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A REVIEW OF THE LITERATURE ON ELECTRO-OPTICAL FLIGHT DISPLAYS.(U)

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A REVIEW OF THE LITERATURE ON ELECTRO-OPTICAL FLIGHT DISPLAYS

Andrew T. Buckler

February 1978
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U. S. ARMY HUMAN ENGINEERING LABORATORY

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This report contains a review of the literature on electro-optical flight displays with special emphasis on rotary-wing aircraft. The primary focus of this review was to find research studies in which different symbology formats were compared experimentally.

Research of this type was found to be, for the most part, sorely lacking in literature. However, some valuable work has been done in efforts to demonstrate the feasibility of certain specific systems. This work should be taken as a baseline in developing candidate symbology formats to be tested empirically to arrive at an optimal standard for rotary-wing E/O displays.

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A REVIEW OF THE LITERATURE ON ELECTRO-OPTICAL FLIGHT DISPLAYS

INTRODUCTION

The Army's Advanced Attack Helicopter (AAH) presents a new challenge for human factors engineers and psychologists. For the first time, pilots will be relying on electro-optical displays to provide the information necessary to operate in the tactical nap-of-the-earth (NOE) environment. The AAH will be equipped with cathode ray tube (CRT) displays in both the pilot and copilot stations. The pilot's display will present basic flight information (altitude, attitude, airspeed, heading, etc.) while the copilot's display will portray primarily navigation and fire control information.

In order to operate in the NOE environment under all conditions, the AAH will be equipped with a pilot night vision system (PNVS). This video presentation will be overlaid with symbolic flight control information. It is readily apparent that the pilot could easily be overwhelmed by all this information on a single display if the format of that display does not provide optimal information transfer. Care must also be taken to insure that the symbology does not overly obscure the video image.

With these concepts in mind, the Army aviation community has undertaken a coordinated effort to develop and standardize symbology for electro-optical (E/O) flight displays for rotary-wing aircraft. Based on information requirements established by the user community, research will be conducted to develop and test alternate symbol formats. This review was done to identify and summarize the work already completed toward achieving this goal.

A few words should be said regarding the scope and limitations of this review. First, although the AAH project is a driving force in this program, the long-range objective is to develop a standard for E/O display design for future helicopters as well. Second, while it is expected that the same basic information will be required for effective flight control in almost any helicopter, fire control information will vary from one aircraft to another depending on the weapons available. Therefore, this review will concentrate on the flight control display.

The primary focus of this review was on research which actually compared different symbol formats rather than studies which were designed either to demonstrate the feasibility of a particular system or to establish information requirements. Also excluded from this discussion were studies dealing with technical aspects of sensor and display hardware. Although these considerations are obviously important to any flight display system, this Laboratory does not possess the expertise necessary to adequately treat these topics. Therefore, no attempt was made to include them in this report.

DISCUSSION

In 1968, Ketchel and Jenney (11) conducted a very thorough overview of E/O flight displays. Their aim was to provide a set of requirements necessary to standardize E/O flight displays. Since their conclusions and recommendations remain valid today, they will serve as a starting point for the current review.

An attempt was first made to define the information required for flight displays both by examining contemporary E/O displays from various aircraft and by compiling the recommendations of a number of studies on the topic. They list 14 bits of information which they find to be generally required in most aircraft:

1. Pitch angle
2. Roll angle
3. Altitude
4. Airspeed
5. Steering
6. Angle of attack
7. Heading
8. Glideslope
9. Glidepath
10. Vertical velocity
11. Range to go
12. Velocity vector
13. Fuel quantity
14. Fuel flow rate

It was noted that hover position and hover ground-speed are omitted primarily due to the fixed-wing bias of most of the studies cited. The authors point out that the requirements may need to be modified for different aircraft and mission profiles. They particularly noted the disproportionately small amount of attention that has been devoted to helicopter display design.

Coding theory was discussed as a basis for developing optimal symbology for flight displays. The authors found that no contemporary theory adequately predicts the suitability of a particular symbol format. Various coding techniques were reviewed--size, shape, color, brightness, flash, and alphanumerics--and it was concluded that shape, color, and alphanumeric coding are most effective. Digital indicators are recommended for setting tasks, where accurate readings are required or for information that changes very slowly and analog indicators are recommended for tracking tasks or readout of rapidly changing values where fine degrees of accuracy are unessential.

The following recommendations were made regarding symbology format and placement:

Altitude - vertically oriented; right side

Airspeed - vertically oriented, left side

Roll Scale - horizontally oriented, top of display

Vertical Velocity - vertically oriented; right side

Heading - horizontally oriented; bottom or along the horizon lines

Finally, display characteristics such as luminance, resolution, etc., were discussed. These issues were also discussed in another more recent report which will be described later in this review.

In 1971, Semple, Heapy, Conway, and Burnette (16) produced a similar review of E/O display data. This report was for the most part more concerned with the physical aspects of the displays such as contrast, brightness, and resolution than with the formatting of flight information. Much of the coding theory material discussed by Ketchel and Jenney (12) is reviewed here with many of the same results and conclusions.

More recently, a literature review was conducted by this Laboratory on the legibility of alphanumerics on E/O displays (6). Table 1 provides a summary of the findings of that review. It should be noted that certain of these recommendations may be applicable to any type of symbol, not just alphanumerics. For instance, resolution and contrast factors are just as important in recognizing a triangle as in reading an "A." These recommendations should be taken as guidelines for the design of other types of E/O symbols.

The remainder of this review will concentrate on the work done since 1968 in developing flight control display symbology formats. An effort was made to search out studies which had compared various symbology formats to determine the optimal methods of presenting flight control information. After an extensive search of the literature, no such research on E/O flight displays was found. Thus, we must rely on the available studies which were seeking either to establish and define information requirements or to demonstrate the feasibility of specific systems. Some of the most notable and useful of these will be discussed here.

Several researchers have shown the value of a flight director display (8, 15). Figure 1 shows a flight director E/O display developed by the NASA Ames Research Center (15). Even with the key provided, the complexity of this display is apparent. This problem will probably be compounded by the addition of a video image background. (Note the two command symbols for the collective and cyclic inputs.) Later researchers (8, 23) have demonstrated the value of the steering command symbols as well.

The most authoritative work to date on helicopter E/O flight displays has been conducted by the US Army Avionics Research and Development Activity, Fort Monmouth, NJ (5, 14, 19, 20, 21, 22). One of these early studies (22) compared a series of increasingly complex E/O flight displays in an effort to determine which information would be required for an accurate hover. Among their conclusions were that some representation of ground position and velocity were required to perform an accurate hover, and that the simplest display tested which included these two bits of information was the best.

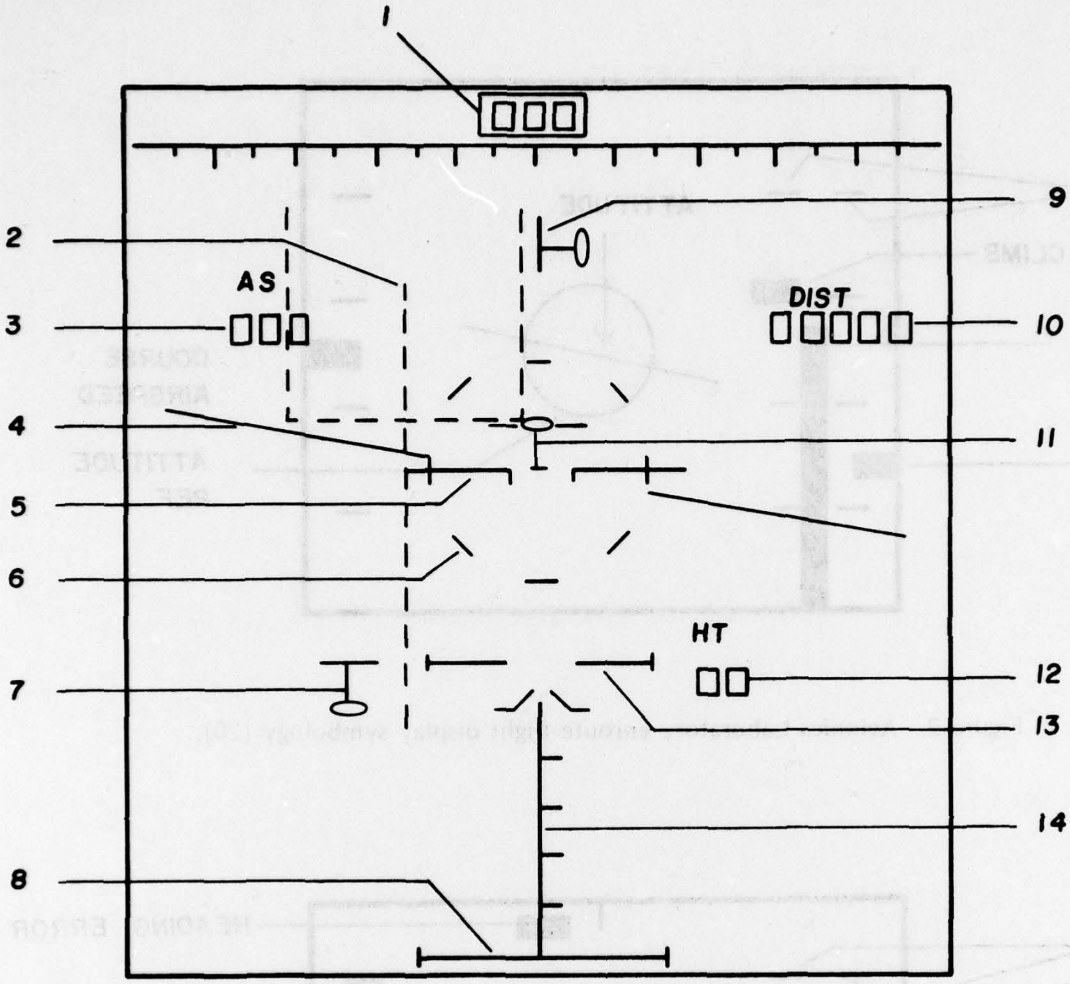
In the later studies (14, 21) using a night vision system as a sensor for ground position, optimal performance was found to occur with a display which portrayed both velocity and acceleration information. Finally, a single display which combines position, velocity, and acceleration information was found to be required for precision hover (19).

The most recent in this series of studies (20) provides an additional flight test of the display concepts developed earlier. Figures 2 and 3 depict the display formats used in these tests. In Figure 3 the pilot's strategy is to keep the acceleration circle over the cross of the ground position which causes the aircraft to translate toward and then stabilize at the desired hover position. Again, the importance of having the three bits of information—position, velocity, and acceleration—to maintain a precise hover is noted and emphasized.The author recommended that further symbology investigations be conducted.

TABLE 1

Summary of Guidelines for Legibility of Alphanumeric Symbols on E/O Displays (6)

Generation Technique	Dot matrix is rated better than stroke-written except under degraded conditions; Research comparing CRT with dot matrix is needed.
Font	Leroy or MIL-M-18012 fonts seem suitable for most applications; Some improvement may be possible for specific generation techniques.
Symbol Subtense	A minimum of 15 minutes is recommended under good conditions and 21-25 minutes under degraded conditions.
Resolution	For CRT's - a minimum of 10 lines per symbol height with good conditions and 16 lines with poor conditions; For dot matrix - a minimum matrix size of 7x9 is recommended for systems use.
Percent Active Area	Increased emitter size and decreased emitter spacing improve performance; Research is needed to determine optimal emitter shapes.
Contrast	Direction of contrast is insignificant except under badly degraded conditions; Symbol to ground contrast should be 10:1 or higher.
Symbol-Width-to-Height	Ratios ranging from 1:2 to 1:1 are acceptable.
Stroke-Width-to-Height	Acceptable ratios range from 1:6 to 1:10.
Symbol Spacing	Values between 26% and 63% of character width are recommended.
Viewing Angle	Decrements begin to occur between 19^{o} and 38^{o}; Consideration should be given to the reflective characteristics of the display in use.
Edge Displayed Symbols	Should be 11% larger for CRT's.
Color	Not really significant for monochromatic displays, so long as blue is avoided; Research is needed for effects of multichromatic displays.



1. HEADING TAPE
2. CENTER OF LANDING PAD
3. AIR (GROUND) SPEED DIGITS
4. HORIZON BAR
5. ROTOR SYMBOL
7. COLLECTIVE STEERING COMMAND
8. LANDING PAD
9. HEADING INDEX RUDDER STEERING COMMAND
10. DISTANCE DIGITS
11. CYCLIC STEERING COMMAND
12. HEIGHT (ALTITUDE) DIGITS
13. AIRCRAFT SYMBOL
14. HEIGHT DEVIATION INCRETMENTS

Figure 1. Hess V/STOLAND display symbology developed by NASA Ames Research Center (15).

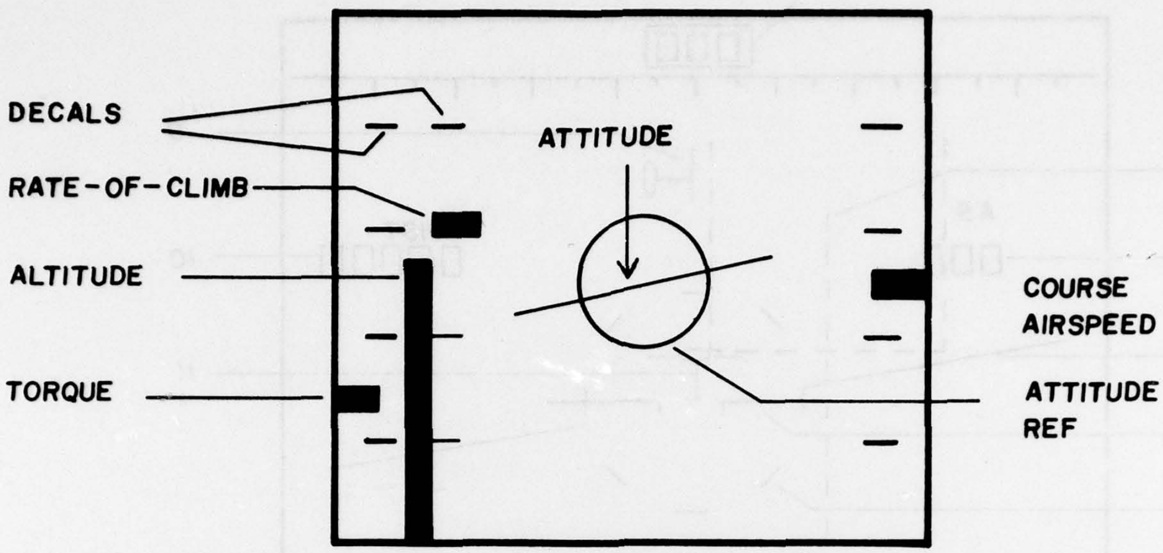


Figure 2. Avionics Laboratory enroute flight display symbology (20).

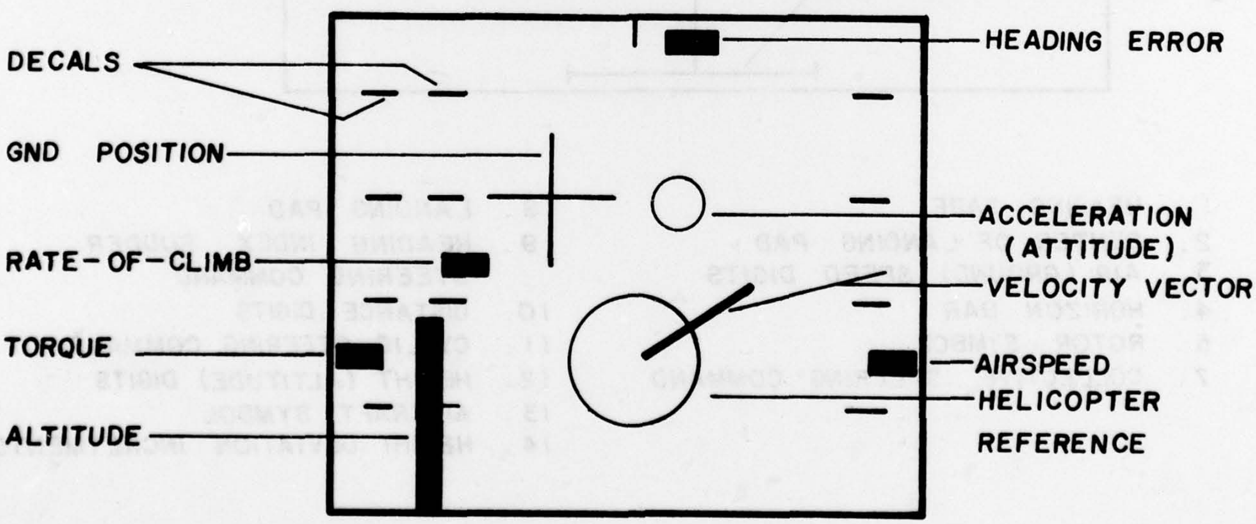


Figure 3. Avionics Laboratory hover display symbology (20).

CONCLUSIONS AND RECOMMENDATIONS

As was stated earlier, the primary goal of this review was to identify and summarize research which has been done up to this time with electro-optical flight symbology for helicopters. Specific interest was to be paid to studies which compared different symbol formats in hopes of finding some basis from which to begin to construct standards for design of future E/O displays. After an extensive review of the available literature, it must be concluded that no such research has been done. This is not to say that the research already cited here is of no value in the current standardization program. Quite the contrary, this work will provide a firm basis upon which candidate alternative display formats may be developed and tested.

Two explanations as to why these comparison studies have not been conducted in the past are readily apparent. First, the E/O technology required to make these displays feasible and practical in the operational helicopter is a relatively recent phenomenon. Second, no one has been able to firmly establish the information required by the pilot in the NOE environment. Many studies have aimed more toward establishing the optimal information package than toward developing the optimal symbology formats to present that information.

It is therefore imperative that the first step toward standardizing E/O flight displays be the establishment of standard information requirements. This can be accomplished by two approaches: (1) analysis of mission tactics and requirements, and (2) research validation of information required for effective aircraft operation. The user community has already undertaken an analysis effort, and the work by the Avionics Research and Development Activity described earlier provides a firm basis for research validation.

However, the work described falls short of determining optimal symbology formats. Alternate formats should be tested, especially for the peripheral scales and symbols such as altitude, airspeed and heading. The symbology developed by the Avionics Laboratory should be considered a baseline upon which to build and modify alternatives to arrive at the optimal. Additional attention must also be given to developing optimal symbology for transition and cruise modes of flight to complement the work already completed with hover symbology.

The guidelines set forth by Ketchel and Jenney (12) should be used to develop and analyze new candidate symbol formats. However, the final determination should be made based on empirical evidence derived through the experimental comparison of various proposed symbol formats. This will assure the selection of optimal symbology for E/O flight display standardization.

BIBLIOGRAPHY

1. Advisory Group for Aerospace Research and Development. Helicopter guidance and control systems. AGARD-CP-86-71, September 1971, (AD 731 670).

2. Advisory Group for Aerospace Research and Development. The guidance and control of V/STOL aircraft and helicopters at night and in poor visibility. AGARD CP-l48, May 1975.

3. Anderson, P., & Toivanen, M. Display and system requirements for low-visibility formation flight: Summary of results. JANAIR Report No. 710803, April 1972 (AD 740 375).

4. Armstrong, G.C. Pilot factors for helicopter refined AD1/HS1 and supporting displays evaluation. AF Flight Dynamics Laboratory, Wright-Patterson Air Force Base, IFC-TR-74-5, June 1975 (AD A013 796).

5. Avionics Laboratory Systems Engineering Team. Low level night operations study. US Army Electronics Command, Ft. Monmouth, NJ, ECOM 4417, June 1976.

6. Buckler, A.T. A review of the literature on the legibility of alphanumerics on electronic displays. Technical Memorandum 16-77, U.S. Army Human Engineering Laboratory, Aberdeen Proving Ground, MD, May 1977.

7. Carel, W.L., Herman, J.A., & Hershberger, M.L. Research studies for the development of design criteria for sensor display systems. Office of Naval Research, NR-213-107, March 1976.

8. Duffy, D.W. An analysis of the effect of a flight director on pilot performance in a helicopter hovering task. Navy Postgraduate School, Monterey, CA, Master's Thesis, March 1976 (AD A025 680).

9. Galluschio, E., Rasinski, J., & Eggleston, R. Helmet-mounted displays as an alternate source of flight information. U.S. Air Force Academy, Colorado Springs, CO., USAFA-TR-77-1, January 1977 (AD A034 724).

10. Honeywell Systems and Research Division. Display requirement study for high altitude hovering. 9B-M-3A, Honeywell, Inc., Minneapolis, MN, May 1969.

11. Jenney, L., Malone T., & Schweikert, G. Heads-up displays: A study of their applicability in civil aviation. Washington, D.C.: NASA, January 1971.

12. Ketchel, J., & Jenney, L. Electronic and optically-generated aircraft displays: A study of standardization requirements. JANAIR, Report No. 680505, May 1968.

13. McDade, J.L. An investigation of advanced pilots vertical display techniques. Naval Air Development Center, Warminster, PA, January 1973 (AD 755 739).

14. Milleli, R., Johnson, D., & Tsoubanos, C. Manual precision hover with superimposed symbology on FLIR image. Washington, D.C.: American Helicopter Society 31st Meeting, May 1975.

15. Palazzo, A.J. A model-based technique for flight director design: Helicopter hovering flight. Navy Postgraduate School, Monterey, CA, Master's Thesis, March 1975 (AD A009 976).

16. Semple, C., Heapy, R., Conway, E., & Burnette, K. Analysis of human factors data for electronic flight display systems. AFFDL-TR-70-174, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, OH, April 1971.

17. Sobocinski, R. Cathode ray tube centered HSI. AFFDL-TR-68-71, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, OH, May 1968.

18. Strothers, D., & Upton, H. Research on displays for V/STOL low level and IMC operations. In AGARD CP-148, May 1975.

19. Tsoubanos, C.M. An investigation of displayed ground referenced position, velocity, and acceleration for precision hover. ECOM-4334, U.S. Army Electronics Command, Ft. Monmouth, NJ, July 1975.

20. Tsoubanos, C.M. Development and flight test evaluation of a self-contained infrared hover system. ECOM-4520, U.S. Army Avionics Research and Development Command, Ft. Monmouth, NJ, August 1977.

21. Tsoubanos, C.M. Stabilized terrain optical position sensor (STOPS). A report on the FY74 Avionics Laboratory In-house Laboratory Independent Research (ILIR). ECOM-4283, U.S. Army Electronics Command, Ft. Monmouth, NJ, December 1974.

22. Tsoubanos, C.M., & Covington, R. Preflight test simulation of superimposed integrated trajectory error displays. ECOM-4184, U.S. Army Electronics Command, Ft. Monmouth, NJ, January 1974.

23. Walchli, R., Rauch, K., Halliday, W., & Gold, T. Flight evaluation of a heads-up display with real-world overlay for instrument approach and landing of V/STOL aircraft. SY-23R-75, Naval Air Test Center, Patuxent River, MD, October 1975 (AD B008 208L).

24. Wolf, J.D. Display and related system requirements for IFR steep approach: Final Report. JANAIR Report No. 711106, January 1972 (AD 736 247).