuracy and is an enhancing system which should be incorporated in all LAMPS helicopters and LAMPS capable ships as soon as possible.

5.2 Anti-Submarine Warfare

The availability of accurate sonobuoy position information increases target tracking capability and improves weapon placement precision in a wartime scenario. Conventional means of plot stabilization are inherently inaccurate and time consuming. In order to maintain an accurate real world tactical plot, aircraft position, buoy position relative to the aircraft, and buoy to buoy relative position must be accurate and timely.

In order to realize the full potential of the GPS, it is essential for the aircraft, the host ship, and the sonobuoy itself to have GPS information. GPS should be implemented in all sonobuoys as soon as possible.

To realize the maximum benefits of a GPS capable sonobuoy and minimize the cost of implementing the technology, further testing should be conducted to determine

the feasibility of implementing a TIDGET-type sonobuoy design.

5.3 Search and Rescue Mission

Whether over land or water, a downed aviator is susceptible to the environment and/or unfriendly forces. Survival is directly related to how quickly and how precisely position can be determined. Incorporating GPS as the search aircraft's primary sensor will allow each search unit to establish its coordinates on a common reference system. This will allow a single unit to more precisely cover a given area. It will also provide a search and rescue coordinator the capability to more efficiently cover a search area with multiple GPS capable assets.

A downed aviator should have the capability to transmit exact location as precisely as possible. Each aviator should have the GPS capability incorporated into survival gear. The GEAR system could be fitted into the seat pans of ejection seat aircraft, but, at four pounds, is too bulky for the normal body worn survival equipment of the helicopter aviator.

Further testing should be commenced to investigate the feasibility of using a GPS TIDGET-type design for emergency location. Since this design relies on the receiving vehicle to process the GPS information the weight and size penalties inherent to the GEAR system could be drastically reduced.

5.4 Naval Gunfire Support Mission

The requirement of having to rely on forward spotters to call in gunfire support is inherently dangerous to the spotter. It also requires that the forward unit be in constant communication with the ship. Further testing should be pursued for placing a translator-type GPS device in each projectile. This would reduce the requirement of having to place a helicopter crew in jeopardy and give the firing ship an autonomous gunfire capability.

5.5 Shipboard Approaches

Helicopters are required to operate almost anywhere under all weather conditions, day or night. The Royal Aerospace Establishment in Great Britain has successfully demonstrated the capability to guide helicopters to well within visual acquisition range of small ships in bad weather conditions. The U.S. Navy should investigate this capability for incorporation into the LAMPS aircraft. The system could be incorporated into the SH-60B tactical data link information exchange. Also, further testing should be conducted into automating the approach by supplying the flight control system with the GPS approach information to further reduce pilot workload.

5.6 Overview

For the military, the principal influence on selection of a particular navigation sensor or mix of navigation sensors is operational need [5]. Effective mission execution in the shipboard LAMPS environment is directly related to the accuracy of the navigational information.

The GPS acts as a force multiplier because, in addition to the individual missions, combined operations with force elements of other services or nations can be executed with a flexibility and precision not possible before [5]. The mission effectiveness will be improved greatly by having access to highly accurate position, velocity, and time information provided by GPS. However, the decision to use GPS will have to be determined on a case-by-case basis to trade off, for example, accuracy and redundancy requirements versus cost [5].

The NAVSTAR GPS is an extremely complex but versatile system that will redefine the way navigation is perceived in the future. The system will provide a common coordinate system which will be readily accessible by all participants. GPS will allow for improved accuracies and will significantly enhance the effectiveness of all LAMPS missions. All follow on research and development should be continued with the appropriate cognizant development agencies. These agencies should be continually informed and included in any subsequent development. Coordination

between the Naval Air Systems Command, the fleet tactical users and development agencies, will bring about a significant benefit to the LAMPS tactical arena in a short period of time.

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VITA

David L. Gay was born in Tucson, Arizona on November 17, 1959. After graduating from Deming High School in Deming, New Mexico, he enlisted in the Navy in the nuclear power program as an Electrician's Mate and completed training at the Navy Nuclear Power School in Orlando, Florida and the S5G Nuclear Power Prototype in Idaho Falls, Idaho. Upon graduation he was selected for a full Navy scholarship to the University of New Mexico in Albuquerque where he earned a Bachelor of Science Degree in Mechanical Engineering. In the Summer of 1984 he started flight school and received his wings of gold in August of 1985 as a helicopter pilot. Following a three year sea tour in HSL-33, a San Diego based SH-2F squadron, he was selected to the Naval Test Pilot School in Patuxent River, Maryland. Following graduation and designation as a Test Pilot, Lt Gay began a tour of service at Rotary Wing Aircraft Test Directorate. During this tour he participated in a state of the art mine hunting program called MAGIC LANTERN. His first contact with the capability of the GPS was while deployed with the sensor during Desert Storm. It is this event and the subsequent GPS testing at Patuxent River that are the inspiration for this thesis.