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13. ABSTRACT (Maximum 200 words)

This is a report of COMOPTEVFOR's follow-on operational test and evaluation (OT-IIB) of the NAVSTAR Global Positioning System (GPS) User Equipment (UE) as installed in the P-3C update III aircraft, performed under CNO Project 190-4. The purpose of OT-IIIB was to determine the operational effectiveness and suitability of the GPS UE as installed in the P-3C update III, to initate tactics development to support promulgation of an OPTEVFOR Tactics Guide (OTG), and to supprot a recommendation regarding extension application (EOA) to platforms with similar Type 3 installations.

The GPS UE, as installed in the P-3C update III aircraft is determined to be operationally effective and not operationally suitable. Approval for fleet introduction in the P-3C of the GPS UE is recommended following correction of the Major interoperability, human factor and documentation deficiencies (see par. 8c) and corrections verified to CNO's satisfaction.

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COMMANDER OPERATIONAL TEST AND EVALUATION FORCE
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3980 (190-4-OT-IIIB)
Ser 643/ 0400
APR 14 1994

From: Commander, Operational Test and Evaluation Force
To: Chief of Naval Operations

Subj: FOLLOW-ON OPERATIONAL TEST AND EVALUATION (FOT&E) OF THE NAVSTAR GLOBAL POSITIONING SYSTEM (GPS) AIR INTEGRATION/ INSTALLATION PROGRAM

Ref: (a) Test and Evaluation Master Plan 190-4 of 14 May 92
(b) COMOPTEVFOR ltr 3960 (190-4-OT-IIB) Ser 611/C194 of 13 May 86
(c) Navy GPS User Equipment (UE) Airset Maintainability/ Built-in-Test (BIT) Assessment Report of 28 Sep 89

Encl: (1) Project 190-4-OT-IIIB Report Details

1. Summary. This is a report of COMOPTEVFOR's follow-on operational test and evaluation (OT-IIIB) of the NAVSTAR Global Positioning System (GPS) User Equipment (UE) as installed in the P-3C Update III aircraft, performed under CNO Project 190-4. The purpose of OT-IIIB was to determine the operational effectiveness and suitability of the GPS UE as installed in the P-3C Update III, to initiate tactics development to support promulgation of an OPTEVFOR Tactics Guide (OTG), and to support a recommendation regarding extension of application (EOA) to platforms with similar Type 3 installations.

a. The GPS UE, as installed in the P-3C Update III aircraft is determined to be operationally effective and not operationally suitable.

b. Approval for fleet introduction in the P-3C of the GPS UE is recommended following correction of the major interoperability, human factors and documentation deficiencies (see par. 8c) and corrections verified to CNO's satisfaction.

c. An EOA is recommended for all Type 3 aircraft integrations (per reference (a)) following correction of the major interoperability and documentation deficiencies (see par. 8c).

2. Background

a. Operational test and evaluation (OT&E) was completed on the GPS UE to support the Milestone III decision. OT-IIC (SH-60B) was conducted from 28 July to 10 December 1989. The system consisted of a production representative 3A receiver, fixed reception pattern antenna (FRPA) FRPA-3 antenna, antenna electronics (AE) unit AE-4, and a platform control display unit. COMOPTEVFOR concluded that the NAVSTAR GPS UE was operationally effective and potentially operationally suitable, and recommended limited production and fleet introduction in Naval helicopters having nonsoftware intensive helicopter applications requiring unintegrated capability.

b. No major deficiencies from previous OT&E were examined during OT-IIIB because they would not apply to this specific integration test.

3. Project Operations. Project operations were conducted from 17 August 1993 to 23 January 1994. A total of 241.2 flight hours were flown using GPS UE as the primary means of navigation. The GPS UE was used to perform routine navigation in the National Airspace System (NAS) and as an aid to tactical navigation (TACNAV) on all P-3C mission events. Specific tactical missions included: 1 antisubmarine warfare (ASW) event on an instrumented range, 14 open-ocean ASW events, 2 antisurface warfare (ASUW) events, an offensive mining event on an instrumented range, 2 mountainous terrain events, and 1 event at high latitude.

4. Limitations. The following limitations did not preclude formulation of conclusions but may require additional testing to resolve the associated critical operational issues (COI) and to complete evaluation of operational effectiveness and operational suitability:

a. Antispoof (AS) capabilities could not be tested because threat-representative antispoofing devices were not available. (Selective Availability (SA)/AS)

b. Three-dimensional (3-D) positioning capabilities could not be determined to the SA/AS threshold because:

(1) GPS altitude information was not displayed to the operator in the P-3C integration. (SA/AS)

(2) In a dynamic environment, the GPS UE did not update the display of position and time at a sufficiently high rate. (SA/AS)

(3) In a dynamic environment, the GPS UE did not display time data with the required precision. (SA/AS)

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5. Critical Operational Issues (COI). COIs were resolved as follows:

Critical Operational Issue	Resolution
Performance Parameters	Resolved (SAT)
SA/AS	Partially Resolved*
Survivability	Resolved (SAT)
Reliability	Resolved (SAT)
Maintainability	Resolved (SAT)
Availability	Resolved (SAT)
Logistic Supportability	Resolved (SAT)
Compatibility	Resolved (SAT)
Interoperability	Resolved (UNSAT)
Training	Resolved (SAT)
Human Factors	Resolved (UNSAT)
Safety	Resolved (SAT)
Documentation	Resolved (UNSAT)

* See Limitations

6. Results and Discussion. Details of tests and results are contained in enclosure (1). Major test results are listed below:

a. Operational Effectiveness

(1) Performance Parameters

(a) Airways Navigation. The P-3C Update III aircraft with GPS installed demonstrated the capability to accurately navigate on airways in the NAS. No deviations from the airways structure were noted during 73.4 hours of airways navigation.

(b) Nonairways Navigation. The P-3C Update III aircraft with GPS installed demonstrated the capability to accurately navigate outside of the NAS and during long over-water flights. No major deficiencies were noted during 131.7 hours of nonairways navigation.

(c) High Latitude Navigation. The P-3C Update III aircraft with GPS installed demonstrated the capability to accurately navigate at latitudes greater than 70° North. No major deficiencies were noted during 6.3 hours of high latitude navigation.

(d) Mountainous Terrain Navigation. The P-3C Update III aircraft with GPS installed demonstrated the capability to accurately and safely navigate in a mountainous area. No major deficiencies were noted during 5.8 hours of mountainous terrain navigation.

(e) ASW Mission Support. The P-3C Update III aircraft with GPS installed demonstrated the capability to support the completion of ASW missions. No major deficiencies were noted during 76.5 hours of ASW missions.

(f) ASUW Mission Support. The P-3C Update III aircraft with GPS installed demonstrated the capability to support the completion of ASUW missions. No major deficiencies were noted during 9.0 hours of ASUW missions.

(g) Mine Warfare Mission Support. The P-3C Update III aircraft with GPS installed demonstrated the capability to support the completion of mining missions. No major deficiencies were noted during 1.4 hours of mining.

(h) Search and Rescue (SAR) Mission Support. The P-3C Update III aircraft with GPS installed demonstrated the capability to support the completion of SAR missions. No major deficiencies were noted during 2.3 hours of SAR.

(i) Coordinated Operations. The P-3C Update III aircraft with GPS installed demonstrated the capability to support the completion of coordinated operations missions. No deficiencies were noted during 8.0 hours of coordinated operations missions.

(j) Replace Tactical Air Navigation (TACAN).

1. The P-3C Update III with the GPS installed demonstrated the capability to replace TACAN for navigation in the NAS and for a non-precision approach. No major deficiencies were noted while using GPS UE to emulate TACAN during routine navigation and non-precision approaches.

2. Although not a requirement of TACAN emulation, the GPS UE is not capable of replacing the air-to-air capability of TACAN, which is routinely used to establish safe separation distance between two aircraft in flight.

3. TACAN emulation was based on the TO/TO and TO/FROM navigation functions of the GPS on stationary points in the NAS. Although not a requirement of TACAN emulation, GPS UE is not capable of fully replacing the TACAN with respect to shipboard air operations.

(2) SA/AS

(a) Jamming Environment. No known jamming occurred during OT-IIIB. The capability of the GPS UE to reject jamming was previously determined to be satisfactory during OT-IIB (reference (b)).

(b) Deceptive Environment. The performance of GPS UE was not tested in a deceptive or spoofing environment (see par. 4a).

(c) SA Environment

1. GPS UE positional accuracy using precise positioning service (PPS) cannot be fully operationally tested (see par. 4b) (criterion: ≤16m spherical error probable (SEP)). Both static (parked) and dynamic (flying) positions were evaluated to determine positional accuracy. It was determined that the PPS mode (measured in two dimensions as circular error probable (CEP)), available when the cryptographic keys were loaded into the GPS receiver, exhibited significantly improved positional accuracy over the standard positioning service (SPS) mode.

2. GPS UE positional accuracy using SPS could not be fully operationally tested in a dynamic environment (see par. 4b(2) and 4b(3)) (criterion: ≤100m (twice the distance root mean squared (2 drms) correctness 95%)).

(3) Survivability

(a) The GPS UE was assessed to reduce the susceptibility of the P-3C. Improvements in tactics were deemed possible as a result of the GPS UE's extremely accurate navigation facilities. Specifically, the improved navigation accuracy may allow modifications to existing tactics in the areas of offensive mining, ASW, and minimum operational safe altitude (MOSA) procedures which should reduce P-3C counterdetection opportunities.

(b) The GPS UE did not materially affect the P-3C's vulnerability characteristics.

b. Operational Suitability

(1) Reliability. The demonstrated mean flight hours between mission critical failures (MFHBMCF) was 120.6 (criterion: MFHBMCF ≥100 hours), based on two mission critical failures in

241.2 hours of operating time. Both mission critical failures occurred during a routine airways transit between NAS Patuxent River, MD and West Palm Beach, FL and resulted in a complete loss of navigation capability for 20 minutes and 30 minutes respectively. The indications received by the pilots were a NAV FAIL annunciation on the Control Display Navigation Unit (CDNU) and NAV flags coming into view on the pilot and copilot Heading Speed Indicator (HSI). Following the flight, a system test was conducted on all GPS UE components. The Initiated Built in Test (IBIT) was not able to isolate the fault to a specific hardware component and further investigation revealed that the loss of GPS UE navigation capability could not be attributed to either the space or control segments. Therefore, the cause of the fault was unknown.

(2) Maintainability

(a) A mean time to repair-hardware (organizational level (O-level)) ($MTTR_{HW-O}$) was not observed during test. No actual mission-critical hardware failures occurred during the test period. A maintainability demonstration, including practice fault isolations and replacement of GPS UE components was conducted. Repair of nine critical failures induced during the maintainability demonstration required a total of 2 hours 24 minutes to complete, for an $MTTR_{HW-O}$ of 16.0 minutes (criterion: $\leq$20 minutes).

(b) A mean time to repair-hardware (intermediate level (I-level)) ($MTTR_{HW-I}$) was not observed during test. No actual mission-critical hardware failures requiring I-level repair occurred during the test period. A maintainability demonstration witnessed by COMOPTEVFOR personnel was conducted from 31 July 1989 to 8 August 1989 (reference c.) to determine the $MTTR_{HW-I}$ for the AN/ARN-151(V) receiver. Repair of 28 critical failures required a total of 10 hours and 38 minutes to complete, for an $MTTR_{HW-I}$ of 22.8 minutes (criterion: $\leq$60 minutes).

(3) Availability. The demonstrated operational availability (A_o) was 0.99 (criterion: $\geq$0.95), based on 3816.0 total hours of aircraft uptime and 50 minutes of downtime.

(4) Logistic Supportability. A review of the GPS UE ILSP, Computer Resources Life Cycle Management Plan (CRLCMP), and NTP was conducted by COMOPTEVFOR. The planned logistic support for the GPS UE, as installed in the P-3C is considered adequate.

(5) Compatibility. No compatibility deficiencies were noted.

(6) Interoperability

(a) On four occasions in flight, the GPS UE indicated that the Signal Data Converter's (SDC) Continuous Built in Test (CBIT) had detected an HSI Distance Measuring Equipment (DME) fault and dropped NAV Flags over the DME wheels. To recover the DME display, and restore positional awareness (ie. to display the complete GPS navigation solution) GPS had to be momentarily deselected at all stations or the SDC manually reset. These recovery procedures could significantly increase pilot workload in an already work intensive environment, such as IFR landings, and hamper pilot performance.

(b) Faults could not be repeated during post-flight troubleshooting at the O-level but were subsequently found by an I-level maintenance activity to be associated with a DME wheel alignment fault. Unlike the CBIT, which tests DME throughout the entire range of DME wheel rotation, the IBIT only tests DME at two positions; this allows DME wheel alignment faults to go undetected during IBIT. Currently, the only reliable way to troubleshoot this type of discrepancy down to the faulty HSI is to remove all three HSIs and have them tested at an I-level maintenance activity; this renders the aircraft unuseable for the period that all HSIs are removed.

(c) Due to the potential magnitude of this problem interoperability was found UNSAT. The potential magnitude of this problem is unknown because the quality of HSI's and HSI maintenance was beyond the scope of this evalution. For further discussion of this subject see Part 5 - Operational Considerations (par. 501).

(7) Training. No major deficiencies were noted.

(8) Human Factors

(a) The flight station CDNU, located on the pilot side of the center instrument pedestal, was found to be UNSAT. This location made operation by the copilot difficult due to the excessive reach required and the parallax created by the awkward viewing angle.

(b) The GPS mode lights obstruct both the pilot's and copilot's view of their respective clocks.

(9) Safety. No deficiencies were noted.

(10) Documentation. Technical manuals were preliminary versions provided by the prime contractor. The primary maintenance publication was generic in nature and provided extremely limited information on the maintenance and operation of the GPS UE, as installed in the P-3C Update III. The operators' manual provided for the CDNU details numerous functions not available in the P-3C. Details of this, together with other minor deficiencies, are contained in enclosure (1).

7. Conclusions

a. The GPS UE, as installed in the P-3C, is operationally effective.

b. The GPS UE, as installed in the P-3C, is not operationally suitable.

8. Recommendations

a. Approval for fleet introduction in the P-3C of GPS UE is recommended following correction of the major interoperability, human factors and documentation deficiencies (see par. 8c) and corrections verified to CNO's satisfaction.

b. An EOA is recommended for all Type 3 aircraft integrations following correction of the major interoperability and documentation deficiencies (see par. 8c).

c. Accomplish the following prior to approval for fleet release and any additional phase of testing:

(1) Improve fault isolation capabilities of the SDC IBIT (see par. 6b(6)). (Interoperability)

(2) Make the CDNU operations and display fully accessible to both pilot and copilot or incorporate second CDNU in flight station (see par. 6b(8)(a)). (Human Factors)

(3) Relocate GPS mode lights so that pilot and copilot clocks are not obscured (see par. 6b(8)(b)). (Human Factors)

(4) Develop complete maintenance and operational documentation for GPS UE as installed in the P-3C (see par. 6b(10)). Documentation should include but not be limited to:

(a) Maintenance instruction manuals.

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(b) Maintenance requirement cards.

(c) Crew station manuals.

(d) Change inputs for P-3C NATOPS Manuals.

(e) Change inputs to NATOPS Instrument Flight Manual.

d. Incorporate the additional recommendations of enclosure (1), Section 6.

J. J. ZERR

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PROJECT 190-4-OT-IIIB REPORT DETAILS

Encl (1)

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Contents

Contents (Cont)

Acronyms and Abbreviations

A_o	Operational Availability
AE	Antenna Electronics
ANJB	Auxiliary Navigation Junction Box
AS	Antispoof
ASUW	Antisurface Warfare
ASW	Antisubmarine Warfare
CB	Circuit Breaker
CBIT	Continuous Built-in-Test
CDI	Course Deviation Indicator
CDNU	Control Display Navigation Unit
CEP	Circular Error Probable
COI	Critical Operational Issue
CTR	Chesapeake Test Range
DDS	Digital Data Set
DME	Distance Measuring Equipment
DT&E	Developmental Test and Evaluation
EHE	Estimate of Horizontal Error
EOA	Extension of Application
ETA	Estimated Time of Arrival
FOM	Figure-of-Merit
FRPA-3	Fixed Reception Pattern Antenna
GPS	Global Positioning System
HSI	Horizontal Situation Indicator
IBIT	Initiated Built-in-test
I-level	Intermediate Level
ILSP	Integrated Logistics Support Plan
INS	Inertial Navigation System
MAF	Maintenance Action Form
MCS	Master Control Station
MFHBMCF	Mean Flight Hours Between Mission Critical Failures
MOSA	Minimum Operational Safe Altitude
MOT	Mark-on-top
$MTTR_{HW-I}$	Mean Time to Repair-Hardware (I-level)
$MTTR_{HW-O}$	Mean Time to Repair-Hardware (O-level)
MV	Magnetic Variation
NAS	National Airspace System
NAVAID	Navigation Aid
NAV/COMM	Navigator/Communicator

Acronyms and Abbreviations (Cont)

NTP	Navy Training Plan
OFP	Operational Flight Program
O-level	Organizational Level
OTD	Operational Test Director
OT&E	Operational Test and Evaluation
PPS	Precise Positioning Service
RNAV	Area Navigation
SA	Selective Availability
SAR	Search and Rescue
SDC	Signal Data Converter
SEP	Spherical Error Probable
SPS	Standard Positioning Service
TACAN	Tactical Air Navigation
TACNAV	Tactical Navigation
UE	User Equipment
VOR	VHF Omnidirectional Receiver
WGS-84	World Geodetic Survey of 1984
3-D	Three Dimensional
2-D	Two Dimensional
2 drms	Twice the Distance Root Mean Squared

References

(a) Test and Evaluation Master Plan 190-4 of 14 May 92

(b) COMOPTEVFOR ltr 3960 (190-4-OT-IIB) Ser 611/C194 of 13 May 86

(c) Navy GPS User Equipment (UE) Airset Maintainability/ Built-in-Test (BIT) Assessment Report of 28 Sep 89

(d) COMOPTEVFOR ltr 3960 (190-4-OT-IIIB) Ser 643/964 of 13 Jul 92

(e) Satellite Signals Navigation Set (SSNS) Operation and Maintenance Instruction Manual (Organizational) (NAVAIR 16-30ARN151-1)

(f) Draft Technical Manual "Maintenance Procedures Organizational" for P-3C NAVSTAR Global Positioning System (written by NAWC-AD Flight Test Engineering Group) of 29 Apr 93

(g) CDNU Operator's Manual of 1 Apr 91 (Collins Avionics & Communications Division, Rockwell International Corporation)

(h) NAVSTAR GPS User Equipment Decision Coordinating Paper (DCP)

(i) Test and Evaluation Master Plan 190-4 (Change 2) of 30 Apr 93

(j) Integrated Multiservice Test and Evaluation Master Plan for NAVSTAR Global Positioning System User Equipment of Jan 90

(k) NTIC Threat Assessment 008-91 Satellite Systems of Aug 91

(l) NTIC Threat Assessment 023-91 ASW Aircraft of Jun 91

(m) NAVSTAR GPS Integrated Logistics Support Plan (ILSP), Volume II, of 25 Oct 93

(n) NAVSTAR GPS Computer Resources Life Cycle Management Plan (CRLCMP) for Navy Nondevelopmental Item (NDI) UE of 30 Jun 92

(o) Navy Training Plan for NAVSTAR GPS User Equipment (UE) (NTP E-70-8215E) of 28 Jul 93

(p) Meeting held at AIRTEVRON on 28 Jul 93 to discuss effect of HSI failures on GPS reliability

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Section 1

Description of Material

101. System Description

a. The NAVSTAR GPS is designed to provide combat mission enhancement to the Navy's airborne combat fleet beyond the turn of the century. The primary mission of the GPS is to provide worldwide, all-weather, real time, and continuous precise geographic, velocity, and time data to the host platform. The GPS is designed to enhance most military missions. Specifically, GPS is designea to:

(1) Provide precise navigation positioning data. Provide extremely accurate velocity and time data.

(2) Enhance use of existing force structure.

(3) Improve force posture.

(4) Improve weapon system survivability.

(5) Increase probability of placing weapons on target.

(6) Enhance night/adverse weather mission capability.

b. GPS is designed to provide a sole means of navigation capability for flight in the NAS, by emulating the current TACAN system.

c. The GPS is a space-based radio navigation and positioning system which consists of three major segments: space, control, and UE.

(1) Space Segment. The GPS program has deployed 21 satellites with 3 on-orbit spares in 10,900 nm circular orbits having 12-hour periods. The satellites are positioned on six spatial planes, with three satellites in each plane. This deployment provides satellite coverage for continuous, worldwide, 3-D position and velocity determination. Each satellite transmits navigation signals at frequencies of 1574.42 and 1227.6 MHz. These signals contain data such as satellite ephemeris, atmospheric propagation correction data, and satellite clock bias information.

(2) Control Segment. Widely separated monitor stations passively track all satellites and collect ranging data from their navigation signals. These data are then processed at the operational control stations and master control station (MCS) for use in satellite orbit determination and systematic error elimination. The MCS is colocated with the consolidated space

operations center near Colorado Springs, CO. The MCS uploads corrected satellite ephemerides, clock drift rates, and propagation delay data to the satellites. This serves as the principle means for satellite maintenance.

(3) UE Segment. GPS UE required for aircraft integration consists of a receiver processor unit, an antenna subsystem, a CDNU, SDC, and a digital data set (DDS). Each UE device is described below:

(a) AN/ARN-151(V)2 Receiver Processor Unit. The AN/ARN-151 is a five-channel, dual frequency receiver designed for highly maneuverable aircraft. The first four channels are reserved for reception of data from four satellites, while the fifth channel receives a message designating the next satellite to be acquired. The receiver provides precise position, velocity, and time information over several interfaces including the MIL-STD-1553B data bus.

(b) Antenna Subsystem (FRPA-3 and AE-4). The antenna subsystem consists of an antenna and AE unit. The standard Navy antenna is the FRPA-3. The AE processes the radio frequency signal received by the antenna and outputs them to the GPS receiver.

(c) Control Display Navigation Unit. The CDNU is a multipurpose device which provides information control, display, and navigation functions and outputs to drive flight instruments and annunciators. In addition to providing control of the GPS receiver, it can incorporate the control heads of other flight station radios and navigation systems to accommodate cockpit space restrictions. The CDNU operational flight program (OFP) used during OT-IIIB was Version 005.

(d) Signal Data Converter. The SDC is an interface component between the GPS UE and the flight instruments. The SDC receives digital information from either the CDNU or GPS receiver and converts the digital input to analog output which drives analog flight instruments.

(e) Digital Data Set. The DDS is a device used for the transfer of digital data between mission planning stations, located on the ground, and the GPS UE installed on the aircraft. When a cartridge, which has been programmed at a mission planning station, is inserted into the DDS receptacle, the information contained on the cartridge can be transferred to the aircraft GPS UE. The information could include permanent or reversionary data bases of waypoint data, flight plans, operational flight programs, and magnetic variation (MV) almanacs.

d. Type 3 Integration. The GPS UE was integrated with the flight station and the NAV/COMM station to emulate TACAN. In addition, the integration included mutual aiding between the LTN-72-9-21 Inertial Navigation Systems (INS) and GPS. This aiding provided the INS with the capability to integrate and filter navigation inputs from the GPS UE. The GPS provides position and velocity data to the LTN-72 Kalman filter to estimate INS errors in position, velocity, tilts, and gyro biases. These corrections can then be applied internally to the INS position to form a hybrid navigation solution. The INS provides the GPS UE with the aircraft attitude, velocity, position, and true heading data for rapid acquisition of GPS signals, and enables the GPS UE to dead-reckon during periods of GPS signal jamming and/or satellite shadowing. No integration existed with any other P-3 mission systems.

102. System Operation. Routine airways navigation, using GPS to emulate TACAN, and nonairways navigation using area navigation (RNAV) capabilities of GPS were performed in accordance with reference (d). In addition, GPS was used to aid the LTN-72-9-21 inertials. The aided INS was then used as the primary navigation source for the CP-901 computer's geographic and TACNAV modes. This configuration was used while the aircraft performed operational missions in the following areas: ASW, ASUW, mining, SAR, and coordinated operations. Missions were also flown in areas of high latitude and mountainous terrain.

103. Training. On-site training courses were provided prior to commencement of OT-IIIB; operators received 2 days of training whereas maintenance personnel received a 1-day course. All training was considered to be fleet representative.

104. Technical Documentation. The following technical documents were used during OT-IIIB:

a. Satellite Signals Navigation Set Operation and Maintenance Instructions Manual (Organizational) (NAVAIR 16-30ARN151-1) (reference (e)).

b. Draft technical manual "Maintenance Procedures (Organizational) for P-3C NAVSTAR Global Positioning System" (Written by NAWC-AD Flight Test Engineering Group) of 29 April 1993 (reference (f)).

c. CDNU Operator's Manual of 1 Apr 91 (Collins Avionics & Communications Division, Rockwell International Corporation) (reference (g)).

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Section 2

Project Background

201. Program History

a. The GPS was developed to satisfy the requirement, stated in reference (h), for an accurate, worldwide, space-based, radio navigation system that provides:

(1) Information in support of:

(a) Command, control, and coordinated battle tactics.

(b) Strategic and tactical warfare.

(c) Accurate and timely fire support.

(d) Combat service support operations.

(2) A mobile navigation system for use on the battle field, in the air, and at sea.

(3) Exact positions for reconnaissance and intelligence missions.

b. Developmental test and evaluation (DT&E), Phase I (Concept Validation), of the GPS subsystem was completed on 11 classes of vehicles from March 1977 to May 1979. This phase of testing recommended the GPS for full scale engineering development.

c. During Phase II full-scale development, seven different host vehicles were used to test three basic configurations of UE.

202. Operational Test and Evaluation

a. OT-IIB (A-6E) was conducted from 16 September 1985 to 4 March 1986. The system consisted of an advanced development model of a five-channel, high dynamics/fast acquisition receiver set (AN/ARN-151). The system was operated by fleet personnel and maintained by contractor personnel. COMOPTEVFOR concluded that the NAVSTAR GPS UE was potentially operationally effective and potentially operationally suitable, and recommended limited production and limited fleet introduction.

b. OT-IIC (SH-60B) was conducted from 28 July to 10 December 1989. The system consisted of a production-representative AN/ARN-151 (V) receiver, FRPA-3 antenna, AE-4 unit, and a platform control display unit. The system was operated and maintained by fleet personnel. COMOPTEVFOR concluded that the NAVSTAR GPS UE was operationally effective and potentially operationally suitable, and recommended limited production and fleet introduction in naval helicopters having nonsoftware intensive helicopter applications requiring unintegrated capability.

Section 3

Scope of the Evaluation

301. Critical Operational Issues. The COIs examined for Project 190-4-OT-IIIB were:

Operational Effectiveness	Operational Suitability
Performance Parameters	Reliability
SA/AS	Maintainability
Survivability	Availability
	Logistic Supportability
	Compatibility
	Interoperability
	Training
	Human Factors
	Safety
	Documentation

302. Evaluation Criteria. The following minimum acceptable operational performance requirements were specified in references (a) and (i):

Characteristic	Parameter	Threshold
Operational Effectiveness		
Positioning	3-D Position Accuracy - (PPS)	16 m SEP
Selective Availability	3-D Accuracy - PPS	16 m SEP
	2-D Accuracy - SPS	100 m (2 drms correctness 95%)
Survivability	Jamming to Signal Ratio	see reference (j)
Operational Suitability		
Reliability	MFHBMCF (Note 1)	$\geq$100 hours
Maintainability	$MTTR_{HW-O}$ (Note 2)	$\leq$20 minutes
	$MTTR_{HW-I}$ (Note 3)	$\leq$60 minutes
Availability	A_O (Note 4)	$\geq$0.95

Notes:

1. MFHBMCF will be calculated using the following formula:

$$\text{MFHBMCF} = \frac{\text{Total Flight Hours}}{\text{Number of Mission Critical Failures}}$$

where a critical failure is defined as any fault, failure, malfunction, or degradation of any component or function which prevents the successful accomplishment of any mission task.

2. $MTTR_{HW-O}$ is defined as:

$$MTTR_{HW-O} = \frac{\text{Total Active Corrective Maintenance Time}}{\text{Total Number of Critical Failures}}$$

3. $MTTR_{HW-I}$ is defined as:

$$MTTR_{HW-I} = \frac{\text{Total Active Corrective Maintenance Time}}{\text{Total Number of Critical Failures}}$$

4. A_O is calculated using the following formula:

$$A_O = \frac{\text{Uptime}}{\text{Uptime + Downtime}}$$

where uptime is that time when the system is either operating or ready for use. Downtime is the time the system is down for repair of critical hardware failures and/or for restoration from mission critical faults. It also includes off-board logistic delays and the time required for planned maintenance. The exact make-up of system uptime and downtime will be evaluated on a case-by-case basis, given consideration of the intended operational employment.

303. Test Chronology. See Project Operations in the basic letter.

304. Limitations

a. The following limitations did not preclude formulation of conclusions but may require additional testing to resolve the associated critical operational issues (COI) and to complete evaluation of operational effectiveness and operational suitability:

(1) Antispoof (AS) capabilities could not be tested because threat-representative antispoofing devices were not available. (Selective Availability (SA)/AS)

(2) Three-dimensional (3-D) positioning capabilities could not be determined to the SA/AS threshold because:

(a) GPS altitude information was not displayed to the operator in the P-3C integration. (SA/AS)

(b) In a dynamic environment, the GPS UE did not update the display of position and time at a sufficiently high rate. (SA/AS)

(c) In a dynamic environment, the GPS UE did not display time data with the required precision. (SA/AS)

b. The following limitations were minor in nature and neither affected resolution of COIs nor the ability to form conclusions regarding operational effectiveness and operational suitability:

(1) Operator training was developed and provided by DT&E support personnel and not by fleet instructors.

(2) $MTTR_{HW-O}$ was not observed because no actual system critical failures occurred during the test period. A maintainability demonstration was conducted, including practice fault isolations and assembly replacements.

(3) $MTTR_{HW-I}$ was not observed because no actual system failures occurred during the test period. Data from a previously conducted maintainability demonstration witnessed by COMOPTEVFOR personnel (reference (c)) was reviewed.

(4) The P-3C Update III with the GPS UE installed was not tested in all environmental or situational conditions.

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Section 4

Tests and Results

401. General Approach. The scenarios employed during operational effectiveness testing of the GPS UE as it was installed in the P-3C Update III aircraft, were developed from NTIC TA 008-91 of August 1991 (reference (k)) and NTIC TA 023-91 of June 1991 (reference (l) and are described below.

a. Scenario A, Nontactical Navigation. In this scenario, the P-3C was operated with GPS as the primary means of navigation. Routine airways navigation, using GPS to emulate TACAN, and nonairways navigation using RNAV capabilities of GPS were performed. Navigation was conducted in accordance with the P-3C NATOPS Manual and Instrument Flight Manual, in mountainous and non-mountainous areas and in areas of high latitude.

b. Scenario B, Tactical Navigation. In this scenario, GPS-aided INS were used as primary navigation source for the CP-901 computer's geographic and TACNAV modes. The aircraft performed operational missions in the following areas: independent and coordinated ASW, ASUW, mining, SAR, coordinated operations, and routine nonairways navigation, including operations in areas of high latitude.

402. Test E-1, Airways Navigation

a. Object. Will the P-3C Update III aircraft, with GPS installed, accurately navigate on airways?

b. Procedure

(1) This test employed Scenario A. The P-3C Update III aircraft with the GPS UE installed was operated in a structured airways system performing routine airways navigation.

(2) The Test Team used GPS to navigate along published Victor and Jet routes. The pilot at the controls selected GPS as the input source for the HSI bearing and course needles while the copilot selected either very high frequency omnidirectional receiver (VOR) or TACAN. The pilot at the controls flew along airways using procedures outlined in the NATOPS Instrument Flight Manual, using GPS as the primary navigation source. While the pilot maintained the required inbound or outbound course (as indicated by a centered course deviation indicator (CDI)), the copilot monitored the deviation from airways centerline by observing the deflection of the CDI. The test team recorded the aircraft's bearing and range from navigation aids (NAVAID) and compared them with GPS bearing and the equivalent slant range calculated to the NAVAID's position any time there was a one dot ($\pm 5^{\circ}$) or greater deviation between the two navigation sources or

when the test team was notified by an air traffic control agency of any significant deviation from airways centerline. GPS figure-of-merit (FOM) and estimate of horizontal error (EHE) were recorded for every deviation and any time a GPS warning indicated an increase of positional uncertainty.

c. Data Analysis. Performance of GPS was determined by comparing GPS airways navigation capabilities with those of current VOR and TACAN systems. Instances where a bearing difference between GPS and VOR or TACAN of ± 5 degrees and/or a DME difference between GPS equivalent slant range and TACAN DME of ±0.5 nm or 3% of the distance measured by TACAN (whichever is greater) were reconstructed to determine actual airways centerline deviation and if aircraft remained within established airways corridor. GPS FOM and EHE information were used to determine if degraded performance is due to satellite signal loss or GPS system malfunction.

d. Results and Discussion. The P-3C Update III aircraft with GPS installed demonstrated the capability to accurately navigate on airways in the NAS. No deviations from the airways structure were noted during 73.4 hours of airways navigation. Navigation waypoints were entered into the CDNU both in the form of waypoint identifiers and as latitude/longitude entries. Additionally, the following points were noted:

(1) The use of GPS allowed more accurate navigation along airways defined by widely separated NAVAIDs.

(2) The capability to enter waypoints into the flight plan, by typing the three or five letter identifier on the CDNU, allowed more expeditious reaction to changes in flight plan routing.

(3) When the waypoint data were not loaded on the DDS, waypoint and flight plan data entry of latitude/longitude was tedious and required significantly more time to complete.

(4) The capability to access multiple flight plans stored on the DDS, as described in the CDNU Operators Manual (reference (g)) was not available due to a CDNU OFP engineering restrictions.

(5) The capability to store a primary waypoint data base, reversionary waypoint data base, almanac data, MV look-up table, and multiple flight plans on a single DDS cartridge was not available. This was due to an engineering restriction in the CDNU OFP which recognizes a maximum of 12 DDS files as being valid.

(6) No capability exists to allow data to be transferred from the CDNU to the DDS cartridge. Although not a

rrequirement this capability would facilitate storage and retrieval of waypoints, MARK data, and flight plans, allowing greater flexibility in the use of the system.

403. Test E-2. Nonairways Navigation

a. Object. Will the P-3C Update III aircraft, with GPS installed, accurately navigate on nonairways?

b. Procedure

(1) This test employed Scenarios A and B. The P-3C Update III aircraft with the GPS UE installed was operated outside a structured airways system performing RNAV as well as long-range, over-water transits.

(2) While navigating, the test team recorded the aircraft's geographic position by performing low level visual mark-on-top (MOT) of fixed radio NAVAIDs and discernible geographic points. The MOT data was then compared to GPS, INS, OMEGA and CP-901 positions. Additionally, laser and radar tracking data provided by both CTR and the AUTEC range were used to make similar assesements of relative navigation accuracies. Deviations, in nautical miles and radial error, as indicated by GPS (DEV_{GPS}) were compared to deviations observed using the INS (DEV_{INS}), OMEGA (DEV_{OMEGA}), and the CP-901 computer (DEV_{CP-901}). GPS FOM and EHE information was used to determine if degraded performance was due to satellite signal loss or GPS system malfunction.

c. Data Analysis

(1) Performance of GPS was determined by calculating the DEV_{GPS}, DEV_{INS}, DEV_{OMEGA}, and DEV_{CP-901} for each geographic position marked or range position and then computing the average deviation for each navigation source (GPS, INS, OMEGA, and CP-901, respectively) using the following formulas:

$$DEV_{NAV} = POS_{GEO} - POS_{NAV}$$

$$AVG\ DEV_{NAV} = \frac{DEV_{NAV\ 1} + DEV_{NAV\ 2} + \ldots + DEV_{NAV\ n}}{n}$$

where NAV was GPS, unaided INS, OMEGA or CP-901 and n was the total number of data points for each respective navigation system.

(2) Nonairways data were analyzed to determine if GPS meets or exceeds national and international navigation accuracy requirements (air defense identification zone penetration, flight information region boundary crossing, etc.) and that no loss of

nonairways navigation accuracy was experienced while using GPS as primary means of navigation over current navigation sources.

d. Results and Discussion. The P-3C Update III aircraft with GPS installed demonstrated the capability to accurately navigate outside of the NAS and during long over-water flights. No major deficiencies were noted during 131.7 hours of nonairways navigation. Navigation waypoints were entered into the CDNU both in the form of waypoint identifiers and as latitude/longitude entries. Table 4-1 lists the average, maximum, and minimum deviations for each nonairways navigation source.

Table 4-1. Nonairways Data

	Average	Maximum	Minimum	Sample Size
GPS	65 m 0.03 nm	93 m 0.05 nm	21 m 0.01 nm	111
INS	3612 m 1.95 nm	10149 m 5.50 nm	1271 m 0.68 nm	35
CP-901	1492 m 0.80 nm	3032 m 1.64 nm	200 m 0.10 nm	14
OMEGA	4495 m 2.42 nm	4564 m 2.46 nm	2831 m 1.53 nm	25
INS (Aided)	106 m 0.06 nm	189 m 0.10 nm	47 m 0.03 nm	44
CP-901 (Aided)	388 m 0.21 nm	461 m 0.25 nm	223 m 0.12 nm	32

Table 4-1 shows that the navigation accuracy provided by GPS was superior to that of current P-3C navigation systems. The data also shows that when the GPS signal is passed to the LTN-72-9-21 INS there was a significant improvement in INS's accuracy. When the hybrid INS/GPS navigation solution was provided as an input to the CP-901 mission computer, there was a significant improvement in the overall mission system accuracy. However, during data collection, test team members noted a discrepancy with the display of position data. In flight, when the FREEZE button was pressed it was discovered that the position data displayed on RNAV Page 1 differed from the data displayed on RNAV Page 2 by an average of 85.9 meters; this led to confusion over which position to accept as the more accurate. For testing purposes the RNAV page 1 solution was used as truth.

404. <u>Test E-3, High Latitude Navigation</u>

a. <u>Object</u>. Will the P-3C Update III aircraft with GPS installed accurately navigate at high latitudes?

b. <u>Procedure</u>

(1) This test employed Scenarios A and B. The P-3C Update III aircraft with the GPS UE installed was operated in areas of high latitude. For the purposes of this test, areas of high latitude were defined as areas where latitude exceeded 70° North or South.

(2) The pilots and/or navigator recorded aircraft position, GPS and INS magnetic variation readings, FOM, and EHE for every data collection point, and when a GPS warning indicated an increase in positional uncertainty. Geographic fixes were taken over NAVAIDs or discernible geographic points to establish ground truth.

c. <u>Data Analysis</u>. MV indicated by the GPS and INS was compared to ground truth values using the following formulas:

$$MV_{DEV\text{-}GPS} = MV_{TRU} - MV_{GPS}$$

$$\text{AVG } MV_{DEV\text{-}GPS} = \frac{MV_{DEV\text{-}GPS\ 1} + MV_{DEV\text{-}GPS\ 2} + \cdots + MV_{DEV\text{-}GPS\ n}}{n}$$

and:

$$MV_{DEV\text{-}INS} = MV_{TRU} - MV_{INS}$$

$$\text{AVG } MV_{DEV\text{-}INS} = \frac{MV_{DEV\text{-}INS\ 1} + MV_{DEV\text{-}INS\ 2} + \cdots + MV_{DEV\text{-}INS\ n}}{n}$$

where n was the total number of data points for each respective navigation system. The following expression should be satisfied to ensure that no loss of navigation accuracy was experienced while using GPS as the sole means of navigation over current navigation sources:

$$\text{AVG } MV_{DEV\text{-}GPS} \leq \text{AVG } MV_{DEV\text{-}INS}$$

d. <u>Results and Discussion</u>. The P-3C Update III aircraft with GPS installed demonstrated the capability to accurately navigate at latitudes greater than 70° North. No major deficiencies were noted during 6.3 hours of high latitude navigation. MV during the period that the aircraft was above 70°N ranged from 24.5°W to 44.5°W.

(1) No degradation in GPS performance was noted during high latitude navigation.

(2) It was determined that the AVG $MV_{DEV-GPS}$ was less than AVG $MV_{DEV-INS}$ (0.5° and 1.1°, respectively). The MV look-up table provided MV data comparable to that of current P-3C systems.

405. Test E-4, Mountainous Terrain Navigation

a. Object. Will the P-3C Update III aircraft with GPS installed accurately and safely navigate in a mountainous area, as defined by the Department of Defense Flight Information Publication General Planning?

b. Procedure

(1) This test employed Scenario A. The P-3C Update III aircraft with the GPS UE installed was operated in areas of mountainous terrain under visual meteorological conditions. Aircraft altitude varied from 500 to 2000 feet above ground level and the aircraft was maneuvered in such a way to place mountain ridges between the satellite and GPS antenna to determine if temporary signal loss caused by satellite eclipsing significantly increased positional uncertainty.

(2) The pilots and/or navigator recorded aircraft position, FOM, EHE for every data point, and any time the GPS indicated an increase of positional uncertainty. Visual fixes were taken at MOT of NAVAIDs and discernible geographic points to establish ground truth.

c. Data Analysis. When a significant increase in either FOM or EHE was noted while in close proximity to mountainous terrain, data were used to reconstruct aircraft position, altitude, and proximity to terrain or other physical obstruction. This information was used with satellite prediction software (System Effectiveness Model Version 3.6) to determine the number of satellites in view of GPS antenna (including azimuth and elevation between satellite and antenna) and aided, in conjunction with the operational experience and judgment of the test team, in determining whether proximity to mountainous terrain and/or satellite eclipsing caused a significant increase in positional uncertainty.

d. Results and Discussion. The P-3C Update III aircraft with GPS installed demonstrated the capability to accurately and safely navigate in a mountainous area. No major deficiencies were noted during 5.8 hours of mountainous terrain navigation. During periods when the signal from one or more satellites was blocked by terrain, the GPS UE demonstrated the capability to provide positions with sufficient accuracy to allow navigation in the ENROUTE, TERMINAL, and APPROACH modes. However, when the aircraft was maneuvered with bank angles in excess of 40°, short term losses of positional accuracy, and corresponding losses of navigation capability using the APPROACH and TERMINAL modes, were experienced. In all instances, navigational accuracy returned within 1-2 seconds. The frequency and duration of navigation accuracy losses will depend not only on the proximity to and the extent, both vertical and horizontal, of the surrounding terrain, but also on bank angle. Consequently, aircraft that are required to fly in closer proximity to terrain and/or to use higher bank angles may suffer greater navigation accuracy losses. The design capability which allows the GPS to use INS information during periods of signal loss or degradation should enable the GPS to reacquire satellite signals more rapidly, thereby minimizing the time that normal GPS accuracy is unavailable. This capability, however, could not be verified because the GPS UE did not give any indications or annunciations when it was being aided by INS data.

406. Test E-5, ASW Mission Support

a. Object. Will the P-3C Update III aircraft with GPS installed support the completion of ASW missions?

b. Procedure

(1) This test employed Scenario B. The P-3C Update III aircraft with the GPS UE installed was operated in both independent and coordinated ASW roles. Current fleet tactics were employed. One mission was conducted on an instrumented range and 14 open-ocean missions were flown.

(2) Plot stabilization error data, with a GPS-aided INS as the primary TACNAV source, were recorded by the tactical coordinator following all sonobuoy MOTs.

c. Data Analysis. ASW mission support was determined by the following:

(1) A CEP comparison of sonobuoy MOT error between the CP-901 computer using inputs from a GPS-aided INS (CEP_{GPS}) and an unaided INS (CEP_{INS}). The data were also compared to historical data for computer-INS (CEP_{INS}), computer-doppler (CEP_{DOP}), and computer-air data (CEP_{AIR}). The following expressions should be satisfied to ensure that no loss of plot stab accuracy was experienced while using a GPS-aided INS as primary TACNAV source:

$$CEP_{GPS} \leq CEP_{INS}$$

$$CEP_{GPS} \leq CEP_{DOP}$$

$$CEP_{GPS} \leq CEP_{AIR}$$

(2) Missions were reconstructed to determine whether, in the operational judgment of the test team, GPS aided in the search, localization, tracking, and attack phases of the ASW mission. The assessment included but was not limited to: buoy-to-buoy positional accuracy and its impact on aircraft-to-target fix accuracy and transition of relative plot to a geographic navigation grid (actual pattern accuracy and target location).

d. Results and Discussion. The P-3C Update III aircraft with GPS installed demonstrated the capability to support the completion of ASW missions. No major deficiencies were noted in 76.5 hours of ASW missions. A dedicated test was conducted to determine the CEP of the CP-901 when a GPS-aided INS was selected as the primary navigation source. The demonstrated CEP_{GPS} was 81 yards. A direct comparison with historical data was not possible due to differences in test conditions. In the operational judgement of the test team the GPS significantly improved plot stabilization, sonobuoy field integrity, surface plot accuracy, etc., which should enhance all aspects of the ASW mission.

407. Test E-6, ASUW Mission Support

a. Object. Will the P-3C Update III aircraft with the GPS installed support the completion of ASUW missions?

b. Procedure. This test employed Scenario B. The P-3C Update III aircraft with the GPS UE installed participated in independent and coordinated ASUW mission events. The P-3C conducted open-ocean ASUW-missions against targets-of-opportunity and dedicated fleet assets using current tactics. The aircrew conducted own-unit HARPOON targeting. In coordinated targeting, target data were passed by voice communications to friendly surface ships to allow an attack solution to be developed on the simulated hostile surface unit.

c. Data Analysis

(1) ASUW missions were reconstructed to determine:

(a) Target track accuracy.

(b) Targeting accuracy by own unit and third party targeting unit.

(c) Voice communications targeting accuracy.

(d) Capability to maintain an accurate/effective surface plot.

(2) Data were analyzed to determine if, in the operational judgment of the test team, GPS supported the

completion of the ASUW mission. The determination included, but was not limited to, an assessment of whether GPS enhanced targeting and surface plot accuracy.

d. Results and Discussion. The P-3C Update III aircraft with GPS installed demonstrated the capability to support the completion of ASUW missions. No major deficiencies were noted during 9.0 hours of ASUW missions. The aided INS was used as the primary input source to the CP-901 mission computer. Due to data link system failures not related to this test, on both the test platform and participating units, a quantitative evaluation of the effect of GPS aiding on data link accuracy was not possible. However, the demonstrated improvement in accuracy provided when using a GPS aided INS as the primary input source for the CP-901 (see Table 4-1) was determined to enhance all aspects of the ASUW mission.

408. Test E-7, Mine Warfare Mission Support

a. Object. Will the P-3C Update III aircraft with GPS installed support the completion of mining missions?

b. Procedure. This test employed Scenario B. The P-3C Update III aircraft with the GPS UE installed conducted opposed on-line mining operations at the Chesapeake Test Range (CTR). Current fleet tactics were employed during all mining runs with the exception that a visually identifiable geographic initial point was not marked prior to commencing a mining run. Instead, the CP-901 computer with inputs from a GPS-aided INS was the sole source of navigation used throughout the mining evolution. Four inert Mk 36 Destructor mines were dropped during the mining event. The mines were bottom scored and recovered after the event.

c. Data Analysis

(1) Data were analyzed in accordance with OPNAVINST C5040.15C Mine Readiness Certification Inspection (MRCI) to determine mining accuracy while using a GPS aided INS as the primary input source for the CP-901 computer.

(2) Events were reconstructed from aircraft data and compared with range results to verify GPS UE performance.

d. Results and Discussion. The P-3C Update III aircraft with GPS installed demonstrated the capability to support the completion of mining missions. No major deficiencies were noted during 1.4 hours of mining. An offensive mining mission was conducted at the CTR. Following the event, the mines were bottom scored and the results compared to the intended mine positions. The average 'corrected' miss distance was 226m which resulted in a MRCI score of 100 points out of a possible 100 points. During data analysis it was discovered that the GPS was displaying positions based on the OLD HAWAII-MAUI datum rather than the World Geodetic Survey of 1984 (WGS-84) (for further discussion see Test S-8 Human Factors (par. 423 d.(3)(e))); this resulted in a 544m error in mine positioning relative to the intended position. Therefore a 'correction' vector was applied prior to determining a score in accordance with current fleet procedures.

409. Test E-8, SAR Mission Support

a. Object. Will the P-3C Update III aircraft with GPS installed support completion of SAR operations?

b. Procedure. This test employed Scenarios A and B. The P-3C Update III aircraft with the GPS UE installed conducted simulated SAR package drops in accordance with current fleet procedures with the exception that SAR package drop points were determined using GPS positions. Using a single sighting of survivors, the test team marked-on-top survivors and maneuvered the aircraft to the SAR package drop position using a calculated range/bearing from initial MOT.

c. Data Analysis. Data were analyzed to determine if, in the operational judgment of the test team, GPS supported the completion of the SAR mission. The determination included, but was not limited to, an assessment of whether GPS enhances current SAR procedures.

d. Results and Discussion. The P-3C Update III aircraft with GPS installed demonstrated the capability to support the completion of SAR missions. No major deficiencies were noted during 2.3 hours of SAR.

(1) The GPS was used to mark the position of a simulated survivor, then a SAR package drop position was generated in the CDNU. The drop position was calculated by offsetting the survivor's marked position by a predetermined bearing (based on wind direction) and range. Once the drop position was calculated it was entered as the active waypoint in the CDNU. The aircraft was then maneuvered to cross the drop point upwind and perpendicular to the direction of the wind. Using this procedure the GPS UE allowed the pilot to consistently position the aircraft upwind of survivors even when visual contact could not be maintained.

(2) The test team also evaluated the capability of the P-3C, with the GPS UE installed, to more accurately fly precise search tracks. Based on the demonstrated improvement in navigation accuracy provided either by stand alone GPS or when using a GPS aided INS as the primary input source for the CP-901 (see Table 4-1), it was assessed that search integrity and efficiency were improved.

(3) During a routine transit originating in Keflavik, Iceland, the test team received a request to provide assistance to an aircraft in distress. Once radio contact was established, the distress aircraft relayed its own GPS position, track, and ground speed. The test team then used the INTERCEPT function of the CDNU to calculate and provide steering information to the point of intercept. At the calculated intercept point - despite poor weather associated with frequent snowstorms - the distress aircraft was sighted. Use of the INTERCEPT function allowed the aircrew a rapid means of determining the point and time of intercept; this ensured timely arrival at the scene of search.

410. Test E-9, Coordinated Operations

a. Object. Will the P-3C Update III aircraft with GPS installed support the completion of coordinated operations missions?

b. Procedure. This test employed Scenario B. The P-3C Update III aircraft with the GPS UE installed conducted coordinated ASW and ASUW missions in accordance with current fleet procedures.

c. Data Analysis. Data were collected during Tests E-5 and E-6 and were analyzed to determine if, based on the operational judgment of the test team, GPS supported the completion of coordinated operations missions. The determination included, but was not limited to, an assessment of whether GPS enhanced targeting and surface plot accuracy and data link position accuracy.

d. Results and Discussion. The P-3C Update III aircraft with GPS installed demonstrated the capability to support the completion of coordinated operations missions. No deficiencies were noted during 8.0 hours of coordinated operations missions.

411. Test E-10, Replace TACAN

a. Object. Will the GPS effectively replace TACAN in the operational environment?

b. Procedure. This test employed Scenario A. The P-3C Update III aircraft with the GPS installed was operated in a structured airways system performing routine point-to-point, airways navigation and nonprecision approach procedures using GPS vice TACAN as primary navigation source.

c. Data Analysis. Data analysis was conducted as in Test E-1. In addition, all data were analyzed to determine if, in the operational judgment of the test team, GPS could effectively replace TACAN in the operational environment.

d. Results and Discussion.

(1) The P-3C Update III with the GPS installed demonstrated the capability to replace TACAN for navigation in the NAS and for a nonprecision approach capability. No major deficiencies were noted while using GPS UE to emulate TACAN during routine navigation and nonprecision approaches.

(2) Although not a requirement of TACAN emulation, the GPS UE is not capable of replacing the air-to-air capability of TACAN, which is routinely used to establish safe separation distance between two aircraft in flight.

(3) TACAN emulation was based on the TO/TO and TO/FROM navigation functions of the GPS on stationary points in the NAS. Although not a requirement of TACAN emulation, GPS UE is not capable of fully replacing the TACAN with respect to shipboard air operations.

(4) A total of 18 nonprecision approaches were flown, using both APPROACH and TERMINAL modes, with no deficiencies. However, the reduced navigation accuracy provided by the SPS (when cryptographic keys were not loaded) resulted in the APPROACH mode only being available 22.2 percent of the time. By comparison, the APPROACH mode was available 100 percent of the time when the PPS was in use (with cryptographic keys loaded). Therefore, crypotographic keys have to be loaded if full availability of the APPROACH mode is to be guaranteed.

412. Test E-11, Jamming Environment

a. Object. Will the GPS provide accurate navigational information in a jamming environment?

b. Procedure

(1) A review was conducted of all reports relating to jamming tests completed by COMNAVAIRSYSCOM, the contractor, or other government agencies.

(2) Jamming-to-signal ratio data from previous developmental and operational testing were analyzed to determine if the GPS met or exceeded the jamming-to-signal ratio threshold listed in reference (a).

c. Data Analysis. Data were analyzed to assess whether potential jamming of the GPS UE will lead to major or total degradation of system performance.

d. Results and Discussion. No known jamming occurred during OT-IIIB. The GPS UE's capability to reject jamming was previously evaluated as satisfactory during OT-IIB (reference (b)).

413. Test E-12, Deceptive Environment

a. Object. Will the GPS provide accurate navigational information in a deceptive environment?

b. Procedure

(1) AS capabilities cannot be operationally tested (see Limitations).

(2) A review was conducted of all reports relating to the AS capabilities of the GPS UE and any testing completed by COMNAVAIRSYSCOM, the contractor, or other government agencies.

c. Data Analysis. Data were analyzed to assess the impact of spoofing on the GPS UE performance.

d. Results and Discussion. The performance of GPS UE was not tested in a deceptive or spoofing environment (see limitations).

414. Test E-13, Selective Availability

a. Object. Will the GPS provide accurate navigational information in a selective availability environment?

b. Procedure

(1) The effects of an SA environment on GPS were assessed by observing performance in the operational environment.

(2) Whenever the test aircraft was at a surveyed location, positional data were recorded and compared to the survey data. The SPS threshold is dependent on national policy (see Limitations).

(3) One event was flown at CTR to determine if GPS met or exceeded positional accuracy requirements. While on the range, the aircraft was tracked using lasers, theodolites, and radar. The aircraft position was recorded at 1-second intervals. Range data were considered ground truth and were compared to position data recorded on the aircraft.

c. Data Analysis

(1) Range data were analyzed to determine if GPS met or exceeded 3-D and 2-D accuracy thresholds.

(2) Data were analyzed to assess the impact of SA on the GPS UE performance.

d. Results and Discussion

(1) GPS UE positional accuracy using precise positioning service (PPS) could not be fully operationally tested (see limitations) (criterion: ≤16m spherical error probable (SEP)). Both static (parked) and dynamic (flying) positions were evaluated to determine positional accuracy. It was determined that the PPS mode (measured in two dimensions as CEP), available when the cryptographic keys were loaded into the GPS receiver, exhibited significantly improved positional accuracy over the standard positioning service (SPS) mode.

(2) GPS UE positional accuracy using SPS could not be fully operationally tested (see limitations) (criterion: ≤100m (twice the distance root mean squared (2 drms) correctness 95%)).

(3) Despite the limitations, a comparison of both static (surveyed ramp spot) and dynamic (flying) positions were evaluated to determine positional accuracy. Table 4-3 lists CEP accuracies using both PPS and SPS modes.

Table 4-3. Selective Availability CEP Data

	PPS		SPS	
	CEP 50th Percentile	Sample Size	2 drms 95% Correctness	Sample Size
Ramp Spot Measurements (Static)	7 m	19	45 m	14
In-flight Measurements (Dynamic)[1]	34 m	111	203 m	29

Note 1: The accuracy of this data, which is based on positions read directly from the CDNU, is limited to an unknown degree by data latency and display rate errors (see limitations).

415. Test E-14, Survivability

a. Object. Will the susceptibility and vulnerability of the P-3C Update III aircraft with the GPS UE installed lead to a major or total degradation in mission performance because of enemy weaponry?

b. Procedure. This test employed all scenarios and was conducted as follows:

(1) The susceptibility of the P-3C Update III aircraft with the GPS UE installed was assessed by observing its performance in its intended operating environment during all missions.

(2) The vulnerability of the P-3C Update III aircraft, with the GPS UE installed, was assessed by reviewing all reports relating to vulnerability testing conducted by COMNAVAIRSYSCOM or the contractor.

c. Data Analysis. Data were analyzed to assess the impact of the GPS UE on the current aircraft survivability characteristics. Analysis included, but was not limited to, considerations of the use and effectiveness of tactics as a susceptibility reduction method.

d. Results and Discussion

(1) The GPS UE was assessed to reduce the susceptibility of the P-3C. Improvements in tactics were deemed possible as a result of the GPS UE's extremely accurate navigation capabilities. Specifically, the improved navigation accuracy may allow modifications to existing tactics in the areas of offensive mining, ASW and MOSA procedures which should reduce P-3C counterdetection opportunities.

(2) The GPS UE does not materially affect the P-3C's vulnerability characteristics.

416. Test S-1, Reliability

a. Object. Will the P-3 Update III aircraft, with the GPS UE installed, be reliable in its intended operating environment?

b. Procedure

(1) Maintenance action forms (MAF) were completed for:

(a) Each failure discovered during system initialization, ground maintenance, or preflight.

(b) Each preventive action which found a failed part.

(2) All in-flight faults, corrective action, and amplifying information were recorded. Faults which required in-flight technician corrective action were recorded on the User Equipment and System Malfunction Log.

(3) Maintenance personnel were interviewed and completed required suitability questionnaires.

c. Data Analysis

(1) Data collected from data sheets, Naval Flight Information Record, MAFs, and the Operational Test Director (OTD) Journal were used to determine the total number of flight hours logged and the number of critical failures and faults of the GPS equipment. MFHBMCF was calculated as:

$$\text{MFHBMCF} = \frac{\text{Total Flight Hours}}{\text{Number of Mission Critical Failures}}$$

(2) The failure's impact on mission accomplishment and the user's ability to work around it were evaluated by the operator.

(3) Data sheets, questionnaires, and OTD Journal entries were analyzed to identify deficiencies that may not have been evident from quantitative analysis.

d. Results and Discussion. The demonstrated mean flight hours between mission critical failures (MFHBMCF) was 120.6 (criterion: MFHBMCF $\geq$100 hours), based on two mission critical failures in 241.2 hours of operating time. Both mission critical failures occurred during a routine airways transit between NAS Patuxent River, MD and West Palm Beach, FL and resulted in a complete loss of navigation capability for 20 minutes and 30 minutes respectively. The indications received by the pilots were a NAV FAIL annunciation on the CDNU and NAV flags coming into view on the pilot and copilot HSI. Following the flight, a system test was conducted on all GPS UE components. The IBIT was not able to isolate the fault to a specific hardware component and further investigation revealed that the loss of GPS UE navigation capability could not be attributed to either the space or control segments. Therefore, the cause of the fault was unknown.

417. Test S-2, Maintainability

a. Object. Will the P-3C Update III with the GPS UE installed be maintainable in the intended operating environment?

b. Procedure. Built-in-test was performed by operators during preflight and postflight. Since no hardware failures occurred during test operations, a maintenance demonstration was conducted to assist in resolution of the Maintainability COI.

c. Data Analysis

(1) The $MTTR_{HW-O}$ was calculated as:

$$MTTR_{HW-O} = \frac{\text{Total Active Corrective Maintenance Time}}{\text{Total Number of Critical Failures}}$$

where total active corrective maintenance time was the total time to self-test, remove, and replace faulty weapons replaceable assemblies.

(2) Maintenance actions requiring unusually large amounts of repair time were examined to determine whether factors such as system design, accessibility of system components, interoperability, documentation, and training of maintenance personnel contributed to the excessive repair time.

d. Results and Discussion

(1) An $MTTR_{HW-O}$ was not observed during test. No actual mission-critical hardware failures occurred during the test period. A maintainability demonstration, including practice fault isolations and replacement of GPS UE components was conducted. Repair of nine critical failures induced during the maintainability demonstration required a total of 2 hours 24 minutes to complete, for an $MTTR_{HW-O}$ of 16.0 minutes (criterion: $\leq$20 minutes). Table 4-3 lists specific maintainability demonstration results.

Table 4-3. O-Level Maintainability Demonstration Results

REPAIRED OR REPLACED ITEM	ELAPSED TIME (minutes)
3A Receiver	5:00
Receiver Batteries	3:12
Flt Station CDNU (Including OFP Load)	17:08
NAV/COMM CDNU (Including OFP Load)	18:14
Antenna Electronics Package	19:06
Bus Coupler (Rack B1/B2)	39:13
Bus Coupler (NAV/COMM)	27:38
Aux Nav J-Box Circuit Card	11:36
Signal Data Converter	2:58

(2) The time to remove and replace the following GPS UE components was longer than necessary because captive nuts and camlock fasteners were not used to secure components:

(a) Bus couplers (4).

(b) AE-4.

(c) Auxiliary Navigation Junction Box (ANJB) access cover.

(3) GPS mode light assemblies did not have replaceable light bulbs. Bulbs are soldered to individual light modules requiring replacement of complete module when lights burned out.

(4) The circuit card pullers included in the P-3C in-flight maintenance kit could not be used to extract circuit cards from the ANJB due to space limitations. The use of pliers or bare hands to remove cards could cause damage to circuit cards and/or ANJB.

(5) An $MTTR_{HW-I}$ was not observed during test. No actual mission-critical hardware failures requiring I-level repair occurred during the test period (criterion: $\leq$60 minutes). A maintainability demonstration, witnessed by COMOPTEVFOR personnel was conducted from 31 July 1989 to 8 August 1989 (reference (c)) to determine the $MTTR_{HW-I}$ for the AN/ARN-151(V) receiver. Repair of 28 critical failures required a total of 10 hours and 38 minutes to complete, for an $MTTR_{HW-I}$ of 22.8 minutes.

418. Test S-3, Availability

a. Object. Will the P-3C Update III aircraft with GPS UE installed be operationally available in the intended operating environment?

b. Procedure. Data collected for Tests S-1 and S-2 were used to determine the impact equipment failures, repair times, and logistic delays had on GPS UE availability.

c. Data Analysis

(1) A_o was calculated using the formula:

$$A_o = \frac{\text{Uptime}}{\text{Uptime + Downtime}}$$

(2) OTD Journal entries, questionnaires, and operator logs were reviewed to assess the GPS UE's availability. Data were analyzed to determine, in the operational judgment of the test team, the impact on the P-3C mission.

d. Results and Discussion. The demonstrated A_o was 0.99 (criterion: $A_o \geq 0.95$), based on 3816.0 total hours of aircraft uptime and 50 minutes of downtime (see Test S-1 Reliability (par. 416 d.)).

419. Test S-4, Logistic Supportability

a. Object. Will the P-3C Update III aircraft with the GPS UE installed be logistically supportable? This test examined the configuration, integration, and efficiency of the following elements of logistic support:

(1) Maintenance planning.

(2) Manpower and personnel.

(3) Supply support.

(4) Technical data.

(5) Computer resources support/software configuration a lans to provide updated system software to the fleet.

b. Procedure. The following procedures were applied as applicable to all components of the GPS UE as installed in the P-3C Update III aircraft:

(1) The configuration, integration, and efficiency of the logistic resources provided to support the GPS UE as installed in the P-3C Update III aircraft were observed throughout the evaluation.

(2) The adequacy of the Integrated Logistic Support Plan (ILSP) was assessed.

(3) Provisions for software configuration management, software block upgrades, and the maintenance and replacement of system software of the CDNU was reviewed.

(4) OTD observations, interview responses, and documentation reviews were recorded in the OTD Journal.

c. Data Analysis. Data from the ILSP, allowance parts list, supply support records and documents, OPNAV forms, premaintenance sheet documentation, technical manuals, and the Navy Training Plan (NTP) were used to assess the degree of logistic support for GPS UE. The primary focus was a comparison between the logistic supportability of the system, as outlined in the ILSP, and the degree of logistic support as implemented and observed during OT-IIIB. Each element of logistic support for the system was evaluated on the basis of its impact on the capability of the P-3C to accomplish its mission.

d. Results and Discussion. A review of the GPS UE ILSP (reference (m)), Computer Resources Life Cycle Management Plan (CRLCMP) (reference (n)), and NTP (reference (o)) was conducted by COMOPTEVFOR. The planned logistic support for the GPS UE, as installed in the P-3C is considered adequate.

420. Test S-5, Compatibility

a. Object. Will the GPS UE as installed in the P-3C Update III aircraft be compatible with its operating environment?

b. Procedure. This test was conducted continuously throughout project operations and consisted of investigating the compatibility of the GPS UE with the physical, functional, environmental, electronic, and electric conditions that existed on-board the P-3C Update III aircraft. Flight crew and maintenance personnel recorded evidence of any of the conditions listed below and their observed effects. The OTD recorded the results in the OTD Journal. The effects of the following conditions were examined:

(1) Physical Conditions. Vibration from the P-3C aircraft's operations and maneuvers.

(2) Functional Conditions. No specific areas of functional compatibility were identified. The OTD recorded any observations which indicated possible functional incompatibilities involving GPS UE.

(3) Environmental Conditions. Extremes of temperature and changes in pressurization which could degrade the performance of the GPS UE.

(4) Electronic and Electrical Conditions. Any electronic or electrical abnormality that could affect or be attributable to installation of the GPS UE were investigated.

c. Data Analysis. Data from questionnaires, logs, and journals were analyzed to determine if any compatibility problems existed. Compatibility problems identified were assessed based on their impact on P-3C mission accomplishment. The primary focus of the assessment was on the degree of degradation to GPS UE performance due to the physical and environmental conditions to which the system was exposed.

d. Results and Discussion. No compatibility deficiencies were noted. The aircraft was taken to northern latitudes above the Arctic circle and to equatorial regions in the Caribbean for environmental considerations and no degradation in the system performance was noted.

421. Test S-6, Interoperability

a. Object. Will the P-3C Update III aircraft with GPS UE installed provide adequate interfaces between the GPS UE and the LTN-72 INS, CP-901 computer, barometric altimeter, navigation instruments, and subsystems?

b. Procedure. Observations of and interviews with aircrew and maintenance personnel were made by the OTD and responses recorded in the OTD Journal.

c. Data Analysis. Analysis was conducted using both effectiveness and suitability data collected throughout OT-IIIB. Interoperability problems identified were assessed based on their impact to P-3C mission accomplishment. The primary focus of the assessment was on the capability of the GPS UE to interface with the LTN-72-9-21 INS. Data were assessed based on the operational experience and judgment of the test team.

d. Results and Discussion

(1) On four occasions in flight, the GPS UE indicated that the Signal Data Converter's (SDC) Continuous Built in Test (CBIT) had detected an HSI Distance Measuring Equipment (DME) fault and dropped NAV Flags over the DME wheels. To recover the DME display, and restore positional awareness (ie. to display the complete GPS navigation solution) GPS had to be momentarily deselected at all stations or the SDC manually reset. These recovery procedures could significantly increase pilot workload in an already work intensive environment, such as IFR landings, and hamper pilot performance.

(2) Faults could not be repeated during post-flight troubleshooting at the O-level but were subsequently found by an I-level maintenance activity to be associated with a DME wheel alignment fault. Unlike the CBIT, which tests DME throughout the entire range of DME wheel rotation, the IBIT only tests DME at two positions; this allows DME wheel alignment faults to go undetected during IBIT. Currently, the only reliable way to troubleshoot this type of discrepancy down to the faulty HSI is to remove all three HSIs and have them tested at an I-level maintenance activity; this renders the aircraft unuseable for the period that all HSIs are removed.

(3) Due to the potential magnitude of this problem interoperability was found UNSAT. The potential magnitude of this problem is unknown because the quality of HSI's and HSI maintenance was beyond the scope of this evalution. For further discussion of this subject see Part 5 - Operational Considerations (par. 501).

(4) The interface between the GPS UE and the LTN-72-9-21 INS allowed mutual aiding between the systems.

(a) When the operator initiated INS aiding, the GPS provided data to the selected INS. The resulting hybrid INS-GPS positional information was displayed to the navigator and could be used as the primary navigation input to the CP-901 mission computer. Table 4-1 shows that the positional accuracy of the GPS-aided INS and CP-901 improved dramatically when compared to an unaided INS and CP-901.

(b) The GPS UE's capability to use INS data during periods of jamming and satellite signal eclipsing was designed to allow the GPS to quickly reacquire satellite signals. This capability could not be verified since no indications were available to the operator that INS aiding of the GPS was taking place.

(5) SDC received synchronization voltage through the NAV/COMM HSI circuit breaker (CB) on the navigation junction box. If the NAV/COMM HSI was removed from the aircraft and the associated CBs were pulled and tagged out, the SDC would fault due to the absence of synchronization voltage.

422. Test S-7, Training

a. Object. Will the training for the GPS UE as installed in the P-3C Update III aircraft be adequate for operator and maintenance personnel?

b. Procedure

(1) The OTD conducted interviews with operators and maintenance personnel and observed operation and maintenance of the GPS UE throughout testing. All apparent training deficiencies were documented in the OTD Journal and on applicable data sheets.

(2) The NTP for NAVSTAR GPS UE (reference (o)), as it pertains to the P-3C was reviewed.

c. Data Analysis. Training was evaluated, data from questionnaires, logs, and journals were analyzed. The operational experience and judgment of the test team was used to determine the impact on the P-3C mission. The primary focus was a comparison between the planned training requirements, as outlined in reference (o), and the actual training accomplished prior to, and during, OT&E.

d. Results and Discussion.

(1) No major training deficiencies were noted.

(2) Prior to commencement of OT-IIIB, GPS UE operator and maintenance training was provided by contractor support personnel. The training received was compared with the training outlined in the NTP (reference (o)). Operator training was considered satisfactory. Maintenance training consisted of a one day organizational level course. However, the NTP (reference (o)) states that "With concurrence of COMNAVAIRLANT/PAC, squadrons may conduct stand-alone aircraft specific training for AT3 NEC holders and/or incorporate the NAVSTAR UE training into existing communications/navigation courses for specific aircraft types." Due to the complexity of the interfaces with existing P-3C navigation systems, the test team concluded that the GPS UE maintenance training should be incorporated into existing navigation/communication training courses rather than relying on stand-alone training at the squadron level.

423. <u>Test S-8, Human Factors</u>

a. <u>Object</u>. Will the human factors features of the GPS UE, as installed in the P-3C, be adequate?

b. <u>Procedure</u>. The OTD observed operators and maintenance personnel performing their duties and recorded human factors deficiencies. The test measured the effects that equipment and system design have on the user in the work environment, including operator workload, GPS UE lighting, information presentation, function selection and system response timing, and tactile feedback. Operators and maintenance personnel completed questionnaires relating to human factors. The OTD conducted follow-up interviews with operator and maintenance personnel.

c. <u>Data Analysis</u>. Applicable human factors data from questionnaires, logs, interviews and journals were collected and recorded in the OTD Journal. The primary focus of the analysis was on the factors which contributed to the effective and efficient accomplishment of the P-3C mission using GPS UE. Data were assessed based on the operational experience and judgment of the test team.

d. <u>Results and Discussion</u>

(1) The flight station CDNU is located on the pilot side of the center instrument pedestal. This location made operation by the copilot difficult due to the excessive reach required and the parallax created by the awkward viewing angle.

(2) The GPS mode lights obstruct both the pilot's and copilot's view of their respective clocks.

(3) The GPS mode lights could not be dimmed sufficiently for night flights.

(4) The GPS annunciator light located at the NAV/COMM station was excessively bright.

(5) The following problems relating to the CDNU software OFP version 005 were all considered to make operation of the system unnecessarily difficult:

(a) No capability existed to display Estimated Time of Arrival (ETA) for flight plan waypoints. ETA is routinely used as part of a standard format for reporting position - both within the NAS and worldwide - when flying in areas not covered by radar, or when requested by an air traffic control agency.

(b) No capability existed to enable the operator to scroll between successive AUXILIARY WAYPOINT DATA pages. This required the operator to perform excessive keystrokes to view data for successive waypoints.

(c) Status of GPS cryptographic key load and use was not readily available nor was the information displayed in an intuitive format. The operator had to navigate three sub-menus (INDEX, ZEROIZE, and GPS) to locate the GPS crypto information. A valid crypto load was indicated by the appearance of two labels, [ZERO KEYS] and [STORAGE CODE] (the latter being an unusable function). Cryptographic keys actually in use by the GPS UE was indicated by a third label DAYS [001].

(d) No capability existed to display GPS bearing and track referenced to True North (^{o}T) for TACNAV. Charts used during tactical missions were referenced to True North.

(e) A datum other than WGS-84 was inadvertently selected prior to one flight. Use of a datum other than WGS-84 for navigation in the NAS and for nonprecision approaches will introduce errors in navigation accuracy without warning to the operator. These errors may prevent the pilot from visually acquiring the runway environment on a nonprecision approach.

424. Test S-9, Safety

a. Object. Will the safety features of the GPS UE as installed in the P-3C Update III aircraft be adequate for operation and maintenance?

b. Procedure. The OTD inspected the installation, materials, and equipment for deficiencies and potential hazards while observing system operation and maintenance. Aircrew and maintenance personnel were watchful for safety hazards throughout the test period. Safety testing was conducted concurrently with effectiveness testing. Observations by the OTD and interviews with operators and maintenance personnel were recorded in the OTD Journal.

c. Data Analysis. Responses to questionnaires and interviews, as well as comments from the OTD Journal, were reviewed for safety related issues. The primary focus of the evaluation was on the safety of maintenance and operating procedures, as well as examination of equipment for personnel hazards. Additionally, documentation was examined to ensure warnings and cautions are used to identify practices and procedures which, if not strictly adhered to, would pose a potential hazard to equipment and personnel. Data were assessed based on the operational experience and judgment of the test team.

d. Results and Discussion. No deficiencies were noted.

425. Test S-10, Documentation

a. Object. Will the documentation provided for the GPS UE as installed in the P-3C Update III aircraft be adequate and accurate?

b. Procedure. The OTD reviewed all GPS UE installation, operation, and maintenance publications. Flight crew and maintenance personnel were observed as they used the documents during project operations. All operator and maintenance personnel reviewed technical manuals and operating procedures manuals for thoroughness and accuracy. Personnel were interviewed regarding documentation adequacy and availability.

c. Data Analysis. Data from questionnaires, logs, and journals were used to assess the operational suitability of GPS UE documentation. The primary focus was on the availability, utility, completeness, legibility, accuracy, and content of all documents. Operational experience and judgment were used to determine the impact on the P-3C mission.

d. Results and Discussion. Technical manuals were preliminary versions provided by the prime contractor. The primary maintenance publication was generic in nature and provided extremely limited information on the maintenance and operation of the GPS UE, as installed in the P-3C Update III. The operators' manual provided for the CDNU details numerous functions not available in the P-3C.

(1) The AN/ARN-151(V) maintenance publication (reference (e)) detailed operations and maintenance procedures for a generic AN/ARN-151(V) system consisting of the following components: 3A receiver, platform CDU, FRPA-3 antenna, and AE-4 package. The manual provided no information on other components of GPS UE installed in the P-3C, such as: CDNU, SDC, DDS, ANJB, cryptographic fill panel, mode light assemblies, GPS/INS interfaces, etc. In practice, this manual proved to be of little

value in troubleshooting and maintaining the GPS UE, as installed in the P-3C.

(2) A preliminary maintenance manual (reference (f)) was developed from source data to provide basic system operation and troubleshooting and maintenance procedures specifically for the GPS UE, as installed in the P-3C. This manual provided sufficient maintenance data to allow the completion of operational testing but is not adequate for fleet use.

(3) The CDNU operators manual (reference (g)) detailed numerous functions not available in the P-3C GPS integration including discussions relating to the vertical navigation capability, wind indications, magnetic heading, storage code function, slant range, track angle error and drift angle.

Section 5

Operational Considerations

501. Operational Considerations. The following discussion relates to HSI problems and their effect on GPS reliability.

a. It was agreed prior to testing (reference (p)) that any HSI failures that could be directly attributed to misalignment of the DME wheel - by subsequent failure of a bench test calibration - would not adversely affect GPS reliability. Prior to testing, a selection of 10 HSIs were deliberately bench tested to establish their calibration status; of these, 60% failed the test due to DME wheel alignment faults. All of the HSIs fitted in the test aircraft were calibrated to the fleet standard prior to commencing test operations. During the test, however, it became necessary to change the NAV/COMM HSI for a fault unrelated to DME wheel alignment. The replacement HSI was not one of the units that had been previously bench tested, however, it had been in use in another aircraft and was considered to be of a fleet representative standard. Subsequently, four HSI failures, resulting in a loss of GPS navigation capability for a total of 20 minutes, occurred. In each instance, the fault was subsequently cleared by deselecting GPS at all three stations or manually reseting the SDC. Had these failures been included in the MFHBMCF calculations, the resulting demonstrated MFHBMCF would have been 40.2 hours (criterion: MFHBMCF≥100 hours). Subsequent troubleshooting on the ground using the IBIT was unable to reproduce the fault as the IBIT only tests DME at two positions rather than throughout the entire range of DME wheel rotation. Currently, the only reliable way to troubleshoot this type of discrepancy down to the faulty HSI is to remove all three HSIs and have them tested at an I-level maintenance activity.

b. While HSIs are not included as part of the GPS UE, they do affect the aircrew's ability to use GPS for navigation. The effect of having a DME wheel alignment fault on one out of three HSIs is to cause short term losses of navigation capability and minor irritation. The effect of having similar faults on one or both of the remaining HSIs was unobserved. At no point in testing did two or more HSI's create problems with the system. However, it is reasonable to expect that navigation capability losses would become more frequent and more of a hindrance, especially when required to use GPS as sole means of navigation. Additionally, if the observed 60% bench test calibration failure rate for HSIs is a fleet representative figure, the following should be considered:

(1) When carrying out integrating of the GPS UE, all aircraft HSIs will need to be bench tested to ensure that they meet the required specification. Potentially this could require a greater maintenance effort during aircraft modification by

increasing the anticipated time of a GPS installation than was originally envisioned. Hence, the downtime of the aircraft may be increased, limiting its operational use, or, to reduce downtime, CO's will delay installations until the AIMD's schedules allow them to perform HSI checks to ensure successful GPS integrations. GPS integrations will then occur at a rate dictated by the AIMD's workload. Either way successful GPS installations will be slower than currently expected.

(2) Previous equipment integrated with the HSI's was not as sensitve as GPS and work adequately. Therefore, the HSI's had not needed and may not necessarily be maintained to their strict specified requirements for adequate fleet use. As previously noted 6 of 10 failed these strict specified requirements. It is likely that the reliability of HSIs will decline as a result of the higher tolerances imposed by the SDC's CBIT. The result may be a larger number of reported HSI failures because of the GPS integration and, subsequently, more I-level maintenance man hours being expended servicing HSIs to maintain them to the specifed requirements to allow successful GPS operation.

Section 6

Additional Recommendations

601. Additional Recommendations

a. Consider incorporation of captive nuts and camlock fasteners in the mounting hardware for the following components:

(1) Bus couplers (4).

(2) AE-4.

(3) ANJB access cover. (par. 417 d.(2))

b. Modify GPS mode light assemblies to allow individual light bulbs to be replaced at the O-level. (par. 417 d.(3))

c. Modify the SDC IBIT to enable it to detect DME wheel misalignment faults initially detected in flight. (par. 421 d.(1))

d. Provide SDC synchronization voltage from the pilot or copilot HSI CB on the navigation junction box. (par. 421 d.(3))

e. Incorporate GPS UE maintenance training specific to the P-3C into existing navigation/communications training courses. (par. 422 d.)

f. Provide a capability to dim the pilot and copilot GPS mode lights to suit individual needs. (par. 423 d.(3))

g. Redesign GPS annunciator light at NAV/COMM station to reduce excessive brightness. (par. 423 d. (4))

h. The following are recommendations relating to the CDNU OFP:

(1) Modify software so that when the FREEZE mode is selected, the positional data displayed on the RNAV 1 and RNAV 2 pages are the same. (par. 403 d.)

(2) Provide the capability to display ETA to waypoints on CDNU FLIGHT PLAN and PROGRESS pages. (par. 423 d.(5)(a))

(3) Provide a means to scroll between successive AUX WAYPOINT DATA pages. (par. 423 d.(5)(b))

(4) Improve display of information relating to GPS cryptographic key presence in the GPS receiver and whether it is in use. (par. 423 d.(5)(c))

(5) Provide the capability to display bearing and track information in the CDNU referenced to True North. (par. 423 d.(5)(d))

(6) Require operator confirmation prior to changing CDNU reference datum. (par. 423 d.(5)(e))

(7) Allow multiple flight plans to be retrieved from DDS cartridge. (par. 402 d.(4))

(8) Remove software engineering restriction which limits total number of files accessible from DDS cartridge to 12. (par. 402 d.(5))

(9) Investigate feasibility of allowing waypoint data, MARK data, and flight plans to be transferred from the CDNU to the DDS cartridge. (par. 402 d.(6))

(10) Provide an indication to the operator that INS data is being used by/available to the GPS UE. (par 405 d.)

i. Advise fleet maintainers that the specified tolerances need to be tested on HSIs during intermediate maintenance. (par. 501 b.(2))

Section 7

Services Provided

701. Services Provided. The following services were provided during OT-IIIB:

a. COMSUBLANT provided one dedicated SSN for AUTEC operations (26 October 1993).

b. COMSURFLANT provided one Ticonderoga class cruiser for dedicated ASUW operations (29 November 1993 and 2 December 1993).

c. CTR provided 4 hours of dedicated range time, weapons retrieval, and data collection services (24 September 1993).

d. AUTEC provided 4 hours of dedicated range time, weapons retrieval, and data collection services (26 October 1993).

e. WPNSTA Jacksonville, FL, provided one Mk 46 REXTORP at Cecil Field (25 October 1993).

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