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DEFINITION OF DISPLAY/CONTROL REQUIREMENTS FOR ASSAULT TRANSPORT NIGHT/ADVERSE WEATHER CAPABILITY

R. Joseph Milelli and Gary W. Mowery
Program Engineers
Martin Marietta Corporation
Orlando, Florida

Carmen Pontelandolfo
HNVS Project Engineer
Naval Air Development Center
Warminster, Pennsylvania

Abstract

The U.S. Marine Corps is currently developing a Helicopter Night Vision System (HNVS) to improve low-altitude night and/or adverse weather assault transport capabilities. Martin Marietta Aerospace, under contract to the Naval Air Development Center, has performed a number of man-in-the-loop simulation experiments in its Simulation and Test Laboratory (STL) to define the minimum display and control requirements for the assault transport mission. These simulation studies have investigated forward looking infrared (FLIR) sensor requirements, along with alternative displays such as panel mounted displays (PMD), helmet mounted displays (HMD), and integrated control display units. Also explored were navigation requirements, pilot/copilot interaction, and overall cockpit arrangement. Based on pilot performance and opinion data, pilot use of an HMD and copilot use of a PMD appear as both the preferred and most effective night navigation combination.

Introduction

State-of-the-art forward looking infrared (FLIR) systems make it possible for transport helicopters to conduct missions under conditions that would normally preclude operations. The transport mission requires the transport helicopter to fly at extremely low altitudes at the highest speed possible. Pilots must also approach and land in unimproved landing zones. Personnel and equipment must be quickly offloaded because the aircraft must depart to permit landing of the remaining formation. This mission must be accomplished day and night and in adverse weather conditions.

The United States Marine Corps is presently developing and evaluating design requirements for a Helicopter Night Vision System (HNVS) that would improve transport helicopter low-level night and reduced visibility capabilities.

In support of this effort, tradeoff analyses and system alternative studies were conducted to determine which type of night vision system could provide pilots with precise visual cues required as an aid to navigation and for terrain avoidance. Several types of systems were examined, such as night vision goggles, pyroelectric vidicon, active gated TV, low light level TV, and forward looking infrared (FLIR) devices. Related Army and Navy studies have concluded that FLIR devices perform better than other electro-optical systems on a significantly greater number of occasions. Consequently, a FLIR system capable of being configured and integrated into the assault transport helicopter was selected as the night vision system with the best potential for satisfying HNVS mission requirements.

The HNVS concept, shown in Figure 1, is based on a FLIR system that is mounted on the forward section of the assault helicopter. FLIR imagery is provided on panel mounted displays (PMDs) or helmet mounted displays (HMDs) for the pilot and copilot. The FLIR permits the pilot to operate under conditions of total darkness, and flight symbology superimposed on the FLIR imagery minimizes the pilot's and copilot's scan patterns. In addition, support avionics (such as a self-contained navigation system, radar altimeter, aircraft transducer, central computer, and control panels) are also required. The entire system will be designed to enable the mission to be performed safely with a minimal workload for both pilot and copilot.

Prior simulation experiments conducted in Martin Marietta's man-in-the-loop facility using a six-degree-of-freedom motion base concentrated primarily on basic system design parameters and aircrew interaction using panel mounted displays during the enroute portion of the transport mission. The Navy continued the simulation studies to 1) further expand, verify, and refine the data base during the approach and landing portion of the transport mission; 2) to evaluate alternative displays; 3) to further refine the overall cockpit configuration, and 4) to evaluate incorporation of a control display unit to support the navigation requirements of the mission. Results of the these studies were compared with data obtained in actual flight tests of FLIR and helmet display technologies at Yuma Proving Grounds.

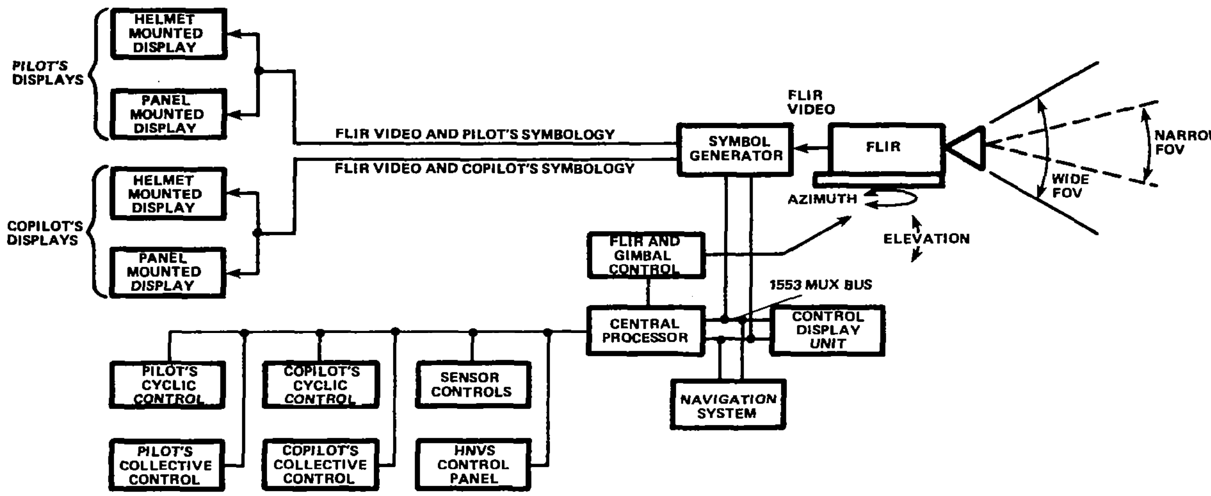

Figure 1. HNVS Block Diagram

Man/Machine Simulation Objective

The objective of the man/machine simulation experiment was to obtain human factors data for low-level assault transport operations using night vision sensors and ancillary hardware during the approach and landing portion of the mission. These data were collected and analyzed, then recommendations were developed that have been reviewed for incorporation into flight test evaluations and HNVS system specifications.

Approach

The HNVS simulation experiment used classical modeling, validation, and experimentation techniques. A highly realistic CH-53D cockpit developed for prior enroute simulations was used for these studies. Thirty-five operational fleet Marine pilots participated as subjects in the experiment and represented both CH-53 and CH-46 squadrons. These pilots had between 270 and 4000 helicopter flight hours, with an average of 695 hours. Experiments were conducted to investigate aircrew performance during approach and landing using different display combinations of panel mounted and helmet mounted displays, including the copilot's use of a Virtual Head Up Display (HUD). Additionally, pilot performance was investigated using a control display unit to assist in the visual navigation requirements. A variable landing zone size was used to increase workload as a a measure of system performance.

CH-53 Cockpit

The CH-53D cockpit is shown on a six-degree-of-freedom motion base in Figure 2. The interior of the cockpit (Figure 3) was precisely modeled to CH-53D dimensions using consoles and control panels from a stricken aircraft. A special-purpose rotorcraft simulator modeled the CH-53D aerodynamic characteristics. The Automatic Flight Control System (AFCS), the Stability Augmentation System (SAS), and the outerloop attitude and heading hold modes were modeled on analog computers. McFadden Systems three-axis force control loaders were used to duplicate the control system's mechanical characteristics.

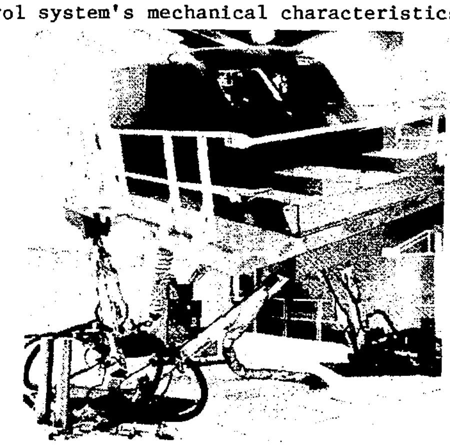

Figure 2. Cockpit on Motion Base

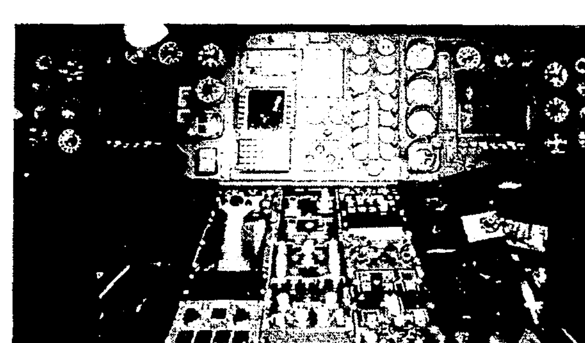

Figure 3. Cockpit Interior

HNVS Controls

The HNVS controls, readily accessible to both pilots, were arranged to provide rapid and accurate control selection and actuation. Sensor control was provided on both collectives and on the center console. Symbology select and field-of-view (FOV) select were provided on both cyclic controls and the center console.

Panel Mounted Displays (PMD)

The instrument panel (Figure 3) was modified with the installation of two nine-inch diagonal CRT displays for presentation of simulated terrain imagery to the pilot and copilot. The displays were located so that the pilot and copilot design eyepoints were at the outside edge of the display from a viewing distance of 34 inches. Brightness and contrast controls were located directly below each display. A red filter was installed over the display for simulated night operations. A 50-degree FOV provided on the nine-inch monitor, at the design eye distance of 34 inches, yielded a 0.30:1 minification of the real-world view.

Helmet Mounted Display (HMD)

The Integrated Helmet and Display Sight System (IHADSS), shown in Figure 4, was installed in the cockpit for both pilot and copilot. The sight determined the pointing directions of the pilot's line of sight (LOS), and the HMD provided both pilot and copilot with collimated video displays. The IHADSS was used to slave the HNVS sensor to the pilot's LOS and display HNVS imagery to both pilot and copilot HMDs. Since copilots might find it objectionable or become disoriented with the HMD continually presenting sensor imagery while they scanned instruments in the cockpit, a virtual HUD presentation was included for the copilot. As the copilot turned his helmet away from a 30- by 40-inch window located straight ahead, the terrain image moved off the HMD as if he were looking at a stationary HUD. The 50-degree FOV provided on the HMD yielded a 1:1 real-world view to the pilots.

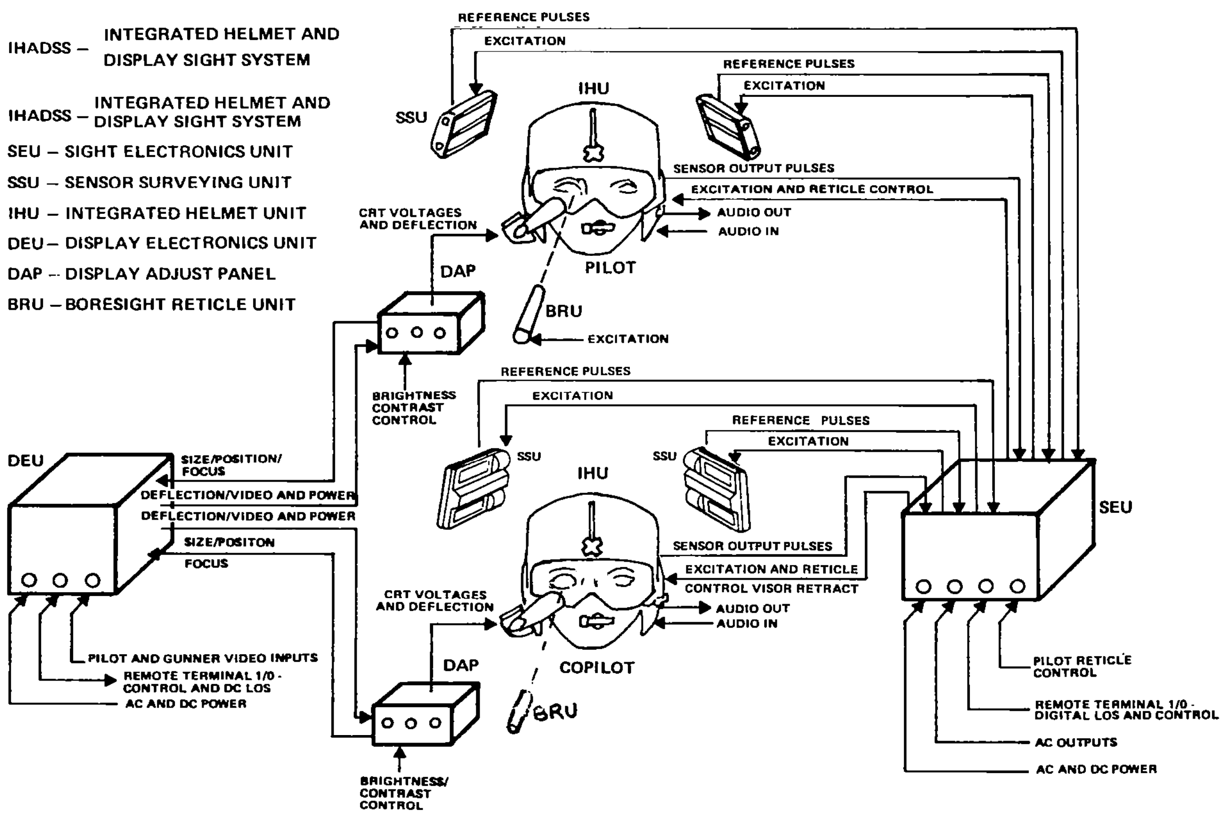

Figure 4. IHADSS System Diagram

Control Display Unit (CDU)

The CDU (Figure 5) was the primary man/machine interface for navigation initialization and mode control. It consists of a CRT display, master function switches, line key, and an alphanumeric key set that enables the copilot to view either the mission flight plan, or the navigation plot showing fly-to-point data, reference points, and aircraft position along a projected course.

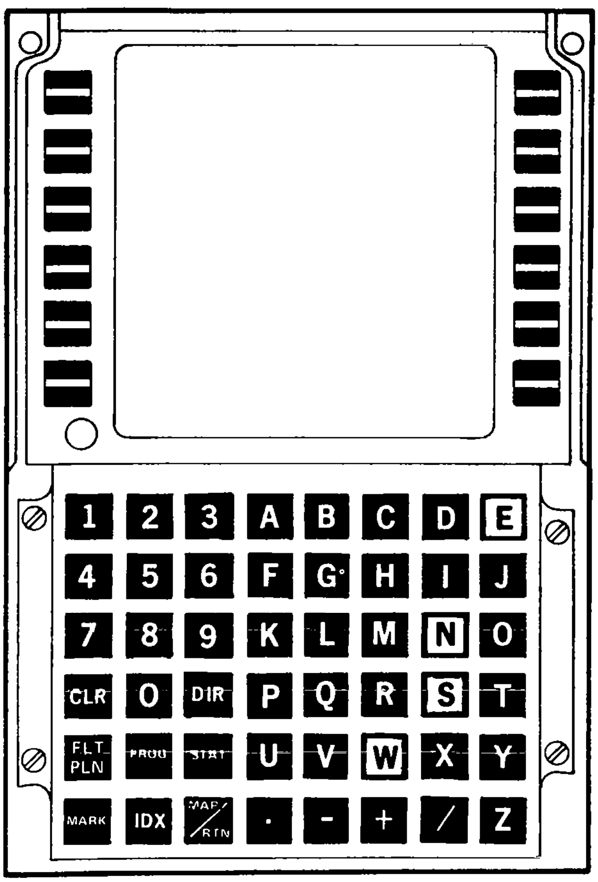

Figure 5. Control Display Unit

Symbology

Two symbology formats were provided. The Flight Symbology format (Figure 6) was developed as a piloting aid during enroute flight and commencement of approach to hover. The Hover/Transition Symbology format (Figure 7) was designed as an aid to transition the aircraft from forward flight to hover and as a precise hover aid. Numerous symbology formats were evaluated during the simulation. The Flight and Hover/Transition Symbology formats provided the best pilot performance for aircraft control during the entire enroute and hover portions of the mission.

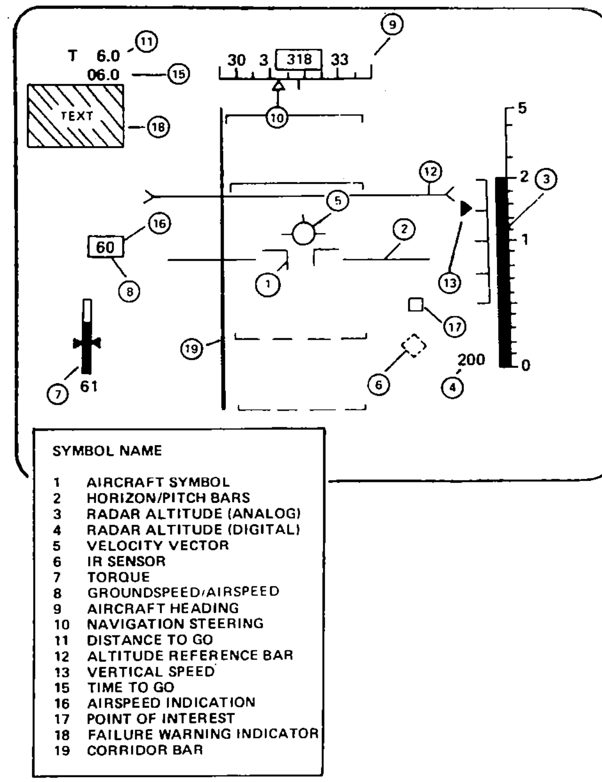

Figure 6. Flight Symbology Format

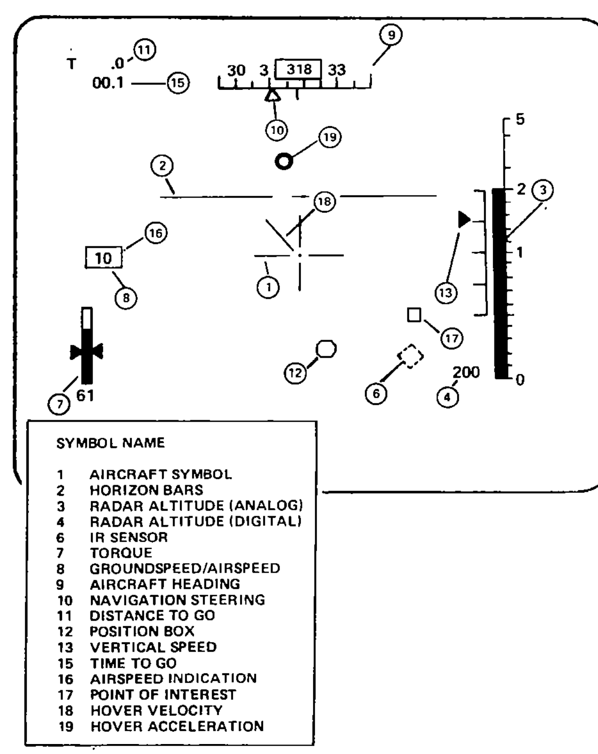

Figure 7. Hover/Transition Symbology Format

Hybrid Computing System

The simulation was controlled by a hybrid computing system consisting of two Sigma 5 digital computers, three EAI 231-RV analog computers, appropriate instrumentation, and interface and peripheral equipment. The computer arrangement controlled the aerodynamics, processed position commands to the terrain model (Figure 8) and TV, handled operational mode logic and switching functions, generated commands to position symbology on the cockpit displays, and stored performance data.

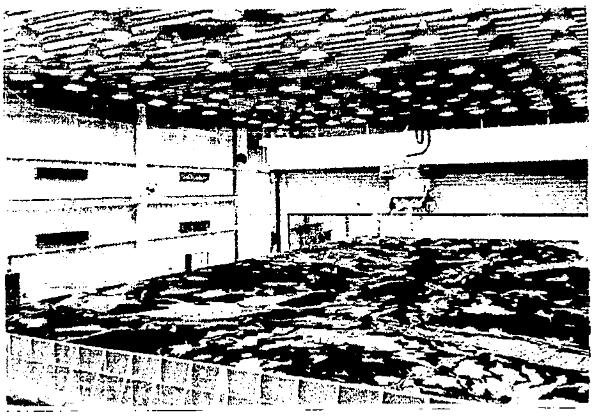

Figure 8. Terrain Model

Experimental Procedures

Pilots were given an orientation to Martin Marietta's Simulation and Test Laboratory (STL), a system briefing, and an experiment briefing. Ground school was conducted on HNVS cockpit controls and displays. The pilot groups then progressed through fixed and motion-base familiarization flights, and finally progressed to training configurations that mirrored the data acquisition procedures. When all pilots approached their learning asymptote, as evidenced by their performance, data collection commenced. Before each session of data runs, a briefing structured to resemble an air intelligence briefing was held. Pilots were given a map of the area, a flight card, and a simulated 8 by 10 inch black and white reconnaissance photos of checkpoints and the landing zone. Route legs and checkpoints were presented on the map. The pilots participated in informal debriefing sessions at the conclusion of data run sets, and they completed extensive debriefing questionnaires when they completed all data sessions. The informal debriefing sessions and questionnaires were designed to obtain subjective information from the participants on relevant HNVS issues.

Pilot Performance Data

A large number of pilot performance measures was gathered during the data runs, and several measurements of pilot performance were taken as part of each evaluation. Pilot performance data tends to support pilot opinion data, but it is not as pronounced, a result typical in simulation programs.

Display Combination Evaluation

To determine the effects of display combinations on crew performance during approach and landing, three treatment conditions were tested: 1) pilot and copilot using PMDs, 2) pilot using HMD and copilot using PMD, and 3) pilot and copilot using HMDs. Each combination was evaluated in landing zones with two difficulty levels. The large zone was 3.5 rotor diameters (difficulty level 2) or more, and the small landing zone was 3.4 rotor diameters or less (difficulty level 1).

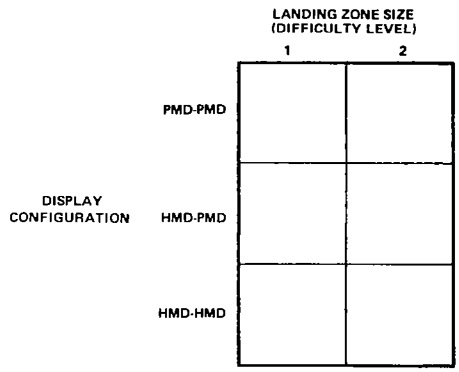

Figure 9. Experimental Matrix for Approach and Landing PMD/HMD/CDU Evaluation

The data matrix for this evaluation is shown in Figure 9. A Greco Latin Square design allowed order effects to be evenly distributed across all subjects and treatments.

Touchdown and Approach Data for Display Combination Evaluation

The touchdown performance data were analyzed on five dependent variables (landing time, radial landing error, X drift, Y drift, and Z drift) and three approach variables (percent under 100 feet, average altitude, and average groundspeed). The independent variables were three display configurations: PMD-PMD, PMD-HMD, and HMD-HMD. Table 1 shows the levels of significance resulting from this analysis. The significant difference in landing error was expected as a function of zone size. Although no display combinations resulted in significant performance differences, trends in favor of the HMD combinations do appear. The HMD-PMD combination had the greatest time under 100 feet, the lowest mean radar altitude, the only mean altitude under 100 feet, and the least amount of Z drift. Tables 2 through 5 show the touchdown and approach results, along with relative rankings of these results between display configurations. The HMD-HMD combination had the shortest landing time and the best overall ranking on touchdown performance. These results indicate that the pilot's display affects performance most significantly, and performance is better with the HMD.

Table 1. Pilot Performance in HMD-PMD Evaluation: Touchdown and Approach

DEPENDENT VARIABLES	OVERALL MEAN	STANDARD DEVIATION	INDEPENDENT VARIABLES: DISPLAY CONFIGURATION	INDEPENDENT VARIABLES: DIFFICULTY LEVEL	INDEPENDENT VARIABLES: INTERACTION
TOUCHDOWN:					
LANDING TIME	234.52S	100.70	NS**	NS	NS
RADIAL LANDING ERROR	31.67 FT	34.41	NS	p = 0.046	NS
-X DRIFT	-1.61 FT/S	1.68	NS	NS	NS
+X DRIFT	2.41 FT/S	3.18	NS	NS	NS
-Y DRIFT	-1.88 FT/S	1.89	NS	NS	NS
+Y DRIFT	1.24 FT/S	1.29	NS	NS	NS
Z DRIFT	4.46 FT/S	2.88	NS	NS	NS
APPROACH:					
PERCENT UNDER 100 FEET	38.68 %	28.81	NS	LANDING ZONE DOES NOT AFFECT APPROACH VARIABLES	
AVERAGE GROUNDSPEED	59.57 KN	12.36	NS		
AVERAGE ALTITUDE	119.03 FT	56.79	NS		

Table 2. HMD-PMD Evaluation: Touchdown Performance Trends

DISPLAY CONFIGURATION	LANDING ZONE SIZE AND TOUCHDOWN VARIABLES: LANDING TIME (SECONDS) LARGE	SMALL	LANDING ERROR (FEET) LARGE	SMALL	-X DRIFT (FT/S) LARGE	SMALL	+X DRIFT (FT/S) LARGE	SMALL	-Y DRIFT (FT/S) LARGE	SMALL	+Y DRIFT (FT/S) LARGE	SMALL	Z DRIFT (FT/S) LARGE	SMALL
PMD-PMD	233	277	36	21	0.89	1.89	3.66	1.23	1.39	2.15	1.24	1.32	4.69	4.57
HMD-PMD	234	220	44	27	1.85	1.23	3.03	4.59	0.98	2.58	1.26	1.28	4.16	3.74
HMD-HMD	224	210	40	19	3.35	1.82	1.92	1.55	2.62	0.08	0.95	1.30	4.52	4.93

Table 3. HMD-PMD Evaluation: Relative Rankings of Touchdown Trends

LANDING ZONE SIZE AND TOUCHDOWN VARIABLES

DISPLAY CONFIGURATION	LANDING TIME (SECONDS) LARGE	SMALL	LANDING ERROR (FEET) LARGE	SMALL	-X DRIFT (FT/S) LARGE	SMALL	+X DRIFT (FT/S) LARGE	SMALL	-Y DRIFT (FT/S) LARGE	SMALL	+Y DRIFT (FT/S) LARGE	SMALL	Z DRIFT (FT/S) LARGE	SMALL	OVERALL RANK
PMD-PMD	2	3	1	2	1	3	3	1	2	2	2	3	3	2	3*
HMD-PMD	3	2	3	3	2	1	2	3	1	3	3	1	1	1	2
HMD-HMD	1	1	2	1	3	2	1	2	3	1	1	2	2	3	1

*1 = BEST RANKING

Table 4. HMD-PMD Evaluation: Approach Performance Trends

DISPLAY CONFIGURATION	APPROACH VARIABLES: PERCENT UNDER 100 FEET	AVERAGE GROUNDSPEED	AVERAGE ALTITUDE
PMD-PMD	35.91	59.63	131.75
HMD-PMD	44.27	58.70	107.10
HMD-HMD	38.51	59.78	113.24

Table 5. HMD-PMD Relative Rankings of Approach Trends

DISPLAY CONFIGURATION	APPROACH VARIABLES: PERCENT UNDER 100 FEET	AVERAGE GROUNDSPEED	AVERAGE ALTITUDE	OVERALL RANK
PMD-PMD	3	2	3	3*
HMD-PMD	1	3	1	1.5
HMD-HMD	2	1	2	1.5

*3 = WORST RANKING

Smoothness of Approach and Landing for Display Combination Evaluation

Regression analyses were run on the distributions. The radar altitude for the last nautical mile before touchdown was significantly (p = 0.10) smoother for the HMD-PMD configuration than for that of the PMD-PMD. Figure 10 shows the radar altitudes approaching the landing zone (LZ) as lower and smoother for the HMD-PMD configuration. Significant differences in distance distributions were also found in pitch angle. The pitch angle for the HMD-HMD configuration was significantly (p = 0.0028) smoother than the PMD-PMD configuration, and difficulty level 1 (small LZ) was significantly smoother than level 2 (large LZ). This difference is shown in Figures 11 and 12. Examining the time distribution indicated that the rate of descent was more consistent for the larger LZs. The display combination trends, although not statistically significant, show the PMD-PMD combination to be more erratic across all variables than both configurations in which the pilot uses the HMD.

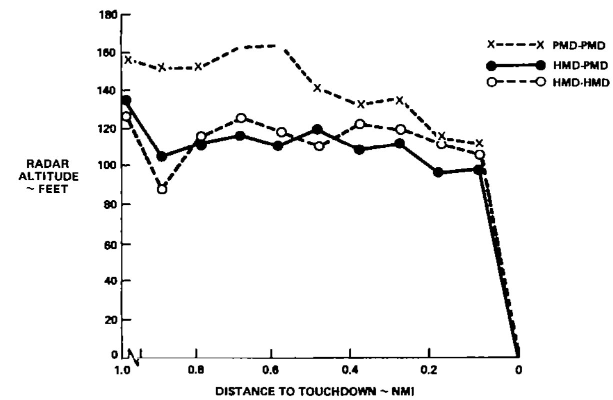

Figure 10. Radar Altitude during Landing Phase

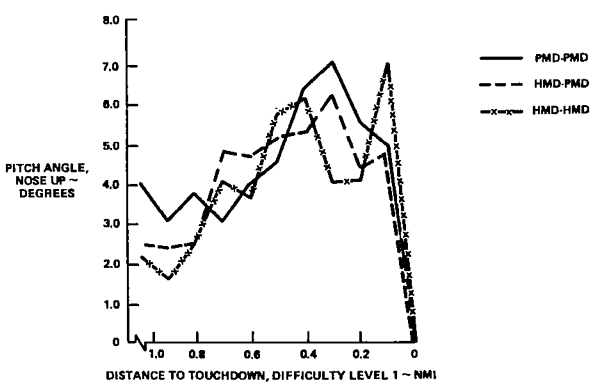

Figure 11. Pitch Angle during Landing Phase: Small LZ

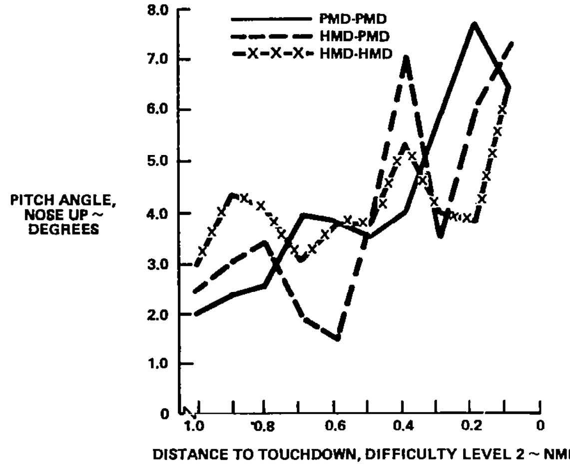

Figure 12. Aircraft Pitch Angle during Landing Phase: Large LZ

Crash Rates for Display Combination Evaluation

An examination (by chi-square analysis) of the frequency of noncrash landings per attempts showed no significant differences due to display configurations of LZ size. Any frequency differences appeared due to chance and not experimental conditions.

Virtual Head Up Display (HUD) Evaluation

The virtual HUD evaluation varied the copilot display combinations from PMD, HMD, and HMD virtual HUD while the pilot remained on the HMD. The ANOVA results shown in Table 6 indicate that route change as a variable has a significant effect on percentage of time under 100 feet and average groundspeed. Runs without route changes had a higher percentage under 100 feet with the virtual HUD configuration (73.5 percent), followed by common HMD video (57.5 percent) as shown in Table 7. In runs that contained a route change, the HMD-PMD configuration had the highest percentage of time under 100 feet (56 percent). Overall, the HMD configuration with the virtual HUD had the lowest average radar altitude. However, the variability between display combinations is small, i.e., only 11 feet. Runs with a route change had faster average groundspeeds than those without (Table 8). This increase in groundspeed was predictable, since the altitudes of changed routes tended to be higher. The virtual HUD has the fastest groundspeed in runs with changes and the lowest in runs without. Overall, the HMD-HMD combination video had the fastest average groundspeed.

Table 6. Pilot Performance in Virtual HUD Evaluation: Enroute*

DEPENDENT VARIABLES	OVERALL MEAN	STANDARD DEVIATION	INDEPENDENT VARIABLES: DISPLAY CONFIGURATION	ROUTE DIFFICULTY	ROUTE CHANGE	INTERACTION
PERCENT UNDER 100 FEET	55.34 %	14.42	NS**	NS	p = 0.01	NS
AVERAGE GROUNDSPEED	69.10 KN	16.01	NS	NS	p = 0.02	NS
AVERAGE ALTITUDE	104.99 FT	17.18	NS	NS	NS	NS

*SIGNIFICANCE LEVEL LIMITED TO p ≤0.10
**DIFFERENCES NOT SIGNIFICANT

Table 7. Virtual HUD Evaluation: Average Altitude Enroute

DISPLAY COMBINATION	DIFFICULT ROUTE: NO ROUTE CHANGE	DIFFICULT ROUTE: ROUTE CHANGE	EASY ROUTE: NO ROUTE CHANGE	EASY ROUTE: ROUTE CHANGE	OVERALL MEAN
HMD-PMD	120.58 (42%)*	105.08 (56%)	95.04 (62%)	125.10 (37.5%)	111.45
HMD-HMD (COMMON VIDEO)	93.39 (62%)	118.18 (45%)	112.45 (57.5%)	106.02 (54%)	107.51
HMD-HMD (VIRTUAL HUD)	84.06 (73.5%)	113.00 (47%)	83.11 (73.5%)	122.86 (37.5%)	100.75

*PERCENT OF TIME UNDER 100 FEET

Table 8. Virtual HUD Evaluation: Average Altitude Enroute

DISPLAY COMBINATION	DIFFICULT ROUTE: NO ROUTE CHANGE	DIFFICULT ROUTE: ROUTE CHANGE	EASY ROUTE: NO ROUTE CHANGE	EASY ROUTE: ROUTE CHANGE	OVERALL MEAN	SURROGATE TRAINER*: DAYLIGHT NOE	SURROGATE TRAINER*: NIGHT NOE
HMD-PMD	68.16	67.06	65.94	69.99	67.78	–	–
HMD-HMD (COMMON VIDEO)	71.58	64.97	73.01	85.76	73.83	27	16
HMD-HMD (VIRTUAL HUD)	62.48	80.84	65.14	65.98	68.61	–	–

For comparison, data collected for the Army's Surrogate Trainer is shown in Table 8. The Surrogate Trainer is a AH-1S helicopter equipped with a AN/AAQ-11 Pilot Night Vision Sensor (FLIR), IHADSS, symbol generator, and navigation system. The groundspeed data shown for both day (27kts) and night (16kts) flights highlights the differences between the Army's tactic of nap-of-the-earth (NOE) flight and the low-level flight concepts utilized by Marine pilots in the simulator. A typical altitude plot is presented in Figure 13, which indicates the pilot flew the helicopter below 15 feet. This altitude is significantly lower than the 107.51 mean altitude when the HMD-HMD configuration was used in the simulator.

These differences underscore the inverse relationship between clearance altitude and groundspeed and potentially reflect the difference in aircraft size.

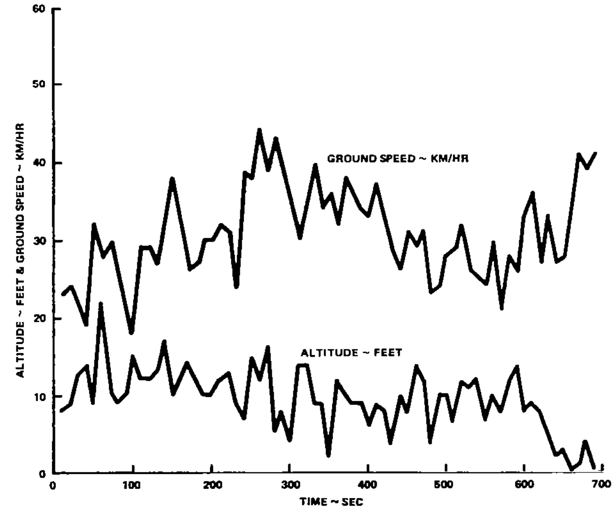

Figure 13. Typical Night NOE Flight Profiles for Surrogate Trainer

Control Display Unit (CDU) Evaluation

Copilot performance was evaluated as a function of display combination during low-level flights over longer routes that required a substantial navigation workload. An enroute course change was added as a variable so that the difficulty of the copilot inserting a route change into the CDU midway in a mission could be evaluated. Figure 14 contains the data matrix. Random route conditions were used so that pilots could not predict course changes. All enroute data runs required the copilot to manually capture the LZ.

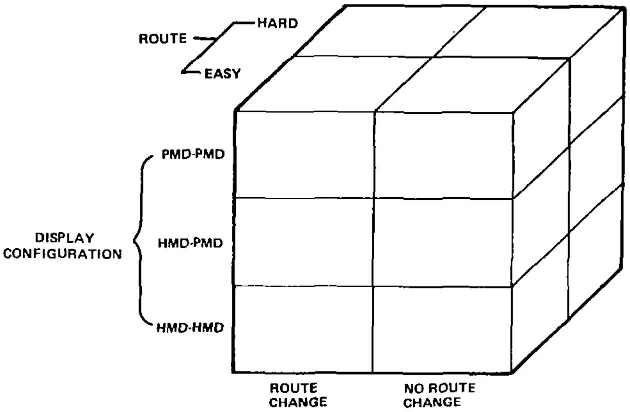

Figure 14. Experimental Matrix for Approach and Landing PMD-HMD-CDU Evaluation

Capturing the LZ required a specific three-key operation of the flight plan master function key (MFK) and line keys 9 and 6. Most runs had an addendum to this sequence, which was several scale changes (line keys 11 and 12). Discrete data was examined to determine actual sequences. There were 2 errors in 17 operations when this sequence was performed, and both involved parallax problems with line key 9.

The random enroute change also involved a specific sequence of events to properly execute the new route and capture checkpoints in the old. The PMD-PMD configuration had the fewest CDU errors (6), followed by the HMD-PMD configuration (7) and the HMD-PMD configuration (11). There were 11 line key errors and 13 total MFK errors encountered during route changes. Tables 9 and 10 display the type of errors that occurred. These tables show consistent problems with parallax and misunderstanding of key functions. The copilots depressed line keys several times in succession in trying to obtain a response or to correct an error. The copilots did not cue in on the CDU feedback (for example, the asterisk that appears with the capture function). These errors indicate that the display arrangement needs to be correctd and CDU feedback must be furnished when a function key is initialized.

Table 9. Line Key Errors during Route Changes

FREQUENCY	ERROR SEQUENCE
4	DEPRESSED LINE KEY 8 INSTEAD OF 9
1	DEPRESSED LINE KEY 4 INSTEAD OF 3
2	DEPRESSED LINE KEY 10 INSTEAD OF 9
1	DEPRESSED LINE KEY 2 INSTEAD OF 3
2	SEVERAL LINE KEY ENGAGES AFTER ONE MFK
1	SEVERAL PAGE CHANGES AFTER ONE DIR

Table 10. Master Function Key Errors during Route Changes

FREQUENCY	ERROR SEQUENCE
3	DEPRESSED FTL/PLN INSTEAD OF DIR
2	DEPRESSED MARK INSTEAD OF FTL/PLN
3	DEPRESSED STAT INSTEAD OF DIR
2	DEPRESSED PROG INSTEAD OF DIR
2	DEPRESSED MARK INSTEAD OF DIR
1	DEPRESSED MAP/RTN INSTEAD OF FLT/PLN

Pilot Performance Data Summary

The size of the landing zones affected pilot performance more consistently and predictably than any other factor. The smaller zones required more precise maneuvering, which resulted in longer landing times, higher radar altitudes during approach, smaller radial error, etc. To land in these zones, the pilot must have the helicopter under control. The pilots evaluating the HMD-PMD combination generally performed better using the HMD. Ease of slewing the sensor allowed pilots to examine terrain features and maintain low altitude with comparative ease. The pilots' landing approaches and touchdowns were also smoother when using the HMD.

During the enroute portion of the mission, crew performance in flatter terrain was slightly better while the pilot used the PMD, but performance in mountainous terrain was better when the pilot used the HMD. Copilot operation of the CDU indicated that it is a useful part of the navigation system that reduces the dead reckoning navigation workload task. However, the excessive number of copilot input errors during route changes indicates that changes need to be made in keyboard layout and in CDU feedback cues.

Pilot Opinion Data

After the data runs, the pilots were asked to rate the safety and ease of display configurations during an approach to the landing zone (Figures 15 and 16). While there was little variability in response, consistent trends were apparent. Pilots rated the HMD safer and easier than dual PMDs in all phases. The variability is small, but the pilot's HMD display is apparently the critical preferred feature.

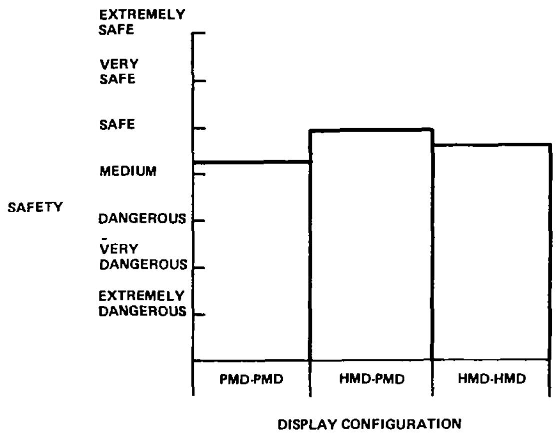

Figure 15. Safety of Approach to LZ

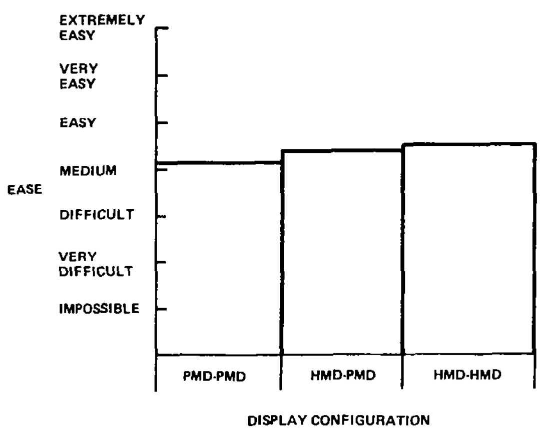

Figure 16. Ease of Approach to LZ

Participants were asked to indicate the minimum safe target altitude at 60 to 80 knots and the maximum safe target groundspeed at 50 to 100 feet above ground level (AGL) that was attainable on an actual night mission. Table 11 shows the pilot ratings of actual mission altitudes and speeds. They believe that lower altitudes and higher speeds are attainable when the pilot uses the HMD.

Table 11. Minimum Safe Altitude at 60 to 80 Knots and Maximum Safe Speed at 100 to 150 Feet AGL

TERRAIN	RADAR ALTITUDE (FT) AND SPEED (KN) BY DISPLAY CONFIGURATION					
	PMD-PMD		HMD-PMD		HMD-HMD	
	ALTITUDE	SPEED	ALTITUDE	SPEED	ALTITUDE	SPEED
FLAT	61.88	106.56	64.06	115.94	64.29	107.86
ROLLING HILLS	95.63	85.36	90.00	93.21	92.86	86.67
MOUNTAINOUS	143.44	62.86	129.38	66.43	122.14	63.33
OVERALL MEAN	100.32	84.93	94.48	91.86	93.10	85.95

Pilots showed a consistent preference for the HMD-PMD configuration across all aspects of mission ease and safety. The HMD-HMD virtual HUD was considered the most dangerous and difficult display configuration. However, pilots expressed a preference for the copilot to use the PMD for map reading and navigation. They felt that the virtual HUD made it difficult to turn their head and use the CDU, and that the time required to regain the display created a dangerous situation. All pilots felt the HMD-PMD configuration was the safest, most effective configuration; the HMD-HMD virtual HUD configuration was felt to be the least effective and safe.

Seventy-five percent of the pilots felt the CDU helped to maintain low altitude, and 50 percent felt it helped to increase groundspeed. These respondents felt the CDU simplified navigation duties and increased orientation, which allowed more time for concentration on flight tasks. Copilots felt the tactical map display was useful.

Pilot Opinion Data Summary

Evaluating the HMD-PMD combination resulted in a definite preference for the pilot to have a helmet display. The copilot preferred an HMD for mission ease and a PMD for mission safety. The enroute evaluation indicates a consistent preference for the HMD-PMD configuration.

Copilots felt that the virtual HUD configuration was more difficult and dangerous than the HMD-HMD or HMD-PMD configurations. They also preferred the HMD-PMD configuration.

The CDU was found to be an extremely useful navigation tool. It enables copilots to accurately assess present position, desired position, and overall mission. The HMD increased copilot task loading, but operation of the CDU was still possible.

Conclusions

The simulation experiments have demonstrated the ability of pilots and copilots to fly a night mission at low altitudes, ranging from 50 to 150 feet AGL, with the night visionics equipment package tested.

Although this experiment required no data to be generated on dead reckoning versus navigation system requirements, both pilot performance and opinion data reinforced that crew station workload was reduced with Doppler command steering information. Incorporating the CDU navigation capability was also instrumental in further reducing navigation workload.

Most pilots preferred flying the night transport mission with the HMD instead of the PMD, regardless of which display configuration the copilot was using. The precise slewing of the sensor with the HMD using a pilot's natural head movements allowed control over the sensor without changing hand position on the collective during critical flight maneuvers, which is required when operating the sensor manually.

By contrast, most copilots preferred using the PMD. They found constantly moving imagery somewhat distracting when performing the CDU line key and master function tasks.

The copilot group evaluating the virtual HUD mode of IHADSS did not find this mode useful. Of particular concern was losing symbolic aircraft attitude and altitude information and losing imagery while performing cockpit tasks using the virtual HUD.

The preferred cockpit display configuration was to have the pilot use the HMD and the copilot use the PMD. The HMD provides the pilot with precise slewing control over the sensor and more visual feedback information than available with the PMD. The PMD provides the copilot with sufficient aircraft position, attitude, and altitude information, yet simplifies cockpit workload tasks. The PMD does not introduce the visual interference characteristic of the HMD or the complete loss of aircraft information characteristic of the virtual HUD.

Copilots found the CDU to be a useful navigational aid in reducing the navigation workload task. The present keyboard inputs required for enroute changes, however, are somewhat cumbersome through nonalignment of CDU symbology with the appropriate line keys. The result was copilot confusion and numerous copilot input errors. Through lack of an indication for positive CDU line key actuation, numerous other copilot line key input errors resulted.

Further HNVS Efforts

As a result of these experiments, a baseline HNVS configuration has been established and is presently being evaluated in actual flight tests by the Naval Air Development Center and Naval Air Test Center. The cockpit configuration is identical to that utilized in the simulation studies. Addtionally, an HNVS System Specification has been developed by the Naval Air Development Center for procuring actual production prototype hardware for flight test. The HNVS System Specification was developed, in large part, from data generated during this and prior simulation experiments.

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