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QUALITATIVE EVALUATION OF A CONFORMAL VELOCITY VECTOR DISPLAY FOR USE AT HIGH ANGLES-OF-ATTACK IN FIGHTER AIRCRAFT

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SUMMARY

A piloted simulation study has been conducted in the Langley Differential Maneuvering Simulator (DMS) to evaluate the utility of a display device designed to illustrate graphically and conformally the approximate location of a fighter aircraft's velocity vector. The display device consisted of two vertical rows of light-emitting diodes (LED's) located toward the center of the cockpit instrument panel, with one row of lights visible to the left of the control stick and the other row visible to the right of the control stick. The light strings provided a logical extension of the head-up display (HUD) velocity vector symbol at flight-path angles which exceeded the HUD field-of-view. Four test subjects flew a modified F/A-18 model with this display in an air-to-air engagement task against an equally capable opponent. Their responses to a questionnaire indicated that the conformal velocity vector information could not be used during the scenarios investigated due to the inability to visually track a target and view the lights simultaneously.

INTRODUCTION

During the course of fighter aircraft display format research, many pilots have expressed a desire to have the direction in which the aircraft is traveling (aircraft's velocity vector) presented in the cockpit. The pilots felt that displaying the velocity vector conformally (relative to the outside world) would be beneficial during all phases of flight since the control systems in today's fighter aircraft are designed to maneuver the aircraft about this vector. Thrust-vectored control systems being developed for the next generation of fighter aircraft have accentuated this perceived need even further as agility requirements push normal operations into the post-stall region.

A piloted simulation study was conducted to evaluate the utility of a display device designed to illustrate graphically and conformally the approximate location of a fighter aircraft's velocity vector. The display device consisted of two vertical rows of lights located toward the center of the cockpit instrument panel to each side of the control stick. The light strings provided a logical extension of the head-up display (HUD) velocity vector symbol at flight-path angles which exceeded the HUD field-of-view.

This paper describes the conformal velocity vector display and experiment in detail. Subjective results, garnered from pilot questionnaires and discussions, are also presented.

SIMULATION CHARACTERISTICS

Aircraft Model

The aircraft simulation model utilized for this study was a non-linear, six degree-of-freedom, rigid-body dynamic model of a F/A-18 fighter aircraft modified to include thrust-vectoring capabilities. Thrust-vectoring enabled post-stall maneuvering of the aircraft at angles-of-attack up to a maximum of 70°. A description of the modified F/A-18 aircraft model can be found in reference 1.

Simulator

This study was conducted in the Langley Differential Maneuvering Simulator (DMS) (ref. 2, pp. 94 and 95, and ref. 3). The DMS consists of two identical fixed-based, visual flight simulators, each housed in a 12.2 m diameter (40 ft.) projection sphere (fig. 1). The facility was designed to provide a means of simulating two piloted aircraft operating in a differential mode. A dynamic sky/Earth scene was generated in each simulator sphere along with a target aircraft image. The target image presented to each pilot represents the aircraft being flown by the pilot in the adjacent sphere. For this study, however, only one sphere was utilized and the target aircraft was driven by the Tactical Guidance Research and Evaluation System (TGRES, pronounced "tigress"). TGRES is a software program that uses knowledge-based guidance to determine the most appropriate air-combat maneuver possible for the target aircraft relative to the position of the piloted aircraft (refs. 1 and 4), thus providing an intelligent and equally-capable opponent.

Cockpit

The simulator cockpit utilized three color cathode ray tubes (CRT's), each with a 6.5 in. square viewing area, to display aircraft state information (fig. 2). A wide-angle HUD was also provided. Other controls utilized included a control stick, dual throttles, and rudder pedals. The controls were programmed and configured for the modified F/A-18 aircraft.

VELOCITY VECTOR DISPLAY IMPLEMENTATION

A conformal velocity vector display was implemented in the simulator cockpit to indicate the location of the velocity vector of the aircraft. This was accomplished by physically placing two vertical rows of light-emitting diodes (LED's) toward the center of the cockpit instrument panel with one row of lights visible to the left of the control stick and the other row visible to the right of the control stick (fig. 3). This was made possible by installing the LED's in rectangular plexiglass frames. Two rows of lights were used instead of a single row to prevent total obstruction by the control stick while the pilot was maneuvering the simulated aircraft. The lights positioned closest to the angular location of the velocity vector were illuminated. The concept employed was that a straight line drawn between the pilot's eye and the illuminated lights would form a vector parallel to the aircraft's velocity vector.

The lights were spaced in six-degree increments beginning at 16° at the HUD and ending at 58° on the cockpit floor (fig. 4). It was thought that during an air combat task the velocity vector lights would be seen with the pilot's peripheral vision, therefore, the lights were flashed in order to make them more noticeable to the pilot. Each light flashed at a 5 Hz rate, however, the light positioned at 58° flashed at 10 Hz for all angles greater than 58°. If the position of the velocity vector was within one degree of the corresponding angular position value for a light, only that light would be illuminated. However, when the location of the velocity vector was between light angular position values, the two adjacent lights would be lit accordingly. For example, if the aircraft's velocity vector was positioned at 37°, the LED's located at 34° and 40° would flash simultaneously.

EXPERIMENT DESCRIPTION

Four pilots with varying degrees of air-combat experience participated in this study. The pilots were asked to engage in air-to-air combat with the target aircraft. While maneuvering against the opponent, the subjects were to evaluate the conformal velocity vector display and determine the utility of knowing the directional location of the velocity vector. The test was conducted on a strictly subjective basis with a questionnaire (appendix A) being given to each pilot at the completion of the session.

RESULTS AND DISCUSSION

This section discusses the comments obtained from the questionnaire and observations made during the pilot sessions.

It is well known that during air-to-air combat, the most important task for the pilot is to track the opponent visually and never lose sight of him. However, it was felt that the conformal velocity vector lights would be seen with the peripheral vision of the pilot and aid in engagement with an adversary. Due to the large angular differences that occur between the two aircraft and the human field-of-view limitations, however, it was impossible for the test subjects to see the lights during the majority of the engagement without looking away from the opponent. This was particularly true at high angles-of-attack when the illuminated lights were near the floor of the cockpit. As a result, all four pilots concluded that the conformal velocity vector display could not be utilized during the air-to-air engagement. Furthermore, they felt that the velocity vector information was not necessary for the scenarios utilized during this air-combat simulation, which was contrary to the information needs perceived prior to this evaluation by the pilots and display designers alike.

The velocity vector display presented the conformal location of the velocity vector in the vertical plane only. One pilot suggested illuminating either the right or left row of lights to indicate the direction of sideslip. This feature would provide more information about the vector to the pilot; however, the illuminated lights could be obstructed by the control stick while maneuvering the aircraft.

Although the velocity vector display was not useful during the simulated air-combat task, there may be other tasks or maneuvers, such as the "Herbst maneuver," that could be performed more proficiently with displays of this type. The Herbst maneuver is a 180° change of heading that is conducted by manipulating the aircraft into the post-stall range and then turning as rapidly as possible, completing the maneuver at the point of departure (ref. 5). Another application that could possibly benefit from the velocity vector display would be the very steep landing approaches that may be made by a Short Take-Off and Landing (STOL) fighter. This type of landing is made at slow speeds and high angles-of-attack, which preclude the use of a HUD since the velocity vector is outside of the HUD field-of-view. The velocity vector display could be used to indicate the approximate touch down point upon landing.

CONCLUDING REMARKS

Although it was thought that pilots might be able to obtain peripheral information from a conformal presentation of the aircraft's velocity vector, this study indicated that this was not possible during air-to-air engagements. The test subjects could not see the lights while visually tracking a target due to the large angular differences that occur between the two aircraft and the human field-of-view limitations. Although this implementation of a conformal velocity vector display was not advantageous for the scenarios investigated in this simulated air-combat environment, there may be other tasks that could benefit from this type of information display.

APPENDIX A

Velocity Vector Lights Display Questionnaire

The simulated flight that you've just completed incorporated a set of lights in the cockpit which indicated the spatial location of the velocity vector at high angles-of-attack. Please answer the following questions regarding the utility of this display concept.

1. Did you find the velocity vector lights useful under any of the simulated flight conditions? If so, which flight conditions and how were they useful?

2. Are there any other flight tasks that you can think of in which the velocity vector lights would be useful? If so, how would the lights be used to accomplish the task that you've just described?

3. How would you change the velocity vector lights to make them more useful to you?

4. Looking back over your answers, what would you conclude about the usefulness of the velocity vector lights and why?

Thank you for your time and comments. Hopefully, your efforts will lead us to a better understanding of the pilot's needs in tomorrow's high performance aircraft. If you are interested in the final results of this test, please leave your name and address so that I can mail you a copy of the results.

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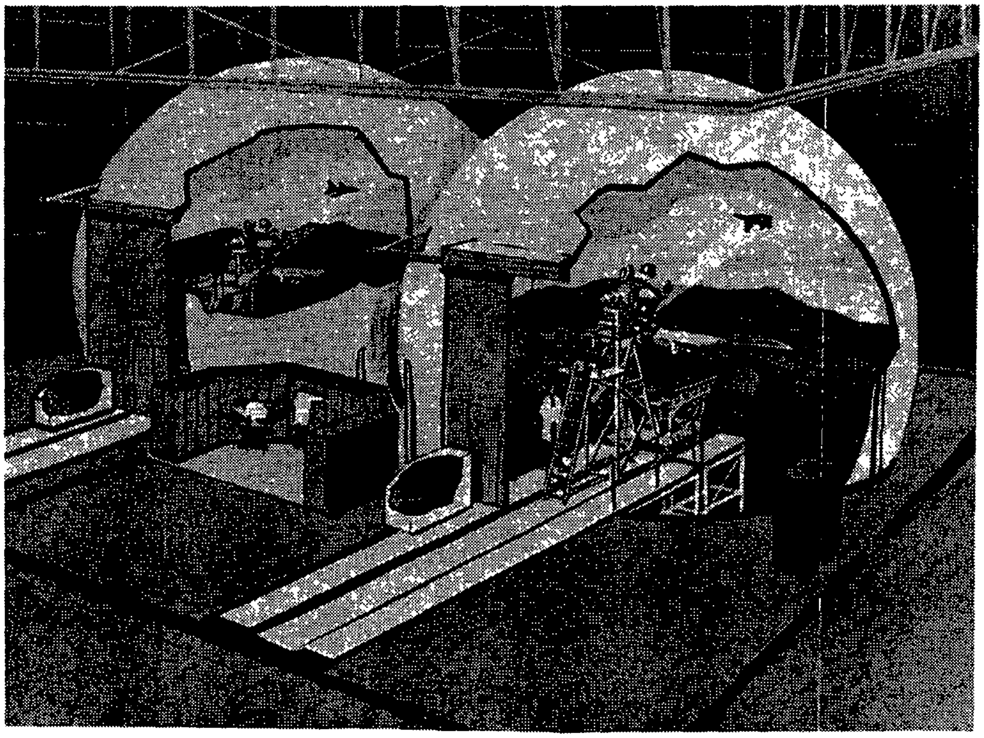

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Figure 1. Artist rendition of the Differential Maneuvering Simulator.

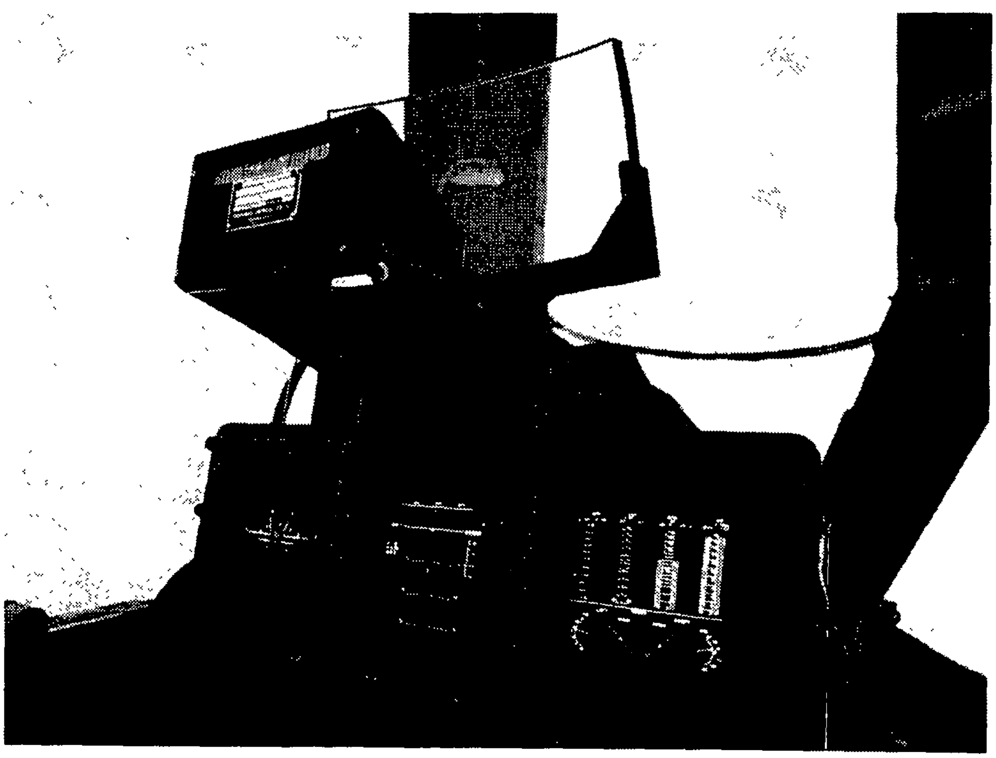

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Figure 2. DMS instrument panel.

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Figure 3. DMS cockpit emphasizing velocity vector lights.

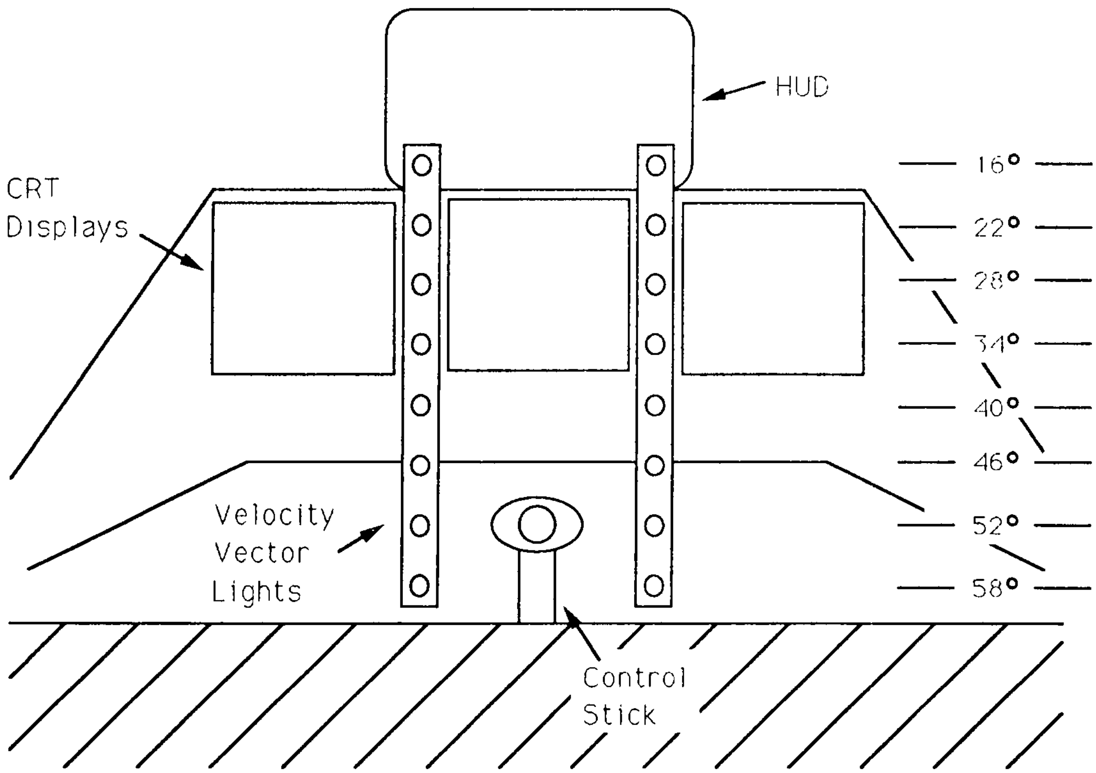

Figure 4. Angular position of velocity vector lights.

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15. Supplementary Notes

16. Abstract

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