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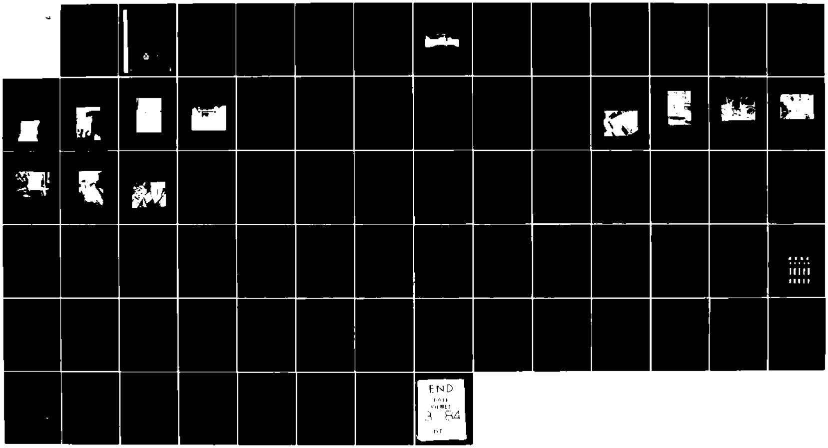

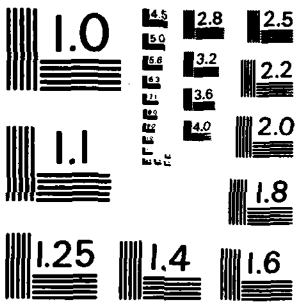

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DEPARTMENT OF DEFENCE

ROYAL AUSTRALIAN AIR FORCE

AIRCRAFT RESEARCH AND DEVELOPMENT UNIT

EDINBURGH, SOUTH AUSTRALIA

TECHNICAL INVESTIGATION NO 760

EVALUATION OF INSTALLATION OF LIGHTWEIGHT DOPPLER NAVIGATION SYSTEM (LDNS) IN IROQUOIS UH-1H AIRCRAFT

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The purpose of this task was to evaluate the prototype installation of a K510A-009-01 Lightweight Doppler Navigation System (LDNS) in a UH-1H Iroquois helicopter for the utility helicopter transport and gunship missions. After initial 'shakedown' flights at Bankstown, NSW a detailed evaluation of the installation was conducted in the Adelaide and Woomera, SA areas during the period 1 to 30 June 1982. Productive flight test time totalled 24.1 flight hours, including 2.9 at night.

The installation of the LDNS will significantly increase the mission effectiveness and capabilities of the RAAF UH-1H Iroquois fleet by providing crews with accurate navigation data in a readily usable format. The range of navigation information was comprehensive and well suited to both tactical and Search and Rescue (SAR) operations. The LDNS also significantly increased the operational capability of the UH-1H by enhancing Night Vision Goggle operations.

Several deficiencies identified by the evaluation have been corrected by modification action; however, the remaining deficiencies, unless rectified, will prevent realization of full system potential. Recommendations are made to overcome these deficiencies.

-13-

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AIRCRAFT RESEARCH AND DEVELOPMENT UNIT

EVALUATION OF INSTALLATION OF LIGHTWEIGHT DOPPLER NAVIGATION SYSTEM (LDNS) IN IROQUOIS UH-1H AIRCRAFT

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DEPARTMENT OF DEFENCE

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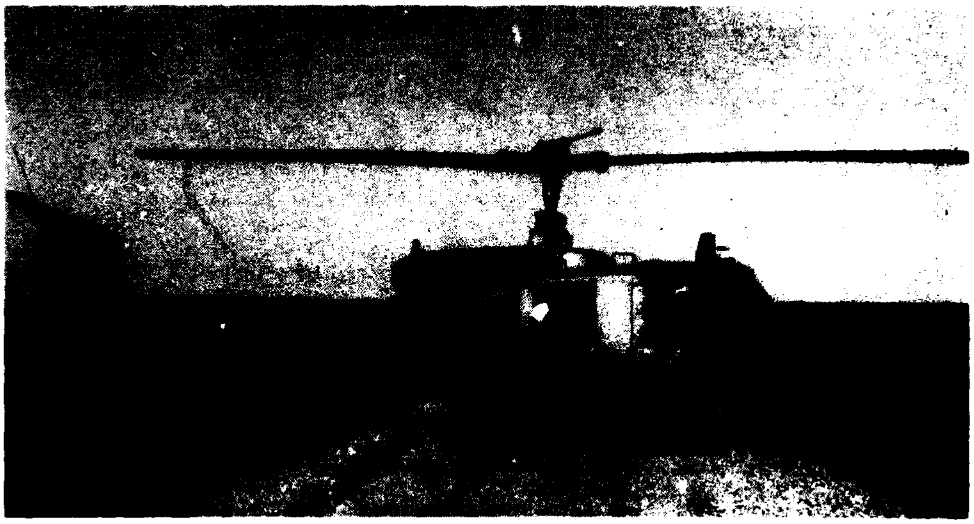

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EVALUATION OF INSTALLATION OF LIGHTWEIGHT DOPPLER NAVIGATION SYSTEM (LDNS) IN IROQUOIS UH-1H AIRCRAFT

1. INTRODUCTION

1.1 Background

1.1.1 Reference A specified the requirement for a Lightweight Doppler Navigation System (LDNS) to be fitted to UH-1H aircraft. The Singer Company, Kearfott Division (SKD) LDNS, Part No K510A-009-01, was selected and purchased. An addendum to Reference A was approved to purchase a Steering and Hover Indicator Unit (SHIU), Part No K350A-013-02, to overcome suspected inadequacies of the LDNS display. Hawker de Havilland (Australia) was contracted to carry out a prototype installation of the equipment at Bankstown, NSW. In Reference B, Headquarters Support Command (HQSC) tasked Aircraft Research and Development Unit (ARDU) to evaluate the prototype installation of the LDNS before a fleet-wide modification was undertaken.

1.1.2 Task requirements were to:

a. evaluate the integration of the LDNS components in the cockpit;

b. evaluate the ability of the various displays to provide sufficient navigation information for tactical and general flying operations;

c. determine the navigation accuracies over representative mission profiles;

d. determine the operating envelope of the system;

e. evaluate the electromagnetic compatibility of the system; and

f. evaluate engineering aspects of the LDNS including reliability, maintainability, construction, alignment/calibration procedures and the use of 'zipper-tubing' on LDNS electrical looming.

1.1.3 An additional task was to make recommendations for a cockpit configuration which would include installation of new communications equipment, a radar warning receiver and the use of Night Vision Goggles (NVG). These evaluations will now be reported under separate tasks; however, the use of NVGs, in conjunction with the LDNS, is briefly discussed in this report.

1.1.4 Significant test results have been reported in References C and D, and at a briefing to Air Force Office, Support Command, helicopter squadron and Army representatives at ARDU on 12 and 13 August 1982. This report finalizes the requirements of Reference A.

1.2 Purpose. The purpose of this task was to evaluate the prototype installation of the K510A-009-01 LDNS (including the K350A-013-02 SHIU) in an Iroquois UH-1H, for the utility helicopter transport and gunship missions.

2. DESCRIPTION OF EQUIPMENT UNDER TEST

2.1 Description of LDNS K510A-009-01

2.1.1 The K510A-009-01 LDNS is manufactured by SKD and is a development of the AN/ASN-128 LDNS being acquired by the US Army. The system determines aircraft velocity by measurement of Doppler radar frequency shift. In conjunction with the aircraft heading and vertical reference systems the system computes and displays the following navigation information:

a. present position (computed) or waypoint data (manually entered) in latitude and longitude (degrees, minutes and tenths of a minute) or Universal Transverse Mercator (UTM) co-ordinates (Grid Zone Designation, 100 kilometre Square Identification and eight figure Easting and Northing co-ordinates resolved to 10 metres respectively);

b. ground speed (computed) in knots or kilometres per hour;

c. true track (computed) in degrees;

d. crosstrack distance (computed) in nautical miles and tenths of a nautical mile or kilometres and tenths of a kilometre;

e. track angle error (computed) in degrees;

f. distance to selected waypoint (computed) in nautical miles and tenths of a nautical mile or kilometres and tenths of a kilometre;

g. bearing to selected waypoint (computed) in degrees;

h. time to selected waypoint at present groundspeed (computed) in minutes and tenths of a minute;

i. spheroid code of waypoint UTM co-ordinates (manually entered);

j. magnetic variation of waypoint (manually entered) in degrees and tenths of a degree (East or West);

k. wind speed and direction (manually entered) in knots or kilometres per hour and degrees true (respectively) for water motion compensation;

l. sea current speed and direction (manually entered) in knots or kilometres per hour and degrees true (respectively) for water motion compensation;

m. target or waypoint speed and direction (manually entered) in knots or kilometres per hour and degrees true (respectively) for tracking a moving target or waypoint; and

n. waypoint location at which the computed present position will be stored if the Target Store push-button is depressed.

2.1.2 SKD states that the K510A-009-01 LDNS has the following advantages not found in the AN/ASN-128 systems under acquisition by the US Army:

a. read-out of English units for speed and distance when the MODE switch is in LAT/LONG (read-out of metric units in UTM or BACKUP);

b. in TEST mode, gives heading, pitch and roll angle read-outs on Computer/Display Unit to check for correct inputs;

c. allows entry of ASN-43 compass magnetic deviations (12 values), to compensate for the input of magnetic heading;

d. allows compensation for effect of wind speed and direction and sea currents on water surface motion;

e. allows entry of target motion (speed and direction), thus providing tracking of a moving target; and

f. inclusion of additional Electromagentic Interference (EMI) circuitry.

2.1.3 LDNS Components. The LDNS consists of three major components or Line Replaceable Units (LRUs) installed in the aircraft, with associated electrical looms, a junction box, a 'WATER MOTION' switch and circuit breakers. The three major components are briefly described in the following paragraphs. A full description is given in Reference E. A block diagram of the system is at Annex A.

2.1.4 Radar Receiver/Transmitter Antenna. The Radar Receiver/Transmitter Antenna (RTA) consists of a printed grid antenna assembly on which is mounted a box containing receiver/transmitter electronic components. The RTA was located in a housing on the underside of the UH-1H tail boom just aft of the main cabin section of the fuselage. The RTA produces four non-coplanar Frequency Modulated Continuous Wave (FMCW) radar beams. The four beams are radiated sequentially at a frequency of 7.5 Hz. The RTA installation is shown in Figure 2.1.

Note: Looking forward from beneath the tail boom

FIGURE 2.1 - RECEIVER/TRANSMITTER ANTENNA INSTALLATION

2.1.5 Radar Signal Data Converter. The radar Signal Data Converter (SDC) contains electronic components which process the following signals into an appropriate digital serial format:

a. Doppler signal and leakage (from RTA);

b. antenna calibration constants (from RTA);

c. heading (from aircraft compass); and

d. pitch and roll (from aircraft vertical gyro).

The SDC was mounted in the right 'chin' window area of the aircraft as shown in Figure 2.2.

FIGURE 2.2 - SIGNAL/DATA CONVERTER INSTALLATION

2.1.6 Computer/Display Unit. The Computer/Display Unit (CDU) comprises a general purpose digital computer and a control and display panel incorporating a keyboard and annunciator lights. The computer processes inputs from the SDC and navigation information is displayed as outlined in paragraph 2.1.1. The CDU was mounted in the left of the centre pedestal as shown in Figure 2.3.

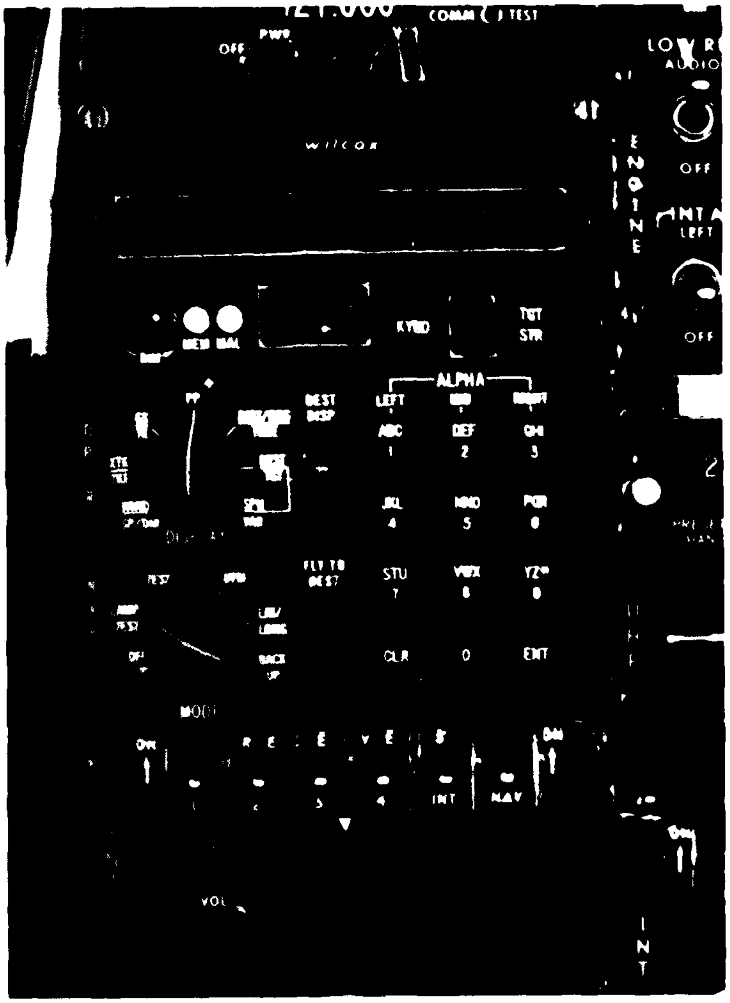


FIGURE 2.3.- COMPUTER/DISPLAY UNIT INSTALLATION

2.2 Description of SHIU K350A-013-02. The SHIU was mounted on the right side of the instrument panel in lieu of the VHF-FM homing indicator. The SHIU processes the Auxiliary Digital Data output from the CDU into analogue and numeric displays for use by the pilot in steering and hovering the aircraft. In the Navigate mode, the SHIU displays groundspeed (knots or kilometres per hour), distance to go to a selected waypoint (nautical miles or kilometres), cross track distance or track angle error. In the Hover mode, the SHIU displays the three components of aircraft velocity and distance to go to a selected waypoint. Three annunciator lights (MEM, MAL and GEO) are also included on the indicator face. Figure 2.4 shows the SHIU face. Unless specifically stated, the term 'LDNS' in the body of this report includes the SHIU.

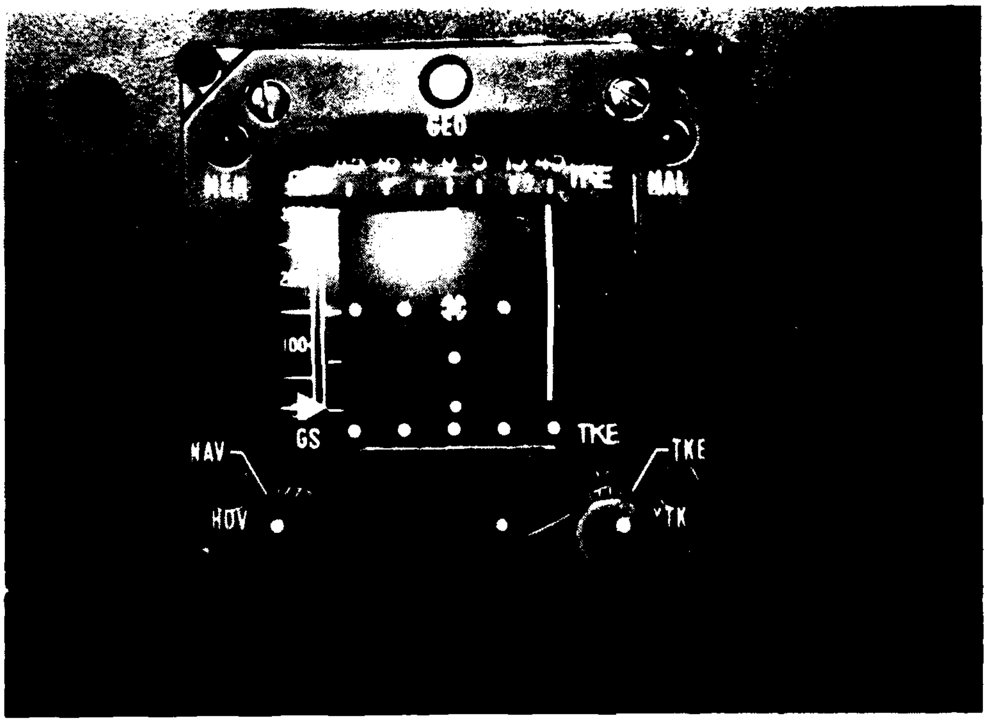


FIGURE 2.4 - FACE OF STEERING AND HOVER INDICATOR UNIT

2.3 Description of Test Aircraft. A detailed description of the Iroquois UH-1H helicopter is contained in Reference F. The prototype installation of the LDNS was carried out on aircraft A2-455. This aircraft was representative of operational utility helicopters except for the following:

a. prototype Iroquois Modification 7210.008-223, Strobe Lighting Kit, was installed;

b. an IR suppression kit was not installed;

c. a rescue hoist was not installed;

d. M60 side/door guns were not installed;

e. armour plated seats were not installed;

f. an auxiliary fuel tank was fitted in the right quarter compartment; and

g. for overwater flights, floats were attached in accordance with DI(AF) AAP 7210.007-2-1 Iroquois Maintenance Manual.

3. SCOPE OF TESTS

3.1 Tests Made

3.1.1 Initial Evaluation. A limited engineering assessment and shakedown flights of the prototype LDNS installation were conducted in the Bankstown, NSW area on 24 May 1982. The shakedown flights totalled 2.7 flight hours (1.7 day and 1.0 night) and included legs over land and inshore water.

3.1.2 Detailed Evaluation. A detailed evaluation of the installation was conducted in the Adelaide and Woomera, SA areas during the period 1 to 30 June 1982. For this phase of the evaluation, productive flight test time totalled 24.1 hours, including 2.9 hours of night flying. Evaluations and tests made are listed in the following paragraphs.

3.1.2.1 Human Factors Aspects. Human factors aspects evaluated included:

a. the layout of controls and displays;

b. the labelling and readability of controls and displays;

c. the operation of controls; and

d. the lighting of controls and displays.

3.1.2.2 Navigation Accuracies. The following LDNS navigation accuracies were tested:

a. velocity accuracy (overland);

b. position accuracy (non-tactical, overland);

c. position accuracy (tactical, overland);

d. effect of external load; and

e. position accuracy (overwater).

3.1.2.3 LDNS Operating Envelope. Tests were made to determine the LDNS operating envelope in terms of aircraft attitude, altitude and minimum sea state.

3.1.2.4 System Utility. The following aspects of system utility were evaluated:

a. pre-flight procedures and Built-In Test (BIT);

b. system operating procedures;

c. suitability and usefulness of displayed navigation information (CDU and SHIU); and

d. suitability and usefulness for NVG operations.

3.1.2.5 Engineering Aspects. Engineering aspects evaluated included reliability, maintainability, construction, alignment and calibration procedures and the use of zipper-tubing.

3.2 Test Conditions. Test conditions are detailed in the Methods of Test and Results and Discussion section of this report (Sections 4 and 5).

3.3 Test Envelope. The flight tests were conducted within the normal operating envelope of the Iroquois UH-1H helicopter as described in Reference F, Section 5.

3.4 Anthropometric Measurements. The anthropometric measurements of the pilot who conducted the evaluation are given in Table 3.1. Relevant test results in this report are based on this data. The percentiles in Table 3.1 are based on the data for flying personnel as published in Reference G.

TABLE 3.1 - PILOT'S ANTHROPOMETRIC MEASUREMENTS

Parameter	Value	Percentile
Mass	90.5 kg	92%
Stature	1,786 mm	60%
Sitting Height	930 mm	61%
Eye Height Sitting	836 mm	82%
Functional Arm Reach	815 mm	60%
Bideltoid Breadth	485 mm	70%
Acromial Height, Sitting	635 mm	81%
Stool Height	434 mm	89%
Buttock-Knee Length	622 mm	67%

3.5 Factors Restricting Scope. There were several factors which restricted the scope of the evaluation. These included:

a. Only one aircraft (A2-455) was modified for the LDNS installation as a prototype. This precluded an evaluation of the possible effects of differing aircraft characteristics (eg gunship configuration).

b. Only one set of LDNS components was used throughout the tests. Insufficient flying hours were available to change components and refly the same profiles as the baseline set. The incomplete Ground Support Equipment (GSE) at No 2 Aircraft Depot did not permit a full ground check of individual LDNS computer boards. However, each major component was tested and found serviceable.

c. Tests overwater were made with floats attached. No tests were made to determine if the floats affected the Doppler radar beams, thus limiting the overwater test results to one configuration.

d. Time constraints and limitations on flying hours and manpower also limited the scope of the evaluation. The requirement to evaluate the LDNS in the operational role meant that detailed testing in some areas was not possible.

3.6 Aircraft Compass Swing. Prior to departure for the Woomera phase of the evaluations, an aircraft compass swing was carried out on A2-455 with the aircraft positioned on the surveyed compass swing area at RAAF Base Edinburgh, SA. A Wild-Company Datum Compass, Part No B3, was used as the reference datum. Reference H states the readability of the B3 is $\pm 1^{\circ}$; no accuracy is quoted. The swing was conducted in accordance with Reference I. The AN/ASN-43 Remote Magnetic Indicator (RMI) indications were recorded and processed separately. The result of the compass swing (Annex B) met the requirements of Reference I. The residual heading deviations for each 30 degrees of arc were entered in the CDU in accordance with the procedure given in Reference E.

3.7 Standards, Requirements and Declarations of Performance

3.7.1 ASCC Air Standards. The Air Standardization Co-ordinating Committee (ASCC) Air Standards (AIR STD) relevant to the evaluation are listed in Table 3.2. The applicable requirements of these AIR STDs are detailed in Annex C. An extract from AIR STD 53/14 is given in Table 3.3.

TABLE 3.2 - ASCC AIR STANDARDS

AIR STD	Date	Title
10/30H	15 Oct 80	Aircrew Station Warning, Cautionary and Advisory Signals (1)
10/38C	3 Apr 79	Principles of Presentation of Information (1)
10/47A	3 Apr 79	Legends in Aircrew Stations (1)
10/62B	15 Oct 80	Aircrew Station Control Panels (1)
53/9C	30 Jun 66	Lightweight Doppler Navigation Equipment for Helicopters (1)
53/12A	15 May 80	The Specification for Evaluation of the Accuracy of Airborne Doppler Ground Velocity Sensors (2)
53/13A	15 Mar 80	The Specification and Evaluation of the Accuracy of Airborne Navigation Systems (2)
53/14	15 Dec 74	Definition of Sea State for use in Connection with Doppler Navigation (3)

Notes: 1. See Annex D for detailed requirements.

2. These Standards relate to test methods and data analysis.

3. The definition of sea state used is the code established by the World Meteorological Organization (See Table 3.3).

TABLE 3.3 - SEA STATE CODES AND DESCRIPTIONS

Code Figure (1) (Sea State)	Descriptive Term	Wave Height (2) (m)
0	Calm (Glassy)	0
1	Calm (Rippled)	0 to 0.1
2	Smooth (Wavelets)	0.1 to 0.5
3	Slight	0.5 to 1.25
4	Moderate	1.25 to 2.5
5	Rough	2.5 to 4
6	Very Rough	4 to 6
7	High	6 to 9
8	Very High	9 to 14
9	Phenomenal	over 14

Notes: 1. The exact bounding height is to be assigned to the lower code figure; eg a height of 4 metres is coded as 5

2. Wave height is measured from crest to trough

3.7.2 AFSR No 5006 Requirements. The applicable requirements of Air Force Staff Requirement (AFSR) No 5006 (Reference A) are detailed in Annex D

3.7.3 Declaration of Performance. In Reference K, Table 2-2, SKD states the LDNS navigation accuracies in terms of terminal error with various heading references. These are summarized in Table 3.4.

TABLE 3.4. - LDNS NAVIGATION ACCURACIES (SKD)

Heading Reference and Accuracy	Perfect (0 deg error)	ASN-43 (Improved) (0.5 deg, 1 [illegible])	ASN-43 (Current Spec) (1.0 deg, 1 [illegible])
Navigational Accuracy (CEP) (1,2)	0.3%	0.7%	1.3%

Notes: 1. Based on terminal error as a percentage of distance gone.

2. Exclusive of water motion.

4. METHODS OF TEST

4.1 Human Factors Aspects. Human factors aspects of the LDNS were evaluated in accordance with the methods outlined in Reference L.

4.2 Navigation Accuracies. Groundspeed and position accuracies of the LDNS were tested over representative mission profiles at heights and groundspeeds typically flown by UH-1H aircraft. The tests included overland and overwater flights. Overland tests were conducted at Woomera, SA while overwater tests were conducted in an area bounded by Investigator Strait and the Gulf St Vincent, SA. Test areas, routes and more detailed descriptions of test methods used to assess navigation accuracy are given in Annex E. As explained in Annex E, the tests did not fully comply with the requirements of ASCC AIR STD 53/12A and 53/13A (see Table 3.2).

4.3 LDNS Operating Envelope

4.3.1 Attitude Limits. The LDNS was tested to determine the attitude limits in the pitch and roll axes. The aircraft was manoeuvred independently in each axis at a slow steady rate until the attitude limit in that axis was reached. The limit was defined when the LDNS ceased normal operation and switched to memory mode.

4.3.2 Altitude Limits. The LDNS was evaluated for proper operation throughout the normal altitude envelope of the UH-1H Iroquois from zero to 10,000 ft AGL overland and 50 to 5,000 ft ASL overwater

4.3.3 Minimum Sea State. The minimum sea state for proper LDNS operation was determined for straight and level flight during the overwater position accuracy tests (see Annex E). If the LDNS switched to memory mode, the system was set to TEST and cycled back to LAT/LONG after a 'GO' had been obtained. If lock-on was not obtained after two cycles, the aircraft was flown at progressively lower heights (50 ft minimum) and the system recycled to check for lock-on. The minimum sea state (for a particular altitude) was defined when the LDNS entered the memory mode and could not be restored to proper operation after two cycles from TEST to LAT/LONG.

4.4 System Utility. The LDNS control and display combination was evaluated in ground tests and throughout the flight test program for suitability and usefulness in a hostile tactical environment. The evaluation included the use of NVG in conjunction with the LDNS. The test method for this aspect is detailed in Section 4.5.

4.5 Use of NVG in Conjunction with LDNS

4.5.1 The use of NVG in conjunction with the LDNS was evaluated during a low level tactical night flight involving the use of F4934A NVG by the crew. Before commencing NVG operations, a ground evaluation of cockpit configuration and lighting was made with the cockpit blacked-out. As a result of this evaluation, the aircraft was configured for NVG operations as outlined in Reference M, with the following exceptions (due to the limited scope of the evaluation):

a. The cockpit was not painted matt black.

b. Navigation and anti-collision lights (strobe lights on A2-455) were selected OFF in lieu of being covered with adhesive tape.

c. The landing and search lights were pre-set for autorotative flight. A pink light filter was not available for installation on the landing light.

d. The thin IR reflective tape was not available to mark gauges on the instrument panel.

e. An emergency throw switch for instrument lighting was not installed; however, the rheostat for the secondary lighting system for the instrument panel was tagged with strips of tape squeezed into a semi-rigid column extending approximately 50 mm from the overhead panel so that the control could be quickly located and activated if required.

f. The NVG-compatible cockpit illuminator was not available.

4.5.2 Local flying with the reconfigured cockpit was conducted in the Edinburgh area to gain sufficient experience in NVG operations before undertaking a low level tactical night flight. The crew and their duties were as follows:

a. Pilot: overall command and flying

b. Co-pilot: management of aircraft systems (including LDNS) and monitoring of flight instruments.

c. Navigator: monitoring of flight progression on prepared map, advice on approaching obstructions/hazards, co-ordination of data recording.

d. Crewman and Flight Fitter: Normal duties for UH-1H operations

4.5.3 The pre-surveyed route used for the low level tactical night flight is shown in Annex F. The waypoints annotated were entered in the LDNS CDU. The mission simulated a patrol insertion at Waypoint 5. The leg Waypoint H to Waypoint 1 was flown at approximately 1,000 ft AGL. The aircraft was landed at the airfield (Waypoint 1), and then proceeded at approximately 150 ft AGL to Waypoint 4. From this feature to the destination (Waypoint 5) the aircraft was flown Nap of Earth (NOE), down the creek line, and landed at the destination pad. After a break of approximately five minutes the aircraft returned to homeplate (Waypoint H) by similar profiles.

4.5.4 Comments regarding the evaluation were recorded on tape by a recorder connected into the aircraft intercommunication system.

4.6 Engineering Aspects. The engineering aspects of the LDNS installation were assessed on an opportunity basis throughout the flight test program. Any failures of the equipment were noted and investigated. Additionally, maintainability and construction of the LDNS were evaluated by personnel from ARDU Radio Development Flight (RDF). The major components of the LDNS were dismantled and inspected. Any deficiencies were noted. The alignment and calibration procedures were evaluated in a desk-top study by an ARDU structures engineer. Also, any deficiencies relating to use of the zipper-tubing were noted.

4.7 Electromagnetic Compatibility. The Electromagnetic Compatibility (EMC) of the LDNS in combination with other aircraft systems was not assessed throughout the flight test program. However, any noticeable effects were noted and investigated.

5. RESULTS AND DISCUSSION

5.1 Human Factors Aspects

5.1.1 General. In Reference K, page 1-7, SKD states that the LDNS (in isolation) meets the human engineering design criteria of MIL-STD-1472C and MIL-H-46855 (see also Annex D, Serial 15). The human factors aspects of the system, as installed in A2-455, were evaluated by project personnel during ground and flight operations. Problems or deficiencies noted in the systematic ground evaluations were further explored during flying operations ranging from environment. Any further deficiencies uncovered as a result of the flying operations were noted. For these evaluations, the Design Eye Points (DEP) for the pilot (right seat) and co-pilot (left seat) were used as the positional references in the cockpit.

5.1.2 Layout of Controls and Displays

5.1.2.1 Computer/Display Unit (CDU). The CDU was positioned in the middle of the left rack of the centre pedestal. With restraint harnesses locked, all controls on the CDU were well within the functional reach of the co-pilot. The controls were just within functional reach of the pilot, except for the DIM knob which was just out of reach. However, with the inertia reel released, the pilot could easily reach and operate the DIM control. The CDU keyboard was readily accessible and convenient to use from the co-pilot's station, but slightly difficult to access from the pilot's station. The angle between the line-of-sight to the CDU displays and the plane of the display panel was approximately 75° for the co-pilot and 45° for the pilot. Views of the CDU from the DEP of the pilot and co-pilot are shown in Figures 5.1 and 5.2. Given the constraints of the cockpit, the CDU position was optimal for co-pilot use and was satisfactory. The applicable requirements of AIR STD 10/38C were met (see Annex C, Serial 5).

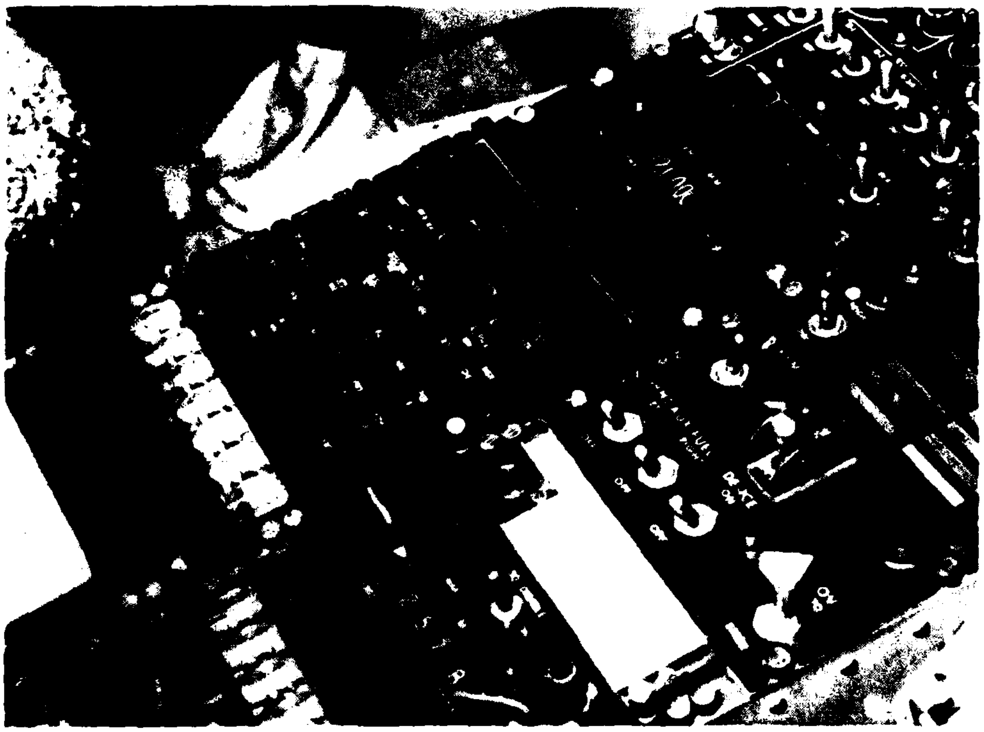


FIGURE 5.1 - VIEW OF CDU FROM PILOT'S DESIGN EYE POINT

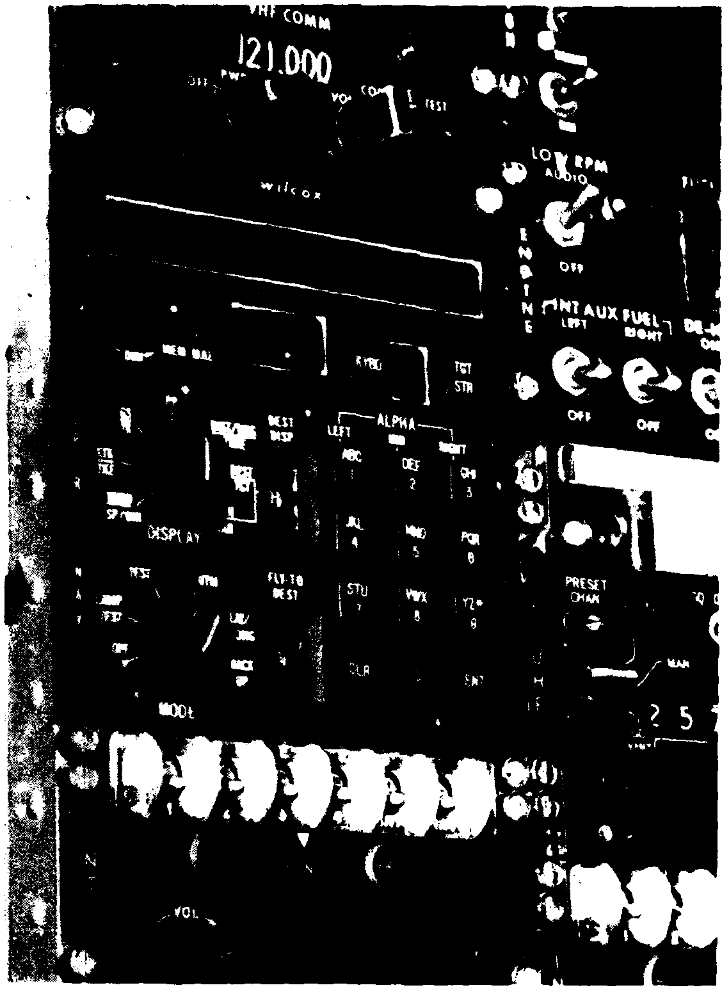


FIGURE 5.2 - VIEW OF CDU FROM CO-PILOT'S DESIGN EYE POINT

5.1.2.2 Steering and Hover Indicator Unit (SHIU). The SHIU was positioned under the pilot's primary flight instruments in lieu of the VHF-FM homing indicator, and was intended to be used by the pilot only. The SHIU controls were well within the functional reach of the pilot; however, the angle between the pilot's line-of-sight to the instrument and the plane of the instrument face was only approximately 50°. This led to significant parallax errors. A view of the SHIU from the pilot's DEP (approximately) is shown in Figure 5.3. During tactical flying, the pilot was required to regularly consult the instrument for steering and distance-to-go information. The instrument was positioned well away from the scan pattern used by the pilot for good look-out (obstacle/collision avoidance, identification of features, landing pads, possible threats). As a consequence, look-out by the pilot was slightly degraded. This, in combination with the parallax errors, made the position of the SHIU unsatisfactory. The instrument should be repositioned to reduce parallax errors and bring the instrument closer to the visual scan used by the pilot for tactical flying. Revised positioning will be assessed and reported under Reference N. The applicable requirement of AIR STD 10/30H and 10/38C were met (see Annex C, Serials 3 to 5).

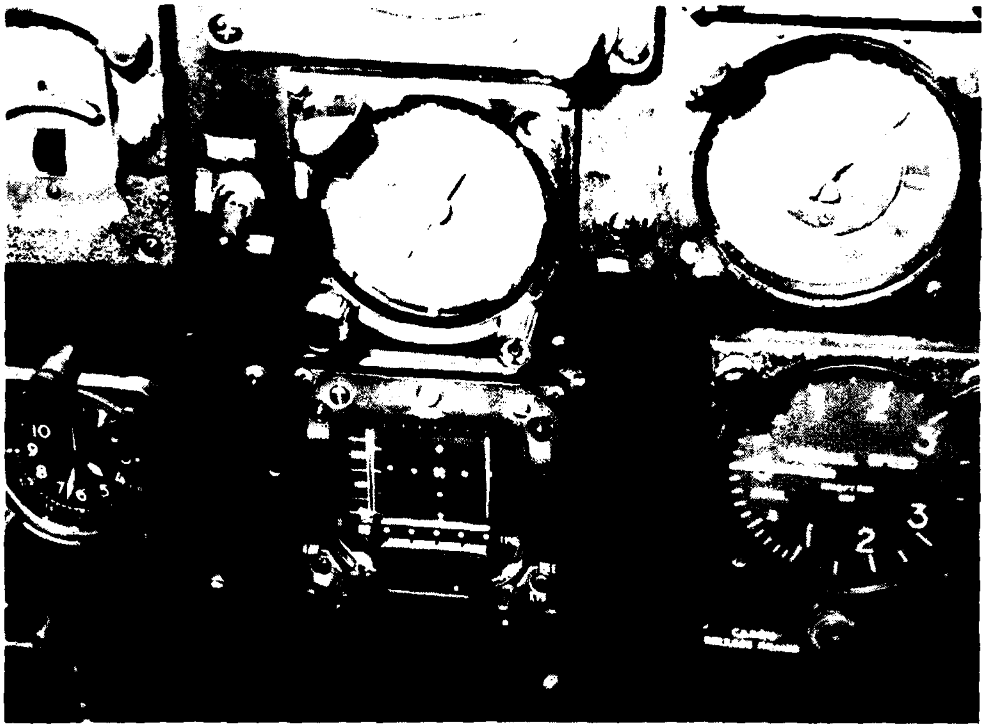


FIGURE 5.3 - VIEW OF SHIU FROM PILOT'S DESIGN EYE POINT

5.1.2.3 Water Motion Switch. The water motion switch was mounted on the main instrument panel just above the IFF control panel. A view of the switch from approximately the DEP of the pilot's station is shown in Figure 5.4. The switch was well outside the functional reach of the pilot and co-pilot with harnesses locked. Even with the harness inertia reel released, the switch was still difficult to reach and operate from the pilot's station. The switch did not appear to be positioned in accordance with any human engineering principle (namely functional grouping, importance, optimization, frequency-of-use or sequence-of-use). In addition to finding the switch difficult to reach and operate, pilots in a high workload situation, such as a night overwater Search and Rescue (SAR) mission, may forget to operate the switch at the appropriate time. If the switch was functionally grouped with one of the frequently used LDNS components (CDU or SHIU) the likelihood of forgetting to operate the switch would be reduced. The position of the water motion switch was unsatisfactory. The switch should be functionally grouped with either the CDU or SHIU. ARDU has recommended, at meetings associated with Reference N, that the switch be placed on the right of the new CDU lighting panel.

FIGURE 5.4 - VIEW OF WATER MOTION SWITCH FROM PILOT'S DESIGN EYE POINT

5.1.2.4 DC Circuit Breakers. Protection of LDNS DC circuitry was provided by five circuit breakers. The circuit breakers were not functionally grouped, as two of the circuit breakers were located on the overhead DC circuit breaker panel as shown in Figure 5.5, while the other three circuit breakers were mounted just in front of the map case on the left of the centre pedestal, as shown in Figure 5.6. The crew was able to easily reach and operate the circuit breakers on the overhead panel. The three circuit breakers on the left of the centre pedestal could only be reached by the co-pilot with harness unlocked; however, operation of the left circuit breaker was extremely difficult. Operation of the mid and right circuit breakers was impossible due to the protruding map case. Reference C recommended that the three circuit breakers on the left of the centre console be relocated in a functional grouping with the two on the overhead panel so that the system could be quickly isolated in event of an in-flight emergency such as an electrical fire. Initial investigations by HQSC project staff indicated that adequate system protection was provided by the two LDNS circuit breakers on the overhead panel and other aircraft system circuit breakers. The initial layout of the DC circuit breakers was unsatisfactory. The HQSC investigations were substantiated, and the three circuit breakers on the left of the centre pedestal were deleted. This resulted in a satisfactory arrangement.

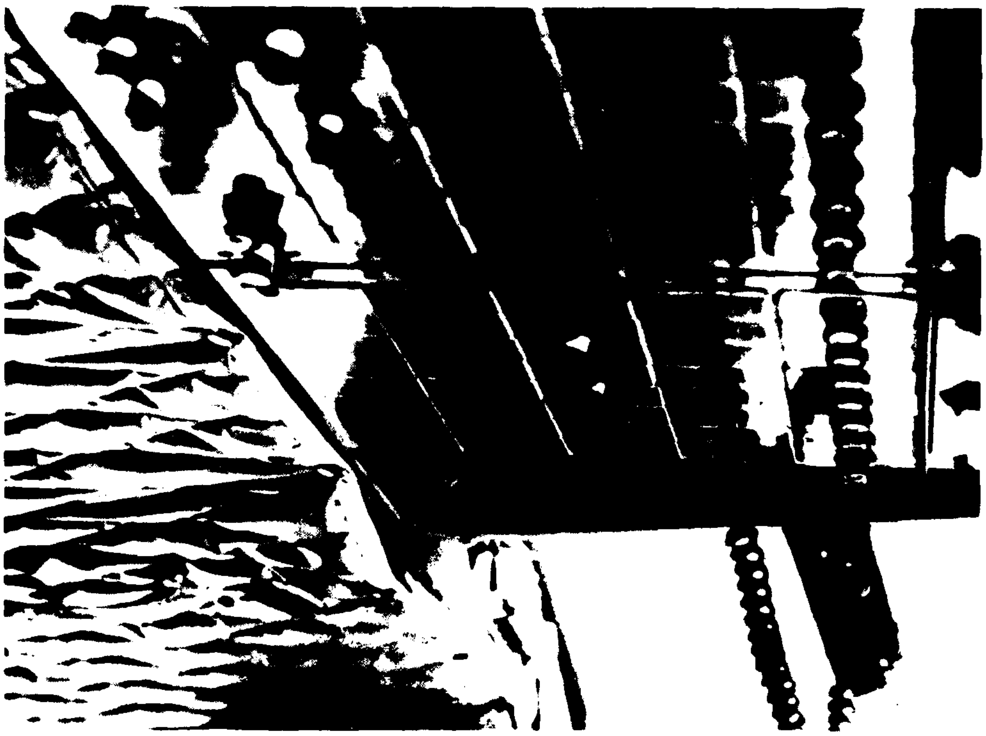


FIGURE 5.5 - VIEW OF OVERHEAD CIRCUIT BREAKERS FROM PILOT'S DESIGN EYE POINT

FIGURE 5.6 - VIEW OF CIRCUIT BREAKERS ON LEFT OF CENTRE PEDESTAL FROM CO-PILOT'S DESIGN EYE POINT

5.1.2.5 AC Circuit Breaker. The AC circuit breaker was mounted on the AC circuit breaker panel on the right wall of the centre pedestal below the collective lever of the right pilot's station. A view of the circuit breaker panel from approximately the DEP of the pilot's station is shown in Figure 5.7. The circuit breaker occupied the forward-most position on the bottom row. With the restraint harness locked, the pilot could not reach the circuit breaker. Even with the restraint harness unlocked, operation of the circuit breaker was extremely difficult and would be hazardous in-flight due to possible fouling of the flight controls by the torso and limbs of the pilot. Although the probability of using the circuit breaker is extremely low, it should (ideally) be readily accessible to at least one member of the crew. The position of the circuit breaker was therefore unsatisfactory, although this deficiency was ultimately attributable to the poor positioning of the AC circuit breaker panel in toto. The long-term objective should be to reposition the entire AC circuit breaker panel to a position readily accessible to the pilot.

FIGURE 5.7 - VIEW OF AC CIRCUIT BREAKER PANEL FROM PILOT'S DESIGN EYE POINT

5.1.3 Labelling and Readability of Controls and Displays

5.1.3.1 CDU MODE and DISPLAY Switches. When viewed from the DEP of the pilot or co-pilot, several of the labels pertaining to switch position were obscured by the knobs. To ensure that the switches were in the correct positions, the pilot or co-pilot had to lean towards the CDU so that a more direct line-of-sight was established and so that the labels could be read. With familiarity, the crew members memorized the various functions associated with switch positioning, but selection mistakes still occurred occasionally. Obscuration of the switch labelling will lead, on occasions, to diversion of crew attention from their primary tasks and will therefore slightly degrade mission performance. The deficiency probably arose as a result of constructing the three-dimensional piece of equipment from two-dimensional drawings, combined with the non-ideal viewing angle. The obscuration of several labels pertaining to the MODE and DISPLAY switches, by the switch knob, when viewed from the pilot's or co-pilot's DEP, was unsatisfactory. The acquisition of equipments which have similar deficiencies should be avoided in future.

5.1.3.2 CDU DISP and FLY-TO DEST Thumb-wheels. The thumb-wheel characters were displayed in small windows beneath transparent (apparently plastic) covers. Under most daylight conditions, the thumb-wheel characters were unreadable due to reflections on the transparencies. The pilots had to continually shade the windows with gloved hands whenever a thumb-wheel selection was made or checked. This was found to be extremely annoying and distracting. The obscuration of thumb-wheel letters and numerals, caused by reflections on the windows during daylight operations, was unsatisfactory. The thumb-wheel windows should be modified to prevent reflections obscuring the characters.

5.1.3.3 CDU MEM Indicator Lamp. When viewed from the co-pilot's DEP, the MEM caution light on the CDU was obscured by the DIM control knob immediately to the left of the light. The co-pilot was therefore often unaware of activation of the MEM light until informed by the pilot. Memory mode operation of the LDNS was easily detected by the pilot since the slaved SHIU MEM light fell well within his usual peripheral field-of-view. Although unsatisfactory, obscuration of the CDU MEM light by the DIM control knob (as viewed from the co-pilot's DEP), was acceptable as the pilot easily detected the simultaneous illumination of the SHIU MEM light.

5.1.3.4 CDU Keyboard Push-buttons. The keyboard push-buttons were located on the right of the CDU and were identified by etched, white-painted letters and numerals. The labels were unambiguous and easily read by both pilots in all day lighting conditions. The labels of frequently used push-buttons (eg KYBD) may become worn or grubby with extended periods of use and may therefore become unreadable. This could be rectified by maintenance action. The labelling and readability of the keyboard push-buttons was satisfactory.

5.1.3.5 CDU Alpha-Numeric Displays. The CDU displays comprised three windows (Target Store Indicator, Centre Display and a main display nominally divided into Left and Right Displays). Alpha-numeric information was displayed in these windows by means of red-filtered incandescent lamps. The displays were generally sunlight-readable with the dimming control adjusted to full bright. In some light conditions, it was difficult to discern decimal points and degrees; however, this did not greatly affect interpretation. From some viewing positions commonly used by Iroquois pilots, the left- or right-most filaments of the tubes were obscured; however, when viewed from the DEP of either pilot station, no obscuration occurred. Due to the design of the individual tubes, minor ambiguities arose when reading the display, for example, misinterpreting the letter 'S' as numeral '5'. These ambiguities were of no real consequence and did not detract greatly from overall interpretation of displayed information. The readability of the alpha-numeric displays was satisfactory.

5.1.3.6 SHIU Control Knobs. Two control knobs labelled NAV/HOV and TKE/XTK were located, respectively, on the bottom left and bottom right of the instrument. White dots marked on the tops of the knobs and white line-up marks located on the base of the knobs were intended to give the pilot an indication of the modes selected; however, any parallax caused misalignment of the dots and lines (due to the large vertical separation) and could have led to misinterpretation. Flags labelled GS/VV and TKE/XTK were attached to the knobs and appeared in windows in the bottom left and bottom right, respectively, of the SHIU face, depending on selected mode. This helped to overcome ambiguities caused by the poor design of the control knob line-up marks. The design of the SHIU control knob line-up marks was unsatisfactory and should be avoided in future equipments.

5.1.3.7 SHIU Groundspeed/Vertical Velocity Scale. The groundspeed/vertical velocity scale was located on the left of the instrument and marked in 50 unit intervals from 0 to 300. A GS/VV pointer passed over this scale to indicate groundspeed in either knots or km/h, depending on CDU mode selection, or vertical speed in HOV mode. The base of the pointer obscured some of the groundspeed scale numerals, causing slight difficulty in reading accurate groundspeeds during quick scans. The SHIU groundspeed scale and pointer arrangement was unsatisfactory and should be avoided in future designs.

5.1.3.8 SHIU TKE Scale. The SHIU TKE scale was located at the top of the indicator, adjacent to the vertical pointer. With the instrument located as per paragraph 5.1.2.2, the numerical markings were obscured by the outer SHIU frame when viewed from the pilot's DEP, although the corresponding graduation marks were visible. The obscuration of SHIU TKE scale numerals made interpretation of displayed information difficult and was therefore unsatisfactory. The deficiency may be overcome by relocation of the SHIU as recommended in paragraph 5.1.2.2.

5.1.3.9 SHIU GEO Light. An indicator lamp with a diffuse white filter and labelled GEO was mounted at the middle top of the SHIU. The lamp illuminated when the CDU was placed in LAT/LONG mode and served as an indication to the pilot that SHIU displays were either knots or km/h (groundspeed) and nautical miles or km (distance to go). The GEO labelling bore no real relevance to the LAT/LONG function and was initially confusing. Additionally, illumination of the light was hard to detect in direct sunlight. The labelling and readability of the SHIU GEO light were therefore unsatisfactory, and these features should be avoided in future equipments. The applicable requirements of AIR STD 10/30H were met (see Annex C, Serial 2).

5.1.3.10 Legend Abbreviations and Keyboard Arrangement. Except for the GEO label (see paragraph 5.1.3.9) the abbreviations used on the LDNS were unambiguous. The legend abbreviations and keyboard arrangement were satisfactory. The keyboard arrangement was logical. The applicable requirements of AIR STD 10/47A and 10/62B (see Annex C, Serials 6 and 7) were met.

5.1.4 Operation of Controls

5.1.4.1 General. The operation of LDNS controls was generally satisfactory, except for two minor deficiencies discussed in this section.

5.1.4.2 CDU Keyboard Push-buttons. The CDU push-buttons were spring-loaded. Data entry occurred on the release of the push-button. There was no real tactile cue of push-button activation, and this led to slight difficulties and occasional data entry mistakes in the high vibration environment of the UH-1H. The main causes of these errors were, firstly, that the operator occasionally did not fully depress the push-button prior to release, and secondly, 'double-tapping', where a second inadvertent keystroke was made due to helicopter vibrations acting on the operator's hand. The difficulty of use and occasional mistake made when using the keyboard push-buttons in the airborne environment prolonged data entry procedures and, as a result, slightly increased workload. The lack of sufficient tactile cues when using the CDU keyboard push-buttons was unsatisfactory. Future equipments intended for use in a high vibration environment should incorporate features to overcome inadvertent/incorrect data entry when using keyboard push-buttons.

5.1.4.3 CDU Thumb-wheels. The CDU thumb-wheels were similar to items found on other aircraft radio/navigation equipments; however, the raised grips seemed smaller than most others. This caused slight difficulty when operating the thumb-wheels with a gloved hand, as sometimes the wheel did not 'click' to the next position. The operator often compensated for the thumb-wheel readability deficiency discussed in paragraph 5.1.3.2 by mentally counting through the waypoint letters/numerals and then checking for correct selection. If some 'clicks' were missed due to the difficulty in using the thumb-wheel with a gloved hand, a further selection iteration was required. This was annoying and added to operator workload. The operation of the CDU thumb-wheels with a gloved hand was unsatisfactory. The thumb-wheels on future designs should be improved to be more compatible with use by a gloved hand.

5.1.5 Lighting of Controls and Displays

5.1.5.1 General. The LDNS lighting system used 5 VDC in lieu of 28 VDC which is UH-1H standard. In the initial installation CDU panel and MEM/MAL light (CDU and SHIU) intensities were controlled by the centre pedestal lighting rheostat through a step-down voltage circuit. The SHIU lighting was controlled by the pilot's flight instruments rheostat and the CDU display intensity by the DIM control knob on the CDU. During the evaluation, several LDNS lighting deficiencies became apparent.

5.1.5.2 CDU Panel and Keyboard Lighting. The CDU panel lighting was satisfactory until KYBD push-button was depressed to 'freeze' the displays or enter data. Depressing the KYBD push-button caused the panel and keyboard lights to almost extinguish. The entire panel (excluding displays) then became unreadable at night, even with maximum intensity selected. Investigations revealed that the stepped-down 5 VDC power supply was unable to meet the extra load demand required to illuminate the CDU keyboard push-buttons consequent to activation of the KYBD push-button. Programming of the LDNS was therefore impossible at night without the aid of a secondary light source. The CDU panel and keyboard lighting was therefore unacceptable for night operations. This deficiency was reported by ARDU in Reference C. As a result of this report, a new lighting system for the CDU was designed, incorporating a stable 5 VDC power supply and a CDU LIGHTS rheostat mounted on a small panel immediately aft of the LDNS CDU in the centre pedestal. Although not ideal, this gave a satisfactory solution.

5.1.5.3 MEM and MAL Indicator Lamps. The intensities of the amber MEM and MAL lights on the CDU and SHIU were controlled by the centre pedestal rheostat for the initial installation. When the centre pedestal lights were correctly adjusted, the MEM and MAL lights were excessively bright when they illuminated during visual night operations. The brightness of the lights dazzled the pilots and caused loss of external reference and difficulty in reading flight instruments. The brightness of the MEM/MAL lights, compared to other cockpit lighting, therefore constituted a flight safety hazard. Further, during daylight operations, the centre pedestal lighting had to be selected ON for the MEM and MAL lights to function. The excessive brightness of the MEM/MAL indicator lamps, combined with the requirement to select centre pedestal lighting ON during daylight operations, rendered the MEM/MAL lighting system unacceptable. At the Reference D meeting, ARDU recommended that, since the MEM and MAL indicator lamps were intended to provide cautionary advice to the pilots, their lighting control should be slaved to the aircraft Master Caution system, which incorporated a BRIGHT/DIM function. This was subsequently adopted and, following design and incorporation of the required modifications, found to be satisfactory. The applicable requirements of AIR STD 10/30H were met (see Annex C, Serial 1).

5.1.5.4 Reflections of CDU Displays. During night operations, reflections from letters and numerals of the CDU displays occurred in the pilots' windscreens. The reflections occupied the area directly in front of the pilot's field-of-view and, although adjusted for proper balance and readability for direct viewing, were disproportionately bright compared to reflections from other centre pedestal equipment lighting. The reflections were found to be distracting and occasionally caused loss of visual contact with other aircraft equipped with flashing red anti-collision lighting as they passed in front of the test aircraft. These reflections were therefore assessed as unsatisfactory. The deficiency has been overcome by the incorporation of glareshields attached to the CDU, just above the main, centre and target store displays.

5.2 Navigation Accuracies

5.2.1 Velocity Accuracies

5.2.1.1 A total of 1,216 data points was collected to determine the velocity accuracy of the LDNS in a UH-1H without an external load. The accuracy of the total velocity errors (X, Y, Z axes) was 0 $\pm$0.53 mps(1σ) or 0 $\pm$1.03 kn(1σ) for the groundspeed range +10 to +120 kn. Annex G, Table 1 lists the results in ASCC AIR STD 53/12A format.

5.2.1.2 The ASCC requirement for velocity accuracy was $\pm$1 kn (2σ) for the velocity range -50 to +100 kn and $\pm$1% (2σ) for the velocity range +100 to +250 kn. The datum accuracy was 0 $\pm$0.2 mps (1σ) or 0 $\pm$0.4 kn. For the groundspeed range tested the LDNS groundspeed accuracy was 0 $\pm$1.26 kn (2σ) and did not meet the ASCC requirement overland in UH-1H A2-455 without an external load (see Annex C, Serials 10 and 11).

5.2.1.3 A total of 418 data points was collected to determine the velocity accuracy of the LDNS in a UH-1H with an external load. The accuracy of the total velocity errors (X, Y, Z axes) was -0.08 $\pm$0.26 mps (1σ) or -0.15 $\pm$0.51 kn (1σ) for the groundspeed range +30 to +100 kn. Annex G, Table 1 lists the results in ASCC AIR STD 53/12A format.

5.2.1.4 The ASCC requirement did not distinguish between an aircraft with or without an external load when quoting required accuracies. For the groundspeed range tested, the LDNS groundspeed accuracy did not meet the ASCC requirement in UH-1H A2-455 with an external load, overland, as the mean error was -0.08 mps (-0.15 kn)(see Annex C, Serials 10 and 11).

5.2.1.5 Assuming the datum accuracy was constant for all tests including with and without an external load), there was a slight degradation in groundspeed accuracy when an external load of 4 x 44 gallon drums was carried. The degradation cannot be considered to be representative of possible errors for other types of external loads cleared for carriage by UH-1H aircraft.

5.2.1.6 No tests of velocity accuracy overwater were conducted, as no instrumentation was available.

5.2.2 Position Accuracies - General

5.2.2.1 Tests for position accuracy were divided into three main areas: straight and level flight overland; straight and level flight overwater; and NOE flight. The carriage of an external load was expected to affect the velocity accuracy and thus the position accuracy of the LDNS. Therefore, tests were conducted overland in straight and level flight with an external load to determine the possible effect on position accuracy caused by the carriage of an external load.

5.2.3 Position Accuracy Overland - Straight and Level

5.2.3.1 The position accuracy tests overland were conducted at medium level (500 and 5,000 feet) and at low level (10 and 50 feet), over the same ground track oriented 305°T/125°T. The medium level tests used radar-derived positions as the datum positions. The radars were Adour Precision Instrumentation Radars. The low level tests used surveyed man-made ground features as datum positions. The overall position error (radial) was 0.67% $\pm$0.43% (CEP) of the Actual Distance Gone (ADG). Annex G, Table G.2 lists the results for Cross Track Error (CTE), Along Track Error (ATE) and Radial Error (RE) for straight and level flight overland. The overall CTE, ATE and RE are calculated as individual errors. The RE for each level and the overall RE are not the root sum square of CTE and ATE in each case.

5.2.3.2 From the results, the large CTE at low level is significantly different to that at medium level. CTE is mainly attributable to heading reference error. The compass calibration deviations calculated prior to the tests (listed in Annex A) indicated large deviations in the north-west quadrant. The deviations indicated a larger CTE should occur in the 305°T track. However, the results show the track of 125°T had the larger CTE. This could be caused by the compass calibration using the Wild Datum B3 not being accurate (paragraph 3.6). A separate Technical Investigation (TI 831) has been initiated to investigate this possibility. Discussions with Aeronautical Research Laboratories (ARL) scientists revealed that, at low level, the AN/ASN-43 compass is susceptible to significant local area magnetic deviations, which are not apparent in medium to high level flight. A magnetic survey of the Woomera range area was unavailable. Post-test investigations revealed no other significant reasons for the increased low level CTE.

5.2.3.3 The ATE for all runs was consistently less than the ADG. This could have been caused by the velocity used for calculating distance gone being slightly low (negative velocity error). No major reason was found for the mean ATE being displaced negatively.

5.2.3.4 The AFSR 5006 required the radial error to be less than 0.5% (no confidence limit) of ADG, excluding observable systematic errors such as heading reference error. The A error of the compass swing equates to a mean error of -0.29^{o} which is equivalent to a CTE of 0.51%. The datum position accuracy was ±30 m (90%) which is equivalent to an RE of 0.3% over [illegible] km. Therefore, the mean error observed lies within the errors that were measurable. No confidence level was given in AFSR 5006 for the radial error. For this report the error of ±0.5% was assumed to be CEP. Thus the LDNS position accuracy error of ±0.4% of ADG met the requirements of AFSR 5006, overland in straight and level flight (See Annex D, Serial 13).

5.2.3.5 Tests were conducted to determine if an external load affected the position accuracy of the LDNS and, if so, to what extent. The tests were conducted at 500 feet AGL in straight and level flight. The results of the tests are listed in Annex G, Table G 3.

5.2.3.6 From the results, there was a degradation of mean radial error, with no significant degradation in the CEP of the LDNS position accuracy when an external load was carried at 500 teeet AGL. As the velocity accuracy was degraded by an external load, the position accuracy was expected to be degraded, in particular the ATE. The results show the position accuracy degradation was not of the same ratio as the velocity accuracy degradation. There were significant differences in CTE in both directions. There were no significant differences in ATE in both directions. The carriage of a metallic external load may have affected the AN/ASN-43 compass accuracy. No tests were conducted to determine this possibility.

5.2.4 <u>Position Accuracy Overland - Nap of Earth Flight</u>

5.2.4.1 The NOE flight tests were conducted to determine if constant manoeuvring affected the LDNS position accuracy. A total of 24 data points was collected. The overall radial error was 2.19% ±0.74% (CEP) of ADG. The CTE was -0.17% ±1.80% (CEP). The ATE was -0.07% ±0.[illegible] (CEP). The LDNS did not meet the requirements of AFSR 5006 for NOE flights overland.

5.2.4.2 The AN/ASN-43 compass has a slow alignment settling period (greater than two minutes). The constant manoeuvring usually did not allow the compass to settle on a new heading before another heading change was made. Thus errors were introduced into the LDNS, and were the cause of the CTE. As the tests were in several directions, including reciprocal tracks, the overall CTE is not a clear guide to the performance of the LDNS, whereas the overall RE, based on individual absolute values of CTE, is a better indication of the system performance.

5.2.5 <u>Position Accuracy Overwater - Straight and Level</u>

5.2.5.1 The overwater flights were conducted to determine if any significant difference in the LDNS position accuracy occurred due to a different reflecting surface for the Doppler radar beams. The tests were conducted over two days. The sea current and wind vector inserted into the LDNS CDU on the first day of the tests overwater were 360^{o}T at 2 kn and 220^{o}T at [illegible] kn respectively. On the second day, the sea current was the same; the wind vector was 280^{o}T at 5 kn. A total of 10 data points was collected.

5.2.5.2 The overall RE was 2.07% ±1.12% (CEP) of ADG. The CTE was -1.51% ±1.30% (CEP) and the ATE was -0.04% ±0.97% (CEP). The LDNS did not meet the requirements of AFSR 5006 in overwater, straight and level flight.

5.2.5.3 The CTE lies outside the limits of the compass error but is most probably caused by the residual compass deviations, and the across track velocity errors being increased overwater. The ATE limits are wider than the overland straight and level ATE, indicating the velocity error of the LDNS overwater is slightly degraded. The effect, if any, of the carriage of floats on the Doppler radar beams, and hence position error, was not tested. The increased error may have been due in part to the Doppler signal being affected by the floats.

5.2.6 <u>Summary of Navigation Accuracy Conclusions</u>

5.2.6.1 Overall, the LDNS did not meet the ASCC requirements for velocity but met the AFSR 5006 requirements for position accuracy overland in straight and level flight. The LDNS did not meet the position accuracy requirement in NOE or overwater flight. An external load degraded both the velocity and position accuracies. However, the navigation accuracies of the LDNS were generally satisfactory for UH-1H operations.

5.3 <u>LDNS Operating Envelope</u>

5.3.1 <u>Attitude Limits</u>. Using the methods outlined in paragraph 4.3.1, the attitude limits for LDNS operation overland (Woomera, SA area) were determined to be ±30 degrees in pitch and ±60 degrees in roll at low heights (up to 500 ft AGL). No 'unlocks' attributable to attitude limitations were observed during low level tactical flying (overland). At approximately 5,000 ft AGL, occasional unlocks occurred at 30 degrees of pitch and roll. At 10,000 ft AGL, the LDNS would not maintain lock at greater than 20 degrees of pitch or roll, and some unlocks occurred during straight and level flight. These tests showed that the LDNS attitude operating limits reduced as a function of aircraft height above terrain. Flight over other areas showed that the limits were also dependent on terrain type. For example, lock was held at 8,000 ft AGL (approximately) up to 20 degrees of pitch and roll over mountainous areas of the Great Dividing Range in South-East Queensland. Unlocks occurred overwater (Sea State 4, see Table 3.3) at 3,000 ft and 30 degrees of roll. Although dependent on height and terrain type, the attitude limits were generally in excess of attitudes typically used by Iroquois pilots involved in corresponding missions, for example, tactical low level flying overland, or an overwater SAR task. The attitude limits did not, therefore, impinge adversely on use of the LDNS in the UH-1H. The aircraft attitude limits for normal LDNS operation were therefore satisfactory. The requirements of AIR STD 53/9C (see Annex C, Serials 12 to 17) and AFSR 5006 (see Annex D, Serials 3 and 4), were not fully met.

5.3.2 <u>Altitude Limits</u>. Within the limits established in paragraphs 5.3.1 and 5.3.3, the LDNS operated normally at all altitudes tested, from ground level to 10,000 ft AGL overland, and 50 ft to 5,000 ft ASL overwater. No specific limitation attributable to altitude alone could be found, and this feature was therefore assessed as satisfactory. The applicable requirements of AIR STD 53/9C (see Annex C, Serial 18) and AFSR 5006 (see Annex D, Serial 2) were met.

5.3.3 Minimum Sea State. Using the method described in paragraph 4.3.3, the minimum Sea State for proper LDNS operation during straight and level flight was determined to be 2 to 3, as defined in Table 3.3. At Sea State 3, occasional unlocks occurred at altitudes as low as 1,000 ft. It was sometimes necessary to recycle through the TEST mode to regain lock under these conditions. With Sea State 2, the LDNS entered MEMORY mode and could not be manually unlocked even when flying at 50 ft ASL. The failure of the LDNS to properly operate in straight and level flight over Sea States of 3 or less will detract from overwater SAR and deployment mission effectiveness on a considerable percentage basis, especially in tropical areas where winds of less than [illegible] knots predominate for large time periods. The failure of the LDNS to properly operate during straight and level flight over Sea States less than 3 was unsatisfactory. The applicable requirements of AIR STD 53/9C (see Annex C, Serial [illegible]) and AFSR 5006 (see Annex D, Serials 15 and 17) were not met.

5.4 System Utility

5.4.1 Pre-flight/Built-In-Test (BIT). Apart from system programming, the pre-flight procedures were straightforward, uncomplicated and quickly accomplished. The LRUs, connectors, looming and circuit breakers were checked for condition and security as part of the walk-around inspection, and did not add significantly to the time required for completion. Operational serviceability of the system was determined by selecting aircraft DC and AC electrical power ON, then selecting, in turn, LAMP TEST, then TEST, via the CDU mode switch. In the LAMP TEST position, all alpha-numeric display tube filaments, MEM and MAL indicator lamps, edge lighting and push-button lamps illuminated on the CDU and SHIU, providing the system was fully serviceable. Any failures were eye-catching and quickly detected. Following a successful LAMP TEST, the mode switch was placed to TEST. As the BIT progressed, a series of alpha-numeric characters (of no consequence to the pilot) were displayed on the left display of the CDU. Approximately 15 seconds after selecting TEST, 'GO' appeared in the left display of the CDU, providing the BIT did not detect any failures. Failures were indicated by illumination of the MAL indicator lamps and a message code on the CDU left and right displays. If a malfunction occurred during flight, as indicated by illumination of the MAL lamps, the failure could be identified by selecting TEST mode and noting the failure code. Approximately five seconds after obtaining a 'GO' in TEST mode, the CDU-indicated aircraft heading, pitch and roll to the nearest 0.1 degree. During the flight test program, all system failures were detected by the BIT. The pre-flight and BIT procedures were simple, quick and effective and therefore satisfactory. The applicable requirements of AIR STD 53/9C were met (see Annex C, Serial 26).

5.4.2 BIT Operation Without AC Power. If operation of the BIT (TEST Mode) was attempted without the aircraft inverter (AC electrical power) selected ON, the CDU indicated a malfunction (MN) and failure code S050000. Although normal programming was possible, indication of a malfunction was correct since vertical gyro and heading gyro inputs are required for correct LDNS operation, and both of these systems are AC-powered. Reference E, Table 3-7, however, shows actions for failure code S050000 as:

> 'Replace timer/interface circuit card 1A2, and retest. If same failure code appears, replace A/D converter circuit 1A1'.

This was initially confusing since pre-flight inspections and system checkouts are not normally performed with AC power ON. The remedy for failure code S050000 in Reference E, Table 3-7 was misleading. Notes should be included in Reference E, and Reference F amended to reflect that AC power is required to be ON for full system check-out.

5.4.3 System Operating Procedures

5.4.3.1 General. Although some system operating procedures were simple, logical and quickly accomplished, and therefore well suited to Iroquois operations, there were several procedures that were either over-complicated or required an excessive number of keystrokes to accomplish. These procedures, which are discussed in the following paragraphs, increased operator training time, the likelihood of mistakes and pilot workload.

5.4.3.2 Entering UTM Waypoints

5.4.3.2.1 Entry of a UTM waypoint was accomplished by selecting UTM mode, display switch to DEST/TGT and rotating the DEST DISP thumb-wheel to the desired letter or numeral. Consider entry of Grid Zone identifier 54H, area CV, easting 9876, northing 1234 as Waypoint H. Data entry would proceed as follows:

a. Select Waypoint H on thumb-wheel.

b. Depress KYBD push-button. Observe that display freezes and TGT STR indicator blanks.

c. Depress KYBD push-button. Observe that centre display blanks. Enter grid zone identifier by depressing keys 5, 4, 3, 2 (where 3, 2 = H).

d. Depress KYBD push-button. Observe that left and right displays blank. Depress keys 1, 3(=C); 8, 7(=V); 9, 8, 7, 6, 1, 2, 3, 4.

e. If satisfied that data is correct, depress ENT key.

This procedure stores the data in Waypoint H location, ready for navigation. Following waypoint entry, UTM spheroid and waypoint variation should also be checked/entered. Although logical in defining a grid reference by progressing from the large area identifiers down to the eight numeral reference, the process became extremely repetitive and time-consuming when a large number of waypoints was to be entered. For most UH-1H operations, it is highly unlikely that flights would cover an area where several Grid Zone identifiers would be used. For this reason, several keystrokes could have been saved if the Grid Zone identifier was set up to be entered last instead of first, since it would be highly probable that the data was already correct from a previous waypoint entry.

5.4.3.2.2 Consider entry of the previously-used waypoint data if the Grid Zone identifier had been correct, and if the programming change outlined in paragraph 5.4.3.2.1 was employed:

a. Select Waypoint H on thumb-wheel.

b. Depress KYBD push-button. Observe that display freezes and TGT STR indicator blanks.

c. Depress KYBD push-button. Observe that left and right displays blank. Enter grid reference CV98761234 by depressing keys 1, 3(=C);8, 7(=V); 9, 8, 7, 6, 1, 2, 3, 4.

d. Check centre display to see if Grid Zone identifier is correct for waypoint being entered (in this example it is). If correct, depress ENT key.

5.4.3.2.3 The procedure outlined in paragraph 5.4.3.2.2 may save several keystrokes when programming a large number of waypoints for a tactical area of operation. Although satisfactory, the procedure for entering a large number of UTM waypoints was not ideally suited to tactical UH-1H operations and could have been better 'streamlined'.

5.4.3.3 Entering Waypoint Variation Due to the destination variation constraint, the variation for each waypoint had to be entered after programming the co-ordinates for that waypoint (UTM or LAT/LONG). In the SPH/VAR display selection, the left display indicated UTM spheroid and the right display indicated waypoint variations. If UTM mode was in use, entry of the applicable spheroid for one waypoint set the system to that spheroid for each waypoint and for navigation use. The following procedure was used to program waypoint variation:

a. Mode was selected to UTM, LAT/LONG or BACK-UP

b. Display was selected to SPH/VAR

c. DEST DISP thumb-wheel was rotated to desired setting

d. The KYBD push-button was depressed. The displays froze and the TGT STR indicator blanked

e. If the UTM spheroid information was correct, the KYBD was depressed twice, to blank the right (VAR) display.

f. The variation was then programmed and entered.

The requirement to 'pass through' the spheroid code each time a waypoint variation was programmed, caused the procedure to be time-consuming and increased the probability of mistakes due to the inordinately high number of keystrokes required. Additionally, since waypoint variation was 'dumped' each time waypoint co-ordinates were programmed, pilots in a high workload or quick response environment were prone to forget to enter waypoint variation, possibly seriously degrading navigation accuracy. The procedure for entering waypoint variation was over-complicated and time-consuming, and therefore unsatisfactory. The procedure could have been better 'streamlined' by using the left display for VAR and the right display for SPH when display was selected to SPH/VAR

5.4.3.4 Entering Wind, Sea Current and Target Motion Entry of wind (speed/direction), sea current and target motion was accomplished in either UTM or LAT/LONG mode with display selected to WIND SP/DIR. When initially selected, asterisks appeared in each of the displays. Depressing the KYBD push-button called up wind effect (WE) parameters. A second activation of the KYBD push-button called up sea current (SC) parameters. The third activation called up target motion (TM) parameters. This 'step-through' procedure was the result of combining the three factors WE, SC and TM on the same display position for programming. The procedure to enter data for any of these parameters was illogical, in that the ENT key was depressed before data was actually entered. Consider entry of a sea current of 4 knots/030 degrees. The following procedure was followed

a. Select mode to LAT/LONG.

b. Select display to WIND SP/DIR. Asterisks are displayed.

c. Depress KYBD push-button. WE XXX is displayed.

d. Depress KYBD push-button. SC XXX is displayed.

e. Depress ENT push-button, then KYBD push-button twice. Left display blanks.

f. Enter speed (0, 0, 4).

g. Depress KYBD push-button. Right display blanks.

h. Enter direction (0, 3, 0).

i. Depress ENT push-button.

Unless the operator was highly conversant with system operating procedures, this somewhat illogical keystroke sequence was easily forgotten and led to mistakes. RAAF UH-1H operations only occasionally involve flight over water, and the majority of these flights are high workload, quick-response SAR missions. Due to irregularity of use and the illogical keystroke sequence, Iroquois pilots will often have to consult LDNS pilot's notes to correctly program the system. This will be found to be frustrating and time-consuming in the high workload, quick response environment. The procedure for programming wind, sea current and target motion was illogical, time-consuming and therefore unsatisfactory.

5.4.3.5 System Initialization/Update. Several methods were available to initialize or update the system. The evaluation revealed that all but the DIST/BRG/TIME method of initialization/update were too lengthy or distracting to be of practical use in the tactical environment. In the DIST/BRG/TIME method, the aircraft was flown to visually on top of the selected FLY-TO waypoint. The display switch was selected to DIST/BRG/TIME. When the aircraft was over the waypoint, the KYBD push-button was depressed, and the displays froze. If update/initialization was required, the ENT push-button was then depressed. The update was then effective from the time of initially depressing and releasing the KYBD push-button. The two other updating procedures involved flight over a recognized landmark, either in anticipation of, or after, a visual fix. Both methods involved reading the landmark co-ordinates from the map, then entering the data in a procedure similar to that outlined in paragraph 5.4.3.2.1. The distraction and workload involved with these types of updates in a tactical environment were prohibitive in that the system operator (probably co-pilot) had to devote his full attention to the LDNS and map reading for a period of approximately five minutes. The requirement for these types of updates could be avoided by thorough pre-flight planning. If well defined waypoints were selected at approximately 10 to 20 km intervals, the aircraft could be flown to successive waypoints and DIST/BRG/TIME updates made if necessary. If high accuracy at final destination was required, a final update could be performed at a waypoint (or 'gate-in') no more than five kilometres away. This method of navigation proved very effective during tactical flying. If waypoints were programmed before departure, and the successive waypoints were overflown (with updates as required), crew workload during tactical flying was considerably reduced compared to non-LDNS-equipped aircraft operations. The pilot flying the aircraft could make the most effective use of terrain between waypoints without becoming too concerned that the 'navigator' would become lost. The 'navigator' was only required to monitor the LDNS performance and position. Due to the large reduction in the navigation workload, the crew was able to be more tactically aware and devote more attention to higher priority tasks, such as lookout for enemy air and ground forces. Initialization/update procedures, other than the DIST/BRG/TIME method, were unacceptable for use in the tactical environment. Given thorough pre-flight planning, navigation using DIST/BRG/TIME updates was very effective during tactical flying.

5.4.3.6 Target Store Operations. The target store facility on the CDU enabled the LDNS-derived Present Position (PP) to be automatically stored in the waypoint location shown by the target store indicator when the TGT STR push-button was depressed. Waypoint locations 6 through 9 were available for this purpose, and were cycled through in sequence with each activation of the TGT STR push-button. Waypoint data stored in the location shown by the target store indicator was dumped when the TGT STR push-button was depressed. This greatly restricted the usefulness of this feature. For example, consider an aircraft proceeding from Waypoint 5 to Waypoint 6, with 6 displayed in the target store indicator. An enemy ground installation is sighted and the TGT STR push-button is depressed to store PP at the time of sighting (for post-flight intelligence debriefing or other purposes). The navigator is then required to either move the stored target position to another waypoint location, or reprogram the original Waypoint 6 data into another waypoint (which would, of course, dump the original data for that waypoint). Either of these operations is lengthy and relatively complicated, and would detract significantly from operator performance of other, more tactically important, duties. Crews may circumvent this difficulty by one of the following methods:

a. Having waypoint locations 6 to 9 vacant (if not essential to use) so that they can be used for target storage purposes. This reduces the overall utility of the system.

b. Instead of using the target store method, the operator may enter PP in a waypoint location that is of no further or little use.

c. Selecting display to PP and depressing the KYBD push-button, then manually copying the data for subsequent programming or debrief.

Although the ability to quickly store target position information was valuable in the tactical environment, the implications of the use of the feature, as mechanized in the LDNS, detracted from system utility, and was therefore unsatisfactory. The deficiency could be overcome by incorporating extra storage locations specifically for target store operations.

5.4.4 Displayed Navigation Information. The range of navigation information available for display is detailed in paragraph 2.1.1 for the CDU and paragraph 2.2 for the SHIU. The most useful and most commonly used CDU display was DIST/BRG/TIME. Other displays (PP, GS/TK and XTK/TKE) were less frequently used, but provided comprehensive navigation information. The capability to change quickly from UTM to LAT/LONG mode (by one movement of the mode switch) was also useful when changing from Operational Navigation Charts (1:1,000,000 scale) to tactical maps (usually 1:50,000 scale). This facility also allowed programming in one mode, and airborne navigation in the other. The SHIU NAV mode displays were well suited and very useful for flying in the tactical environment. By reference to the SHIU, the pilot flying the aircraft was able to take far more advantage of terrain, or make quick decisions in relation to avoiding action (for example, running to a hide) while still remaining cognizant of the relative position of the next waypoint, or final destination. This information was also extremely useful in SAR operations. The range of navigation information was comprehensive and well suited to tactical and SAR operations. In this respect, the introduction of the LDNS will significantly enhance tactical and SAR operations by RAAF UH-1H aircraft. The applicable requirements of AFSR 5006 were generally met (see Annex D, Serials 5 to 12).

5.4.5 Night Vision Goggle (NVG) Operations NVG operations in conjunction with the LDNS are described in Section 4.5. This evaluation identified several serious deficiencies, pertaining to use of NVG in UH-1H aircraft, which will be reported on under other tasks. The majority of these deficiencies involved cockpit lighting and human factors aspects of the NVG. In other than an extremely familiar area, visual navigation when using NVG created an unacceptably high pilot workload. This was due to the difficulty in reading maps through the NVG and the difficulty in scanning for identifiable features to obtain a visual fix. The availability of LDNS navigation information overcame several of these problems. The LDNS operator was able to verbally direct the pilot to successive waypoints by reference to LDNS displays. To maintain accuracy, updates were performed whenever LDNS position error was in excess of 200 metres at any waypoint. By selection of readily identifiable waypoints such as ruins and road intersections and by updating the LDNS, the crew was able to navigate accurately and covertly to the destination. Iroquois crews will find the LDNS a valuable asset for NVG operations. The installation of the LDNS significantly increased the operational capability of the UH-1H by enhancing NVG operations.

5.5 Engineering Aspects

5.5.1 Evaluation by ARDU Radio Development Flight (RDF)

5.5.1.1 General The LDNS, as supplied by SKD, and fitted to Iroquois A2-455, was evaluated by ARDU RDF personnel. The evaluation was conducted in two areas, namely construction and installation aspects.

5.5.1.2 Construction Aspects The evaluation of construction aspects concentrated on the RTA, SDC and CDU. Overall, the LDNS was very well constructed. The following points highlight both positive and negative features of the units concerned.

5.5.2 Receiver/Transmitter Antenna

5.5.2.1 The antenna section was well made and of solid construction. There appeared to be no chance of warping or distortion.

5.5.2.2 The unit was totally sealed against RF and environmental factors.

5.5.2.3 The 'O' rings under the screw-heads appeared to be for 'once only' use. These should be replaced after each screw removal.

5.5.2.4 The electronic section was well constructed. The layout was good and the assembly was easy to dismantle for servicing.

5.5.2.5 The Printed Circuit Board (PCB) was shockmounted with the connectors held to the board by screws.

5.5.2.6 The components on the PCB were mounted using a solidified black substance in the form of 'fingers' to prevent individual movement.

5.5.2.7 The wave guide section was well constructed and laid out.

5.5.2.8 All looms were tied with waxed string.

5.5.3 Signal/Data Converter

5.5.3.1 Fifteen screws had to be removed to expose the inside of the box. Six screws held each of the circuit card assemblies in the box and sixteen screws held each card to its frame. This made extraction of a card very tedious.

5.5.3.2 The PCBs were manufactured from 0.1 inch thick substrate and were mounted on a diecast frame (by sixteen screws), one board on each side of the frame. This method of construction resulted in a very rigid board assembly

5.5.3.3 The soldering throughout the SDC was of a very high standard

5.5.3.4 Two types of conformal coating were used on the PCBs, namely 'epoxy/varnish' and 'silastic'.

5.5.3.5 The PCB/frame assembly was difficult to remove from the box without use of the extraction tool. ARDU was not supplied with these tools

5.5.3.6 Most of the larger components (transistors, capacitors, ICs) were mounted as per paragraph 5.5.2.6.

5.5.3.7 Servicing could become awkward due to the conformal coatings and mounting substances.

5.5.3.8 The power supply module had some uninsulated wire within 0.05 inch of the chassis. This wire was attached to a high power IC and arcing could result under certain conditions.

5.5.3.9 The power supply module PCB was very thin (although two-layered) and was bonded, in toto, to the chassis which acted as a heat sink All component leads were treated as for a 'flat pack' IC.

5.5.3.10 The mother board was soldered well and the wiring was tied with waxed string.

5.5.3.11 Some corrosion was evident on the diecast box under the mating surfaces of the power supply/chassis mounting

5.5.4 <u>Computer/Display Unit</u>

5.5.4.1 The PCBs were difficult to remove without the special extraction tool.

5.5.4.2 In the CDU examined, PCB 'A6' appeared to be too wide and was therefore warped. The PCB was too difficult to remove.

5.5.4.3 Individual PCBs were not marked with their corresponding locations in the mainframe; that is, 'A1' to 'A6'. There was no indication on the PCBs as to their locations. The main connectors to the mother board were keyed, thus preventing incorrect insertion of the boards.

5.5.4.4 The top connector plugs on PCBs 'A1' and 'A2' had to be removed before the PCBs could be extracted. Removal of the plugs was very awkward. Extraction of the PCBs was still difficult as the top connectors fouled. Also, the PCBs each had eight top connector plugs.

5.5.4.5 The top connector plugs for PCBs 'A1' and 'A2' were poorly marked and could be misplaced.

5.5.4.6 The mother board was connected to the mainframe via connector plugs, not hard-wired.

5.5.4.7 The mother board was quite well wire-wrapped. Some capacitors had been added to the power supply PCB connector by soldering them to the wire-wrap pins and glueing to the board. This area was poorly constructed and not up to the high standard achieved elsewhere within the CDU.

5.5.4.8 Dust and moisture sealing of the keyboard push-buttons was achieved by the use of rubber boots over the push-button shafts. These boots flexed when the push-buttons were operated and may eventually tear.

5.5.4.9 There were no seals around either of the CDU thumb-wheels to prevent the ingress of dust or moisture. This could eventually cause failure of the CDU.

5.5.4.10 Replacement of any component on the front of the CDU (except light bulbs or alpha-numeric tubes) would necessitate complete dismantling of the CDU as the box was diecast in one piece; that is, the front panel was unable to be removed in isolation.

5.5.4.11 The panel lights were part of the plastic face plate and appeared not to be replaceable. If one light fuses it may be necessary to replace the whole panel.

5.5.4.12 The bottom cover plate of the CDU did not incorporate a gasket. The bottom of the unit was therefore not sealed against the ingress of dust or moisture.

5.5.5 Installation Aspects

5.5.5.1 The evaluation of the installation of the LDNS in Iroquois UH-1H A2-455 covered the SDC, CDU, RTA, SHIU and junction box.

5.5.5.2 Signal/Data Converter. The SDC was reasonably accessible and could be interchanged in approximately six minutes with the aid of a Phillips head screwdriver.

5.5.5.3 Computer/Display Unit. The CDU was held in the centre pedestal by eight Dzuz fasteners. The connector plugs were difficult to connect and disconnect unless surrounding control boxes were removed, because the backshells were of the 90 degree type and the connecting cable was clamped too short.This greatly increased the time required to interchange units, and barely met the 15 minute limit. The time was reduced by unclamping and extending the connector cable. This eliminated the need to remove other control boxes.

5.5.5.4 Receiver/Transmitter Antenna. The mounting housing for the RTA attains sufficient rigidity only when complete. With the rear panel and RTA removed, the housing was quite flexible and prone to accidental, permanent deformation possibly leading to antenna misalignment. The access panel stringer on the housing was likely to damage the antenna face upon installation or removal. Installation or removal of the RTA was further complicated by the poor accessibility of the earthing strap and connector plug. A right-angled screwdriver had to be employed to install the earthing strap. The connector plug access hole into the tail boom was too small. If the connector is bumped during installation of the RTA, it can lodge inside the tail boom. It could not then be retrieved by hand through the access hole. If the hole was sufficiently enlarged, both hand retrieval of the connector and satisfactory access to the earthing strap would be possible. The poor access to RTA components increased the time required to interchange units to approximately 35 minutes. The applicable requirements of AFSR 5006 were not met (see Annex D, Serial 25).

5.5.5.5 Steering and Hover Indicator Unit. The SHIU was mounted on the instrument panel by four Phillips head screws. With these undone, the unit could be eased out of the instrument panel and disconnected. Unit interchange was therefore quick (approximately five minutes) and easy.

5.5.5.6 Junction Box. The junction box was mounted deep within the nose electronics compartment of the aircraft. The mounts for the junction box were very flimsy without the unit installed. Due to the location of the box, access to install or remove the plugs was very limited. This made the junction box extremely difficult and time-consuming to install or remove (removal and reinstallation took approximately 45 minutes). The applicable requirements of AFSR 5006 were not met (see Annex D, Serial 25).

5.5.6 Conclusion - ARDU RDF Evaluation

5.5.6.1 The LDNS was a well constructed set of avionics equipment. Except for those deficiencies noted, ARDU RDF was impressed by this system.

5.5.7 System Reliability. System reliability could not be rigorously tested due to insufficient operating time. However, during the flight test program, totalling 26.3 flying hours, only one failure was detected by the BIT. When landing at Woodside, SA, on deployment for NVG operations, the MAL lights illuminated. Mode was selected to TEST and code MN S050000 was displayed. Since this could have indicated AC power supply problems (see paragraph 5.4.2), aircraft inverter selections and AC voltages were checked and found correct. The LDNS was then cycled to OFF then TEST. The BIT then registered GO, and subsequent system operation was normal. Another failure was detected during ground checking of a spare CDU. Four of the alpha-numeric tubes on the CDU display were found to be faulty and had to be replaced. SKD representatives stated that these tubes were supplied by a sub-contractor and were not subject to SKD quality control, other than normal pre-delivery system checks. The new tubes operated satisfactorily for the remaining 50 hours (approximately) of system operation at ARDU. Within the scope of the test program, system reliability was satisfactory. Deduction of accurate system reliability statistics would have required a much larger data base. Rigorous tests against the applicable requirements of AIR STD 53/9C (see Annex D, Serial 25) and AFSR 5006 (see Annex D, Serial 22) could not be conducted within the scope of the flight test program.

5.5.8 Electromagnetic Compatibility. A full EMC test would be very time-consuming and complicated. ARDU does not have the resources to perform a full EMC evaluation. The only electromagnetic interference observed was slight SHIU command bar movement when the VHF-AM radio was keyed on one occasion. There were no observable effects due to strobe light or other equipment operation. The electromagnetic compatibility of the system was assessed as satisfactory. The applicable requirements of AFSR 5006 were met (see Annex D, Serial 21).

5.5.9 Antenna (RTA) Alignment Procedures

5.5.9.1 The LDNS Antenna (RTA) is housed in a 'bucket' as described in paragraph 5.5.5.3. When fully fitted, the framework is designed to align the fore/aft axis of the RTA to less than ±0.1 degree relative to the aircraft longitudinal axis. There are two alignment holes on the port side of the 'bucket' through which two plumb lines fall to allow alignment with two top hat lugs located at Stations 38.00 and 205.06 under the aircraft main fuselage frame. On the prototype installation, the two holes on the RTA frame were not drilled correctly, causing an apparent misalignment of the RTA. Subsequent investigation and correct drilling allowed a correct alignment procedure to be completed. Annex H is the recommended alignment procedure. A Wild B3 theodolite was used to determine the alignment angles. Hawker de Havilland maintain that the alignment can be visually checked; however, by using a theodolite, a more accurate alignment can be achieved.

5.5.9.2 The recommended method of adjusting any RTA misalignment by manufacturing a new spigot plate was found to be time-consuming and not necessarily the most accurate way of correcting misalignment. In some cases, if the spigot plate was incorrectly made, the whole procedure would have to be restarted. A possible solution to this is being studied by HQSC.

5.5.9.3 A correct RTA alignment is essential for accurate navigation by the LDNS. Thus, if the tail boom is removed, an RTA alignment check should be completed.

5.5.10 Compass/LDNS Calibration Procedures. The development and evaluation of revised compass swing procedures for LDNS-equipped aircraft will be reported fully under Reference N. Irrespective of the course of action taken as a result of Reference N, Iroquois operating units may still find that significant LDNS errors occur for specific aircraft and LRU combinations. If this is the case, units should 'tune' the system by following the procedures laid down in Reference E, paragraphs 2-13h and 2-13i; that is, change the along track calibration correction and enter computed magnetic compass deviation corrections. These corrections should be applied only after a sufficient quantity of LDNS error data has been gathered to show consistency.

5.5.11 Use of 'Zipper-tubing'. Zipper-tubing was used to encase all main looming in the LDNS installation. The tubing was made from pliable black plastic and a 'press and seal' zipper was incorporated along the length of the tubing. The wires comprising the loom were surrounded by plaited wire braiding, earthed to the airframe, to reduce EMI. The zipper-tubing covered this braiding and the completed looms were then held in place by ADEL clamps and plastic cable tie straps. The zipper-tubing offered good protection of the enclosed looming, but slightly restricted the flexibility of the assembled loom. The zipper-tubing should increase the service life of the installed looming due to the extra protection afforded, and was satisfactory for use in this application.

6. CONCLUSIONS

6.1 General. The installation of the Lightweight Doppler Navigation System (LDNS) will increase significantly the mission effectiveness and capabilities of the RAAF UH-1H Iroquois fleet by providing crews with accurate navigation data in a readily usable format. However, several deficiencies associated with the installation will unless rectified, prevent realization of full system potential.

6.2 Enhancing Characteristics

6.2.1 The range of navigation information was comprehensive and well suited to tactical and SAR operations. In this respect, the introduction of the LDNS will significantly enhance tactical and SAR operations by RAAF UH-1H aircraft (paragraph 5.4.4).

6.2.2 The installation of the LDNS significantly increased the operational capability of the UH-1H by enhancing Night Vision Goggle operations (paragraph 5.4.5).

6.3 Unacceptable Characteristics

6.3.1 The initial lighting system for the Computer/Display Unit (CDU) panel and keyboard was unacceptable. The system was redesigned and modifications incorporated. A satisfactory system resulted (paragraph 5.1.5.2).

6.3.2 The excessive brightness of the MEM/MAL indicator lamps, combined with the requirement to select centre pedestal lighting ON during daylight operations, rendered the MEM/MAL lighting system unacceptable. Following modifications, the lights were slaved to the aircraft caution system. The modified system was satisfactory (paragraph 5.1.5.3).

6.3.3 Initialization and update procedures, other than the DIST/BRG/TIME method, were unacceptable for use in a tactical environment. Given thorough pre-flight planning, navigation using DIST/BRG/TIME updates was very effective during tactical flying (paragraph 5.4.3.5). This was satisfactory.

6.4 Unsatisfactory Characteristics

6.4.1 The position of the Steering and Hover Indicator Unit (SHIU) was unsatisfactory. Revised positioning will be assessed and reported under Technical Investigation No 817 (paragraph 5.1.2.2).

6.4.2 The position of the water motion switch was unsatisfactory (paragraph 5.1.2.3).

6.4.3 The initial layout of the DC circuit breakers was unsatisfactory. Following investigations by HQSC staff, modifications were made and a satisfactory arrangement resulted (paragraph 5.1.2.4).

6.4.4 The position of the AC circuit breaker was unsatisfactory. This deficiency was ultimately attributable to the poor positioning of the AC circuit breaker panel (paragraph 5.1.2.5).

6.4.5 The obscuration, caused by switch knobs, of several labels pertaining to the MODE and DISPLAY switches, when viewed from the pilot's or co-pilot's Design Eye Points (DEPs), was unsatisfactory (paragraph 5.1.3.1).

6.4.6 The obscuration of thumb-wheel letters and numerals, caused by reflections on the thumb-wheel windows during daylight operations, was unsatisfactory (paragraph 5.1.3.2).

6.4.7 Although unsatisfactory, obscuration of the CDU MEM light by the DIM control knob (as viewed from the co-pilot's DEP), was acceptable as the pilot easily detected the simultaneous illumination of the SHIU MEM light (paragraph 5.1.3.3).

6.4.8 The design of the SHIU control knob line-up marks was unsatisfactory (paragraph 5.1.3.6).

6.4.9 The SHIU groundspeed scale and pointer arrangement was unsatisfactory (paragraph 5.1.3.7).

6.4.10 The obscuration of SHIU TKE scale numerals was unsatisfactory (paragraph 5.1.3.8).

6.4.11 The labelling and readability of the SHIU GEO light was unsatisfactory (paragraph 5.1.3.9).

6.4.12 The lack of sufficient tactile cues when using the CDU keyboard push-buttons was unsatisfactory (paragraph 5.1.4.2).

6.4.13 The operation of the CDU thumb-wheels with a gloved hand was unsatisfactory (paragraph 5.1.4.3).

6.4.14 Reflections from the CDU displays were unsatisfactory. The deficiency was overcome by the incorporation of glare shields on the CDU (paragraph 5.1.5.4).

6.4.15 The failure of the LDNS to properly operate during straight and level flight over Sea States less then 3 was unsatisfactory (paragraph 5.3.3).

6.4.16 The procedure for entering waypoint variation was over-complicated and time-consuming, and therefore unsatisfactory (paragraph 5.4.3.3).

6.4.17 The procedure for programming wind, sea current and target motion was illogical and time-consuming, and therefore unsatisfactory (paragraph 5.4.3.4).

6.4.18 Although the ability to quickly store target position information was valuable in the tactical environment, the implications of the use of the feature, as mechanized in the LDNS, detracted from system utility, and the target store system was therefore unsatisfactory (paragraph 5.4.3.6).

6.4.19 The installation and removal procedures for the Receiver/Transmitter Antenna (RTA) and LDNS junction box were unsatisfactory (paragraphs 5.5.5.3 and 5.5.5.5).

6.5 <u>Satisfactory Characteristics</u>

6.5.1 Given the constraints of the cockpit, the CDU position was optimal for co-pilot use and was satisfactory (paragraph 5.1.2.1).

6.5.2 The labelling and readability of the keyboard push-buttons were satisfactory (paragraph 5.1.3.4).

6.5.3 The readability of the alpha-numeric displays was satisfactory (paragraph 5.1.3.5).

6.5.4 The legend abbreviations and keyboard arrangement were satisfactory (paragraph 5.1.3.10).

6.5.5 The aircraft attitude limits for normal LDNS operation were satisfactory (paragraph 5.3.1).

6.5.6 No specific limit on LDNS operation, attributable to altitude alone, could be found (paragraph 5.3.2).

6.5.7 The pre-flight and Built-In-Test (BIT) procedures were simple, quick and effective, and therefore satisfactory (paragraph 5.4.1).

6.5.8 Although satisfactory, the procedure for entering a large number of waypoints was not ideally suited to tactical UH-1H operations and could have been better 'streamlined' (paragraph 5.4.3.2).

6.5.9 The LDNS was well constructed (paragraph 5.5.1.2).

6.5.10 The installation and removal procedures for the Signal/Data Converter (SDC), CDU and SHIU were satisfactory (paragraphs 5.5.5, 5.5.5.2 and 5.5.5.4).

6.5.11 Within the scope of the test program, system reliability was satisfactory (paragraph 5.5.7).

6.5.12 The electromagnetic compatibility of the system was assessed as satisfactory (paragraph 5.5.8).

6.5.13 The use of zipper-tubing should increase the service life of the installed looming due to the extra protection afforded and was satisfactory in this application (paragraph 5.5.11).

6.6 Navigation Accuracies

6.6.1 The LDNS velocity accuracy did not meet the requirements of ASCC AIR STD 53/9C overland. This was unsatisfactory but acceptable for UH-1H operational roles.

6.6.2 The LDNS position accuracy overland in straight and level flight met the requirements of AFSR 5006 and was satisfactory.

6.6.3 The LDNS position accuracy in Nap of Earth (NOE) and overwater flight did not meet the requirements of AFSR 5006. The data base for NOE and overwater tests was too small for confident statistical analysis and further testing is required.

7. RECOMMENDATIONS

7.1 The SHIU should be repositioned to reduce parallax errors and bring the instrument closer to the visual scan used by the pilot for tactical flying. Revised positioning will be assessed and reported on under Technical Investigation No 817 (paragraph 5.1.2.2).

7.2 The water motion switch should be functionally grouped with either the CDU or SHIU. The better solution is for the switch to be placed on the right of the new CDU lighting panel (paragraph 5.1.2.3).

7.3 The AC circuit breaker panel should be moved to a position readily accessible to the pilot (paragraph 5.1.2.5).

7.4 The acquisition of equipments which have label obscurations should be avoided in future (paragraph 5.1.3.1).

7.5 The CDU thumb-wheel windows should be modified to prevent reflections obscuring the characters (paragraph 5.1.3.2).

7.6 Deficiencies similar to the poor design of the SHIU control knob line-up marks and VV/GS scale and pointer should be avoided in future designs (paragraphs 5.1.3.6 and 5.1.3.7).

7.7 Deficiencies similar to the poor labelling and readability of the SHIU GEO light should be avoided in future equipments (paragraph 5.1.3.9).

7.8 Future equipments intended for use in a high vibration environment should incorporate features to overcome inadvertent or incorrect data entry when using keyboard push-buttons (paragraph 5.1.4.2).

7.9 The thumb-wheels on future designs should be improved to be more compatible with use by a gloved hand (paragraph 5.1.4.3).

7.10 Notes should be included in Reference E, and Reference F amended, to reflect that AC power is required to be ON for full system check-out (paragraph 5.4.2).

7.11 The software programming of future navigation equipment should be thoroughly evaluated before being introduced to service, to eliminate the deficiencies found in the LDNS software program (paragraphs 5.4.3.2, 5.4.3.3 and 5.4.3.4).

7.12 The RTA alignment procedures (paragraph 5.5.9.2 and Annex G) should be revised to reduce the potential for error in manufacturing the spigot plate and thus reduce the time taken to correctly align the RTA.

7.13 Units should 'tune' the LDNS by following the procedures laid down in Reference E, paragraphs 2-13h and 2-13i (paragraph 5.5.10).

7.14 If the position accuracy of the LDNS in NOE and overwater flight is required to be known more accurately, further flight testing is recommended to determine the errors using a larger data base. (paragraph 5.2.5.1).

7.15 The Adour radars used to determine datum positions did not produce an accuracy, in position, one order of magnitude better than the LDNS position being measured. However, the datum velocity accuracy was 67 times the velocities being measured. With high accuracy navigation systems being tested, consideration should be given to the use of more accurate tracking systems.

8. REFERENCES

A. Air Force Staff Requirement No 5006 For Doppler Navigation Systems For UH-1H Iroquois Helicopters, November 1977

B. HQSC 3000/7/1-760 (4), Technical Investigation No 760, Evaluation of AN/ASN128 Lightweight Doppler Navigation System in UH-1H Iroquois Aircraft, 11 June 1981

C. Message TN466/CO ARDU, TI 760 Interim Report - LDNS in UH-1H, 3 May 1982

D. HQSC 2670/01/500-9 Pt2 (55), Minutes of a Meeting to Discuss Technical Investigation No 760, held at HQSC on 6 July 1982, 29 July 1982

E. DI(AF) AAP 7842.041-2M, Lightweight Doppler Navigation System (LDNS) K510A-009-01, 23 November 1981

F. DI(AF) AAP 7210.007-1, Flight Manual Iroquois UH-1H, dated 1 April 1974, amended to AL 18 of 18 October 1981

G. Department of Defence, Defence Science Technology Organization, Aeronautical Research Laboratories, 'Anthropometric Survey of RAAF Aircrew, 1971', Systems Note 51, July 1976

H. DI(AF) AAP 7645.025-2M, Datum Compass Part No B3 (Wild), 23 July 1973

I. No 9 Squadron Unit Maintenance Order 8-1

J. DI(AF) OPS 4-6, Operations and Operational Training, OPS 4-6, RAAF Aircraft Compasses, amended 8 October 1981

K. The Singer Company, Kearfott Division, 'Lightweight Doppler Navigation Systems (LDNS)', Publication ETO-1347, January 1982

L. United States Naval Test Pilot School, 'Human Factors Crew Station Evaluation Guide', January 1979

M. United States Army Directorate of Training Developments, Course Development Division, Fort Rucker, Alabama, 'Aircraft Modification/Preparation Requirements for Night Hawk/Night Vision Goggles Flight', File No 9405-0.5,January 1979

N. HQSC 3000/7/1-817 (4), Technical Investigation No 817, Evaluation of Proposed Instrument Panel Configuration Change, UH-1H Iroquois Aircraft, 23 August 1982

O. HQSC 3000/7/1-831 (4), Technical Investigation No 831, Development of an Electronic Compass Swing Capability for UH-1H LDNS-Equipped Aircraft, 16 November 1982

9. PROJECT PERSONNEL

Project Officer/Pilot. Flight Lieutenant L.R. Ward, AFC, BSc

Project Navigator. Flight Lieutenant K.W. McPherson, CGIA

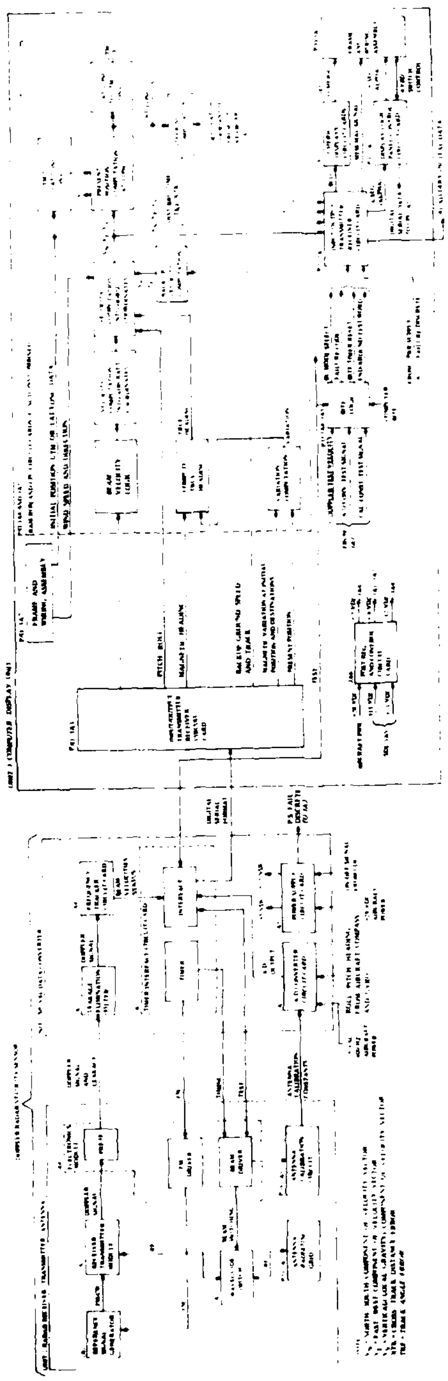
Project Engineers. Mr K. McLeod, CEng

Warrant Officer C.G.C. Short

Sergeant C.W. Lake

ANNEX A TO
REPORT NO TI 760

BLOCK DIAGRAM OF LDNS



RESULTS OF COMPASS SWING

Aircraft: A2-455

Date: 1 Jun 82

Location: Compass swing area, RAAF Base, Edinburgh, SA.

Results

Heading (deg)	Deviation (deg)
000	-0.2
030	-0.1
060	-0.1
090	-0.6
120	-0.0
150	-0.3
180	-0.0
210	-0.3
240	-0.1
270	-0.2
300	-0.8
330	-0.8

Computed Coefficients: A: -0.29
B: +0.11
C: -0.15
D: +0.20
E: +0.06

TAM 52
Revised Ju 79
Formerly A 254
Stock No 7530 66 091 4114

Department of Defence

COMPASS DEVIATION FOURIER ANALYSIS PROFORMA

Coeff A	= -0.3
$B^2 + C^2$	= 0.0[illegible]
$D^2 + E^2$	= 0.0[illegible]
ΣV^2	= 0.48

AIRCRAFT NO A2-455 CALIBRATION DATE 01JUN82

COMPASS TYPE SERIAL NO AN/ASN 43 ANALYSED BY FLTLT McPHERSON

TABLE 1 **CALCULATION OF COEFFICIENTS**

Hdg	Dev Obs (δ)		Sin	δ x Sin θ		Cos	δ x Cos θ		Sin	δ x Sin 2θ		Cos	δ x Cos 2θ	
θ	+	−	θ	+	−	θ	+	−	2θ	+	−	2θ	+	−
000		0.2	0.0	0.0	0.0	+1.0		0.20	0.0	0.0	0.0	+1.0		0.20
030		0.1	+0.5		0.05	+0.9		0.09	+0.9		0.09	+0.5		0.05
060		0.1	+0.9		0.09	+0.5		0.05	+0.9		0.09	−0.5	0.05	
090		0.6	+1.0		0.60	0.0	0.0	0.0	0.0	0.0	0.0	−1.0	0.60	
120		0.0	+0.9		0.00	−0.5	0.00		−0.9	0.00		−0.5	0.00	
150		0.3	+0.5		0.15	−0.9	0.27		−0.9	0.27		+0.5		0.15
180		0.0	0.0	0.0	0.0	−1.0	0.00		0.0	0.0	0.0	+1.0		0.00
210		0.3	−0.5	0.15		−0.9	0.27		+0.9		0.27	+0.5		0.15
240		0.1	−0.9	0.09		−0.5	0.05		+0.9		0.09	−0.5	0.05	
270		0.2	−1.0	0.20		0.0	0.0	0.0	0.0	0.0	0.0	−1.0	0.20	
300		0.8	−0.9	0.72		+0.5		0.40	−0.9	0.72		−0.5	0.40	
330		0.8	−0.5	0.40		+0.9		0.72	−0.9	0.72		+0.5		0.40
	0	3.5		1.56	0.89		0.59	1.46		1.71	0.54		1.30	0.95
SUMS	÷ 12	−3.5		÷ 6	0.67		÷ 6	−0.87		÷ 6	1.17		÷ 6	0.35
COEFF	A = −0.29			B = 0.11			C = −0.15			D = 0.20			E = 0.06	

TABLE 2 **CALCULATED DEVIATIONS AND COMPARISON WITH OBSERVED DEVIATIONS**

$B_1 = B \times 0.5 = +0.06$ $B_2 = B \times 0.9 = +0.10$ $C_1 = C \times 0.5 = -0.07$ $C_2 = C \times 0.9 = -0.13$ $D_1 = D \times 0.9 = +0.18$ $E_1 = E \times 0.5 = +0.03$

Hdg θ		000 +	000 −		030 +	030 −		060 +	060 −		090 +	090 −		120 +	120 −		150 +	150 −
Calculation of Deviations	+A		0.29	+A		0.29	+A		0.29	+A		0.29	+A		0.29	+A		0.29
	0	0.00	0.00	+B_1	0.06		+B_2	0.10		+B	0.11		+B_2	0.10		+B_1	0.06	
	+C		0.15	+C_2		0.13	+C_1		0.07	0	0.00	0.00	−C_1	0.07		−C_2	0.13	
	0	0.00	0.00	+D_1	0.18		+D_1	0.18		0	0.00	0.00	−D_1		0.18	−D_1		0.18
	+E	0.06		+E_1	0.03		−E_1		0.03	−E		0.06	−E_1		0.03	+E_1	0.03	
SUMS		0.06	0.44		0.27	0.42		0.25	0.39		0.11	0.35		0.17	0.50		0.22	0.47
Dev Cal (δx)		−0.38			−0.15			−0.11			−0.24			−0.33			−0.25	
Dev Obs (δ)		−0.20			−0.10			−0.10			−0.60			0.00			−0.30	
Res V (δ-δx)		+0.18			+0.05			+0.01			−0.36			+0.33			−0.05	
Res V²		0.03			0.00			0.00			0.13			0.11			0.00	

Hdg θ		180 +	180 −		210 +	210 −		240 +	240 −		270 +	270 −		300 +	300 −		330 +	330 −
Calculations of Deviations	+A		0.29	+A		0.29	+A		0.29	+A		0.29	+A		0.29	+A		0.29
	0	0.00	0.00	−B_1		0.06	−B_2		0.10	−B		0.11	−B_2		0.10	−B_1		0.06
	−C	0.15		−C_2	0.13		−C_1	0.07		0	0.00	0.00	+C_1		0.07	+C_2		0.13
	0	0.00	0.00	+D_1	0.18		+D_1	0.18		0	0.00	0.00	−D_1		0.18	−D_1		0.18
	+E	0.06		+E_1	0.03		−E_1		0.03	−E		0.06	−E_1		0.03	+E_1	0.03	
SUMS		0.21	0.29		0.34	0.35		0.25	0.42		0.00	0.46		0.00	0.67		0.03	0.66
Dev Cal (δx)		−0.08			−0.01			−0.17			−0.46			−0.67			−0.63	
Dev Obs (δ)		0.00			−0.30			−0.10			−0.20			−0.80			−0.80	
Res V (δ-δx)		+0.08			−0.29			+0.07			+0.26			−0.13			−0.17	
Res V²		0.01			0.08			0.00			0.07			0.02			0.03	

ANNEX C TO
REPORT NO TI 760

ASCC AIR STANDARD REQUIREMENTS

Serial	AIR STD	Paragraph	Requirements	Results	Conformance
	[illegible]30H	9a	Colour codes for visual signals:		
1			a. Cautionary Signal - Yellow or Amber.	MEM MAL lights amber.	Met
2			b. Advisory Signal - White or Blue for status.	[illegible] white.	Met
3		13a	Light signals not installed within pilot's basic flight instrument group.	Light signals not [illegible] within basic flight [illegible], dependent [illegible]	Met
4	10/3BC	8e	'Fly-to' principle to be used for direction indications.	All analogue presentation employed 'fly-to' principle.	Met
5		8f	Line-of-sight to any display preferably perpendicular, but never less than 4[illegible].	[illegible]	Met Met [illegible]
6	1[illegible]4[illegible]A	Annex A	Legend nomenclature as listed.	Abbreviations [illegible]	Met
7	10/62B	Annex A	Keyboard arrangement as illustrated.	Keys are arranged as illustrated.	Met
8	[illegible]	8a	Speed range for [illegible]: a. [illegible] b. [illegible]	[illegible] Not tested	Likely to meet [illegible]
9		8b	Velocity [illegible] normal flight attitudes, [illegible] tance 10 miles overland):		
10			a. [illegible]		Not Met
11			b. [illegible]		Not Tested
		8c	Maintain accuracies in Serial 10 and 11 with:		
12			a. Pitch attitude: ±[illegible] deg.	Operated satisfactorily up to [illegible] ft AGL.	Met
13			b. Roll attitude: ±30 deg.	Operated satisfactorily up to 5,000 ft AGL.	Met
14			c. Pitch rate: 20 deg/sec.		
15			d. Roll rate: 60 deg/sec.	Not rigorously tested, but accuracies not seriously degraded during low level tactical and NOE flying.	
16			e. Yaw rate: 30 deg/sec.		Expected to meet
17			f. Angular acceleration, from zero, any axis: 50 deg/sec^2.		
18		8d	Operate at altitudes from 10 feet to 10,000 feet above surface.	Operated satisfactorily.	Met
19		8e	Operate in all weather.	Not rigorously tested, but no effects due to weather were apparent.	Expected to meet
20		8f	Operate over: a. Land.	Operated satisfactorily over land.	Met
21			b. Ice.	Not tested.	-
22			c. Water (Sea State Beaufort 1,3 equivalent to AIR STD 53/14 and WMO Sea State 2).	Doppler constantly in memory mode during straight and level flight over Sea State 2.	Not Met
23			Incorporate means to correct ground speed when flying over sea.	Compensation for water motion incorporated.	Met
24		9a	Maximum system weight 80 pounds.	Combined weight of LRUs, in isolation, 30 lbs.	Met (LRUs in isolation)
25		9d	System reliability: not more than one failure per 1,000 hours of operation.	Not rigorously tested.	-
26		9e	Failure of equipment self evident, and fail 'safe' where possible.	BIT and MAL indicator lamp incorporated.	Met
27		9g	Transmit in the Ke frequency band which is centred at 13,[illegible] MHz.	Transmission frequency 13,3[illegible] MHz.	Met

ANNEX D TO
REPORT NO TI 760

SUMMARY OF STATEMENT OF CHARACTERISTICS FROM AFSR 5006

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]		
		[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	Met
		[illegible]	[illegible]	Met [illegible]
		[illegible]		
		[illegible]	[illegible]	Not Met
		[illegible]	[illegible]	Met
		[illegible]	[illegible]	Met
		[illegible]		
[illegible]		[illegible]	[illegible]	Not Met
[illegible]		[illegible]	[illegible]	Met
[illegible]		[illegible]	Displayed [illegible] and [illegible] employed	Met
[illegible]		[illegible] optional [illegible]	SHI [illegible]	Met
[illegible]		e. [illegible]	Displayed wind speed, direction and sea current speed direction or … for water …	Met.
	[illegible]	A[illegible]		
[illegible]		a. Radial error attributable to nav system itself, after exclusion of … setting errors, errors from the compass system or other sources, not to exceed …% of distance travelled. If error pattern … rather than circular, major axis of …% ellipse not to exceed …% of distance travelled.	…% [illegible]	Met.
		Accuracy …		
14		a. Accuracy … that achieved … of sea state … or greater. At lower sea states, some degradation permissible, … of the … and … limits	…% [illegible]	Not Met.
	[illegible]	Operations …		
[illegible]		a. Maintain … lowest possible value of sea state.	Did not operate satisfactorily below Sea State …	Not Met
[illegible]		b. Memory capability … drift and ground speed … event lock is broken.	Memory mode incorporated.	Met.
[illegible]		… system to search for and obtain lock-on with minimum delay, automatic lock.	Automatic lock incorporated but, for Sea State … or less, manual recycling was often required if … occurred.	Not Met.
18		d. Incorporate two-position Doppler bias correction for operations over sea or other surfaces of low reflectivity. Device to scale Doppler velocities in accordance with surface properties.	Compensation for water motion incorporated.	Met.
19		e. Operation of bias correction automatic if possible.	Manual operation only. Doubtful that the desired feature is feasible.	Not Met
	[illegible]	Compatibility		
[illegible]		a. Equipment fully compatible with helicopter operations.	Several deficiencies identified.	Not fully met.
21		b. Exhibit acceptable levels of EMI and EMC.	No significant EMI or … effects observed.	Met
	11	Reliability		
[illegible]		a. Total system MTBF at least … hours.	Not rigorously tested.	-
[illegible]	1[illegible]	Weight not greater than … kilograms.	Combined weight of LRUs, … installation, … kg.	Met (… installation …)
[illegible]	1[illegible]	Built-in Test Equipment (BITE) to give an accurate Go/NoGo check (95% confidence level).	BIT incorporated. 95% confidence level not rigorously substantiated.	Expected to meet
[illegible]	14	Faulty LRU replacements and BITE checkout within … minutes.	RIA replacement took … minutes. Junction box removal and installation took 45 minutes.	Not Met.
2[illegible]	15	Comply with MIL-STD-1472 and MIL-H-46855.	Not rigorously tested, but SKD claim compliance.	Met (SKD claim).

TEST METHODS - LDNS NAVIGATION ACCURACIES

1. General

1.1 Overland navigation accuracy tests (groundspeed and position) were conducted in the Woomera, SA area, using the range facilities provided by the Trials and Technology Support Division (TTSD) of DRCS AEL. The aircraft was tracked by kinetheodolites for the groundspeed tests and by radars for some of the position accuracy tests. The kinetheodolites and radars established datum groundspeeds and geographical positions respectively. Except where stated otherwise, LDNS-derived navigation information was automatically recorded by a data logger developed by ARDU RDF. As the radars were unable to track the aircraft below 100 ft Above Ground Level (AGL) because of ground clutter, known surveyed geographical features were overflown to establish datum positions for the low level test flights.

1.2 A lack of suitable tracking equipment precluded comprehensive testing of LDNS groundspeed and position accuracies overwater; however, limited position accuracy tests were completed by using lighthouses as datum geographical positions.

1.3 In all tests, the Australian National Spheroid (ANS) was selected in the LDNS CDU as the LAT/LONG basis for commonality with datum fixing which was all referenced to ANS.

2. Groundspeed Accuracy Tests - Overland

2.1 Table 2.1 lists the nominal heights AGL and groundspeeds used for these tests. The tests were flown over a pre-determined track of two kilometres length. Entry and exit gates to the track were marked on the ground by a series of white tyres as shown in Figure 2.1. The track was oriented 330°T/ 150°T. As groundspeed was considered to be independent of track direction, data was collected on flights in both directions. Changes of groundspeed were made during procedural turns and a straight track of not less than 30 seconds flight time was flown immediately preceding the entry gate to each data collection run. The kinetheodolites tracked, and made a cine film record of, the aircraft during the runs from -4 seconds to +60 seconds (or 2 km, whichever was the shorter) relative to the start gate for each run.

TABLE 2.1 - NOMINAL HEIGHTS AND GROUNDSPEEDS
(GROUNDSPEED ACCURACY TESTS)

Height (ft)	Groundspeed (kn)	Configuration
10	10, 20, 30, 40, 50, 60, 70, 80	Clean
50	30, 40, 50, 60, 70, 80, 90, 100	
500	50, 60, 70, 80, 90, 100, 110, 120	
5,000	80, 90, 100, 110	
500	30, 40, 50, 60, 70, 80, 90, 100,	With external Load

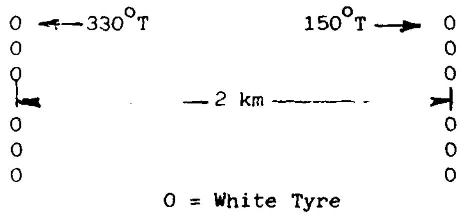


FIGURE 2.1 - DIAGRAM OF TRACK USED FOR GROUNDSPEED TESTS

2.2 Heights from 10 ft to 500 ft AGL were maintained by reference to the radar altimeter. At 5,000 ft AGL the airborne reference was the barometric altimeter with the local helipad pressure (QFE) set on the subscale. Indicated height was maintained within the following limits:

a. 10 ±3 ft AGL;

b. 50 ±10 ft AGL;

c. 500 ±20 ft AGL; and

d. 5,000 ±50 ft AGL.

2.3 To minimize errors due to aircraft pitching, the pitch attitudes (and indicated airspeeds) required for the various nominal groundspeeds were established before the start of each run, and maintained with minimal changes.

2.4 The aircraft was flown both in a clean configuration and with an external load of 4 x 44 gallon drums contained in a A22 bag and suspended by a six metres (approximately) strop. The load was carried to determine the effects, if any, on LDNS accuracy due to interference caused by metallic objects entering the Doppler radar beams. The load was not representative of the large range of equipment cleared for external load operations by UH-1H aircraft.

3. Position Accuracy Tests - Overland

3.1 Table 3.1 lists the nominal heights AGL and groundspeeds used for the overland position accuracy tests. Reference heights and limits were established as per paragraph 2.2.

TABLE 3.1 - DIRECTIONS, HEIGHTS AND GROUNDSPEEDS USED IN POSITION ACCURACY TESTS (OVERLAND)

Track (°T)	Height AGL (ft)	Nominal Groundspeeds (kn)	Configuration
305	10	60, 75, 100	Clean
and	50	70, 85, 100	
125	500	80, 90, 100, 110	
	5,000	80, 90, 100, 110	
305 and 125	500	80, 90, 100, 110	With external Load

3.2 The tests at 500 ft AGL and 5,000 ft AGL were flown over a predetermined straight track of approximately 37 km length, oriented 305°T/125°T. This track is shown in Appendix 1, Figure 1. A DRCS Air Direction Officer (ADO) monitored the position of the aircraft as derived by the tracking radars and displayed in real time on a plotting table. The ADO advised the aircraft crew of any cross-track deviations observed. This enabled the crew to maintain the aircraft within 200 m of the desired track by using bank angles and heading changes of less than five degrees.

3.3 The tests at 10 feet and 50 feet were flown over the same track, but for a shorter distance (22 km), because of insufficient terrain features. Track was maintained to within 10 m by visually overflying a straight dirt road. Ground features along the dirt road, such as cattle grids and fence gates, were used as datum geographic positions. The LDNS-derived present position was manually recorded on prepared data cards as the aircraft was called 'on top' the various features by visual reference.

3.4 As the position accuracy of the LDNS was suspected to be heading dependent, tests at each height and groundspeed combination were flown once in each direction, so that any heading dependency at a height and groundspeed combination might be detected. Changes of height and groundspeed were made (if required) during procedural turns at the end of each run. The aircraft was maintained in straight flight for at least one minute before the start of a run to allow the AN/ASN-43 compass sufficient time to settle on heading. The LDNS-derived groundspeed was used as the airborne reference for attaining the desired nominal groundspeed.

3.5 The external load described in paragraph 2.4 was also carried for one series of radar-tracked position accuracy test flights.

3.6 In addition to the essentially straight and level test flights listed in Table 3.1, typical tactical mission profiles were also flown to evaluate system performance in a simulated combat scenario. These profiles primarily involved terrain flight, including contour flying at 50 ft above obstacles and Nap of Earth (NOE) flight. Known geographical features (cattle grids, fence gates, survey trigonometrical points, road intersections) were used as turning points for these flights. The area and turning points used are shown in Appendix 1, Figure 2. The Universal Transverse Mercator (UTM) grid references of the features were entered as waypoints in the LDNS CDU. The aircraft was flown to each turning point feature by visual reference and the LDNS-derived present position was manually recorded on prepared data cards as the aircraft passed 'on top' the particular feature. The terrain flight (especially NOE) involved considerable manoeuvring, height and groundspeed changes.

4. Position Accuracy Tests - Overwater

4.1 Appendix 1, Figure 3 shows the routes used for overwater position accuracy tests. For these tests, the aircraft was configured with float landing gear. Tests were not conducted to determine the effect, if any, of the floats on the Doppler signal. The tests were flown at a nominal height of 3,000 ft Above Sea Level (ASL). If Doppler unlock occurred when overwater, the Doppler system was recycled (to TEST and then back to LAT/LONG after 'GO' was obtained). If lock was still not obtained, the aircraft was flown at progressively lower heights until the LDNS locked on to the returned Doppler radar beams. The aircraft barometric altimeter, set to the local area Mean Sea Level (MSL) pressure (QNH), was used as the height reference for flight above 1,500 ft. The aircraft radar altimeter was used as the height reference for flight at or below 1,500 ft.

4.2 During the overwater test flights, lighthouses were used for datum geographic positions and turning points. The geographic positions of the lighthouses were obtained from the Admiralty List of Lights and Fog Signals, NP 83, Volume K, 1979, Indian and Pacific Oceans, South of the Equator. The Lat/Long of the lighthouses were entered as waypoints in the LDNS CDU. The aircraft was flown from lighthouse to lighthouse by reference to the LDNS navigation information until the turning point was visually acquired. The aircraft was then flown to the turning point by visual reference and the LDNS-derived present position was manually recorded on prepared data cards as the aircraft passed 'on top' the particular lighthouse.

4.3 The LDNS had the facility to enter sea current and wind speed/direction into the CDU for water motion corrections. Dopplers measure velocity relative to the terrain below the aircraft. If the sea beneath the aircraft is moving, its motion must be considered when deriving position from the Doppler information. Sea movement takes two basic forms; tidal flow and water transport. Tidal flow is a general name encompassing ocean currents and tidal flows in rivers and estuaries. It may be corrected for by applying a downstream vector to the indicated Doppler position. Although wave motion basically involves vertical motion only, wind across the surface of the water causes eddies with water motion downwind on the surface and upwind below the surface. Doppler energy is reflected by the surface and hence measurements are made relative to the moving surface. Correction can be made by correcting the Doppler position with a downwind vector using the surface wind direction and a fraction of the surface wind speed (usually one-fifth). SKD used 0.9 $(\text{windspeed})^{1/2}$. The actual sea current and water motion corrections were entered directly into the CDU and stored in the computer memory. The CDU completed the necessary computations to adjust the Doppler position for the corrections only when the Water Motion Switch was switched to the 'ON' position. For the overwater tests, the sea current for the test area was obtained from the South Australian Department of Marine and Harbours who used Admiralty charts to derive the current. The surface wind, provided by the local Bureau of Meteorology, was confirmed by the crew by visual observation of the sea surface before insertion into the CDU. The Water Motion Switch was switched 'ON' when the Doppler beams from the RTA were considered to be clear of land.

5. Special Test Equipment

5.1 Data Logger. A data logger developed by ARDU RDF was used to record the Auxiliary Digital Data output of the LDNS CDU, at a sampling rate of one data set per second referenced to Greenwich Mean Time (GMT). The GMT time signal was obtained from a Speech Time Recorder (STR). The STR clock was synchronized with the Woomera range time datum (a Field Master Clock) before and after each flight involving automatic recording. No drift was noted for any of the synchronizations. Data recorded by the data logger, kinetheodolites and radars was correlated by reference to GMT for analysis. The following set of parameters was recorded by the data logger at each sampling (accuracies shown in parentheses):

a. Greenwich Mean Time (0.1 sec);

b. distance to go (0.01 n mile);

c. groundspeed (1 kn);

d. UTM Northings (four figures);

e. UTM Eastings (four figures);

f. distance off course (0.1 n mile);

g. calculated course between waypoints (0.1°);

h. track angle error (0.1°);

i. heading velocity (0.1 km/h);

j. drift velocity (0.1 km/h);

k. vertical velocity (0.1 km/h); and

l. 100 km square identifier.

5.2 Kinetheodolites. For the groundspeed test described in paragraph 2.1, datum groundspeeds were derived from measurements made by two Contraves kinetheodolites. The kinetheodolites tracked the aircraft in azimuth and elevation and recorded the data on cine film every 0.1 sec. The data was reduced to give aircraft velocities in X, Y, Z planes (X plane being the ground track over which the aircraft flew) and total velocity.

5.3 Tracking Radars. For the position accuracy tests described in paragraph 3.2, the datum geographic positions were derived from measurements made by two Adour precision tracking instrumentation radars. The radars tracked the aircraft continuously throughout each run. The bearings and ranges obtained from the radars were converted to geographical co-ordinates and height above MSL. The geographical positions were presented in latitude and longitude, and UTM co-ordinates based on the ANS.

6. Airborne Height References

6.1 Radar Altimeter. An AN/APN-109(V) radar altimeter installed in the aircraft was used as the datum height reference as described in paragraphs 2.1, 3.1 and 4.1. As there were no RAAF calibration tests for the AN/APN-109 (V), the radar altimeter reading was checked at zero on the ground before each flight. The heights indicated on the radar altimeter during flight were assumed then to be correct.

6.2 Barometric Altimeter. Two Kollsman Instrument Corporation barometric altimeters type E.22061-04-018 installed in the test aircraft were used for datum height reference for tests above 1,500 feet AGL. Barometric altimeters are calibrated during bay servicing before fitment to aircraft. The serial numbers and dates of fitment of the barometric altimeters used in the flight tests were:

a. Pilot Altimeter: Serial No 34951 fitted 16 Sep 81.

b. Co-pilot Altimeter: Serial No 34903 fitted 22 Mar 82.

7. Datum Accuracies

7.1 Datum Accuracies Required. As a general principle, a datum should be accurate to one order of magnitude better than the resolution of the parameter being measured. The LDNS CDU displayed groundspeed in knots or km/h to 1 kn or 1 km/h respectively. The heading, drift and vertical velocities (output from the CDU) were recorded by the data logger to 0.1 km/h. The datum speed should have been accurate, therefore, to 0.1 kn or 0.1 km/h for groundspeed and 0.01 km/h for heading, drift and vertical velocities. The LDNS CDU displayed position in latitude and longitude to 0.1 minute of arc (185 m) and in UTM to 10 m for Eastings and Northings. The datum positions should have been accurate, therefore, to 0.01 minute of arc (18.5 m) for latitude and longitude or one metre for UTM position.

7.2 Datum Accuracies Achieved. The velocities derived from kinetheodolite data were accurate to 0.2 m/s, 0.72 km/h (90% confidence). The geographic positions derived from tracking radar data were accurate to 30 m (90% confidence). The positions of features used for visual 'on tops' for the tests described in paragraphs 3.3 and 3.6 were taken from an Australian 1:50,000 Topographic Survey Map, Hanson, South Australia, Series R742, Sheet 6136-II, Edition 2-AAS, dated 1981. Map accuracy was given as: 90% of well defined detail lie within ±12.5 m of the true position. Build-up flights at Edinburgh indicated that the aircraft could be judged visually 'on top' a ground feature to within ±5 m for flight at or below 100 ft AGL. The datum position accuracy for low level overland flights was, therefore, ±17 m, which was within the desired accuracy. For the overwater tests (paragraphs 4.1 and 4.2), lighthouse positions were given to the nearest 0.1 minute of arc in the Admiralty List, and the aircraft could be judged to be visually 'on top' the lighthouse to within ±50 m, giving an overall datum position accuracy of approximately ±250 m. The datum accuracies required and achieved are summarized in Table 7.1.

TABLE 7.1 - DESIRED AND ACHIEVED DATUM ACCURACIES

Parameter	Desired Accuracy	Achieved Accuracy (90% confidence level)
Groundspeed	0.03 m/s	0.34 m/s
Velocity X, Y, Z	0.003 m/s	0.20 m/s
Overland position-Lat/Long	0.01 minute of arc (18.5 m)	30 m (radar) 17 m (visual)
Overland position-UTM	1 m	30 m (radar) 17 m (visual)
Overwater position-Lat/Long	0.01 minute of arc (18.5 m)	250 m (visual)

8. Crew Duties

8.1 The flight tests for navigation accuracies required four crew members. The crew duties were:

a. Pilot: Overall command and flying.

b. Navigator: Recording LDNS CDU digital readouts, monitoring groundspeed and height during data collection runs.

c. Radio Technician: Operation and maintenance of data logger.

d. Crewman Technical/Flight Fitter: Normal duties for UH-1H operations.

9. Data Analysis

9.1 Velocity Tests

9.1.1 The kinetheodolites used for the velocity tests were unable to determine the fore and aft axis of the aircraft Thus, the aircraft rotor head was used as the datum aircraft reference point for all velocity tests. The datum velocity of the aircraft was determined in three orthogonal axes, X axis being the aircraft track over the ground (forward positive). The three LDNS velocities were recorded by the data logger. The velocity used by the LDNS for computations was calculated in three orthogonal axes, X being the aircraft heading (fore/aft axis). Therefore, no direct comparison of the velocities in each plane could be made. However, the total velocities for each run were calculated by Root Sum Squaring (RSS) the individual orthogonal velocities for the kinetheodolite-derived velocities and the LDNS velocities.

9.1.2 As GMT was recorded by the kinetheodolites and the data logger, time was used to correlate datum velocities and the LDNS velocities. Velocity error was calculated by subtracting the datum kinetheodolite velocity from the LDNS velocity for a particular time. For each run, an arithmetic mean and standard deviation were calculated. The velocity errors for runs at each height and velocity were combined statistically and an arithmetic mean and standard deviation calculated. All runs were combined statistically (excluding the runs where an external load was carried) to find an overall arithmetic mean and standard deviation of velocity errors. A Least Squares Straight Line (LSSL) fit to observed doppler velocity errors against actual velocity was made to determine scale factor error, bias error and spread of velocity errors about the LSSL, to comply with ASCC AIR STD 53/12A method of presenting Doppler velocity errors. A comparison was made between the 500 feet (without an external load) run and the 500 feet (with an external load) run to determine if the load affected the velocity accuracy of the LDNS. A comparison was also made to the AFSR 5006 requirements. A Student 't' test of means was used to determine if a significant statistical difference existed between the AFSR mean and the observed mean. Similarly, a Fisher (F) test of standard deviations was used to determine any significant statistical difference between standard deviations.

9.2 Position Tests - General Analysis

9.2.1 In general, ASCC AIR STDs require that Doppler position accuracy be determined from fixes not less than 18.5 km (10 n miles) apart. This usually allows any perturbations in localized compass deviations to be averaged out over that distance. As the aim of this trial was to test the LDNS over a variety of operational roles, time did not allow an analysis based on a minimum of 18.5 km between fixes. For the medium level tests, tracked by the Adour radars, 5 km was used between fixes, for the analysis. At low level, the average distance between fixes was 3 km. The NOE tests used an average of 6 km between fixes. The overwater fixes were greater than 18 km apart.

9.2.2 All data reduction and analysis were referenced to ground level, using the ANS as the common spheroid. All calculations were completed using UTM co-ordinates. Height error caused by the aircraft being at height was less than 0.03% at 5,000 ft and was disregarded in all calculations.

9.2.3 For all position accuracy tests, a mean and standard deviation of Along Track Error (ATE), Cross Track Error (CTE) and Radial Error (RE) expressed as percentages of Actual Distance Gone (ADG), were calculated for each run. By statistically comparing each mean and standard deviation, runs were combined where possible. If a compass error was present, the CTE (right or left of track) would be the opposite sign on reciprocal tracks. Thus, to combine runs of reciprocal tracks, the absolute values of CTEs were used for statistical comparison. However, for the final analysis, the signs of the CTE for each run were unchanged to present an overall CTE.

9.2.4 The overall arithmetic mean and standard deviation of each error were calculated for all runs. Overland, overwater and NOE results were produced separately to show any marked differences. If the overall mean was not zero, the cause of the error was investigated The error can be caused by a misalignment of the heading reference system, incorrect datum co-ordinates or some other abnormal system condition. The standard deviation (1σ) was converted to Circular Error Probable (CEP) or 50% level of confidence using the conversion factor 0.8326. The CEP is an indication of the pure system error.

9.2.5 The mean and CEP of observed errors (expressed as percentages of ADG) were compared to the AFSR 5006 requirements. The AFSR requirement was $\pm$0.5% of ADG. No confidence level was given (for example at 1σ or CEP). Thus a direct comparison was not possible technically. However, a CEP of $\pm$0.5% was assumed

9.3 Position Tests Overland

9.3.1 For the medium level tests, the Adour radars were used to determine position in Eastings, Northings and height (AGL). The data logger recorded position in Eastings and Northings. Time in GMT was recorded on the radar tapes and the data logger, and was used to correlate datum and LDNS positions.

9.3.2 For each run the first datum fix was used as the origin for the run. The corresponding first LDNS position fix was corrected to the first datum fix. The correction vectors were applied to each subsequent LDNS position in that run. ATE and CTE were then calculated. The RE was the RSS of ATE and CTE.

9.3.3 The low level tests used 'on top' position calls to event the data logger. Positions were extracted from the data logger and errors established in the same method as the medium level tests.

9.3.4 The NOE tests used the same eventing procedure as the low level tests. The distance flown between fixes was determined from the data logger recording of position every second. The distance between the positions recorded every second was determined and accumulated for the period between evented fixes. Whilst not ideal, no other method of accurately determining ADG was available. Analysis was then completed as above. The NOE tests were used to determine if constant aircraft manoeuvring (heading, pitch, roll and altitude) had an effect on position accuracy.

9.3.5 Position accuracy tests were conducted with the aircraft carrying an external load to determine if the load affected the position accuracy. Analysis of data was the same as for the other overland tests. A comparison was made between similar runs with and without an external load to determine any significant difference.

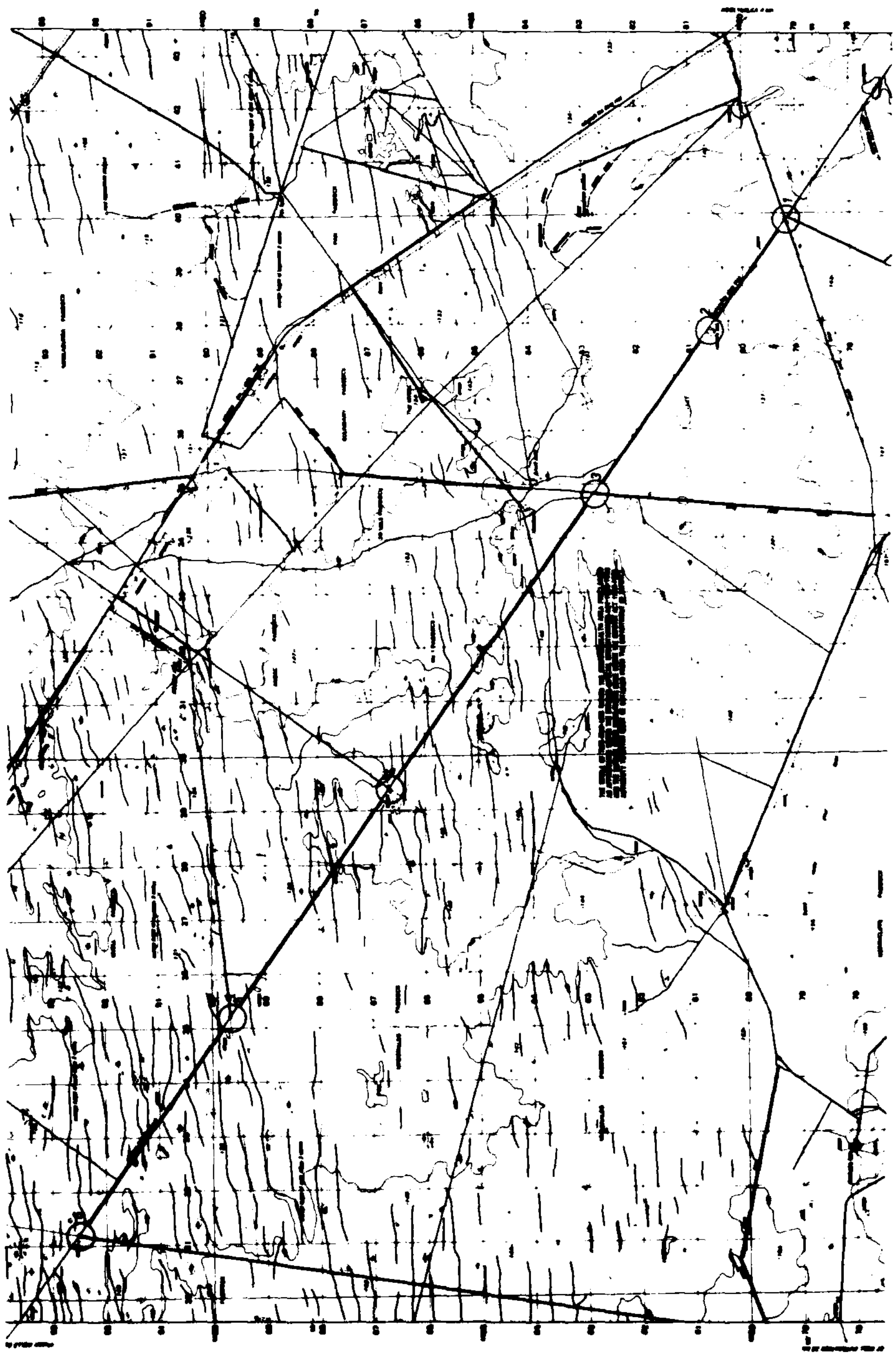
9.4 Position Tests Overwater

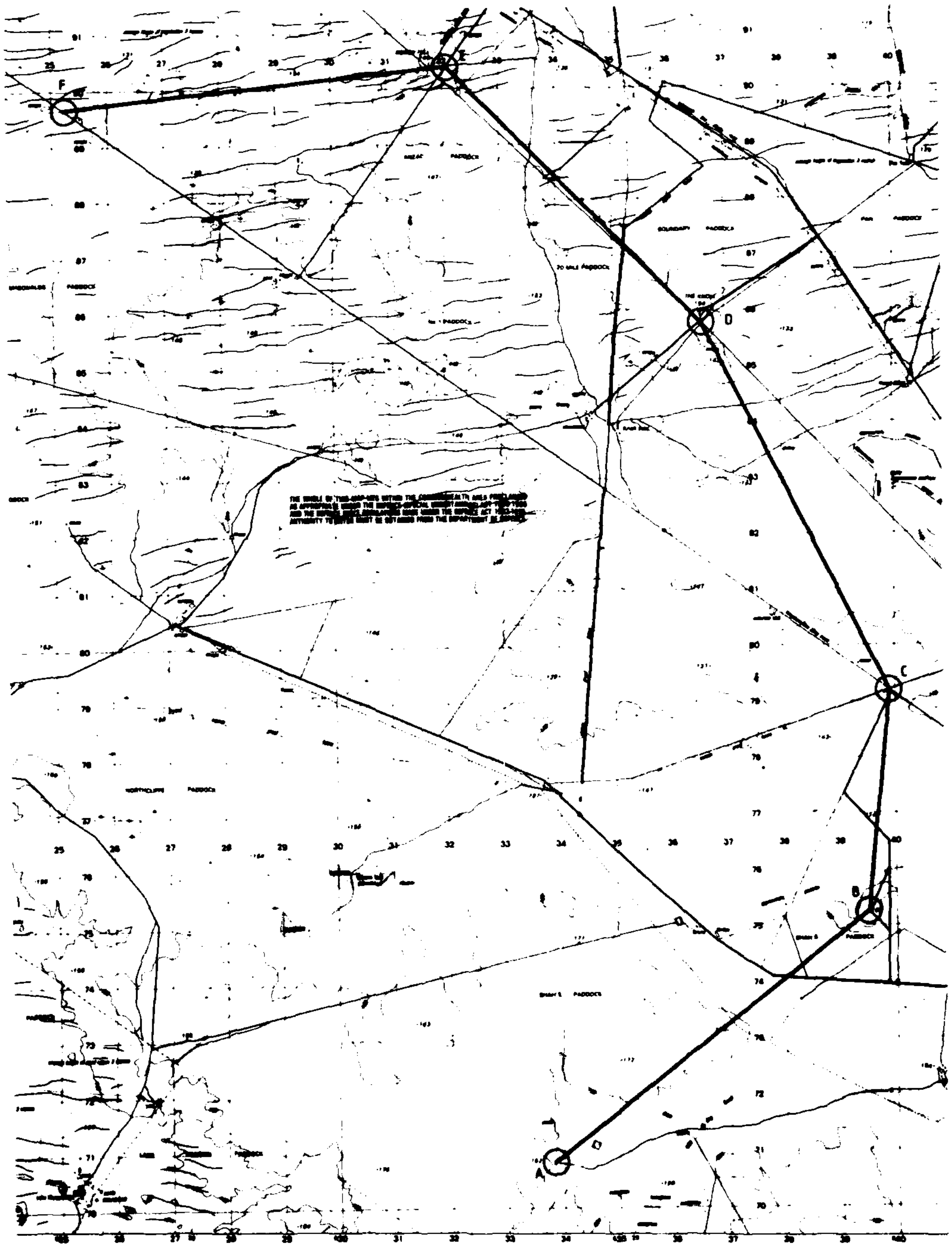
9.4.1 The aim of determining position error overwater was to establish if flight overwater affected the Doppler radar signals and to what extent this might affect position errors. To test this aspect of the LDNS effectively, flights had to be well clear of land so the Doppler radar beams were not reflecting from the coastline and the beams were over representative sea conditions. In the time available, testing over a wide range of sea states was not possible. No datum instrumentation was available to establish position overwater. Thus, lighthouses were used as datum positions. In the area and time available for flight testing, a limited number of fixes was taken. Data analysis assumed the aircraft tracked directly between lighthouses, as no accurate method of determining the track flown was available. Data reduction used latitude and longitude instead of Eastings and Northings. Analysis was the same as the overland position analysis.

Appendix: 1. Flight Routes Used for TI 760

APPENDIX 1 TO
ANNEX E TO
REPORT NO TI 760

FLIGHT ROUTES USED FOR TI 760

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B
C
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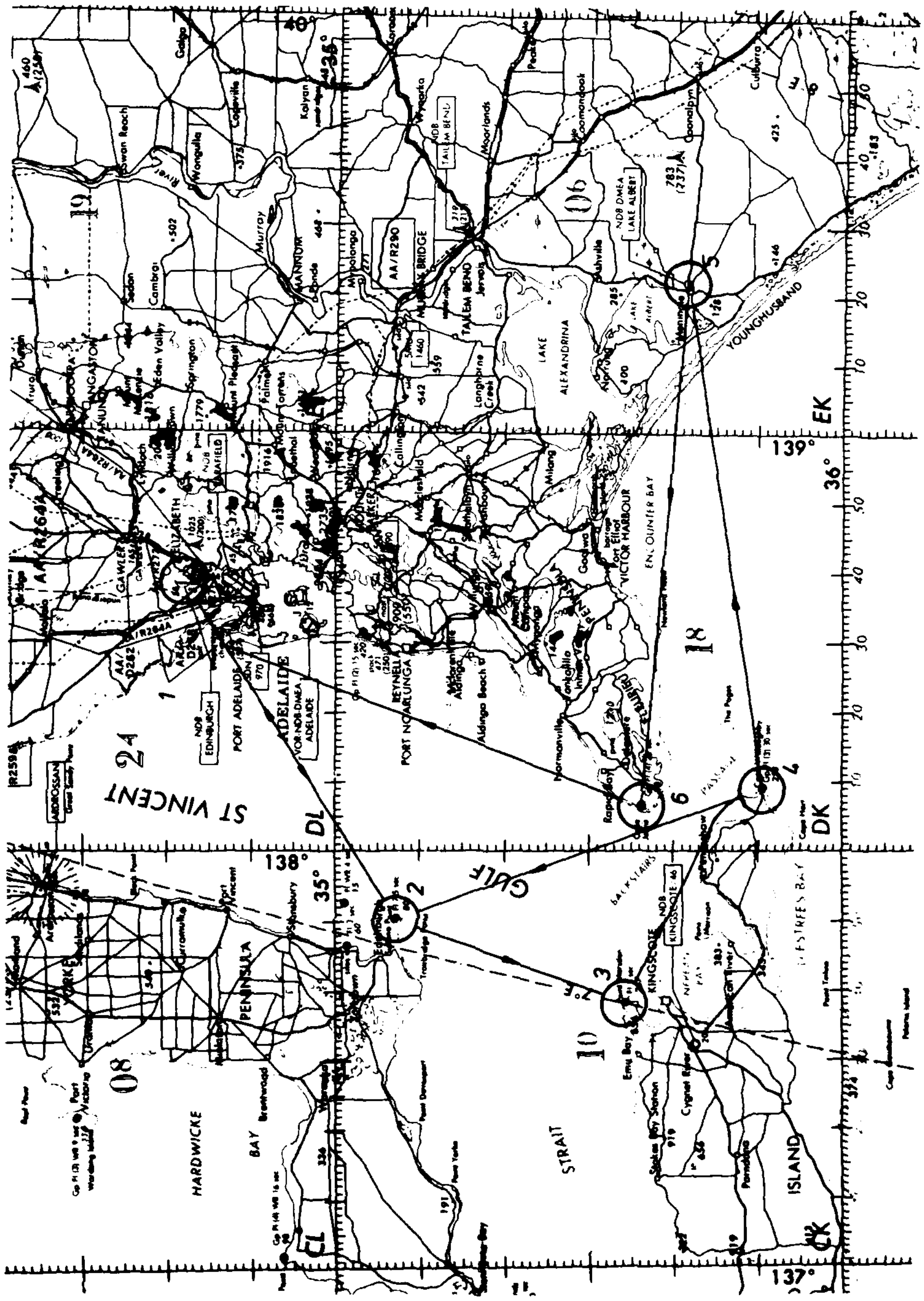
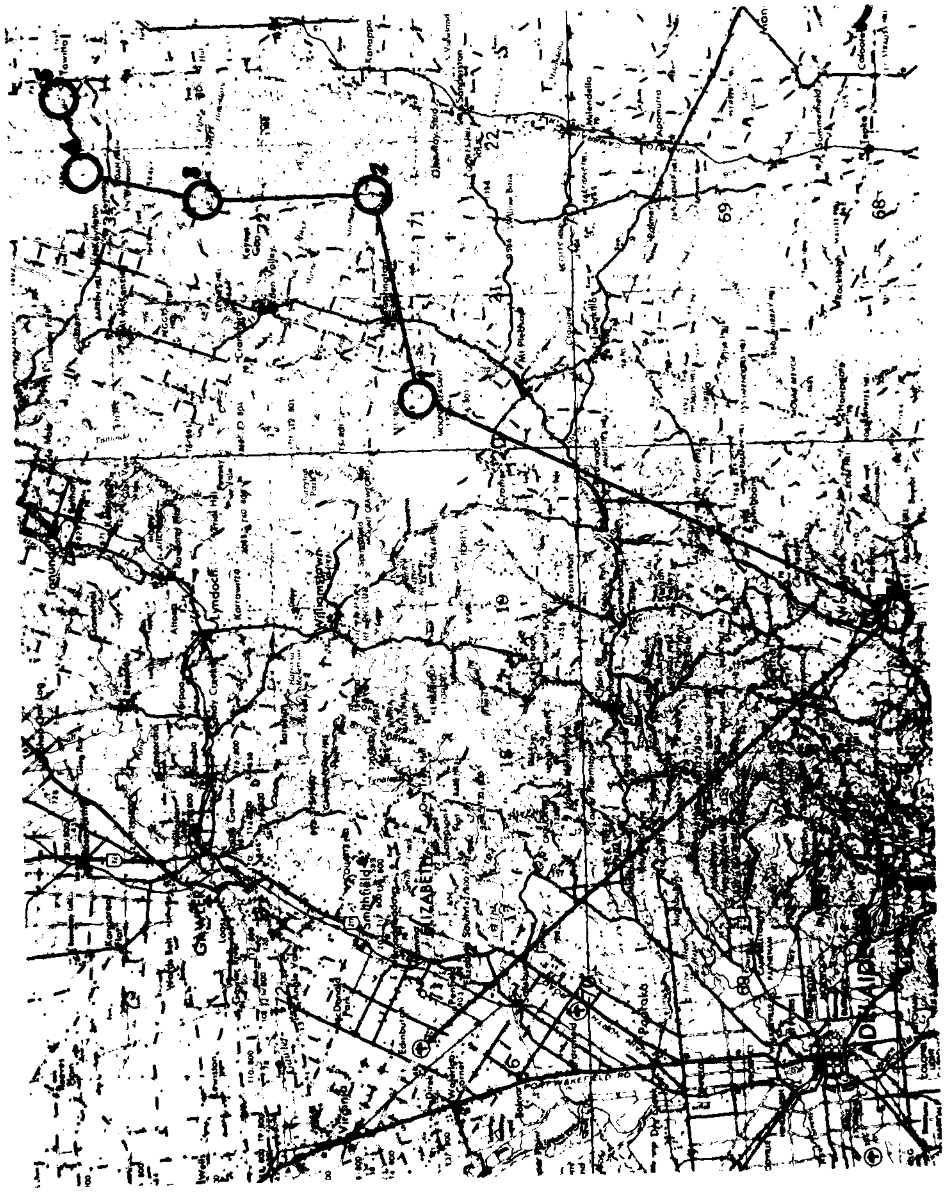
E
F


ST VINCENT
GULF
STRAIT
LAKE ALEXANDRINA
ENCOUNTER BAY
VICTOR HARBOUR
PORT ADELAIDE
ADELAIDE
PORT NOARLUNGA
HARDWICKE
BAY
ISLAND
KINGSCOTE
YOUNGHUSBAND
138°
139°
137°
35°
36°

ANNEX F TO
REPORT NO TI 760

ROUTE USED FOR NVG OPERATIONS



LDNS VELOCITY AND POSITION ACCURACY RESULTS

TABLE G.1 - DOPPLER GROUNDSPEED SENSOR ERRORS

OVERLAND

Groundspeed Total (m/s)	Bias (m/s)		Scale Factor (%)		Residual (m/s)	Sample Size
	μ	σ	μ	σ	σ	
+5.1 to 61.8 (Clean Configuration)	-0.06	0.002	0.19	0.10	0.001	1,216
+15.4 to +51.4 (External Load)	-0.20	0.007	0.19	0.11	0.004	418

Direction	Medium Level CTE (%ADG ±%CEP)	Low Level CTE (%ADG ±%CEP)	Medium Level ATE (%ADG ±%CEP)	Low Level ATE (%ADG ±%CEP)	Medium Level RE (%ADG ±%CEP)	Low Level RE (%ADG ±%CEP)
$125^{o}T$	-0.32 ±0.25(1)	+1.41 ±0.34	-0.15 ±0.15(2)	-0.09 ±0.15	0.44 ±0.20	1.42 ±0.34
$305^{o}T$	+0.20 ±0.23	-0.19 ±0.27	-0.23 ±0.13	-0.08 ±0.27	0.41 ±0.13	0.41 ±0.24
$125^{o}T/305^{o}T$	-0.05 ±0.33	+0.62 ±0.74	-0.19 ±0.14	-0.08 ±0.22	0.43 ±0.17	0.93 ±0.52
Overall	0.28 ±0.64		-0.49 ±0.35		0.67 ±0.43	

Notes: 1. Negative equals left of track made good

2. Negative equals less than ADG.

TABLE G.2 - POSITION ACCURACY RESULTS - OVERLAND STRAIGHT AND LEVEL

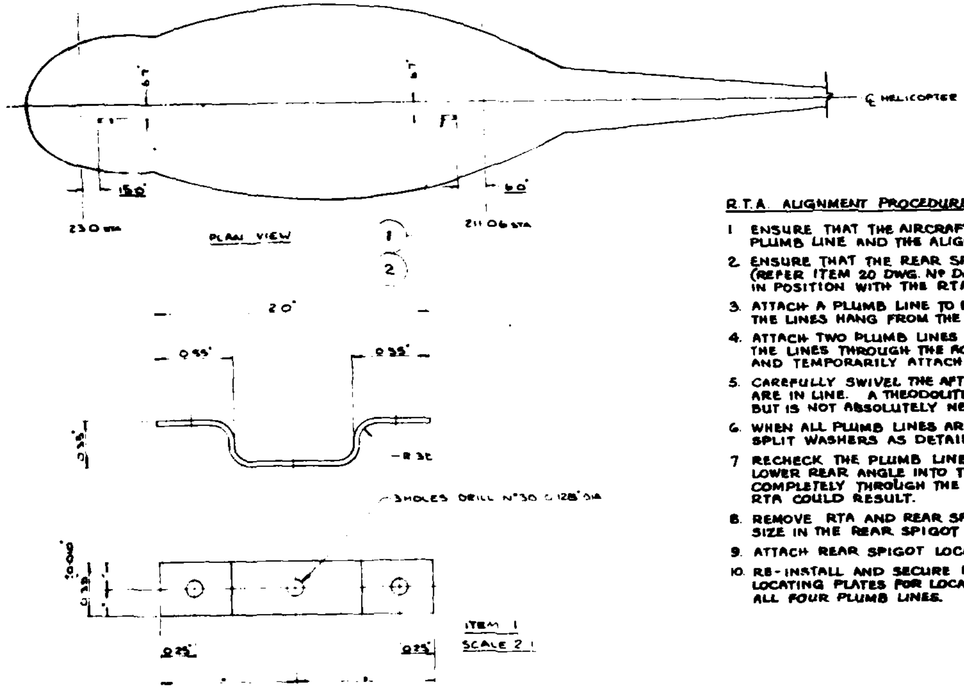
Direction	CTE No Load (%ADG ±%CEP)	CTE With Load (%ADG ±%CEP)	ATE No Load (%ADG ±%CEP)	ATE With Load (%ADG ±%CEP)	RE No Load (%ADG ±%CEP)	RE With Load (%ADG ±%CEP)
$125^{o}T$	−0.35 ±0.32(1)	−0.58 ±0.10	−0.29 ±0.11(2)	−0.28 ±0.06	0.56 ±0.20	0.65 ±0.10
$305^{o}T$	−0.03 ±0.10	+0.52 ±0.25	−0.34 ±0.08	−0.41 ±0.10	0.36 ±0.09	0.67 ±0.24
$125^{o}T/305^{o}T$	−0.19 ±0.27	+0.02 ±0.49	−0.32 ±0.10	−0.35 ±0.10	0.46 ±0.21	0.66 ±0.19

Notes: 1. Negative equals left of track made good.

2. Negative equals less than ADG.

TABLE G.3 - POSITION ACCURACY RESULTS - WITH AND WITHOUT AN EXTERNAL LOAD

IROQUOIS LDNS RECEIVER/TRANSMITTER ANTENNA ALIGNMENT PROCEDURE



R.T.A. ALIGNMENT PROCEDURE.

1. ENSURE THAT THE AIRCRAFT IS HORIZONTALLY LEVEL USING A PLUMB LINE AND THE ALIGNMENT POINTS IN THE CABIN.
2. ENSURE THAT THE REAR SPIGOT LOCATING PLATE DA8180112-31 (REFER ITEM 20 DWG. Nº DA8180112) IS ONLY TEMPORARILY SET IN POSITION WITH THE RTA SAT IN THE MOUNTING.
3. ATTACH A PLUMB LINE TO EACH ALIGNMENT BRACKET ENSURING THAT THE LINES HANG FROM THE INBOARD EDGE OF THE BRACKET.
4. ATTACH TWO PLUMB LINES TO THE L.H. EDGE OF THE RTA BY PASSING THE LINES THROUGH THE ACCESS HOLES IN THE L.H. SIDE OF THE RTA MOUNTING AND TEMPORARILY ATTACH BY TAPING TO THE TOP OF THE RTA.
5. CAREFULLY SWIVEL THE AFT END OF THE RTA UNTIL ALL THE PLUMB LINES ARE IN LINE. A THEODOLITE OR SIMILAR INSTRUMENT CAN BE USED TO ASSIST BUT IS NOT ABSOLUTELY NECESSARY.
6. WHEN ALL PLUMB LINES ARE IN LINE, SECURE THE RTA WITH THE SCREWS AND SPLIT WASHERS AS DETAILED ON DWG. Nº DA8180112.
7. RECHECK THE PLUMB LINES AND IF STILL IN LINE PRE-DRILL THROUGH THE LOWER REAR ANGLE INTO THE REAR SPIGOT LOCATING PLATE. DO NOT DRILL COMPLETELY THROUGH THE REAR SPIGOT LOCATING PLATE AS DAMAGE TO THE RTA COULD RESULT.
8. REMOVE RTA AND REAR SPIGOT LOCATING PLATE AND DRILL HOLES TO FINAL SIZE IN THE REAR SPIGOT LOCATING PLATE AND LOWER REAR ANGLE.
9. ATTACH REAR SPIGOT LOCATING PLATE AS DETAILED ON DWG. Nº DA8180112.
10. RE-INSTALL AND SECURE RTA IN THE ASSEMBLY NOW USING BOTH SPIGOT LOCATING PLATES FOR LOCATION, AND RE-CHECK ALIGNMENT AGAIN USING ALL FOUR PLUMB LINES.

AIRCRAFT RESEARCH AND DEVELOPMENT UNIT

TECHNICAL INVESTIGATION NO 760

EVALUATION OF INSTALLATION OF LIGHTWEIGHT DOPPLER NAVIGATION SYSTEM (LDNS) IN IROQUOIS UH-1H AIRCRAFT

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