PERSONAL EXPERIENCE WITH THE PVHD AND OPINION OF SITUATIONS IN WHICH A WIDE FIELD OF VIEW (FOV) PVHD MIGHT BE HELPFUL

by

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My initial introduction to the PVHD occurred in early 1980 accompanying the AFFTC bioenvironmental engineer while he was conducting a laser safety survey of the static cockpit display described in Paper 13. At that time, I was Chief of Aerospace Medicine at Edwards AFB and was more interested in the eye hazard implications. During our evaluation, I sat in the mock cockpit with the laser horizon on and, in turning around to make a seat adjustment, inadvertently glanced momentarily with my right eye directly into its beam. The brightness, of course, startled me. Though after-images persisted for a brief time, I was pleased to find no loss of acuity. (I am myopic and was wearing minus lenses at the time.)

Major Dave Edmondson, then at the USAF Test Pilot School, pointed out the principle of the PVHD and urged me to fly the incandescent light device of Vic Horton and Einar Enevoldson in their T-37 aircraft at NASA Ames Research Center's Dryden Flight Research Facility. One ride was sufficient to convince me that this was indeed a "better mousetrap." Light intensity was low requiring a dark night for adequate use, but the light PVHD worked as advertised. It provided excellent attitude information without the pilot having to look at it, even with the attitude director indicator (ADI) masked. Unusual attitude recoveries were simple, although from steeply banked positions, one might attempt to recover by rolling inverted. Precise attitude control was facilitated during precision approaches, again with the ADI taped over. One could easily monitor attitude with peripheral vision, thus freeing up central vision for tasks requiring acuity, such as monitoring performance instruments. It unquestionably simplified this task.

Having recently been reassigned to the Air Force Inspection and Safety Center as Chief of Life Sciences, I was in a position to analyze USAF aircraft mishaps. The following incidents are characteristic of the type that may have been prevented by a wide field of view attitude indicator such as the PVHD:

- Two-seat fighter aircraft departed single-ship into a low (500 foot) overcast; emerged 15 to 20 seconds later in a 45° dive, 90° of left bank. Wings rolled level and had started pullout just before impact.

- Observation aircraft departed single-ship into a low broken deck conducting a weather check; in and out of clouds on downwind, then entered a larger darker cloud. Emerged 10 to 15 seconds later in a 45° dive, 90° of right bank. Rolled wings level and had started pullout just before impact.

- Single-seat fighter aircraft on night-weather formation sortie was wingman in left fingertip descending in cloud, breaking out over lightless terrain at about 20,000 feet. The wingman drifted below lead, crossing to the right beneath. He called "lost wingman," continued to roll right, and descended to impact mountains 10,000 feet below.

- Single-seat fighter aircraft on a night-weather formation sortie called "lost wingman" in the clouds and impacted shortly thereafter.

- Single-seat fighter aircraft, number 4 on a daytime departure into weather, entering overcast at about 300 feet AGL. Apparently attempting to track and trail his element mates on his radar scope, he entered a descending right turn to impact.

- Single-seat interceptor aircraft returning single-ship to land, at night, through heavy rainshowers; broke out of a low ceiling left of course; quite likely had one or more warning lights. While angling toward the runway, allowed himself to get too low and struck tall trees less than two miles from the runway. Fatigue also a factor.

- Cargo craft making a circling approach to an unfamiliar airfield in lightless surroundings on a "black-hole" night. During turn to downwind, may have mistaken a lighted tower for conflicting traffic. Entered inadvertent, overbanked descent to impact. Fatigue also a factor.

- Two-seat fighter aircraft on a daytime dogfight mission departed controlled flight while defending against a gun pass and descended into a hazy undercast. Aircraft emerged at about 1,500 feet AGL in a slow spiral. Dual sequenced ejection initiated out of the envelope.

- Two-seat fighter aircraft on a daytime mission departed controlled flight during an intercept and descended into undercast of heavy clouds. Initially thought he had recovered control but then noted the ADI rolling at low altitude and wisely ejected in time.

- Single-seat fighter aircraft flying as wingman on a daytime weather departure into turbulent clouds. Lead became concerned about a collision and called, "Level at 17,000, climbing to 18,000," leaving his wingman in an approximate 30° left bank. Due to radio static, the wingman had misunderstood this call, and by the time he had transitioned back inside the cockpit, his ADI was rolling and showing mostly black. He confirmed the unusual attitude of the ADI on his head up display (HUD), and managed to begin a recovery as he broke through the overcast, pulling over 9g to barely miss the rocks.

- Single-seat fighter aircraft on a night formation radar delivery. Went head-down to the radar scope allowing a 2,000-foot descent to go undetected, impacting short of the target on run-in line. Fatigue also a factor.

- Single-seat fighter aircraft evaluating gunnery techniques on the range, daytime, turned toward downwind, channelized attention on the weapons delivery computer, failed to catch a descent, and flew into the ground.

- Single-seat fighter aircraft, daytime, preparing for a gunnery competition. While on downwind setting up for his third pass, went head-down to his weapons delivery computer, failed to monitor a slow roll descent, and initiated recovery a fraction of a second too late.

- Single-seat fighter aircraft, number 2 on a dark night range mission. Made a radar laydown pass and pulled off into a climbing left turn, during which the flight lead inititated a pre-briefed lead change, passing number 2 on his left. Number 2 indicated he'd entered clouds, then indicated some problem, most likely caution lights. He impacted within 20 to 30 seconds having rolled from a climbing left turn to an inverted right dive, 180° out of phase. Misinterpretation of the ADI or more likely, the HUD, was suspected. (HUDs are not optimized for instrument flying; in the ordnance delivery mode, the pitch ladder, which is mated to the velocity vector (flight path marker), slews all over the face of the combining glass – rendering interpretation difficult.) It is quite easy to misinterpret an upright climb from an inverted dive (Fig. 1).

- Single-seat fighter aircraft leading a number 3 ship to the range between cloud decks announced he had a problem and rolled abruptly into a hard left turn, presumably to return to base, immediately entering clouds. He emerged briefly only to enter lower clouds and impacted cloud-covered mountains at a fairly steep dive. There was a mismatch between the ADI and the standby attitude indicator, which, erroneously, indicated a climb.

- Single-seat fighter aircraft on a single-ship, black-night approach through weather claimed spatial disorientation while in the clouds in icing conditions from 8 to 4 miles out. Shortly after breaking out left of course due to cross-winds, he felt an unfamiliar "thump" (possible ice ingestion), neglected to monitor his vertical velocity indicator (VVI), struck an approach antenna, lost control, and ejected successfully. This pilot was task saturated.

- Bomber aircraft on a night terrain avoidance ordnance; delivery circuit failed to note a slight 1° to 2° descent into slightly rising terrain. Ground impact destroyed aircraft. Fatigue also a factor.

- Helicopter was letting down to a terrain avoidance low level, following a night aerial refueling. Failed to catch mis-set altitude warning and impacted terrain.

- Cargo plane returning from predawn exercise, permitted a 1° descent to go unnoticed for about one minute, impacting the surface. Fatigue also a factor.

- Cargo plane shooting an approach to minimums in low ceilings and blowing fog. Attempted to go visual prematurely, failed to detect an excessive VVI, and hit short, causing major damage.

- Reconnaissance aircraft shooting approach to minimums in blowing snow. Landed short.

- Single-seat fighter aircraft on night intercepts called "Tally-ho" while belly up to his target; had apparently mistaken surface lights for his target. Lost over 11,000 feet and impacted near surface lights. Fatigue also a factor.

- Single-seat fighter aircraft leading a night two-ship to the range. Coming off his initial pass, no spot from the bomb was seen. Turning to downwind, it appeared the pilot was trying to troubleshoot the "no" release. Allowed a descending turn to go undetected and impacted. Chronic fatigue a factor.

- Single-seat aircraft flying as wingman on aerial refueling sortie. Following top-off lead, called he was passing to assume lead, and also told wingman to ensure proper function of navigation equipment. While head-down checking his navigation equipment, the wingman drifted up and into lead and was killed.

- Trainer, solo, attempted to cross a high thunderstorm, flamed out engines, descended into clouds, apparently became disoriented while attempting restart, and crashed before completion of ejection sequence.

- Trainer, solo, flamed out at altitude, descended into clouds, became disoriented attempting restart, and ejected safely.

- Single-seat fighter aircraft lost control above an undercast, became disoriented attempting recovery in the clouds, and ejected safely.

- Single-seat fighter aircraft pilot making a daytime route weather abort became task saturated trying to locate his element mates on radar while changing TACAN channels; inattentive to his altimeter and VVI for nearly one minute during which his aircraft descended nearly 4,000 feet to impact. Fatigue also a factor.

- Single-seat fighter aircraft flying as wingman on a daytime departure into low clouds, entering clouds on the right wing. Within 15 to 20 seconds, both aircraft emerged through the 1,000-foot cloud bases in a steep dive, the wingman now on the left wing. Lead pulled hard; both aircraft struck vegetation.

- Single-seat fighter aircraft at night descended through a 2,000-foot cloud deck breaking out over a lightless black-hole across which a lone interstate highway ran. As he attempted to level off, his "ears" told him he was climbing vertically, yet the highway reflection off the top of his canopy told him he was in a steep dive. He fought hard to make the ADI indicate straight-and-level but admits he came very close to ejecting. After a minute or so, he was able to see city lights on the horizon, and immediately his disorientation vanished.

- Single-seat attack aircraft pilot climbing into weather on a route abort focused all his attention on the ADI to the exclusion of the airspeed indicator, stalled, lost control, and ejected.

Characteristics common to these incidents included night, weather, formation, false horizons, and situations requiring head-down time. These conditions led to either or both of two general types of spatial disorientation (SDO): that which alerts the pilot that something is amiss (such as the leans or pilot's vertigo), and that which does not alert him that anything is wrong. The aircraft is not on rails, and unless one pays attention to his attitude, the aircraft may insidiously and subliminally roll and/or pitch somewhat into unexpected, unanticipated, and unwanted attitudes. Many pilots refer to this latter form of SDO as "mis"orientation. Because the pilot is not alerted that anything has changed, he may postpone his instrument cross-check for too long a time. The insidious nature of "mis"orientation renders it every bit as lethal as the recognized form, if not more so. It would appear that the PVHD would be most helpful in preventing the unrecognized type of disorientation, though hopefully, it would also help him cope with the recognized form as well.

Other situations which would appear to benefit from the PVHD might include:

— Naval operations around the carrier, such as traps and catapult launches.

— Helicopter operations, particularly hovering over loose material such as dust or snow in which the rotor-wash kicks up particle concentrations sufficient to block visibility.

— Operations with special vision restricting devices that compound the difficulty of maintaining attitude.

Needs of the pilot: flying under conditions in which the pilot can visually reference the true surface, or the true horizon, the only instrument needed is an airspeed indicator. In flying under conditions where he cannot use the surface as a height reference, he may also need an altimeter. However, if he is flying in conditions denying valid references to the plane of the surface or to the true horizon, his most important instrument becomes some form of attitude indicator. Prior to the development of artificial horizons, pilots could maintain relatively level flight by mentally integrating the turn and slip indicator (needle and ball) with airspeed and altimeter. With the advent of the artificial horizon, the pilot now had one instrument that integrated for him all the information required for attitude. This single instrument has become far and away the most important gauge to the pilot and flying in instrument meteorological conditions. Many military aircraft incorporate a type of attitude indicator which also provides heading information and is known as the attitude director indicator ar ADI. In order to maintain awareness of his flying situation (situation awareness (SA)) pilots are trained to employ a cross-check of those instruments providing critical control parameters. This composite instrument cross-check is commonly a scan that refers to the ADI more frequently than to any other instrument. When a pilot feels disoriented, he is commonly instructed to focus the majority of his attention on the ADI and to force it to indicate straight-and-level flight. The larger the ADI, the easier this is to do. Large ADIs should be or should become the rule in the design of instrument aircraft. Whereas it may be permissible to miniaturize some instruments, this does not apply to the ADI. The ADI is one instance where big is definitely better.

In aircraft subject to night/weather formation flying, it would appear ideal to provide an artificial horizon that is wide enough to be monitored out of the corner of the wingman's eye. Preferably, it should also occupy a prominent location at or near the center of the instrument panel. A large, prominent, and commanding ADI is all the more important in the presence of design features that distract and disorient pilots — such as a head position high in a fishbowl canopy prone to glare and reflections. It should also enable him to transition quickly from outside to inside.

Theoretically, the Malcolm Horizon PVHD should serve admirably as a wide FOV attitude indicator, thus reducing spatial "mis"orientation and disorientation, easing and expediting the transition to instruments, and significantly reducing cockpit workload.

Anxious to see the laser PVHD in action, I requested a ride in the USAF/TPS RF-4C aircraft. Major Terry Lutz and Captain Blaine Hammond had been conducting flights with the rear cockpit hooded. I was more interested in noting how the PVHD fared in visually disorienting situations, such as in the weather or in formation. I was also interested in noting how it fared in brighter conditions, such as above cloud, below a cirrus deck, or while head-down as in a range pattern. Hence, we flew unhooded with Blaine Hammond piloting.

The PVHD worked as advertised providing continuous attitude information through 360° rolls and to its stops on loops; however I had several criticisms:

— The quality of the horizon projection needed improvement; bright dots were substituted for the horizon at lower power settings, and when the line appeared to connect the dots, it wavered continuously. I would prefer a nice crisp, sharp, unwavering line as I had seen with Lyle Schofield's model.

— The horizon line was only 18 inches wide; it did not seem that it could be monitored "subliminally" by the peripheral visual fields when head-out as in flying formation, or when head-down. However, it was much easier to "sneak a peek" at it, head-out or head-in.

This brings me to an anecdote regarding the PVHD. The PVHD was installed in the front cockpit of the single-seat night attack (SSNA) A-10 aircraft as described in Paper 9. It was projected onto the instrument panel as shown on page 95 of these proceedings. While conducting tests over a range one pitch-black night, the front-seat pilot initiated pulloff from an ordnance delivery pass. There was some problem with the ordnance, which he began to troubleshoot by looking back and forth from the left multifunction display to the armament control panel on the center pedestal. During the ensuing 10 to 15 seconds, he looked back and forth 4 to 5 times across the position of the PVHD. He had initiated a wings-level climb, but now, with his attention diverted from monitoring his flightpath, the aircraft began a slow roll to the right reaching over 90° of bank. The PVHD worked as advertised, rotating downward and counterclockwise, then moving back toward center as the aircraft began to descend. Though the pilot was looking back and forth across the PVHD, he never caught the unusual attitude. Finally, the safety pilot in the rear cockpit noticed the altimeter begin to unwind and alerted the front-seater to watch his altitude, not his attitude — for he had not caught the unusual attitude either.

Though this is only anecdotal, it indicates to me, at least, that one cannot depend on the PVHD to automatically alert oneself to odd attitudes anymore than the real horizon. One must devote some attention to his attitude. The advantage of the PVHD is that this can be done easily with the peripheral visual fields. There may, however, be some implications for training in its proper use.

Cockpit compatibility cursory evaluation: Following the conference, several participants (Einar Enevoldson, an Ames Dryden test pilot; Art Kennedy of Garrett of Canada, which manufactures the Malcolm Horizon; and I) evaluated the PVHD at night, in three aircraft cockpits at Ames Dryden: F-111, F-15, and F-16.

— F-111. With plenty of instrument panel available, the PVHD appeared quite compatible. Canopy reflections were no problem. Centering roll axis produced the roll-pitch illusion seen in the T-37 aircraft. If used in the F-111 aircraft, it would seem wise to center the roll axis in front of the pilot.

— F-15. There appears to be sufficient panel to display the PVHD, although the pilot's line of sight is somewhat higher. Monitoring is possible during head-out simulating formation flying, as well as going head-down. There were occasional annoying reflections off certain instruments, though none off the HUD or canopy. Interestingly, the PVHD does not show up when projected onto multifunction display (MFD) surfaces, although this could apparently be corrected with a different surface coating.

— F-16. Though F-16 aircraft instrument panels vary somewhat from block to block, they're all similar when it comes to the Malcolm Horizon:

> Surface on the upper portion of the panel is limited and that surface which is available is broken up by the HUD control panel which juts out 5 to 6 inches from the plane of the instrument panel.

The PVHD does appear to be compatible with the F-16 airplane cockpit if it were projected below the HUD control panel over the bottom row of instruments (airspeed indicator, ADI, and (in block 10) the altimeter). Here it would appear to be quite useful to a pilot while he is head-down.

Aimed too low, the PVHD strikes the pilot's knees which jut up above displays on the center pedestal, due to the tilt-back seat.

Canopy reflections might be a problem. PVHD occasionally generated reflections.

Summary: Personal experience with the PVHD indicates that it should have great promise in easing cockpit workload, improving situational awareness, and reducing spatial disorientation.

It should not be assumed that the PVHD will automatically cue the pilot to his attitude without some training or exposure. Some measure of attention needs to be devoted to attitude although this can easily be accomplished by the peripheral visual fields without tying up central vision.

The PVHD would appear useful in any aircraft that flies in spatially disorienting/misorienting conditions, such as night, weather, or formation. It would appear to be particularly useful in aircraft, that by their design, are especially disorienting in such circumstances.

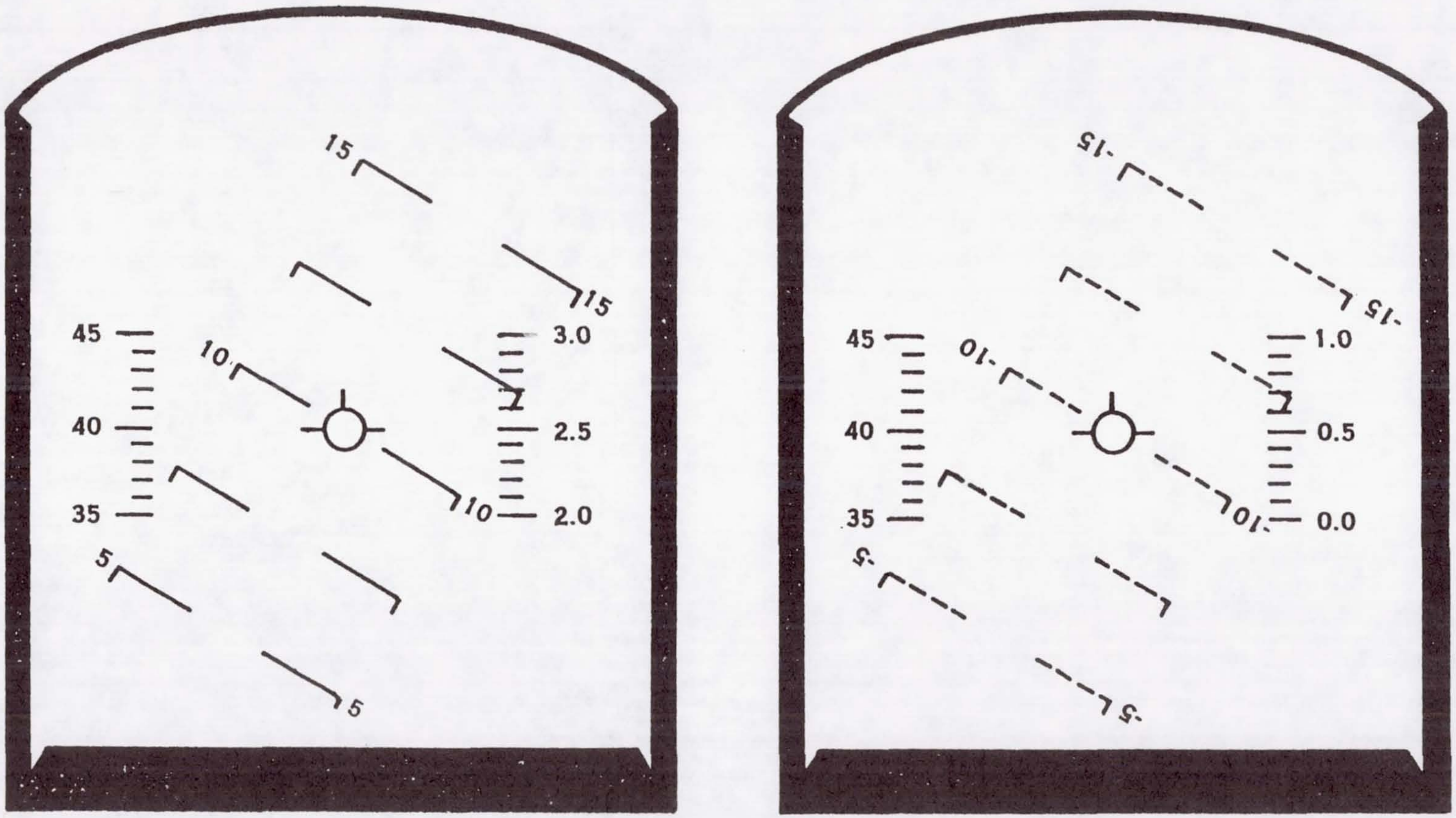

Figure 1.