PILOT-IN-THE-LOOP EVALUATION OF A NOVEL ACCELERATION SYMBOL FOR THE RNLAF AS-532 U2 COUGAR HELICOPTER HUD

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Abstract: The National Aerospace Laboratory NLR supported the Royal Netherlands Air Force (RNLAF) with a stepped-up introduction of an Aviator's Night Vision Imaging System / Head-up Display (ANVIS/HUD) on her Cougar helicopters, following an Urgent Operational Requirement (UOR) for the deployment in the International Security Assistance Force (ISAF).

The acquired Elbit Systems Ltd. helmet mounted ANVIS/HUD-24 system is intended to increase flight safety, in particular in operations where visual reference of the pilot is impeded, for instance during a brown-out or during shipboard operations – day and night. Where many HUDs present symbols for velocity and acceleration, a novel symbol for these parameters was proposed for use on the Cougar Helicopter.

During a pilot-in-the-loop evaluation with the help of NLR's Helicopter Pilot Station, acceleration scaling and filter characteristics were explored in combination with the adapted display configuration. Furthermore, some failure mode conditions, identified in a Functional Hazard Analysis (FHA) were evaluated - as part of the airworthiness program.

Given the UOR, a quick but capable simulator setup was accomplished. The evaluation gave insight in the effectiveness of the new symbol for landing and hovering in situations with reduced visual reference. The tests resulted in practical values for the novel acceleration vector's characteristics for the initial ANVIS/HUD requirement. Also, the initial classification of the display failure conditions as identified in the FHA could be confirmed.

1. INTRODUCTION

In April 2006 the National Aerospace Laboratory NLR was tasked by the RNLAF to support the airworthiness certification of a helmet mounted Aviator's Night Vision Imaging System / Head-up Display (ANVIS/HUD) for the RNLAF AS-532 U2 Cougar helicopter, following an Urgent Operational Requirement (UOR). The UOR resulted from the political decision to deploy the Cougar helicopters as part of the International Security Assistance Force (ISAF) in Afghanistan, September 2006.

The ANVIS/HUD system assures display of flight information to the pilot regardless of where the pilot is looking. It allows the Pilot Flying (PF) to ultimately lower his scanning rate and to prolong his outside focus. The system therefore aims at an increase of flight safety, in particular in operations where visual reference of the pilot is impeded, for instance during a brown-out or during shipboard landing. A brown-out occurs when operating in dry areas, were sand and dust is blown up due to the helicopter airflow.

The monocular Helmet Mounted Eye HUD of the acquired Elbit Systems Ltd (ESL) ANVIS/HUD-24 system is mounted in front of the right eye (Fig. 1). The night Eye HUD is mounted on the already in use ITT ANVIS 9 Night Vision Goggles (NVG).

Figure 1: Day (left) and Night Eye HUD of the ESL ANVIS/HUD-24 system.

2. SYMBOLOGY

2.1 General specification

The Eye HUD displays flight information, similar to that presented on the Primary Flight Display (PFD) and Navigation & Mission Data display (NMD). The certification process of the ANVIS/HUD is performed in two steps: first the hardware modification, which includes an RNLAF adapted set of Super Puma symbology, followed by an upgrade to a final requirement specified by the RNLAF, including the novel acceleration vector symbol that is the subject of this paper. Up to four display pages can be configured for the system; each page has a normal and a decluttered mode (Fig. 2).

The symbology is presented on a 25 degrees circular Field-Of-View (FOV) in day mode (day Eye HUD), and 32 degrees in night mode (night Eye HUD). The symbology is not head-slaved and not conformal to the pilot's point of view, as a line-of-sight (LOS) capability is not part of the present modification.

2.2 Acceleration and velocity symbology

Acceleration cues are especially important when hovering, landing or taking off. They help the pilot to precisely reach and maintain position. The introduction of an acceleration symbol is therefore justified, in particularly under conditions with reduced outside visual reference. With the primary intention to limit the amount of visible symbols on the display, a novel symbol was proposed that directly depicts the acceleration (A) vector, and indirectly the velocity (V) vector. In contrast with common helicopter HUD designs, the V-vector itself is not drawn.

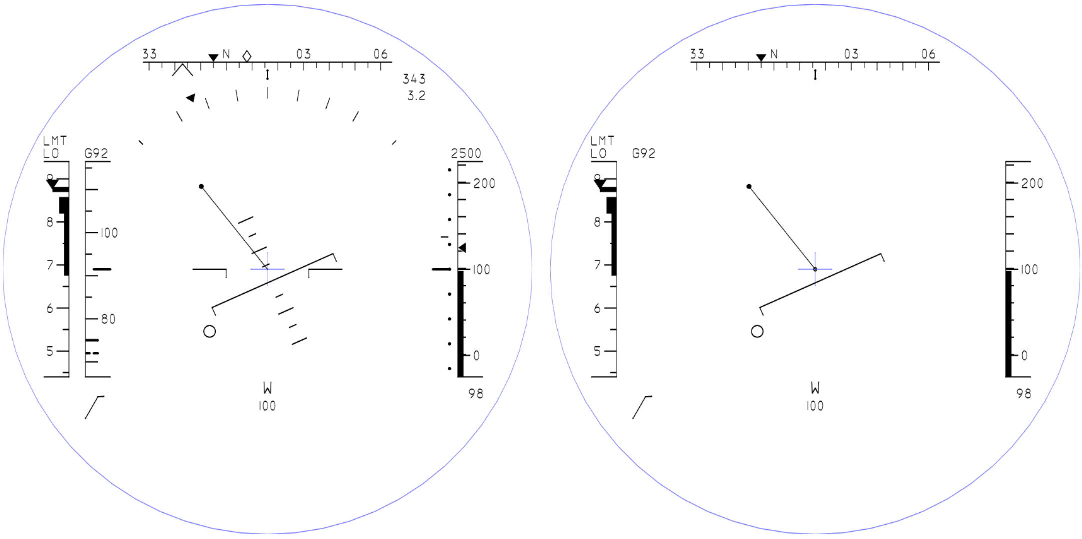

Figure 2: Normal Take-off and Landing page (left) and decluttered Hover page (right). The circle represents the outline of the Eye HUD FOV, the crosshair the centre.

The new symbol consists of a line that is ended by a dot (Fig. 3). The line extends from the imaginary V-vector. The length of the line indicates the magnitude of the acceleration, while the angle of the line indicates its direction. When the helicopter flies with a constant speed, i.e. zero acceleration, only the dot is visible. In this case, the dot's position resembles the magnitude and direction of the V-vector. Both the imaginary V-vector and the A-vector are considered to be earth-referenced.

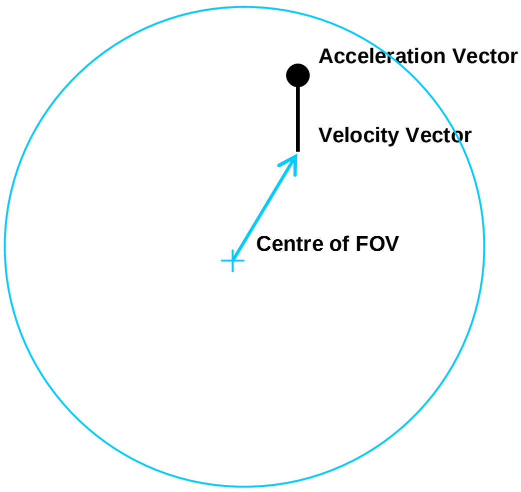

Figure 3: The new acceleration vector symbol and (imaginary) velocity vector.

3. EVALUATION SETUP

3.1 Objectives

Pilot-in-the-loop evaluations were performed to assess the effectiveness of the proposed A-vector for landing and hover, in situations with reduced visual reference. A proper scaling and filtering of the acceleration vector were to be obtained as part of setting the requirements for the final ANVIS/HUD symbology on the RNLAF Cougar. Display failure conditions, identified in the FHA, were to be incorporated to gain understanding of their impact within the foreseen operational framework.

3.2 Participants

Two RNLAF pilots participated in the trials. One pilot was a Cougar test pilot involved with the ANVIS/HUD modification program. The other pilot had just completed initial helicopter training and was awaiting conversion to the Cougar helicopter. He was not aware of the specifics of this program and did not previously see the ANVIS/HUD display symbology.

3.3 Apparatus

The tests were performed on NLR's fixed-base Helicopter Pilot Station (HPS) facility [x] (Fig. 4). The pilot was seated in a generic helicopter cockpit mock-up, controls and flight dynamics were configured to resemble those of the Cougar helicopter. The outside visual scene was generated using a three-channel projection system. Specifically for the tests, a simulation of reduced visual reference at low altitude and low speed was prepared that resembled a brown-out condition.

A RNLAF specified page configuration was drawn up and generated using the NLR's rapid display prototyping tool "Vincent" [1]. The display was then projected over the outside visual scene using a beamer. Resolution, FOV and update rate were matched, as far as possible, to those of the applicable Eye HUD. Some symbols, of lesser importance for the tests, were not displayed.

Figure 4: The HPS test configuration.

3.4 Tasks

Two landing scenarios were defined (Fig. 5). In the first scenario the sector waypoint was located next to a tank. The pilots had to land next to that tank, keeping the tank on the rightmost screen of the three-channel visual system. In the second scenario, the sector waypoint was located in a confined area: an open area surrounded by buildings. The pilots had to land in this confined area. In both scenarios the initial condition was located 1.5 km from the sector waypoint. Both scenarios were located on Schiphol airport, with a detailed visual database of the area, including three-dimensional representations of buildings and airport features.

The following conditions were available during the trials:

Outside view:
- Perfect
- Simulated brown-out

Time-of-day:
- Normal daylight vision
- Night with simulated NVG (green channel only)

Wind:
- No wind
- Steady wind
- Gusting wind

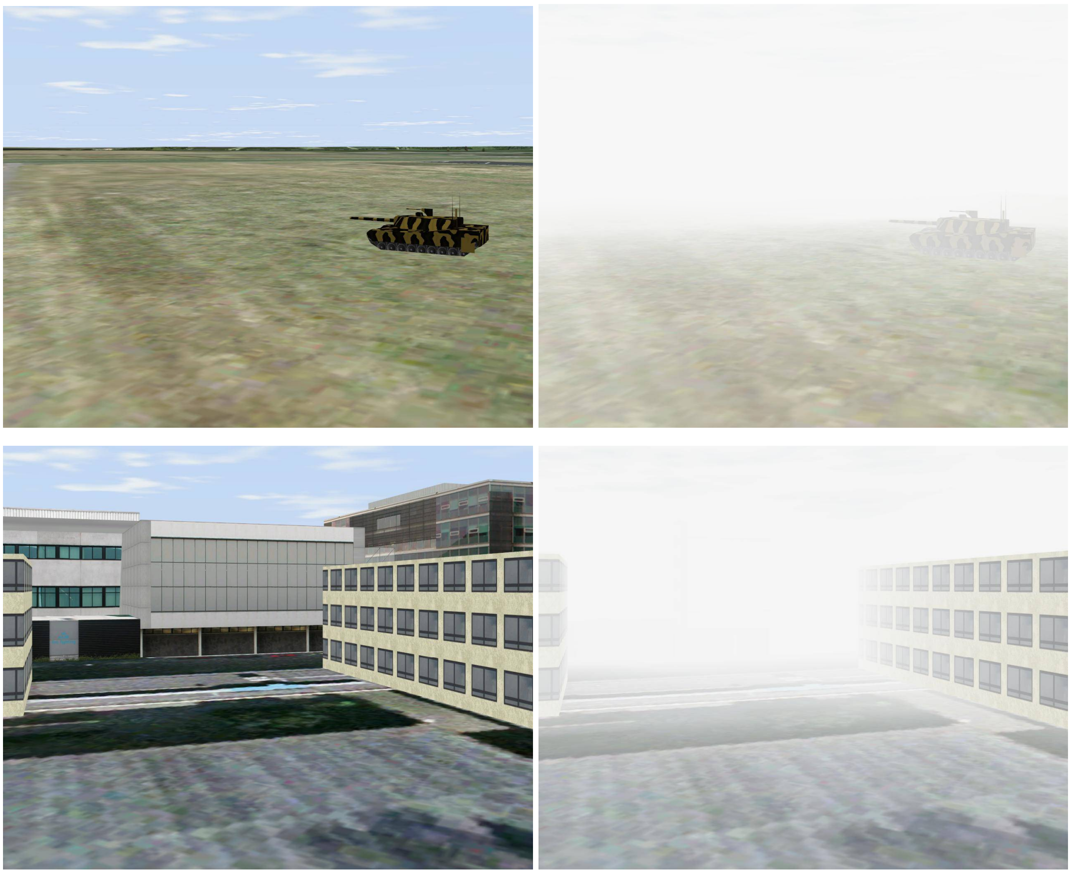

Figure 5: Outside scene when landing next to the tank (top) or in the confined area (bottom). Outside visual cues were either perfect (left) or with simulated brown-out (right).

3.5 Procedures

After briefing the HPS setup and the purpose of the test, the pilots familiarized with the simulated flight characteristics, control forces and the visual system. It was also the opportunity for the inexperienced pilot to get familiarized with the HUD symbology. Upon finishing familiarization, a formalized training phase was entered. Each pilot flew nine training runs *without* simulated brown-out. The first (tank) scenario was flown in daylight and simulated NVG conditions; the second (confined area) scenario was flown in daylight. All scenarios were performed three times, respectively without wind, with steady wind and with gusting wind. Then the loss of visual cues (simulated brown-out) was fine-tuned with the help of the test pilot.

Eleven experimental runs were flown by the test pilot in brown-out condition, including four runs with deliberate, but unannounced display failure conditions. Each run with a display failure was repeated without. The inexperienced pilot was not exposed to the display failures and flew eight experimental runs. Landing spot, time-of-day, and wind settings were varied. Pilots had to control the helicopter according to the following criteria: (1) groundspeed 3 kts or less at touchdown; (2) heading between 020 and 030; and (3) for the tank scenario: positioned alongside the tank or for the confined area scenario: inside the confined area.

Several predefined A-vector scale values were flown in order to arrive on an optimum sensitivity of the symbol. This corresponds to the length of the A-vector as a function of the magnitude of the acceleration. A-vector filtering characteristics were established informally on a separate occasion.

A questionnaire with questions related to handling qualities and A-vector sensitivity (scale) was completed after each experimental run. This questionnaire included the Cooper-Harper Handling Qualities Rating Scale [3]. Verbal comments of the pilots were recorded. The tests were concluded with a debriefing. All together, a total of approximately eight hours was spent on the ANVIS/HUD evaluation.

4. EVALUATION RESULTS

A total of 19 experimental runs were flown by two pilots (Fig. 6). All runs flown were rated as ‘controllable’ on the Cooper-Harper scale, but naturally the amount of required effort varied. Note that this includes the ratings of the pilot previously unaware of the ANVIS/HUD. Apparently, the use of the symbology in general and the new symbol in particular, is quite intuitive.

Based on sensitivity ratings given for each of the A-vector scaling levels, and considering the verbal comments given by the pilots, a suitable scaling for the A-vector could be determined. It is recommended to let the distance from the centre of the FOV to the roll scale correspond to 5 m/s^2. The night Eye HUD has a larger FOV than the day Eye HUD, and this is taken into account in this recommendation.

The selected filter for the A-vector was a simple low-pass filter with a 0.5 s time constant. This filter sufficiently reduces noise in the symbol, while eliminating a noticeable lag between accelerations and their display.

Observations confirmed the initial classification, as they were identified in the FHA, of display failure conditions related to the presentation of this novel symbol and the helicopter roll data.

5. CONCLUDING REMARKS

Given the UOR, a pragmatic but capable simulator setup was accomplished. The evaluation gave insight in the effectiveness of the new acceleration symbol for landing and hovering in situations with reduced visual reference. It delivered practical values for the acceleration vector's characteristics, but these values need to be verified in actual flight before operating with the final configuration of the ANVIS/HUD system. Also, the initial classification of the display failure conditions as identified in the FHA could be confirmed.

Based upon the availability of research facilities, such as Vincent [1] and HPS [2], and a track record in human-in-the-loop evaluations, including studies towards HMDs [4], NLR was able to answer the RNLAF tasking in a matter of a few weeks. While writing this paper, flight test with the final configuration of the RNLAF ANVIS/HUD, including the novel acceleration symbol, are performed. The first impressions are positive: scaling and filtering as determined in the simulator trials are working as intended.

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Figure 6: Pilot concentrated on performing the task.