THE EFFECTS OF COMPUTER BASED FLIGHT SIMULATORS DURING AVIATION PILOT TRAINING IN AMERICAN UNIVERSITIES

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A Field Study

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Education Specialist

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Alfred W. Rogers

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Abstract

The purpose of this research was to determine the effects of increased use of flight simulators in the curricula of American universities offering aviation degrees. The university systems have been criticized for increasing simulator use as a cost saving measure while the quality of the graduate pilots has declined. This research studied two aspects of aeronautical science, student grades and safety, and correlated changes from 1982 through 1996. Student grades were compiled from 18 American university programs having 20 or more aviation students. These grade means were correlated with this nation's aviation accident rate over the same time continuum. The results showed a strong correlation between the increase in simulator use and time from 1982 through 1996. The student grades have increased slightly but not enough to show a significance attributed to simulator use. There was a slight but significant correlation in the decrease in accident rate when compared to the increase in simulator use.

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CHAPTER 1

Introduction

Since the Wright brothers made their first successful flight in 1903, there has been a desire on the part of many people to learn to pilot an aerodynamic structure. In the early days, designers built their aircraft based on theory and practice. They learned to pilot the aircraft using the same process. Some pilots died trying to perfect a theory, a design or learning to fly their invention. As World War I drew near, aircraft designers were in such demand that designing and piloting became separate professions. Many designers concentrated on the study of aerodynamics in an effort to build combat aircraft that were fast, safe and efficient to the war effort. Men, most with no aviation background, were trained to fly these modern inventions.

The educational process of training pilots has been primarily the same until recent years. Early pilots were told how to fly a maneuver, flew with an instructor for a demonstration, practiced with the instructor on board, and then were allowed to practice until they were successful most of the time.

Today, there are literally thousands of aircraft flying over the United States each day (Kaps, 1996). Many of these are commercial aircraft transporting travelers for business and pleasure. The commercial airline business is successful, in part, due to the safety record of highly trained pilots. This training is a long and arduous process culminating in the logging of thousands of hours of safe flying before being allowed to transport passengers for hire. Until recently, most of those pilots were

trained by the military through the same process used by World War I pilots. The pilot's ultimate graduation was surviving years of daily combat missions flown over Germany, Korea or Vietnam.

Statement of the Problem

There is a new era of training pilots that has evolved with the invention of computers and simulations. More and more of the pilot training is performed on the ground in boxes called flight simulators. Even pilots preparing for combat, have very little time flying the actual aircraft compared to their predecessors. Society can no longer depend on wars to give pilots thousands of flight hours. Yet today, as commercial travel increases, there is a greater demand for highly trained pilots (Johnson, 1993).

Whether one teaches first graders letter sounds, shapes, colors, and numbers or pilots to fly combat and commercial aircraft, the use of computers is a valuable tool. The issue is to what extent should the computer tool be used. In the aviation world, can a pilot be trained to fly with the same or greater level of expertise using the computer simulator instead of the aircraft?

It is rare to find an American that has not been on an airplane. Flying has become very commonplace, even to vacationers. As long as the public feels it is safer to fly than drive, they will continue their travel using the speed and efficiency of flying. If pilots are poorly trained and unable to correctly identify and solve

in-flight emergencies, the commercial aviation industry will suffer. As noted in recent pilot strikes, the President of the United States has the power to order pilots back to work. The successful training of pilots is essential to this nation's defense and transportation systems. "Aviation is critical to the U.S. economy and both the aviation industry and the U.S. economy must be given the tools necessary to perform its tasks" (Whiteside, 1993, p. 14).

Research was required to determine the best approach to training military and commercial pilots. Data was compiled by exploring the different aviation training programs as they have evolved. There has been a government standard that has prevailed from the early days of aviation set forth by the Federal Aviation Administration (FAA). All private, commercial or military pilots must adhere to the same oral, written and practical competencies. By comparing the accident rates caused by pilot error and test scores of flight students, the outcome as computer based training has increased was apparent. With this information, an educator can predict the best curriculum in terms of computer based training for future pilots.

Research Questions

The increased use of flight simulators as a flight student progresses toward a four-year Bachelor of Science Degree in Aviation has been educationally effective. Has the increased use reached a point of negative impact on training and safety?

1. Knowing universities are increasing the use of simulators over the actual aircraft, has the quality of training, based on FAA test scores, been effected?

2. Has the greater use of flight simulators in training had an impact on aviation safety?

Hypotheses

Null Hypothesis One: The grades of student aviators flying simulators is statistically insignificant as compared to the students who flew the actual aircraft.

Null Hypothesis Two: The amount of flight simulator training for student aviators at universities is statistically insignificant as compared to the aeronautical accident rate caused by pilot error.

Definition of Terms

Accident rate - The number of accidents per 100,000 flight hours.

Aircraft transition - The process of qualifying a licensed pilot to fly in an additional aircraft.

Aviation accident - Any accident involving an aircraft that results in a loss of life or damage in excess of $100,000.

Federal Aviation Administration (FAA) - An office of the federal Department of Transportation responsible for all policies, regulations, procedures, safety and oversight of aviation in the United States.

Flight simulator - Any land based device that replicates any portion of aeronautical flight for the purpose of training pilots.

Flying hours - Time logged by pilots from the point the aircraft leaves the ground until it lands rounded to the nearest tenth of an hour.

Licensed pilot - A pilot who has demonstrated aviation proficiency and certified by the Federal Aviation Administration. This certification process begins with a private pilot's license.

National Transportation Safety Board (NTSB) - The office of the federal Department of Transportation responsible for investigating all transportation accidents to include aviation accidents.

Pilot error - A term used in aircraft investigation to identify an incorrect action or failure to comply with a procedure that resulted in an aircraft accident.

Refresher training - The process of continuing education used by licensed pilots to practice all aviation maneuvers, especially those not encountered in routine flight.

Importance of the Study

The primary source of commercial airline pilots prior to 1973 was the United States military. Following the Vietnam war, the national strategy and public opinion of America demanded that this nation would never engage in another long, protracted war. That fact and the beginning of wide spread computer based training has had a direct impact on military pilots logging thousands of hours before they transition into

commercial aviation industry. As a result, many universities began offering aviation degrees that included a commercial pilot's license. The use of computer based flight simulators has increased in all universities while the actual time spent piloting the aircraft has declined (Strickler, 1993).

After a pilot received a commercial license, that pilot was hired by an airline and transitioned to an aircraft. The FAA allows the pilot to receive 100% of that training in a simulator. The simulators have become so realistic that the transfer of training from the simulator to the aircraft is unquestioned by most experts.

If the FAA allows industry to train the licensed pilot into an aircraft using 100% simulation, will the universities be far behind? The cost of flying a simulator is approximately 10% of the cost of flying the actual aircraft (Gerson, 1995). Will the business practice of saving money outweigh quality training and safety?

This study is intended to show an increasing use of simulators by university aviation programs from the 1980s to the present. Data was provided in the study that identified the accident rates caused by pilot error over the same time frame to determine if there was a correlation. Additional data validated the test scores of student aviators over the given time and determined if the increase in simulator use has had an effect. All commercial pilots are given the same standardized tests regardless of whether they were trained on a simulator, the aircraft or a combination of both. After the correlation was completed, the study showed the optimum amount of simulator training and aircraft training needed in the curriculum for the university

to provide a safe quality pilot for the aviation industry, if the difference in simulator use is significant. If not, universities will continue to increase the use of simulator time over aircraft time as a cost saving measure to attract students to the university's program.

Assumptions

Hundreds of studies have demonstrated that computer based training is effective. The same is true in the aviation business of training pilots, whether for the military or industry. Flight simulators are effective as a training tool and save money when compared to flying the actual aircraft.

All licensed pilots are qualified to fly a particular type of aircraft since the evaluation is standardized by the Federal Aviation Administration. For the purposes of this study, the mean grades of each pilot group was considered separately, all other human factors being equal. The assumption was made that the use of flight simulator training had some impact on pilot performance.

According to investigations from the National Transportation Safety Board, most aviation accidents are caused by pilot error. The Federal Aviation Administration has designed a training syllabus that teaches every known aircraft emergency situation. Some of these tasks are so dangerous they must be taught in a simulator. Most tasks are taught in the aircraft for reliability. The pilots are expected to master each of the tasks before they receive a pilot's license. It is assumed if a

pilot makes a mistake causing an aircraft accident, it was due, directly or indirectly, to insufficient or lack of quality training. Training in flight simulators or the actual aircraft will have some effect on flight safety.

Limitations of the Study

Human experimental testing over the careers of commercial pilots would be the best method to test this hypothesis. Due to time and expense, that is not practical for this study.

These data were limited to the years 1982 through 1996. Prior to 1982, very few simulators were being used by the university system. Using that data would have invalidated the research. Safety records from the National Transportation Safety Board were not complete after 1996.

CHAPTER 2

Review of Literature

Aeronautical Education Takes Off

The International Civil Aviation Organization's (ICAO) long-term forecast projects a market for 11,000 new transports worth $800 billion by 2010 (Bacon, 1993). This world wide industry has grown to an amazing enterprise this century. In the early years, the pilot was the backbone of the industry acting as inventor, flyer, manager and mechanic. The key was experience. Today, the industry requires expertise in business, accounting, meteorology, medicine and the legal profession. This ancillary support to keep the aviation industry competitive requires a formal educational system. In Bales' study (as cited in Bryan & Thuemmel, 1997, p. 2) "85% of the air crews learned how to fly in the military; by decade's end only a third will have that claim." The university institutions were teaching an aviation profession to the pilots that would carry them past the cockpit into the aviation board rooms. While this was important to the industry, the universities cannot forget to teach pilot skills.

Of 143 institutions offering pilot education, they issued 10,500 pilot certificates in 1992 (Crehan, 1995). The training of professional pilots for a world wide industry has become a lucrative business in itself. Designing the best curriculum for this process had many implications. One was a curriculum that was cost effective. Learning to fly was very expensive so many have ignored the risk of

entering the aviation field since jobs were so competitive.

"The time is ripe for new and innovative ideas to emerge to offset the downward spiral in student motivation and performance. Aviation educators need to become more actively involved in the American educational system and enrichment programs" (Fleener-Ryan, 1993, p. 20). In flight programs, many institutions are now using flight training devices (simulators) extensively (Kitley, 1996). This has been a major factor in the decision to offer aviation majors by many universities. Students could now afford to obtain an education, earn a pilot certificate and be trained in a life long industry.

The Use of Flight Simulators is Growing

"As a whole these devices, which we'll call simulators do one thing-simulate flight-and they have a single purpose-to facilitate learning. Their potential as a teaching tool is limitless" (Falkner, 1997, p. 46). Numerous studies have been published on the effectiveness of training using flight simulators. There was no doubt that flight simulators were effective tools for learning and save thousands of dollars per hour of flying jet aircraft. The argument over how much simulator training should be allowed and what procedures should be taught remained a topic of concern.

Flight simulators were initially used to teach simple flight procedures. As computer based training became more sophisticated, motion, sound, and visuals were added. There are flight simulators with fidelity so realistic they could be used for all

phases of training. In theory, a pilot can be type-certified in a simulator and walk out to the actual airplane and fly it (George, 1996).

Flight simulators were never intended to replace time flown in the aircraft. They were designed to enhance aviation training. Even the most sophisticated simulator was used to transition a trained pilot from one aircraft to another. Yet, most aviation programs teaching initial flight students were logging more time in the simulator than the aircraft.

The personal computer based aviation training devices (PCATD) was the latest trend in aviation training. As the name implies, these were systems wired to personal computers. "An experience of less that ten thousand dollars will provide a PCATD including software, computer hardware, and a flight control system. This should be within the reach of most flight schools" (Taylor, Lintern, Hulin, Talleur, Emanuel & Phillips, 1996, p. 1). The focus seemed to be on cost effectiveness rather than the competent training of a professional pilot.

"The use of simulators and flight training devices is becoming increasingly important in aviation education. Colleges and universities are recognizing the value of operating these machines to maximize training dollars" (Petrin & Young, 1994, p.32).

Aviation Professionals Value Safety Above All Else

Commercial pilots are responsible for hundreds of lives every day. There is no greater responsibility. Pilots take their profession very seriously. Many are concerned by the lack of training of young pilots graduating from universities. "Intensive experience with video games is often thought to develop abilities such as timing, psychomotor coordination and perceptual judgement. By this view, the ready availability of video games in our society may be producing a group of psychomotor geniuses" (Lintern, 1992, p. 337). The designers of simulators are assuming these psychomotor skills will transition from the simulator to the actual aircraft. The aviation industry and educational institutions need to insure this is true before endorsing such ideas. Risk assessment and safety are the keys to decision making, not cost effectiveness.

The pilot error rate for commuter aircraft accidents was six times higher in 1986-1988 than it was for 1979-1985 according to Oster, Strong, and Zorn's study (as cited in Bowman, 1992). The NTSB reported in its 1991 review of general aviation accidents that the pilot was the cause factor in 86.6% of all general aviation accidents (NTSB, 1991). It appears that the rate of aviation accidents caused by pilot error was increasing. It is unknown whether or not these pilots played video games while they were growing up.

"The stress associated with actual flight is greater than that in simulated flight. Fifty percent increases in heart rate were found in actual flight but not in a ground

based simulator," according to Wilson, Skelly and Purvis' study (as cited in Gawron & Bailey, 1995, p. 287). There was obviously a difference in flying an aircraft and a high fidelity realistic simulator.

Summary of Literature Review

The literature review has shown the tremendous interest in aviation education by the number of recent articles. There was a difference in the type of training required for a seasoned professional pilot needing a refresher or transition to another aircraft and the beginning flight student (Moore, Telfer & Smith, 1994). While the simulator was a valuable training tool, how it was used and to what extent is still unknown. This study shows the change in pilot error accident rates and the changes in student pilot's grades over time while the use of simulators has increased.

CHAPTER 3

Methodology

In the 1970s, two events occurred that had an impact on this study. The first was the end of the Vietnam war. Like World War II and the Korean War, aviation was used extensively for years, resulting in pilots logging thousands of hours of on-the-job training in aircraft emergency procedures. Most of these were reserve officers who left the military after the war to fly for our nation's commercial industry. Presently, many of these pilots have retired or will retire in the next few years. The second event was the certification of simulators by the FAA that allowed commercial pilots to receive up to 100% of their training in the simulator. Their first flight in the actual aircraft may have been a supervised flight with paying customers on board.

Since 1973, the preponderance of flight training has shifted from the military to the university. There are 143 universities in the United States offering aviation training and they all use simulators. This study analyzed data from 18 universities to determine the optimum effectiveness of simulator training versus actual aircraft training in designing a university curriculum.

The foremost issue with the general public is safety. Annual accident rates from 1982 to the present were recorded in a graph showing the change in the accidents caused by pilot error only, eliminating accidents caused by mechanical failure or any other cause. Accident rates were measured by accidents per 100,000 hours of flying. All commercial accidents resulting in a death were investigated by

the National Transportation Safety Board. These accident reports were not available to the public due to possible litigation, but for purposes of future safety and education, parts of the reports were obtained. For the purpose of this study, only the date of the accident and the fact that the cause was pilot error was significant.

A sampling of 18 university curricula over the same time period revealed that all aviation programs have increased the use of simulators. The amount of that increase was recorded in a graph to show a trend. Simulators were designed to mimic the exact internal replicas of the actual cockpit and flight characteristics. Simulators included all types that are certified by the FAA or used in the college curriculum. This included current software packages that could be used on a home personal computer, non-motion simulators and full motion simulators that cost twenty million dollars. The full motion simulators were so realistic that the FAA allowed flight hours to be logged by the pilots even though the machine never leaves the ground. They duplicate vibration, weather, aircraft sounds, radio calls, temperature control and lighting. Even simulator seats were the same as those in an aircraft. The simulators were also divided into visual and instrument trainers. The visual trainers were used to teach landings and takeoffs while the instrument trainers had no outside visual cues to orient the pilot to the ground. The university curriculum was analyzed to define the use of simulators and actual aircraft in terms of hours logged with an instructor.

Lastly, all aviation programs have the same evaluation requirements standardized by the FAA. This was an oral examination, written examination and practical demonstration of proficiency of maneuvers graded on a numerical scale. A sampling of 18 universities will provide the numerical grades of 684 aviation students displayed in a graph in an effort to show a trend of aviator student proficiency over time.

All this data was correlated to determine the best mix of simulator and actual aircraft training in an university curriculum, understanding the commercial aviation industry will transition the graduate, hopefully, totally trained through the simulator, to a passenger carrying aircraft. An effort was made to determine if the pilots trained primarily on simulators were as effective and safe as the pilots, given the same standards, that are trained primarily in the actual aircraft. The table of data was displayed in a graph to show a visual correlation. The data was also correlated to graph the optimum number of hours of simulator training and actual hours in the aircraft based on safety and academic achievement. This information will be shared with the 18 universities in an effort to standardize training in curriculum design.

The practical reality is flying the simulator costs about 10% of the cost of flying the actual aircraft. From a business point of view, this was a strong incentive to advocate simulator training. The intent of this study was to determine pilot training effectiveness tested through evaluation and safety. The cost effectiveness of

simulator use was without question but was not be considered for the outcome of this study.

Another variable that was present in all avenues of flight was the human factor of stress. Even though humans may react differently to the same situation, each student cannot be trained with an individualized education plan. For the purpose of this study, the goal was an effective standardized university curriculum. Stress and other human factors were addressed in this study but did not have a statistical bearing on the results of the correlation.

The student grades and increase in simulator use were obtained from the universities through the use of a computer survey, mail and direct communication. The grades were numerical results of the practical flight evaluation that is standardized by the FAA. No personal student academic information was transmitted directly. The grades from the 18 universities were averaged by year group and the mean presented chronologically over a 15 year time frame. The accident rates for the same 15 year period were obtained from the NTSB research department.

The correlation was prepared by building a table showing year, averaged hours of simulator use, mean grades of students and accidents rates per 100,000 hours of flying. These data were correlated to show the change in student grades and change in accident rates as simulator use increased over a fifteen year period.

The results of this methodology should assist universities in designing an aviation curriculum utilizing a combination process including flight in the simulators and actual aircraft to optimize safety and effectiveness during the training of pilots in American universities.

CHAPTER 4

Results

This field study was based on the fact that American universities and colleges have taken over the preponderance of pilot training for the commercial airline industry and the use of flight simulators as a major training tool used during that process. Many critics questioned whether these graduates of a four-year university system were qualified to transition into the commercial airliner and safely fly customers for hire.

The research questions whether the student test scores and flight accident rates had increased or decreased while the use of simulators increased over time. The assumption was made that flight training had an impact on flight safety since most aviation accidents are caused by pilot error. The first null hypothesis stated that the grades of students who flew the simulator were statistically insignificant when compared to the students who had previously flown the aircraft. The second null hypothesis stated that the increase in simulator training was statistically insignificant when compared to the previous accident rates of graduates with more actual flight experience.

Simulator Use

As suspected, universities have increased the number of simulators and the number of hours student fly the simulators. This has been increasing with the popularity of the aviation degree, less restrictions by the FAA on the use of simulators and the fact that simulators are becoming less expensive with higher degrees of fidelity. Figure 1 depicts the increased use of simulators from 1982 through 1996.

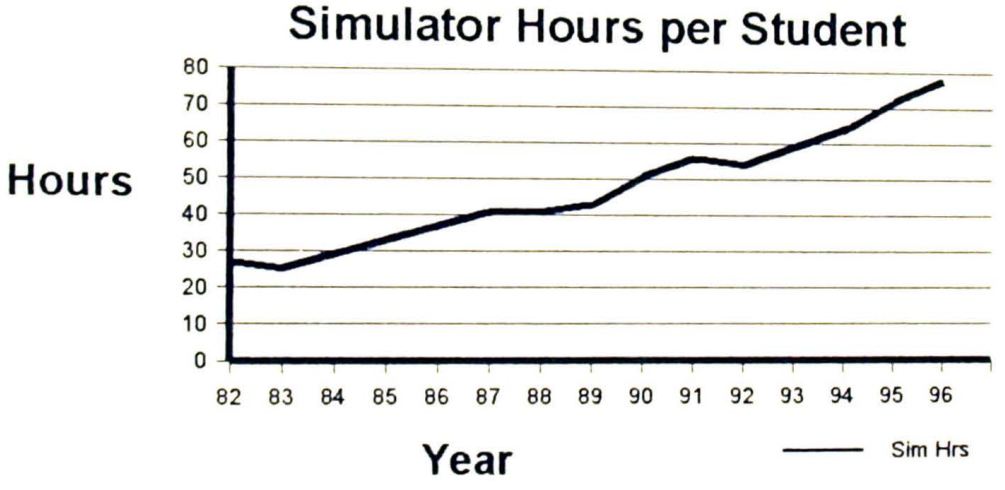

Figure 1. Hours of flight simulator time logged per student, 1982-1996.

Grades of Flight Students

While many critics question the ability of university programs to train qualified pilots, that was not supported in the academic achievement of the students trained from 1982 through 1996. As shown in figure 2, the academic mean of 684 flight students has slightly increased over time. This average was based on a standardized practical FAA flight evaluation. During the same period, colleges and universities were increasing the use of flight simulators.

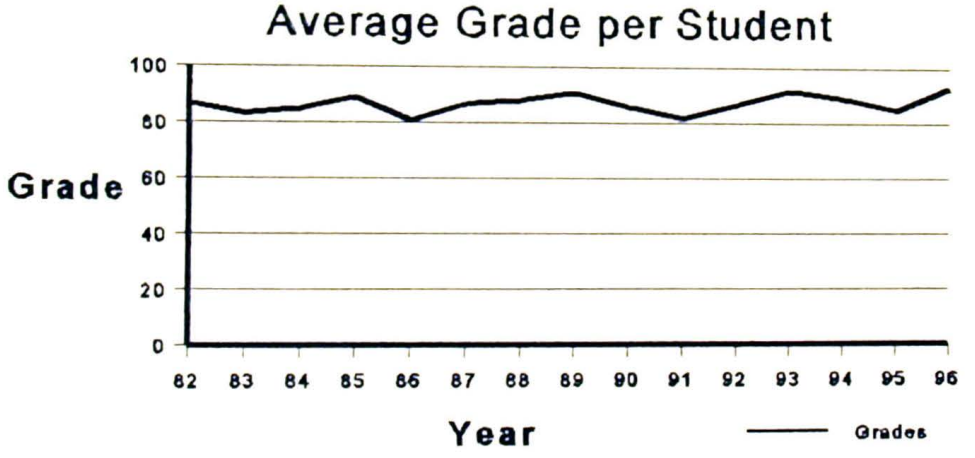

Figure 2. Average grades of students from the FAA flight evaluations, 1982-1996.

Flight Safety

During the years 1982 through 1996, the rate from all aviation accidents in the United States caused by pilot error, declined, as shown in figure 3. Assuming that flight training had an effect on accident rates caused by pilot error, then the increased use of flight simulators has been an effective tool in training safety conscious pilots.

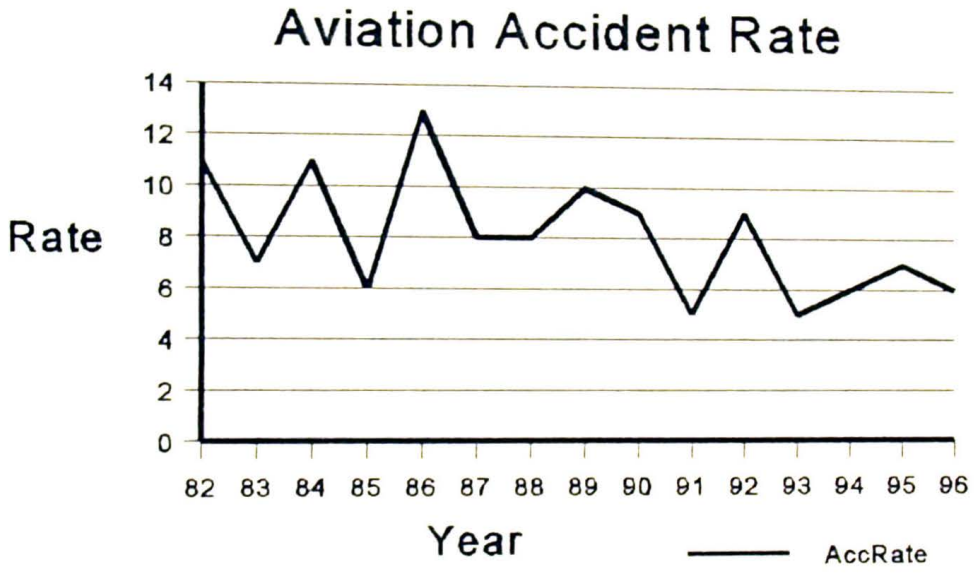

Figure 3. Aviation accidents per 100,000 hours of flight, 1982-1996.

Correlation of Data

Table 1 depicts the correlation of data between the average number of simulator hours a student received in 1982 (27 hours) and the average number received in 1996 (78 hours). There was a strong significant correlation of .984 at the 0.01 level of confidence. Comparing the increase of simulator use to the student grades revealed an insignificant correlation of .392 at the 0.05 level of confidence. This correlation proved null hypothesis one to be true. The grades of student aviators flying simulators are statistically insignificant as compared to the students who flew the actual aircraft. There is a significant negative correlation of -.538 when comparing the accident rate to increased use of simulators. The negative number signifies the decrease in accident rates. This finding does not support null hypothesis two that the amount of flight simulator training for student aviators was statistically insignificant as compared to the aeronautical accident rate.

Table 1. Correlation of aviation data (1982-1996). N=15

	Accident Rate	Grade Mean	Simulat Hours	Year
Accident Rate	1.000	-.364	-.536*	-.538*
Grade Mean	-.364	1.000	.392	.419
Simulat Hours	-.536*	.392	1.000	.984**
Year	-.538*	.419	.984**	1.000

* Correlation is significant at the 0.05 level.

**Correlation is significant at the 0.01 level.

CHAPTER 5

Conclusions

Summary

The purpose of this study was to test the theory that flight simulators have been effective training tools in the education of pilots from four-year universities. The two metrics used for that test were student grades from a standardized flight evaluation and this nation's accident rate. The findings showed an increase in student grades and a decrease in accident rates from 1982 through 1996. The criticism from many senior pilots that young, beginning pilots, are not trained well enough to fly commercial airliners was not supported by this limited study.

Implications

This study only identified two elements used to measure the successful training of a pilot. It is possible that other areas of pilot training were lacking but not identified by this study. The airline industry and education systems have used extensive cooperation in the design of aviation curricula to meet the international market. As with all strategic planning, perhaps it is time to evaluate the process instead of the outcome. Rather than listen to the criticism of the senior pilots, it would be more beneficial to obtain specific information about training deficiencies instead of generalities. This could lead to a redesign of flight simulators or a new training methodology entirely. Like many mid-range employees, many of us could

identify those college subjects that had no added value and other courses that would have been very beneficial to our career preparation. Those airline pilots who graduated from university aeronautical programs 10 years ago could be a valuable asset to curriculum redesign.

Future Research

As stated in the beginning of this field study, experimental research would add credibility and effectiveness to a training program. After a survey of airline pilots and aviation management was completed, those areas needing course development could be designed into a test curriculum. A longitudinal study could track the graduates and measure senior pilot reaction to those trained under the test curriculum. This would be one method to improve the educational process.

One answer to senior pilot criticism may have no scientific basis. It boils down to experience. Young employees have no experience. As a result, many expert pilots assume the training must have been deficient in some way. Flying thousands of hours during combat conditions will never be simulated at a university. It is imperative that industry and the universities continue to research methodology, training effectiveness, training technology and curriculum design.

Conclusion

The training of our youth continues to be the greatest legacy we can give our country. The university system of education in this country is constantly assessing the needs of our culture and that of the international market. As world peace abounds, the aviation industry focused on change and looked to the university system of education to meet the demand for qualified, safe pilots for the next century.

This research study verified that the aviation graduates of four-year university programs are meeting the needs of the aviation industry. The universities are effectively using state-of-the-art computer based simulators to train the next generation of commercial pilots. Perhaps the fidelity and reality of the simulators has reached a training benefit that exceeds that of the actual aircraft. Perhaps the reliability of today's aircraft do not require the same type of training that was required years ago.

In addition to being safe and competent, today's pilots are aeronautical professionals capable of leading and making executive decisions in areas far more complicated than the cockpit. As aeronautical programs and universities expand, it is the responsibility of effective post secondary educators to insure that quality instruction and research continues to support the future needs of our nation.

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VITA

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