A Comparison of the AVS-9 and the Panoramic Night Vision Goggles During Rotorcraft Hover and Landing

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Abstract

A flight test was conducted to assess any differences in pilot-vehicle performance and pilot opinion between the use of a current generation night vision goggle (the AVS-9) and one variant of the prototype panoramic night vision goggle (the PNVGII). The panoramic goggle has more than double the horizontal field-of-view of the AVS-9, but reduced image quality. Overall the panoramic goggles compared well to the AVS-9 goggles. However, pilot comment and data are consistent with the assertion that some of the benefits of additional field-of-view with the panoramic goggles were negated by the reduced image quality of the particular variant of the panoramic goggles tested.

Introduction

The purpose of this flight test was to measure any differences in pilot-vehicle performance and pilot opinion between the use of the current generation AVS-9 Night Vision Goggle (NVG) shown in Fig. 1, and the prototype Panoramic Night Vision Goggle (the PNVGII variant) shown in Fig. 2. These goggles differ in field-of-view (FOV) and image quality. In addition to recording pilot-vehicle performance data, subjective measures were also recorded of the physical reserves of the pilot and image usability.

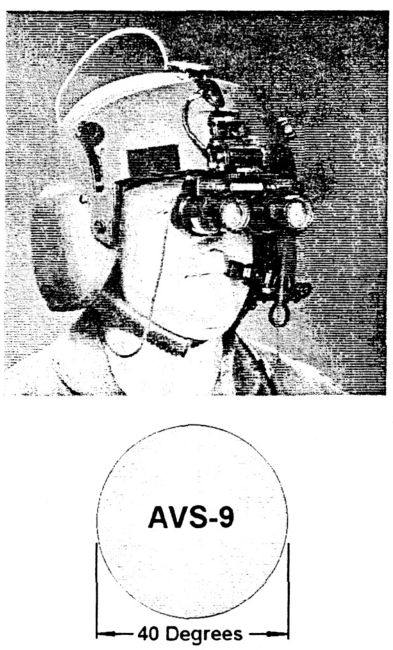


Fig. 1. AVS-9 Night Vision Goggle with 40° FOV.

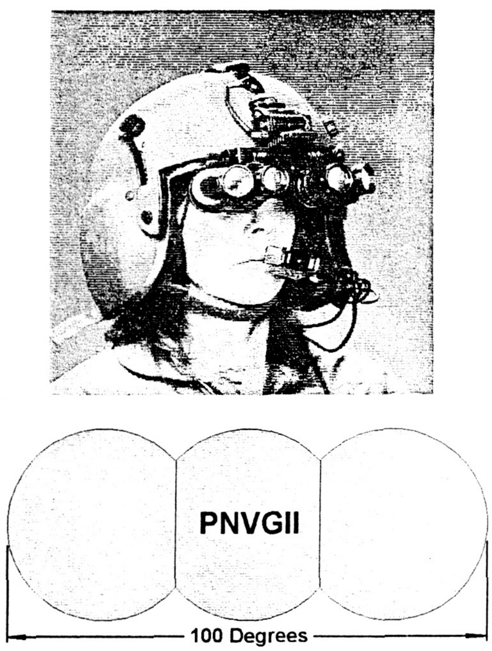


Fig. 2. Panoramic Night Vision Goggle with 100° FOV (US Air Force PNVGII variant).

Night vision goggles (NVGs) enable safer rotorcraft flight low to the ground in degraded visual environments than would be possible with unaided vision. However, NVGs do not provide the same FOV or the same image quality that the pilot has during normal daylight conditions. The FOV of the current generation NVG, such as the AVS-6 and AVS-9, is 40° compared to 200° available to the eye in unaided, daylight conditions (Ref. 1). In an effort to produce NVGs which have a FOV closer to natural vision, the US Air Force (USAF) developed different variants of the panoramic night vision goggle (Ref. 2).

Two variants of the PNVGs were subjectively evaluated by the USAF on F-15, C-5, and C-130 fixed wing aircraft (Ref. 3). Further subjective evaluations were performed by the US Army on UH-60, OH-58, and CH-47 helicopters (no references available). The flight test described in this paper uniquely complements the previous subjective flight evaluations of the PNVGs by providing objective rotorcraft pilot-vehicle performance data from a highly accurate differential global positioning system (DGPS) receiver.

The flight test described in this paper uses similar methods and maneuvers from a previous FOV test conducted jointly by the US Army, the United Kingdom Defence Evaluation and Research Agency (DERA), and NASA (Refs. 4, 5). In this previous helicopter test, pilot-vehicle performance was measured while pilots flew with FOVs up to 100°. A visor-mounted aperture was used to simulate a helmet mounted display (HMD). For most maneuvers, the sample pilot population showed a statistically significant increase in pilot-vehicle performance up to a range between 60°-80° FOV with an unmodified (except for FOV) daylight view of the scene. Given the 100° FOV of the PNVGII goggles, this previous test predicts that pilot-vehicle performance should increase with the use of the PNVGII as compared to the AVS-9 goggle unless the performance is negated by image quality effects or loss of some portion of binocular vision.

The National Research Council (NRC) in Canada also conducted helicopter flight trails with reduced pilot FOV. One NRC test used actual NVGs of 40° and 52° FOV (Ref. 6). The other NRC test used apertures to simulate an HMD up to 100° FOV (Ref. 7). These NRC tests are relevant to the test described in this paper in the methods used more than the data obtained.

With the development of the PNVG, the opportunity was created to apply the experimental methods used previously to an actual wide FOV night vision device. This paper details the flight test matrix, equipment used, results, and analysis of the data comparing the AVS-9 and PNVGII goggles. This flight test was conducted jointly by the US Army Aeroflightdynamics Directorate (AFDD) and NASA Ames Research Center.

Test Methods

Experimental Matrix

For the test described in this paper, three visual conditions were flown: unmodified vision in daylight, AVS-9 at night, and PNVGII at night. The three maneuvers were landing, bob-up, and pirouette. Four pilots flew the test. The complete experimental matrix is shown in Fig. 3. For each combination of pilot and maneuver, the AVS-9 and PNVGII data points were flown one immediately after the other so that conditions were very nearly the same. The first and third pilots started the landing with the PNVGII, started the bob-up with the AVS-9, and started the pirouette with the PNVGII. The second and fourth pilots had the reverse order of goggles used for counterbalancing. The order of the maneuvers was the same for all four pilots.

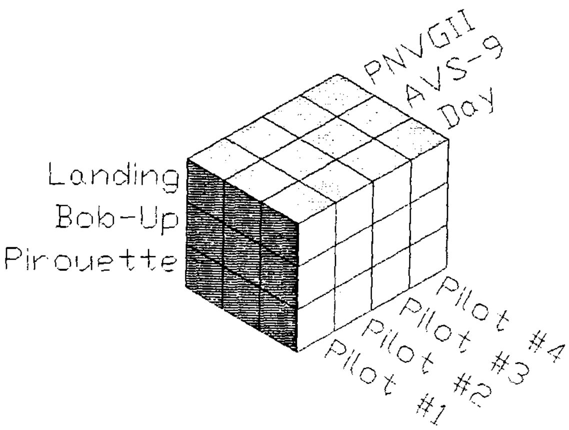


Fig. 3. Experimental matrix.

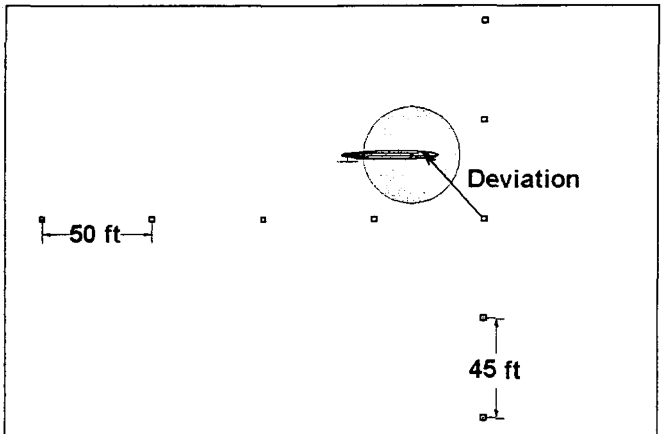
For each cell in the matrix, at least one practice maneuver was flown immediately before data were collected for that cell. Each cell was repeated with data collection at least twice and no more than three times.

Not shown in Fig. 3 are the flights flown entirely for practice. The pilots had one practice daylight flight of 1-2 hours duration before the daylight data collection flight. The pilots had one practice night flight of 1-2 hours total duration with both sets of goggles before the night data collection flight. All cells in the test matrix were completed on the two practice flights for each pilot.

Pilots

All four evaluation pilots were US Army test pilots from the Army Aviation Technical Test Center. All evaluation pilots were AH-1 qualified and current. In addition, all evaluation pilots were NVG qualified, but not necessarily current. None of the evaluation pilots wore corrective lenses while flying the aircraft, day or night. The safety pilot was an NVG qualified and current instructor pilot for the AH-1S. The same safety pilot flew all flights for consistency.

Maneuvers
Three maneuvers were flown which were similar to maneuvers flown in the previous FOV test by the Army, DERA, and NASA. Visual cues were different than the previous test. The first maneuver flown during the current test was the landing maneuver, shown in Fig. 4. The evaluation pilot started the maneuver 200 ft from the landing point, at 20 ft altitude. Within a desired goal of 18 seconds, the pilot landed the aircraft and attempted to place his body position over the landing point and the heading in-line with the course. As the pilot approached the landing point, forward visual markers were no longer visible, forcing the pilot to look left or right at approximately. 90°. The side cones provided parallax cues for longitudinal position, but not lateral position.

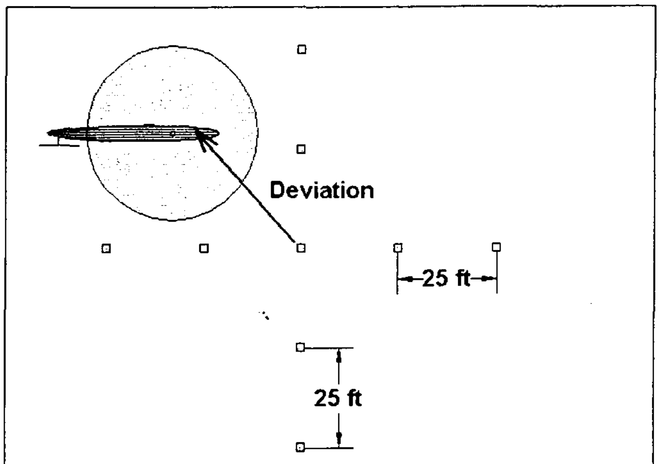


Landing	Desired	Adequate
Time [sec]	18	23
Longitudinal position [ft]	+/-2	+/-4
Lateral position [ft]	+/-2	+/-4
Maintain heading [deg]	+/-5	+/-10

Fig. 4. Landing maneuver.

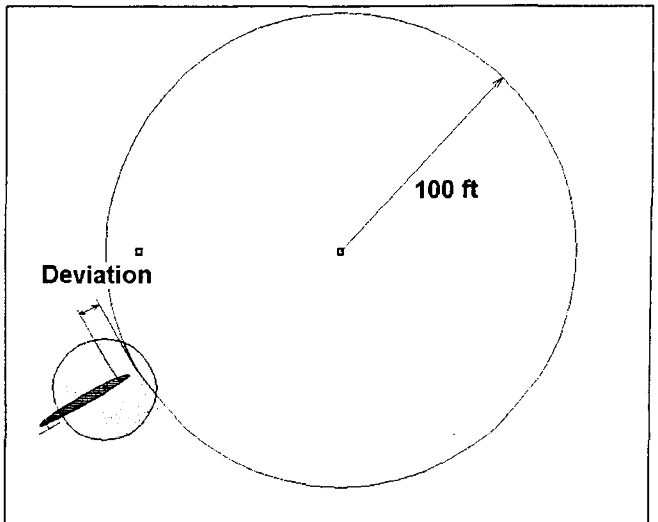
The second maneuver was the bob-up shown in figure 5. In this maneuver, the evaluation pilot started at a 10 foot stable hover with his body position over the hover point and heading in-line with the course. Within a desired goal of 45 seconds, the pilot ascended to what he estimated to be 50 foot altitude, stabilized, performed a 360° constant altitude turn, stabilized, descended to what he estimated to be 10 foot altitude, and stabilized again. During the entire maneuver, the pilot attempted to keep his body position over the hover point.

The final maneuver was the pirouette, shown in Fig. 6. The pilot started at a stable 10 foot hover over the starting point on the circumference of the 100 foot radius circle, with the aircraft pointed toward the visual marker at the center of the circle. Within a desired goal of 45 seconds, the pilot flew the aircraft around the circle, attempting to maintain his body position over the circumference of the circle, and attempting to keep the nose of the aircraft pointed at the center of the circle.



Bob-up/Turn/Bob-down	Desired	Adequate
Time [sec]	45	60
Longitudinal position [ft]	+/-10	+/-15
Lateral position [ft]	+/-10	+/-15
Maintain 50 ft altitude at top [ft]	+/-5	+/-10
Maintain 10 ft alt. at bottom [ft]	+/- 3	+/-5
Maintain heading during ascent and descent [deg]	+/-5	+/-7

Fig. 5. Bob-up maneuver.



Pirouette	Desired	Adequate
Time [sec]	45	55
Longitudinal position [ft]	+/-10	+/-15
Maintain 10 ft altitude [ft]	+/-3	+/-4
Heading toward center [deg]	+/- 10	+/-15

Fig. 6. Pirouette maneuver.

Visual Cues
The landing and bob-up maneuvers were performed over grass using 18 inch high orange traffic cones as visual cues. The center cones at the landing point and bob-up point were reduced in height to about 6 inches in order to keep the cones from contacting the antennas on the bottom of the aircraft. Red chemical lights were placed at night inside these two shortened cones.

The pirouette maneuver was flown over concrete, with a painted white circle of approximately 3 inch thickness marking the circumference. There was also a shortened traffic cone in the center of the circle with a red chemical light placed inside. A full size traffic cone was placed within the circumference of the circle and was visible in front of the pilot to mark the start and stop point of the maneuver.

Lighting Environment

All maneuvers were performed at the Moffett Field, located at the south edge of the San Francisco Bay. Airfield runway and obstruction lights were turned off during the test. Cultural lighting varied with heading. To the north was the dark bay, and city lights 20 or more miles further north. All three maneuvers were started and stopped in this direction. To the east and west were industrial light sources several thousand feet away. To the south was the greatest amount of lighting from the buildings at Moffett Field. Additional testing at a rural site without artificial lighting was not performed due to time and funding constraints. Table 1 lists the amount of the lunar disk illuminated during the test hours for each of the four pilots, designated W, X, Y, and Z.

Table 1.

Pilot W:	No moon during test hours
Pilot X:	97% moon during test hours
Pilot Y:	9% moon during test hours
Pilot Z:	No moon during test hours

Equipment

Night Vision Devices

The AVS-9 goggle is the latest generation goggle used by the USAF, Navy, and certain units of the Army. The AVS-6 goggle is the most widely used goggle in the Army, and is of slightly older design. Both goggles have a binocular, circular, 40° FOV. Both goggles have focusing mechanisms on both the objective (front) lenses and the eyepieces.

Two variants of the PNVG were developed by Night Vision Corporation of Lincolnwood, Illinois. One variant is called the PNVGI, and is intended for fixed wing, ejection-capable aircraft. The other variant is called the PNVGII and is intended for fixed wing transport aircraft and rotorcraft, which do not have ejection seats. Only the PNVGIIs were evaluated in this test. The I-PNVG and A-PNVG developed by Insight Technology of Londonderry, New Hampshire were not yet manufactured at the time of this test.

As shown in Fig. 1 and Fig. 2, the most noticeable difference between the AVS-9 and the PNVGII is the tremendous increase in FOV with the PNVGIIs. This increased FOV on the PNVGII was achieved by using four image intensifier tubes instead of two. The center two tubes are aligned to provide a 30° horizontal, binocular FOV. The left and right tubes provide an additional 35° horizontal, monocular FOV on each side of the center FOV, for a total of 100° horizontal FOV. The vertical FOV of the PNVGII varies up to 40° as shown in Fig. 2.

The only focus mechanisms on the PNVGII are on the objective lenses of the center tubes. Both the AVS-9 and PNVGII have a complete set of mechanisms for centering the exit pupil for each pilots' eyes.

The four tubes of the PNVGII each have less resolution than the AVS-9 goggles, as shown in Fig. 7. Furthermore, the outer tubes of the PNVGII goggles have less resolution than the center tubes. Resolution measurements were taken through the actual devices used in the test. Each evaluation pilot read a tri-bar chart 100-120 ft away at the pirouette test site, through the canopy, under the same lighting conditions that existed during the flight tests. Furthermore, each pilot read the chart looking forward (north), left 90°, and right 90°. Each bar in Fig. 7 therefore shows the average value of 4 pilots x 3 readings each. For reference, the average human has approximately 50 cycles/degree of resolution under ideal daylight conditions (Ref. 8).

The pilots did comment on the differences in resolution between tubes of the PNVGII when viewing the scene at the test site. The pilots did not comment on the differences in resolution of the two tubes of the AVS-9 when viewing the same scene. For the AVS-9, the differences are at a finer resolution where it was apparently less noticeable. Another important difference between the two goggles was the response to bright light sources as detailed in a later section on the pilots' comments.

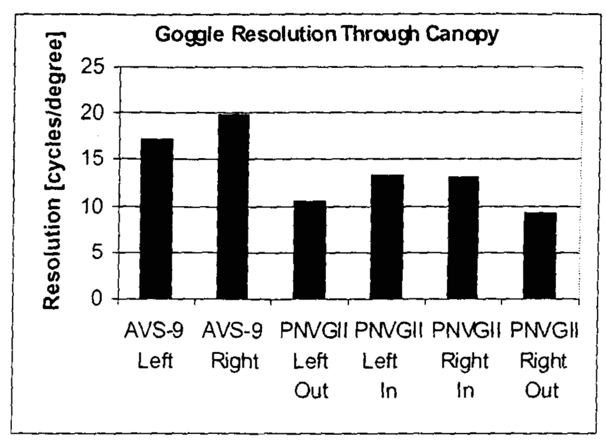


Fig. 7. Resolution measurements for each NVG tube.

Helicopter

An NAH-1S (Cobra) helicopter shown in figure 8 was used for this test. All evaluation pilots flew from the front seat of the aircraft. This seat position provided the pilot with a symmetric and minimally obstructed view of the outside world. The cyclic flight control stick in the front cockpit was non-standard; the control linkage was hydraulically boosted to enable the stick to move with less force than standard AH-1 cyclic side-sticks. Aircraft attitude, altitude, and heading instruments were covered in the front cockpit, forcing the pilot to obtain cues from the scene outside the cockpit.

The aircraft was modified with a carrier phase tracking DGPS, which measured the aircraft flight path in three dimensions. The DGPS antenna was placed on the canopy directly over the front pilot's seat position. The recorded antenna position did not take into account the movement of the pilot's head within the confines of the cockpit. The amount of these head movements was the limit of accuracy for this test as far as recording the pilot's body position. Altitude readings were biased for each maneuver area in order to convert GPS datum altitudes to skid height above the ground. DGPS data was recorded on-board at 10 Hz, and transmitted in real time to the ground at 1 Hz.

The starting and stopping of data recording on the aircraft was controlled from the ground via a radio modem. The pilots called out the start and stop of each maneuver over the radio. Head tracker data could not be used due to dynamic inaccuracies of the installed tracker.

Fig. 8. NAH-1S helicopter.

Results

Position Data

In this section, performance data are provided strictly as a function of the three dimensional position of the pilot's seat location in the horizontal plane, and skid height above the ground in the vertical axis. Post flight analysis showed that the pilots did not have sufficient visual cues to provide accurate handling qualities ratings (Ref. 9).

All aircraft position data shown in Fig. 9 through Fig. 15 were measured with the DGPS system. All combinations of pilot, maneuver, and visual condition represent the average of at least two, and not more than three repetitions of that set of conditions. Due to the small sample size of 4 pilots, statistical tests of significance were not meaningful, and data are discussed in terms of apparent trends.

Figure 9 shows the measured deviation (horizontal distance) from the landing point. If the two horizontal, orthogonal measurements of position are called a and b, then the deviation is computed as follows:

$$\text{Deviation} = (a^2 + b^2)^{1/2} \qquad (1)$$

As shown in Fig. 9, all pilots were able to land the aircraft best during the daylight. Comparing pilot performance between the PNVGII and AVS-9 conditions, three out of four pilots landed the aircraft more accurately with the PNVGII goggles.

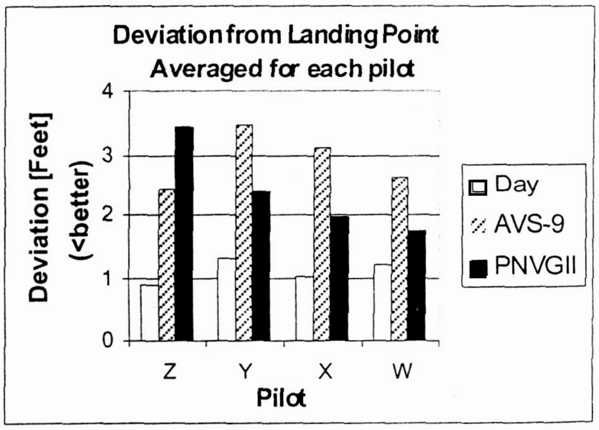


Fig. 9. Position deviation from landing point.

Figure 10 shows the measured maximum deviation (horizontal distance) from the bob-up point, computed for the entire duration of the maneuver using Eq. 1. Daylight data for pilot Z were not obtained due to problems with the instrumentation at that time. As shown in Fig. 10, pilots had less horizontal deviation from the bob-up point during the daylight condition than during the night conditions. Furthermore, three out of four pilots had less drift from the bob-up point with the PNVGII compared to the AVS-9 goggle.

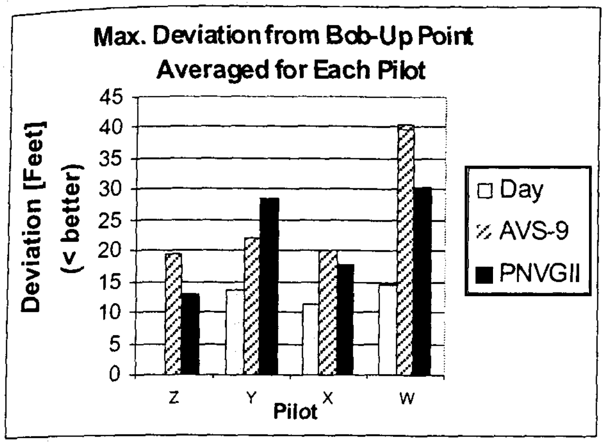


Fig. 10. Position deviation from the bob-up point.

Figure 11 shows the maximum altitude achieved during the bob-up maneuver, averaged for each pilot. The target altitude was 50 foot. In this maneuver, there are only slight differences between the pilots' performance for day compared to night conditions. Furthermore, there are only slight differences between the pilots' performance for the two goggles. In all visual conditions, the pilots stabilized at a higher altitude than the target of 50 foot.

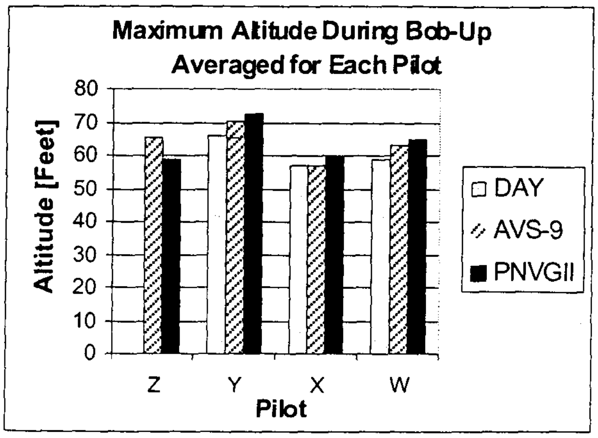


Fig. 11. Maximum altitude during the bob-up.

Figure 12 shows the minimum altitude during the descent portion of the bob-up maneuver. The pilots descended from a stabilized hover at the top of the bob-up (greater than 55 feet) to a target altitude of 10 feet. Altitude estimation was obtained strictly by the use of outside visual cues. There are no strong trends in the data comparing the PNVGII condition to the AVS-9 condition. However, as shown in Fig. 12, all three pilots from which daylight data were obtained completed the descent at higher altitudes during the day compared to the night conditions. Even though the descents at night were completed closer to the target altitude, the pilots did not err on the safe side as much as they did during the day.

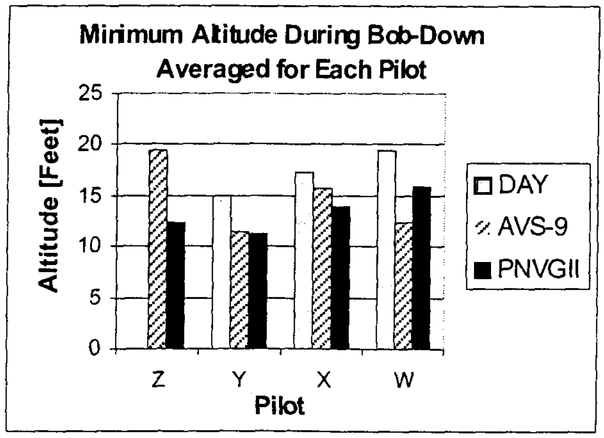


Fig. 12. Minimum altitude during the descent portion of the bob-up maneuver.

Figure 13 shows the maximum deviation of the pilot's nominal body position from the pirouette circle, in the radial direction from the center of the circle. Again, daylight data for pilot Z were not obtained due to problems with the instrumentation at that time. This chart does not show direction, but nearly all deviations were too far aft. The results in Fig. 13 are directly opposite the expected results. All pilots had better positioning performance with the AVS-9, as compared with the PNVGIIs, with one pilot having a substantial difference.

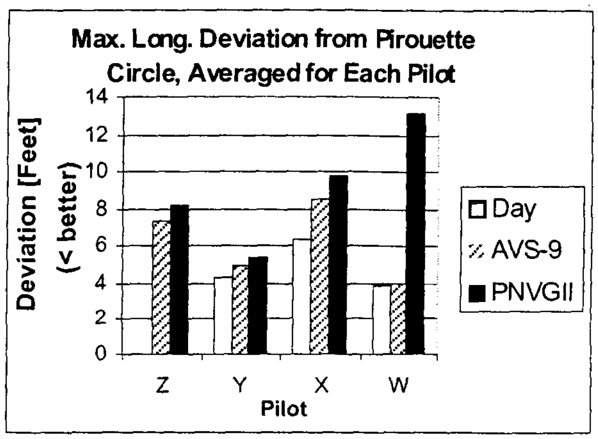


Fig. 13. Longitudinal position deviation from the pirouette circle.

Figure 14 shows the average altitude during the pirouette. Within each data set of any particular pilot, that pilot flew nearly the same altitude during the day, with the PNVGII, or with the AVS-9. The target altitude was 10 feet. In all conditions, the pilots flew higher than the target altitude. The pilots flew slightly higher at night, an error in the direction of safety. Again, there were no direct visual cues by which the evaluation pilots could judge altitude.

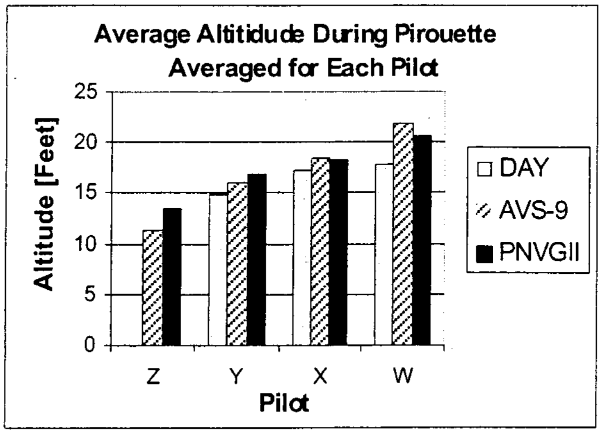


Fig. 14. Average altitude during the pirouette.

Figure 15 shows the difference between the maximum and minimum altitudes during the pirouette. The trend was that the pilots flew more consistently during the day conditions as compared to the night conditions. However, there are no trends in the data between the two night conditions.

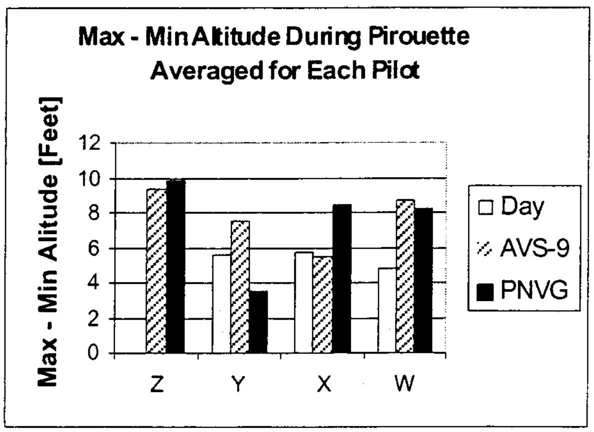


Fig. 15. Altitude variations during the pirouette.

NASA Task Load Index Ratings

Figure 16 shows the NASA Task Load Index (TLX) rating sheet used in this flight test (Ref. 10). The scale was modified to include numbers so that ratings could be transmitted over the radio. The most important result of the TLX rating was that out of the 18 ratings provided by each pilot (6 scales x 3 maneuvers), only in four ratings did a majority of the pilots rate flight with one goggle better than flight with the other goggle.

For each maneuver, the ratings for the PNVGII and the AVS-9 goggles were performed typically within 20 minutes of each other, so relative differences are meaningful. However, one or more days passed between the day and night ratings so the day ratings cannot be meaningfully compared to the night ratings, and are not shown.

Low				Mental Demand					High
1	2	3	4	5	6	7	8	9	10
Low				Physical Demand					High
1	2	3	4	5	6	7	8	9	10
Low				Temporal Demand					High
1	2	3	4	5	6	7	8	9	10
Good				Performance					Poor
1	2	3	4	5	6	7	8	9	10
Low				Effort					High
1	2	3	4	5	6	7	8	9	10
Low				Frustration					High
1	2	3	4	5	6	7	8	9	10

Fig. 16. NASA Task Load Index (TLX) scale, modified with numeric values.

Figure 17 shows the single case where all four pilots rated flight with one goggle over flight with the other goggle. In this single case, pilots rated the flight with the PNVGII better.

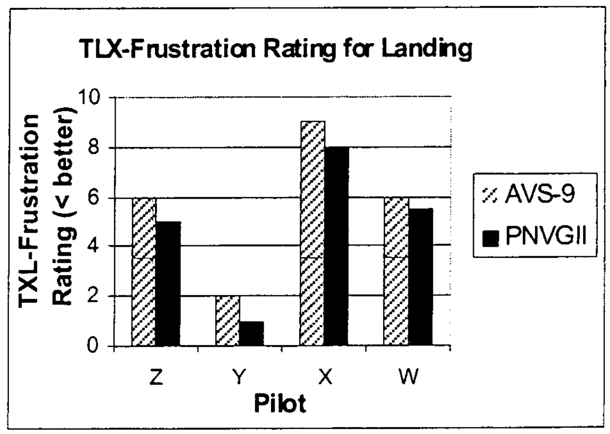


Fig. 17. TLX-Frustration rating for the landing maneuver.

Figure 18 through 20 show the three cases where three pilots rated flight with one goggle over the other. In each of these three cases, flight with the PNVGII was rated better.

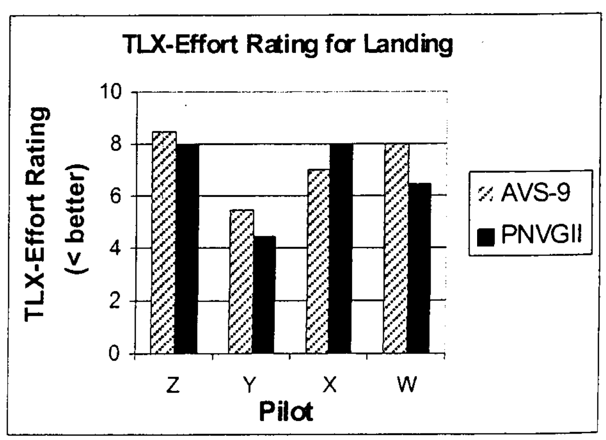


Fig. 18. TLX-Effort rating for the landing maneuver.

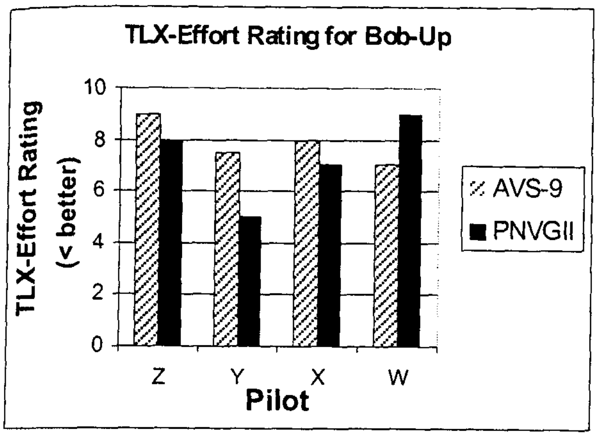


Fig. 19. TLX-Effort rating for the bob-up maneuver.

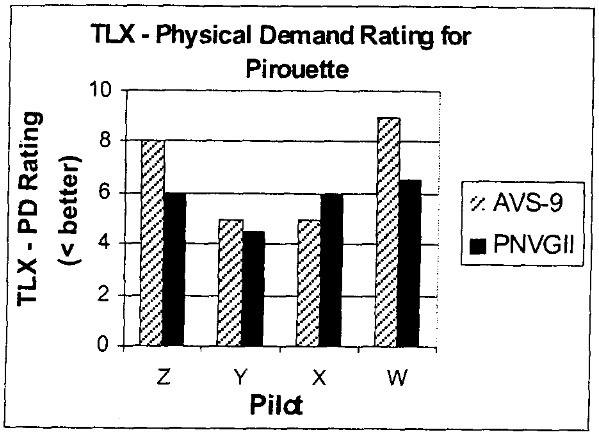


Fig. 20. TLX-Physical Demand rating for the pirouette maneuver.

Situational Awareness Rating

Similar to the six TLX scales, the pilots were also asked to rate their perceived situational awareness (SA). The SA scale was from 0 (poor) to 100 (good). Only for the bob-up maneuver was there a majority of pilots that rated flight with one goggle better than flight with the other goggle, and in this case rated flight with the PNVGII higher as shown in Fig. 21.

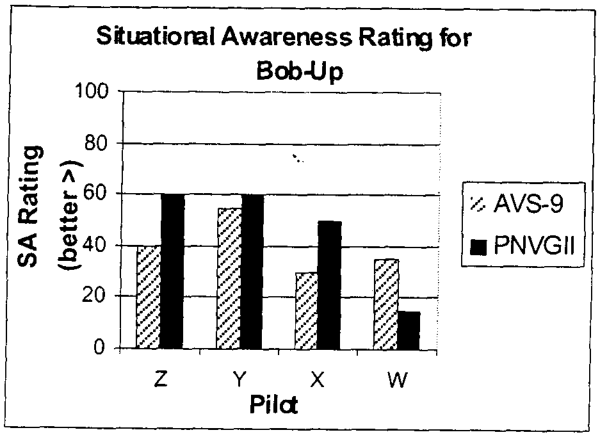


Fig. 21. Perceived SA rating for the bob-up maneuver.

Visual Scene Flyability Rating

Figure 22 shows the Visual Scene Flyability Rating, which is a new scale developed by Psycho-Linguistic Research Associates (see co-author). Only the adjectives were provided to the pilots on the scale, and the pilots reported the adjectives. The numbers assigned to the adjectives are only for data reduction and plotting.

VISUAL SCENE FLYABILITY

Rate the flyability of the helicopter for the maneuver you just flew. To what degree of satisfaction were you able to fly this maneuver **based on the nighttime visual scene that you saw outside the cockpit?** Choose the word below that best matches the flyability you were able to attain.

1 - Excellent
2 - Highly Desirable
3 - Good
4 - Pleasant
5 - Fair
6 - Poor
7 - Very Poor
8 - Bad
9 - Very Bad
10 - Nearly Unflyable

Fig. 22. Visual Scene Flyability scale with numbers added later for data reduction only.

Ratings were provided after each combination of maneuver and visual condition, and after performance feedback was provided to the pilot. For the landing maneuver, three out of four pilots rated the PNVGII goggles better, using {Fair} for the PNVGIIs, and {Poor} for the AVS-9 goggles, as shown in Fig. 23. The remaining pilot rated both goggles the same using the adjective {Poor}.

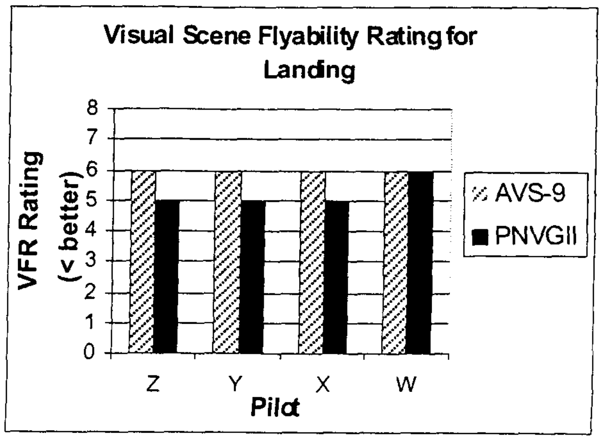


Fig. 23. Visual scene flyability rating for the landing maneuver.

For the bob-up maneuver, three out of four pilots rated the PNVGII goggles better than the AVS-9 goggles, as shown in Fig. 24. These three pilots used {Good} {Fair} to describe the usability of the PNVGII image. These same three pilots used {Fair} and {Very Poor} to describe the usability of the AVS-9 image. The remaining pilot rated the usability of both goggles the same using the adjective {Poor}.

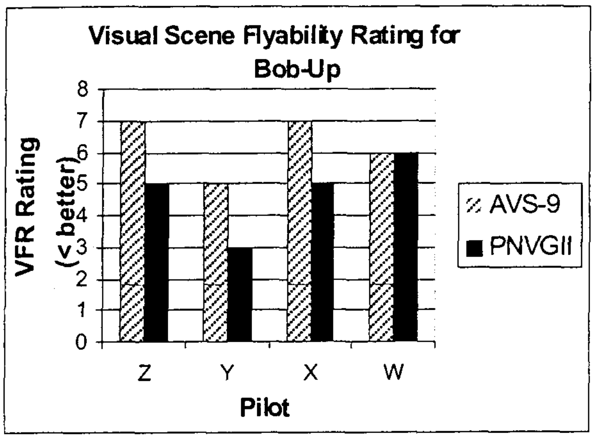


Fig. 24. Visual scene flyability rating for the bob-up maneuver.

For the pirouette maneuver, two pilots rated the usability of the PNVGII image better using {good and fair-poor} vs. {very poor} with the AVS-9, as shown in Fig. 25. One pilot rated the usability of the two goggles the same using {pleasant}. One pilot rated the usability of the AVS-9 image better, using {fair} vs. {poor} with the PNVGII.

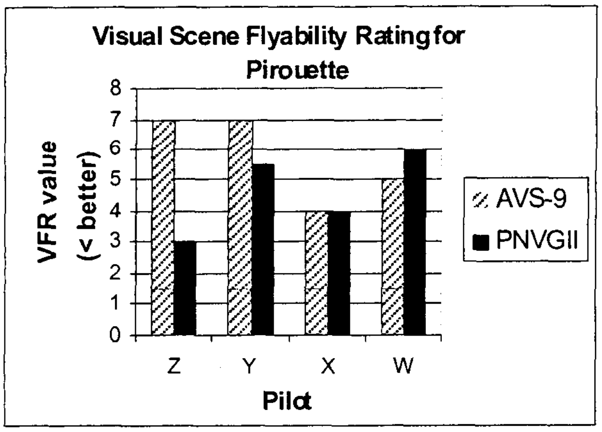


Fig. 25. Visual scene flyability rating for the pirouette maneuver.

In summary, a majority of the pilots rated the PNVGII better for the landing and bob-up maneuver as far as the usability of the visual scene. However, ratings were more mixed and there was no majority in the ratings for the pirouette maneuver. Recall that the pirouette maneuver was the only maneuver flown better with the AVS-9.

Pilot Comments

As background to the pilot's comments, there are some differences that should be noted between the two goggles (Fig. 26). The center FOV of the PNVGII, which has the highest resolution of the three regions, has a width of 30° horizontal FOV, compared to 40° FOV of high resolution imagery available with the AVS-9. There is also a loss of up to 5° of binocular FOV on each side of the center FOV of the PNVGII as compared to the AVS-9 goggle. The center and peripheral regions of FOV of the PNVGII have different responses to bright light sources.

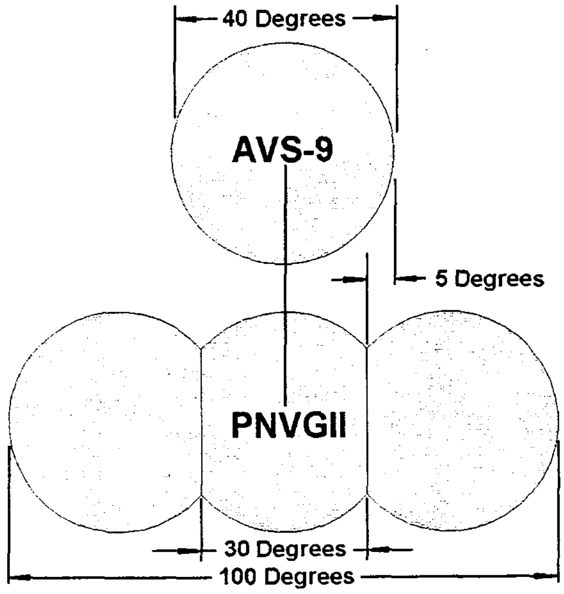


Fig. 26. FOV regions of the PNVGII and AVS-9 goggles.

Unstructured comments were provided by the pilots over the radio. The number one comment from the four pilots was that the image in the peripheral tubes of the PNVGII appeared to be out-of-focus. There were comments from the pilots that they moved their heads to get visual cues within the center FOV of the PNVGIIs, where the image quality was better. However, the pilots also commented that the outer tubes, even though they had lower image quality, still made searching for visual cues easier and faster. The pilots commented that the PNVGII increased their perceived situational awareness.

When looking at bright light sources, one pilot called the reduction in overall contrast with the PNVGII goggles as a "milky" image. Some of the pilots noticed reflections causing double images of bright, point light sources. The change in size of the halo from point light sources crossing the boundary between peripheral and center FOV of the PNVGII goggles was distracting. There were no comments on the reduction in binocular FOV with the PNVGII. One pilot commented that the extra weight of the PNVG made his helmet slip front end down over time.

Conclusions

Objective data were collected for pilot-vehicle performance in an NAH-1S helicopter during hover and landing maneuvers with both the PNVGII and AVS-9 night vision goggles. Subjective data were also collected for the physical reserves of the pilot and image usability.

Since only four pilots flew in this study, statistical tests of significance were not meaningful. Therefore, care must be taken when generalizing the data to the entire pilot population. Data taken with this PNVGII device should not to be confused with other PNVG devices, as there are other variants and manufacturers of PNVG devices. Three concluding points are made:

1. For the maneuvers flown, the PNVGII compared well with the AVS-9 goggle. The pilots commented favorably regarding the increased FOV of the PNVGII goggles. However, the pilots also commented negatively about the image quality of the PNVGII goggles. The assertion is made that the benefits of the increased FOV of the PNVGII goggles are to some extent negated by the reduced image quality.

2. Objective performance data are consistent with the assertion that the benefits of increased FOV are to some extent negated by the reduced resolution of the PNVGII. The pilots did not fly all maneuvers better with either the PNVGII or the AVS-9 goggle. In particular, most of the pilots flew the landing and bob-up maneuvers better with the PNVGII, but flew the pirouette maneuver better with the AVS-9 goggle. One particular case needs to be emphasized. During the descent portion of the bob-up maneuver, the pilots stopped the descent lower to the ground with both the PNVGII and the AVS-9 goggles, than during daylight conditions.

3. Subjective performance data are also consistent with the assertion that the benefits of increased FOV are to some extent negated by the reduced resolution of the PNVGII. In the first set of measures, 14 out of 18 NASA Task Load Index ratings did not have a majority of the pilots rate flight with one goggle over the other. In the second set of measures, 2 out of 3 situational awareness ratings also did not have a majority. In the third set of measures, 1 out of 3 Visual Scene Flyability ratings did not have a majority of the pilots favor one goggle over the other. However, for all three sets of measures, when there was a majority of the pilots who rated flight with one goggle over the other goggle, the majority rated flight with the PNVGII higher.

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