Reasons behind the Lack of Simulator Usage in Part 61 Primary Pilot Training

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REVIEW OF RELEVANT LITERATURE AND RESERACH

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The use of flight simulators, flight training devices (FTD), and basic/advanced aviation training devices (B/AATD) hereafter collectively referred to as S/TDs have been proven through multiple studies to greatly aid in the training of pilots. S/TDs have been used extensively and very successfully by both the air carrier industry (Part 121) and the military for many years, so much so that they have become ubiquitous with pilot training in these aviation sectors. S/TDs offer many advantages over training in an actual aircraft. These advantages include the ability to stop the flight at any point to discuss training points, quickly reset the simulator to perform multiple iterations of a key task, simulate any combination of environmental conditions, and simulate emergencies not safely possible in the real aircraft. Why then, with all of the advantages and a proven record of success, is the use of S/TDs in general aviation (GA) primary flight training and more specifically Part 61 primary pilot training so rare? This paper will examine many of the primary reasons behind the lack of S/TDs in Part 61 primary training. It will explore the regulatory limitations, cost factors, flight instructor motivations and attitude, and the multiple fidelity issues that plague current GA S/TDs targeted at the primary training market. Many of the fidelity issues are perceived shortcoming held by the training industry and federal regulators and not necessarily substantiated by empirical data gained from studies and test. This paper will not attempt to distinguish between perception and facts; only present the information as documented in available literature. After reading this paper it should become apparent to the reader how many of the reasons discussed have conspired to inhibit a broader acceptance of S/TDs in Part 61 primary flight training.

Before exploring the reasons behind the lack of ST/D utilization in Part 61 training it is important to define exactly what Part 61 primary flight training is. Part 61 is the portion of the Federal Aviation Administration (FAA) Federal Aviation Regulation (FAR) that deals with flight training that is designed specifically for flexibility in both the way a flight instructor can teach the required material and the schedule in which the student can complete the training (FAR, 2011). The instructor is usually a Certified Flight Instructor (CFI) who works free lance or for a Fixed Based Operator (FBO) providing pilot training. The CFI is free to teach as they like as long as they train their students to the requirements found in FAR 61.109(a) and the practical test standards (PTS) required for the initial pilot certification. Student pilots work one on one with the CFI to attain the skills necessary to pass the practical test given by an FAA check airman or designated pilot examiner. Part 61 student pilots must have a minimum of 40 hours of flight training before they are eligible to take their check ride (FAR, 2011). 40 hours is the minimum requirement, the national average is 70 hours (Hirschman, 2010). Part 61 training is one of two major producers of newly minted pilots and is not as regimented as the other option for pilot training known as Part 141. Primary pilot training deals with fundamental flight skills required to attain entry level pilot certification. This certification can be in form of Private Pilot, Recreational Pilot, or the more recent Sport Pilot certificate. FBOs provide the instructor, aircraft and facilities for training Part 61 student pilots. FBOs are airport tenants that normally provide an array of services to the airport community. These services include but are not limited to aircraft fuel, charter flights, rental planes, pilot lounge, flight planning resources, and pilot training. Normally the aircraft used in pilot training is owned or leased by the FBO. The FBO provides the logistical support and maintenance for the training aircraft fleet. This paper focuses on Part 61 primary private pilot training provided by many FBOs nationwide.

It is equally important to define what is considered a flight simulator and what is considered a flight or aviation training device. The FAA in FAR 61.1(b)(5) defines a flight simulator to be a device that "is a full-size aircraft cockpit replica of a specific type of aircraft, or make, model, and series of aircraft" and provides at least "a three degree freedom of motion system" (FAR, 2011). Flight simulators of this nature are rarely found in the Part 61 primary training sector mostly due to the high cost associated with the implementation of motion systems. The more commonly found device in Part 61 training is the Flight Training Device or FTD. The FAA in FAR 61.1(b)(7) defines an FTD as "a full-size replica of the instruments, equipment, panels, and controls of an aircraft, or set of aircraft" (FAR, 2011) The FTD is not required to support motion or visual systems. Many FTDs can be quite sophisticated while other can be very rudimentary such as PC based instrument trainers. The most recent addition to the FTD category of training devices is the basic aviation training device (BATD) and the advanced aviation training device (AATD). These devices were introduced in July of 2008 when the FAA published Advisory Circular 61-136, FAA Approval of BATD and AATD (FAA AC 61-136, 2008). Since 2008 the majority of B/AATDs have targeted the GA training sector. Most of today's Part 61 training devices fall into these categories and as such will be the focus of the fidelity issues explored in this paper.

Regulatory Limitations

By far the biggest impediment to more wide scale acceptance of S/TDs in Part 61 training is the regulatory restrictions placed on the amount of S/TD time that can be credited towards meeting the requirements of the private certificate. As of the 2011 FAR section 61.109(k)(1) "a maximum of 2.5 hours of training in a flight simulator of flight training device representing the category, class, and type, if applicable, of aircraft appropriate to the rating sought, may be credited toward the flight training time required" (FAR, 2011). This regulation allows for only a small fraction, just 6%, of the required training to be counted towards the minimum requirements. It is interesting to note that the 2.5 hour credit is the same regardless of the sophistication level of the S/TD, the FAA makes no distinction (FAA, 2011). This limitation has been unchanged in the FAR for over 30 years despite the fact that S/TDs have evolved substantially in levels of sophistication and fidelity during that time. It is unknown as to the exact reasoning behind the FAAs decision to not expand the number of creditable hours. Research into the federal registrar and Notice of Proposed Rule Making (NPRM), both sources where FAA reasoning in decision making is formally documented, did not provide clear answers. It is reasonable to look at the approval process of PCATDs to gain insight into the FAAs thought process (GAO, 1999, p. 6). According to the FAA it has never directly sponsored a study that evaluated the performance of flight training devices. FAA instead has relied on empirical studies and its professional judgment (GAO, 1999, p. 6). The FAA in AC 61-136 references studies conducted by the University of Illinois and Embry-Riddle University as to their decision to greater utilize S/TDs in instrument flight training, however these studies did not address number of flight hours to credit, instead the FAA states they used their experience and professional judgment to derive time to credit (GAO, 1999, p. 8).

With the lack of clear documentation it can be reasonably assumed that the FAA still views S/TDs as lacking in key areas in fidelity as to provide only limited value to the training of student pilots in the required psycho-motor skills necessary to fly competently and safely. The FAA may also view the actual aircraft, many of which are designed specifically for pilot training, as the primary flight training device and do not see a compelling reason to utilize a ground based training device. Airplanes such as the Cessna 152, 172, and Piper PA-28 were designed specifically as training aircraft with benign and forgiving handling qualities. While future advances in fidelity and sophistication of GA S/TDs may cause the FAA to reexamine its restrictions on hours that can be credited toward the certificate, today Part 61.109 stands as a major inhibitor in the widespread adoption of S/TDs in Part 61 training by negatively influencing the financial decision of FBOs to purchase and utilize S/TDs.

Cost

Cost also tends to play a major role in limited S/TD use in Part 61 training. These cost factors manifest themselves in multiple areas. These areas include the cost of simulator acquisition and operation by the FBO, and the limited cost savings realized by the student pilot when utilizing an S/TD for training.

As the level of sophistication in GA simulators rise to address the fidelity areas of weakness explored elsewhere in this paper so does the acquisition cost. On average a GA S/TD cost an FBO between $40,000 and $90,000 (GAO, 1999). This may appear like a real bargain when compared to full-motion simulators used by airlines to train commercial pilots which can cost up to $20 million (GAO, 1999, p. 4). Cost for many GA S/TDs can exceed the cost of a training airplane (Hirschman, 2009). Within the last few years Redbird Corporation has released the most sophisticated GA primary trainer currently on the market (Hirschman, 2010). This simulator provides for three axis motion and a wide 200° FOV_H. The cost of a new Redbird FMX simulator ranges from $59,800 to $67,295 depending on the option packages chosen by the purchasing FBO (Redbird Flight Simulations, n.d.). Compare this cost to the current retail value of $40,000 for a used 1980 Cessna 172N Skyhawk training aircraft (Vref Aircraft Value Reference, n.d.). While operating cost will be lower and profit margins higher for the Redbird its utilization rate will be much lower due to the previously discussed regulatory restrictions on maximum allowable training credit. From a business perspective FBOs may not be able to financially justify the purchase of an S/TD if forecasted utilization will only be 6% per student. At 6% utilization the return on investment will take much longer. Additionally the S/TD could become technologically obsolete before the FBO has recouped its investment leading to a loss. For an FBO the purchase of an S/TD is a large capital expenditure and a risky gamble as to if it will be profitable for the company in the long term. For many FBOs it is a financial gamble they are not willing to take. A safer decision is to opt to have the student conduct 100% of the training in the actual aircraft.

Controlling cost during flight training is a priority for many student pilots who pursue the private certificate through Part 61 venues (Pope, 2011). Normally these pilots are self funded with little or no external financial assistance such as federal student aid or the GI Bill. Cost is a major concern to these individuals. It may initially appear that greater S/TD usage by the student could reduce overall cost substantially by reducing the number of training hours from the national average of 70 to a number closer to the minimum requirement of 40. Upon closer examination this just does not seem to be the case. The more sophisticated the simulator the higher the cost to train in it. An Internet survey of several FBOs nationwide demonstrates this point. At Northampton Airport in Massachusetts the cost to log one hour of training time in a Redbird FMX AATD is $65. To rent a Cessna 152 at the same airport cost $92 (Northampton Airport, n.d.). This is a savings of only $27. At Palo Alto Airport in California the Redbird rents for $69 an hour. A Cessna 150 at the same airport rents for $94 an hour, a delta of only $25 (Advantage Aviation, n.d.) . The last and most pronounced example was found at Hillsboro Airport in Oregon. Only $1 separates the rental cost of the Redbird at $87 an hour from a Cessna 152 at $88 (Oregon Flight Academy, n.d.). There are additional factors that must be taken into account to further realize the fact that S/TD use by the student will save them little money in the training process. A University of Illinois study found a Transfer Effectiveness Ratio (TER) of only .75 when students utilized simulators for primary flight training (Lee, 2005). This equates to spending two hours in an S/TD in order to save 1.5 hours in an actual aircraft. Using this TER and the Northampton Airport rental rates, which provide the greatest hour by hour savings of $27, we find that the student will spend $130 (2HRx$65) utilizing the Redbird in order to save $12 had s/he flown the actual aircraft for 1.5 hours (1.5HRx$92). Beyond the authorized 2.5 hours of time allowed by the FAA it becomes apparent that there is little economic motivation for a student pilot to pursue training in a simulator. This lack of an economic motivator makes it less likely to influence his choice when searching for flight training. Furthermore an established student is less likely to pressure his FBO to purchase an S/TD.

Flight Instructor Motivations & Attitudes

Another reason for lack of greater S/TD utilization in Part 61 primary flight training deals with both FAA regulations and flight instructor motivations and attitudes towards S/TDs. FBOs that offer Part 61 flight training attract a wide array of CFIs. These CFIs are motivated to teach flight training for a variety of reasons. A large percentage of Part 61 CFIs are young, usually between 20-25 years old, and freshly certificated as instructors (Hirschman, 2010). Many of these instructors have obtained the instructor certificate for one purpose: to build flight hours. This is a common career path for aspiring airline pilots. They will teach as CFIs in order to attain the minimum flight hours required to land a more lucrative job as a first officer at a regional airline. A CFI who is providing flight instruction to a student in a training aircraft is allowed to log the flight time as PIC per FAA FAR 61.51(e) (FAR, 2011). This is known as "building time." To these individuals flight instructing is a means to an end. If the individual is not building time while instructing then in their mind they are wasting their time. The lack of utilization of S/TDs due to instructor motivations and attitudes results from long standing FAA regulations. The FAA does not allow flight instructors to log S/TD instruction as PIC flight time (Hirschman, 2010). Providing flight instruction in an S/TD does nothing to further the CFI's ultimate goal of building hours. While the CFI still charges the same hourly rate for instruction as in the real aircraft his motivation is the flight time not the monetary income. For this reason many Part 61 CFIs will strongly encourage students to train in the actual aircraft as opposed to an FTD or simulator regardless of the volume of studies extolling the benefits of S/TD usage (Hirschman, 2010). Student pilots are inclined to trust the judgment and recommendations of their instructors. They may not have enough experience with simulators to be aware of the many advantages such devices can have to enhancing training time. Students see the instructor as the subject matter expert in all things aviation and believe the instructor has their best interest in mind. Sometimes this is not the case.

Lack of Fidelity

A lack of fidelity in current GA S/TDs targeted at the GA primary trainer level is another major reason for the lack of widespread adoption. GA primary trainers up until recently have lacked fidelity in several keys areas. These areas include flight control layout, sound systems, visual systems, motion and control loading. Primary flight training is visually and physically intense, student pilots learn to fly the aircraft from what they see and interpret outside of the cockpit. This type of flying is called "attitude flying." In addition the student is taught to also rely on other senses such as aural and tactile to fly the aircraft. This "seat of your pants" type flying requires a high degree of fidelity from the S/TD. Fidelity usually means higher sophistication and greater cost to produce (Lee, 2005). GA ST/D designs tend to be less sophisticated to keep cost reasonable and affordable. This leads to a generic cockpit layout and lack of fidelity. Overall GA low end S/TDs tend to rely more on instrumentation to convey the aircraft state than on more subtle indicators such as wind noise, motion, vibration, and visual scene (GAO, 1999). This is because instrumentation is much easier and cheaper to model than the physical indicators. While instrument interpretation is a part of the basic skills acquired in primary pilot training the majority of emphasis is on the student's eyes being outside of the airplane (Ortiz, 1994). Sole reliance on instruments is usually not introduced until the pilot begins to train for the instrument rating after initial certification.

Flight control layout and design in most GA primary training devices is usually generic and only loosely resembles the actual training aircraft that the student conducts flight training in. Transfer of training (TOT) is limited under these circumstances and can actually have a negative effect once inside the real aircraft. As training progresses students begin to internalize certain cockpit tasks and depend less on visual confirmation and more on other senses such as their proprioceptive senses for feedback (Lee, 2005). For example, initially when learning the task of takeoff the student will visually confirm that the throttle has been placed in the full forward position. After repetition of the task the student will come to rely only on the extension of his/her arm and the pressure of the throttle handle in his/her hand to confirm that the throttle is fully forward and set for takeoff power. In a simulator that does not accurately replicate the placement of the throttle on the control panel, the axis on which the throttle operates, the limits of its operation and the feel of the knob, the overall positive learning transfer will be of little value (Lee, 2005). In addition switch placement and trim wheel locations if not accurately replicated can result in a student grabbing for air or flipping the wrong switch once in the actual aircraft. This negative transfer of training can become a safety of flight issue during certain circumstances. “Failure to provide these tactile cues for control discrimination adds unnecessary visual workload for the simulator pilot and may force the development skills inappropriate for the aircraft flight operations that the simulator intended to represent (Lee, 2005, p. 59). GA S/TDs will need to become more make and model specific in the future in order to address this TOT issue and overcome this limitation (Lee, 2005, p. 58).

Sound is also a very important aspect in primary flight training that is currently lacking in fidelity for GA S/TDs. Student pilots use their sense of hearing to augment subconsciously many flight task. These include determination of overall engine operation and determination of general airspeed by level of wind noise heard within the cabin. Most low end simulators use very generic engine and ambient sounds (Ortiz, 1994). The changes in engine and propeller sound can provide important feedback to the pilot on the attitude of the aircraft. A propeller that is “unloading” or increasing in RPM usually provides indication that the aircraft has leveled off from a climb or has started a descent. Loading of the propeller or decreasing the RPM usually indicates the aircraft has entered a climb. Within GA S/TDs these sounds are usually absent. Only changes in throttle position incur a change in engine sound. A lack in sound fidelity can cause a primary student to ignore auditory indicators and rely solely on instrument indications resulting in more time spent staring at the flight panel and less time scanning outside the aircraft. Besides ambient sounds radio traffic to include other aircraft and ATC can also be grouped into this fidelity area. Radio communication is a critical aspect of pilot training as the student pilot must master the skill of multitasking by actively listening and responding to the radio while managing other cockpit tasks.

One of the biggest drawbacks of GA S/TDs is the limited visual fidelity in both FOV_H and the detail of the computer generated image. Many GA trainers have a very limited visual field of view (FOV) both horizontally and vertically (GAO, 1999). Primary training is a very visually intensive task. Many of the task from the FAA's Practical Test Standards (PTS) require a 270° field of view (DOT/FAA, 2002). Many simulators only provide 90° FOV_H and limit this view to the front of the aircraft (Redbird Flight Simulations, n.d.). This equates to essentially flying with horse blinders on. Basic private pilot maneuvers such as turns around a point require the pilot to look out the side of the aircraft at a point on the ground, this is impossible to do in the majority of GA S/TDs due to FOV_H limitations (DOT/FAA, 2002). When a student pilot learns to fly the traffic pattern he must be able to determine while flying downwind when to turn to the base leg by looking over his left shoulder at the runway threshold (DOT/FAA, 2002). This maneuver also cannot be replicated in the majority of GA S/TDs due to the limited FOV_H. In addition to utilizing a wide FOV_H student pilots subconsciously utilize the granularity of objects in their peripheral vision to judge height above the ground. This is an extremely critical skill to master when learning to flare an aircraft just prior to landing and can be "one of the most difficult tasks for student pilots to master" (Lee, 2005, p. 6). A lack of detail in the S/TDs CGI can lead to the development of compensatory skills which ultimately lead to a negative TOT for the student.

Another drawback to the training value of GA S/TD is their lack of motion implementation or vibratory indicators. While study after study has demonstrated that motion of a simulator has very little, if any, impact on learning, the FAA still believes in its professional judgment that motion is an important feature to simulators (FAR, 2011). With primary flight training there may be a valid argument for the inclusion of motion as learning to fly is rooted in the foundation of "seat of the pants" flying. Stick and rudder skills are founded on flying where the student develops a true feel for the airplane. Noted aviation columnist Budd Davisson describes this as “the ‘feeling’ that comes from within as the result of every force acting on the airplane being transmitted to the pilot through the seat cushion…. Everything the airplane is doing is focused on your body in the form of subtle sensations brought about mostly by centrifugal and centripigle forces” (Davisson, n.d). Until the introduction of the Redbird FMX simulator most GA S/TD were static installations (Redbird Flight Simulations, n.d). “Seat of the pants” flying is not possible with today’s GA S/TDs even with the more sophisticated Redbird because of the inability to replicate vertical and horizontal G forces. The sensation of yawing, also critical to learning how to master coordinated turns (a PTS task) is also absent in a static S/TD. Without motion or vibration the training of stalls in an S/TD is of little use. Students are taught to identify the onset of a stall by feeling the buffeting of the aircraft as it prepares to stall (DOT/FAA, 2002). This sensation is totally absent within a static S/TD.

The final issue with fidelity involves the lack of control loading in today’s GA S/TDs. Refining motor skills is absolutely critical to the student pilot’s success in primary flight training. General aviation primary flight controls are quite rudimentary compared to sophisticated commercial aircraft which employ hydraulics and fly by wire to move primary control surfaces such as the ailerons, elevators, and rudder. GA training aircraft controls are directly linked to control surface via cables and rods (Lee, 2005, p. 54). All aerodynamic forces applied to the control surfaces are felt by the pilot through the controls. This is why control loading fidelity is so critical within GA S/TDs. These “stick forces” are unique to each aircraft. The task of landing an aircraft is one of the most challenging and difficult task for the student pilot to master. Critical to the successful mastering of this task is refined motor skills to manipulate the yoke or control stick to continually apply back pressure as the aircraft settles into the landing flare and ground effect. Accurate aircraft control loading replication by the S/TD is vital to developing the student's psycho-motor skills. The majority of GA S/TDs have greatly simplified control loading or lack the feature completely. It has been found that large differences between an S/TD and the actual aircraft's control loading can actually create a negative TOT (Lee, 2005, p. 56). The development of both gross and fine motor skills required to master the maneuvers require an S/TD that closely models the training aircrafts control loading. Major differences could do more harm to the student pilot than good, prolonging training, and frustrating both student and instructor.

Conclusion

In conclusion, multiple issues have conspired to block deeper penetration of S/TD utilization into the Part 61 sector of the primary pilot training industry. These issues include federal regulations, cost, flight instructor motivations and attitudes, and general lack of fidelity. A major shift in attitude and currently held beliefs will need to occur at both the federal and industry level before true change can be realized. GA ST/Ds are currently caught in a vicious circle. Because of the cost factor GA S/TDs manufactures tend to build less sophisticated devices. This normally equates to less fidelity. Less fidelity usually means less realism which means lower training value. The FAA translates this perceived low training value into regulations that allow for only a very small fraction of the overall training requirement to be met using the device. The training industry, working within regulatory constraints, does not see a strong enough cost/benefit to make large investments in simulator equipment and technology driving manufactures to reduce cost and sophistication.

Because the cost of high physical fidelity is prohibitively expensive for the low end GA market, change will not occur, at least in the US flight training market, until the FAA concedes that "the purpose of a flight simulator is not to replicate the physical flight environment, but to create the experience of a flight environment for a pilot" (Lee, 2005, p. 83). Once this occurs new research and technology may deliver simulation options that will be less-costly and provide the required training environment to allow the FAA to credit more hours towards the overall requirement. This in turn will substantially reduce the amount of time required in the real aircraft, reducing student training cost, increasing simulator utilization and possibly reducing the average total time required to achieve proficiency for the check ride.

Despite the many issues facing the state of simulator use in GA training today the future may be brighter. While economics may be one of the present stumbling blocks it may also become the catalyst for change in the future. The level of GA flight simulator sophistication continues to rise, while the cost of technology continues to fall. On the traditional training front fuel prices are skyrocketing making actual aircraft operation more and more expensive, the fuel used by GA trainer aircraft, AVGAS, is under attack by environmental groups, today's fleet of trainers continues to age with many aircraft over 50 years old. All of these issues will make actual training aircraft more costly to operate and maintain equating to higher training cost. Higher cost will lead to fewer student pilots pursuing flight training. The industry, with their very survival at stake, will be forced to look at all means available to reduce cost. Growing industry pressure will force the FAA to relook its current regulations. There should be no doubt that simulators will play a key role in this future and will someday be as ubiquitous in Part 61 training as they are in air carrier and military pilot training today.

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