FLIGHT SIMULATION IN AIR FORCE TRAINING. A KNOWLEDGE TRANSFER EFICIENCY PERSPECTIVE

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For decades the issue of training through simulation has been discussed and studied to show its value and importance in fighter pilot training programs. Besides the fact that simulators are less expensive than a real airplane, and eliminate the operational risks that are present in a real flight they bring a significant contribution to the pilot training by their fidelity and realism that they show in such scenarios as in the reality. To measure the efficiency of training transfer from simulator to the aircraft, performance indicators were defined. The purpose of this article is to define these performance indicators and measurement of training transfer within the flight simulator involvement.

Key words: *flight simulation, training effectiveness, training transfer.*

1. INTRODUCTION

Simulation is a method used in aviation that refers to an amount of technology that reproduces the interaction human-aircraft for training purpose, performance evaluation, research and development. Primarly it refers to the creation of ground physical representation to reproduce the technical elements and the behavior of an aircraft under various conditions and in interaction with the human element. The current paper refers to an analysis and description of some numerical indicators that show how the flight simulator influences pilots' training.

2. FLIGHT SIMULATION BENEFITS

Applying simulation as a specific task in training has several characteristic features:

1. A great part of preparation and training for pilots and ground staff is now done in simulators.
2. The obligation of testing through simulation led to the standardization of flight simulators, particularly in the civil, even internationally, to ensure consistency of the system and to correlate links between operators and regulatory authorities and manufacturers of systems.
3. Simulation makes a major contribution to the improvement of safety in aviation, reduces overall costs of training and has a good impact on environmental conservation.
4. Simulation plays a fundamental role in research, development and evaluation of aircraft.

The obvious benefit of using simulation is that time spent for training in a simulator can replace time spent in flight (Caro:1979, p.493). If a simulator is efficient, then the time spent in the simulator can replace the time spent on the plane or even more. For example to practice an ILS landing, with crosswind, in reality it can take more than 20 minutes between approaches, leading to congestion of air traffic, even changes in weather conditions conducive for such training. In simulation, this exercise can be performed many times without resource consumption, without affecting the air traffic or depending on air traffic controller, also the weather conditions can be set and maintained with specific criteria (direction and wind speed introduced by instructor). The aircraft can be re-positioned on the glide path without the need of a traffic circuit or it can be "frozen" to further explanations given to student.

The second major gain is that a simulator can be exploited even 24 hours a day and does not depend on weather conditions and operating cost varies from 5% to 20% of the cost of using an airplane, so the time required for general training and the total cost is reduced.

With all these arguments in the favor of using simulators, numerous discussions during their development on how to define the real effectiveness of training and knowledge transfer in real life were conducted. Even now this issue is not completely defined and understood.

3. PERFORMANCE INDICATORS

Evaluation of efficiency is done by estimating the knowledge transfer time in training, so the degree to which a specific task of learning a maneuver is facilitated by using the simulator. To measure this transfer usually operates at least two groups of students. Learning speed of the procedure using both the plane and the simulator by the first group of students, is measured and compared with the learning speed of a control group that only instructs on the plane.

The first indicator that resulted from these determinations was TEE (Transfer Effectiveness Evaluation). The easiest way to assess the quality of acquiring the knowledge is to measure the performance of certain skills before using the simulator and compare the measurements of the same skills after training in a simulator (Martin:1981). Basically it measures the ability of the pilot to execute a specific maneuver or procedure before and after the training on the simulator and calculates a ratio, resulting in an TEE indicator percentage.

$$TEE=[(T_a-T_{as})/T_a]x100 \qquad (1)$$

where, T_a is the amount of airborne time needed by a control group to reach a specific level without using the simulator; Tas represents the time spent in aircraft necessary for an experimental group that uses simulator in its training to reach the same level as the control group.

To better understand the TEE indicator an example is given: for reaching a certain level for solo flight in traffic circuit, a control group that has never used the flight simulator in its training, needs 8 hours of flight per pilot. Other four groups that have used flight simulator as a training aid, have reached the same level of training after 7, 5, 8 respectively 4 hours of flight. Can say that the 4th group that used only 4 hours of airborne training, the TEE indicator is 50%, and for the group that has flown 7 hours, TEE is 12.5%. In Figure. 1, it can be seen the dependence between hours of flight and TEE indicator.

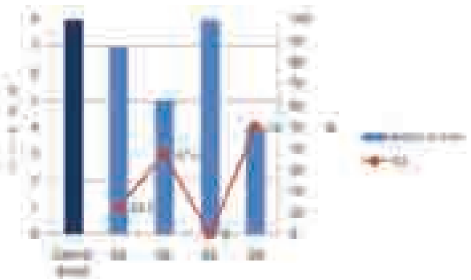

Fig. 1. TEE analysis

As TEE is higher, it can be said that flight simulator played an important role in pilots training. Some civil simulator can prepare pilots to perform solo flight without using the plane before. For so called ZFTT simulators (zero flight time training), TEE is 100%.

Another indicator of efficiency is TER (Transfer Effectiveness Ratio).

$$TER=(T_a-T_{as})/T_s \qquad (2)$$

T_s is the amount of time used in simulator by the experimental group that uses flight simulation in its training process.

In the example below, the four experimental groups have completed a training program to achieve the level of control group as follows (Table 1): each pilot from the first group has used the flight simulator for 2 hours and flown 7 hours; in the second group each pilot has trained 3 hours in flight simulator and 5 hours in airplane, for the third group was used 1 hour of flight simulator and 8 hours of flight, and the fourth, 3 hours of flight simulator and 4 hours of flight.

Table no. 1. Groups' training programs.

	Simulator time	Airborne Time
Control group	0	8
Group 1	2	7
Group 2	3	5
Group 3	1	8
Group 4	3	4

In **Figure 2** an example of TER analysis can be seen.

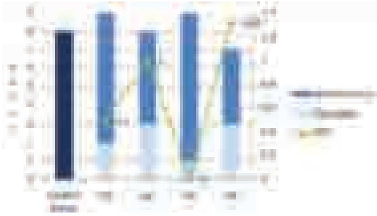

Fig. 2. TER analysis

Therefore, for the first group TER equals 0.5, this means that one hour of airborne training is equivalent of two hours of training in flight simulator. For the second group TER is 1 which means that the training in the flight simulator can fully replace the training in the airplane. TER indicator for the third group is 0.

Usually this indicator is between 0 and 1. If the ratio between the cost of an hour of using the flight simulator and the cost of flying hour is known, and compare it with the TER indicator, some aspects about the economy of flight can be made. If the TER indicator is lower than this ratio, it can be said that the contribution of simulator to the training of pilots was deficient in resources. TER for the fourth group is 1.33 which means that 3 hours of flight simulator equivalent to 4 hours of flight. In this case, due to a less stressful environment, the simulator has helped the pilot to understand the phenomenon of flight, better than would be done in a real flight.

Cumulative results for more maneuvers of the same pilot, show the degree of progress in achieving the performance required by the use of simulators.

Another indicator is CTER (cumulative transfer effectiveness ratio).

This indicator is defined as the ratio of two numbers:

$$CTER=(S_a-S_{as})/S_s \qquad (3)$$

The numerator is a difference between the number of sorties made by a group of pilots who has not used the simulator in its training and the number of sorties made by the group who has used simulator as a training aid in its preparation.

The denominator is the number of sorties made in simulator by the group who used flight simulator.

In the example below, two situations are presented.

The first one is that each pilot in an hour of training, either in simulator or flying, has executed 4 sorties. Each traffic circuit is approximately 15 minutes long. So the training was conducted as follows: the control group performed 32 sorties to gain the desired level, first group has executed 8 sorties in flight simulator and 28 flying, the second group has performed 12 sorties in simulator and 20 in flight, the third group has used 4 sorties in simulator and 32 in flight, and the fourth group has executed 12 sorties in simulator and 16 in flight.

For this situation the values of CTER indicator are the same as those of TER indicator (**Figure 3**)

Fig. 3. CTER analysis 1

But things are different in the second case, in which different groups cannot run 4 sorties per hour, but 3 sorties or 6 in some cases.

Due to air traffic near the airport, some sorties have been made in 10 minutes, others in 20. The third group made a sortie in 20 minutes, so the total sorties executed were 3 in the flight simulator and 24 in airplane, and the fourth group executed a sortie in 10 minutes, a total of 18 sorties in simulator and 24 in flight.

In **Figure 4** it can be seen the dependence between the number of sorties and CTER indicator.

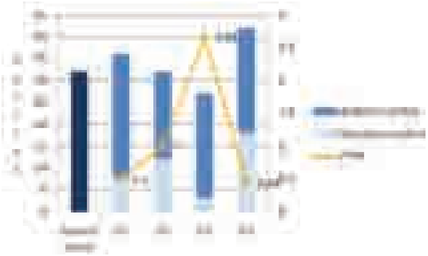

Fig. 4. CTER analysis 2

CTER indicator gives us a comprehensive picture of the economy of flight. As fewer sorties needed to achieve a certain level in training, the CTER indicator is greater.

The last indicator of efficiency is ITER (Incremental Transfer Effectiveness Ratio). ITER indicator give a situation of the economy of flights for a group that a specific criterion must be achieved. Clearly, after a certain number of hours, the benefit of an extra hour in the training device starts to reduce. In other words, there is a point where (depending on the relative hourly training costs) the cost effectiveness of using a flight simulator is a maximum thereafter it reduces towards zero (Allerton:2009).

$$ITER=(T_{a1}-T_{a2})/\Delta_s \qquad (4)$$

T_{a1} represents the amount of airborne time needed by a group to reach a certain level of training; T_{a2} represents the amount of airborne time needed by another group to achieve the same level of training as the first group; Δ_s represents the difference between the time used in simulator by the first group and the time used in simulator by the second.

Table no. 2. ITER analysis

	Control group	Group 1	Group 2	Group 3	Group 4
Control group					
Group 1	0.5				
Group 2	1	2			
Group 3	0	-1	-1.5		
Group 4	1.33	3		2	

In **Table 2** an ITER analysis was conducted. There is no value for ITER indicator of the fourth group in relation with the second, because both groups have used equally the simulator; and the ITER value for group 3 in relation with control group is 0, because both groups have used equally the airplane, so the simulator was used for nothing. After this analysis it can be said that if ITER is positive, then the transfer of knowledge from the simulator is positive. A high value of ITER shows that the proposed performance level was achieved by a group that used the simulator more effective than another, and resources of real airplane were saved.

These indicators show how to guide the training and how to use wisely the flight simulator.

4. CONCLUSIONS

A better understanding of the role and the importance of using flight simulators in pilots training is performed by analyzing and examining these indicators of training transfer effectiveness. In addition, if the economic and financial analysis of using flight simulators as training aids is known, then it can be determined in which way must to guide the training program, and how to properly use the simulator to gain the maximum efficiency. Analyzing this two factors of influence, training transfer effectiveness and financial benefits, it can be said if training was conducted with economy or waste of resources.

It is well known that in practice, things are quite different. The performance level of a group can not be established with certainty only relying on these indicators, but it can make an objective assessment of the use of the simulator as a training aid.

For future work, a cost-benefit analysis is required to determine the real gain of usage the flight simulators in training.

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