AD-A163 408 NAVIGATION EQUIPMENT DOPPLER(U) ARMY TEST AND EVALUATION COMMAND ABERDEEN PROVING GROUND MD 01 AUG 85 TOP-6-2-206

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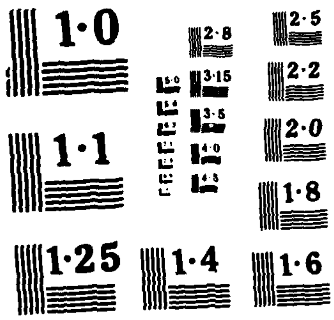

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This Test Operations Procedure describes test methods and techniques for evaluating Doppler Navigation Equipment and Systems and their suitability for employment in the intended tactical environment.

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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

AMSTE-RP-702-102 1 August 1985
Test Operations Procedure 6-2-206*
AD No.

NAVIGATION EQUIPMENT, DOPPLER

1. SCOPE

The objective of this Test Operations Procedure (TOP) is to provide the latest procedures and references (appendix C) for testing and evaluating doppler navigation systems. The procedures are based on previous evaluations of development tests II and III of AN/ASN-128 Lightweight Doppler Navigation Systems (LDNS). Flight Evaluations of both LDNS, AN/ASN-128 (XE-1) and (XE-2) were conducted in the summer of 1977. The AN/ASN-137 Flight Test was completed in 1983 and MIL-N-49098A(AV) was revised to include development specifications on the above tests, entitled "Navigation Set, Doppler AN/ASN-128," 31 January 1984. These procedures may be modified to accommodate new state-of-the-art advances in Doppler Navigation Systems.

This TOP is limited to procedures used in the above mentioned tests and evaluations and the up grade revision of MIL-N-49098A(AV) as of 31 January 1984.

* This TOP supersedes MTP 6-2-206, 27 May 1968.

1.1 Common Engineering Tests

Not included in this TOP are the following common engineering tests which apply to these commodities.

a. TOP 1-2-610, Human Factors

b. TOP 6-2-504, Maintenance/Maintainability

c. TOP 6-2-507, Safety and Health Evaluation-Communications/Electronic Equipment

d. MIL-STD-810D, Environmental Test Methods

f. TOP 6-2-503, Reliability

2. FACILITIES AND INSTRUMENTATION

2.1 Facilities

A range and flight test facility with --

a. Adequate land area and controlled air traffic or traffic-free air space.

b. Ground Control Station.

c. Tracking radar or other space position plotting and recording capability.

d. Test control ground-to-ground and air-to-ground communications.

e. Common range timing.

f. Meteorological support facility.

2.2 Instrumentation

The following instrumentation may be required to support this TOP:

a. Microwave power meters.

b. Frequency meters/counters.

c. Field intensity measuring set.

d. Electronic voltmeters.

e. Signal generators.

f. Oscilloscopes.

g. RF attenuators, terminations, and couplers.

h. Airborne and ground recorders.

i. Telemetering equipment.

j. Spectrum analyzer.

2.3 Characteristics/Requirements

The characteristics of the test instrumentation are determined by the performance specifications of the individual equipment or system being tested. In some cases, instrumentation may have an accuracy an order of magnitude greater than specified for the test item. All instrumentation shall be calibrated by approved methods and instrumentation traceable to the National Bureau of Standards. The major facilities and instrumentation indicated above can provide the necessary characteristics and setups required to perform subtests indicated in this TOP.

3. REQUIRED TEST CONDITIONS

a. Review TECOM Pamphlet 70-3, Research, Development, and Acquisition and Project Engineer's Handbook for guidance on test planning, execution, reporting, and post-test activities.

b. Establish and/or continually maintain a readily accessible project log and project file.

c. Review local installation project officer's handbook, standing operating procedures (SOPs), and implementing directives which govern the administrative processes for preparing test plans, conducting tests, preparing reports, reporting to the Test Resources Management System (TRMS) and budgeting.

d. Acquire and review all descriptive, instructional, and specification materiel on the test items issued by the Government and contractor(s) for checking the test plan subtest objectives, criteria, facility, and instrumentation requirements. MIL-N-49098A(AV), 31 Jan 1984, Navigation Set, Doppler AN/ASN-128 is an appropriate Doppler navigation specification to read.

e. Determine the scheduled availability of the test item.

f. Ensure availability of appropriate facilities and coordinate the test support requirements including qualified personnel, equipment, maintenance, spare parts, and instrumentation.

g. Review the detailed test plan.

h. Record, as a minimum, the following data:

(1) Nomenclature, serial number(s), manufacturer's name, and function of the item(s) under test.

(2) Nomenclature, serial number, accuracy tolerance, calibration requirements, and latest calibration date of test equipment selected for the tests.

(3) Damage to test item(s) incurred during transit and/or manufacturing defects.

(4) Test item photographs.

i. Establish instrumentation or measurement system mean error and standard deviation of error.

j. Determine test item sample size.

k. Check with the responsible frequency management agency to ensure authorization for radiation in the required frequency bands during the anticipated test period if a field test is to be performed.

l. Orient all test personnel on the test objectives, test requirements, schedule of events, and safety precautions.

m. Have on hand the survey nonionizing radiation hazards by the US Army Environmental Hygiene Agency and adhere to all precautions contained therein.

n. Assure that the Airworthiness Release has been received from AVSCOM.

o. Organize test team and establish responsibilities for test conduct, reporting, and data control.

p. Check to ensure that all other aircraft systems are properly functioning and test equipment and accessories are available, operational, and meet certified calibration requirements.

q. Perform an operational check of the test item(s) to ensure normal, correct functioning.

r. Prepare adequate safety precautions to provide safety for personnel and equipment and ensure that all safety regulations are observed throughout the test.

s. Prepare and monitor a test sample plan sufficient to ensure that enough samples of all measurements are taken to provide statistical confidence of final data in accordance with TOP 3-1-002.

t. Select either the Latitude/Longitude (L/L) alphanumeric readout coordinate system or the Universal Transverse Mercator (UTM) coordinate system to provide position data.

u. Calibrate the electronic compass system per MIL-STD-765A.

v. Verify the software/hardware of the navigation computer prior to flight tests.

4. PERFORMANCE TESTS

(NOTE: Because of differences in technical design and construction characteristics caused by advances in the state-of-the-art, detailed test procedures for specific test items cannot be provided. These procedures may be modified when required by the design or characteristics of the test item. Such modification shall not affect the validity of the test results. Some of the test methods below may not be applicable to all test items. Appropriate government and contractor technical manuals (see app C) should be reviewed before testing and the appropriate specific tests determined.

4.1 Electrical Power Tests

4.1.1 RF Power Output

4.1.1.1 Determine if the Lightweight Doppler Navigation Set (LDNS) will operate within the specified performance requirement and criteria of MIL-N-49098A(AV).

4.1.1.1.1 Asssure that the LDNS has met all applicable requirements of MIL-STD-704A, Notice Category B, and the performance of electric system operation defined in Table II, MIL-STD-704A.

4.1.1.1.2 Connect a microwave power meter to the test item as shown in figure 1 and use appropriate RF couplers, if the test item uses cable or wave guide connected antennas which are not integral to the transmitter receiver.

4.1.1.1.3 Turn the test item and power meter on, and allow time for warm up.

4.1.1.1.4 Make a minimum of three measurements of power output in accordance with instuctions furnished with the power meter, and appropriate MIL-N-Doppler specification.

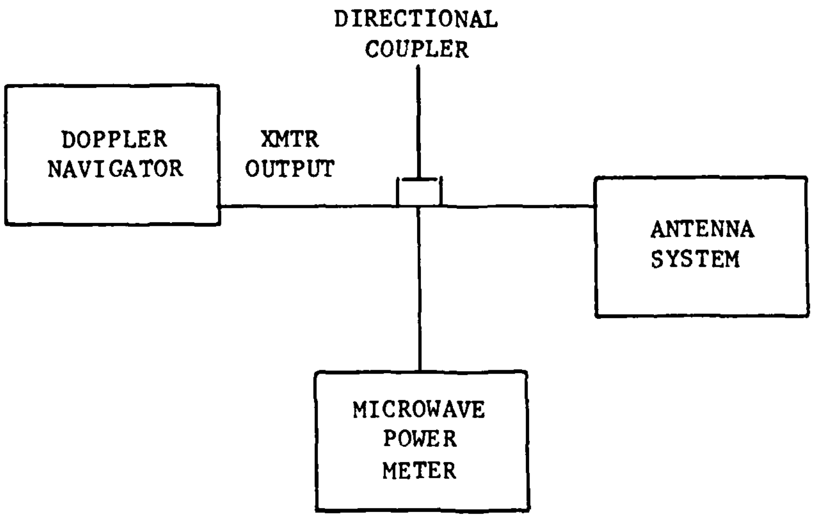

Figure 1. Power output measurement.

4.1.1.1.5 Measure the radiated output power from beams 1, 2, 3, and 4. Verify that the power in each beam does not exceed (100) specified milliwatts.

4.1.1.1.6 Provide special test fixtures which are normally required if the test item is solid state equipment with the antennas an integral part of the transmitter-receiver.

4.1.1.1.7 Refer to the technical manuals of this equipment for specific data on making RF power output measurements, i.e., MIL-N-49098A(AV), paras 3.16.3 and 4.9.13 specification of Navigational Set W/ASN-128( ).

4.1.2 Primary Input Power

4.1.2.1 Determine if the test item would operate within specified performance requirements.

4.1.2.1.1 Use test setup of figure 2 for input power test.

4.1.2.1.2 Use general procedures of TOP 6-2-514 and applicable requirements of MIL-STD-704A, Notice 2, Category B to give specified performance from a 28 Vdc (100 watts max) power source and modes of electric system operation as defined in Table II, MIL-STD-704A.

4.1.2.1.3 Operate the test item in the self-test mode at 16.0 V (emergency battery only) and 20 to 33 Vdc in 0.5-volt increments.

4.1.2.1.4 Monitor and record current drain during the preceding paragraph above.

4.1.2.1.5 Generate and apply to the dc input live, the transient surge voltages, while in the self-test mode, as shown in figure 9 of MIL-STD-704A.

4.1.2.1.6 Use test setup of figure 3 for the transient surge test.

4.1.2.1.7 Apply the positive and negative spike voltages shown in figure 17 of MIL-STD-704A, Notice 2, to the dc input leads of the test item, if the test item is designed to meet these requirements.

4.1.2.1.8 Monitor the input power leads to the test item for transient or spike voltages during on-and-off switching and normal operating modes.

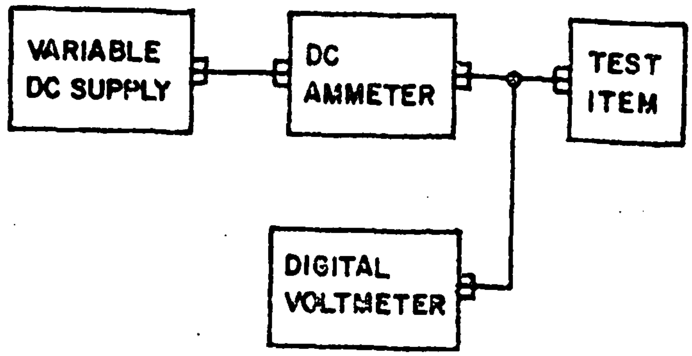

Figure 2. Test setup for input power.

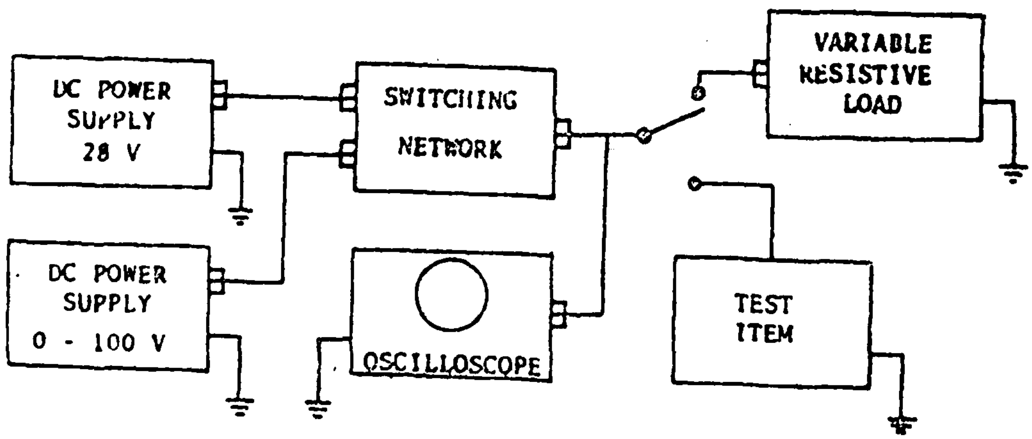

Figure 3. Transient test setup.

4.2 Diagnostic Built-In-Test-Equipment (BITE), SELF TEST

4.2.1 Determine the capability of the BITE.

4.2.1.1 Conduct two forms of self test in a Doppler Navigation System (DNS) that may be so equipped with a continuous check of the Computer Display Unit (CDU) and a test of the RTA, signal data converter (SDC) when the test mode is selected.

4.2.1.2 Check the malfunction (MAL) light for a CDU failure, and set the MODE switch to TEST to read the display failure code.

4.2.1.3 Transmit test data to the CDU for evaluation against stored data if no CDU failure has occurred and the TEST mode is selected.

4.2.1.4 Check for a GO display if the system operation is satisfactory.

4.2.1.5 Check for a Code C, followed by module failure numeric code, which means the failure is in the CDU.

4.2.1.6 Check for a Code R, followed by module failure numeric code, which means the failure is in the receiver/transmitter antenna (RTA).

4.2.1.7 Check for Code S, followed by module failure numeric code, which means the failure is in the SDC.

4.2.1.8 Record SELF TEST indication of operational unit throughout test.

4.2.1.9 Record SELF TEST indication when selected wires of the line replaceable unit (LRU) interconnect cables are disconnected.

4.2.1.10 Activate the SELF TEST function on an operational test item. Note the SELF TEST indications.

4.2.1.11 Disconnect individual wires of the test harness interconnecting cable between the RTA and the SDC LRUs, and note the SELF TEST indications.

4.2.1.12 Analyze the above recorded data and determine if the BITE has the capability to accurately evaluate the test items operational status and correctly identify the failed LRU.

4.3 STATUS LAMPS PERFORMANCE

4.3.1 Determine the accuracy and timeliness of the status lamps.

4.3.1.1 Check to see if the Doppler memory (MEM) lamp indicator illuminates when there is a loss of Doppler velocity data, thus indicating a memory condition.

4.3.1.2 Check to see if the malfunction (MAL) lamp illuminates when there is an equipment malfunction.

4.3.1.3 Record MEM light results during flight and bench testing.

4.3.1.4 Log results of MAL light operation.

4.3.1.5 Observe the operation of MEM light (indicating Doppler loss) during all flight testing using the digital recorder to record when it lights.

4.3.1.6 Make a note in the log book, throughout the testing cycle, whenever the MSL Lamp illuminates as to the cause, actual failure or false alarm.

4.3.1.7 Determine the MEM light activation from the velocity data status bits to assess the lag in its operation. Note the amount of error that is present in the systems when the MEM light comes on.

4.3.1.8 Tabulate actual failures versus false alarm indications and the percentage of false alarms calculated to determine the reliability of the warning light.

4.3.1.9 Evaluate system failures that can occur without a MAL light warning to determine possible effects on the overall system accuracy and dependability.

4.4 FLIGHT ACCURACY

4.4.1 Determine the positioning accuracy of the test item as a funct'on of distance traveled.

4.4.1.1 Use the accuracy requirement for aircraft to be 0.5 to 1.0 percent of distance traveled for Doppler systems (90 percent probability of 1 to 2 percent of distances traveled). Materiel need (MN) for Position and Navigation System (PANS), Section VI, para a(1)(b).

4.4.1.2 Validate all stated performance characteristics for the PANS to 10,000 feet (3048m) above ground level but not exceeding 20,000 feet (6096m) Mean Sea Level (MSL) for aircraft use. MN (PANS) Section VI, para a(10).

4.4.1.3 Do not exceed 2 percent circular error probability (CEP) when inputs of altitude, altitude and velocity meet the limits and accuracy described below, and the computer display unit present CEP for distances traveled of not less than 20 kilometers or 10 nautical miles. (MIL-N-49698A(AV), para 3.17.3.6).

Roll, Pitch and Magnetic Heading
INPUT Accuracy (1 Sigma Value)

Roll, 3.0°; Pitch, 3.0°; Heading (Magnetic), 10°.

NOTES:

1. Roll and pitch data will normally be supplied by the MD-1 or equal.
2. Magnetic heading data will normally be supplied by the Magnetic Compass AN/ASN-43 through an ID-998 or ID-1351.

Operating Conditions

Along Vehicle Axis Velocity (V_x)	-93 to 650 km/hr
Across Vehicle Axis Velocity (V_y)	-185 to +185 km/hr
Vertical Vehicle Veleocity (V_z)	+1500 meters/min
Altitude	0 to 3000 meters MSL

Attitude [to 300 meters (10,000 ft) altitude above terrain]

Terrain	Pitch	Roll
Land	±30°	±45°
Smooth (B1)* Sea (WMO 2)**	±20°	±30°

Azimuth Rate, Pitch Rate and Roll Rate 50 deg/sec max.

*The backscattering cross section per unit surface area of the surface shall be as defined in figure 4. Incident angle for level flight is 25°.

**Per AIR STD 53/14.

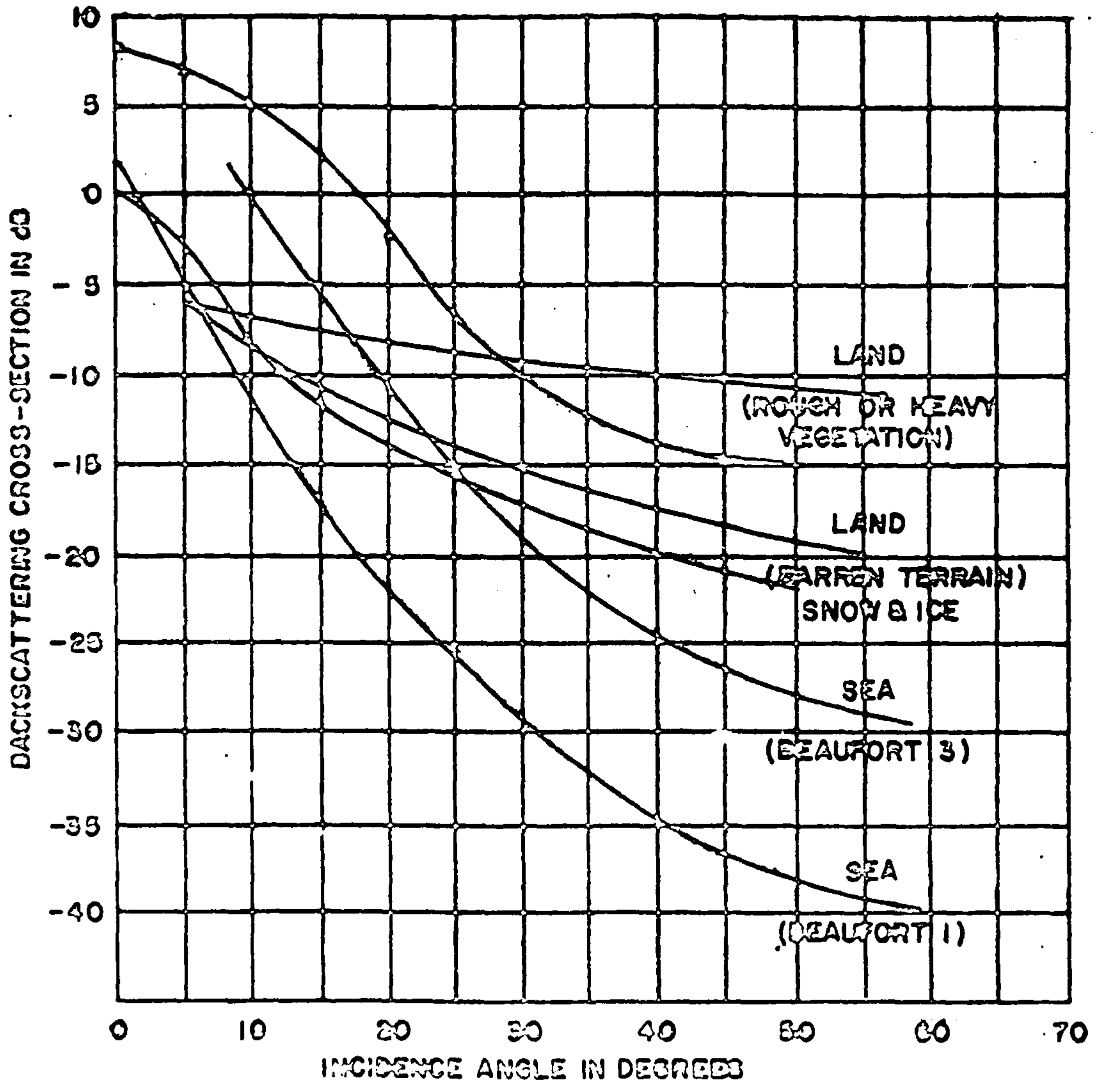

Figure 4. Backscattering cross section/unit surface area for various terrains.

4.4.1.4 Install the test item in a helicopter (AH-IS type) and an airplane (OV-1C type).

a. Limit the testing in the helicopter to its operational capabilities (AH-1S) including a maximum altitude of 10,000 feet (3048 m) above mean sea level (MSL).

b. Include tests in the airplane to high performance climbs, descents, and turns within the limits of the operating conditions (para 4.4.1)

4.4.1.5 Record the test item's performance by an on-board digital data recorder to include at least V_H, V_D, V_V, position (UTM) northing, position (UTM) easting, 100 km square area identifier, true heading-sine, true heading-cosine, and malfunction and memory status indicators.

4.4.1.6 Record the aircraft's actual position and velocity by a time space position information (TSPI) radar (AN/FPS-16 or equivalent). Time correlate this radar data with the on-board recording by use of a time code generator on board the aircraft, synchronized to range time.

4.4.1.7 Conduct flight testing over land, water, and snow and in rain showers. The minimum number independent 20-km flight segments for each configuration is listed in table V.

4.4.1.8 Use a data processing computer to make the following conversions of the recorded tape both for on-board recorder and TSPI radar:

a. Convert on-board digital data to UTM northing, UTM easting, UTM 100 km square area identifier, heading, drift, and vertical velocities, true heading-sine and cosine, malfunction and memory status indicators, and time code in days, hours, minutes, seconds, and hundredths of seconds.

b. Scan TSPI tape (recorded at 10 samples/second rate) and the data with time code that corresponds to each word of on-board data selected.

c. Convert this selected TSPI data to UTM northing (km), UTM easting (km), altitude (m) northing velocity (V_x), km/hr, easting velocity (V_y), km/hr and vertical velocity (V_z) km/hr.

4.4.1.9 Use the converted data and the following procedure, the CEP in the present position and determine as a percent of distance traveled.

a. Separate the data into m blocks representing 20 km segments of flight. Accomplish this with a computer this using equation (1). Iterate the summation of the increments of distance traveled while testing for D_T (total distance traveled) to see if equation 1 is satisfied when $D_T \geq 20$ km. $X_{i,j}$ and $Y_{i,j}$ are UTM coordinates from the TSPI data (expressed in kilometers) at item i for block j. There is a specific value of D_T for each 20 km block of data. Identify these D_T's with the subscript j.

$$D_{T_j} = \sum_{i=0}^{nj} \left[(X_{i+1,j} - X_{i,j})^2 + (Y_{i+1,j} - Y_{i,j})^2 \right]^{1/2} \quad (1)$$

b. Calculate the radial error (E_R) using equation (2) for each 20 km block of data and each value identified with the appropriate subscript j. Denote the subscripts o,j, and v, j the end points of the 20 km block of data. The capitalized variables (X,Y) represent position data from the TSPI radar. The lower case variables (x,y) represent Doppler position data recorded on-board the aircraft.

$$E_{R_j} = \left(\left[(X_{n,j} - X_{o,j}) - (x_{n,j} - x_{o,j}) \right]^2 + \left[(Y_{n,j} - Y_{o,j}) - (Y_{n,j} - Y_{o,j}) \right]^2 \right)^{1/2} \quad (2)$$

c. Calculate the median and mean values of the radial error, where CEP = median.

4.4.1.10 Calculate and present in tabular form for each test aircraft under individual flight condition, and for all flight conditions combined. Base all computations on the percentages in terms of D (where D ↔ 20 km). The information requirements Independent Evaluation Plan/Technical Design Plan (IEP/TDP) included mean and standard deviation for radial position error vector (r), along track error (ate), cross track error (cte); (fig. 7) median and largest r; radial error RMS (root mean square); and radial error GM (geometric mean).

Calculate the radial error RMS and GM by use of the following equations:

$$\text{Radial Error RMS} = \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left(\frac{r}{D}\right)_i^2}$$

$$\text{Radial Error GM} = \sqrt[n]{\prod_{i=1}^{n} \left(\frac{r}{D}\right)_i}$$

Where n is number of 20 km blocks of data.

Determine using figure 8 from the ratio radial error GM/radial error RMS, the corresponding value of the 50 percentile radial error R(50) percentage (CEP in percent).

TABLE V. MINIMUM INDEPENDENT 20 KM FLIGHT SEGMENTS

Terrain	Aircraft Type			Flight Conditions					
	OV-1C	AH-1	Either	High Speed	High Altitude	Night Operation	Cross Country	NOE	Rain Showers
Over Land	X			10					
	X				10				
	X					3			
	X						10		
		X				3			
		X					10		
		X						10	
			X						3
Over Water			X				10		
Over Snow			X				10		

*Night operation can be combined with any of the mission profiles.

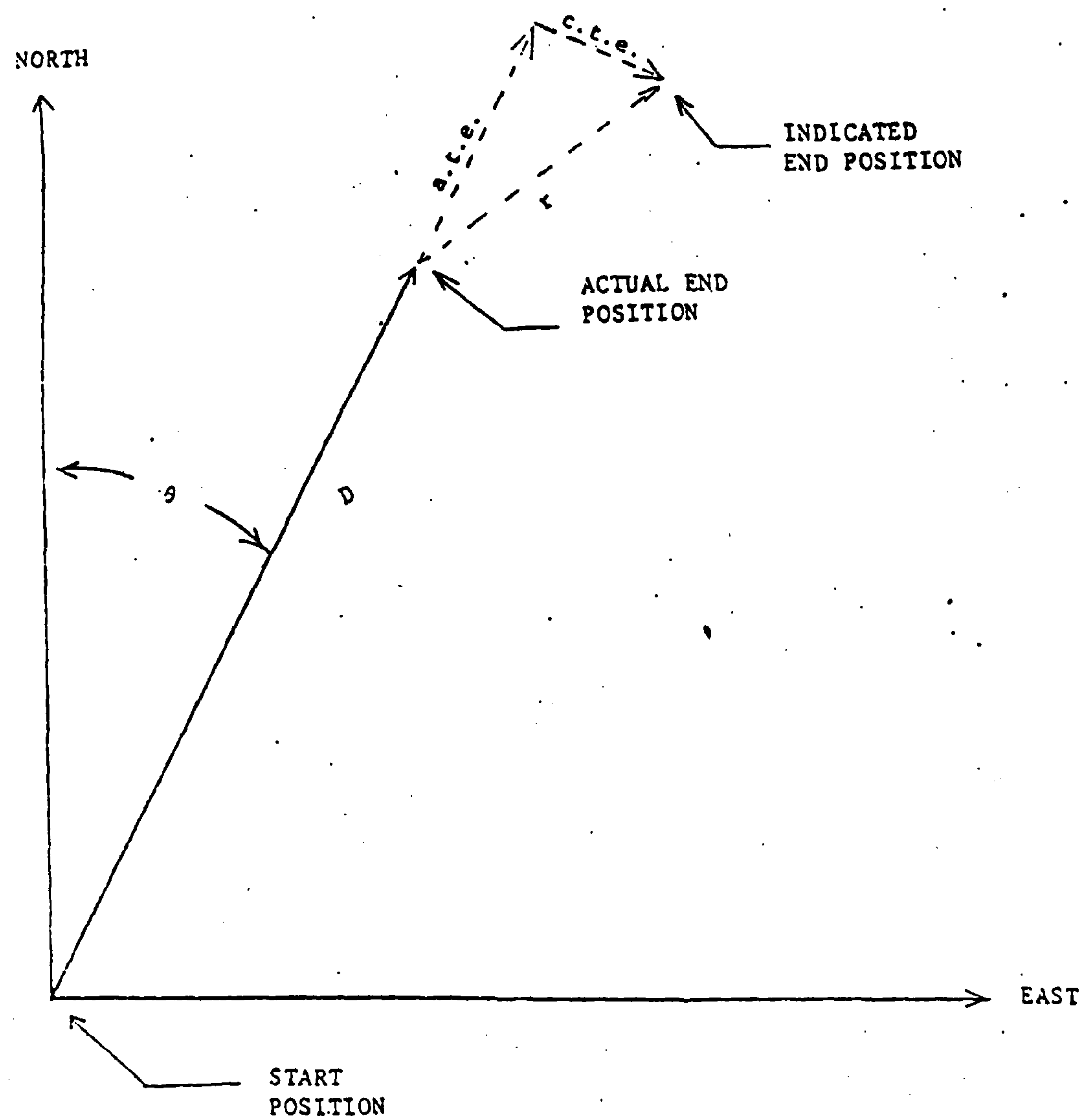

Figure 5. Flight course vector.

5. DATA PRESENTATION

5.1 Electrical Power Tests

5.1.1 RF Power Output

5.1.1.1 Compare the measured power output to the specification and any deviation discussed and data presented to support any conclusion.

5.1.1.2 Tabulate radiated power output of the Doppler Radar Velocity Censor (DRVC) and the RTA at various meteorological and mechanical environments.

5.1.2 Primary Input Power

5.1.2.1 Summarize the power requirements of the Doppler navigation system in a navigation function in the naval, land, and present position display.

5.1.2.2 Show power in the available operation modes at 27.5 Vdc (norminal) in tabular form.

5.1.2.3 Summarize and tabulate transient surge voltage performance for the navigation system under test (SUT).

5.2 Diagnostic BITE, SELF TEST

5.2.1 Record and tabulate all failures attributed to the built in diagnostic equipment, interfaces, components and the BITE system as a whole.

5.3 Status Lamps Performance

5.3.1 Record and tabulate all failures, false alarms, and malfunctions of memory (MEM) and malfunction (MAL) lamps and of the overall system and component errors.

5.4 Flight Accuracy

5.4.1 Velocity Accuracy. Present a summary of results of representative velocity accuracies in tabular format (table B-I, app B) from tolerances shown in paragraph 4.4.1.3 above.

5.4.2 Overland Navigation Accuracy.

5.4.2.1 Present a summary in tabular format (table B-II, app B) of the representative overland navigation accuracy in a helicopter.

5.4.2.2 Present a summary in tabular format (table B-III, app B) of the representative overland navigation accuracy in a high performance airplane.

5.4.2.3 Report the overland navigation accuracy of the test item to be as good as or better than equipment specifications requirements when the AH-1S helicopter is flying straight and level with no rain, up to the 10,000 ft (3048 m) specification limit. Compare the system's navigation accuracy at lower altitudes.

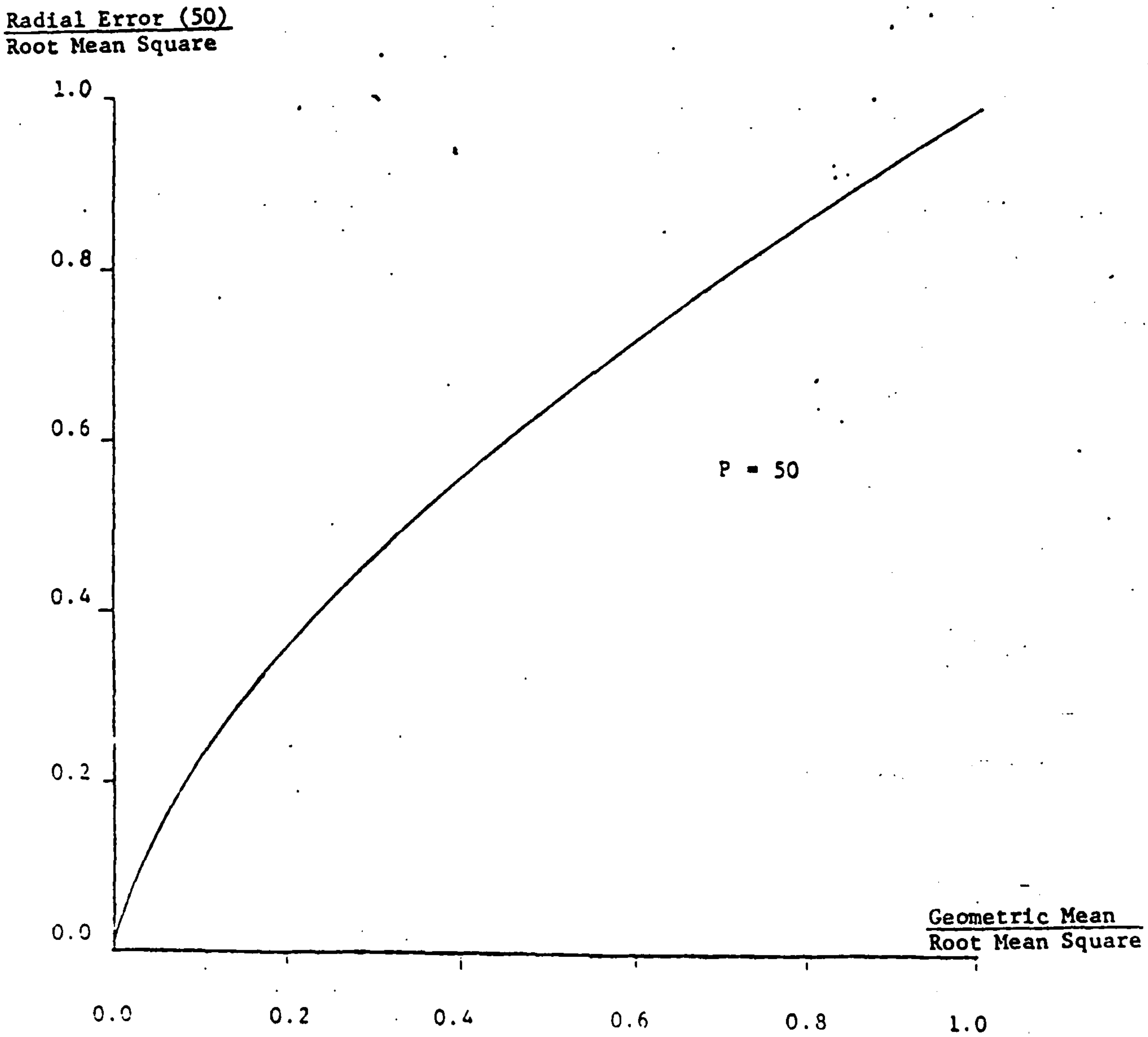

Figure 6. 50 percentile radial error curve (from ASCC AIR STD 53/13).

5.4.3 Over water navigation accuracy.

5.4.3.1 Present a summary in tabular format (table B-IV, app B) of representative over water navigation accuracy in a helicopter.

5.4.3.2 Present a summary in tabular format (table B-V, app B) of representative over water navigation accuracy in a high performance airplane.

5.4.3.3 Compare the over water navigation CEP percentage accuracy as a function of the wind and water conditions.

5.4.4 Land/Water Transition Accuracy. Present in tabular format a summary of navigation accuracy of an AH-1S helicopter when transitioning from water to land and visa versa.

5.4.5 Rain Discrimination Accuracy. Present in table VI of appendix B a summary of over land navigation accuracy in light to moderate rain in an AH-1S helicopter. Present in another table of appendix B a summary of manually recorded data which gives an indication of the navigation accuracy of an AH-1S helicopter while flying over land at low altitudes in heavy rain showers.

5.4.6 NOE Flights. Present a summary of any navigation accuracy data that might be collected by the US Army Aviation Test Board during OT-IIA NOE flights at Fort Rucker in a helicopter.

5.4.7 Have the pilot report with the test item, installed in an OV-1C Mohawk, any indicated operational difficulties at altitudes to 10,000 ft AGL (3048 m) and speeds to 300 knots during flights over land. Check of navigation accuracies are consistent with normal operation considering the accuracy of the installation and the Doppler heading/attitude system used.

5.4.8 Have the pilot report experience during flights over snow, any OV-1C test item difficulty maintaining a good ground track at 9,000-10,000 ft AGL (2743-3048 m). Record when the aircraft pitchs or rolls if the system looses lock and goes into memory until the aircraft is again straight and level.

5.4.9 Present data to show if the system's navigation accuracy in a fixed-wing aircraft (OV-1C) is affected operating at high speed (to 300 knots) or high altitude (to 10,000 ft (3048 m) during flights over land.

5.4.10 Present data to show if the over snow test results indicate the system accuracy may be adversely affected by extended high altitude flights over snow when any flight maneuvers are executed. Check if only straight and level flights appear unaffected during flights over snow.

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APPENDIX A. ABBREVIATIONS

A/D	analog-to-digital
AGL	above ground level
ARM	antiradiation missile
ASL	Atmospheric Science Laboratory
BITE	buit-in test equipment
CDU	Control/Display Unit
CEP	cricular error probability
DF	direction finding
DNC	Doppler Navigation Computer
DPLR	Doppler
DRVS	Doppler Radar Velocity Sensor
EMC	electromagnetic compatibility
EMETF	Electromagnetic Environmental Test Facility
EMI	electromagnetic interference
ENT	enter
ERP	effective radiated power
ESC	equipment serviceability criteria
EW	electronic warfare
FAEF	Frequency Allocation to Equipment File
FEBA	forward edge of the battle area
HFE	human factors engineering
INTACS-EAD	Integrated Tactical Communication System-Echelons Above Division
I/O	input/output
J/S	jamming-to-signal
LAT/LONG	L/L latitude/longitude
LDNS	Lightweight Doppler Navigation System
LORAN	long range navigation
LRIP	low rate initial production
LRU	line replaceable unit
MAL	malfunction
MEM	memory
MET	meteorological
MR	maintenance ratio
MSL	mean sea level
MTBF	mean-time-between-failures
NAV	navigation

NOE	nap-of-the-earth
PANS	Positioning and Navigation System
P(D)	probability of detection
P(J)	probability of being jammed
PQT(G)	Prototype Qualification Test - Government
RAM	reliability, availability, maintainability
RIW	reliability improvement warranty
RPSTL	Repair Parts Special Tools List
RIW	Reliability Improvement Warranty
RTA	receiver/transmitter-antenna
SCORES	Scenario Oriented Recurring Evaluation System
SHIU	Steering/Hover Indicator Unit
SIDTC	Single Integrated Development Test Cycle
TAS	true air speed
TCG	time code generator
TKE	track angle error
TMDE	test, measurement, and diagnostic equipment
TOP	test operation procedures
TSPI	time and space information
UTM	Universal Transverse Mercator
VAR	magnetic variation
VMC	visual meteorological condition
VOR	VHF Omnidirectional Range
VV	vertical velocity
XTK	cross track error

APPENDIX B. TEST DATA

Flight Accuracy data recording.

a. Establish actual aircraft position versus time by data recorded from an FPS-16 tracking radar.

(1) Sample radar data at a rate of 10 times/second and refer it to a range time standard.

(2) Provide position information with radar data in UTM northing and easting coordinates, and altitudes in feet MSL.

(3) Smooth this data using the sliding average method with 11-point smoothing.

(4) Calculate the aircraft's instantaneous ground speed from this smoothed position information as follows:

$$V_t = \text{ground speed (km/hr)} = 3.6\sqrt{\left(\Delta_E^R\right)^2 + \left(\Delta_N^R\right)^2}$$

where symbols designate incremental changes in easting (E) and northing (N) positions per second for the radar (R) or Doppler (D).

b. Record by an on-board recorder the Doppler navigation information, together with range time information form a portable time code generator (TCG).

c. Calculate position accuracy by comparing actual aircraft position with that produced by the Doppler navigation system. Record data produced by the Doppler navigation system at a somewhat slower rate than that produced by the tracking radar. Compare the smoothed data and retain for analysis only those radar points recorded within 0.1 second of a Doppler data recording.

(1) Separate the radar data into blocks of approximately 10 nm (18.520 km) each. Accomplished this by summing nj increments of distance traveled using equation (1) while testing for D_T (total distance traveled) to see if $D_T \geq$ 18.520 km. Use subscript j to identify specific 10 nm blocks.

$$D_{T_j} = \sum_{i=0}^{n_j}\left[\left(\Delta_{E_i}^R\right)^2 + \left(\Delta_{N_i}^R\right)^2\right]^{1/2} \qquad (1)$$

(2) Calculate the radial error (E_R) using equation (2) for each 10 nm blcok of data and each value identified with the appropriate subscript j. Denote subcripts o, j and n, j as the beginning and end points of the 10 nm block of data. Represent data from the TSPI radar with the capitalized variables (X, Y). Represent Doppler data recorded on-board the aircraft with the lower case variables (x, y).

$$E_{R_j} = \left[\left\{ (X_{n,j} - X_{o,j}) - X_{n,j} - x_{o,j}) \right\}^2 + \left\{ (Y_{n,j} - Y_{o,j}) - (y_{n,j} - y_{o,j}) \right\}^2 \right]^{1/2} \quad (2)$$

(3) The CEP is the median of radial error; if the standard deviation of the radial error is somewhat greater than the mean, the CEP becomes approximately equal to the mean radial error. Futhermore, the mean radial error is always greater than or equal to the CEP. Because of its ease of computation and attractive statistical properties, the mean was selected as a conservative estimate of CEP, leading to equation (3).

$$\text{Estimated CEP} = \text{sample mean} = \frac{100}{n} \sum_{j=1}^{n} \frac{E_{R_J}}{D_{T_j}} \quad (3)$$

expressed as a percent of distance travelled.

where n = number of 10 nm blocks of data in a particular flight.

(4) When the antennas under test can not be aligned to the aircrafts' axis within the required ± 6 arc minute tolerance. The Doppler-calculated drift and heading velocities and easting northing displacements are in error. The resultant horizontal velocity and total displacement, however, are correct, within the accuracy of the Doppler subsystem. Determine the antenna misalignment by comparing flight data using different antenna corrections and selecting the correction that minimized navigation error. Compensate for the observed error in the following manner:

DHEAD = recorded Doppler heading = $\tan^{-1} \Delta_E^D / \Delta_N^D$

θ = antenna alignment correction

DHEAD-θ = corrected Doppler heading

C_E = corrected incremental change in Doppler easting position

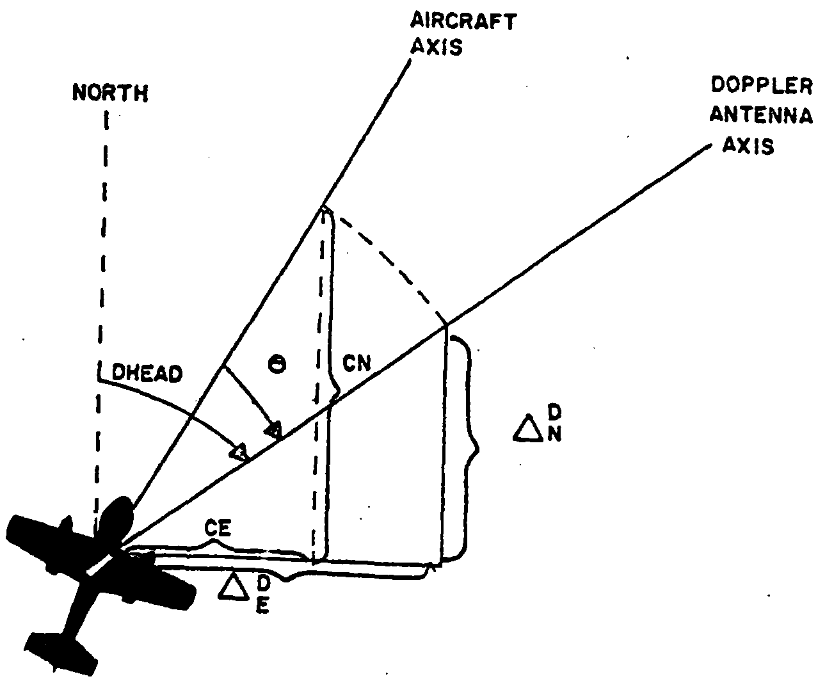
C_N = corrected incremental change in Doppler northing position

$$C_E = \sqrt{\left(\Delta_E^D\right)^2 + \left(\Delta_N^D\right)^2}\ \text{Sin (DHEAD} + \theta)$$

$$C_N = \sqrt{\left(\Delta_E^D\right)^2 + \left(\Delta_N^D\right)^2}\ \text{Cos (DHEAD} + \theta)$$

if $\theta = 0$

then $C_E = \Delta_E^D$ and $C_N = \Delta_N^D$



d. Calculate velocity accuracy by comparing the ground speeds calculated from tracking radar data with those produced by the Doppler navigation system.

(1) The velocity accuracy criteria is with reference to subsystem accuracy and does not address errors introduced by heading or pitch and roll gyros.

(2) Conduct this test in a C-47 type aircraft with the Doppler antenna mounted in a pitch and roll stablized platform. Use reference synchros to provide the Doppler with a 0° pitch, 0° roll, and fixed heading reference during all flight maneuvers. Hold the aircraft altitude constant to minimize vertical velocity.

(3) Position the antenna either on-line with aircraft centerline or 6° to the left to allow evaluation of velocity accuracy with and without aircraft drift velocity component.

(4) Compute Doppler ground speed from the smoothed on-board heading and drift velocity information as follows:

$$v_t \text{ (km/hr)} = \text{ground speed from Doppler} = \sqrt{(v_H)^2 + (v_D)^2}$$

where v_H = Doppler heading velocity

v_D = Doppler drift velocity

(5) The criterion concerning velocity accuracy (see subtest 4.4) allows an error on velocity, averaged over 10 nautical miles, of $\pm$(0.5% of true average velocity +0.20 knot). In order to establish whether these error bounds are met, Doppler velocity and radar velocity are first averaged over 10 nautical miles:

$$\bar{v}_t = \text{average Doppler velocity} = \frac{1}{n} \sum_{i=1}^{n} v_{t_i}$$

$$\bar{V}_t = \text{average radar velocity} = \frac{1}{n} \sum_{i=1}^{n} V_{t_i}$$

where v_{t_i} and V_{t_i} = Doppler and radar velocities during the i^{th} second of the 10 nm block.

n = the minimum number of seconds for which

$$\sum_{i=1}^{n} \frac{V_{t_i}}{3600} \geq 18.52$$

For the error bounds to be met, $\bar{v}_t - \bar{V}_t \leq 0.5\%$ of $\bar{V}_t + 0.3704$, which can be rearranged as:

$$\frac{\left(\bar{v}_t - \bar{V}_t\right) - 0.3704}{\bar{V}_t} \times 100 \leq 0.5 \qquad (4)$$

(Note that 0.20 knot = 0.3704 km/hr.) The left side of inequality (4) was termed "10 nm block error" and is displayed in tables B-I and B-II for representative flights.

TABLE B-I. VELOCITY ERROR

Start Time hr mn sec	Stop Time hr mn sec	Total Distance (meters)	Average Velocity (km/hr)	10 nm Block Error (%)

TABLE B-II. OVER LAND ACCURACY (Helicopter)

Antenna Alignment Correction (Degrees) =

Start Time hr mn sec	Stop Time hr mn sec	Distance (meters)	Radial Error (meters)	CEP (%)

Circular error for 6 blocks of data is ___ percent of distance traveled.

TABLE B-III. OVER LAND ACCURACY (Airplane)

Antenna Alignment Correction (Degrees) =

Start Time hr mn sec	Stop Time hr mn sec	Distance (meters)	Radial Error (meters)	CEP (%)

Circular error 8 blocks of data is __ percent of distance traveled.

TABLE B-IV. OVER WATER ACCURACY (Helicopter)

Antenna Correction Angle (Degrees) = 0.0*

Start Time hr mn sec	Stop Time hr mn sec	Distance (meters)	Radial Error (meters)	CEP (%)

Circular error for 5 blocks of data is ___ percent of distance traveled.

*An align of -0.7 degree yielded considerably worse CEPs.

TABLE B-V. OVER WATER ACCURACY (Airplane)

Antenna Alignment Correction (Degrees) = 5.0

Start Time hr mn sec	Stop Time hr mn sec	Distance (meters)	Radial Error (meters)	CEP (%)

Circular error for 7 blocks of data is ____ percent of distance traveled.

Sample not used as distance traveled is less than 10 nm (18.52 km).

TABLE VI. OVER LAND ACCURACY DURING RAIN

Antenna Alignment Correction (Degrees) =

Start Time hr mn sec	Stop Time hr mn sec	Distance (meters)	Radial Error (meters)	CEP (%)

Circular error probable for 6 blocks of data is ____ percent of distance traveled.

HEADING-SPEED				
MODE	0°	90°	180°	270°
Activation				
Deactivation				
Activation				
Deactivation				
Activation				
Deactivation				

DETAILED TEST SCHEDULE

X = Test Initiation Date

Name of Subtest	Time Increments (Months) X+1	X+2	X+3	X+4	X+5
Pretest Inventory					
Safety					
Human Factors Engineering					
Physical Characteristics					
Primary Power					
Self Test (BITE)					
Status Lamps Performance					
Installation Compatibility					
Flight Accuracy					
Electromagnetic Compatibility					
Reliability					
Maintenance Evaluation					

APPENDIX C

REFERENCES

a. Doppler Navigation Set, AN/ASN-137 Flight Test Report, AVRADCOM Technical Report 83-E-14, December 1983.

b. Development Test III of Lightweight Doppler Navigation Set AN/ASN-128, Publication No. USAEPG-FR-1077, November 1979.

c. Development Test II (DT-II) of Lightweight Doppler Navigation System (LDNS) AN/ASN-128 Final Report, TECOM Publication No. 4-EE-ASN-128-004, November 1979.

d. Flight Evaluation of the Lightweight Doppler Navigation System, AN/ASN-128 (XE-2), R&D Tech Report ECOM-4519, August 1977.

e. Flight Evaluation of the Lightweight Doppler Navigation System, AN/ASN-128 (XE-1), R&D Tech Report ECOM-4512, July 1977.

f. Development Test II of Lightweight Doppler Navigation System AN/ASN-128 Publication No. USA EPG-FR-977, May 1977.

g. Operational Test II (OT-II) of Lightwieght Doppler Navigation System (LDNS) AN/ASN-128 (XE-1, XE-2), Test Design Plan, TECOM Project No. 4-EE-ASN-128-003, December 1976.

h. Evaluation of Three State-Of-The-Art Doppler Navigation System, R&D Tech Report ECOM-4189, January 1974.

i. The Specification for Evaluation of the Accuracy of Airborne Doppler Navigation Systems, Air Standardization Agreement ASCC 53/13A, 15 March 1979.

j. The Specification and Evaluation of the Accuracy of Airborne Doppler Ground Velocity Sensor, Air Standardization Agreement ASCC 53/12, 15 December 1974.

k. TECOM Pam 310-4, Index of Test Operations Procedures.

l. TECOM Supplement 1 w/C1 to AMC Reg 310-6, Quality Assurance Publication.

m. TECOM Pam 70-3, Project Engineers' Handbook.

n. TECOM Reg 70-24, Documenting TECOM Testing.

o. MIL-STD-810D, Environmental Test Methods, 19 July 1983.

p. MIL-N-49098A(AV) Navigational Set, Doppler AN/ASN-128, 31 January 1984.

q. Detailed Test Plan DT III of Lightweight Doppler Navigation Set AN/ASN-128, Project No. 4-EE-ASN-128-004, Publication No. USAEPG-TP-1077, January 1979.

r. Operational Test III of AN/ASN-128, Lightweight Doppler Navigation Set (LDNS), 28 September 1978.

s. MIL-STD-765A, Compass Swinging, Aircraft, General Requirements for, 26 July 1978.

t. MIL-STD-704A, Electric Power, Aircraft, Characteristics and Utilization of, 5 May 1970.

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