ATC SIMULATION FOR FLIGHT TRAINING; THE MISSING LINK

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30 May 2017

Abstract
This paper presents the state of piloted flight simulation fidelity with a focus on the missing link needed to complete the flight simulation experience, namely the simulated ATC environment (SATCE).

To date, there has been a great deal of effort invested in providing the highest level of flight realism possible. However, little investment has gone into systems which are used to improve communication skills with ATC while in a populated active airspace.

It's important to note that the relatively few SATCEs is not due to the lack of technology, since such products have been available for about a decade. The primary reason for its absence is the inability and unwillingness for operators to justify the investment in such a training tool.

In the meantime, the aviation industry has recognized that pilots need to have better communications skills while under abnormal conditions. Consequently ICAO, with help from ARINC Industry Activities / FSEMC, has already taken steps to recommend the inclusion of SATCE characteristics in flight simulation devices.

The aviation and research community need to assist efforts by producing the necessary studies and metrics which can be used to evaluate and validate SATCEs used in flight training.

Keywords: "Simulated Air Traffic Control Environment"; SATCE; ATC Communications; Artificial Intelligent Controllers; "Flight Training"

1. Introduction

Most simulation flight training experiences transfer very well to actual flight. As with any learning technology, the quantity and quality of that transfer will vary depending on the quality of implementation, the fidelity, and the individual involved.

Over the years flight training simulation systems have evolved tremendously and continue to do so. I remember my first time in a Link ANT-18 trainer which looked like a bathtub with small wings. After the training session, which was all about ADF navigation, I had forgotten how it looked and then reflected on how positive the learning experience on navigation was. Fast forward to 2017, my latest flight simulation experience was in a full motion fly-by-wire helicopter simulator whereby a student can not only learn to operate the machine's equipment but can also learn to fly it. Thus it can be said that any training technology which can be appropriate to the training objective with positive results is always valuable (i.e. "fit-for-purpose").

In my current position as product manager for advanced aviation applications such as pilot communications training and automated cockpit systems, I have had the opportunity to observe pilots in training and at work. As a commercially trained pilot myself, I can also reflect back on my real life experiences and how they correlate to the type of training I experienced. This has provided me with some additional insight as to the importance of quality fidelity in training systems.

One of my areas of expertise is in simulated ATC environments (i.e. SATCE) and related communications training systems. As virtually anyone in aviation knows, the pilot's priorities are to Aviate first, then Navigate, followed by Communicate, in that very order. For the most part, simulation technologies have made aviation and navigation a fairly straight forward application. However, the latter item (Communicate) is still proving to be a challenge.

As international aviation grows and spreads out, it continues to be an apparent weak point in the system. Since removing the pilots out of the cockpit is not yet a reality, it's up to those of us who are invested in aviation to come up with better ways to improve how communications are handled during any point-to-point flight.

This paper introduces the SATCE, and its inherent benefits. It will also describe how adding an appropriate (fit-for-purpose) system can be used to fill in the communications' training gap.

2. SATCE, a Brief History

As a result of the growing need for better ATC communications from the cockpit and many discussions with people involved with flight training and simulation, it was in January 2012 that ARINC decided to establish the Simulated Air Traffic Control Environment (SATCE) Working Group. The membership was made up of a wide range of experts across the pilot training industry, which included manufacturers and operators alike. The discussions covered the simulation of ATC communications as well as the generation and management of other traffic.

As a point of disclosure, I was a fulltime member of the SATCE group whereby I contributed to the resulting report in 2016 (ARINC Specification 439A: Simulated Air Traffic Control Environments in Flight Simulation Training Devices).

The group developed guidance on the addition of a SATCE integrated into a Flight Simulation Training Device (FSTD). The final report also includes considerable commentary on various points such as scope, available technologies, integration and qualification aspects, as well as maintenance. In addition, SATCE feature and fidelity requirements were mapped to the type of flight training to be delivered for Multi-Crew Pilots License (MPL) students.

It is meant as a primary reference for users and operators who wish to integrate the aspects of SATCE into their flight training devices. This includes low-level stand-alone training systems, additions to existing FSTDs, or as a component of a full flight simulator. It also helps both users and suppliers involved in the flight simulation industry to meet the upcoming SATCE requirements which should be based on the related guidance material found in ICAO Document 9625 fourth edition (Manual of Criteria for the Qualification of Flight Simulation Training Devices).

3. Who are the SATCE industry participants?

There are a growing number of organizations which make up the current SATCE industry. They come from various fields such as:

- ATC Simulation suppliers
- Dedicated SATCE service providers
- FSTD System suppliers
- Training providers

Some of these entities has implemented many aspects of the feature set mentioned in ARINC 439A. This is primarily due to the type of training market segment which is being targeted. Systems have been tailored for a variety of flight training applications. These can be roughly categorized as:

- Airline operations
- Military
- Rotorcraft
- General aviation
- Primary flight training

However, it’s safe to say that combinations of these are currently being used and/or developed.

4. The Training Benefits

There are several core pilot competencies which have already been identified as probable areas of benefit. With a well-integrated SATCE which has been carefully implemented into the curriculum, it’s expected that the pilot’s overall competency will improve. It‘s inferred that this improvement will produce positive feedback such as an increase in safety levels as well as operational efficiencies. Here are some of the areas which will likely obtain tangible benefits:

- ATC Communications
- Aviation English Practice
- Situation Awareness
- Flight Management
- Work Load Management
- Problem Solving
- Decision Making
- Adherence to proper Procedures
- Airport Familiarization
- Emergency management (Incursions, Low visibility ops, TCAS events, mechanical failure, etc..)

Although these have been identified as good products of SATCE usage (see Ref 1; ARINC 439A), it's still unclear as to what usable metrics can be derived and used by operators as well as regulatory bodies. Consequently, this has given rise to an excellent opportunity for researchers to enter into this new realm.

5. SATCE – The Basics

Now that we're comfortable with the notion of a SATCE and its benefits, how does it actually work and what is the purpose for the presented feature set?

The core purpose of adding an ATC system in any FSTD is simply to build and exercise aviation communication skills under various situations. These situations can range from normal exchanges while on the ground, to extreme situations caused by inflight emergencies.

This might sound like a simple task, but it's far more complex than one might expect. This is due to the fact that the core technologies used are still relatively new and need to be employed with care. They are speech recognition and artificial intelligence (AI).

Just think of the many ways that you can greet someone in English. For that simple exchange of information and correct intent to occur as planned by the sender, the receiver will need enough context to be able to process the words used in the phraseology. An example is; "*How's it hanging?*" vs a simple "*Hello*". It turns out that it's not just a matter of mapping the words in a phrase to interpretations which warrant applicable actions. An aviation example of this would be; "*Approach, my engine is not up to snuff... I may need to land*" might be interpreted by the controller as an ordinary request to land sometime in the near future, thus in the controller's busy mind, no immediate action is necessary. In this case, the pilot really needed to land due to an engine malfunction and failed to properly communicate the urgency of the situation. The point being that it's difficult enough for two humans to exchange correct information. The task of making an artificially intelligent synthetic air traffic controller capable of capturing the correct meaning of any humanly spoken phrase can be quite complex. Any such technology must be able to capture enough appropriate context along with the words in the phrase so as to make the correct judgement and decision which will make up the communication to the pilot. It should also be mentioned that there is an added layer of difficulty introduced when the pilot transmits a message by sending two or more smaller transmissions which are sent several seconds apart and omitting the callsign. A well trained and experienced human controller can usually overcome this weakness while a computerized entity will probably have difficulty.

Most SATCEs are modeled after real world ATC systems which follow either FAA or ICAO standards, or both. In the case of military operations, procedures and methods are particular to the needs which are exceptional to all others.

Any SATCE design should strive to reach the highest level of realism as perceived by an average pilot during the course of known flight conditions. The simulation's model is real life which represents a system of segregated airspace volumes, various rules established by government bodies, and air traffic management principles which are used and respected by air traffic controllers and pilots alike.

The anatomy of a SATCE is comprised of two main components. One being the air traffic management part which is known as ATC. The other being a target (or traffic) generator which fills the airspace with other moving objects. Figure 1 below shows the layout of components of a typical SATCE system.

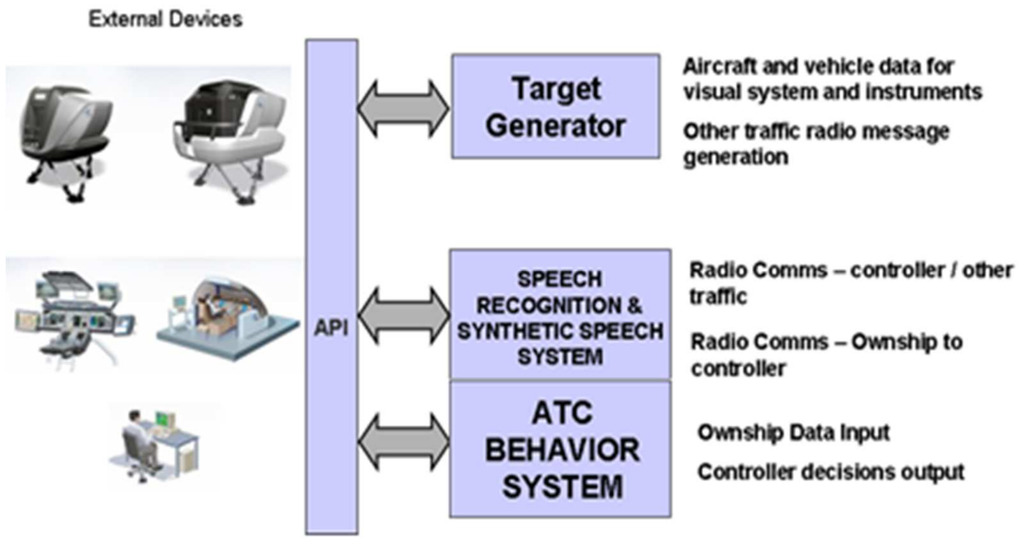

Figure 1: SATCE Components

The target generator's job is to produce radio chatter on the various ATC radio frequencies, which is correlated with the objects displayed on the outside visuals and cockpit displays (see Figure 2 below).

Figure 2: Out-of-cockpit view

As a result, the FSTD pilot becomes immersed and is now required to manage his/her time between operating the ownship and the possible effects from ATC and nearby aircraft. This is how the level of realism is raised to the point whereby the pilot feels the added pressure resulting in the increase of workload.

The ATC system, along with the synthetic speech output and human speech recognition input sub-systems, works together to produce a living airspace around the airport. This zone features the ownship which is operating alongside with the other virtual aircraft.

It's important to note, that virtual aircraft are operated by synthetic pilots which have similar flight related needs as the ownship's human pilot. The synthetic controllers offer services to any pilot that provides a request on a first come first served basis. There is no scripting involved. Pilots and controllers follow established procedures which require communications at specific points in the flight.

For example, a pilot says "*Ground, Flight 21 is ready for taxi to runway*". Consequently, the synthetic controller needs to supply the taxi clearance to the correct runway with a route which makes sense with respect to the airport operations at the time.

In order to make that happen, there has to be a conversion of the analog signal sent by the human pilot in form of sounds made by speaking. This, in turn, gets transmitted to a digital converter and is then sent to a computerized language interpreter to form the words and phrase. Subsequently, the artificially intelligent (AI) ATC controller will pick up the resulting phrase which is processed based on the gathered context. A simple example of context is the location of the aircraft calling ATC (Ex. on the ground or airborne). Once all the pertinent information is taken into account, the AI controller will be able to respond with the correct response.

Since SATCE systems are simulations of aircraft traffic management which are operated by multiple artificially intelligent controllers and pilots, it is difficult to measure performance without defining the parameters needed to retrieve the necessary metrics. Hence, this remains an ongoing discussion.

6. Existing Studies

Numerous studies have been made with respect to the aspects of communications between ATC and pilots. However, there are only a few published studies which deal specifically with SATCE usage in actual flight training.

Seneca College in Toronto Canada has taken steps to examine the possible benefits from using the technology in ab-initio flight training. As another point of disclosure, these are studies which I had proposed as a result of solicitations made by the school. Although the equipment was provided by my company, the studies were carried out independently by the school between 2012 and 2014. Another team funded by the Natural Sciences and Engineering Research Council of Canada, studied distractions in the cockpit which included ATC communications. That report was released in June 2016.

Here are the summarized highlights drawn from the conclusions of each of these reports:

1. **The Effects of ATC Communication Simulation in Initial IFR Simulator Training** by Eugene Gadassik and Michal Warzyszynski, Seneca School of Aviation, Toronto, 2012
It was concluded from the research's findings that the use of ATC simulation software in initial IFR training was beneficial to the students at Seneca College's School of Aviation. Several students exhibited a low level of proficiency in read-back articulation and profited from the exposure to the ATC platform.

2. **The Effects of Computer Based Communications Trainers in Initial IFR Training** by Ian R. Bruce & Andrew J. Powers, Seneca School of Aviation, Toronto, 2014
It was determined that simulated ATC is a useful tool to improve the communication abilities of students in the IFR environment. The Test Group who used the system had shown a slightly greater improvement over the Control Group across three of the six grading criteria and a more consistent improvement over all six grading criteria.

3. **AUDIO DISTRACTIONS IN THE COCKPIT** by Yacine Hamadene, Taylor Ryerson and John Shanly, Natural Sciences and Engineering Research Council of Canada - Aviation Innovation Enhancement Funded Research, Toronto, 2016
Utilizing a SATCE should be implemented into training programs to enhance the ability to manage distractions in flight.

These reports have clearly identified that SATCE usage is beneficial. Each of the authors have tried to produce metrics which could be used to evaluate the benefits and the possible returns. It is evident that this aspect needs to be reviewed and studied further in much greater depth.

7. Industry Acceptance

Some training providers have already foreseen the benefits of a SATCE and have already made the necessary investments. These are the early adopters which will spearhead the way forward for the rest of the industry. The remaining group will continue to observe and wait for the time that it can be more clearly justified within their individual business context.

It is clear that the adoption by various regulators will certainly ignite acceptance. ICAO, ARINC, and IATA are leading the way with improved criteria. The industry as whole still needs additional guidance which will be needed to more precisely determine what level of SATCE is needed and at what cost, along with the expected benefits. In addition, the insurance industry will also need to play an active role in determining the cost benefits which might be enjoyed by organisations that train with this technology.

8. What is currently needed?

Despite early adoption, new guidance, and the use of the latest functional technologies, a number of challenges have been identified before industry can widely accept the notion of acquiring a SATCE. They are:

- Government regulations
- Definition of a common set of metrics used to evaluate and certify such systems
- How to validate training results obtained when used in flight training
- Pilot testing procedures
- Improvements in speech recognition within the cockpit environment
- Augmented artificial intelligence related to air traffic management
- The establishment of a common user interface standard

It should be said that these do not need to be completely overcome before any usage can occur. On the contrary, continued practice along with advancements will produce a continual stream of improvements to the fidelity of FSTD's along with the resulting increase in the quality of training.

9. What is the future for SATCE?

This technology as with all others is constantly evolving and improving with usage. It's expected that one day soon; synthetic controllers will be able to emulate human controllers with admirable precision and efficiency. The flow of multiple types of traffic within a virtual world will be modeled so well that it will be hard to tell what is real and what is not.

That does not mean that the current SATCE implementations are of little use today. This is where the concept of appropriate or "fit for purpose" comes into play. By using a current state-of-the-art SATCE in a manner which enhances the fidelity within the cockpit, it's fairly certain that pilot competencies will only get better.

It can easily be foreseen that this type of technology can not only be used to improve a pilot's ATC communication and cockpit related skills, but it can be used in other areas such as:

- Cabin crew training
- Company & dispatch procedures
- UAV operations
- Airport driver training
- Emergency service response training

10. Conclusion

In order to be fully accepted as part of the established flight training fidelity feature set, a SATCE must not only be proven to be a “good thing”, but it must demonstrate to have enough value to the operator. This will require that many other parties enter the SATCE research arena. Currently the need is for researchers and trainers to join in and study how to best employ each aspect of a SATCE and measure the results. This can be carried out by university based training facilities which are involved in Multi Crew Pilot License (MPL) Training. Such entities will be able to employ their pedagogical experience to derive usable metrics.

As with any other technology, such a system will be a benefit as long as it’s properly integrated into any training program. The feature set used must be such that the “fit-for-training” motto is respected.

References:

1. ARINC Specification 439A: Simulated Air Traffic Control Environments in Flight Simulation Training Devices. Sept. 2016

2. ICAO Document 9625 Ed4, Manual of Criteria for the Qualification of Flight Simulation Training Devices, 2015

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5. AUDIO DISTRACTIONS IN THE COCKPIT by Yacine Hamadene, Taylor Ryerson and John Shanly, Natural Sciences and Engineering Research Council of Canada - Aviation Innovation Enhancement Funded Research, Toronto, 2016