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A FURTHER STUDY OF PILOT PERFORMANCE DURING EXTENDED LOW SPEED, LOW LEVEL NAVIGATION

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DEFENCE RESEARCH BOARD
DEPARTMENT OF NATIONAL DEFENCE
CANADA

MEMORANDUM

Stewart Harrison

H/SIC

DE-LIMITING TWO DOCUMENTS

1. With respect to your Memo of 13 January 2005 concerning the de-linmiting of DRML 248-1 and 248-2.

2. This fell through the cracks. I came across it while cleaning up my office recently.

3. I believe these two reports should be made available to the public. I see no reason to restrict distribution.

4. My argument is as follows:

    a. The material is now over 40 years old.
    b. The contents do not describe current operational environments.

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2074

Abstract

The report considers an extension of the problem studied in 1961 in which pilots were required to navigate accurately over unfamiliar terrain whilst flying very low. In the earlier trials two-hour sorties were flown of which a small section was near to the ground. The present series required pilots to fly two hour sorties entirely at very low level.

The main findings were that in general, pilots could navigate accurately and simultaneously fly low for an extended period of time, and critical incidents again occurred which, though subsidiary to the main task, could cause serious accidents. The detailed results, especially those relating to eye movements during map reading, confirmed the findings of the previous trial.

A FURTHER STUDY OF PILOT PERFORMANCE DURING EXTENDED LOW SPEED, LOW LEVEL NAVIGATION

INTRODUCTION

The problems facing Army pilots required to navigate accurately over unfamiliar terrain while flying very low were studied previously (Lewis 1961). In that study Canadian Army pilots were required to fly low during a relatively short middle portion of navigational sorties lasting approximately two hours. The present paper reports a subsequent study in which similar sorties were flown entirely at very low level.

PROCEDURE

In general the procedure followed was similar to that used before.

Aircraft

Two L19, 100 m.p.h. aircraft were used.* One, the test aircraft, flew low and was instrumented to record absolute (radar) altitude. Ciné photographs of the pilot's eyes and the view forward were taken. The test aircraft carried the investigator, who kept a lookout for wires and operated recording equipment. The seco d aircraft flew above the test aircraft at all times and carried an observer whose sole task was to plot accurately the track of the lower aircraft.

Trial Design

A simple design required each of seven pilots to fly eight different sortie tracks which were randomized. Each sortie was approximately 200 miles long and was flown to a typical operational plan (Figure 1, page 13).

Terrain

The trial was flown over the forests and steeply undulating terrain found within a 100 mile radius of Bonnechère airport, Ontario. The forests consist mainly of trees averaging 75 feet in height, and occupied 89% of the total track distance. Lakes were flown over and these occupied 5% of the

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*It was assumed that results obtained would apply equally to low speed fixed wing aircraft and helicopters fitted with stability augmentation systems.

track. The remainder consisted of open farmland, short brush, or marshland. Turning points were relatively small and at times inconspicuous, e.g., junctions of third class roads and farm tracks, derelict farm buildings, tips of small lakes, junctions of streams and narrow rivers, etc.

Bonnechère airport was selected as the base for the trials since it was relatively unused at the time of the trial and therefore enabled the sorties to be flown at very low level from take-off to landing.

Maps and Roller-Map Aid

National topographic $\frac{1}{50,000}$ sheets: (scale one mile to one inch and a quarter) covered the tracks.

A roller-map display, carrying joined strips of the $\frac{1}{50,000}$ sheets, was designed and installed in the test aircraft.* (Figure 2, page 13). The display presented an area six miles square with the track drawn as a centre line oriented along the longitudinal axis of the aircraft.

Pilots

Each of the seven participating pilots had between 350 and 1000 hours flying time on light aircraft. Though practiced in reading large scale maps they were unaccustomed to combining the skills of navigating and piloting near to the ground for an extended period.

Instructions

On the evening before flying the trial, each pilot attended a detailed briefing. Critical instructions were summarized as follows:

a) "Fly with the aircraft trimmed slightly nose-up at all times.

b) The trial investigator will not speak to you in the air other than to warn you of wires should you not appear to have seen them. Therefore, if you hear an i/c transmission be prepared to climb a little - quickly!

c) Be especially careful of High Tension cables. We will fly over several. Remember that there is a very thin top cable which is difficult to see! Do not fly beneath cables.

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*A file of $\frac{1}{50,000}$ sheets covering the sortie being flown was available in the pilot's map case. This could be referred to in the event that the pilot strayed out of the area presented on the roller-map section.

d) The following instructions are given in order of importance:

i) Reach the turning points in the tactical triangle
ii) Stay on track
iii) *Fly as low as possible with safety."

Daily Flying Schedule

Aircraft were ferried from Camp Petawawa to Bonnechère Airport at 0730 hours each morning by the participating aircrews. These flights took approximately 20 minutes. A field maintenance team then prepared the test aircraft while the subject pilot briefed himself. Up to one hour was allowed for self-briefing, though the pilots rarely took longer than 45 minutes. In this briefing the pilot examined maps and the roller-map covering the first sortie.

The first sortie was then flown.

Upon returning to Bonnechère the aircrews consumed a hot lunch and the subject pilot briefed himself for the second sortie. Meanwhile the aircraft were checked, re-fueled, and the cameras and flight recorder reloaded.

The second sortie was then flown.

Upon completion of the second sortie the aircraft were ferried back to Camp Petawawa. In this way each pilot flew two sorties a day on four consecutive days.**

Performance Scores

Low level navigation was scored in four main ways:

a) the number of turning points reached in the tactical triangle was noted as a gross score,

*"This must not be interpreted to mean a hair-raising series of tree-grazing or grass mowing dashes. Remember you will be flying and navigating for a considerable period of time. Give yourself a little leeway in height, say, between 10 and 20 feet."

**There were departures from this design due to bad weather. (See Procedural Problems Affecting Trial Design, page 4).

b) the length of the track flown was compared with the intended track length,

c) corridors were superimposed over intended tracks and where the tracks actually flown deviated from the corridor, the lengths of the deviations along the corridor were summed, and

d) the extent to which the flown track departed laterally from a corridor was noted.

Procedural Problems Affecting Trial Design

Unforeseen problems were again encountered which disturbed the balance of the experimental design. These complications made refined statistical tests of the data inappropriate.

1. Local restrictions, which included the ferrying of aircraft to and from a nearby camp at the beginning and end of each working day, left insufficient time for a short comparison flight which had been planned.

2. Bad weather necessitated a rearrangement of the daily schedule for two pilots. These pilots flew three sorties in one day and a single sortie on a later day. Bad weather was also the cause of diversions from tracks in avoidance of severe rain and snowstorms which, in one instance, compelled the pilot to return to base by a direct route. On these occasions only sections of the sortie could be scored.

3. Pilots experienced difficulty in realigning the gyro-compass with the magnetic compass in prolonged turbulence. Gyro-compass precision contributed to an undue proportion of track-keeping errors which occurred to the right of the track.

RESULTS

Sortie Effectiveness

The most severe test of sortie effectiveness, namely the number of turning points reached in the tactical triangle, shows that of 161 turning points, 92% were reached. This figure was calculated from the number of occasions that the aircraft entered a circle of 1/4 mile radius about the turning point.

A further test, of operational significance, was the ability of pilots to run straight in to the turning point without making search turns. Ninety per cent of the turning points in the tactical triangle were reached from a straight run in to a circle of 1/8 mile radius. It should not be assumed, however, that the turning points were necessarily approached directly along track.

Track Keeping

All tracks were straight lines. Again, performance in track-keeping appears to be a useful measure. Errors in maintaining track stem from, a) setting course in the wrong direction---a rare error, b) searching for the turning point---an infrequent error in the trial, and c) losing track and failing through an appreciable distance to return to track---the most common error. Figure 3, page 14, summarizes performance in terms of distance flown in excess of track length. Figure 4, page 14, shows the percentage of track flown outside corridors of arbitrary width. Table I lists the largest single errors of distance from track.

Table I

LARGEST SINGLE DISTANCE TRACK ERRORS. MILES.

Pilot	Base to Triangle	Triangle to Base	Triangle Leg I	Triangle Leg II	Triangle Leg III
1	1.7	1.1	3.7	1.5	1.5
2	1.5	6.7	4.9	3.1	3.1
3	4.7	2.8	3.5	2.1	2.1
4	0.7	1.7	1.5	0.7	1.3
5	2.9	4.5	1.1	2.2	2.3
6	4.4	4.5	1.4	2.6	2.0
7	2.2	1.9	1.5	1.2	1.6

Critical Incidents

On twelve occasions pilots were warned by the investigator that they were about to fly through wires. Surprisingly, these were high tension cables. The supporting masts and cables seem to blend at times with the background of tree foliage and branches.* Pilots seem to look 'through' the wires and indeed the masts when searching ahead for identifiable ground features.

On two occasions fuel tank switching was neglected until a time so long after the safe time that the investigator considered it essential to warn the pilot.

During the last of three sorties flown by one pilot within one day, the pilot became obviously confused and after repeated attempts to locate his position agreed that he could no longer safely fly low and navigate. The incident occurred toward the end of the tactical triangle and after some five hours of low flying and navigating in one day. The sortie was abandoned at that point and the aircraft returned directly to base at a safer altitude. The other pilot who flew three sorties in one day did not seem to encounter unusual difficulties.

There were several instances of near collision with birds.

Eye and Head Movements During Map Reading

Ciné-film samples totalling 322 eye movements to and from the map during map reading were compared for the roller-map display and the hand-held map. From the frame-by-frame analysis of these samples it was found that the eyes were occupied** with map reading 28% of the time when the hand-held map was used and 23% with the roller-map display.

The frequency distribution of map-reading time for the hand-held map (Figure 5, page 15) is similar to that reported previously (Lewis 1961) but a relative increase in the number of looks of 0.5 to 1.0 second duration is noted for the roller-map display. Whether such short looks were useful remains uncertain.

A further comparison was made between these map-reading conditions to determine the extent of radial head movements. Figure 6, page

*The investigator, whose main concern was lookout for wires, had extreme difficulty at times in seeing the wires, even though he anticipated and knew their position.

**On several occasions the aircraft was 'pulled-up' abruptly to pass over obstructions. Pilots commented that this occurred when trees were seen rather late after glances at the map.

15, suggests a marked decrease in radial head movement when the roller-map display was used.

Roller-Map Display

No clear improvement in navigating performance was found to result from the use of the roller-map display. In completing a post-trial questionnaire, however, six of the pilots listed the display as 'Invaluable', the other 'Helpful'. One disadvantage of the display in an operational setting would be the time required to prepare the roller-strips.

Height

The radar altimeter recorded accurately the height of the aircraft above the ground, and not its height above the tree tops. Since the terrain was heavily wooded along 89% of the tracks flown a correction of 75 feet must be applied to the raw data to obtain an approximation of actual aircraft height, as shown in Figure 7, page 16.

Ground Turbulance

Difficulties in recording normal acceleration occurred often enough to make this record unreliable. It was therefore discarded.

DISCUSSION AND CONCLUSIONS

Performance at Low Level

The trials again revealed a number of difficulties likely to be encountered by pilots flying and navigating close to the ground. In general, pilots can navigate accurately and stay very low throughout sorties lasting over two hours and flown twice in one day. Had these sorties been flown by solo pilots or by pilots assisted by a co-pilot with responsibilities other than look-out, e.g., tactical observation, a number would have terminated abruptly because of collision with high tension cables.

Failure to switch fuel tanks is an omission which again occurred and is understandable in the light of the demanding nature of the task.

Several findings closely parallel those of the previous study. These therefore now have added weight, especially in view of the fact that pilots in the trial flew some 12,000 miles at low level.

1. Pilots can navigate over unfamiliar terrain whilst flying very low throughout extended sorties.

2. "Head-down" time (eyes in the cockpit), is of the order of 25%.

3. Telephone wires and high tension cables are at times not seen.

4. Pilots become so engrossed in the navigating task that they occasionally forget to switch fuel tanks---a critical omission at low level.

5. Observations in flight establish the real risk of aircraft striking wires, trees and birds.

Simplifying the Task.

1. As stated before, "Head-up" displays and automatic aircraft navigation aids would reduce the time that the pilot has his eyes in the cockpit. The cockpit of an aircraft to be flown extensively near to the ground should be specially designed and equipped.

2. Since the Army pilot has an increasing operational requirement to fly very close to the ground, special emphasis should be given to training in this type of flying and navigation.

It is concluded that the Army pilot can navigate through a sortie of over two hours duration whilst remaining very low. He requires up to an hour in which to brief himself. He may experience difficulty if required to fly more than two such sorties within one day. He will commit critical errors in subsidiary aspects of the skill because of difficulties inherent in the task.

ACKNOWLEDGMENTS

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The pilots who flew the test and chase aircraft deserve special thanks.

REFERENCES

1. Lewis, R. E. F. Pilot performance during low speed, low level navigation. Defence Research Board of Canada. DRML Report No. 248-1. 1961.

2. Floyd, W. E., and Welford, A. T. "Fatigue". London. 1953. Lewis.

Figures

FIG. 1. SORTIE PLAN

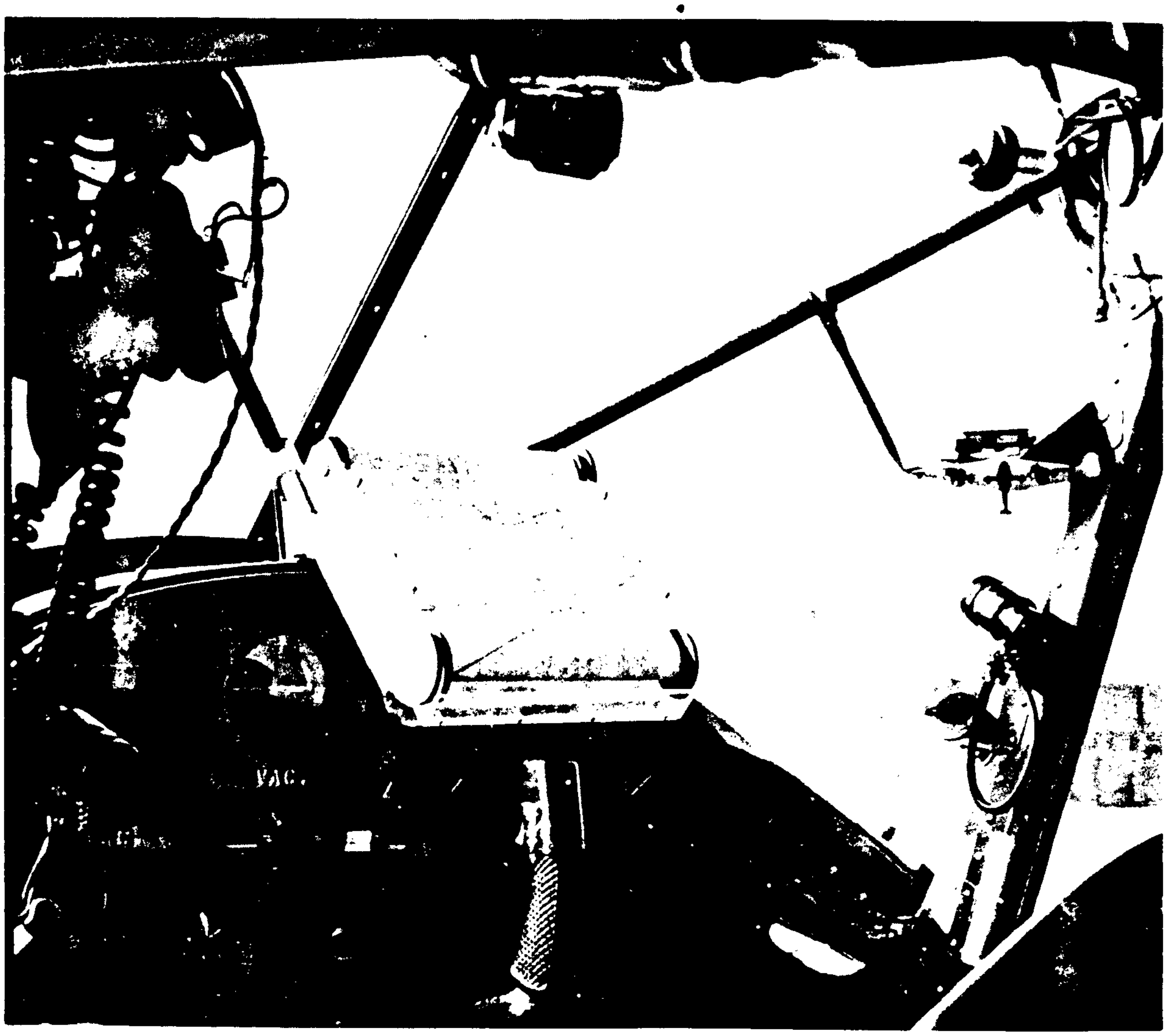

FIG. 2. ROLLER MAP DISPLAY INSTALLATION

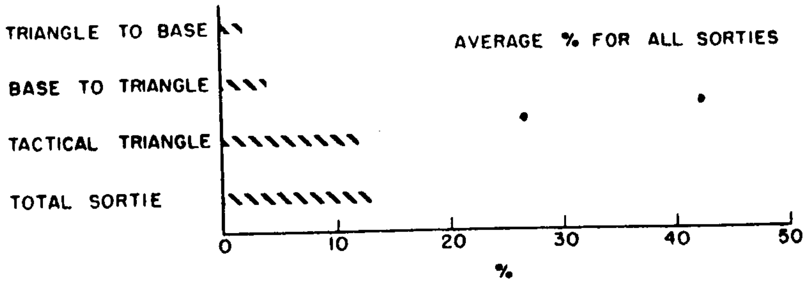

FIG. 3 DISTANCE FLOWN BEYOND TRACK LENGTH

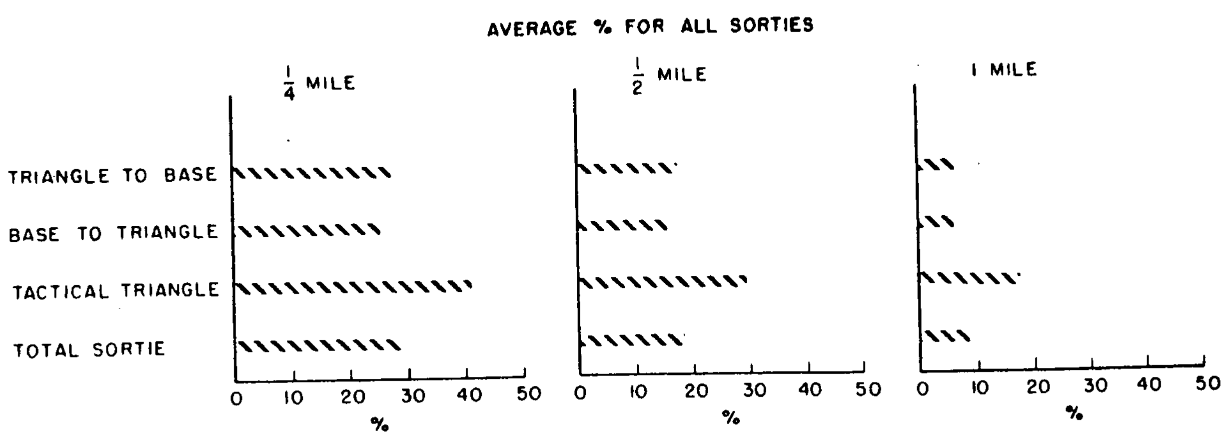

FIG. 4. TRACK FLOWN OUT OF CORRIDORS

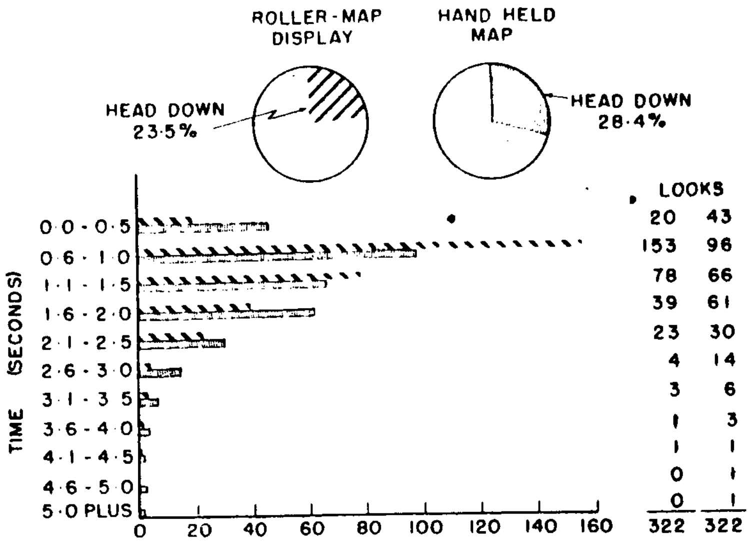

FIG. 5 FREQUENCY DISTRIBUTION OF MAP READING LOOKS

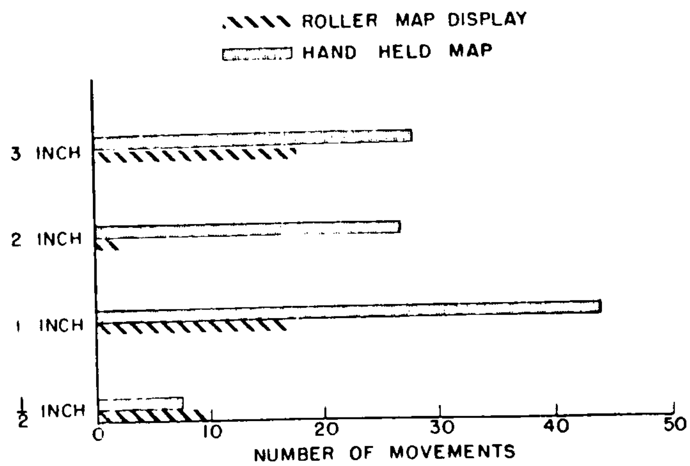

FIG. 6 RADIAL FORWARD HEAD MOVEMENT DURING MAP READING

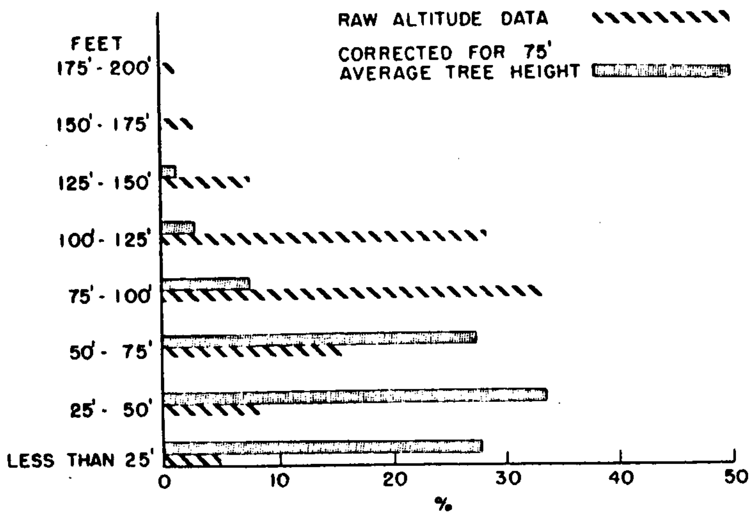

FIG. 7 AIRCRAFT HEIGHT DURING EXTENDED LOW LEVEL NAVIGATION AVERAGED OVER ALL SORTIES