EXTRACTS FROM THE TEST PLAN FOR IN-FLIGHT EVALUATION OF THE NT-33A PERIPHERAL VISION DISPLAY

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INTRODUCTION

The Peripheral Vision Display (PVD) presents the pilot with a gyro stabilized artificial horizon projected onto his instrument panel by means of a laser light source. During instrument flight conditions, such a display allows the pilot to gain attitude awareness by sensing the horizon line through his peripheral vision. The pilot can therefore detect changes to aircraft attitude without continuously referring back to his flight instruments.

A second generation PVD unit was installed in the USAF/Calspan NT-33A during late 1982. An NT-33A flight evaluation of the display provides a unique opportunity to utilize a Workload Assessment Device (WAD) to obtain quantitative data regarding the utility of the PVD in reducing pilot workload.

This test plan describes the experimental design and procedures for a two phase NT-33 PVD flight evaluation program. Six NT-33 flights will be flown at Buffalo, N.Y. during February 1983. These flights will consist of a calibration flight, a familiarization flight, and four data flights. The second phase of the PVD evaluation program will be flown at Edwards AFB during April 1983. Approximately two familiarization flights and six data flights will be flown at this time.

The general nature of the experiment covered by this test plan is as follows. The evaluation pilot (EP) flies the NT-33 in simulated instrument conditions created by means of a hood covering the front cockpit. He is tasked with performing a series of mild instrument maneuvers which emphasize angle of bank control. The NT-33 variable stability system (VSS) is used to provide the aircraft with a lightly damped Dutch roll with a high roll-to-yaw ratio. A mild random disturbance is introduced into the three aircraft axes by means of the VSS. The Workload Assessment Device (WAD) generates a random sequence of letters which are displayed on a readout located below the pilot's instrument panel. The evaluation pilot must respond to these letters with a 'yes' or 'no' as quickly as possible by pressing the appropriate cockpit button. His answers and reaction times are recorded by the WAD and are processed to determine pilot workload. The above tasks are performed with the PVD alternately on and then off. Differences in WAD data are used to quantify changes in pilot workload due to the Peripheral Vision Display.

OBJECTIVES

The objectives of the PVD flight evaluation program in the NT-33 are as follows:

- To obtain quantitative data regarding the utility of the PVD in reducing pilot workload during a high workload instrument flight environment; and
- To determine if the PVD improves pilot performance in eliminating large excursions from the desired aircraft attitude.

SCHEDULE

The following table shows the approximate dates, location, and purpose of all PVD evaluation program flights. Each flight will be of 1.5 hours duration. Chase aircraft flights are also included on the schedule.

Table 1

PVD Flight Evaluation Program Schedule

DATE	LOCATION	MISSION	FLT. HRS.
2-9 Feb 83	Buffalo	1 calibration flight	1.5 hr
7-18 Feb 83	Buffalo	1 familiarization flight	1.5 hr
		4 data flights	6.0 hr
		5 chase flights	7.5 hr
29 Mar-8 Apr 83	Edwards AFB	2 familiarization flights	3.0 hr
		6 data flights	9.0 hr
		8 chase flights	12.0 hr

NT-33 FLT. HRS.		CHASE FLT. HRS.	
Buffalo:	9.0	Buffalo:	7.5
Edwards:	12.0	Edwards:	12.0
Total:	21.0	Total:	19.5

PROJECT PILOTS

The number of PVD project evaluation pilots will be kept small in order to allow each pilot to fly several data flights. This will enable each pilot to gain sufficient experience with the PVD to learn to use the display to its best advantage.

The evaluation pilot who will take part in the PVD flights at Buffalo is Captain A. Lamoureaux, Canadian Forces.

During the flights at Edwards AFB, two Air Force Test Pilot School staff pilots, Major Lawrence Davis and Major Wayne Staley, will serve as evaluation pilots.

The NT-33 safety pilot will be from the Calspan engineering pilot staff.

TEST SYSTEM

NT-33A AIRCRAFT:

The test aircraft is the USAF/Calspan NT-33A in-flight simulator (Reference 1) operated by Calspan under contract to the USAF Flight Dynamics Laboratory. The NT-33A variable stability system (VSS) uses a response feedback technique to generate the dynamic response of the simulated aircraft. In this program the VSS will be set to provide Level 1 flying qualities in the longitudinal axis. The lateral/directional axes will be programmed to create a lightly damped Dutch roll ($\zeta = 0.1$) with a high roll-to-yaw ratio ($\phi/\beta = 3.5$). The variable stability system gains are scheduled with aircraft fuel quantity so that the dynamics remain constant throughout the flight.

A special circuit is available on the NT-33 which creates random disturbance inputs that can be entered into any of the VSS control axes. In this way a low level disturbance can be created and added to the aircraft's three axes to further complicate the evaluation pilot's flying task. The level of this turbulence is scaled to the NT-33's changing moments of inertia as fuel is consumed.

To simulate instrument flight conditions, and at the same time to darken the cockpit sufficiently to enable the evaluation pilot to see the PVD laser line under bright ambient light conditions, a hood will be manufactured for the front cockpit of the NT-33. Since this hood will severely limit the forward visibility of the rear seat safety pilot, the hood will be used only during in-flight evaluation of the PVD and taken down for take-off and landing.

The programmable Head-Up-Display will be removed from the NT-33 front cockpit during the PVD evaluation program. In the center front instrument panel a 5" attitude indicator will be installed. This will provide a conventional head down instrument scan pattern for the evaluation pilot.

WORKLOAD ASSESSMENT DEVICE:

The Workload Assessment Device (WAD) was developed by Systems Research Laboratories, Inc. (SRL) for the Systems Engineering Test Directorate of the Naval Air Test Center (NATC). The device consists of a processor and recording system located in the nose of the aircraft, a display system in the front cockpit, and a control terminal in the rear cockpit. The processor generates a random sequence of letters which are presented to the evaluation pilot either visually on the HUD or aurally over the pilot's intercom. During this program the visual presentation mode will be utilized; however, the WAD letters will be displayed on a small Liquid Crystal Diode (LCD) display below the front instrument panel instead of on the HUD. To control the WAD system, a handheld keyboard terminal is mounted to the rear cockpit left instrument panel. The WAD recording system uses a small cassette to record workload measurement data as well as up to 16 channels of other flight parameters.

During the workload test, the WAD presents one letter at a time to the evaluation pilot at a random interval of from 2 to 15 seconds. The mean inter-stimulus interval (ISI) will be set to 5 seconds, so that during a four minute evaluation approximately 50 letters will be presented to the evaluation pilot. While the pilot performs his primary flying tasks, he must also note each WAD letter and determine whether it is a

member of his "positive" set of letters (called MSETS) which he memorized prior to flight. He must perform this secondary task of responding to the WAD letters as quickly and accurately as possible; however, he must not let his response to the WAD degrade his primary piloting tasks. The evaluation pilot responds to each letter by pulling the control stick trigger when a letter is "positive" (that is, a member of his set) or depressing the upper stick button when the letter is "negative" (that is, not a member of his memorized set). As soon as the pilot responds, either correctly or incorrectly, the letter disappears. If a response is not received within a set period of time, a time-out error response is logged. Four different sizes of "positive" letter sets, containing zero, one, two, and four letters (MSET0 through MSET4, respectively) are used to obtain a complete workload evaluation. The zero letter set is a baseline in that no mental "sorting" is required for the evaluation pilot to respond — every letter is "negative." As the positive letter set size increases from one to four, more processing time is required by the evaluation pilot to determine if a letter is "positive" or "negative." Further information concerning use of the Workload Assessment Device can be found in Reference 2.

PERIPHERAL VISION DISPLAY:

The Peripheral Vision Display (PVD) or Malcolm Horizon was manufactured by Garrett Manufacturing, Ltd. for the Canadian Forces. The display provides a large horizon line which allows the pilot to maintain aircraft attitude without looking directly at his gyro reference. The PVD horizon line is produced by a Helium-Neon laser which rapidly sweeps across the instrument panel. This line remains parallel with the outside horizon through 360 degrees of aircraft roll. The line also moves in pitch to reflect aircraft pitch attitude changes. A switch is available to the evaluation pilot which allows him to select 1:1, 1:2, or 1:3 pitch scaling of the PVD line with respect to true pitch attitude. During this workload study, the 1:3 pitch scale will be used.

Other controls available to the evaluation pilot include a roll trim and pitch trim adjustment, a brightness control, and an on/off switch. The evaluation pilot switches are located on a remote control unit attached to the front cockpit left canopy rail. Other system components include a processor unit located above the safety pilot's instrument panel, and a laser projector located above and behind the evaluation pilot's right shoulder. Details of the PVD installation in the NT-33A can be found in References 3 and 4.

INSTRUMENTATION:

The 28-channel NT-33A digital tape recorder can record pilot control forces and displacements, aircraft response variables such as angles, angular rates, accelerations, and altitude.

A voice tape recorder is available for use during the PVD workload program. The voice recorder will be left on throughout each PVD evaluation to record pilot comments, WAD letters, and external distractions.

The Workload Assessment Device will record the evaluation pilot's responses to the visual letters as well as his reaction times. In addition, aircraft angle of

bank information will be recorded at a rate of 4 samples per second using one of the 16 available analog-to-digital recording channels.

FLIGHT TEST PROCEDURES

FAMILIARIZATION FLIGHTS:

The first flight that each evaluation pilot receives during this program will be a familiarization flight. The purposes of the familiarization flights are to:

- expose the evaluation pilot to routine NT-33 procedures;
- practice PVD, WAD, and VSS procedures;
- practice performing the instrument maneuvers;
- gain familiarity with use of the PVD; and
- collect preliminary PVD workload data.

Inflight procedures for the familiarization flights will be very similar to the evaluation flight procedures. Fewer WAD data runs will be performed on the familiarization flights than on subsequent data flights so that the evaluation pilot can devote more time to instrument maneuvering using the PVD.

EVALUATION FLIGHTS:

Each PVD data flight will consist of ten workload measurement evaluations. Each evaluation will consist of a four minute instrument maneuvering primary task concurrent with a WAD secondary task. The primary task requires the evaluation pilot to maintain a constant airspeed and altitude while accomplishing a sequence of constant angles of bank. As these maneuvers are performed the evaluation pilot must alter his instrument scan to allow him to observe the WAD letter display as much as possible without degrading his maneuvering task.

Four runs of the primary task are performed with the PVD turned off and another four runs are performed with the PVD turned on. During these runs the WAD 0, 1, 2, and 4 member letter sets are each used once.

Detailed flight cards will be generated for each flight, however, the following steps will help clarify the procedures for a typical evaluation flight.

- Cruise flight is established above 10,000' MSL at 250 KIAS.
- Front cockpit hood installed.
- PVD turned off.
- VSS engaged, evaluation pilot (EP) flies NT-33 with unstable spiral.

- Artificial lateral turbulence turned on (if required).
- Safety pilot (SP) turns on digital recorder, voice recorder, starts WAD.
- EP starts clock for 4 minute task.
- EP performs maneuvering primary task and responds to WAD secondary task.
- At end of 4 minutes, SP takes control of aircraft, stops WAD, turns off digital recorder, maneuvers to remain in designated airspace.
- EP makes comments concerning run, resets clock.
- Procedures are repeated until 4 runs are made using WAD MSETS 0, 1, 2, and 4.
- EP turns on PVD.
- Procedures are repeated for 4 more runs using WAD MSETS 0, 1, 2, and 4.
- Front cockpit hood removed.
- Return to base.

EVALUATION TASK:

The instrument maneuvering task which will be used during the PVD evaluation program will emphasize holding a set aircraft attitude for fairly long periods of time. The task will be coordinated with the clock so that the pilot's instrument scan will concentrate on aircraft attitude, airspeed, altitude, and time, with as much scan to the WAD visual letter display as is possible. With the PVD turned on, the pilot can set his precise attitude using the attitude indicator, and then rely on peripheral cues from the PVD horizon bar to warn him of changes to the set aircraft attitude. This may allow the pilot to devote more attention to the WAD visual display.

The sequence of specified angles of bank for the primary instrument task will be simple to avoid the necessity of having the evaluation pilot refer to an in-flight instruction card during the task. The following instrument task, or variations thereof, will be used for the PVD evaluation.

- Maintain 250 KIAS and constant altitude throughout the maneuver.
- First minute: hold wings level.
- Second minute: hold 30° bank to the left.
- Third minute: hold 30° bank to the right.
- Fourth minute: hold wings level.

TEST DATA

The most significant data collected during the PVD evaluation flights will be the workload information recorded on the WAD cassette recorder and the aircraft response data collected on the NT-33 digital recorder.

The Workload Assessment Device recorder provides information concerning the letters presented to the pilot as a secondary task, the responses made by the pilot, and the time it took the pilot to respond. Discrete angle of bank information will also be recorded by the WAD, but this information is intended primarily as a backup to the NT-33 digital recorder. Statistical reduction and print out of the WAD data can be accomplished using the WAD portable ground support unit. Interpretation and analysis of the workload data will be accomplished under the direction of Dr. Samuel Schiflett of the Naval Air Test Center.

Data concerning pilot performance in maintaining the desired aircraft flight condition will be collected by the NT-33 digital recorder. Angle of bank, pitch attitude, and altitude excursions are of primary interest in determining pilot performance during the instrument flight maneuvers. Time histories of appropriate parameters can be made using the "Quicklook" digital playback system located at the USAF Test Pilot School and at Calspan.

The voice recordings made during PVD evaluations will be reviewed to obtain pilot comments concerning workload, utility of the PVD, operation of the Workload Assessment Device, and whether external distractions interfered with any of the data runs.

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