UNIVERSITY OF NORTH DAKOTA

Determining Appropriate Levels of Automation

FITS SRM Automation Management Research

Charles L. Robertson, PhD

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One of the benchmarks of SRM is automation management. This study determined the best practice for managing the automation in a Technically Advanced Aircraft (TAA). The study combined a survey of current TAA users, aircraft and avionics manufacturers, and lab research to determine the best methods for managing automation during complex and stressful flight scenarios. The centerpiece event was a series of trials in the UND Technically Advanced Aircraft Performance (TAAP) lab culminating in suggestions for improved understanding of automation use, levels of automation, and a set of automation management best practices.

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Determining Appropriate Levels of Automation

A cultural change in pilot training is needed. Pilots need to become flight managers rather than strictly stick and rudder manipulators. The instructor community needs to change the traditional focus of flight training from its almost single focus on "stick and rudder skills" to flight manager. In this context, a flight manager is a pilot that controls all aspects of flight not just the controls of an airplane. Currently, the focus in the typical flight-training program is only on the psychomotor technical skills needed to fly an airplane (K. W. Lovelace, personal communication, April 16, 2009). This focus does not preclude teaching critical thinking (judgment and decision-making) and flight management, but historically it does not. In fact, according to the Aviation Instructor's Handbook, "In the past, some students were introduced to ADM [Aeronautical Decision Making] concepts toward the completion of their training or not at all" (p. 9-9, 1999). The concept of flight management is beginning to be recognized by the instructor community and in the research surrounding technically advanced aircraft (TAA) (p. 8-14, Aviation Instructor's Handbook, 2008). Early FAA Industry Training Standards (FITS) research identified a need for critical thinking and flight management skills to be taught throughout pilot training to improve general aviation safety.

Background

Why do critical thinking and flight management skills need to be taught? Eighty percent of the general aviation (GA) accidents are caused by human factors or have human factor as a contributing factor. Formerly, human factors errors were called "pilot errors" (p. 8-14, Aviation Instructor's Handbook, 2008). Pilot error more clearly communicates the nature of the safety problem; that is, pilots are making bad decisions or using bad judgment, which leads to accidents. The results of the FITS studies show significant improvements in pilot performance, situational awareness, and aeronautical decision-making occur when the training includes scenario-based training, learner centered grading, and single-pilot resource management (Robertson, Petros, Schumacher, McHorse, Ulrich, 2006). The FITS study also showed that you are able to teach pilots judgment and decision-making skills, which the research teams believe is what accounts for the significant improvements. However, the researchers observed that the pilots participating in the study, typically, did not use the available automation, including the autopilot, effectively (Robertson, Petros, Schumacher, McHorse, Ulrich, 2006).

The FAA is forecasting that general aviation (GA) operations will be increased due to personal use for transportation. Many indicators appear to support the FAA forecast while the enhancement in avionics improves the GA capability to serve in this role. These changing travel patterns mean GA aircraft are going further and carrying more passengers. Both will likely mean that pilots will have fewer opportunities to practice and rehearse basic piloting skills while at the same time they must increase the precision with which they perform (R. A. Wright, 2002). Furthermore, crowded skies are likely cause a continued tightening of navigational standards. All of this means there will be an increased demand for effective automation use.

One effort to improve GA safety included providing additional information to the pilot through enhanced avionics systems. GA aircraft were equipped with a variety of glass and non-glass cockpit designs that incorporated advanced avionics systems. However, many instructors expressed their concerns to the FITS research team that these improvements would distract the pilot and consequently lead to more GA accidents rather than fewer. The FITS research team set out to determine what training practices, if any, would prepare pilots to use the enhanced avionics systems effectively. The team determined that a single pilot version of Crew resour5ce Management (CRM) training could adopted by GA pilot. Single Pilot Resource Management

(SRM) is the single pilot version of CRM training and it includes the concepts of Aeronautical Decision Making, (ADM), Risk Management (RM), Task Management (TM), Automation Management, (AM), Controlled Flight into Terrain (CFIT) Awareness, and Situational Awareness (Robertson, Petros, Schumacher, McHorse, Ulrich, 2006). Management skills include risk, automation, and information management. Simply put, specific avionics training means teaching the particular “glass cockpit” equipment. At this time, there is no standardization of the various installations of glass cockpits in GA (Robertson, Petros, Schumacher, McHorse, Ulrich, 2006). The information presented to the pilot and the method to obtain the information is not the same even within a specific avionics line. For example, various aircraft manufacturers install the Garmin G-1000 System with different screens, autopilots, sub-systems, and functionality. They each have unique operating procedures and display information differently (see Garmin and Avidyne user’s Manuals).

To meet this challenge, the FITS research teams developed and tested new training methods. The research studies showed, when using three basic concepts throughout flight training, significant improvements in pilot performance and aeronautical decision-making resulted (Robertson, Petros, Schumacher, McHorse, Ulrich, 2006; French, Blickensderfer, Ayers, Connolly, 2005). These three basic concepts are scenario-based training (SBT), learner-centered grading (LCG), and single pilot resource management (SRM).

Research Questions

To realize actual improvements in GA safety, appropriate use of automation must be established and trained. This study attempts to answer several research questions (a) why is the available automation not being used (b) when should the automation be used, (c) how should the automation be used, (d) why should the automation be used, (e) what are the impediments to effective automation use, and (f) what are the best practices for automation use? To take advantage of the automation becoming available in GA, it is necessary to include training on how to use the automation effectively. However, we must first answer the question about what is effective use of the automation. The answers to these questions should provide guidance on appropriate use of automation, best practices, and a basis for developing automation training.

Literature Review

Generally speaking, the literature on automation reflect that one or more of four elements (knowledge, trust, comfort, and bias) determine when and where automation will be used, more so than capability and reliability of the automation (Scherman, 1997). Determining how to use the automation more effectively will not be useful until pilots are willing to use the automation. Pilots base the decision to use the automation on knowledge, trust, comfort, and bias rather than on a conscious decision to use it. The pilot will need to learn the how to operate and use the new equipment as he or she would have to with any other new piece of equipment. Using a training program to acquire the necessary knowledge and skills is typically a more efficient and effective way to develop expertise in new technology than trial and error. Once basic system and procedural knowledge in acquired, the operator can practice until they obtain trust and comfort with the new system. Studies involving complex automated systems clearly indicate the importance of developing trust before an operator is willing to use the new automation (Scherman, 1997). It is likely that every pilot that has gone through the introduction of any new technology has experienced this process for himself or herself or they have seen their student anguish through the process. The remaining determinate is bias. Bias can include an array of pertinent topics; however, in the context of this paper, bias will be limited to the macho pilot's attitude toward the need to develop and maintain superior "stick and rudder" skills.

The nature of pilot training ingrains bias from the very beginning. A pilot acquires various pilot certificates and ratings based on meeting the minimum established performance standard without assistance. Currency and flight review criteria drive the requirement to maintain at least the minimum “stick and rudder” skills necessary to operate the aircraft safely. Until recently, judgment and pilot decision training was not an integral part of initial pilot training programs and practical tests did not fully examine them.

The automation literature provides us with a one possible definition of various levels of automation. That is, (a) no automation (no autopilot or autopilot off), (b) basic automation (autopilot in pitch and role hold only), (c) simple automation (autopilot in heading mode with altitude hold), (d) full automation (autopilot in navigation with altitude or vertical speed hold), and (e) advanced automation (autopilot in the flight management system [FMS] mode with altitude select). Observations were made of flight operations in an air carrier that had various aircraft equipped with three of these autopilots levels. The basic automation (autopilot with only pitch and role hold) is more common in GA than in today’s air carrier, so this level is included. Effectively, the no automation level is present in every aircraft since the automation can be turned off, if installed.

Methodology

Once the advantages of effective use of the automation, including the autopilot, are recognized, the questions change to what should we teach the pilot to do with the autopilot so the pilot has time to use the automation. This study is in two parts, the first part used a data collection instrument to examine the issues surrounding automation and autopilot use and to determine an answer to what we should teach, and the second part included pilot performance test with participants using four different levels of automation. The study begins with the issues surrounding automation and autopilot use.

The literature suggested that knowledge, trust, comfort, and automation bias drives the use of the automation. The comparisons made in this study assumed and reflected these drivers. The data collection instrument, see Appendix A, was a questionnaire provide to the general pilot population. The questionnaire asked question in six categories (a) demographics, (b) automation attitude, (c) automation trust, (d) automation competency, (e) automation techniques, and (f) appropriate levels of automation. The study used demographic information to learn about the participants and to identify comparison groups. Then the study compared the self-reported agreement with the statement in the data collection instrument for each of the remaining questions between FITS verses Non-FITS training, Glass verses Non-Glass, Autopilot verses No Autopilot training, Autopilot and Moving Map verses No Autopilot and no Moving Map, various Age groups, and various Flight Hour groups. The next section discusses the analyses of the data for the data collection instrument.

Data Analysis for Data Collection Instrument

One hundred and eighty (N=180) questionnaires were analyzed in the study. Thirteen of the questionnaires were not complete and were excluded where the necessary data was missing. Additionally, the participants had the opportunity to respond as not sure (NS) when they were not sure. This resulted in some comparisons having an N as low as 100. The descriptive data shown below includes the total number participants and the group size with the respective analysis. Table 1 shows 97% of the participants were men and 3% were women; 85.7% were between the ages of 16 and 24, 10.7% were between the ages of 25 and 34, 3.6% were 35 or older; and 54.8% had 0 to

200 flight hours, 32.7% had 200 to 500 total flight hours, and 12.6% had more than 500 flight hours.

Table 1. Participant Data

Sex			Age			Hours		
Groups	Size	Percent	Groups	Size	Percent	Groups	Size	Percent
Male	n=164	97.0	16-24	n=144	85.7	0-200	n=92	54.8
Female	n=5	3.0	25-34	n=18	10.7	200-500	n=55	32.7
			35-44	n=2	1.2	500-1000	n=9	5.4
			45-60	n=3	1.8	1000-2500	n=5	3.0
			>60	n=1	0.6	>2500	n=7	4.2
	N=169			N=168			N=168	

Missing data not included in the percentages.

Table 2 shows that 60.5% had moving maps and autopilot, and 39.5% did not have a moving map and autopilot; 19.5% had no glass and 65.9% had glass (PFD, MFD, or Both); and 33.1% had RNAV, 37.3% do not have RNAV, and 29.5% were not sure.

Table 2. Equipment Data

Moving Map			Glass Cockpit			RNAV		
Groups	Size	Percent	Groups	Size	Percent	Groups	Size	Percent
Yes	n=101	60.5	No	n=33	19.5	Yes	n=55	33.1
No	n=66	39.5	PFD	n=2	1.2	No	n=62	37.3
			MFD	n=6	3.6	NS	n=49	29.5
			Both	n=103	60.9			
			NS	n=25	14.8			
	N=167			N=169			N=166	

Missing data not included in the percentages. NS=not sure.

Table 3. Training Data

FITS Accepted			Formal Autopilot Training		
Groups	Size	Percent	Groups	Size	Percent
Yes	n=45	26.8	Yes	n=88	52.1
No	n=60	35.7	No	n=81	47.9
NS	n=63	37.5			
	N=169			N=169	

Missing data not included in the percentages. NS=not sure.

Table 3 shows that 26.8% had or were in a FITS accepted training program and 35.7% had not received FITS accepted training, and 52.1% have had formal autopilot training and 47.9% had not received formal autopilot training.

The analyses begin with a test of the differences between the means of the participants that received FITS training, including FITS training in progress, and non-FITS training. T-test analyzed automation attitude, trust, competency, and techniques, and appropriate level of automation. All test of significance used an alpha level of < .05. Shown in Table 4 is a summary of this analysis. Shown in Appendix B are the complete results of the analysis. Similarly, summaries of the other analyses are in this section and the complete results are in Appendixes C, D, E, F, G, H, and I.

Table 4 shows a summary of the significant mean differences between the groups for FITS verses Non-FITS training. Significant differences were found in questions 13, 18, 20, 21, 22, 24, 28, 29, and 30 (Sig (2-tailed) = .015, .010, .000, .000, .000, .004, .025, .030, and .004, respectively). Again, the questions are in Appendix A. Table 4 also shows the mean score for significant results. Question 13, automation attitude, shows Sig (2-tailed) = .015 and the mean = 2.77/3.37 for the FITS verses Non-FITS trained pilot participant. The remaining findings are in a similar manner and the complete analyses, again, are in Appendix B.

Table 4. Summary of FITS/Non-FITS Training Results

t-Test		Sig (2-tailed)		Mean	
	Levene's Test	Equal	Not Equal	FITS	Non-FITS
Attitude 13		.015		2.77	3.37
Trust 18		.010		4.16	3.52
Competency 20		.000		3.98	3.08
Competency 21	.000		.000	4.41	3.23
Competency 22	.012		.000	3.89	2.60
Competency 24		.004		3.93	3.27
Techniques 28		.025		4.05	3.59
Techniques 29		.030		4.30	3.92
Levels 30		.004		2.55	3.24

Note. Statistical significance is < .05. When Levene’s Test is significant, use the equal variance not assumed in these cases.

Table 5 shows a summary of the significant differences in means between groups for formal autopilot training verses no formal autopilot training for questions 15, 18, 19, 20, 21, 22, 23, 24, 26, 28, 29, and 31 (Sig (2-tailed) = .037, .000, .006, .000, .000, .000, .000, .000, .026, .002, .014, and .030, respectively). This time question 15 is the example. Question 15 shows the results of the t-test (Sig (2-tailed) = .037, mean = 3.63/3.24). Read the remaining results in Table 5 in a similar manner and the complete analyses are in Appendix C.

Table 5. Summary of Formal Autopilot Training Results

t-Test		Sig (2-tailed)		Mean	
	Levene's Test	Equal	Not Equal	A/P Training	No-A/P Training
Attitude 15	.000		.037	3.62	3.24
Trust 18	.000		.000	4.10	2.56
Trust 19	.000		.006	2.33	1.71
Competency 20	.000		.000	3.78	2.24
Competency 21	.000		.000	4.22	2.20
Competency 22	.000		.000	3.67	1.80
Competency 23	.000		.000	3.48	1.75
Competency 24	.000		.000	3.90	2.16
Techniques 26	.009		.026	4.30	3.96
Techniques 28	.000		.002	4.02	3.53
Techniques 29		.014		4.16	3.80
Levels 31	.000		.030	3.23	2.79

Note. Statistical significance is < .05. Equal variances cannot be assumed when Levene's Test is significant; therefore, the 2-tailed significances for not equal are used in these cases.

Table 6 summarizes the combined training affect, (a) Group 1 received FITS and formal autopilot training, (b) Group 2 received only FITS training, (c) Group 3 received only autopilot training, and (d) Group 4 did not receive FITS or autopilot training. Table 6 shows significant differences between groups for an ANOVA analyses on questions 13, 18, 20, 21, 22, 23, 24, and 30 (Sig = .030, .001, .000, .000, .001, .000, and .005, respectively). The table also shows the significant pairs of groups on the Post Hoc LSD test. For example, Groups 1 and 4 were the only results that had a significant difference on the Post Hoc LSD test between groups was for question 13 (Sig = .003) and the mean scores for these groups were 2.66 and 3.55, respectively. Similarly,

Table 6. Summary of Combined Training Experiences

	ANOVA	Post Hoc LSD Significant Between Groups					Mean			
	Sig	1-2	1-3	1-4	2-3	3-4	G1	G2	G3	G4
13	.030			.003			2.66			3.55
18	.001	.004	.021	.000			4.43	3.11	3.73	3.26
20	.000	.008	.004	.000		.025	4.20	3.11	3.40	2.77
21	.000		.016	.000		.002	4.57	3.78	3.77	2.64
22	.000	.004	.001	.000		.001	4.17	2.78	3.13	2.06
23	.001	.000		.004	.003	.049	3.57	1.56	3.27	2.52
24	.000	.027		.000		.022	4.12	3.22	3.67	2.87
30	.005		.042	.000			2.40		3.00	3.45

Note. Statistical significances is <.05.

question 18 showed Post Hoc LSD significant differences between Groups 1-2, 1-3, and 1-4 (Sig = .004, .021, and .000, respectively) with means = 4.43/3.11, 4.43/3.73, and 4.43/3.26, respectively). That is, Group 1 mean = 4.43 and Group 2 mean = 3.11 and so on. Read the remainder results of the analysis in a similar manner and the complete analyses are in Appendix D.

Table 7 shows a summary of the significant differences in means for airplanes equipped with “glass” flight instruments existed in questions 13, 16, 25, 26, 27, and 30 (Sig (2-tailed) = .007, .039, .007, .001, .037, and .008, respectively). For this study, a glass cockpit has a primary flight display (PFD), multifunctional display (MFD), or both, while non-glass has neither. Another question asked if one or more of the airplanes the participants fly are technically advanced aircraft (TAA). TAA is a broader term that may or may not include glass but it must have a GPS, moving map, and autopilot. Those findings will be addressed next. Question 16, automation trust, is the example this time on how to read these results reported in the table. Levene’s Test was significant (Sig = .050); therefore, the t-test results must be read under the equal variances not assumed column (Sig (2-tailed) = .039, mean = 3.55/2.89). The complete analyses are in Appendix E.

Table 7. Summary of Glass Flight Instruments Results

t-Test		Sig (2-tailed)		Mean	
	Levene's Test	Equal	Not Equal	Non-Glass	Glass
Attitude 13		.007		3.55	2.89
Trust 16	.050		.039	3.91	3.44
Techniques 25		.007		3.75	4.25
Techniques 26		.001		3.84	4.38
Techniques 27		.037		4.03	4.36
Levels 30		.008		3.31	2.70

Note. Statistical significances are < .05. * When Levene’s Test is significant, use the equal variance not assumed result.

Table 8 shows a summary of the significant differences in means for TAA for questions 16, 18, 19, 20, 21, 22, 23, 24, 26, 28, 29, and 31 (Sig (2-tailed)= .016, .000, .015, .000, .000, .000, .000, .000, .037, .003, .011, and .027, respectively). In this study, define TAA as an airplane equipped with an autopilot, global positioning system navigational equipment (GPS), and a moving map display. Using question 16 as the example for reading Table 8, Levene’s Test (Sig =

.000), t-test (Sig = .016), and means = 3.74/3.21. Read the remaining results in the same manner.

The complete results are in Appendix F.

Table 8. Summary of Technically advanced aircraft Results

t-Test		Sig (2-tailed)		Mean	
	Levene's Test	Equal	Not Equal	TAA	Non-TAA
Trust 16	.000		.016	3.74	3.21
Trust 18	.000		.000	3.91	2.53
Trust 19	.000		.015	2.26	1.67
Competency 20	.000		.000	3.59	2.26
Competency 21	.000		.000	4.08	2.00
Competency 22	.000		.000	3.42	1.74
Competency 23	.000		.000	3.19	1.86
Competency 24	.000		.000	3.61	2.27
Techniques 26		.037		4.29	3.98
Techniques 28		.003		3.98	3.48
Techniques 29		.011		4.14	3.76
Levels 31	.000		.027	3.22	2.73

Note. Statistical significances are < .05. Use equal variance not assumed results when Levene's Test is significant.

Table 9 shows significant differences in means for area navigation (RNAV) equipped airplanes for questions 11, 12, 15, 18, 19, 20, 21, 22, 23, and 24 (Sig (2-tailed)= .035, .027, .016, .000, .010, .000, .000, .000, .000, and .000, respectively). Please read this table like Table 8 and find the complete results in Appendix G.

Table 9. Summary of Area Navigation Results

t-Test		Sig 2-tailed		Mean	
	Levene's Test	Equal	Not Equal	RNAV	N/RNAV
Attitude 11	.007		.035	4.30	4.68
Attitude 12		.027		3.89	4.26
Attitude 15	.011		.016	3.72	3.21
Trust 18	.000		.000	4.11	2.81
Trust 19	.000		.010	2.31	1.61
Competency 20	.000		.000	3.78	2.58
Competency 21	.000		.000	4.20	2.58
Competency 22	.000		.000	3.63	2.06
Competency 23	.000		.000	3.40	1.95
Competency 24	.000		.000	3.74	2.53

Note. Statistical significances are < .05. Use the equal variance not assumed results when Levene's Test is significant.

Table 10 shows significant differences in the means between the groups for various age groups. Questions 11, 13, and 15 showed significant differences in the mean scores on the ANOVA (Sig = .004, .013, and .035, respectively) (see Table 10). Question 11 showed significant differences in means between groups 1-4 (mean = 4.38/2.75 and Sig = .003), 2-3 (mean = 4.65/3.00 and Sig = .037), and 2-4 (mean = 4.65/2.75 and Sig = .001) on the LSD Post Hoc

Table 10. Summary of Age Results

	ANOVA	Post Hoc LSD Significant Between Groups						Mean			
	Sig	1-2	1-3	1-4	2-3	2-4	3-4	G1	G2	G3	G4
Attitude 11	.004			.003	.037	.001		4.38	4.65	3.00	2.75
Attitude 13	.013		.016	.043	.043			3.14	2.88	1.00	1.67
Attitude 15	.035			.047				3.34			4.50

Note. Statistical significances are < .05.

analysis. Question 13 showed significant differences in means between groups 1-3 (mean = 3.14/1.00 and Sig = .016), 1- 4 (mean = 3.14/1.75 and Sig = .027), and 2-3 (mean = 2.88/1.00 and Sig = .043) on the LSD Post Hoc analysis. Question 15 showed significant differences in means between groups 1- 4 (mean = 3.34/4.50 and Sig = .047) on the LSD Post Hoc analysis. The means for all significant group differences are in the four columns at the right of the table (see Table 10). Complete results are in Appendix H.

Table 11 shows significant differences in means for various flight hour groups for nineteen of the questions asked on the questionnaire. Questions 11, 13, 14, 18, 20, 21, 22, 23, 24, 28, and 29 showed significant differences between the groups on the ANOVA (Sig = .010, .008, .009, .000, .000, .000, .000, .000, .000, .024, .037, respectively), the significant individual group differences on the LSD Post Hoc test, and the mean score for each group. Complete results are in Appendix I.

Finally, independent sample t-test analyses were made on the men verses women but there are no significant differences for any of the questions. The lack of significant differences may be due to the small number of women participants rather than there not being any differences between men and women. Nevertheless, there are no statistical findings to report.

Table 11. Summary of Flight Hour Results

	ANOVA Sig	Post Hoc LSD Significant Between Groups 1-2	1-3	1-4	1-6	2-3	2-4	2-6	3-6	4-6	Mean G1	G2	G3	G4	G6
11	.010				.007			.001	.024	.008	4.27	4.60	4.38	4.80	3.14
13	.008				.002			.005			3.22	3.13			1.71
14	.009		.009		.023						2.48		1.50		1.57
18	.000	.000	.000	.012	.003						2.69	4.04	4.75	4.40	4.43
20	.000	.000	.000	.001		.043					2.49	3.53	4.63	4.80	
21	.000	.000	.000	.001	.012						2.46	4.13	4.88	4.80	4.00
22	.000	.000	.000	.000	.010	.044	.039				2.09	3.38	4.50	4.80	3.57
23	.000	.000	.016	.000						.011	2.00	3.48	3.38	4.60	2.29
24	.000	.000	.002	.000	.024						2.44	3.72	4.13	4.80	3.71
28	.024	.001									3.57	4.15			
29	.037	.003									3.80	4.27			

Note. Statistical significance is < .05.

Now the pilot performance testing and analysis part of the study will be presented.

Data Analysis for Pilot Performance Data

Sixteen scenarios were analyzed in this portion of the study. Each participant flew a prescribe scenario (see Appendix J) using one of four levels of automation. The four levels of automation were (a) autopilot on with the flight plan loaded in the navigation equipment, (b) autopilot off with the flight plan loaded, (c) autopilot on without flight guidance, and (d) autopilot off without flight guidance. The pilot performance was measured during for each level of automation using the same scenario. The scenario included a planned portion and an un-planned portion. The planned portion began with the aircraft taxing into position for takeoff, the takeoff and climb to the planned en-route altitude, radar vectors to join a victor airway, and navigation along the airway. The participant was given a weather report (trigger event) that required a diversion, which began the un-planned portion. This portion included an opportunity to choose the action the pilot could take followed by instructions for recovery. Consequences of all choices lead to returning the aircraft back to the departure airport. The instructions included radar vectors to intercept the localizer followed by a clearance to fly the ILS for landing. The next section discusses the analyses of the pilot performance data.

Table 12 shows significant differences in the means for altitude differences between the groups on the ANOVA (sig = .020) and positive mean differences between the groups for heading and indicated airspeed (sig = .071, .076, respectively).

Table 12. ANOVA for Pilot Performance

		Sum of Squares	df	Mean Square	F	Sig.
HDG_Dif	Between Groups	397.315	3	132.438	3.030	.071
	Within Groups	524.549	12	43.712		
	Total	921.863	15			
ALT_Dif	Between Groups	27387.111	3	9129.037	4.820	.020
	Within Groups	22728.268	12	1894.022		
	Total	50115.379	15			
IAS_Dif	Between Groups	719.653	3	239.884	2.953	.076
	Within Groups	974.881	12	81.240		
	Total	1694.533	15			

Note: Statistical significance is <.05.

Table 13 shows the significant individual group differences on the LSD Post Hoc Test. Significant heading differences occurred between groups 1 - 4 (sig = .016) and 3 – 4 (sig = .042). Groups 2 – 4 showed better heading performance, but not significantly better (sig = .062). Significant altitude differences occurred between groups 1 – 4 (sig = .062) and 3 – 4 (sig = .010) and better altitude performance, but not significantly better between groups 1 – 2 (sig = .062). Finally, significantly better indicated airspeed performance was shown between groups 1 – 4 and better performance between groups 1 – 3 (sig = .073) and 2 -4 (sig = .056); however, it was not significantly better.

Table13. Pilot Performance LSD Post Hoc Test

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
HDG_Dif	1	2	-3.49225255	4.67506042	.469	-13.6783342	6.6938291
		3	-2.47687400	4.67506042	.606	-12.6629556	7.7092076
		4	-1.31177360E1	4.67506042	.016	-23.3038176	-2.9316544
	2	1	3.49225255	4.67506042	.469	-6.6938291	13.6783342
		3	1.01537855	4.67506042	.832	-9.1707031	11.2014602
		4	-9.62548345	4.67506042	.062	-19.8115651	.5605982
	3	1	2.47687400	4.67506042	.606	-7.7092076	12.6629556
		2	-1.01537855	4.67506042	.832	-11.2014602	9.1707031
		4	-1.06408620E1	4.67506042	.042	-20.8269436	-.4547804
	4	1	13.11773600*	4.67506042	.016	2.9316544	23.3038176
		2	9.62548345	4.67506042	.062	-.5605982	19.8115651
		3	10.64086200*	4.67506042	.042	.4547804	20.8269436
ALT_Dif	1	2	-63.33693553	30.77354640	.062	-130.3867332	3.7128622
		3	-6.61934003	30.77354640	.833	-73.6691377	60.4304577
		4	-1.00110149E2	30.77354640	.007	-167.1599464	-33.0603510
	2	1	63.33693553	30.77354640	.062	-3.7128622	130.3867332
		3	56.71759550	30.77354640	.090	-10.3322022	123.7673932
		4	-36.77321315	30.77354640	.255	-103.8230109	30.2765846
	3	1	6.61934003	30.77354640	.833	-60.4304577	73.6691377
		2	-56.71759550	30.77354640	.090	-123.7673932	10.3322022
		4	-9.34908087E1	30.77354640	.010	-160.5406064	-26.4410109
	4	1	1.00110149E2	30.77354640	.007	33.0603510	167.1599464
		2	36.77321315	30.77354640	.255	-30.2765846	103.8230109
		3	93.49080865*	30.77354640	.010	26.4410109	160.5406064

IAS_Dif	1	2	-2.75813928	6.37338421	.673	-16.6445506	11.1282720
		3	-12.51159743	6.37338421	.073	-26.3980087	1.3748139
		4	-1.62545797E1	6.37338421	.025	-30.1409909	-2.3681684
	2	1	2.75813928	6.37338421	.673	-11.1282720	16.6445506
		3	-9.75345815	6.37338421	.152	-23.6398694	4.1329531
		4	-13.49644038	6.37338421	.056	-27.3828517	.3899709
	3	1	12.51159743	6.37338421	.073	-1.3748139	26.3980087
		2	9.75345815	6.37338421	.152	-4.1329531	23.6398694
		4	-3.74298223	6.37338421	.568	-17.6293935	10.1434291
	4	1	16.25457965*	6.37338421	.025	2.3681684	30.1409909
		2	13.49644038	6.37338421	.056	-.3899709	27.3828517
		3	3.74298223	6.37338421	.568	-10.1434291	17.6293935

*. The mean difference is significant at the 0.05 level.

Note:

Group 1 – autopilot on with flight plan loaded.
Group 2 – autopilot off with the flight plan loaded.
Group 3 – autopilot on with no flight plan loaded.
Group 4 – autopilot off with no flight plan loaded.

This section reported summaries of the analyses. A copy of the data collection instrument and the scenario are in Appendix A and Appendix J with the details of the analyses in Appendix B through Appendix I. Appendix J contains the scenario for the pilot performance testing. The next section will present a summary of the significant findings. A discussion of the results, conclusion, limitations, and recommendation will follow in the last section.

Summary of Findings

Significant differences between group means are in each of the five areas (automation attitude, automation trust, automation competency, automation techniques, and appropriate level of automation) for one or more questions in the nine comparisons except combined training, age, and flight hours. A summary of the findings are in Table 14 beginning with the training, followed by the equipment, age, and flight hours.

Table 14. Summary of Statistically Significant Analyses

Questions	Attitude					Trust			Competency					Techniques					Level	
	11	12	13	14	15	16	18	19	20	21	22	23	24	25	26	27	28	29	30	31
FITS Training			*				*		*	*	*		*				*	*	*	
A/P Training					*		*	*	*	*	*	*	*		*		*	*		*
Training			*				*		*	*	*	*	*						*	
Glass			*			*								*	*	*			*	
TAA			*	*		*	*	*	*	*	*	*	*		*		*	*		*
RNAV	*	*			*		*	*	*	*	*	*	*							
Age	*		*		*															
Flight Hours	*		*	*			*		*	*	*	*	*				*	*		

Note. * Statistical significance is < .05.

The analysis of the FITS verses Non-FITS training showed significant differences in all five areas examined including automation attitude (question 13), automation trust (question 18), automation competency (questions 20, 21, 22, and 24), automation techniques (questions 28 and 29), and appropriate level of automation (question 30) (see Table 14). Formal autopilot training verses no formal autopilot training also showed significant differences in all five areas including attitude (question 15), trust (questions 18 and 19), competency (questions 20, 21, 22, 23, and 24), techniques (questions 26, 28, and 29), and appropriate level (question 31) (see Table 14). The combined training (FITS and formal autopilot training) showed significant differences in four of the five areas examined including attitude (question 13), trust (question 18), competency (20, 21, 22, 23, and 24), appropriate level (question 30) (see Table 14).

Training affected two automation attitude questions (questions 13 and 15). Question 13, “automation should only be used during an extended en-route phase and during a precision instrument approach,” addresses the participant’s attitude about automation and its use. Non-FITS trained participants agreed with the statement and FITS trained participants disagreed with the statement. Participants with formal autopilot training showed stronger agreement with statement “the status of the automation including the autopilot is an important consideration in the risk management (go-no go) decision" (question 15) than the group without formal autopilot training. The combined training effect was only significant in question 13 where the group receiving FITS and formal autopilot training disagreed while the group that did not receive either type of training agreed.

Training also affected two automation trust questions (questions 18 and 19). Questions 18, "I know how to update the navigation program (flight plan) to comply with ATC instruction…," addressed the participant's trust in the automation. Participants receiving FITS accepted training reported stronger agreement with the statement than participants that did not receive FITS training. Participants receiving formal autopilot training agreed with the statement while the participants that did not receive formal autopilot training disagreed. Participants receiving both FITS and formal autopilot training, in the combined effect analysis, agreed more strongly than those that received FITS only, autopilot only, or neither FITS and autopilot. Question 19, "I turn off the automation if the flight plan changes in-flight rather than reprogramming the RNAV/GPS," also addressed the participant's trust in the automation. However, question 19 only showed significant differences on the analysis of the formal autopilot training. In this case, the participants with formal autopilot training disagreed more strongly than those without.

All of the automation competency questions, except question 23 for the FITS/Non-FITS training analysis, showed significant differences; (a) question 20, "I know how to use all of the functions of the navigation and automation equipment…," (b) question 21, "I am proficient using the basic functions of the autopilot and navigation equipment," (c) question 22, "I am proficient using the advanced functions of the autopilot and navigation equipment," (d) question 23, "I do not encounter 'automation surprise' when I am using the automation," (e) question 24, "I know effective techniques to counter complacency." In the FITS/Non-FITS training analysis, questions

20, 21, 22, and 24 showed stronger agreement with the statement, except on question 22 where the FITS trained group agreed and the Non-FITS group disagreed. For the formal autopilot/no-formal autopilot training analysis, questions 20 through 24, all participants receiving formal autopilot training agreed with the statement while those without formal autopilot training disagreed. For the combined training effect, the same pattern occurred with the FITS and formal autopilot training; that is, those receiving training stronger agreement with the statement or showed agreement verses disagreement with the statement. One additional result is worthy of note; that is, the group with FITS and without formal autopilot training compared to the group without FITS and with formal autopilot training showed a disagreement verses agreement on question 23. This finding is discussed further in the conclusion section.

The FITS and formal autopilot training analysis showed significance on questions 28 and 29. Additionally, the formal autopilot training analysis showed significance on question 26. However, the combined effect of the two events showed no significances in automation techniques. Examining the questions in sequence, question 25, "approaching a waypoint, the direction of turn, and the roll out heading should be reviewed to monitor the automated tracking," addresses automation technique. In this result, the participants receiving formal autopilot training agreed more strongly with the statement. In questions 28 and 29; "between waypoints, the aircraft position should be verified by checking the distance and radial from an off-track NAV aid" and "when visibility permits, the aircraft position should be verified by checking the visual position against the moving map position;" respectively; both the FITS and formal autopilot trained participants agreed more strongly with the automation technique questions than those without the respective training.

Training affected two questions in the final area, appropriate level of automation. Question 30, "the HDG and ALT modes of the autopilot should not be selected until established on a programmed leg of the flight," and question, "select the HDG and ALT SEL/HLD (VNA) modes of the autopilot as soon after takeoff as legally permissible and then selecting the NAV/GPSS mode as soon as course guidance is available," FITS training and the combined training events showed significant differences on question 30 and formal autopilot training showed significant differences on question 31. On question 30, the FITS and combined trained groups disagreed with the statement while the groups without FITS and without FITS and formal autopilot training (combined training events) agreed. On question 31, the group receiving formal autopilot training agreed with the statement and those without autopilot training disagreed.

In airplane equipped with "glass" flight instrument verses no "glass" only four areas including attitude (question 13); trust (question 16); techniques (questions 25, 26, 27); and appropriate level (question 30) showed significant differences between the group means (see Table 14). On question 13, "automation should only be used during extended en-route phase and during a precision instrument approach," the participants with glass disagreed with the statement while those without glass agreed. On question 16, "I trust the automation will accurately and precisely control the airplane during all phases of flight; except takeoff, initial climb-out, short final, and landing," the participants without glass showed stronger support for the statement than those with glass. On questions 25, 26, and 27 ("before activation a GPS/RNAV flight plan, the flight plan information should be compared to the NAV log…;" "approaching a waypoint, the direction of turn and roll out heading should be reviewed…;" and "at the waypoint, the course, distance, and time to the next waypoint should be cross-checked…; respectively) showed stronger support by the participants with glass than those without glass. Finally, on question 30, "the HDG and ALT modes of the autopilot should not be selected until established on a programmed leg," showed disagreement by the participants with glass, while those without glass agreed.

The analyses of TAA, where TAA is defined as having an autopilot, GPS, and a moving map, showed significant differences on questions 16, 18, and 19 in trust; questions 20, 21, 22, 23, 24 in competency, questions 26, 28, and 29 in techniques; and question 31 in appropriate level (see Table 14). On questions 16, "I trust the automation will accurately and precisely control the airplane during all phases of flight…," showed stronger support for the statement for the participants flying TAA than the participants flying non-TAA. On question 19, "I know how to update the navigation program (flight plan) to comply…," participants flying TAA showed agreement for the statement, while participants flying non-TAA disagreed. On question 19, "I turn off the automation if the flight plan changes in-flight rather than reprogramming…," participants flying TAA showed less disagreement with the statement than those flying non-TAA. That is, when the airplane is equipped with an autopilot and a moving map the participants use the automation more. On all the automation competency questions, the participants flying TAA agreed with the statement, while those flying non-TAA disagreed. Respectively, questions 20 through 24 were "I know how to use all of the functions…," "I am proficient using the basic functions…," "I am proficient using the advanced functions…," "I do not encounter 'automation surprise'…," and "I know effective techniques to counter complacency." On question 26, 28, and 29; "approaching a waypoint, the direction of turn and the roll out heading should be reviewed…," "between waypoints, the aircraft position should be verified…," and "when visibility permits, the aircraft position should be verified…," respectively; the participants flying TAA more strongly agreed with the statements than those flying non-TAA. On question 31, "select the HDG and ALT

SEL/HLD (VNAV) modes of the autopilot as soon after takeoff as legally permissible…," the participants flying TAA agreed with the statement, while those flying non-TAA disagreed.

In the analyses of RNAV verses without RNAV, only automation attitude (questions 11, 12, and 15; automation trust (questions 18 and 19); and competency (questions 20, 21, 22, 23, and 24) showed significant differences (see Table 14). Questions 11 and 12, "obtaining and maintaining "stick and rudder skills" is paramount…" and "automation should be reduced "one-level" if the pilot is unsure…," respectively, showed less agreement with these statements by participants flying RNAV equipped airplanes than did those flying non-RNAV equipped airplanes. On question 15, "the status of the automation including the autopilot is an important consideration in the risk management (go-no go) decision" the participants flying RNAVs agreed more with the statement than did those flying without RNAVs. Participants flying RNAVs agreed with "I know how to update the navigation program…," question 18, while those flying non-RNAV equipped airplanes disagreed. On question 19, "I turn off the automation if the flight plan changes…," the participants flying RNAVs disagreed more strongly. Finally, the participants flying RNAVs agreed while those flying non-RNAV equipped airplanes disagreed with the automation competency statements. These questions are (a) question 20, "I know how to use all of the functions of the navigation…;" (b) question 21, "I am proficient using the basic functions…;" (c) question 22, "I am proficient using the advanced functions…;" (d) question 23, "I do not encounter 'automation surprise'…;" and (e) question 24, "I know effective techniques to counter complacency."

The analyses of the various age groups only showed significant difference in the automation attitude questions. The significant differences were on questions, 11, 13, and 15, (see Table 14). On question 11, "obtaining and maintaining 'stick and rudder skills' is paramount…," three age groups had significant differences (a) the participants 16 to 24 years old agreed with the statement while the 45 and older disagreed; (b) participants 25 to 34 agreed while participants 35 to 44 were neutral; and (c) participants 25 to 34 agreed while the 45 and older disagreed. On question 13, “automation should only be used during an extended enroute phase and during a precision instrument approach,” again three age groups had significant differences (a) the participants 16 to 24 years old agreed with the statement while the 35 to 44 year old group strongly disagreed; (b) participants 16 to 24 years old agreed with the statement while the 45 and older disagreed; and (c) participants 25 to 34 disagreed while participants 35 to 44 were neutral. On question 15, “the status of the automation including the autopilot is an important consideration in the risk management (go – no go) decision,” the participants 16 to 24 years old agreed with the statement while the 35 to 44 year old group strongly agreed.

Finally, Table 14 shows the significant differences of the various flight hour groups. The analyses showed four of the five areas had significant differences including attitude (questions 11, 13, and 14); trust (question 18); competency (questions 20, 21, 22, 23, and 24); and techniques (questions 28 and 29) (see Table 14) for the various flight hour groups. On question 11, “obtaining and maintaining ‘stick and rudder skills’ is paramount…,” four of the five of the groups with 0 to 1,500 flight hours agreed stronger with the statement than the participants with over 2,500 flight hours. On question 13, “automation should only be used during an extended enroute phase and during a precision instrument approach,” the 0 to 200-hour and the 200 to 500-hour groups agreed with the statement while the over 2,500-hour group disagreed. On question 14, “automation is not a good workload management tool…,” the 0 to 200-hour group disagreed with the statement while the 500 to 1,000-hour and the over 2,500-hour groups more strongly disagreed. On the automation trust question 18, “I know how to update the navigation program…,” the 0 to 200-hour group disagreed with the statement while the 200 to 500-hour, 500 to 1,000-hour, 1,000 to 1,500-hour, and the over 2,500-hour agreed. On question 20 (automation competency), “I know how to use all of the functions of the navigation and automation equipment…,” the 0 to 200-hour group disagreed with the statement while the 200 to 500-hour, 500 to 1,000-hour, and 1,000 to 1,500-hour groups agreed and the 500 to 1,000-hour agreed more strongly than the 200 to 500-hour group. On question 21, “I am proficient using the basic functions of the autopilot and navigation equipment,” again the 0 to 200-hour group disagreed while the remaining groups, except the 1,500 to 2,500-hour group, agreed. On question 22, “I am proficient using the advanced functions…,” the 0 to 200-hour group disagreed while the remaining groups, except the 1,500 to 2,500-hour group, agreed all so the 500 to 1,000-hour and 1,000 to 1,500-hour groups agreed more strongly than the 200 to 500-hour group. On question 23, “I do not encounter ‘automation surprise’…,” the 0 to 200-hour group disagreed while only the 200 to 500-hour, 500 to 1,000-hour, and 1,000 to 1,500-hour groups agreed; furthermore, the over 2,500-hour group agreed more strongly than the 1,000 to 1,500-hour group. On question 24, “I know effective techniques to counter complacency,” the 0 to 200-hour group disagreed with the statement while the other group, except the 1,500 to 2,500-hour group, agreed. Finally, on questions 28 and 29 (automation techniques), “between waypoints, the aircraft position should be verified…” and “when visibility permits, the aircraft position should be verified…,” the 200 to 500-hour group agreed more strongly with the statement than the 0 to 200 hour group.

The summary shows significant differences on 20 of the 23 questions asked in the data collection instrument (see Appendix A) resulting in 65 significant findings (see Table 14). Only automation trust, question 17, and appropriate level of automation, questions 32 and 33, showed no significant differences between groups on any of the analyses.

Next is a summary of the pilot performance statically significant data. Table 15 shows that the between groups mean altitude differences were significant on the Oneway ANOVA. It also shows there were significant mean differences between desired and actual altitude, heading, and indicated airspeed for the LSD Post Hoc Tests; that is, the average deviation was significant for several of the pilot performance measurements. These Post Hoc Tests showed significant mean differences were between groups 1 – 4 in altitude, heading, and indicated airspeed. The Post Hoc Tests also showed there were significant differences in the heading and indicated airspeed means deviation for groups 3 – 4.

Note:

Group 1 – autopilot on with flight plan loaded.
Group 2 – autopilot off with the flight plan loaded.
Group 3 – autopilot on with no flight plan loaded.
Group 4 – autopilot off with no flight plan loaded.

Table 15. Summary of Statically Significant Pilot Performance Data

	Alt Difference	HDG Difference	IAS Difference
Between Groups	*		
Groups 1 – 4	*	*	*
Groups 3 – 4	*	*	

Note. * Statistical significance is < .05.

The results and conclusions are presented in the next section. Limitations and recommendations will follow.

Conclusion

Sixty-four of the significant findings reported in the analysis of the data showed improvements in automation attitude, trust, competency, and techniques and appropriate level of automation when the use of automation is taught in pilot training. These are important findings because they indicate the cultural change needed to improve GA safety does occur when pilots receive automation training. There was one exception to this positive trend. That exception was in the comparison between glass verses non-glass equipped airplane for question 16 (automation trust) “I trust the automation will accurately and precisely control the airplane during all phases of flight; except takeoff, initial climb-out, short final, and landing.” This finding showed a stronger agreement with the statement for the non-glass group than the glass group. Unfortunately, whether the lower level of trust reported by the group with glass equipment was due to their lack of proficiency using glass, a belief that the glass does not provide the accuracy or precision the non-glass equipment provides, or some other reason is unknown. This question will need additional research to determine the cause and possible resolution of this trust issue.

A closer look at the 64 significant findings showed significant improvements in (a) automation attitude, trust, competency, and techniques, and the appropriate level of automation with FITS training; (b) automation attitude, trust, competency, and the appropriate level of automation with formal autopilot training; (c) automation attitude, trust, and the appropriate level of automation with the combined FITS and formal autopilot training; (d) automation attitude and techniques, and the appropriate level of automation with glass equipped airplanes; (e) automation attitude, trust, competency, and techniques, and the appropriate level of automation with moving map and autopilot equipped airplanes; (f) automation attitude, trust, and competency with RNAV equipped airplanes; (g) automation attitude for different age groups; and (h) automation attitude, trust, competency, and techniques for various flight hour groups. Collectively, these findings indicate that the pilot’s attitude about, trust of, and competency using the installed automation can be improved with training. The findings also indicate the type of available automation is important. Furthermore, pilots can be taught effective techniques and appropriate level of automation use. Training does have a positive effect on the participant’s attitude about the use of the automation. All of this is important because effective use of the automation is necessary in today’s airspace and will likely become required tomorrow. Earlier FITS studies concluded that effective use of the automation is important to general aviation safety due, in part, to the complexity of today's advanced avionics (Robertson, Petros, Schumacher, McHorse, Ulrich, 2006).

The study also shows that pilot performance is significantly improved when autopilot was used (group 1's heading, altitude, and indicated airspeed was significant better than group 4's control of these measurements). Furthermore, it was observed that the participants did not use the advanced avionics, accomplish the aircraft checklist, nor update the weather information as they proceeded to the final destination when the autopilot was not engaged.

This study confirms the suggestion made in the literature and in the earlier FITS studies that the workload changes with each level of automation. That is, the pilot spends less time manipulating the flight controls as the level of automation progresses from no automation to full automation, but spends more time manipulating the automation. For example, when the autopilot is off the pilot spends his or her time flying the aircraft and when the automation is at the full automation level, the pilot spends very little time manipulating the controls of the aircraft. However, the pilot must set up, select, and program the appropriate automation, including the autopilot. At the advanced automation level, the pilot must program the automation and select the appropriate modes and only needs to monitor the aircraft. This may be a shift in workload from controlling the aircraft to controlling the automation. In other words, the workload shifts from "Stick and rudder" manual flight to automation management. Ultimately, the workload typically decreases as the pilot moves toward the higher levels of automation, provided the pilot is proficient in using the automation.

Also, note that the pilot's dependency on proficiency shifts as the pilot progresses through the levels of automation. That is, when the autopilot is not used or not available, the pilot is completely dependent on “stick and rudder” and navigation skills. As the pilot increases the levels of automation, the pilot becomes less dependent on these manual skills and is more dependent on the automation. This does mean that the pilot is more dependent on automation proficiency. Another way to look at this is to consider the loss of pilot proficiency that normally occurs as the pilot flies less frequently. That is, as pilot proficiency decreases the pilot’s dependency on the automation increases, which increases the need for automation proficiency. Pilot proficiency is vitally important to aviation safety with or without automation; however, in the real world pilot proficiency varies from time to time; thus, it makes sense to provide the pilot with one more tool to ensure a safe flight.

Limitations

Note that 87% of the participants were between the ages of 16 to 24 year old and 86% had fewer than 500 total flight hours. Consequently, we should not assume the participants are representative of the general aviation pilot population; thus, we should be careful in attempting to generalize these findings. However, the number of significant findings suggests it is appropriate to adopt the following recommendations and we should do further research. Nevertheless, participant population does represent the general pilot population typically involved in pilot training. This is important because it could be the group where the cultural change can be made that will lead to improved GA safety.

Finally, the sample size in the pilot performance testing was small; however, significant differences were found. The differences were consistent with the findings in previous studies (FITS Effectiveness); therefore, this is an important study.

Recommendations and Best Practices

During the FITS effectiveness studies (Ayers, 2005 and Robertson, Petros, Schumacher, McHorse, & Ulrich, 2006), researchers observed that participants did not use the available automation. This led the researchers to ask the question “why not?” Attempting to answer this question led to this study and the search for best practices for automation use. Additionally, the literature on automation, including aviation automation and non-aviation automation situations, suggests knowledge, trust, comfort, bias, and choice govern the use of automation. The data collection instrument in Appendix A obtains data about automation attitude, trust, competency, techniques, and appropriate level of automation. Ultimately, we must address automation knowledge, trust, comfort, bias, and choice before automation will be able to use the automation effectively. Finally, once the pilot is ready to use the automation, how should it be use? That is, what is an effective way to use the automation? What is the appropriate level of automation? Are there different levels of appropriate use for different times during the flight? This study attempted to answer these questions.

Again, during the initial FITS effectiveness studies (Ayers, 2005 and Robertson, et al., 2006), it was assumed that the participants would use the autopilot to free up the pilot to access the information provided by the advanced automation. That is, we assumed given the opportunity and impetus to use the automation the pilots would use it. As mentioned above, the researchers observed that typically this did not occur, in fact, most participants avoided using the autopilot. When the participants were asked why they did not use the autopilot, the normal response was that they did not know they were allow to use it and/or they did really know how to use the autopilot. The prevailing attitude is to emphasize psychomotor skills in primary pilot training programs and leave the mastery of the autopilot to a trial and error learning while flying or to the airlines during the line-oriented flight training (LOFT). These observations led to the second training question, “have you received formal autopilot training?”

Include autopilot training in pilot training and emphasize autopilot training in FITS accepted training. Teach pilots how to be effective flight managers including how to use the autopilot to manage the pilot’s workload is one way to improve general aviation safety. Teach the pilot that the automation is a tool to improve the pilot’s management of the flight and safety of flight. The pilot must become proficient in using all available equipment installed on the airplane. Glass cockpits increase the complexity of the flight instrument and navigation equipment, thus increasing the need for information management. That is, so much information is available to the pilot, in an airplane equipped with a glass cockpit; he/she cannot display it all at the same time. Consequently, the pilot must choose what information to display and know where to find the other information. This, in turn, requires the pilot to navigate to the appropriate page to obtain the necessary/available information. To access the advanced avionics information, typically, the pilot typically should select an appropriate mode of the autopilot (to be able to free up conscious memory and maintain precise airplane control). Of course, using an appropriate mode of the autopilot is not limited to information management and can be effectively used throughout the flight to control the airplane more precisely.

Based on the results of this study, a panel of experts developed a list of best practices and answered the question about what should be taught. The panel included Certified Flight Instructors with total airplane flight hours ranging between less than 1,000 hours and more than 10,000 hours. The panel maintained that mastering physical flight skills should not be sacrificed during initial pilot training for automation competency but that pilots need competency in both physical flight (“stick and rudder”) and automation skills.

This study addresses best practices in a normal flight sequence. Accomplish automation management, like all other tasks the pilot must perform, when the workload permits. Consider a plan of action for the use of the automation, during the preflight planning phase. The plan of action should have the flight plan being loaded and stored in the MFD/GPS after engine start and before takeoff at the latest, and then the flight plan should be updated throughout the flight as changes occur and workload permits. If the workload does not permit immediate updating, then do it as soon as practical thereafter. The pilot should consider initiating a delay to permit updating the flight plan and automation settings if there is no foreseeable or timely opportunity. Such delays are avoidable when the pilot correctly pre-plans a workflow. Yes, this does sound like the workload management problem typically discussed in planning a cross-country or instrument flight.

The appropriate mode of the autopilot is often different under varying conditions and circumstances. That is, the appropriate mode of automation will be different for different conditions or under circumstances. Again, during the planning phase of flight, the pilot should determine, when to use and what level of automation to use. This consideration should include what waypoints to program into the Flight Plan including departure airport, departure procedure, enroute, arrival procedure, and destination airport. For example, for the enroute waypoints, enter the NAVAIDS defining the route of flight and intersections along the route of flight in the flight plan. Why? Because the GPS provides a Great Circle Route course and published routes use a rhumb line course (p. 3.28, Instrument Procedures Handbook, 2004). The difference between the two courses is inconsequential when the distance between the waypoints is short. This allows the GPS to be primary navigation along published routes. Furthermore, intersections provide convenient entry points along planned routes of flight, if needed. Further discussions are in the departure phase of flight.

The Flight Plan should be loaded whenever electrical power is available to the navigational equipment. Note; in most cases, the Active Flight Plan is deleted or dumped if the airplane electrical power is turned off or interrupted. Therefore, store the Flight Plan either after it is loaded or enter the Flight Plan after the last anticipated power interruption. Nevertheless, it is a best practice to store the Active Flight Plan after entering. It is also recommended that you should enter the Flight Plan before takeoff. Circumstances may make it desirable to modify this best practice; for example, the Air Traffic Control clearance to the destination along a different route than the one that was planned. When anticipating a different route, ATC advises the pilot to expect a change to the route of flight, reduce the Flight Plan to the departure airport, initial route of flight, and the destination airport only. This action clears the Flight Plan of all unwanted entries so that individual entries do not need to be deleted one at a time and all unintended entries have been removed. This approach is only usable when time allows the remaining route of flight to be entered in flight; such as, during legs that are long enough to complete all required/needed duties and still have time to enter the route; in other words, when the workload permits. Nevertheless, enter enough of the flight plan to allow easy navigation to the next enroute point, and then enter the remainder of flight plan when time permits. A word of caution, if the airplane reaches the last entry on the Flight Plan, the airplane will automatically proceed via a direct course to the destination. Reestablishing the appropriate/cleared route of flight involves several steps and concentration. This is poor or mismanagement of the automation; so, avoid this problem by entering the Flight Plan before takeoff.

Prior to takeoff, the initial heading, cleared altitude, and desired climb rate should be preset and/or the command bars should be set for takeoff. This provides the pilot with clues/reminders and it will allow the pilot the option to engage the autopilot as soon as possible after takeoff. It is desirable to have the autopilot fly the airplane in high traffic and high workload areas as much as possible so the pilot is free to clear for other traffic and attend to other duties. Often the takeoff clearance will include instruction to takeoff and maintain runway or a specified heading to a lower than planned altitude. In these cases, the airplane is hand flown through the takeoff to an altitude where it is safe to turn the autopilot on. A safe altitude for turning the autopilot on will be no lower than 400' AGL, airplane under control and in the proper attitude, and at or above the minimum altitude for autopilot engagement in a climb (this altitude is either published in the pilot operating handbook/airplane manual or double the published upset altitude for the specific autopilot). When the preset items are set, the airplane has reached a safe altitude, and the airplane is under control, the pilot can engage the autopilot heading, vertical speeds, and altitude select modes.

Now the appropriate mode will depend on departure and/or departure control. Enter and use new headings and altitudes until cleared to fly a navigated course or the departure procedure allows a navigation mode. Typically, you need to make heading changes to fly to an assigned course, to a transition fix, or to join the enroute course. The departure typically presents a navigation problem because you cannot accurately predict the actual ground track. Most GPS navigation systems provide a course from the center of the departure airport to a fix, waypoint, or transition fix. The takeoff normally takes the airplane away from the center of the airport; consequently, simply selecting the NAV (navigation) mode will cause the airplane to make a hard turn to intercept the active leg. The pilot must determine an appropriate mode after takeoff to the en-route course. For example, if the clearance is to join the planned/cleared route, the pilot either needs to (a) determine a desired intercept heading, set the heading bug, engage the HDG mode of the autopilot, and then arm the NAV mode or (b) select the appropriate waypoint, select Direct To, activate the leg, and then select the NAV mode. In the latter case, including intersections along the route of flight provides easy selection of the appropriate waypoint/fix to join the cleared route. In every case, the pilot must select the appropriate navigation source for the autopilot to follow. Selecting a navigation source is different for each avionics system. Finally, to use VOR navigation, the CDI must be set to the desired course before selecting the NAV mode. This step, setting the CDI to the desired course, is not required when using GPS navigation because the GPS will automatically set the course. Note you can turn off the GPS function that automatically sets the course, so ensure this function is set the way you want it to work.

Normally, during the enroute phase of flight, the NAV and ALT (altitude hold) modes are used. This may lead to complacency. Techniques for avoiding complacency include implementing a 5P check between waypoints and monitoring the RNAV (area navigation) system by cross checking the progress of the flight. The GPS is an RNAV system, so the pilot should monitor the flight's progress when using the GPS too. Several techniques can be used to monitor the airplane's position including (a) doing cross checks of the bearing and distance information provided by the navigation log and the avionics (Flight Plan) (b) at each waypoint or fix along the route of flight check that the bearing and distance information agree with the navigation log. Additionally, for legs that are 30-minutes or longer, do a mid-point accuracy check. An accuracy check is comparing the airplane's position as shown on a moving map or RNAV to the ground (visually) or a ground-based navigational aid, such as a VOR.

Typically, the pilot does not know which runway will be the active until he/she is close to the destination; therefore, the approach is not selected and loaded during the pre-takeoff phase of flight. Select and load the appropriate instrument approach during a period when the workload permits. Often this is after the weather at the airport of intended landing is checked but it should be before starting the descent checklist and descent.

The approach procedure should not be activated until cleared for the approach by ATC or when it is determined to be appropriate because activating the approach typically changes the active leg to a direct course to the selected IAF (initial approach fix). In other words, it sets the active flight plan to a direct course from the airplane's present position to the IAF and deletes all waypoints/fixes between the airplane's present position and the IAF. Consequently, the approach should not be activated until the pilot wants to proceed directly to the IAF or in the case where vectoring is to be provided, the approach can be activated as soon as vectoring begins and the HDG mode has been selected.

Next, we will address three additional situations. These situations are adding a departure, an arrival, and/or an instrument approach procedure to the flight plan. Typically, these procedures are appended to the of the Active Flight Plan like the instrument approach procedure and may not automatically provide the correct sequence of waypoint for the intended or desired route of flight. That is, normally you should enter the flight plan by entering the departure airport first followed by the route of flight to the destination airport. Adding a departure, arrival, or instrument approach later, appends the procedure to the end of the Active Flight Plan. That is, added after the destination airport identifier. This often changes your route of flight. The departure procedure should follow the departure airport and take the airplane to a transition fix where the enroute portion begins. Clear the intervening waypoints if they exist or select and activate the appropriate leg. Similarly, clear or skip intervening waypoints when entering an arrival or an instrument approach procedure. For the instrument approach, do this by activating the approach. Remember that the Active Flight Plan changes to "Direct To" routing when activated and skips all intervening waypoints. The Garmin 430 does not provide an "Activate" the Arrival Procedure option. In this case, the pilot must manually activate the appropriate leg or clear the intervening waypoint in the Flight Plan.

The appropriate level of automation for these three situations will depend on the how much time the pilot has to program and activate these procedures. For example, if ATC issues a change to the clearance that requires a turn away from the entered flight plan course, the HDG mode will most likely be need to be selected with the heading bug being set for a turn in the proper direction and then refined as the correct heading is determined, this assumes insufficient time is available to select and activate the procedure before the turn is needed. Once the procedure is loaded and activated, you can reset the autopilot to the NAV or APP mode as desired. Remember to check the flight plan page (FLP) to ensure that the proper leg is active and the proper waypoints are in the flight plan.

In summary, best practices for cross-country and instrument flights include planning to use the automation. Using the automation effectively involves planning a workload flow for using the automation, planning a route of flight with adequate waypoint to accomplish the desired route, load and save the flight plan, engage the autopilot when able and it is safe to do so, use full automation when possible. When there is insufficient time to program the automation, use lower levels of automation, such as HDG and ALT mode or autopilot off, and return to the highest level of automation practical when it is safe.

The recommendation to use the automation should not be taken to mean that the pilot can allow his/her “stick and rudder” skills to diminish. Pilots must determine how to maintain their pilot proficiency and how to effectively control of the airplane on each flight. The pilot’s proficiency in controlling the airplane by hand and his proficiency using the automation are important considerations in the “go no-go” decision. The pilot should always be mindful that the automation may fail and the pilot will be very dependent on his/her pilot skills. The automation should be an additional tool available to enhance aviation safety not a substitution for pilot skills.

Many safety initiatives have recognized that situational awareness and a good decision process are necessary to prevent accidents. FITS has suggested that the mental skills supporting the decision process must also be enhanced (Robertson, Petros, Schumacher, McHorse, Ulrich, 2006). That is, pilots need better thinking skills. Advanced automation can provide the pilot with better and more current information but the pilot must be able to access and process this information. This leads to shifting the pilot's role from its psychomotor skills focus to becoming a flight manager. The flight manager is a pilot that masters his/her piloting and management skills. The effective flight manager is the pilot that relegated the routine manual manipulation of the airplane to the autopilot so the pilot can constantly assess the flight situation, access and gather the appropriate information, and make better decisions. Unfortunately, the old system was not working as, 80% of the general aviation accidents were due to pilot error or had a pilot error-contributing factor. Effective use of the automation and better thinking skills are part of the solution (p. 8-14, Aviation Instructor's Handbook, 2008). This study used the term pilot error because it more clearly identifies the underlying problem than the currently accepted term human factor. Arguable, human factors more accurately identifies that it is not a single bad decision but rather a series of errors that lead to an accident. Nevertheless, effective flight management allows the pilot the opportunity to assess, detect, and correct the error chain; thus, preventing the accident.

Appendix A

FITS Automation Data Collection Instrument

Questions 1 through 33 must be answered to complete the questionnaire.

Demographic Data - is needed to determine if there are age, experience, etc. differences in attitude, trust, and competency.

1. Sex:	Male	Female				
2. Age:	16-24	25-34	35-44	45-60	Over 60	
3. Current flying experience (hours):	0 to 200	200 to 500	500 to 1000	1000 to 1500	1500 to 2500	over 2500
4. Certificates held:	Prvt	Comm	CFI	ATP	CFI/ATP	
5. Primary type of flying:	Personal	Corp/Bus	Comm	Airline		
6. One or more of the aircraft I fly is equipped with at lease a moving map and an autopilot:	Yes	No				
7. Have you received FITS accepted training (Yes, No, IP[in progress], or NS [not sure or do not know]):	Yes	No	IP	NS		
8. I have received formal training in the use of the automation including the autopilot in one or more aircraft:	Yes	No				

9. Is one or more of the aircraft you fly equipped with a PFD, MFD, or Both (No, PFD, MFD, Both, or NS [not sure or do not know]):	No	PFD	MFD	Both	NS

10. Is one or more of the aircraft you fly equipped with an autopilot and an RNAV (Yes, No, or NS [not sure or do not know]):	Yes	No	NS

Automation Attitude - indicate your level of agreement with the following statements regarding your attitude about aircraft automation including the autopilot.	N/A	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
11. Obtaining and maintaining "stick and rudder skills" is paramount, automated flight (using the autopilot) should not be attempted until the pilot's stick and rudder skills are competent and proficient.						
12. Automation should be reduced "one-level" if the pilot is unsure about what the automation is doing. (click here for an explanation of "one-level" of automation)						
13. Automation should only be used during an extended en-route phase and during a precision instrument approach.						
14. Automation is not a good workload management tool because it increases the mental workload imposed on the pilot during critical phases of flight.						
15. The status of the automation including the autopilot is an important consideration in the risk management (go – no go) decision.						

Automation Trust – indicate your level of agreement with the following statements regarding your trust in aircraft automation.	N/A	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
16. I trust the automation will accurately and precisely control the airplane during all phases of flight; except takeoff, initial climb-out, short final, and landing.						

17. I feel the automation including the autopilot can be like having another pilot in the aircraft.	○	○	○	○	○	○
18. I know how to update the navigation program (flight plan) to comply with ATC instruction, in-flight situations, and other desired changes to the route of flight.	○	○	○	○	○	○
19. I turn off the automation if the flight plan changes in-flight rather than reprogramming the RNAV/GPS.	○	○	○	○	○	○

Automation Competency – indicate your level of agreement with the following statements regarding your competency in using the installed aircraft automation.	N/A	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
20. I know how to use all of the functions of the navigation and automation equipment installed in the airplane I fly.	○	○	○	○	○	○
21. I am proficient using the basic functions of the autopilot and navigation equipment.	○	○	○	○	○	○
22. I am proficient using the advanced functions of the autopilot and navigation equipment.	○	○	○	○	○	○
23. I do not encounter "automation surprise" when I am using the automation.	○	○	○	○	○	○
24. I know effective techniques to counter complacency.	○	○	○	○	○	○

Automation Techniques – indicate your level of agreement with the following statements regarding your use of these techniques.	N/A	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
25. Before activating a GPS/RNAV flight plan, the flight plan information should be compared to the NAV log and discrepancies are resolved.	○	○	○	○	○	○
26. Approaching a waypoint, the direction of turn and the roll out heading should be reviewed to monitor the automated tracking.	○	○	○	○	○	○
27. At the waypoint, the course, distance, and time to the next waypoint should be cross-checked against the NAV log.	○	○	○	○	○	○
28. Between waypoints, the aircraft position should be verified by checking the distance and radial from an off-track NAV aid.	○	○	○	○	○	○
29. When visibility permits, the aircraft position should be verified by checking the visual	○	○	○	○	○	○

position against the moving map position.

Appropriate Levels of Automation – indicate your level of agreement with the following statements regarding the appropriate level of aircraft automation.	N/A	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
30. The HDG and ALT modes of the autopilot should not be selected until established on a programmed leg of the flight.	○	○	○	○	○	○
31. Select the HDG and ALT SEL/HLD (VNA) modes of the autopilot as soon after takeoff as legally permissible and then selecting the NAV/GPSS mode as soon as course guidance is available.	○	○	○	○	○	○
32. User defined waypoint should be programmed so the NAV/GPSS and ALT SEL/HLD (VNAV) modes can be used during all phases of flight from initial climb to the DH or MDA.	○	○	○	○	○	○
33. The autopilot and command bars should be turned off for all traffic pattern and visual work.	○	○	○	○	○	○

The following space is for additional comments, please provide any additional information you feel will help us improve aircraft automation/autopilot training. Note: additional comments are not necessary to complete the questionnaire.

Skip this section

Please describe the type of aircraft automation/autopilot training you have received.

Describe your attitude about the use of aircraft automation/autopilot.

Describe your level of trust in aircraft automation/autopilot.

Describe your competency in using aircraft automation/autopilot.

Describe what you feel is the appropriate use of aircraft automation/autopilot.

List three techniques you would recommend to combat automation-induced complacency.

Thank you for your participation.

Submit

Appendix B

Analysis of FITS Verses Non-FITS

Tables 16 through 25 show the results of analyses of each question asked on the data collection instrument. The questions are divided into five groups of related questions. These groups are automation attitude, trust, competency, and techniques, and appropriate level of automation. Two tables provide the results of each group of questions. The participant group statistics including the group size and mean are presented before the associated independent samples test (t-test). The mean scores of the groups (FITS verses Non-FITS trained) are in the group statistics table while results of the test of significant differences between the groups are in the independent samples test table.

Table 16 shows the group statistics for FITS verses Non-FITS trained participants for the five automation attitude questions (see the questions in Appendix A).

Table 16. FITS Verses Non-FITS Group Statistics for Automation Attitude Variables

	FITS Training	N	Mean	Std. Deviation	Std. Error Mean
Attitude 11	Yes	44	4.20	1.193	.180
	No	60	4.53	.812	.105
Attitude 12	Yes	44	3.80	1.047	.158
	No	60	4.03	.956	.123
Attitude 13	Yes	44	2.77	1.179	.178
	No	60	3.37	1.235	.159
Attitude 14	Yes	44	2.09	.960	.145
	No	59	2.24	.897	.117
Attitude 15	Yes	44	3.61	1.039	.157
	No	60	3.57	1.198	.155

Table 17 shows the independent samples test for FITS verses Non-FITS trained participants for the automation attitude group of questions. Question 11 shows a significant finding (Sig = .017) on the Levene's test for equality of variances. This means we must use the equal variances not assumed results for the t-test. In this case, t = -1.580, df = 71.228, Sig. (2-tailed) = .098, etc. must be used and there is no significant difference between the mean scores of the FITS/Non-FITS groups (FITS mean score = 4.20 and Non-FITS = 4.53 (see Table 16)). Question 13, on the other hand, shows that there is a significant difference (t = -2.470, df = 102, Sig (2-tailed) = .015 (see Table 14)) between the mean scores for the FITS and Non-FITS groups (mean = 2.77/3.37 (see Table 16)). Question 13 (see Appendix A), asks for the participant agreement or disagreement with the statement "Automation should only be used during an extended en-route phase and during a precision instrument approach." There were significant differences in the mean scores of the participant's responses; that is, the FITS trained participants disagreed with the statement while the Non-FITS participants agreed with the statement. None of the other automation attitude questions showed significant differences between the group means.

Table 17. Independent Samples of FITS verses Non-FITS for Automation Attitude Variables

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Attitude 11	Equal variances assumed	5.868	.017	-1.672	102	.098	-.329	.197	-.719	.061
	Equal variances not assumed			-1.580	71.228	.119	-.329	.208	-.744	.086
Attitude 12	Equal variances assumed	.820	.367	-1.204	102	.231	-.238	.198	-.630	.154
	Equal variances not assumed			-1.187	87.741	.238	-.238	.200	-.636	.160
Attitude 13	Equal variances assumed	.396	.531	-2.470	102	.015	-.594	.240	-1.071	-.117
	Equal variances not assumed			-2.488	95.147	.015	-.594	.239	-1.068	-.120
Attitude 14	Equal variances assumed	.008	.931	-.795	101	.429	-.146	.184	-.512	.219
	Equal variances not assumed			-.787	89.192	.433	-.146	.186	-.516	.223
Attitude 15	Equal variances assumed	.306	.582	.209	102	.835	.047	.225	-.399	.493
	Equal variances not assumed			.213	99.087	.832	.047	.220	-.390	.484

Note. Statistical significance is < .05.

Table 18 shows the group statistics for the participants that received FITS (Yes) verses those that did not receive FITS training (No) for the four automation trust questions. The question number and training group are in the first column; n (group size) is in the second column, group mean in the third column, standard deviation in the fourth column, and standard error of mean in the last column.

Table 18. FITS Verses No FITS Group Statistics for Automation Trust Variables

	FITS Training	N	Mean	Std. Deviation	Std. Error Mean
Trust 16	Yes	44	3.84	1.055	.159
	No	60	3.73	1.006	.130
Trust 17	Yes	44	3.32	1.157	.174
	No	60	3.33	1.188	.153
Trust 18	Yes	44	4.16	1.033	.156
	No	60	3.52	1.372	.177
Trust 19	Yes	44	2.05	1.140	.172
	No	60	2.25	1.480	.191

Table 19. Independent Samples of FITS verses Non-FITS for Automation Trust Variables

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Trust 16	Equal variances assumed	.085	.771	.528	102	.599	.108	.204	-.297	.512
	Equal variances not assumed			.524	90.221	.602	.108	.205	-.300	.516
Trust 17	Equal variances assumed	.131	.718	-.065	102	.948	-.015	.233	-.478	.448
	Equal variances not assumed			-.065	94.196	.948	-.015	.232	-.476	.446
Trust 18	Equal variances assumed	3.365	.069	2.610	102	.010	.642	.246	.154	1.131
	Equal variances not assumed			2.724	101.911	.008	.642	.236	.175	1.110
Trust 19	Equal variances assumed	7.810	.006	-.765	102	.446	-.205	.267	-.735	.326
	Equal variances not assumed			-.796	101.723	.428	-.205	.257	-.714	.305

Note. Statistical significance is < .05.

Table 19 shows the independent samples test for FITS verses Non-FITS training for the automation trust questions. Again, this table only shows one question (Trust 18) has a significant difference between the means on the t-test for equality of means. In this case, the Levene's test for equality of variances is not significant; therefore, assume and use equal variances. The automation trust, question number 18, shows the means (FITS = 4.16, Non-FITS = 3.52 (see Table 19)) and the t-test results (t = 2.610, DF = 102, Sig (2-tailed) = .010 (see Table 19)) indicating a significantly stronger agreement with the statement for the FITS trained participants.

Table 20. FITS Verses No FITS Group Statistics for Automation Competency Variables

	FITS Training	N	Mean	Std. Deviation	Std. Error Mean
Competency 20	Yes	44	3.98	1.000	.151
	No	60	3.08	1.225	.158
Competency 21	Yes	44	4.41	.923	.139
	No	57	3.23	1.669	.221
Competency 22	Yes	44	3.89	1.146	.173
	No	60	2.60	1.498	.193
Competency 23	Yes	44	3.16	1.684	.254
	No	60	2.88	1.508	.195
Competency 24	Yes	43	3.93	1.009	.154
	No	60	3.27	1.205	.156

Table 20 shows the group statistics for FITS verses Non-FITS training for the five automation competency questions. Table 21 shows that four of the five automation competency questions (questions 20, 21, 22, and 24) had statistically significant differences between the FITS and Non-FITS trained groups (Sig (2-tailed) = .000, .000, .000. and .004, respectively).

The Levene's test for equality of variances is significant for question 21 and 22 (Sig = .000 and .012, respectively); thus, equal variances cannot be assumed (see Table 21). Therefore, the equal variances not assumed results for questions 21 and 22 are used (t = 4.521, df = 90.632, Sig (2-tailed) = .000 and t = 4.961, df = 101.796, Sig (2-tailed) = .000, respectively). All five questions show a stronger agreement with the statement (FITS/Non-FITS means = 3.98/3.08, 4.41/3.23, 3.89/2.60, 3.16/2.88, and 3.93/3.27, respectively). However, the difference in means between groups was not significant for question 23. Therefore, we will not consider the findings on automation competency (question 23) further.

Table 21. Independent Samples of FITS verses Non-FITS for Automation Competency

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Competency 20	Equal variances assumed	1.963	.164	3.966	102	.000	.894	.225	.447	1.341
	Equal variances not assumed			4.091	100.783	.000	.894	.218	.460	1.327
Competency 21	Equal variances assumed	20.204	.000	4.219	99	.000	1.181	.280	.626	1.737
	Equal variances not assumed			4.521	90.632	.000	1.181	.261	.662	1.700
Competency 22	Equal variances assumed	6.587	.012	4.763	102	.000	1.286	.270	.751	1.822
	Equal variances not assumed			4.961	101.796	.000	1.286	.259	.772	1.801
Competency 23	Equal variances assumed	2.248	.137	.877	102	.383	.276	.314	-.348	.900
	Equal variances not assumed			.862	86.630	.391	.276	.320	-.360	.912
Competency 24	Equal variances assumed	1.719	.193	2.944	101	.004	.664	.225	.216	1.111
	Equal variances not assumed			3.032	98.490	.003	.664	.219	.229	1.098

Note. Statistical significance is < .05.

Table 22. FITS Verses No FITS Group Statistics for Automation Techniques Variables

	FITS Training	N	Mean	Std. Deviation	Std. Error Mean
Techniques 25	Yes	44	4.16	.834	.126
	No	59	4.02	1.008	.131
Techniques 26	Yes	44	4.30	.701	.106
	No	59	4.19	.798	.104
Techniques 27	Yes	44	4.32	.674	.102
	No	59	4.10	.959	.125
Techniques 28	Yes	44	4.05	.939	.142
	No	59	3.59	1.036	.135
Techniques 29	Yes	44	4.30	.765	.115
	No	59	3.92	.934	.122

Table 22 shows the group statistics for FITS verses Non-FITS training for the five automation techniques questions. Table 23 shows the t-test results (independent sample) for the FITS/Non-FITS automation techniques questions and shows questions 28 and 29 had significant differences (Sig (2-tailed) = .025 and .030, respectively (see Table 23)). The means were 4.05/3.59 and 4.30/3.92, respectively (see Table 22). Table 23 also shows the automation techniques questions 28 and 29 had significant differences (Sig (2-tailed) = .025 and .030, respectively) with mean equal to 4.05/3.59 and 4.30/3.92, respectively (see Table 22).

Table 23. Independent Samples of FITS verses Non-FITS for Automation Techniques

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Techniques 25	Equal variances assumed	.154	.696	.761	101	.449	.142	.187	-.229	.513
	Equal variances not assumed			.782	99.876	.436	.142	.182	-.218	.503
Techniques 26	Equal variances assumed	.563	.455	.722	101	.472	.109	.151	-.191	.409
	Equal variances not assumed			.735	98.230	.464	.109	.148	-.185	.403
Techniques 27	Equal variances assumed	.029	.865	1.279	101	.204	.216	.169	-.119	.552
	Equal variances not assumed			1.344	100.691	.182	.216	.161	-.103	.536
Techniques 28	Equal variances assumed	2.460	.120	2.280	101	.025	.452	.198	.059	.846
	Equal variances not assumed			2.313	97.149	.023	.452	.196	.064	.840
Techniques 29	Equal variances assumed	.081	.777	2.204	101	.030	.380	.172	.038	.722
	Equal variances not assumed			2.269	100.062	.025	.380	.168	.048	.713

Note. Statistical significance is < .05.

Table 24 shows the group statistics for FITS verses No FITS training for the four appropriate level of automation. Table 25 shows one significant result, question 30, for the FITS verses Non-FITS trained pilots (Sig (2-tailed) = .004). Table 24 shows the mean = 2.55/3.24 for

FITS/Non-FITS, respectively.

Table 24. FITS Verses No FITS Group Statistics for Level of Automation Variables

	FITS Training	N	Mean	Std. Deviation	Std. Error Mean
Level 30	Yes	44	2.55	1.266	.191
	No	59	3.24	1.119	.146
Level 31	Yes	44	3.18	1.317	.198
	No	59	3.17	1.147	.149
Level 32	Yes	44	3.11	1.224	.185
	No	59	3.31	1.149	.150
Level 33	Yes	42	3.45	1.131	.174
	No	58	3.72	1.089	.143

Table 25. Independent Samples of FITS verses Non-FITS for Level of Automation

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Level 30	Equal variances assumed	1.170	.282	-2.933	101	.004	-.692	.236	-1.160	-.224
	Equal variances not assumed			-2.881	86.072	.005	-.692	.240	-1.169	-.214
Level 31	Equal variances assumed	.513	.476	.051	101	.960	.012	.243	-.471	.495
	Equal variances not assumed			.050	85.210	.961	.012	.248	-.482	.506
Level 32	Equal variances assumed	.142	.707	-.814	101	.418	-.191	.235	-.658	.275
	Equal variances not assumed			-.806	89.421	.422	-.191	.238	-.663	.280
Level 33	Equal variances assumed	.317	.575	-1.212	98	.228	-.272	.224	-.717	.173
	Equal variances not assumed			-1.205	86.507	.232	-.272	.226	-.720	.177

Note. Statistical significance is < .05.

Appendix C

Analysis of Formal Autopilot Training

The results of the analysis of the pilot receiving and not receiving formal autopilot training are in this appendix. Group statistics and independent samples test (t-test) for each of the questions follows. The presentation of the results will follow the format used in Appendix B; that is, the t-test analysis will follow the group statistics and includes tables 26 through 37.

Table 26 shows the group statistics for formal autopilot trained verses no formal autopilot training for the five automation attitude questions. Table 27 shows the results of the independent sample (t-test) analysis of the formal autopilot training for automation attitude variables. One question showed a significant difference in the group mean, question 15. The Levene's test for equality of variances was significant (Sig = .000); consequently, the equal variance cannot be assumed and the not equal significance must be used. These results showed t = 2.106, df = 127.910, and Sig (2-tailed) = .037, with the mean = 3.62/3.24 for the autopilot trained verses no autopilot training, respectively.

Table 26. Group Statistics for Automation Attitude in Formal Autopilot Trained

	A/P Training	N	Mean	Std. Deviation	Std. Error Mean
Attitude 11	Yes	87	4.47	.900	.097
	No	80	4.21	1.240	.139
Attitude 12	Yes	87	4.01	.883	.095
	No	80	3.80	1.152	.129
Attitude 13	Yes	87	2.94	1.195	.128
	No	80	3.19	1.323	.148
Attitude 14	Yes	86	2.21	.959	.103
	No	70	2.37	1.119	.134
Attitude 15	Yes	87	3.62	.852	.091
	No	80	3.24	1.407	.157

Table 27. Independent Samples Test of Automation Attitude in Formal Autopilot Training

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Attitude 11	Equal variances assumed	3.636	.058	1.552	165	.122	.259	.167	-.070	.588
	Equal variances not assumed			1.532	143.246	.128	.259	.169	-.075	.593
Attitude 12	Equal variances assumed	4.479	.036	1.338	165	.183	.211	.158	-.101	.524
	Equal variances not assumed			1.324	147.768	.188	.211	.160	-.104	.527
Attitude 13	Equal variances assumed	1.057	.305	-1.258	165	.210	-.245	.195	-.630	.140
	Equal variances not assumed			-1.252	159.518	.212	-.245	.196	-.631	.141
Attitude 14	Equal variances assumed	3.880	.051	-.974	154	.331	-.162	.166	-.491	.167
	Equal variances not assumed			-.959	136.603	.339	-.162	.169	-.496	.172
Attitude 15	Equal variances assumed	20.689	.000	2.147	165	.033	.383	.178	.031	.736
	Equal variances not assumed			2.106	127.910	.037	.383	.182	.023	.743

Note. Statistical significance is < .05.

Two of the four automation trust questions showed significant differences (see Tables 25 and 26). Table 28 shows the group statistics for the automation trust questions and Table 29 shows the results of the independent samples t-test for automation trust and questions 17 and 18 showed significant differences between the group means.

Table 28. Group Statistics for the Automation Trust in Autopilot Training

	A/P Training	N	Mean	Std. Deviation	Std. Error Mean
Trust 16	Yes	87	3.70	.929	.100
	No	80	3.35	1.510	.169
Trust 17	Yes	87	3.55	.997	.107
	No	80	3.26	1.338	.150
Trust 18	Yes	87	4.10	.915	.098
	No	80	2.56	1.834	.205
Trust 19	Yes	87	2.33	1.128	.121
	No	80	1.71	1.685	.188

Table 29 also shows significant on the Levene's test for equality of variances for all four questions (Sig = .000, .015, .000, and .000, respectively); however, only questions 18 and 19 show a significant mean difference in the t-test results (Sig (2-tailed) = .000 and .005, respectively). Thus, worthy of further consideration. Since Levene's test is significance, the equal variances not assumed results must be used for question 18 and 19 (t = 6.779, 113.859, Sig (2-tailed) = .000 and t = 2.773, 136.216, Sig (2-tailed) = .006, respectively (see Table 29)).

Table 29. Independent Samples Test for Automation Trust in Formal Autopilot Training

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Trust 16	Equal variances assumed	23.661	.000	1.826	165	.070	.351	.192	-.029	.731
	Equal variances not assumed			1.791	129.175	.076	.351	.196	-.037	.739
Trust 17	Equal variances assumed	5.995	.015	1.592	165	.113	.289	.182	-.070	.648
	Equal variances not assumed			1.573	145.435	.118	.289	.184	-.074	.653
Trust 18	Equal variances assumed	69.198	.000	6.953	165	.000	1.541	.222	1.103	1.979
	Equal variances not assumed			6.779	113.859	.000	1.541	.227	1.091	1.991
Trust 19	Equal variances assumed	40.497	.000	2.818	165	.005	.621	.220	.186	1.056
	Equal variances not assumed			2.773	136.216	.006	.621	.224	.178	1.064

Note. Statistical significance is < .05.

The results of the analysis of the automation competency for formal autopilot training verses no formal autopilot training are in Tables 30 and 31. The results of all five of automation competency questions are significant (Sig (2-tailed) = .000) (see Table 31). The mean scores are shown in Table 32 (mean = 3.78/2.24, 4.22/2.20, 3.67/1.80, 3.48/1.75, and 3.90/2.16, respectively).

Table 30. Group Statistics for Automation Competency for Formal Autopilot Training

	A/P Training	N	Mean	Std. Deviation	Std. Error Mean
Competency 20	1	87	3.78	.933	.100
	2	80	2.24	1.701	.190
Competency 21	1	87	4.22	.945	.101
	2	76	2.20	1.898	.218
Competency 22	1	87	3.67	1.031	.110
	2	79	1.80	1.659	.187
Competency 23	1	86	3.48	1.114	.120
	2	80	1.75	1.775	.198
Competency 24	1	86	3.90	.783	.084
	2	80	2.16	1.732	.194

Table 31. Independent Samples Test of Automation Competency in Formal Autopilot Training

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Competency 20	Equal variances assumed	39.860	.000	7.352	165	.000	1.544	.210	1.129	1.959
	Equal variances not assumed			7.187	120.308	.000	1.544	.215	1.119	1.969
Competency 21	Equal variances assumed	85.772	.000	8.769	161	.000	2.021	.230	1.566	2.476
	Equal variances not assumed			8.418	106.674	.000	2.021	.240	1.545	2.497
Competency 22	Equal variances assumed	29.373	.000	8.804	164	.000	1.869	.212	1.450	2.288
	Equal variances not assumed			8.617	127.970	.000	1.869	.217	1.440	2.298
Competency 23	Equal variances assumed	70.791	.000	7.562	164	.000	1.727	.228	1.276	2.178
	Equal variances not assumed			7.443	131.107	.000	1.727	.232	1.268	2.186
Competency 24	Equal variances assumed	94.102	.000	8.405	164	.000	1.733	.206	1.326	2.140
	Equal variances not assumed			8.205	108.240	.000	1.733	.211	1.314	2.151

Note. Statistical significance is < .05.

Table 31 shows Levene's tests were significances for all five questions as well. Thus, we must use the equal variances not assumed results. These results are t = 7.187, df = 120.308, Sig (2-tailed) = .000; t = 8.418, df = 106.674, Sig (2-tailed) = .000; t = 8.617, df = 127.970, Sig (2-

tailed) = .000; t = 7.443, df = 131.107, Sig (2-tailed) = .000; and t = 8.205, df = 108.240, Sig (2-tailed) = .000; respectively (see Table 31).

Table 32 shows the group statistics for the automation techniques with formal autopilot training verses no formal autopilot training. Table 33 shows the t-test results for these questions had significant differences on questions 26, 28, and 29. The mean scores for question 26, 28, and 29 are 4.30/3.96, 4.02/3.53, and 4.16/3.80, respectively (see Table 32).

Table 32. Group Statistics for Automation Techniques in Formal Autopilot Training

	A/P Training	N	Mean	Std. Deviation	Std. Error Mean
Techniques 25	1	86	4.16	.733	.079
	2	80	3.93	1.290	.144
Techniques 26	1	86	4.30	.533	.057
	2	80	3.96	1.247	.139
Techniques 27	1	86	4.23	.697	.075
	2	80	4.06	1.246	.139
Techniques 28	1	86	4.02	.782	.084
	2	80	3.53	1.211	.135
Techniques 29	1	86	4.16	.717	.077
	2	80	3.80	1.130	.126

Table 33 also shows the results of the Levene's and the independent samples tests. For the three questions with significant t-test results, Leven's test showed significances on questions 26 and 28. Consequently, we must use the equal variances not assumed results for these two questions while we will use the equal variances assumed results on question 29. The independent samples test of automation techniques for formal autopilot training results are t= 2.253, df = 105.290, and Sig (2-tailed) = .026; t = 3.123, df = 133.449, Sig (2-tailed) = .002; and t = 2.488, df = 164, and Sig (2-tailed) = .014; respectively (see Table 33).

Table 33. Independent Samples Test of Automation Techniques for Formal Autopilot Training

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Techniques 25	Equal variances assumed	6.884	.010	1.472	164	.143	.238	.161	-.081	.557
	Equal variances not assumed			1.445	123.266	.151	.238	.165	-.088	.563
Techniques 26	Equal variances assumed	7.075	.009	2.311	164	.022	.340	.147	.049	.630
	Equal variances not assumed			2.253	105.290	.026	.340	.151	.041	.639
Techniques 27	Equal variances assumed	4.207	.042	1.095	164	.275	.170	.155	-.137	.477
	Equal variances not assumed			1.074	122.110	.285	.170	.158	-.143	.483
Techniques 28	Equal variances assumed	17.973	.000	3.170	164	.002	.498	.157	.188	.809
	Equal variances not assumed			3.123	133.449	.002	.498	.160	.183	.814
Techniques 29	Equal variances assumed	3.841	.052	2.488	164	.014	.363	.146	.075	.651
	Equal variances not assumed			2.450	132.095	.016	.363	.148	.070	.656

Note. Statistical significance is < .05.

Table 34. Group Statistics for Level of Automation in Formal Autopilot Training

	A/P Training	N	Mean	Std. Deviation	Std. Error Mean
Level 30	1	86	2.65	1.060	.114
	2	80	2.91	1.434	.160
Level 31	1	86	3.23	.978	.105
	2	80	2.79	1.548	.173
Level 32	1	86	3.30	1.096	.118
	2	80	3.00	1.378	.154
Level 33	1	84	3.51	1.012	.110
	2	79	3.38	1.333	.150

Tables 32 and 33 complete the formal verses no formal autopilot training analysis. Table 34 shows the mean scores for the two training groups. Table 35 shows that only questions 30, 31, and 33 had significant results and Table 34 shows the mean scores for the questions are 2.65/2.91, 3.23/2.79, and 3.51/3.38 (respectively).

Table 35 also shows Levene's test were significant for questions 30, 31, and 33; therefore, the equal variances assumed results are used sig. = 0.046, 0.000, and 0.040 (respectively) (see Table 35).

Table 35. Independent Samples Test of Level of Automation for Formal Autopilot Training

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Level 30	Equal variances assumed	4.052	.046	-1.342	164	.182	-.261	.195	-.646	.123
	Equal variances not assumed			-1.327	144.950	.186	-.261	.197	-.650	.128
Level 31	Equal variances assumed	14.081	.000	2.230	164	.027	.445	.200	.051	.839
	Equal variances not assumed			2.195	131.691	.030	.445	.203	.044	.846
Level 32	Equal variances assumed	.099	.753	1.570	164	.118	.302	.193	-.078	.683
	Equal variances not assumed			1.557	150.816	.122	.302	.194	-.081	.686
Level 33	Equal variances assumed	4.268	.040	.716	161	.475	.132	.185	-.233	.497
	Equal variances not assumed			.710	145.336	.479	.132	.186	-.236	.500

Note. Statistical significance is < .05.

Appendix D

Analysis of Combined Training

This appendix shows the findings of analysis of the combined effects of the FITS and formal autopilot training. The findings are shown in Tables 36 through 41 beginning with the descriptive data followed by an analysis of variances (ANOVA) on each of the five groups of questions (automation attitude, trust, competency, and techniques, and appropriate level of automation).

To examine the combined effects of the FITS and formal autopilot training, the participant responses for the FITS and formal autopilot training questions became four new groups. These groups were (a) Group 1– participants that received FITS and formal autopilot training, (b) Group 2 – participants that received FITS but no formal autopilot training, (c) Group 3 – participants that received formal autopilot and no FITS training, and (d) Group 4 – participants that did not receive either type of training.

Table 36 shows the descriptive data for the automation attitude questions for the combined training events and Table 37 shows question 13 has a significant between group difference (F = 3.108, Sig = .030). A Post Hoc LSD test showed which of the four groups had significant between group differences. For question 13, the significant between group difference was between Groups 1 and 4 (mean = 2.66/3.55, Sig = .003).

Table 36. Descriptive Data for Automation Attitude in Training

						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Attitude 13	1	35	2.66	1.162	.196	2.26	3.06	1	5
	2	9	3.22	1.202	.401	2.30	4.15	2	5
	3	30	3.20	1.270	.232	2.73	3.67	1	5
	4	31	3.55	1.179	.212	3.12	3.98	0	5
	Total	105	3.12	1.238	.121	2.88	3.36	0	5

Table 37. ANOVA of Automation Attitude for Combined Training Events

		Sum of Squares	df	Mean Square	*F*	Sig.
Attitude 11	Between Groups	6.151	3	2.050	2.112	.103
	Within Groups	98.991	102	.970		
	Total	105.142	105			
Attitude 12	Between Groups	3.981	3	1.327	1.346	.264
	Within Groups	100.557	102	.986		
	Total	104.538	105			
Attitude 13	Between Groups	13.472	3	4.491	3.108	.030
	Within Groups	145.919	101	1.445		
	Total	159.390	104			
Attitude 14	Between Groups	3.725	3	1.242	1.437	.237
	Within Groups	86.428	100	.864		
	Total	90.154	103			
Attitude 15	Between Groups	1.004	3	.335	.259	.855
	Within Groups	130.558	101	1.293		
	Total	131.562	104			

Note. Statistical significance is < .05.

None of the other automation attitude questions showed any significant between group differences; therefore, they will not be considered further in the combined training events analysis.

Tables 38 and 39 show the descriptive data and ANOVA results for the automation trust questions. Question 18 shows significant between group difference (F = 0.404, Sig = .001, see Table 39). The Post Hoc LSD test shows Groups 1 - 2, 1 - 3, and 1 - 4 (Sig = .004, .021, and .000, respectively) (mean = 4.43/3.11, 4.43/3.73, and 4.43/3.26, respectively (see Table 38).

Table 38. Descriptive Data for Automation Trust in Combined Training Events

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Trust 18	1	35	4.43	.608	.103	4.22	4.64	3	5
	2	9	3.11	1.616	.539	1.87	4.35	0	5
	3	30	3.73	1.258	.230	3.26	4.20	0	5
	4	31	3.26	1.460	.262	2.72	3.79	0	5
	Total	105	3.77	1.280	.125	3.52	4.02	0	5

Table 39. ANOVA on Automation Trust for Combined Training Events

		Sum of Squares	Df	Mean Square	*F*	Sig.
Trust 16	Between Groups	3.566	3	1.189	1.144	.335
	Within Groups	104.948	101	1.039		
	Total	108.514	104			
Trust 17	Between Groups	9.949	3	3.316	2.556	.059
	Within Groups	131.041	101	1.297		
	Total	140.990	104			
Trust 18	Between Groups	27.252	3	9.084	6.404	.001
	Within Groups	143.262	101	1.418		
	Total	170.514	104			
Trust 19	Between Groups	4.146	3	1.382	.764	.517
	Within Groups	182.768	101	1.810		
	Total	186.914	104			

Note. Statistical significance is < .05.

Tables 40, 41, and 42 show the results of the descriptive data, ANOVA, and Post Hoc LSD analyses of the automation competency questions for the combined training events. All four questions show significant between group differences on the ANOVA (F = 10.047 and Sig = .000, F = 11.137 and Sig = .000, F = 15.839 and Sig = .000, F = 6.104 and Sig = .001, and F = 7.833 and Sig = .000, respectively) (see Table 41). The Post Hoc LSD analysis, Table 42, shows the between group differences were Groups 1-2 (mean = 4.20/3.11 and Sig = .008), Groups 1-3 (mean = 4.20/3.11 and Sig = .004), and Groups 1-4 (mean = 4.20/2.77 and Sig = .000) for question 20 while the mean scores are shown in Table 40. For question 21, the between group differences (see Table 42) were Groups 1-3 (mean = 4.57/3.77 and Sig = .016), Groups 1-4 (mean = 4.57/2.64 and Sig = .000), and Groups 2-4 (mean = 3.78/2.64 and Sig = .027). The between group differences for question 22 were Groups 1-2 (mean = 4.17/2.78 and Sig = .004), Groups 1-3 (mean = 4.17/3.13 and Sig = .001), Groups 1-4 (mean = 4.17/2.06 and Sig = .000), and Groups 3-4 (mean = 3.13/2.06 and Sig = .001). For question 23, Groups 1-2 (mean = 3.57/1.56 and Sig = .000), Groups 1-4 (mean = 3.57/2.52 and Sig = .004), Groups 2-3 (mean = 1.56/3.27 and Sig = .003), and Groups 3-4 (mean = 3.27/2.52 and Sig = .049) had significant

Table 40. Descriptive Data of Automation Competency for Combined Training Events

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Competency 20	1	35	4.20	.759	.128	3.94	4.46	2	5
	2	9	3.11	1.364	.455	2.06	4.16	1	5
	3	30	3.40	.968	.177	3.04	3.76	0	5
	4	31	2.77	1.359	.244	2.28	3.27	0	5
	Total	105	3.46	1.209	.118	3.22	3.69	0	5
Competency 21	1	35	4.57	.502	.085	4.40	4.74	4	5
	2	9	3.78	1.716	.572	2.46	5.10	0	5
	3	30	3.77	1.331	.243	3.27	4.26	0	5
	4	28	2.64	1.789	.338	1.95	3.34	0	5
	Total	102	3.74	1.502	.149	3.44	4.03	0	5
Competency 22	1	35	4.17	.822	.139	3.89	4.45	2	5
	2	9	2.78	1.563	.521	1.58	3.98	0	5
	3	30	3.13	1.167	.213	2.70	3.57	0	5
	4	31	2.06	1.590	.286	1.48	2.65	0	4
	Total	105	3.13	1.494	.146	2.84	3.42	0	5
Competency 23	1	35	3.57	1.290	.218	3.13	4.01	0	5
	2	9	1.56	2.128	.709	-.08	3.19	0	5
	3	30	3.27	1.143	.209	2.84	3.69	0	5
	4	31	2.52	1.710	.307	1.89	3.14	0	5
	Total	105	3.00	1.575	.154	2.70	3.30	0	5
Competency 24	1	34	4.12	.946	.162	3.79	4.45	0	5
	2	9	3.22	.972	.324	2.48	3.97	2	5
	3	30	3.67	.661	.121	3.42	3.91	2	5
	4	31	2.87	1.455	.261	2.34	3.40	0	4
	Total	104	3.54	1.165	.114	3.31	3.77	0	5

between group differences. The between group differences for question 24 were Group 1-2 (mean = 4.12/3.22 and Sig = .027), Groups 1-4 mean = 4.12/2.87 and Sig = .000), and Groups 3-4 mean = 3.67/2.87 and Sig =.004).

Table 41. ANOVA on Automation Competency in Combined Training Events

		Sum of Squares	df	Mean Square	*F*	Sig.
Competency 20	Between Groups	34.949	3	11.650	10.047	.000
	Within Groups	117.108	101	1.159		
	Total	152.057	104			
Competency 21	Between Groups	57.931	3	19.310	11.137	.000
	Within Groups	169.922	98	1.734		
	Total	227.853	101			
Competency 22	Between Groups	74.269	3	24.756	15.839	.000
	Within Groups	157.865	101	1.563		
	Total	232.133	104			
Competency 23	Between Groups	39.598	3	13.199	6.104	.001
	Within Groups	218.402	101	2.162		
	Total	258.000	104			
Competency 24	Between Groups	26.611	3	8.870	7.833	.000
	Within Groups	113.236	100	1.132		
	Total	139.846	103			

Note. Statistical significance is < .05.

Table 42. Post Hoc Analysis of the Automation Competency for Combined Training Events

LSD			Mean Difference	Std. Error	Sig.	95% Confidence Interval	
						Upper Bound	Lower Bound
Competency 20	1	2	1.089(*)	.402	.008	.29	1.89
		3	.800(*)	.268	.004	.27	1.33
		4	1.426(*)	.266	.000	.90	1.95
	2	1	-1.089(*)	.402	.008	-1.89	-.29
		3	-.289	.409	.482	-1.10	.52
		4	.337	.408	.411	-.47	1.15
	3	1	-.800(*)	.268	.004	-1.33	-.27
		2	.289	.409	.482	-.52	1.10
		4	.626(*)	.276	.025	.08	1.17
	4	1	-1.426(*)	.266	.000	-1.95	-.90
		2	-.337	.408	.411	-1.15	.47
		3	-.626(*)	.276	.025	-1.17	-.08
Competency 21	1	2	.794	.492	.110	-.18	1.77
		3	.805(*)	.328	.016	.15	1.45
		4	1.929(*)	.334	.000	1.27	2.59
	2	1	-.794	.492	.110	-1.77	.18
		3	.011	.500	.982	-.98	1.00
		4	1.135(*)	.505	.027	.13	2.14
	3	1	-.805(*)	.328	.016	-1.45	-.15
		2	-.011	.500	.982	-1.00	.98
		4	1.124(*)	.346	.002	.44	1.81
	4	1	-1.929(*)	.334	.000	-2.59	-1.27
		2	-1.135(*)	.505	.027	-2.14	-.13
		3	-1.124(*)	.346	.002	-1.81	-.44

LSD			Mean Difference	Std. Error	Sig.	95% Confidence Interval Upper Bound	Lower Bound
Competency 22	1	2	1.394(*)	.467	.004	.47	2.32
		3	1.038(*)	.311	.001	.42	1.66
		4	2.107(*)	.308	.000	1.50	2.72
	2	1	-1.394(*)	.467	.004	-2.32	-.47
		3	-.356	.475	.456	-1.30	.59
		4	.713	.473	.135	-.23	1.65
	3	1	-1.038(*)	.311	.001	-1.66	-.42
		2	.356	.475	.456	-.59	1.30
		4	1.069(*)	.320	.001	.43	1.70
	4	1	-2.107(*)	.308	.000	-2.72	-1.50
		2	-.713	.473	.135	-1.65	.23
		3	-1.069(*)	.320	.001	-1.70	-.43
Competency 23	1	2	2.016(*)	.550	.000	.93	3.11
		3	.305	.366	.407	-.42	1.03
		4	1.055(*)	.363	.004	.34	1.77
	2	1	-2.016(*)	.550	.000	-3.11	-.93
		3	-1.711(*)	.559	.003	-2.82	-.60
		4	-.961	.557	.088	-2.07	.14
	3	1	-.305	.366	.407	-1.03	.42
		2	1.711(*)	.559	.003	.60	2.82
		4	.751(*)	.377	.049	.00	1.50
	4	1	-1.055(*)	.363	.004	-1.77	-.34
		2	.961	.557	.088	-.14	2.07
		3	-.751(*)	.377	.049	-1.50	.00
Competency 24	1	2	.895(*)	.399	.027	.10	1.69
		3	.451	.267	.094	-.08	.98
		4	1.247(*)	.264	.000	.72	1.77
	2	1	-.895(*)	.399	.027	-1.69	-.10
		3	-.444	.404	.274	-1.25	.36
		4	.351	.403	.385	-.45	1.15
	3	1	-.451	.267	.094	-.98	.08
		2	.444	.404	.274	-.36	1.25
		4	.796(*)	.273	.004	.26	1.34
	4	1	-1.247(*)	.264	.000	-1.77	-.72
		2	-.351	.403	.385	-1.15	.45
		3	-.796(*)	.273	.004	-1.34	-.26

Note. * The mean difference is significant at the .05 level.

Next, the automation techniques questions for the combined training events were analyzed; however, none of the questions had significant between group differences. Therefore, this analysis is not included in this study.

Tables 43 and 44 show the results of the analysis of the appropriate level of automation questions for the combined training events. Question 30 shows a significant difference between groups on the ANOVA (*F* = 4.615 and Sig = .005). Table 43 shows the mean scores and the Post Hoc LSD analysis shows significant differences between Group 1-3 and 1-4 (mean = 2.40/3.00, Sig = .042; and mean = 2.40/3.45, Sig = .000; respectively).

Table 43. Descriptive Data for Level of Automation for the Combined Training Events

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Level 30	1	35	2.40	1.143	.193	2.01	2.79	0	5
	2	9	3.11	1.616	.539	1.87	4.35	0	5
	3	29	3.00	1.069	.199	2.59	3.41	0	5
	4	31	3.45	1.121	.201	3.04	3.86	0	5
	Total	104	2.94	1.221	.120	2.70	3.18	0	5

Table 44. ANOVA on Level of Automation for Combined Training Events

		Sum of Squares	df	Mean Square	F	Sig.
Level 30	Between Groups	18.688	3	6.229	4.615	.005
	Within Groups	134.966	100	1.350		
	Total	153.654	103			
Level 31	Between Groups	4.490	3	1.497	1.022	.386
	Within Groups	146.395	100	1.464		
	Total	150.885	103			
Level 32	Between Groups	.888	3	.296	.210	.889
	Within Groups	141.026	100	1.410		
	Total	141.913	103			
Level 33	Between Groups	9.252	3	3.084	2.649	.053
	Within Groups	112.907	97	1.164		
	Total	122.158	100			

Note. Statistical significance is < .05.

Appendix E

Glass Verses Non-Glass Analysis

Appendix E shows the findings of analysis of the "glass" verses non-glass airplane cockpit. "Glass" in this study was defined as having a primary flight display (PFD), multifunctional display (MFD), or both. The findings are shown in Tables 45 through 54 beginning with the group statistics being presented first and followed by the independent samples test (t-test) on each of the five groups of questions (automation attitude, trust, competency, and techniques, and appropriate level of automation).

Table 45 shows the group statistics for the automation attitude questions with glass verses non-glass equipped airplanes. The independent samples findings follow in Table 46. Again, question 13 shows a significant between group difference (Sig = .007) (see Table 45) and Table 45 shows the mean scores 3.56/2.89 for the non-glass verses glass, respectively.

No other questions showed significant between group differences in the automation attitude group of questions. Therefore, we will not consider these questions further.

Table 45. Group Statistics for Automation Attitude with Glass

	Glass - Non-glass	N	Mean	Std. Deviation	Std. Error Mean
Attitude 11	1	33	4.55	.938	.163
	2	110	4.50	.886	.084
Attitude 12	1	33	3.97	1.104	.192
	2	110	4.00	.846	.081
Attitude 13	1	33	3.55	1.371	.239
	2	110	2.89	1.144	.109
Attitude 14	1	33	2.42	.902	.157
	2	99	2.11	.946	.095
Attitude 15	1	33	3.67	1.164	.203
	2	110	3.40	1.110	.106

Table 46. Independent Samples for Automation Attitude with Glass

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Attitude 11	Equal variances assumed	.223	.637	.255	141	.799	.045	.178	-.307	.398
	Equal variances not assumed			.247	50.331	.806	.045	.184	-.324	.415
Attitude 12	Equal variances assumed	1.564	.213	-.168	141	.867	-.030	.181	-.388	.327
	Equal variances not assumed			-.145	43.876	.885	-.030	.208	-.450	.390
Attitude 13	Equal variances assumed	3.235	.074	2.749	141	.007	.655	.238	.184	1.125
	Equal variances not assumed			2.494	46.169	.016	.655	.262	.126	1.183
Attitude 14	Equal variances assumed	.113	.737	1.665	130	.098	.313	.188	-.059	.685
	Equal variances not assumed			1.705	57.251	.094	.313	.184	-.055	.681
Attitude 15	Equal variances assumed	.000	.990	1.197	141	.233	.267	.223	-.174	.707
	Equal variances not assumed			1.167	50.758	.249	.267	.229	-.192	.726

Note. Statistical significance is < .05.

Tables 47 and 48 shows the findings for the automation trust group of questions in the analysis of the airplanes equipped with glass and those not equipped with glass flight instruments. Only question 16 showed a significant difference between the groups in the automation trust group. Question 16 was significant (T = 2.112, df = 57.471, and Sig = .039)

Table 47. Group Statistics for Automation Trust with Glass

	Glass - Non-glass	N	Mean	Std. Deviation	Std. Error Mean
Trust 16	1	33	3.91	1.100	.192
	2	110	3.44	1.216	.116
Trust 17	1	33	3.55	1.252	.218
	2	110	3.43	1.088	.104
Trust 18	1	33	3.09	1.487	.259
	2	110	3.63	1.561	.149
Trust 19	1	33	2.39	1.638	.285
	2	110	1.91	1.358	.130

(see Table 48) with non-glass/glass mean = 3.91/3.44 (see Table 47). The equal variances not assumed data was used because Levene's test was significant (Sig = .050) (see Table 48).

Table 48. Independent Samples for Automation Trust with Glass

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Trust 16	Equal variances assumed	3.902	.050	2.001	141	.047	.473	.236	.006	.940
	Equal variances not assumed			2.112	57.471	.039	.473	.224	.025	.921
Trust 17	Equal variances assumed	1.383	.242	.528	141	.598	.118	.224	-.324	.560
	Equal variances not assumed			.490	47.407	.627	.118	.241	-.367	.604
Trust 18	Equal variances assumed	.186	.667	-1.749	141	.082	-.536	.307	-1.142	.070
	Equal variances not assumed			-1.797	54.915	.078	-.536	.299	-1.135	.062
Trust 19	Equal variances assumed	2.524	.114	1.712	141	.089	.485	.283	-.075	1.045
	Equal variances not assumed			1.548	45.986	.128	.485	.313	-.146	1.115

Note. Statistical significance is < .05.

Table 49 and 50 show the findings for the automation competency questions for the glass verses non-glass equipped airplanes. None of the five measurements of automation competency were significant; therefore, these findings will not be considered further.

Table 49. Group Statistics Automation Competency with Glass

	Glass - Non-glass	N	Mean	Std. Deviation	Std. Error Mean
Competency 20	1	33	3.12	1.409	.245
	2	110	3.27	1.508	.144
Competency 21	1	29	3.21	1.497	.278
	2	110	3.58	1.768	.169
Competency 22	1	33	2.73	1.567	.273
	2	110	3.00	1.653	.158
Competency 23	1	33	2.52	1.642	.286
	2	109	2.82	1.728	.165
Competency 24	1	33	3.12	1.495	.260
	2	109	3.25	1.522	.146

Table 50. Independent Samples for Automation Competency with Glass

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Competency 20	Equal variances assumed	1.727	.191	-.514	141	.608	-.152	.295	-.735	.432
	Equal variances not assumed			-.533	55.836	.596	-.152	.284	-.721	.418
Competency 21	Equal variances assumed	.709	.401	-1.047	137	.297	-.375	.358	-1.083	.333
	Equal variances not assumed			-1.153	50.620	.254	-.375	.325	-1.028	.278
Competency 22	Equal variances assumed	.082	.775	-.841	141	.402	-.273	.324	-.914	.368
	Equal variances not assumed			-.866	55.151	.390	-.273	.315	-.904	.359
Competency 23	Equal variances assumed	.054	.816	-.888	140	.376	-.301	.339	-.972	.370
	Equal variances not assumed			-.913	55.215	.365	-.301	.330	-.963	.360
Competency 24	Equal variances assumed	.033	.857	-.420	140	.675	-.126	.301	-.722	.469
	Equal variances not assumed			-.424	53.681	.673	-.126	.298	-.725	.472

Note. Statistical significance is < .05.

The findings for the automation techniques for glass are in Tables 51 and 52. Three of these findings are significant including questions 25, 26, and 27 (T = -2.749, df = 140, and

Table 51. Group Statistics for Automation Techniques with Glass

	Glass - Non-glass	N	Mean	Std. Deviation	Std. Error Mean
Techniques 25	1	32	3.75	1.136	.201
	2	110	4.25	.840	.080
Techniques 26	1	32	3.84	1.110	.196
	2	110	4.38	.649	.062
Techniques 27	1	32	4.03	.967	.171
	2	110	4.36	.726	.069
Techniques 28	1	32	3.72	.991	.175
	2	110	3.88	.955	.091
Techniques 29	1	32	3.94	.914	.162
	2	110	4.16	.761	.073

Sig = .007; T = -3.455, df = 140, and Sig = .001; and T = -2.106, df = 140, and Sig = .037; respectively (see Table 52). The mean scores for these groups (non-glass/glass) are 3.75/4.25, 3.84/4.38, and 4.03/4.36, respectively (see Table 51).

Table 52. Independent Samples for Automaton Techniques with Glass

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Techniques 25	Equal variances assumed	.010	.920	-2.749	140	.007	-.505	.184	-.867	-.142
	Equal variances not assumed			-2.334	41.345	.025	-.505	.216	-.941	-.068
Techniques 26	Equal variances assumed	.052	.820	-3.455	140	.001	-.538	.156	-.846	-.230
	Equal variances not assumed			-2.614	37.371	.013	-.538	.206	-.955	-.121
Techniques 27	Equal variances assumed	.301	.584	-2.106	140	.037	-.332	.158	-.644	-.020
	Equal variances not assumed			-1.803	41.689	.079	-.332	.184	-.705	.040
Techniques 28	Equal variances assumed	.044	.834	-.843	140	.401	-.163	.193	-.546	.219
	Equal variances not assumed			-.826	48.990	.413	-.163	.198	-.560	.234
Techniques 29	Equal variances assumed	.502	.480	-1.413	140	.160	-.226	.160	-.543	.090
	Equal variances not assumed			-1.277	44.249	.208	-.226	.177	-.583	.131

Note. Statistical significance is < .05.

Table 53 and 54 show one of the level of automation questions with and without glass was significant, question 30 (T = 2.690, df = 140, and Sig = .008) (see Table 54). Table 53 shows the group means (non-glass/glass) for this question is 3.31/270. No other questions were significant; thus, we will not consider them further.

Table 53. Group Statistics for Level of Automation with Glass

	Glass - Non-glass	N	Mean	Std. Deviation	Std. Error Mean
Level 30	1	32	3.31	1.148	.203
	2	110	2.70	1.130	.108
Level 31	1	32	3.22	1.237	.219
	2	110	3.05	1.187	.113
Level 32	1	32	3.31	1.120	.198
	2	110	3.25	1.119	.107
Level 33	1	32	3.78	1.099	.194
	2	108	3.44	1.061	.102

Table 54. Independent Samples for Level of Automation with Glass

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Level 30	Equal variances assumed	.036	.850	2.690	140	.008	.613	.228	.162	1.063
	Equal variances not assumed			2.665	49.791	.010	.613	.230	.151	1.074
Level 31	Equal variances assumed	.024	.878	.682	140	.496	.164	.241	-.312	.640
	Equal variances not assumed			.667	48.834	.508	.164	.246	-.331	.659
Level 32	Equal variances assumed	.025	.876	.298	140	.766	.067	.225	-.377	.511
	Equal variances not assumed			.298	50.398	.767	.067	.225	-.385	.519
Level 33	Equal variances assumed	.272	.603	1.607	138	.110	.346	.215	-.080	.772
	Equal variances not assumed			1.576	49.396	.121	.346	.220	-.095	.787

Note. Statistical significance is < .05.

Appendix F

Autopilot and Moving Map Analysis

Appendix F shows the significant findings for the autopilot and moving map equipped airplane. Again, the tables show the analyses by the five groups of questions as shown in Appendix E. The tables showing the automation attitude questions will be presented first followed by the each of the remaining groups of questions.

Tables 55 and 56 show the findings for the automation attitude questions had significant between group differences for the autopilot and moving map equipped verses airplanes not equipped with an autopilot and a moving map. Table 56 shows none of the automation attitude questions for autopilot and moving map equipped airplanes had any significant differences. However, note that questions 13 and 14 do appear to show significant differences until the Levene's test is considered. In both cases, the Levene's test is significant (Sig = .013 and .007, respectively) (see Table 56). This means that the equal variances not assumed line must be used and neither is significant (Sig = .055 and .052, respectively) (see Table 56). Therefore, we will not consider these questions for autopilot and moving map further.

Table 55. Group Statistics for Automation Attitude with Autopilot and Moving Map

	Moving Map	N	Mean	Std. Deviation	Std. Error Mean
Attitude 11	1	100	4.46	.989	.099
	2	65	4.18	1.211	.150
Attitude 12	1	99	3.96	.936	.094
	2	66	3.83	1.158	.143
Attitude 13	1	99	2.89	1.142	.115
	2	66	3.29	1.390	.171
Attitude 14	1	98	2.14	.942	.095
	2	56	2.50	1.160	.155
Attitude 15	1	99	3.57	.928	.093
	2	66	3.24	1.447	.178

Table 56. Independent Sample for Automation Attitude with Autopilot and Moving Map

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Attitude 11	Equal variances assumed	1.365	.244	1.598	163	.112	.275	.172	-.065	.616
	Equal variances not assumed			1.532	117.310	.128	.275	.180	-.081	.631
Attitude 12	Equal variances assumed	3.533	.062	.771	163	.442	.126	.164	-.197	.450
	Equal variances not assumed			.739	118.970	.461	.126	.171	-.212	.464
Attitude 13	Equal variances assumed	6.272	.013	-2.014	163	.046	-.399	.198	-.790	-.008
	Equal variances not assumed			-1.937	120.490	.055	-.399	.206	-.807	.009
Attitude 14	Equal variances assumed	7.451	.007	-2.078	152	.039	-.357	.172	-.697	-.018
	Equal variances not assumed			-1.964	96.463	.052	-.357	.182	-.718	.004
Attitude 15	Equal variances assumed	20.749	.000	1.749	163	.082	.323	.185	-.042	.688
	Equal variances not assumed			1.608	100.485	.111	.323	.201	-.076	.722

Note. Statistical significance is < .05.

Table 57 and 58 show the findings for the automation trust questions with autopilot and moving maps. Questions 16, 18, and 19 show significant differences (t = 2.449, df = 98.359, and Sig (2-tailed) = .016; t = 5.342, df = 99.017, and Sig (2-tailed) = .000; and t = 2.482, df = 1113.416, and Sig (2-tailed) = .015; respectively) (see Table 58). Note that the equal variances not assumed was used because Levene's test was significant on all three questions (Sig = .000, .000, and .000, respectively) (see Table 58). The mean scores for the three questions were 3.74/3.21, 3.91/2.54, and 2.26/1.67, respectively (see Table 57).

Table 57. Group Statistics for Automation Trust with Autopilot and Moving Map

	Moving Map	N	Mean	Std. Deviation	Std. Error Mean
Trust 16	1	99	3.74	.965	.097
	2	66	3.21	1.554	.191
Trust 17	1	99	3.42	1.126	.113
	2	66	3.36	1.260	.155
Trust 18	1	99	3.91	1.170	.118
	2	66	2.53	1.866	.230
Trust 19	1	99	2.26	1.258	.126
	2	66	1.67	1.658	.204

Table 58. Independent Sample for Automation Attitude with Autopilot and Moving Map

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Trust 16	Equal variances assumed	31.001	.000	2.679	163	.008	.525	.196	.138	.912
	Equal variances not assumed			2.449	98.359	.016	.525	.214	.100	.951
Trust 17	Equal variances assumed	.456	.501	.323	163	.747	.061	.188	-.310	.431
	Equal variances not assumed			.316	128.418	.753	.061	.192	-.319	.441
Trust 18	Equal variances assumed	38.159	.000	5.833	163	.000	1.379	.236	.912	1.846
	Equal variances not assumed			5.342	99.017	.000	1.379	.258	.867	1.891
Trust 19	Equal variances assumed	26.125	.000	2.621	163	.010	.596	.227	.147	1.045
	Equal variances not assumed			2.482	113.416	.015	.596	.240	.120	1.072

Note. Statistical significance is < .05.

Tables 59 and 60 show the findings for the automation competency questions for the autopilot and moving map. Table 60 show all five automation competency questions were significant (t = 5.465, df = 100.753, and Sig (2-tailed) = .000; t = 7.908, df = 90.688, and Sig (2-tailed) = .000; t = 6.935, df = 109.296, and Sig (2-tailed) = .000; t = 5.054, df = 115.436, and Sig (2-tailed) = .000; and t = 5.370, df = 97.802, and Sig (2-tailed) = .000; respectively). Again, the Levene's tests were significant for all five questions (Sig = .000, .000, .000, .000, and .000,

Table 59. Group Statistics for Automation Competency with Autopilot and Moving Map

	Moving Map	N	Mean	Std. Deviation	Std. Error Mean
Competency 20	1	99	3.59	1.125	.113
	2	66	2.26	1.748	.215
Competency 21	1	99	4.08	1.131	.114
	2	63	2.00	1.884	.237
Competency 22	1	99	3.42	1.246	.125
	2	65	1.74	1.680	.208
Competency 23	1	98	3.19	1.397	.141
	2	66	1.86	1.805	.222
Competency 24	1	98	3.61	1.109	.112
	2	66	2.27	1.811	.223

Table 60. Independent Sample for Automation Competency with Autopilot and Moving Map

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Competency 20	Equal variances assumed	25.839	.000	5.941	163	.000	1.328	.224	.887	1.770
	Equal variances not assumed			5.465	100.753	.000	1.328	.243	.846	1.810
Competency 21	Equal variances assumed	45.071	.000	8.788	160	.000	2.081	.237	1.613	2.548
	Equal variances not assumed			7.908	90.688	.000	2.081	.263	1.558	2.604
Competency 22	Equal variances assumed	17.805	.000	7.368	162	.000	1.686	.229	1.234	2.138
	Equal variances not assumed			6.935	109.296	.000	1.686	.243	1.204	2.168
Competency 23	Equal variances assumed	25.213	.000	5.309	162	.000	1.330	.251	.835	1.825
	Equal variances not assumed			5.054	115.436	.000	1.330	.263	.809	1.852
Competency 24	Equal variances assumed	48.866	.000	5.873	162	.000	1.340	.228	.889	1.790
	Equal variances not assumed			5.370	97.802	.000	1.340	.249	.845	1.835

Note. Statistical significance is < .05.

respectively) so the equal variances not assumed values were used. The mean scores for the automation competency questions were 3.59/2.26, 4.08/2.00, 3.42/1.74, 3.19/1.86, and3.61/2.27, respectively (see Table 59).

Table 61. Group Statistics for Automation Techniques with Autopilot and Moving Map

	Moving Map	N	Mean	Std. Deviation	Std. Error Mean
Techniques 25	1	98	4.17	.838	.085
	2	66	3.92	1.194	.147
Techniques 26	1	98	4.29	.703	.071
	2	66	3.98	1.130	.139
Techniques 27	1	98	4.24	.826	.083
	2	66	4.03	1.215	.150
Techniques 28	1	98	3.98	.963	.097
	2	66	3.48	1.099	.135
Techniques 29	1	98	4.14	.862	.087
	2	66	3.76	1.053	.130

Tables 61 and 62 show the findings for automation techniques with autopilot and moving map and three of the questions 26, 28, and 29 show significant differences. Table 61 shows the mean scores for these questions (mean = 4.29/3.98, 3.98/3.48, and 4.14/3.76, respectively). Table 62 shows the significant differences for these questions ($t = 2.101$, $df = 162$, Sig (2-tailed) = .037; $t = 3.047$, $df = 162$, Sig (2-tailed) = .003; and $t = 2.565$, $df = 162$, Sig (2-tailed) = .011; respectively).

Table 62. Independent Sample for Automation Techniques with Autopilot and Moving Map

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Techniques 25	Equal variances assumed	3.297	.071	1.572	162	.118	.249	.159	-.064	.562
	Equal variances not assumed			1.470	107.343	.145	.249	.170	-.087	.585
Techniques 26	Equal variances assumed	1.593	.209	2.101	162	.037	.301	.143	.018	.584
	Equal variances not assumed			1.926	98.850	.057	.301	.156	-.009	.611
Techniques 27	Equal variances assumed	.740	.391	1.347	162	.180	.215	.159	-.100	.529
	Equal variances not assumed			1.253	104.921	.213	.215	.171	-.125	.554
Techniques 28	Equal variances assumed	3.367	.068	3.047	162	.003	.495	.162	.174	.815
	Equal variances not assumed			2.970	126.887	.004	.495	.167	.165	.824
Techniques 29	Equal variances assumed	.555	.457	2.565	162	.011	.385	.150	.089	.682
	Equal variances not assumed			2.467	120.388	.015	.385	.156	.076	.694

Note. Statistical significance is < .05.

Table 63. Group Statistics for Level of Automation with Autopilot and Moving Map

	Moving Map	N	Mean	Std. Deviation	Std. Error Mean
Level 30	1	98	2.71	1.131	.114
	2	66	2.88	1.441	.177
Level 31	1	98	3.22	1.031	.104
	2	66	2.73	1.594	.196
Level 32	1	98	3.29	1.121	.113
	2	66	2.95	1.408	.173
Level 33	1	96	3.41	1.101	.112
	2	65	3.51	1.301	.161

Table 64. Independent Sample for Level of Automation with Autopilot and Moving Map

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Level 30	Equal variances assumed	2.568	.111	-.817	162	.415	-.165	.201	-.562	.233
	Equal variances not assumed			-.780	116.618	.437	-.165	.211	-.582	.253
Level 31	Equal variances assumed	14.014	.000	2.427	162	.016	.497	.205	.093	.902
	Equal variances not assumed			2.239	101.391	.027	.497	.222	.057	.938
Level 32	Equal variances assumed	.174	.677	1.671	162	.097	.331	.198	-.060	.722
	Equal variances not assumed			1.599	117.977	.112	.331	.207	-.079	.741
Level 33	Equal variances assumed	.981	.323	-.533	159	.595	-.101	.190	-.477	.275
	Equal variances not assumed			-.516	121.853	.607	-.101	.197	-.491	.288

Note. Statistical significance is < .05.

Tables 63 and 64 show the findings for the level of automation questions with autopilot and moving map verses airplanes not equipped with autopilot and moving map. Question 31 is the only question that shows a significant between group difference for level of automation ($t = 2.239$, $df = 101.391$, Sig (2-tailed) = .027) (see Table 64). Table 63 shows the mean scores for question 31 is 3.22/2.73. The equal variances not assumed values are use since Levene's test is significant (Sig = .000) (see Table 64).

Appendix G

Area Navigation (RNAV) Analysis

This appendix presents the analysis of the data collection instrument questions related to airplanes equipped with RNAV verses without RNAV equipment. Again, the tables show the analyses by the five groups of questions as shown in Appendix E. The tables showing the automation attitude questions are first and followed by the each of the remaining groups of questions.

Tables 65 and 66 show the findings for the automation attitude questions had significant between group differences for the RNAV equipped verses airplanes not equipped with an RNAV. Table 65 shows the mean scores for the participants with RNAV equipment, RNAV 1, and those without RNAVs, RNAV 2. The results for questions 11, 12, and 15 are significant t = -2.148, df = 83.161, Sig (2-tailed) = .035; t = -2.242, df = 114, Sig (2-tailed) = .027; and t = 2.436, df = 113.880, Sig (2-tailed) = .016; respectively (see Table 66). Note that the Levene's test for equality of variances is significant (Sig = .007 and .011), so the variances not assumed

Table 65. Group Statistics for Automation Attitude with RNAV

	RNAV	N	Mean	Std. Deviation	Std. Error Mean
Attitude 11	1	54	4.30	1.143	.156
	2	62	4.68	.672	.085
Attitude 12	1	54	3.89	1.058	.144
	2	62	4.26	.700	.089
Attitude 13	1	54	2.93	1.179	.160
	2	62	3.10	1.264	.160
Attitude 14	1	54	2.19	1.011	.138
	2	52	2.37	1.067	.148
Attitude 15	1	54	3.72	1.036	.141
	2	62	3.21	1.230	.156

results for question 11 and 15, respectively, were used. Table 65 shows the mean scores for questions 11, 12, and 13 were (Mean = 4.30/4.68, 3.89/4.26, and 3.72/3.21, respectively) for automation attitude with RNAV.

Table 66. Independent Samples for Automation Attitude with RNAV

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Attitude 11	Equal variances assumed	7.534	.007	-2.222	114	.028	-.381	.172	-.721	-.041
	Equal variances not assumed			-2.148	83.161	.035	-.381	.177	-.734	-.028
Attitude 12	Equal variances assumed	.137	.712	-2.242	114	.027	-.369	.165	-.695	-.043
	Equal variances not assumed			-2.182	89.757	.032	-.369	.169	-.705	-.033
Attitude 13	Equal variances assumed	1.460	.229	-.749	114	.455	-.171	.228	-.623	.281
	Equal variances not assumed			-.753	113.441	.453	-.171	.227	-.620	.279
Attitude 14	Equal variances assumed	.663	.417	-.893	104	.374	-.180	.202	-.580	.220
	Equal variances not assumed			-.892	103.126	.374	-.180	.202	-.581	.220
Attitude 15	Equal variances assumed	6.757	.011	2.408	114	.018	.513	.213	.091	.934
	Equal variances not assumed			2.436	113.880	.016	.513	.210	.096	.929

Note. Statistical significance is < .05.

Tables 67 and 68 show the results of the analyses of the automation trust questions for RNAV. The mean scores for questions 18 and 19 were 4.11/2.81 and 2.31/1.61, respectively (see Table 67). Table 68 shows only questions 18 and 19 had significantly different means for

Table 67. Group Statistics for Automation Trust with RNAV

	RNAV	N	Mean	Std. Deviation	Std. Error Mean
Trust 16	1	54	3.65	.935	.127
	2	62	3.32	1.457	.185
Trust 17	1	54	3.48	.966	.131
	2	62	3.39	1.136	.144
Trust 18	1	54	4.11	1.022	.139
	2	62	2.81	1.898	.241
Trust 19	1	54	2.31	1.163	.158
	2	62	1.61	1.712	.217

the RNAV (t = 4.689, df = 96.111, Sig (2-tailed) = .000 and t = 2.611, df = 107.900, Sig (2-tailed) = .010, respectively). The equal variances results were used for both questions because the Levene's test was significant (Sig = .000 and .000, respectively) (see Table 68).

Table 68. Independent Samples for Automation Trust with RNAV

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Trust 16	Equal variances assumed	16.771	.000	1.408	114	.162	.326	.231	-.132	.784
	Equal variances not assumed			1.450	105.222	.150	.326	.225	-.120	.771
Trust 17	Equal variances assumed	1.931	.167	.478	114	.633	.094	.197	-.297	.485
	Equal variances not assumed			.484	113.943	.630	.094	.195	-.292	.481
Trust 18	Equal variances assumed	43.365	.000	4.513	114	.000	1.305	.289	.732	1.877
	Equal variances not assumed			4.689	96.111	.000	1.305	.278	.752	1.857
Trust 19	Equal variances assumed	21.757	.000	2.545	114	.012	.702	.276	.155	1.248
	Equal variances not assumed			2.611	107.900	.010	.702	.269	.169	1.235

Note. Statistical significance is < .05.

Tables 69 and 70 show the results of the analyses of the automation competency questions with RNAV. Table 69 shows the mean scores for question 20, 21, 22, 23, and 24

Table 69. Group Statistics for Automation Competency with RNAV

	RNAV	N	Mean	Std. Deviation	Std. Error Mean
Competency 20	1	54	3.78	1.003	.137
	2	62	2.58	1.788	.227
Competency 21	1	54	4.20	1.155	.157
	2	62	2.58	1.963	.249
Competency 22	1	54	3.63	1.218	.166
	2	62	2.06	1.764	.224
Competency 23	1	53	3.40	1.276	.175
	2	62	1.95	1.877	.238
Competency 24	1	54	3.74	1.067	.145
	2	62	2.53	1.799	.228

(mean = 3.78/2.58, 4.20/2.58, 3.63/2.06, 3.40/1.95, and 3.74/2.53, respectively). Table 70 shows all five questions were significant and Levene's test was significant at the .000 level. Consequently, we must use the equal variances not assumed results. The results of the independent samples test (t-test) were t = 4.518, df = 98.272, Sig (2-tailed) = .000; t = 5.506, df = 100.817, Sig (2-tailed) = .000; t = 5.617, df = 108.604, Sig (2-tailed) = .000; t = 4.883, df = 107.827, Sig (2-tailed) = .000; t = , df = , Sig (2-tailed) = ; and t = 4.464, df = 101.232, Sig (2-tailed) = .000; respectively (see Table 70).

Table 70. Independent Samples for Automation Competency with RNAV

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Competency 20	Equal variances assumed	30.347	.000	4.357	114	.000	1.197	.275	.653	1.741
	Equal variances not assumed			4.518	98.272	.000	1.197	.265	.671	1.723
Competency 21	Equal variances assumed	45.369	.000	5.323	114	.000	1.623	.305	1.019	2.227
	Equal variances not assumed			5.506	100.817	.000	1.623	.295	1.038	2.208
Competency 22	Equal variances assumed	18.603	.000	5.481	114	.000	1.565	.286	.999	2.131
	Equal variances not assumed			5.617	108.604	.000	1.565	.279	1.013	2.117
Competency 23	Equal variances assumed	35.624	.000	4.743	113	.000	1.445	.305	.841	2.048
	Equal variances not assumed			4.883	107.827	.000	1.445	.296	.858	2.031
Competency 24	Equal variances assumed	33.856	.000	4.317	114	.000	1.208	.280	.654	1.763
	Equal variances not assumed			4.464	101.232	.000	1.208	.271	.671	1.746

Note. Statistical significance is < .05.

Tables 71 and 72 show the results of the analyses on the automation techniques questions for RNAV; however, there are no significant results. There will be no further consideration of these findings.

Table 71. Group Statistics for Automation Techniques with RNAV

	RNAV	N	Mean	Std. Deviation	Std. Error Mean
Techniques 25	1	53	4.04	.960	.132
	2	62	4.19	.902	.115
Techniques 26	1	53	4.21	.817	.112
	2	62	4.40	.712	.090
Techniques 27	1	53	4.19	.833	.114
	2	62	4.42	.841	.107
Techniques 28	1	53	3.92	.917	.126
	2	62	3.85	1.006	.128
Techniques 29	1	53	4.19	.878	.121
	2	62	4.06	.787	.100

Table 72. Independent Samples for Automation Techniques with RNAV

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Techniques 25	Equal variances assumed	1.441	.232	-.896	113	.372	-.156	.174	-.500	.189
	Equal variances not assumed			-.892	107.797	.374	-.156	.175	-.502	.191
Techniques 26	Equal variances assumed	.392	.533	-1.372	113	.173	-.196	.143	-.478	.087
	Equal variances not assumed			-1.358	104.042	.177	-.196	.144	-.481	.090
Techniques 27	Equal variances assumed	1.404	.239	-1.473	113	.144	-.231	.157	-.541	.080
	Equal variances not assumed			-1.474	110.518	.143	-.231	.157	-.541	.079
Techniques 28	Equal variances assumed	4.422	.038	.386	113	.700	.070	.181	-.288	.428
	Equal variances not assumed			.389	112.515	.698	.070	.179	-.286	.425
Techniques 29	Equal variances assumed	.349	.556	.800	113	.426	.124	.155	-.183	.432
	Equal variances not assumed			.793	105.481	.430	.124	.157	-.186	.435

Note. Statistical significance is < .05.

Tables 73 and 74 show the results of the level of automation questions for RNAV. However, none of these results was significant and these results will not be considered further.

Table 73. Group Statistics for Level of Automation with RNAV

	RNAV	N	Mean	Std. Deviation	Std. Error Mean
Level 30	1	53	2.70	1.170	.161
	2	62	2.92	1.219	.155
Level 31	1	53	3.15	1.116	.153
	2	62	2.89	1.344	.171
Level 32	1	53	3.26	1.112	.153
	2	62	3.11	1.189	.151
Level 33	1	51	3.33	1.108	.155
	2	62	3.50	1.211	.154

Table 74. Independent Samples for Level of Automation with RNAV

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Level 30	Equal variances assumed	.068	.794	-.988	113	.325	-.221	.224	-.665	.222
	Equal variances not assumed			-.992	111.460	.324	-.221	.223	-.663	.221
Level 31	Equal variances assumed	1.360	.246	1.133	113	.259	.264	.233	-.197	.725
	Equal variances not assumed			1.150	112.915	.253	.264	.229	-.191	.718
Level 32	Equal variances assumed	.351	.555	.701	113	.485	.151	.216	-.276	.579
	Equal variances not assumed			.704	112.060	.483	.151	.215	-.274	.577
Level 33	Equal variances assumed	.124	.725	-.756	111	.451	-.167	.220	-.603	.270
	Equal variances not assumed			-.763	109.726	.447	-.167	.218	-.600	.266

Note. Statistical significance is < .05.

Appendix H

Analysis of Age Groups

This appendix shows the analyses of the age groups in Tables 75 through 77. Only three of the questions showed significances and these were all automation attitude questions (11, 13, and 15). The data collection instrument provided five age groups for the participants to select. Group 4 was 45 to 60 and group 5 was 60 and over. Due to the size of group 5 (n = 1), the groups were revised such that group 4 became 45 and over. The following are the resulting groups: group 1 (16-24), group 2 (25-34), group 3 (35-44), and group 4 (45 and over).

Table 75 shows the mean scores for the significant questions. Only three of the questions showed significant results. The mean scores for the three significant questions were groups 1-4 (4.38/2.75), 2-3 (4.65/3.00), and 2-4 (4.65/2.75) for question 11; 1-3 (3.14/1.00), 1-4 (3.14/1.75), 2-3 (2.88/1.00) for question 13; and 1-4 (3.34/4.50) for question 15.

Table 75. Descriptive Data for Automation Attitude by Age

						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Attitude 11	1	143	4.38	1.054	.088	4.20	4.55	0	5
	2	17	4.65	.606	.147	4.34	4.96	3	5
	3	2	3.00	2.828	2.000	-22.41	28.41	1	5
	4	4	2.75	1.500	.750	.36	5.14	1	4
	Total	166	4.35	1.084	.084	4.18	4.52	0	5
Attitude 13	1	143	3.14	1.270	.106	2.93	3.35	0	5
	2	17	2.88	.993	.241	2.37	3.39	1	4
	3	2	1.00	.000	.000	1.00	1.00	1	1
	4	4	1.75	.500	.250	.95	2.55	1	2
	Total	166	3.05	1.261	.098	2.86	3.25	0	5
Attitude 15	1	143	3.34	1.210	.101	3.14	3.54	0	5
	2	17	3.88	.485	.118	3.63	4.13	3	5
	3	2	4.50	.707	.500	-1.85	10.85	4	5
	4	4	4.50	.577	.289	3.58	5.42	4	5
	Total	166	3.43	1.167	.091	3.25	3.61	0	5

The results of the ANOVA showed the three significant automation attitude questions were question 11 (F = 4.694 and Sig = .004), question 13 (F= 3.691 and Sig = .013), and question 15 (F= 2.943 and Sig = .035) (see Table 76).

Table 76. ANOVA for Automation Attitude by Age

		Sum of Squares	Df	Mean Square	F	Sig.
Attitude 11	Between Groups	15.494	3	5.165	4.694	.004
	Within Groups	178.241	162	1.100		
	Total	193.735	165			
Attitude 12	Between Groups	.751	3	.250	.234	.872
	Within Groups	172.894	162	1.067		
	Total	173.645	165			
Attitude 13	Between Groups	16.795	3	5.598	3.691	.013
	Within Groups	245.718	162	1.517		
	Total	262.512	165			
Attitude 14	Between Groups	8.042	3	2.681	2.570	.056
	Within Groups	157.468	151	1.043		
	Total	165.510	154			
Attitude 15	Between Groups	11.618	3	3.873	2.943	.035
	Within Groups	213.153	162	1.316		
	Total	224.771	165			

Note. Statistical significance is < .05.

Table 77 shows the Post Hoc LSD significant group were (a) groups 1-4 (Sig = .003), 2-3 (Sig = .037), and 2-4 (Sig = .001) for question 11; (b) groups 1-3 (Sig = .016), 1-4 (Sig = .027), and 2-3 (Sig = .043) for question 13; and (c) groups 1-4 (Sig = .047) for question 15.

Table 77. Post Hoc LSD Test for Automation Attitude by Age

			Mean Difference	Std. Error	Sig.	95% Confidence Interval Upper Bound	Lower Bound
Attitude 11	1	2	-.269	.269	.318	-.80	.26
		3	1.378	.747	.067	-.10	2.85
		4	1.628(*)	.532	.003	.58	2.68
	2	1	.269	.269	.318	-.26	.80
		3	1.647(*)	.784	.037	.10	3.20
		4	1.897(*)	.583	.001	.75	3.05
	3	1	-1.378	.747	.067	-2.85	.10
		2	-1.647(*)	.784	.037	-3.20	-.10
		4	.250	.908	.784	-1.54	2.04
	4	1	-1.628(*)	.532	.003	-2.68	-.58
		2	-1.897(*)	.583	.001	-3.05	-.75
		3	-.250	.908	.784	-2.04	1.54
Attitude 13	1	2	.258	.316	.416	-.37	.88
		3	2.140(*)	.877	.016	.41	3.87
		4	1.390(*)	.624	.027	.16	2.62
	2	1	-.258	.316	.416	-.88	.37
		3	1.882(*)	.921	.043	.06	3.70
		4	1.132	.684	.100	-.22	2.48
	3	1	-2.140(*)	.877	.016	-3.87	-.41
		2	-1.882(*)	.921	.043	-3.70	-.06
		4	-.750	1.067	.483	-2.86	1.36
	4	1	-1.390(*)	.624	.027	-2.62	-.16
		2	-1.132	.684	.100	-2.48	.22
		3	.750	1.067	.483	-1.36	2.86
Attitude 15	1	2	-.547	.294	.065	-1.13	.03
		3	-1.164	.817	.156	-2.78	.45
		4	-1.164(*)	.581	.047	-2.31	-.02
	2	1	.547	.294	.065	-.03	1.13
		3	-.618	.857	.472	-2.31	1.08
		4	-.618	.637	.334	-1.88	.64
	3	1	1.164	.817	.156	-.45	2.78
		2	.618	.857	.472	-1.08	2.31
		4	.000	.993	1.000	-1.96	1.96
	4	1	1.164(*)	.581	.047	.02	2.31
		2	.618	.637	.334	-.64	1.88
		3	.000	.993	1.000	-1.96	1.96

* The mean difference is significant at the .05 level.

Appendix I

Analysis of Flight Hours

This appendix shows the results of the ANOVA for the various flight experience groups. The current flight experience (flight hours) was divided into six groups (a) group 1 (0 to 200), (b) group 2 (200 to 500), (c) group 3 (500 to 1,000), (d) group 4 (1,000 to 1,500), (e) group 5 (1,500 to 2,500, and (f) group 6 (over 2,500 hours).

Three of the automation attitude questions had significant differences between groups, questions 11 (Sig = .010), 13 (Sig = .008), and 14 (Sig = .009) (see Table 79).

Table 78. Descriptive Data for Automation Attitude by Flight Hour

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Attitude 11	1	91	4.27	1.174	.123	4.03	4.52	0	5
	2	55	4.60	.655	.088	4.42	4.78	2	5
	3	8	4.38	1.408	.498	3.20	5.55	1	5
	4	5	4.80	.447	.200	4.24	5.36	4	5
	6	7	3.14	1.574	.595	1.69	4.60	1	5
	Total	166	4.36	1.079	.084	4.19	4.52	0	5
Attitude 13	1	91	3.22	1.323	.139	2.94	3.50	0	5
	2	55	3.13	1.106	.149	2.83	3.43	1	5
	3	8	2.50	1.309	.463	1.41	3.59	1	5
	4	5	2.20	1.095	.490	.84	3.56	1	4
	6	7	1.71	.488	.184	1.26	2.17	1	2
	Total	166	3.06	1.263	.098	2.87	3.25	0	5
Attitude 14	1	81	2.48	1.119	.124	2.23	2.73	0	5
	2	54	2.24	.910	.124	1.99	2.49	1	5
	3	8	1.50	.535	.189	1.05	1.95	1	2
	4	5	1.60	.548	.245	.92	2.28	1	2
	6	7	1.57	.787	.297	.84	2.30	1	3
	Total	155	2.28	1.035	.083	2.11	2.44	0	5

The Post Hoc LSD test showed (a) question 11 had significant differences between group means for Groups 1-6 (Sig = .007, means = 4.27/3.14), Groups 2-6 (Sig = .001, means = 4.60/ 3.14), Groups 3-6 (Sig = .024, means = 4.38/ 3.14), and Groups 4-6 (Sig = .008, means = 4.80/ 3.14); (b) question 13 had significant differences for Groups 1-6 (Sig = .002, means = 3.22/1.71) and Groups 2-6 (Sig =.005, means = 3.13/1.71), and (c) question 14 had significant differences for Groups 1-3 (Sig = .009, means = 2.48/1.50) and Groups 1-6 (Sig =.023, means = 2.48/1.57) (see Table 78).

Table 79. ANOVA for Automation Attitude by Flight Hour

		Sum of Squares	df	Mean Square	F	Sig.
Attitude 11	Between Groups	15.166	4	3.792	3.451	.010
	Within Groups	176.864	161	1.099		
	Total	192.030	165			
Attitude 12	Between Groups	4.309	4	1.077	1.029	.394
	Within Groups	168.511	161	1.047		
	Total	172.819	165			
Attitude 13	Between Groups	21.456	4	5.364	3.569	.008
	Within Groups	241.942	161	1.503		
	Total	263.398	165			
Attitude 14	Between Groups	14.064	4	3.516	3.493	.009
	Within Groups	151.007	150	1.007		
	Total	165.071	154			
Attitude 15	Between Groups	8.402	4	2.100	1.562	.187
	Within Groups	216.496	161	1.345		
	Total	224.898	165			

Note. Statistical significance is < .05.

Table 80 shows the group means for question 18. Question 18 is the only flight hour automation trust question that showed a significant differences between the means on ANOVA (Sig = .000) (see Table 81). A Post Hoc LSD analysis showed significant differences between

Table 80. Descriptive Data for Automation Trust by Flight Hour

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Trust 18	1	91	2.69	1.736	.182	2.33	3.05	0	5
	2	55	4.04	1.105	.149	3.74	4.34	0	5
	3	8	4.75	.463	.164	4.36	5.14	4	5
	4	5	4.40	.548	.245	3.72	5.08	4	5
	6	7	4.43	.535	.202	3.93	4.92	4	5
	Total	166	3.36	1.626	.126	3.11	3.61	0	5

group means for Groups 1-2 (Sig = .000, means = 2.69/4.04), Groups 1-3 (Sig = .000, means = 2.69/ 4.75), Groups 1-4 (Sig = .012, means = 2.69/ 4.04), and Groups 1-6 (Sig = .003, means = 2.69/4.4 3) for question 18 (see Table 80 for group means).

Table 81. ANOVA for Automation Trust by Flight Hour

		Sum of Squares	df	Mean Square	F	Sig.
Trust 16	Between Groups	6.318	4	1.579	1.005	.407
	Within Groups	253.031	161	1.572		
	Total	259.349	165			
Trust 17	Between Groups	11.789	4	2.947	2.173	.074
	Within Groups	218.355	161	1.356		
	Total	230.145	165			
Trust 18	Between Groups	94.587	4	23.647	11.141	.000
	Within Groups	341.726	161	2.123		
	Total	436.313	165			
Trust 19	Between Groups	2.148	4	.537	.249	.910
	Within Groups	346.702	161	2.153		
	Total	348.849	165			

Note. Statistical significance is < .05.

All five of the flight hour automation competency questions had significant differences between groups on the ANOVA (a) question 20 (Sig = .000), question 21 (Sig = .000), question 22 (Sig = .000), question 23 (Sig = .000), and question 24 (Sig = .000) (see Table 83). Post Hoc LSD test showed (a) question 20 had significant differences between group means for Groups 1-2 (Sig = .000, means = 2.49/3.53), Groups 1-3 (Sig = .000, means = 2.49/ 4.63), Groups 1-4 (Sig = .001, means = 2.49/4.80), and Groups 2-3 (Sig = .043, means = 3.53/4.63); (b) question 21 had significant differences between group means for Groups 1-2 (Sig = .000, means = 2.46/4.13), Groups 1-3 (Sig = .000, means = 2.46/ 4.88), Groups 1-4 (Sig = .001, means = 2.46/4.80), and Groups 1-6 (Sig = .012, means = 2.46/4.00); (c) question 22 had significant differences between group means for Groups 1-2 (Sig = .000, means = 2.09/ 3.38), Groups 1-3 (Sig = .000, means = 2.09/ 4.50), Groups 1-4 (Sig = .000, means = 2.09/4.80), Groups 1-6 (Sig = .010, means = 2.09/3.57), Groups 2-3 (Sig = .044, means = 3.38/4.80), Groups 2-4 (Sig = .039, means =

3.38/4.50); (d) question 23 had significant differences between group means for Groups 1-2 (Sig = .000, means = 2.00/ 3.48), Groups 1-3 (Sig = .016, means = 2.00/ 3.38), Groups 1-4 (Sig = .000, means = 2.00/4.60), and Groups 4-6 (sig =.011, means = 4.60/2.29); and (e) question 24 had significant differences between group means for Groups 1-2 (Sig = .000, means = 2.44/ 3.72), Groups 1-3 (Sig = .002, means = 2.44/ 4.13), Groups 1-4 (Sig = .000, means = 2.44/4.80), and Groups 1-6 (sig =.024, means = 2.44/3.71).

Table 82. Descriptive Data for Automation Competency by Flight Hours

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Competency 20	1	91	2.49	1.682	.176	2.14	2.84	0	5
	2	55	3.53	.997	.134	3.26	3.80	1	5
	3	8	4.63	.518	.183	4.19	5.06	4	5
	4	5	4.80	.447	.200	4.24	5.36	4	5
	6	7	3.43	1.512	.571	2.03	4.83	0	4
	Total	166	3.05	1.560	.121	2.81	3.29	0	5
Competency 21	1	87	2.46	1.829	.196	2.07	2.85	0	5
	2	55	4.13	1.123	.151	3.82	4.43	0	5
	3	8	4.88	.354	.125	4.58	5.17	4	5
	4	5	4.80	.447	.200	4.24	5.36	4	5
	6	7	4.00	1.826	.690	2.31	5.69	0	5
	Total	162	3.28	1.781	.140	3.01	3.56	0	5
Competency 22	1	90	2.09	1.626	.171	1.75	2.43	0	5
	2	55	3.38	1.254	.169	3.04	3.72	0	5
	3	8	4.50	.535	.189	4.05	4.95	4	5
	4	5	4.80	.447	.200	4.24	5.36	4	5
	6	7	3.57	1.618	.612	2.07	5.07	0	5
	Total	165	2.78	1.657	.129	2.53	3.04	0	5
Competency 23	1	91	2.00	1.745	.183	1.64	2.36	0	5
	2	54	3.48	1.209	.165	3.15	3.81	0	5
	3	8	3.38	1.302	.460	2.29	4.46	1	5
	4	5	4.60	.548	.245	3.92	5.28	4	5
	6	7	2.29	1.496	.565	.90	3.67	0	4
	Total	165	2.64	1.707	.133	2.38	2.90	0	5
Competency 24	1	91	2.44	1.721	.180	2.08	2.80	0	5
	2	54	3.72	.998	.136	3.45	3.99	0	5
	3	8	4.13	.835	.295	3.43	4.82	3	5
	4	5	4.80	.447	.200	4.24	5.36	4	5
	6	7	3.71	.488	.184	3.26	4.17	3	4
	Total	165	3.07	1.586	.123	2.82	3.31	0	5

Table 83. ANOVA for Automation Competency by Flight Hours

		Sum of Squares	df	Mean Square	F	Sig.
Competency 20	Between Groups	76.769	4	19.192	9.512	.000
	Within Groups	324.846	161	2.018		
	Total	401.614	165			
Competency 21	Between Groups	133.545	4	33.386	13.889	.000
	Within Groups	377.393	157	2.404		
	Total	510.938	161			
Competency 22	Between Groups	111.360	4	27.840	13.148	.000
	Within Groups	338.785	160	2.117		
	Total	450.145	164			
Competency 23	Between Groups	99.918	4	24.979	10.574	.000
	Within Groups	377.985	160	2.362		
	Total	477.903	164			
Competency 24	Between Groups	85.912	4	21.478	10.530	.000
	Within Groups	326.354	160	2.040		
	Total	412.267	164			

Note. Statistical significance is < .05.

Two of the five flight hour automation techniques questions had significant differences between groups on the ANOVA question 28 (Sig = .024) and question 29 (Sig = .037) (see Table 85). The Post Hoc LSD test showed questions 28 had significant differences between group means for Groups 1-2 (Sig = .001, means = 3.57/4.15) and question 29 had significant differences between Groups 1-2 (Sig = .003, means = 3.80/4.27) (see Table 84 for means).

Table 84. Descriptive Data for Automation Techniques by Flight Hours

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound	Lower Bound	Upper Bound
Techniques 28	1	90	3.57	1.132	.119	3.33	3.80	0	5
	2	55	4.15	.705	.095	3.95	4.34	2	5
	3	8	3.75	1.282	.453	2.68	4.82	1	5
	4	5	3.60	1.673	.748	1.52	5.68	1	5
	6	7	4.00	.577	.218	3.47	4.53	3	5
	Total	165	3.79	1.041	.081	3.63	3.95	0	5
Techniques 29	1	90	3.80	1.062	.112	3.58	4.02	0	5
	2	55	4.27	.679	.092	4.09	4.46	2	5
	3	8	4.25	.707	.250	3.66	4.84	3	5
	4	5	3.80	1.304	.583	2.18	5.42	2	5
	6	7	4.29	.488	.184	3.83	4.74	4	5
	Total	165	4.00	.944	.073	3.85	4.15	0	5

Table 85. ANOVA for Automation Techniques by Flight Hours

		Sum of Squares	df	Mean Square	F	Sig.
Techniques 25	Between Groups	6.537	4	1.634	1.520	.199
	Within Groups	171.972	160	1.075		
	Total	178.509	164			
Techniques 26	Between Groups	7.461	4	1.865	2.086	.085
	Within Groups	143.048	160	.894		
	Total	150.509	164			
Techniques 27	Between Groups	2.830	4	.708	.697	.595
	Within Groups	162.382	160	1.015		
	Total	165.212	164			
Techniques 28	Between Groups	11.939	4	2.985	2.883	.024
	Within Groups	165.636	160	1.035		
	Total	177.576	164			
Techniques 29	Between Groups	8.962	4	2.241	2.616	.037
	Within Groups	137.038	160	.856		
	Total	146.000	164			

Note. Statistical significance is < .05.

None of the flight hour level of automation questions was significant. Consequently, this analysis is not included in the study.

Appendix J

Levels of Automation Scenario

Scenario

This mission is one of four that measures pilot performance while using various levels of automation installed on the SR22. In Scenario 1, you are to use the automation. That is, the flight plan is to be loaded into the GPS. The autopilot is to be engaged as soon as possible after takeoff and it is to be used through short final. See aircraft performance information listed below. In Scenario 2, you will program (load the flight plan in the GPS) into the GPS but you will not use the autopilot. In Scenario 3, you will not load the flight plan but the autopilot throughout the flight as in Scenario 1. Finally, Scenario 4, you will not load the flight plan and will not use the autopilot.

Scenario: You are to fly to Fargo and pick up a passenger, then fly to St Paul, MN (St Paul Downtown airport) to attend a Vikings game. Your friend is your best friend and is an avid Vikings fan. The game starts at 2:00 pm on January 10th, you will need to arrive in St Paul at 11:00 am to make it to the game on time, you plan to spend the night in St Paul, and return on the 11th.

Profile: This is a day IFR flight, on January 10^{th,} from KGFK (Grand Forks International) to KFAR (Hector Field) in the Cirrus SR22 aircraft. The second leg is from KFAR to St Paul. As much as possible, make all decisions as though this is a real flight, in real weather conditions. You are an experienced instrument pilot with over 500 hours in your SR22, you have recently completed an instrument proficiency check, and have completed 5 takeoffs and landings (three at night) within the last two weeks.

Weather: In the Red River Valley is generally 1000 ft ceilings with ¾ mile visibility with moderate snow. No forecasted or reported icing.

Alternate airport: Jamestown Regional Airport with forecasted weather 3000/2 with light snow.

NOTAMS: Nothing significant

Filed Clearance: KGFK direct JOCOR V181 FAR direct KFAR at 5000 ft.

Aircraft performance:

Rotate at 70 knots

Climb with full power at 78 to 82 (VX) knots, with an obstacle; 95 to 101 (V_Y) knots, no obstacle; or cruise climb 110 to 120 knots (transition when desired)

Cruise at 55% to 85% power (at 5,000 feet use 81%, 20.4 GPH, 169 - 170 knots)

Approach:

0% flaps – 90 to 95 knots
50% flaps – 85 to 90 knots (27 – 31% power) (maximum flap setting with autopilot)
100% flaps – 80 knots (28% power)

Autopilot can be engaged at 400 feet AGL and disengaged at 50 feet AGL. (maximum flaps with the autopilot on is 50%)

Flap speeds:

50% – 119 knots maximum
100% – 104 knots maximum.