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AB INITIO TRAINING IN THE GLASS COCKPIT ERA: NEW TECHNOLOGY MEETS NEW PILOLTS
A Preliminary Descriptive Analysis

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The Aerospace Department at Middle Tennessee State University and the NASA Langley Research Center entered into a cooperative agreement in 2003. The project is named the SATS Aerospace Flight Education Research (SAFER) and is part of NASA's Small Aircraft Transportation System (SATS) initiative. The SATS project envisions a future flight environment that employs small aircraft to transport people and cargo from point to point using smaller, under utilized airports instead of major gridlocked airports. The aircraft used in the SATS vision would take advantage of a range of emerging technologies including glass cockpits, new structures, and new engines. But with the understanding that the best aircraft and the best systems are still only as good as its operator, MTSU Aerospace set out to explore how pilot training might be different in the SATS environment. The SAFER project therefore takes beginner pilots and completes their initial Visual Flight (VFR) and Instrument Flight (IFR) flight training in technically advanced aircraft to determine how best to educate the next generation of pilots in the next generation of aircraft.

Introduction

Once the use of "glass cockpit" technology was reserved for airline and military flight crews. Today this technology can be purchased off-the-shelf from several general aviation aircraft manufacturers. Placing a general aviation pilot directly into such a sophisticated cockpit has many worried. The General Aviation Technically Advanced Aircraft (TAA)– Safety Study (2003) has already identified several accidents attributed to the fact that the pilots were not familiar with the technology available to them in their aircraft. Several studies are underway to aid pilots as they transition from round-dial airplanes to computerized flight displays – but that is not the emphasis of the study at MTSU. The SAFER project brings in potential pilots with little or no previous experience and teaches them to fly from the beginning with TAA.

The Students

All the students of the SAFER project are college students majoring in Aerospace at Middle Tennessee State University. To become eligible for the SAFER project students had to meet two criteria. First, they must have already been accepted into the program's flight laboratory, which requires a 2.5 cumulative college GPA, or a 2.8 high school GPA for incoming freshman students. Second, the students must have had less than five flight hours of experience with a flight instructor. Fifteen students formed the first cohort of SAFER students. The training began in September 2004 as the fall semester started. The second cohort began in January 2005 as the spring semester started.

The Training Syllabus

The features of the Garmin G-1000 system make it possible to blend the world of visual flight and the world of instrument flight – but that is not the traditional way that students are taught today. Students are taught visual flying first and pass a series of tests to obtain the Private Pilot Certificate. The Private Pilot then takes on additional training and testing to become Instrument Rated and this allows the pilot to fly in and through the clouds. The Primary Flight Display of the G-1000 provides a representation of the horizon that is far advanced from basic attitude gyro indications. The system, in effect, turns a dark night into daylight, and clouds into clear weather. The researchers wanted to take advantage of this capability and sought to teach the new students both the visual and instrument skills all at once.

Part of the cooperative agreement with NASA called for the SAFER project to work in conjunction with the FAA Industry Training Standards (FITS) initiative. The FITS group had previously developed a generic flight training syllabus that combined the training for both Private Pilot and the Instrument Rating into one. The SAFER team took the generic FITS combination syllabus and rewrote it for specific use at MTSU. In time, the syllabus was approved by the FAA under Part 141 and added to

MTSU's existing Air Agency Certificate. The MTSU version of the FITS syllabus (2004) became the first combination Private and Instrument Course for Technically Advanced Aircraft ever approved by the FAA.

The syllabus was unique in two other important ways. First, the entire combination Private and Instrument course is scenario based. Traditionally, pilots are trained using a series of maneuvers that the student masters with drill and practice. The SAFER syllabus still teaches basic skills, sometimes referred to as "stick and rudder" skills, but instead of drill and practice, the maneuver is incorporated into an overall scenario lesson. The very first lesson of the SAFER syllabus is a flight to another airport – a mission, rather than a set of maneuvers. The second unique feature of the SAFER syllabus is that it has no minimum flight time requirements. Traditionally trained students must meet several minimum flight time requirements to move from one step to another and to receive FAA pilot certification. It would be possible for a pilot to have achieved an acceptable performance level in a particular area of training, but still be required to take additional training just to reach the minimum flight time number. Students in the SAFER project are judged by performance only not flight time. When students complete each lesson of the SAFER syllabus they are recommended for testing regardless of how many or how few flight hours they have accrued.

The FAA Exemption

A major problem for the SAFER students is that they are training in a time of transition. The syllabus that they use and the airplane that they use are all new, but the FAA testing is old. Today, the Code of Federal Regulations 14, Part 61.65(a)(1) (2005) requires that an applicant for the Instrument Rating, already be the holder of the Private Pilot Certificate. But the SAFER syllabus bypasses the Private Pilot test when students would otherwise be eligible to take it. Instead, the SAFER students remain as student pilots until the day that they take the combination test and become Private Pilots and Instrument Pilots all at once. So the SAFER syllabus, is in fact, in violation of the Federal Aviation Regulations. To remedy this incongruency, the SAFER researchers petitioned the FAA for relief from 61.65(a)(1) and on December 10, 2004, the FAA granted an exception to this rule for the SAFER project. FAA exemption number 8456 (2004) allows the SAFER students to take a single practical test to gain both Private Pilot and Instrument Pilot privileges. The exemption came with a new Practical Test Standard (PTS) that is to be used by a pilot examiner when administering the combination test. The exemption has only been granted to MTSU and the SAFER project and extends until December 1, 2006.

The exemption has not eliminated all "old versus new" roadblocks to the training. The SAFER students still are required to take two knowledge tests that are administered via computer. The two tests contain questions that are not applicable to technically advanced aircraft. The new PTS that came along with the exemption is better than two separate tests, but still requires many drill-and-practice type maneuvers that do not match well with the SAFER scenario based syllabus. This forces the SAFER students to step out of the role of the scenario and occasionally revert back to pure maneuver practice simply to meet the requirements of the test. Using the old form of testing with the new form of training has become a very real impediment to the students that lengthens the time of training and pushes instructors to "teach to the test" rather than "teach for the real world" as the SAFER project intends to do.

The Methodology

The researchers of the SAFER project are in the preliminary stages of the data collection. The project is on going and the final report of findings will come at the conclusion of the project. The researcher are gathering data to help answer some of the basic research questions: If you teach people to fly from the very beginning using glass cockpits, are there any topics and/or skills that have been taught traditionally that are now no longer necessary? Will glass cockpits create new challenges for beginners that have not been contemplated previously? Can pilots learn essential skills faster and more completely using TAA? To help find some answers, the researchers started a comparison between the SAFER students and the performance of past students that were taught in traditional ways.

The Airplanes

In 2003, the Aerospace Department was able to purchase 25 new airplanes for their professional pilot degree program. Of these, eleven were

Diamond DA40s. As a part of the NASA cooperative agreement, five of the DA40s came to MTSU with the Garmin G-1000 glass cockpit system installed. These five airplanes were taken out of the traditional flight training fleet and are used exclusively within the SAFER project.

Early Findings

The researchers first looked backward to evaluate traditional flight training from the first flight until a person became an Instrument Rated Pilot. The pilot training records of past students served as archival data of traditional flight training. Nineteen past student training records were used in the study. Researchers took the training records of students who had taken both their Private Pilot and Instrument Pilot training all at MTSU and all used the traditional FAA approved syllabus. The traditional syllabus adopted by MTSU and approved by the FAA is the Jeppesen Private Pilot Syllabus (2002) and the instrument portion of the Jeppesen Instrument and Commercial Syllabus (2003). The two publications are commercially available and widely used as an industry standard throughout civilian flight training. The traditional path from first flights to Instrument Rated pilot goes first through the Private Pilot curriculum and testing, then through a series of visual flights to other airports (cross country), and finally to the specific training that leads to testing for the Instrument Rating.

Bottlenecks

Using the archival data provided by the FAA training records, the researchers examined the process of traditional training. What was discovered was a pattern of predictable bottlenecks throughout the training. A bottleneck, for this purpose, is defined as a lesson or area of training that requires the student to receive additional instruction, beyond that which is prescribed in the FAA syllabus, to reach mastery of that lesson or area. These bottlenecks represent areas that are more difficult for students, in that it requires more training to achieve the completion standards. One of the basic research questions is: Do the SAFER students experience the same bottlenecks in their training as traditional students do? Would SAFER students have less problems, or different problems than their counterparts who received the type of training that is available nationwide to the general public and to other college students? In order to answer this question the researchers first identified the traditional bottlenecks in the three phases of the training: Private Pilot, Cross Country, and Instrument.

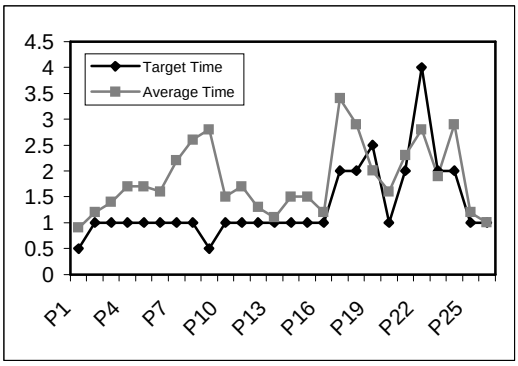

Figure 1. *Private Pilot Bottleneck. Flight Hours versus Lesson Numbers.*

Figure 1 illustrates the bottlenecks faced by traditional students during their Private Pilot training. The Target Time or recommended number of flight hours that should allow mastery in the topics and maneuvers contained in the lesson. The Target Time comes from the Jeppesen Private Pilot syllabus. The Average Time is the actual average hours it took for the traditional students to achieve mastery. It is clear that there are two predictable bottlenecks in this curriculum: Lessons 7 - 9, and Lessons 17 – 18. Lessons 7, 8, and 9 occur just prior to the students first solo flight. Lessons 17 and 18 cover cross-country navigation planning.

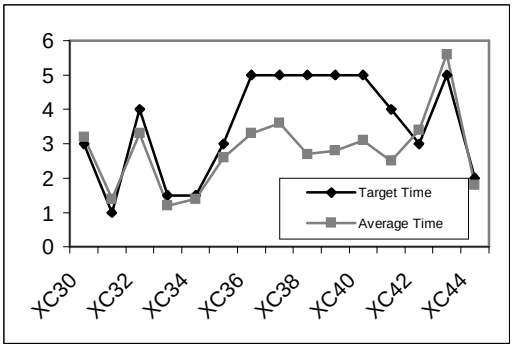

Figure 2. *Cross Country Bottlenecks. Flight Hours versus Lesson Numbers.*

Figure 2 illustrates the relationship between the target flight hours and the actual average time students needed in the cross-county phase. As Figure 2 indicates, students have few bottlenecks in this part of the curriculum. In fact, from Lessons 36 – 42, the students are actually flying

less than prescribed. These lessons each require a flight to another airport with varying distances, but all greater than 50 nautical miles. One possible reason for the fact that average flight time is less than prescribed time in Lessons 39 through 42 is so students can make up for time overruns during the Private Pilot phase of training. If a student passes the Private Pilot tests with above average total flight time, this could be made up by undercutting the prescribed cross-country flight time.

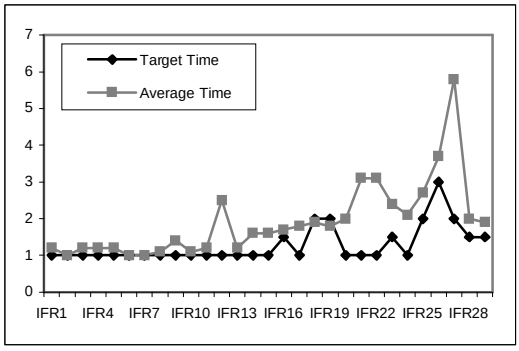

Figure 3. *Instrument Rating Bottleneck. Flight Hours versus Lesson Numbers.*

Figure 3 illustrates that last portion of the path to the Instrument Rating – the actual instrument training. Three bottlenecks are evident in the Jeppesen syllabus for instrument lessons: Lesson 12, Lessons 20 and 21, and Lesson 27. Lesson 12 contains the skill of VOR tracking and radial intercepting as well as partial panel tracking. Lessons 20 and 21 contain the ILS instrument approach, including the partial panel ILS. Lesson 27 is an instrument cross-country review flight.

Setbacks

Figures 1, 2, and 3 all illustrate the average number of flight hours that was required by students to reach mastery on that lesson. The researchers also observed the number of "setbacks" that a student experienced. A setback, in this case, is the need for a student to repeat a lesson that was previously flown. Among the archival data retrieved from the traditional student's training records, 449 setbacks were discovered. Of these, 77 setbacks took place just prior to the first solo flight – an area identified as a bottleneck in Figure 1. This number is 17.1% of all the setbacks experienced by traditional students. Setbacks continued for the traditional students throughout the remainder of the curriculum: 37.6% of the setbacks occurred during the Private Pilot and Cross Country phases of training past the first solo, and 45.2% of the setbacks took place within the instrument phase of the training. This tends to indicate that traditional students run into difficult lessons throughout the entire curriculum in all phases of Private, Cross Country and Instrument – there is never a time when it becomes "easier" for them.

First SAFER Student Data

Since the SAFER syllabus does not have minimum flight times for the course or for each lesson, there is no target flight time number to compare with actual flight time averages, as was the case with the traditional students' data. This makes a direct comparison between Traditional and SAFER student performance more difficult. Also, the Traditional students and the SAFER students do not come across the same topics in the same order, so a lesson-by-lesson comparison is also not direct. However, over the course of the SAFER syllabus, the same set of mastery skills are required, so an evaluation of student setbacks among the groups is possible.

The SAFER students within the first cohort experienced a total of 97 setbacks. Again, a setback is a repeated lesson. Lessons from both traditional and SAFER syllabi require a mastery of the subject matter before the student moves on to the next lesson, so a repeated lesson indicates that the student had difficulty with the subject matter contained in the lesson. Of the 97 setbacks, 59 took place among the SAFER students in the first nine, pre-solo lessons. This represents 60.8% of the total setbacks. The traditional students only had 17.1% of their setbacks occur during this portion of the curriculum.

	Traditional	SAFER
Pre Solo	77 of 449 17.1%	59 of 97 60.8%
Pvt & X-C	169 of 449 37.6%	15 of 97 15.4%
Instrument	203 of 449 45.2%	23 of 97 23.7%

Table 1. *Setback Percentages*

Table 1 presents the comparison of setbacks among the two pilot groups. The traditional students had far fewer setbacks in the early, pre-solo training, but their setbacks increase as they progress through the syllabus. The SAFER students had the greatest difficulty early on, but their setbacks diminished as they continued through the SAFER syllabus.

Skills Comparison

The lessons in the traditional curriculum produced student bottlenecks at Private Pilot lessons 7, 8, 9, and 17, and in the Instrument syllabus at lessons 12, 20, 21, 24, and 27. These lessons each contain many maneuvers and procedures embedded within each lesson, but there is a main area of lesson emphasis in each case. A bottleneck is an area in which students experience difficulty, so the main area of that lesson's emphasis would therefore be the source of that difficulty. Takeoff, landing, and emergency procedures present a significant challenge to all beginning flight students – especially landings. Evidence of this fact is shown by the bottleneck present with traditional students at lessons 7, 8, and 9, and by the disproportionately large number of setbacks at Lesson 9 for the SAFER students. This is the phase of flight where Traditional students out performed the SAFER students – see Table 1 where just prior to solo is where 60% of all SAFER setbacks took place and where only 17% of Traditional students setback took place. Beyond this phase of flight training however, the SAFER students reduced their number of setbacks precisely in areas where Traditional student hit bottlenecks.

On Lesson 17, Traditional students hit a bottleneck – see Figure 1. This area of emphasis is Cross Country Flight Planning. This lesson requires the student to obtain and assess weather information that is pertinent to a proposed visual flight. The student must plan a course of flight allowing for wind drift. The student must calculate time, speed, and fuel consumption for the flight and become extremely familiar with aeronautical charts that depict the terrain features that the flight will traverse. Many traditional students experience a setback at this point, requiring repeat lessons and often multiple repeated lessons. Among the Traditional students there was 0.75 setbacks per student on Lesson 17. In the SAFER syllabus, Lesson 11 is the first lesson in which Cross Country Flight Planning becomes the complete responsibility of the student. Note that SAFER students start conducting mission-oriented flights to other airports from Lesson 1, so at this point they have already been exposed to the elements of Cross Country Planning. SAFER students experienced very few setbacks – an average of only 0.18 setbacks per student on Lesson 11.

Holding patterns prove to be difficult for students when learning the basics of instrument flying. Figure 3 indicates a gap between the target flight time and the actual flight time required to master Holding Patterns at Lessons 14, 15, and 16. Traditional students had 1.06 setbacks per student through these lessons. SAFER students also had difficulty with Holding Patterns. SAFER Lessons 24 and 25 cover Holding Patterns and students on these two lessons had an average of 0.85 setbacks per student.

One of the two largest bottlenecks that faced the Traditional students in the Instrument phase of training took place at Lesson 20 – 22. Lessons 20, 21 and 22 require the student to meet completion standards in the skills of Instrument Landing System (ILS) approaches and Partial Panel Approaches. The ILS requires excellent finesse of the airplane and Partial Panel work requires excellent situational awareness. Eleven percent of all Traditional student setbacks occurred in these three lessons alone, producing an average of 3.2 setbacks per student. At Lesson 22 of the SAFER syllabus, students have been tracking the ILS localizer for several lessons, but Lesson 22 is where full ILS and Partial Panel approaches are among the completion standards. SAFER students had no setbacks on Lesson 22.

The final test of an instrument pilot's readiness is IFR Flight Planning. This requires the instrument pilot to plan and assess the weather, and the weather minimums. The pilot must calculate speed, time, and fuel consumption, but also plan on a flight to an alternate airport if the weather is unsuitable at the intended destination. The pilot must be able to file and later receive an IFR clearance and be able to expertly communicate with air traffic controllers all through the flight. Traditional students had a setback at this lesson with an average of 1.18 setbacks per student. The recommended amount of flight time to complete this lesson is 2.0 flight hours. Traditional students however took 5.8 hours, on average, to meet the completion standards of the lesson. In the SAFER syllabus, the IFR Flight Planning review lesson is number 26. No SAFER students had a setback on Lesson 26.

A comparison of average student setbacks across the entire curriculum reveals that SAFER students have more setbacks in the pre-solo phase than do the Traditional students. But Traditional students continue to have setbacks in

rising numbers throughout, while SAFER students have a reduction in setbacks. Figure 4 illustrates the average number of setbacks among student for the Pre-solo lesson, the remainder of the Private and Cross Country training, and the Instrument Rating instruction.

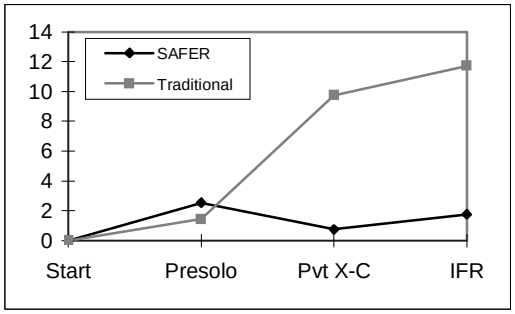

Figure 4. *Setbacks per student. Traditional students versus SAFER students.*

Conclusions

The researchers understand that we are dealing with small groups and that much more data must be taken before any claims can be made. But at this point the SAFER students have a greater number of setbacks in the lesson just prior to the first solo flight than do traditional students. The flight instructors that teach in the SAFER project say that the SAFER syllabus is very "front end loaded." This means that SAFER students are being taught cross-country flight planning, navigation, and instrument flight principles all before the first solo. The evidence, including Figure 4, seems to suggest that SAFER students pay a penalty for this expanded curriculum at the very start of the course. Traditional students are not taught cross country planning, navigation, and instrument principles before solo, and spend their time practicing takeoffs and landings in anticipation of the first solo. This focused attention on solo among traditional students may be why they perform with fewer setbacks in the pre-solo phase. But it appears that the "penalty" the SAFER students pay in the early lessons, are repaid later in the syllabus. The SAFER students seem to start reaping the rewards of their expanded curriculum after the first solo as the need for repeat lessons drops off to an average of only 0.76 setbacks per student between solo and the end of the SAFER stage 2 – which is approximately the cross country stage for Traditional student. Traditional students at this point experience an average of 9.73 setbacks. The evidence indicates that the largest benefit of the SAFER project is toward the end when both groups are preparing for the tests that cover the Instrument Rating. In that last phase of training the Traditional students had an average of 11.73 setbacks each, while the number of average setbacks among SAFER students was 1.76 each.

All the data presented here should be considered preliminary. The second SAFER cohort is underway at the time of this writing and the researchers will wait to see what additional data will bring to the conclusions. It is important to emphasize here that one of the overriding interest of the SATS program is to see if pilots can be trained in technically advanced aircraft that will meet or exceed the current training standards and to accomplish this in less time and with less money. The early information shows that the SAFER students who have completed the program and passed the combination Private Pilot and Instrument Rating test have done so with an average of 88.66 flight hours. The student who followed the traditional path completed the Instrument Rating at an average of 134.3 flight hours. The difference between the averages is approximately 45 hours. Forty-hours of flight instruction and airplane rental could cost the pilot approximately $6,000.

Although early in the project, the researchers are confident that the use of "glass cockpit" technology together with scenario training has great promise. Data from the remainder of the SAFER project will produce a list of "best practices" for flight instructors to use when teaching in TAAs. Ultimately, the project should lead to improvements and alterations to how pilots are to be trained in an environment of emerging technologies.

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