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Analysis of Pilot Performance Using Precision Visual Flight Rules

Thomas Morrissey
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Thomas Morrissey entitled "Analysis of Pilot Performance Using Precision Visual Flight Rules." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.

Ralph Kimberlin, Major Professor

We have read this thesis and recommend its acceptance:

U. Peter Solies, Richard J. Ranaudo

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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Anne Mayhew________
Vice Chancellor and
Dean of Graduate Studies

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ANALYSIS OF PILOT PERFORMANCE USING PRECISION VISUAL FLIGHT RULES

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Thomas Andrew Morrissey
December, 2004

Dedication

This thesis is dedicated to a good friend and fellow scholar at the Space Institute. Miller Wilder and I worked on several projects together during our short time at the Space Institute. We worked closely as a team during the PVFR project to ensure it ran smoothly. On June 13, 2004, Miller was killed just after take-off while towing a glider in Arizona. His passion was aviation in all forms. He flew airplanes, seaplanes, sailplanes, and just about anything else that would leave the ground. He reignited my interest in soaring as well as convinced me to buy my own airplane. We had talked about coming back to UTSI as old and senile men for the opening of the UTSI time capsule. I know we will meet again someday in the next world. Until then, Rest in Peace my friend.

Acknowledgements

The data for this analysis was provided by a joint project of the UT Space Institute, NASA Ames, FAA, and STI Inc. It is important to express my sincere thanks to these organizations for allowing me to use the data in support of my thesis. Without their cooperation and helpfulness, this analysis would not be possible.

My graduate school career was only possible because I had several people standing behind me along the way. I must recognize the love and support of my parents and sisters. Without them, I do not think I could have made it this far. As my advisor, Dr. Ralph Kimberlin played a significant role in both teaching and advising me as a graduate student and pilot. He has transferred more knowledge than he probably realizes. I am very grateful to have such an experienced and wise mentor. Lastly, I must acknowledge the motivation and support of Dr. John Ogg at Dowling College. Even though I was busy at work, he took the time to motivate me with advice and deadlines for my thesis and presentation. There are many more people who have helped along the way. It would not be possible to list all of them without running out of paper.

ABSTRACT

Precision Visual Flight Rules (PVFR) seeks to allow helicopter pilots to fly predetermined routes in high density traffic areas with greater precision by using a Global Positioning System (GPS). An analysis of the cross-track error during the PVFR developmental testing is presented. The primary objective is to determine the dominant factors which effect pilot performance using this higher standard of precision. Factors which are investigated include: total flight time, recent helicopter flight time, pilot ratings, and experience with the particular aircraft and GPS model. A conclusion is presented on which factors need to be addressed before opening up PVFR routes to the public. In particular, prior GPS model experience and time of day play a significant role in determining pilot performance flying PVFR routes.

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LIST OF ABBREVIATIONS

CTE	Cross Track Error
DGPS	Differential Global Positioning System
GPS	Global Positioning System
IFR	Instrument Flight Rules
NMEA	National Marine Electronics Association
NPS	Navy Postgraduate School
PCATD	Personal Computer Assisted Training Device
PIC	Pilot In Command
PVFR	Precision Visual Flight Rules
RMSE	Root Mean Squared Error
SD	Standard Deviation
SNI	Simultaneous Non Interfering Operations
VFR	Visual Flight Rules

Disclaimer

All results and conclusions in this paper are strictly those of the author. They do not represent the views or findings of the FAA, NASA, UTSI, or STI, Inc.

Chapter I

Introduction

Background

The University of Tennessee Space Institute conducted developmental testing for the certification of Precision Visual Flight Rules (PVFR) routes. The purpose of this new routing structure is to allow helicopter pilots to fly simultaneous non-interfering (SNI) operations in high traffic density areas. The system is designed to provide pilots with better route depiction and guidance in order to reduce the off-course (cross-track) error. By reducing the off-course error, the airspace system in congested areas can handle more aircraft without increasing the risk of an accident or airspace incursion. The primary objective of this analysis is to determine what factors, if any, can be used to predict pilot performance on PVFR routes.

The ability to predict pilot performance is desired by many groups. These groups include our armed forces, air carriers, and insurance companies. The Air Force desires this ability in order to screen out potential candidates for pilot slots. Likewise, air carriers must screen resumes to determine which pilots would be successful in training and make safety conscious captains. Insurance companies seek to minimize risk by identifying various factors in order to determine which pilots pose more of a danger. For example, many insurance companies prescribe certain limitations on open pilot clauses to

reduce their liability. These limitations may include minimum total flight time, recency of experience, minimum pilot hours on the particular type of aircraft, and a checkout by a designated check-airman. All of these factors were investigated in this analysis of pilot performance during the PVFR certification test flights.

A generalized pilot performance prediction model is highly desirable. The scope of this study is limited to helicopter pilots flying PVFR routes. Unjustified inferences must not be made from the conclusions presented. For example, these results cannot logically be applied to airplane pilots flying in instrument meteorological conditions. Neither airplane pilots nor instrument conditions were flown during the certification testing of PVFR routes. In addition, all flying was done in the OH-58A+ helicopter.

Literature Review

Previous research works appropriate to this study fall into two categories. The first category is pilot performance predictors. Much background work has been done in trying to identify what factors significantly influence pilot performance. The second research category is GPS user interfaces, seeking to examine human factors issues when using different GPS models. GPS user interface research is appropriate to this study because GPS is used to provide route guidance. Once the PVFR routes are released to the public, it may be used with several different GPS models.

Roy and Beringer [1] conducted a study on instrument-rated airplane pilots. The goal of their study was to determine the value of personal computer assisted training devices (PCATD) in recognizing and handling instrument failures in simulated instrument conditions. The two airplanes used for the study were the Piper Archer (PA-

28) and Beechcraft Bonanza (A36). During the study, pilots were asked to fill out flight experience questionnaire forms. These questions surveyed experience with the specific model of aircraft, certificates and ratings, date of instrument rating, pilot-in-command hours (PIC), instrument hours, and flying time during the last 90 days (as PIC, in IFR, or instrument instruction). The investigators found no significant correlations between pilot experience variables and performance variables. One significant result is that PIC hours had a correlation with performance score. Higher PIC hours was correlated with a lower (better) performance score. The Spearman's Rho for this correlation was -.622. Also, it is worth noting that all occurrences (four) of the safety pilots having to take over occurred in the Bonanza. Two of the four take-over scenarios involved pilots with prior Bonanza experience. This can attribute some error to complex aircraft systems and some error to unfamiliarity with particular aircraft type.

Unfortunately, there are some shortcomings to their research as it applies to PVFR. First, this study was conducted in airplanes using all instrument rated pilots. PVFR will be used in helicopters with a mix of visual and instrument rated pilots. Secondly, this study recorded performance as judged by an evaluator who flew as a safety pilot. This introduces some subjectivity as to what the following performance grades are: successful partial panel, required more effort, barely controlled, and safety pilot took over. In any case, their pilot experience conclusions are worth noting as background research.

In Safe Skies for Tomorrow [2], the US Congress study acknowledges a lack of pilot ability predictors. Furthermore, it goes on to say that pilot hours do not give the complete picture. In essence, there are two characteristics of flight hours: quantity and

quality. Therefore, this study challenges the finding of Roy and Beringer that more PIC hours correlate to better pilot performance. While it may have shown a correlation in a small sample size (n=25), the US Congress study suggests that pilot hours fail to capture the larger picture. This may include a combination of training hours, experience with equipment, quality of training, and a number of other factors. Also, it is important to note that the study suggests investigating alternative predictors of pilot performance and skill as it may prove useful.

> *"Total time, whether hours in a logbook or years in a crew position, does not give the complete picture of pilot experience, skill, or quality of training. For example, full-motion flight simulators or advanced training devices enable a pilot to meet with more emergencies and unusual situations in a 4-hour training session than he may experience on the line during a 20-year career. However, few measures of pilot ability other than flight-time have been collected broadly and consistently. Alternative measures or tests of skill and experience could prove useful."*

Mulhern [3] compiled a list of factors that induce stress and affect helicopter pilot performance. His list includes six categories of stress sources in helicopters. The first category is altitude, particularly altitude changes below five thousand feet. The next category is speed because it requires increased alertness. The third category is extreme hot or cold environments. The fourth category is aircraft design and is particularly applicable to this analysis. This category examines lighting, cockpit design, cabin environment, instrument locations, accessibility of switches and controls, seat comfort, visibility, and noise level. The fifth category is aircraft characteristics. These include the

inherent instability of helicopters. Lastly, weather and time of day are sighted as stress sources during helicopter flying. Mulhern makes a parallel between night flying and instrument flying. This puts the non-instrument rated pilots at a disadvantage during night flight.

Mulhern's list of helicopter stress sources is very appropriate to this analysis. Most of the factors on his list were kept constant for all PVFR subject pilots. However, this list suggests comparing instrument and visually rated pilots for performance during the night flights. This will either confirm or reject Mulhern's statement paralleling night flying with instrument flying. In addition, visibility could arguably deteriorate performance rates for those pilots not used to flying with goggles (ie. night vision or helmet mounted displays). Unfortunately, pilot experience with night vision or helmet mounted displays was not surveyed during the PVFR experience questionnaire.

GPS user interfaces present safety concerns to the implementation of PVFR. In my previous research work [4], it was noted that 85% of survey respondents felt more pilot training is necessary on GPS operations. The issue of GPS interface standardization is controversial to say the least. The survey showed 46% favored standardization, 19% were neutral, and 35% were against standardization. Strong arguments were presented for both opinions. Some felt it was necessary to improve safety while others felt it would put an end to the competitive free-market. Several conclusions were formed in my previous research. First, each GPS model requires a unique series of pressing functional buttons to obtain a desired function. Next, the location of functional buttons varied widely between models. One exercise to illustrate this point is to utilize Figure 1 (Sample GPS interfaces). Find the location of the "direct to" functional button. This

Figure 1 – Sample GPS Interfaces

button is denoted by the symbol: D>. In addition to varying function locations and programming sequences, it should also be noted that each model has unique display modes. Some models are relative to North while others are relative to the aircraft's course.

CHAPTER II

PVFR Test Plan

Sample Method & Route Selection

The flight test plan [5] consisted of ten pre-selected pilots flying a given GPS route. In addition, two alternate pilots were selected in case any issues arose with the primary sample pilots. The sample selection method was not random or independent. The Federal Aviation Administration specified certain criteria which the sample pilots were required to satisfy. Pilots with eyeglasses were excluded from the sample population. This is because the subject pilots were required to wear goggles with a head-and-eye tracker. Glasses would cause a glare in the video and make it difficult to determine where the eyes were focused. In addition, a certain number of visually rated pilots and instrument rated pilots had to be selected. The target goal for the project was five VFR rated pilots and five IFR rated pilots.

The test program called for both day and night flights to be conducted. The goal was to achieve approximately a 70 to 30 ratio of day to night flights. Night flights presented some additional concerns that the program manager felt were necessary to address. These concerns include increased workload on the pilot, extra challenges to visually rated pilots, and reduced visibility both in and out of the cockpit. The route was setup to simulate airspace, restricted areas, altitude changes, and compulsory reporting points. The route used waypoints in the Tullahoma, Tennessee area as shown in Figure 2.

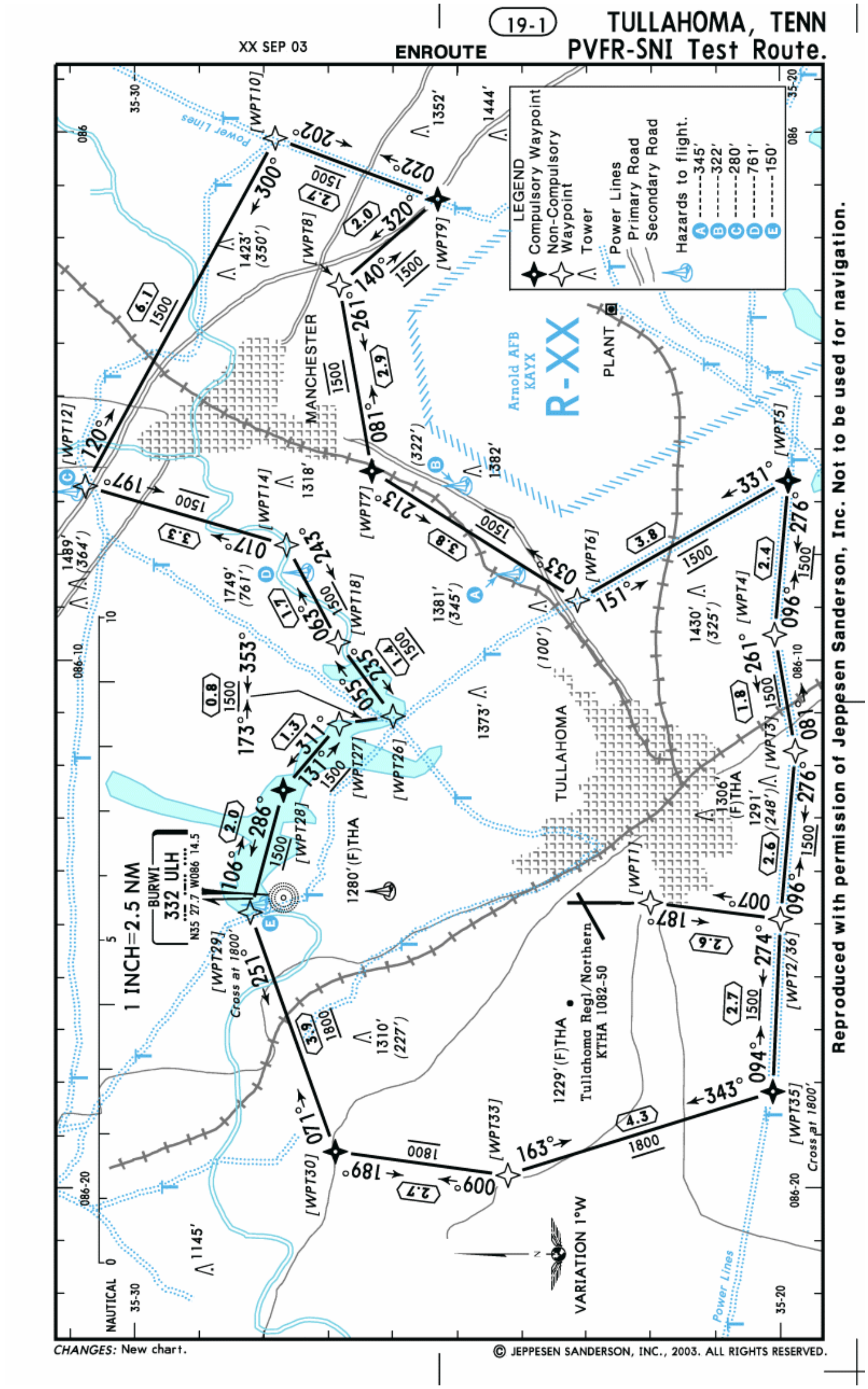

Figure 2 – PVFR Route used in Flight Test

Equipment

The Space Institute's Army OH-58A+ helicopter was used in the PVFR developmental test flights. The aircraft was chosen for several reasons. First, it represents a typical helicopter found in the civilian world since it is essentially the same as the Bell 206 Jetranger. This criterion is important because it should reduce errors due to unfamiliarity with the specific aircraft model. The aircraft is widely used in the Army and Navy. This makes it easier to use helicopter pilots from the armed forces without the unfamiliar aircraft concern. Also, the next phase of testing involves simulation facilities at the Navy Postgraduate School (NPS) in Monterrey, California. This aircraft model is available in simulator form at the NPS. The helicopter model is shown in figure 3 below.

The KLN 89B GPS model was chosen for several reasons. It is certified for use in Instrument Flight Rules (IFR). This means it is capable of reliable navigation guidance with tighter lateral tolerances. The unit only takes up approximately 12.6 square inches of panel space and weighs about 2.5 pounds. This allows the aircraft modification to have very little impact on weight and balance and panel arrangement. In addition, the KLN 89B is relatively inexpensive and easy to operate as compared with other IFR-certified GPS units.

Figure 3 – Flight Test Helicopter

CHAPTER III

Instrumentation

Different instruments and data sheets were used to record the applicable data during the certification test flights. These instruments included two dual-channel Ashtech Z12 GPS units, a KLN 89B GPS, a laptop, serial port connectors, and two software packages. The datasheet recorded various items such as mandatory reporting points, obstacle reports, weather conditions, and notable events during each flight. The PVFR observer log is shown in Figure 4.

Dual-channel GPS units were used to verify the accuracy and integrity of the data. The advantage of the dual channel GPS is that timing errors are different on the low and high frequency channels. Therefore, the unit can internally calculate most of the position errors by comparing the two channels alone. One dual channel unit was placed in the aircraft to record its position along the route. The other dual channel unit was stationed on the ground at a pre-surveyed marker. This unit was used to determine approximate timing errors for the local area. It has a known actual position. Next, the GPS calculates its position based on the satellites. The difference between the actual position and the "calculated" position gives us the necessary timing error. In differential GPS (DGPS), this error is broadcasted to airplane GPS units. However, the PVFR certification flights did not make use of DGPS. It used software to post-process the data and correct out any timing errors.

PVFR Observer Log (Flight Test Engineer and UTSI Test Control)

Pilot No:			
Date:		**Time:**	

AWOS

Baro Setting		Greenhouse to Bridge of Nose Ht.	
Ceiling			
Visibility			
Wind Speed		Night Flight Hours (Night Pilots Only)	
Wind Direction			

Reporting Points

Waypoint 5	Yes - No	Time:	
Waypoint 7	Yes - No	Time:	
Waypoint 9	Yes - No	Time:	
Waypoint 28	Yes - No	Time:	
Waypoint 30	Yes - No	Time:	
Waypoint 35	Yes - No	Time:	

Hazards to Flight Report (Flight Test Engineer Only)

Tower A	Yes - No	Time:	
Tower B	Yes - No	Time:	
Tower C	Yes - No	Time:	
Tower D	Yes - No	Time:	
Tower E	Yes - No	Time:	

Noteable Events During Flight

Figure 4 – PVFR Observer Log

Pilots were provided with analog course guidance through a course deviation indicator (CDI). This is more desirable since it does not update on a set frequency. Instead, it is providing continuous navigation output as the pilot is flying and making corrections to his course. The purpose of the two Ashtech Z12 units was to serve as the truth system for the KLN 89B data. The subject pilots never interacted with or saw the information from the two Ashtech units. It was utilized after each flight by post-processing the truth system's data. The KLN 89B unit is shown in Figure 5 below.

Additionally, the data from the KLN 89B was recorded to a laptop during each flight. This data was transferred via a serial cable using the National Marine Electronics Association (NMEA) standard. The next step was to compare the post-processed data from the dual channel units with the data from the KLN 89B. This setup used the dual channel units to be the truth system for the KLN data. The dual channel units showed the KLN data to be accurate to around 2.5 centimeters. The NMEA standard reports several items as shown in Table 1 below. During this study, the cross track error was screened to only analyze it when the active waypoint was between WPT2 and WPT35. This created exclusive Excel Worksheets with only the applicable data to be analyzed.

Figure 5 – KLN 89B GPS

Table 1 – Sample Raw KLN 89B Data

TIME1	TIME2	LAT1	LAT2	LON1	LON2	ALT	TRACK(M)
19:25:44	69944	N 35 1982	35.330334	W 086 1169	-86.194832	1612	93
19:25:46	69946	N 35 1982	35.330334	W 086 1164	-86.194	1612	93
19:25:48	69948	N 35 1982	35.330334	W 086 1158	-86.193001	1612	93
19:25:50	69950	N 35 1983	35.330502	W 086 1153	-86.192169	1612	92
19:25:52	69952	N 35 1984	35.330666	W 086 1147	-86.19117	1612	90
19:25:54	69954	N 35 1985	35.330833	W 086 1142	-86.190331	1612	82
19:25:56	69956	N 35 1986	35.331001	W 086 1137	-86.189499	1612	81
19:25:58	69958	N 35 1987	35.331165	W 086 1132	-86.188667	1612	81
19:26:00	69960	N 35 1988	35.331333	W 086 1126	-86.187668	1612	83
19:26:02	69962	N 35 1988	35.331333	W 086 1121	-86.186836	1612	84

GR SPEED	DTW	CTE1	CTE2	DTRK(M)	ACTIVE WPT	BTW(M)	MAG VAR
84	1.8	L0006	-0.06	82.7	WPT4	84.7	-2.8
84	1.8	L0005	-0.05	82.7	WPT4	84.4	-2.8
84	1.7	L0004	-0.04	82.8	WPT4	84.2	-2.8
83	1.7	L0004	-0.04	82.8	WPT4	84.1	-2.8
83	1.6	L0004	-0.04	82.8	WPT4	84.2	-2.8
82	1.6	L0004	-0.04	82.8	WPT4	84.3	-2.8
81	1.5	L0005	-0.05	82.8	WPT4	84.4	-2.8
81	1.5	L0005	-0.05	82.8	WPT4	84.5	-2.8
80	1.5	L0005	-0.05	82.8	WPT4	84.7	-2.8
80	1.4	L0005	-0.05	82.8	WPT4	84.7	-2.8

CHAPTER IV

Analysis

Various parameters were recorded to measure performance on the specified route. These parameters included GPS track, altitude, cross-track error, and ground speed. The main concern for the project was the pilot's ability to fly a route with an improved lateral tolerance. Therefore, cross-track error is the primary gauge for pilot performance on the route. Cross-track error is defined as the lateral distance from the helicopter's position to its intended position on the route. It is measured in hundredths of a nautical mile. For example, a cross-track error of .10 nautical miles is equivalent to 600 feet off course.

The method for evaluating navigation performance is provided by Rantanen et al [6] in their report entitled "Derivation of Pilot Performance Measures from Flight Data Recorder Information." They suggest five measures of pilot performance during navigation. These measures are (1) standard deviation (SD), (2) root mean square error (RMSE), (3) number of deviations, (4) time outside tolerance, and (5) mean time to exceed tolerance. Since no tolerance limits have been established thus far in the PVFR certification, the last three methods are not useful. Therefore, navigation performance will be evaluated based on SD and RMSE. The definitions for SD and RMSE are provided by Rantanen et al below.

> *"Standard deviation (SD) describes the amount of variability around the mean of any measure. A small SD in case of piloting an aircraft will usually be indicative of good performance. This measure does not, however,*

provide any information about possible error relative to given criteria.

RMSE can be used to reduce the tracking performance along a specified parameter (e.g., altitude, or VOR radial) in the entire segment of an IPC flight into a single number. A low number typically indicates good performance. The RMSE is calculated by squaring individual errors, adding them together, dividing this sum by their total number, and then taking a square root of this quantity. The RMSE hence summarizes the overall error."

Several methods were employed to analyze the data. The raw data comes in the format of a spreadsheet reporting data at two-second intervals. This data includes every parameter mentioned above (latitude, longitude, altitude, active waypoint, cross-track error, etc.) Next, the data was screened to only include cross-track error during the test portion of the flight. This excludes the data recorded during engine start-up, take-off, final approach, and shutdown. This was accomplished by a macro that screened the cross-track error for when the active waypoint was between "Waypoint 2" and "Waypoint 35." This data was then copied into an Excel data sheet sorted by pilot number and time of day (ie. day or night). The raw data summary sheet is included in Table 1 of Appendix A. One item worth noting is that pilot P4 was unable to participate due to another obligation. In addition there are two pilots denoted by A1 and A2. The "A" denotes "Alternate."

A distribution analysis was performed to determine the descriptive statistics of each pilot's cross-track error. The results of the descriptive statistics for each pilot are contained in Appendix B. The main difference between each pilot's distributions was the range. For example, P8 ranged from 0 to 1.85 nautical miles off course. On the low side,

P5 only ranged between 0 and 0.21 nautical miles. This begs the question of why there is such a major difference. What makes Pilot 5 that much better than Pilot 8?

As each pilot arrived, they were asked to complete a background questionnaire. This survey asked for their total flight time, helicopter time in the last 6 months, experience in the OH-58 helicopter, experience with the KLN 89-B GPS, and whether or not they were instrument rated. For the purposes of analyzing performance, the cross-track error was compared across the different factors. In addition, a correlation was done between flight time and cross-track error. Lower cross-track error equates to better pilot performance. If a high negative correlation existed (close to -1), it would say that pilots with more flight time perform better navigationally. On the converse, a high positive correlation (close to +1) would indicate that pilots got lazy with their navigation as they attained more experience. Finally, a correlation close to zero would indicate there is little or no relationship between flight time and pilot performance. In addition a comparison was done between the pilot's performance during the day and night flights. This is to check if pilots perform better, the same, or worse while flying at night using PVFR.

CHAPTER V

Results

The results of the data analysis are attached in Appendix A. The first task involved the one way analysis between cross-track error and each of the following separate factors: experience in the OH-58A+ helicopter, experience with the KLN 89-B GPS, and whether or not the pilot was instrument rated. The most obvious influential factor is prior experience with the KLN 89B GPS. All three of the pilots with prior GPS model experience performed better than the average. The next influential factor appears to be whether or not the pilot is instrument rated. The least influential factor appears to be prior experience in the OH58 A+ helicopter model. The results are shown Figures 6, 7 and 8 of Appendix A.

An anomaly exists with the helicopter model versus RMSE comparison. It appears that pilots with no previous OH58 A+ flying experience were focused solely on navigating the aircraft. This resulted in a reliance on the project pilot for handling other aspects of the aircraft (torque, N1, collective, cabin environment, etc.). On the other hand, pilots with prior OH58 A+ experience were flying the aircraft as a whole and not concentrated specifically on the navigation guidance. This resulted in slightly higher RMSE values for the pilots with prior helicopter model experience.

The next analysis involved a Pearson's correlation between cross-track error and flight time / helicopter flight time in the last six months. Neither of these correlations

was significant to a 95% confidence. Total flight time to cross-track error showed very little correlation between each other (-0.274). Recent helicopter time (in the last six months) also showed very little correlation. It was also not statistically significant with a Pearson's correlation of only -0.204. The results are shown in Tables 3 and 4 of Appendix A.

The final analysis was a comparison of the day and night flights for each pilot individually. Only five of the pilots did both a day and night flight. All five of these pilots showed a statistically significant difference between their day and night flying performances. Every pilot performed significantly worse during their night flight as compared with their corresponding day flight. The results are shown in Figure 9 of Appendix A.

Conclusion

There are some important conclusions that can be made based on the preceding analyses. First, the most obvious influential factor in pilot performance with PVFR routes is the time of day. Pilots flying these routes need to spend more preparation time for a night flight as opposed to a day flight. The results showed a near doubling and tripling of the RMSE for the same pilot on a night flight. The next conclusion would stress the necessity for a strong familiarity with the GPS being used and the helicopter being flown. While that conclusion may seem like common sense, too many pilots think it is not an influencing factor in their performance. The good news for PVFR developers is that total flight time, recent flight time, and instrument ratings only play a minor role in determining pilot performance. This means that limitations do not need to be placed for

pilot experience and ratings in order to utilize the benefits of the PVFR routes. In summary, the factors which play the largest role are in order: time of day, GPS experience, and helicopter model experience. These are items that can be easily trained to improve proficiency.

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Appendix A

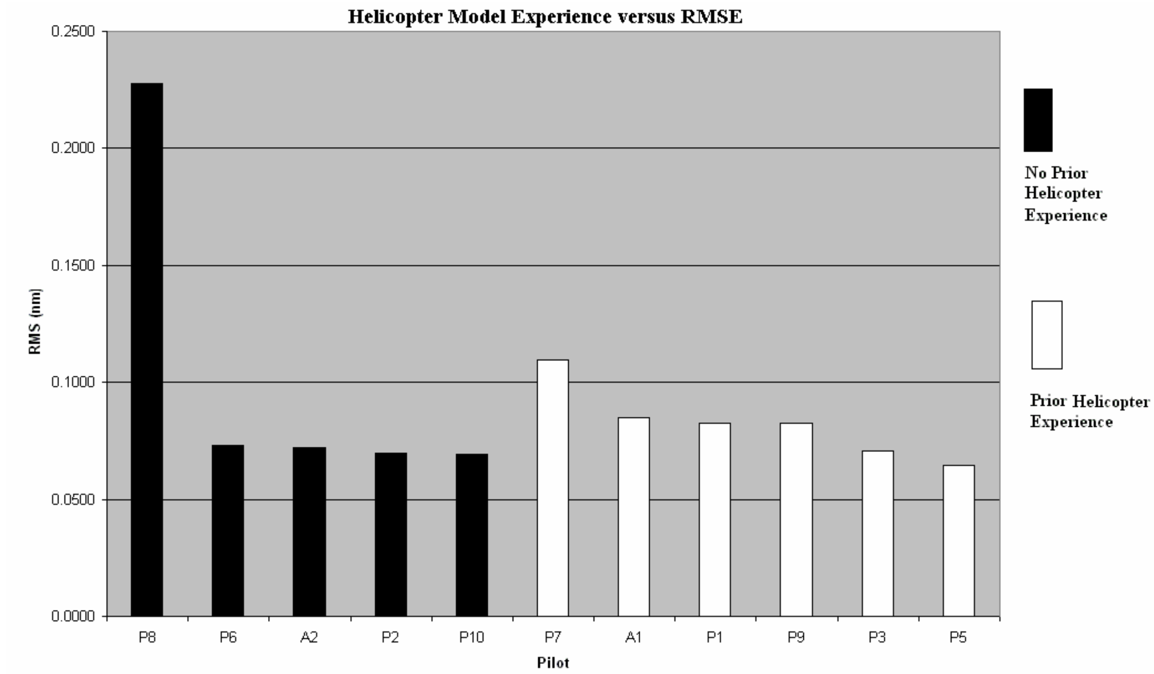

Figure 6 – Prior Helicopter Model Experience vs. RMSE

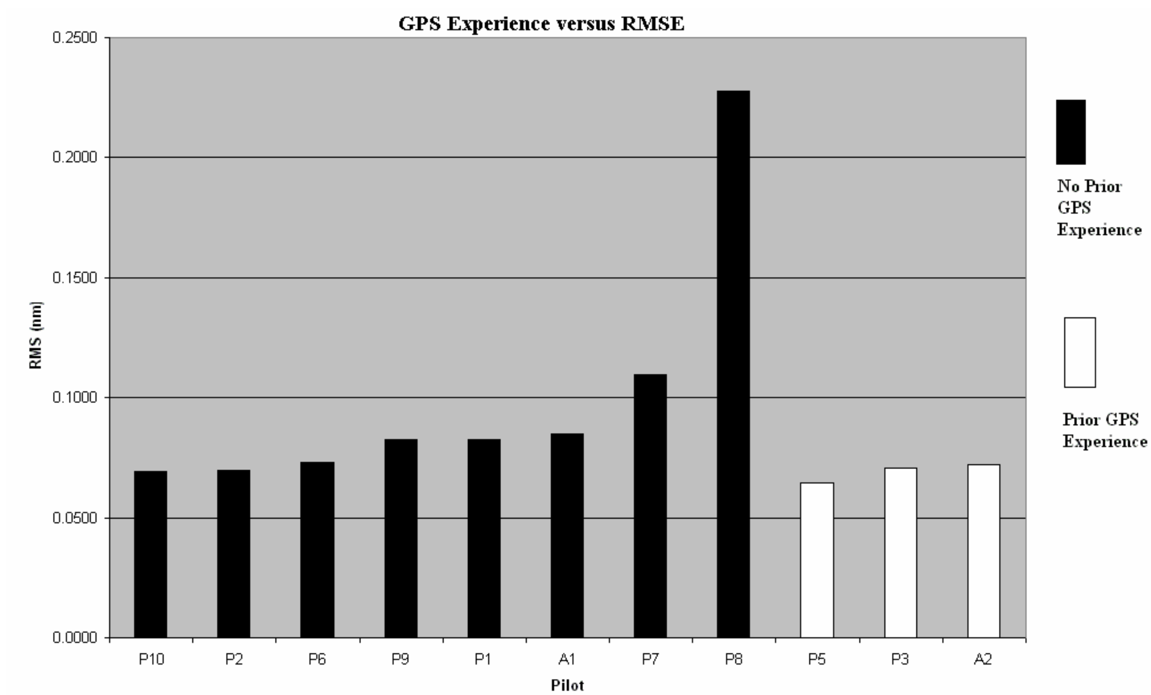

Figure 7 - Prior GPS Model Experience vs. RMSE

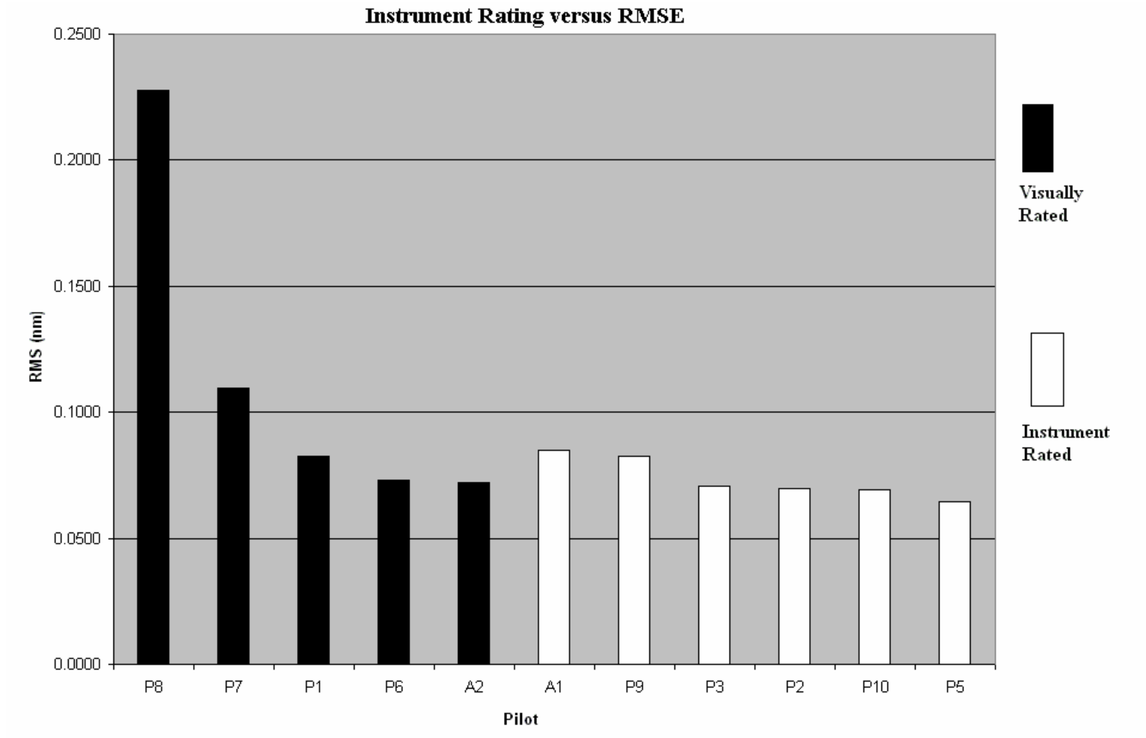

Figure 8 – Instrument Rating versus RMSE

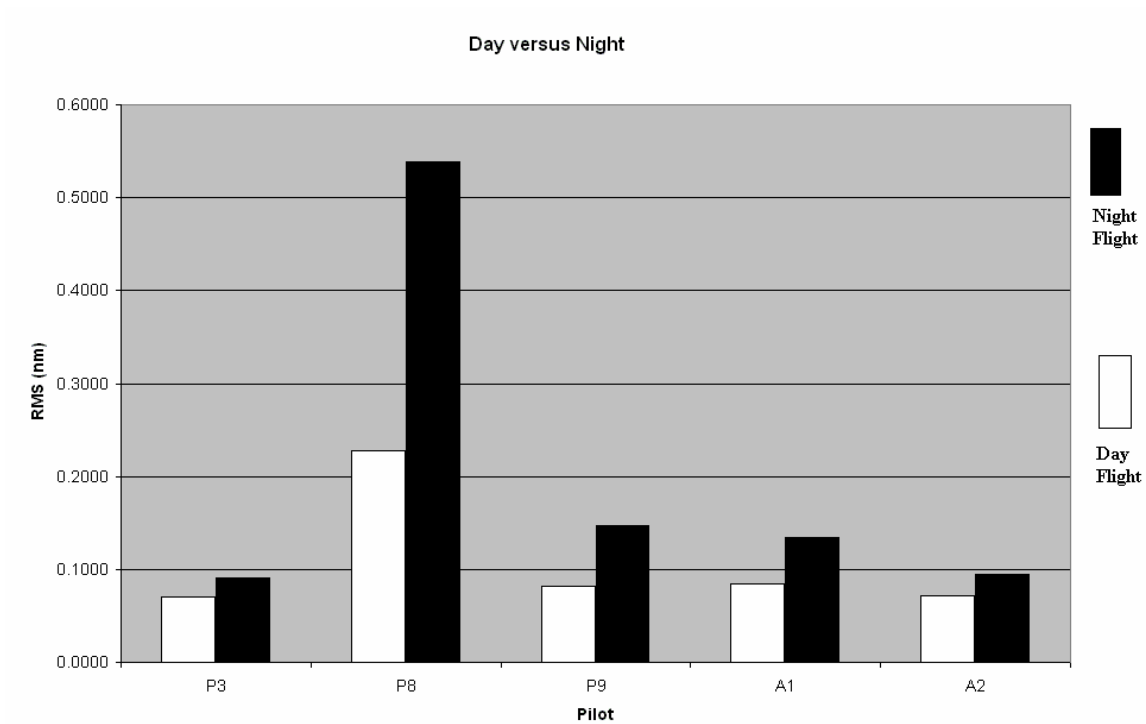

Figure 9 – Comparison of Day and Night Flights by Pilot

Table 2 – Raw Data Summary Sheet

Pilot	Total Time	Last 6 Months	Helicopter Experience	GPS Experience	Instrument Rated	RMSE (day)	RMSE (night)
A1	2600	0	yes	no	yes	0.0849	0.1339
A2	865	60	no	yes	no	0.0720	0.095
P1	7500	500	yes	no	no	0.0826	
P2	2120	0	no	no	yes	0.0695	
P3	650	400	yes	yes	yes	0.0709	0.0904
P5	4050	110	yes	yes	yes	0.0643	
P6	750	6	no	no	no	0.0731	
P7	278	56	yes	no	no	0.1098	
P8	535	35	no	no	no	0.2278	0.5389
P9	2172	105	yes	no	yes	0.0825	0.1476
P10	14700	175	no	no	yes	0.0691	

Table 3 – Correlation of Total Flight Time to RMSE

Correlations

		Total Flight time	RMS
Total Flight time	Pearson Correlation	1	-.274
	Sig. (2-tailed)	.	.416
	N	11	11
RMS	Pearson Correlation	-.274	1
	Sig. (2-tailed)	.416	.
	N	11	11

Table 4 – Correlation of Recent Flight Time to RMSE

Correlations

		RMS	Last 6 months time
RMS	Pearson Correlation	1	-.204
	Sig. (2-tailed)	.	.548
	N	11	11
Last 6 months time	Pearson Correlation	-.204	1
	Sig. (2-tailed)	.548	.
	N	11	11

Appendix B

P1 Day	
Mean	0.054316547
Standard Error	0.001760803
Median	0.03
Mode	0.01
Standard Deviation	0.062278668
Sample Variance	0.003878633
Kurtosis	4.605793907
Skewness	2.10552245
Range	0.35
Minimum	0
Maximum	0.35
Sum	67.95
Count	1251
Confidence Level(95.0%)	0.003454452

P3 Day	
Mean	0.047949827
Standard Error	0.001536818
Median	0.03
Mode	0.01
Standard Deviation	0.052251814
Sample Variance	0.002730252
Kurtosis	6.550025369
Skewness	2.303064025
Range	0.31
Minimum	0
Maximum	0.31
Sum	55.43
Count	1156
Confidence Level(95.0%)	0.003015269

P2 Day	
Mean	0.048174873
Standard Error	0.001460222
Median	0.03
Mode	0.01
Standard Deviation	0.050117754
Sample Variance	0.002511789
Kurtosis	6.899979265
Skewness	2.172279022
Range	0.35
Minimum	0
Maximum	0.35
Sum	56.75
Count	1178
Confidence Level(95.0%)	0.002864927

P3 Night	
Mean	0.055596026
Standard Error	0.002050182
Median	0.03
Mode	0.02
Standard Deviation	0.071256744
Sample Variance	0.005077523
Kurtosis	7.302389529
Skewness	2.611330845
Range	0.42
Minimum	0
Maximum	0.42
Sum	67.16
Count	1208
Confidence Level(95.0%)	0.004022315

P5 Day	
Mean	0.047331164
Standard Error	0.00124381
Median	0.04
Mode	0.01
Standard Deviation	0.043604364
Sample Variance	0.001901341
Kurtosis	1.916226298
Skewness	1.451296802
Range	0.21
Minimum	0
Maximum	0.21
Sum	58.17
Count	1229
Confidence Level(95.0%)	0.002440229

P7 Day	
Mean	0.075329768
Standard Error	0.002385416
Median	0.05
Mode	0.01
Standard Deviation	0.079902528
Sample Variance	0.006384414
Kurtosis	1.841647795
Skewness	1.520534577
Range	0.4
Minimum	0
Maximum	0.4
Sum	84.52
Count	1122
Confidence Level(95.0%)	0.004680377

P6 Day	
Mean	0.052740304
Standard Error	0.001471317
Median	0.04
Mode	0.01
Standard Deviation	0.050669726
Sample Variance	0.002567421
Kurtosis	5.969997733
Skewness	2.131092145
Range	0.31
Minimum	0
Maximum	0.31
Sum	62.55
Count	1186
Confidence Level(95.0%)	0.002886674

P8 Day	
Mean	0.16748422
Standard Error	0.004639115
Median	0.13
Mode	0.01
Standard Deviation	0.154490197
Sample Variance	0.023867221
Kurtosis	-0.13262702
Skewness	0.891178466
Range	0.62
Minimum	0
Maximum	0.62
Sum	185.74
Count	1109
Confidence Level(95.0%)	0.009102443

P8 Night	
Mean	0.411135693
Standard Error	0.009462542
Median	0.32
Mode	0.14
Standard Deviation	0.348447745
Sample Variance	0.121415831
Kurtosis	2.398049371
Skewness	1.481244339
Range	1.85
Minimum	0
Maximum	1.85
Sum	557.5
Count	1356
Confidence Level(95.0%)	0.018562824

P9 Night	
Mean	0.108706265
Standard Error	0.00284938
Median	0.08
Mode	0.07
Standard Deviation	0.099890995
Sample Variance	0.009978211
Kurtosis	5.590139242
Skewness	1.994632905
Range	0.61
Minimum	0
Maximum	0.61
Sum	133.6
Count	1229
Confidence Level(95.0%)	0.005590194

P9 Day	
Mean	0.058351836
Standard Error	0.001703692
Median	0.04
Mode	0.03
Standard Deviation	0.05830013
Sample Variance	0.003398905
Kurtosis	4.005800947
Skewness	2.052256278
Range	0.29
Minimum	0
Maximum	0.29
Sum	68.33
Count	1171
Confidence Level(95.0%)	0.003342633

P10 Day	
Mean	0.079842845
Standard Error	0.005732242
Median	0.02
Mode	0.01
Standard Deviation	0.199313952
Sample Variance	0.039726051
Kurtosis	24.73930933
Skewness	4.827059161
Range	1.43
Minimum	0
Maximum	1.43
Sum	96.53
Count	1209
Confidence Level(95.0%)	0.011246259

A1 Day	
Mean	0.061765217
Standard Error	0.001720536
Median	0.04
Mode	0.01
Standard Deviation	0.0583462
Sample Variance	0.003404279
Kurtosis	2.745407751
Skewness	1.564263345
Range	0.3
Minimum	0
Maximum	0.3
Sum	71.03
Count	1150
Confidence Level(95.0%)	0.003375743

A2 Day	
Mean	0.04868984
Standard Error	0.001585349
Median	0.03
Mode	0.02
Standard Deviation	0.053103286
Sample Variance	0.002819959
Kurtosis	4.130376254
Skewness	1.925245693
Range	0.32
Minimum	0
Maximum	0.32
Sum	54.63
Count	1122
Confidence Level(95.0%)	0.003110583

A1 Night	
Mean	0.089650767
Standard Error	0.00290517
Median	0.06
Mode	0.02
Standard Deviation	0.099541818
Sample Variance	0.009908574
Kurtosis	5.418206101
Skewness	2.200900061
Range	0.54
Minimum	0
Maximum	0.54
Sum	105.25
Count	1174
Confidence Level(95.0%)	0.005699912

A2 Night	
Mean	0.056974038
Standard Error	0.002274115
Median	0.03
Mode	0.01
Standard Deviation	0.076004458
Sample Variance	0.005776678
Kurtosis	8.23807058
Skewness	2.732200624
Range	0.44
Minimum	0
Maximum	0.44
Sum	63.64
Count	1117
Confidence Level(95.0%)	0.004462028

Vita

Thomas Morrissey grew up in Queens, New York. He graduated from Xavier High School in June, 2000. While in high school, Tom played trombone in the school band, was a lieutenant in Army JROTC, and earned his private pilots license. Saint Louis University was the next step in his life plan. He completed a Bachelors Degree in Aeronautics in May, 2003. Immediately following graduation, he moved to Tullahoma, Tennessee to study at the University of Tennessee Space Institute. After completing all resident course work, Tom took a job as a flight instructor at Dowling College in Shirley, New York. His future plans are to fly professionally for an airline and retire as a college professor.