Design of a Procedure Analysis Tool (PAT) for the FAA Human Factors Certification Process

Heather Johnson, Houda Kerkoub, Shaida Latifi, Mumtahina Mahmud, and Alexis Nittoli

Abstract— **Before any device is operated within a cockpit, it has to undergo Federal Aviation Authority (FAA) evaluation to insure compliance with safety standards and minimize design-related flightcrew errors. This evaluation is called the Human Factors Device Certification. This process, accomplished by inspection and by human-in-the-loop testing, is time-consuming and cost-intensive. New regulations, FAR 25.1302, that require analysis of all tasks increase the costs and time. The Procedure Analysis Tool (PAT), described in this paper, is a decision support tool for the FAA inspectors and Designated Engineering Representatives (DERs) to meet the requirements of the FAR. The PAT uses the Monte Carlo method to simulate cockpit procedures and assess the compliance of the device. In this way all the tasks can be assessed in a reasonable time and cost budget.**

Keywords- Procedure Analysis Tool; Federal Aviation Administration; modernization; certification; Designated Engineer Representatieve.

I. Introduction

A. *New Modernization Program*

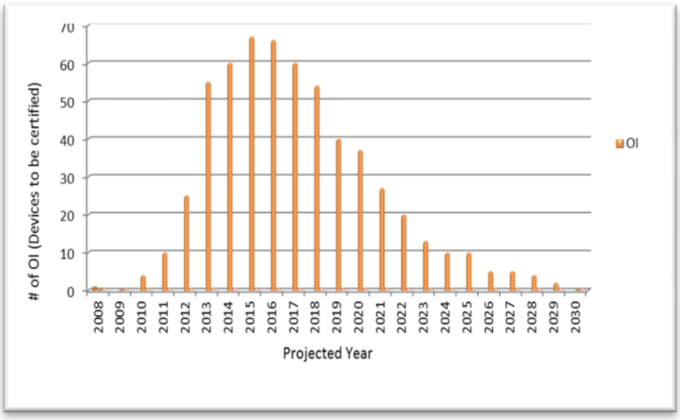
Each year, the hustle of passengers' increases … In fact, within the time span of 35 years, from 1995-2030, the projected amount of passengers is expected to increase from 580 million to 1.2 billion [3]. With this flux of passengers, the number of daily flights is expected to double from 30,000 flights to over 60,000 flights [4]. This increase is looming over the United States aviation agencies because the air transportation infrastructure is aging. This causes more and more delays and cancellations, and increase of maintenance costs for the aviation manufacturers, all while the safety regulations remain stagnate.

Businesses and governments have recognized these problems and have been working on a sky modernization program called NextGEN. NextGEN will transform ground navigation into satellite-based navigation [1]. This means that Air Traffic Control will have satellite-based surveillance, navigation and network-centric operations. By the year 2025, the Joint Planning and Development Office plan to bring NextGEN into action. The primary goal is to significantly increase the safety security capacity, efficiency, and environmental compatibility of air transportation operations. By doing so, NextGen will improve the overall economic well-being within the aviation market.

With all these improvements, NextGen is expected to cost $40 billion dollars; however, even if the cost seems step, the project amount it will save is roughly $123 billion dollars [2]. To equate the amount saved, 400 new NextGEN-equipped jumbo jets could be manufactured [5].

The NetGEN modernization program is bringing new devices to be installed in the cockpit, yet new device need certification before being operated. Further, NextGEN consists of 9 implementation portfolios and each portfolio includes a set of Operational Improvements that provide specifics about the expected enhancements. The portfolios are: (1) improved surface operations, (2) improved approaches and low visibility, (3) closely spaced, parallel, converging and intersecting runway operations, (4) Performance Based Navigation (PBN), (5) Time Based Flow Management (TBFM), (6) Collaborative Air Traffic Management (CATM), (7) automation support for separation management, (8) on demand National Air Space (NAS) information, and (9) Environment and Energy E&E [1]. An example of an Operational Improvement (OI) linked to the performance based navigation portfolio is: increase capacity and efficiency using area navigation and required navigation performance. The implementation of this OI requires aircraft to be equipped with PBN equipment, and therefore it requires certification before this equipment is installed in the cockpit. Figure 1 shows the number of OIs projected to apply between 2008 to 2030 as a result of NextGEN [6].

Figure 1- Number of Certification Related OIs between 2008 and 2030



Further, each operational improvement is associated with its set of certification related research actions with an approximate ratio of (1:2). A research action takes about 3.5 years [6]. Therefore, approximately 1.75 years are dedicated to each operational improvement. An OI also corresponds to 2 to 3 devices to be certified. On the other hand, the number of inspectors available to perform the certification is constant creating the gap shown on Figure 2. This figure shows that the required time to certify new devices in 2014 would need over

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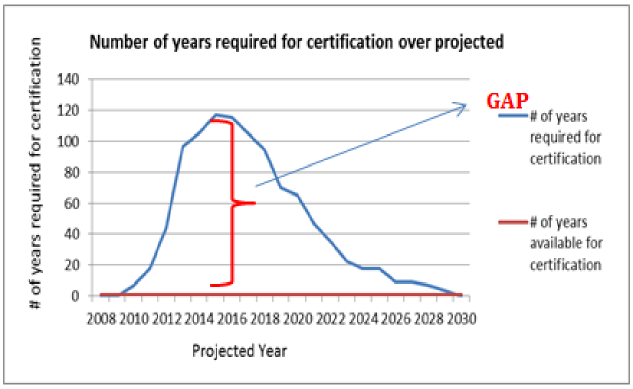
100 years to be completed whereas the number of years available (based on labor hours) is constant [6].

Figure 2



B. New Regulations

Each year, human errors account for 56% of the total causes of air accidents. High cognitive demand in a complex and dynamic environment ultimately lead to flightcrew errors. This motivated the government to establish new federal aviation regulations to ensure the design of devices reduces or avoids crew errors and addresses crew capabilities and limitations in task performances [7].

Federal Aviation Regulation (FAR) 25.1302 details the new rules and regulations on the human factors certification of devices. Complementary to the FAR 25.1302 is the Advisory Circular (AC) 25.1302. The AC gives guidelines for the design and Means Of Compliance (MOC) for the installed equipment on airplanes to minimize errors by the crew and enables the crew to detect and manage errors that may occur [8]. The AC is then broken into supporting the crew in planning and decision making and reducing errors by making decision requirements and enforcing accessible and usable control and information by the flight crew in a manner consistent with urgency, frequency, and task duration [8]. Since the certification process is heavily based on task performance, Standard Operating Procedure (SOP) will be used to design the tool proposed in this paper. SOPs are a set of guidelines given to flightcrew by the airline upon hiring. They detail the procedures, tasks, and duties of flightcrew, including when to perform them. SOPs are specific to the airplane flown and each procedure consists of tasks and subtasks. For this project, Swiss European SOPs for the Avro RJ100 airplane were used as a test case. The RJ100 SOPs include 104 procedures, 642 tasks, and 1,263 subtasks [13].

The principle used to build the proposed tool is the Time to Complete the Task (TCT), and the Failure to Complete the Task (FtoCT) that will be further explained in the Method of Analysis section. To measure the TCT, each task was decomposed according to the Task Specification Language (TSL). The model captures both the decision-making actions as well as the physical actions. Predictions are based on the salience of the cue to prompt the next operator action [9]. The time to complete each task is measured in seconds and is replicated multiple times to obtain a frequency distribution of pilots performing a task against the time to perform the task. The FtoCT is the case where the task is not performed within a predefined timeframe and considered to be failed. The frequency distribution mentioned above will help identify the probability of FtoCT. P(FtoCT) will be assessed to identify devices linked to tasks with high probability of failure to complete the task. These devices will fail the certification process.

C. Opportunity

The new modernization program that is bringing new devices into the market combined with the new federal aviation regulation on certification that is producing additional work for the inspectors are creating a gap in the certification process. This gap generates the opportunity for a time effective and cost efficient certification process that can be realized by the Procedure Analysis Tool (PAT).

II. Stakeholder Analysis

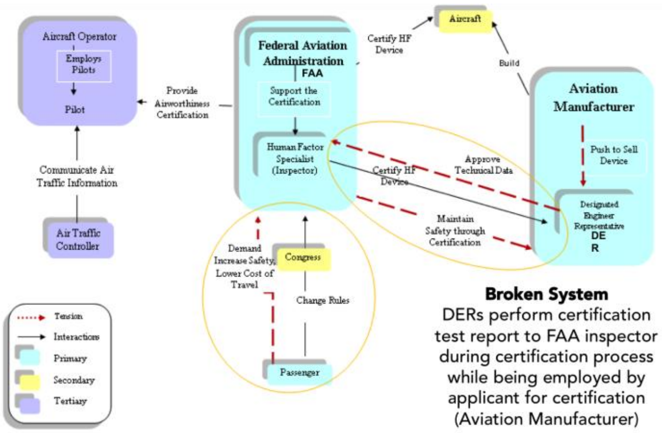
The United States Federal Aviation Administration is responsible for licensing pilots, aircraft maintenance technicians, aircraft, airports, and new aviation devices [10]. Since safety and protection of any aviation danger is a primary FAA goal, FAA is therefore the main stakeholder. When any aircraft or device is built, the FAA human factor specialist (the inspector) must check every element that needs to be considered. The Designated Engineering Representatives (DERs) work for the aviation manufacturer and push the aviation manufacturer to keep safety a priority during the certification process [10].

A. Tensions – A Broken System

Stakeholder conflicts arise when the needs of a particular stakeholder group compromises the expectations of others. In this scope, there are two main tensions that are at the origin of a broken system.

The first tension lies between the Designated Engineering Representative and the aviation manufacturers they work for. The aviation manufacturer builds the devices to be put inside the aircraft and hires DERS to inspect their system. The aviation manufacturers want their device to be certified, yet the DERs must ensure the required safety standards are for certification [8].

The second tension exists between the DERs and the FAA human factors inspector. The DERs inspect the device for safety and must report whether such a device passes means for certification. If there are errors within the device, the DERs are under pressure to report failures to the inspectors on one hand and on the other hand, they are pressured by their employers to sell their products – the devices. This situation



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creates internal conflicts within the manufacturer entity.

B. *Win-Win Analysis*

A win-win analysis is defined as solving policy problems by finding solutions that exceed the best initial expectation of all major groups. The procedure analysis tool would save time in inspecting these new devices. Moreover, it will reduce the errors and increase the accuracy of work. This helps to mitigate all rework. In this win-win analysis, in addition to the above mentioned benefits, pressure on the DERs is eliminated because the PAT would provide an objective proof of certification to FAA human factors inspectors as well as for the manufacturer.

III. Problem Statements

The demand for certifying new devices is project to peak in the years 2013-2018 [6]. An increasing gap exists between the number of available human factor inspectors and the number of new devices to be certified; yet the current methods are lack efficiency. There are four problems with the current certification process:

1. Tensions exist between stakeholders: the DER who is employed by the aviation manufacturer (the applicant of device certification) must report to both their employer and FAA during the certification process.
2. The current process is expensive and time consuming.
3. There is a lack of cockpit interaction within the current certification process.
4. The current means of compliance, or the current way new devices are certified is subjective.

IV. Proposed Solutions

Each Problem statement mentioned above is matched with a similarly numbered solution shown below:

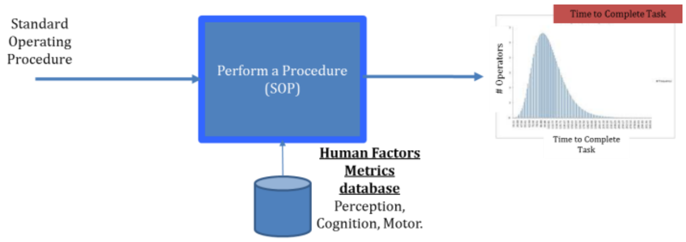
1. Procedure Analysis Tool will create a win-win by relieving stress from the DERs and give inspectors objective and quantifiable measures to evaluate functions.
2. Simulation will drastically reduce the certification time and associated costs.
3. PAT will model the flight operators' interactions within the cockpit environment using the SOPs.
4. Procedure Analysis Tool will generate decision output based on human based model with clear fail/pass threshold.

V. Method of Analysis

The PAT models perceptual, cognitive, and motor processes to simulate pilot operations in the cockpit environment. The input to the PAT is the Standard Operating Procedures (SOP). The PAT combines SOPs with a database of Human Factors Metrics expressed in statistical distributions of time to complete an action in seconds. The output of the tool is a frequency distribution of the number of pilots plotted against the time to complete the task. Figure 3 shows a model for the tool with input, output, and where the human factors database comes into play.

A device displaying good human factors is expected to enable the operators to complete their tasks in a proficient manner.

Figure 3 - Process Modeled by PAT

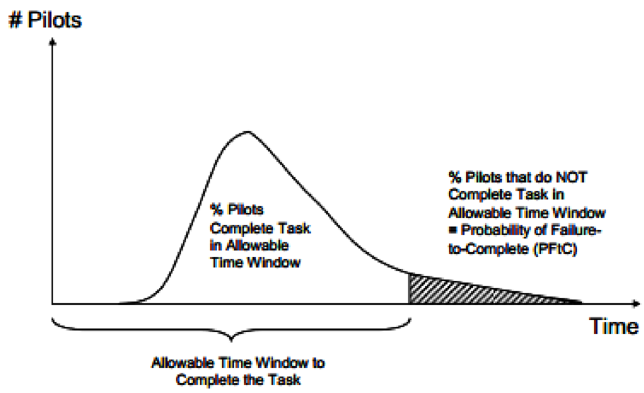


On the other hand, task proficiency is the ability to complete a task within the allowable time window. The opposite of proficiency is failure to complete the task i.e.: not being able to complete the task in a timely manner [11].

The approach taken in this study is to analyze Time to Complete the Task (TCT) and the probability of failure to complete the task as an indication of whether the device should pass the certification test or not. A device showing high probability of failure to complete the task is a device that will not pass the certification test.

The probability of Failure to Complete the Task is explained by the graph below

Figure 4 - Distribution of Time-to-Complete a Task. The shaded region represents the percentage of pilots that did not meet the Proficiency standard. This defines the Probability of Failure-to-Complete the task [11]



Design of experiment to Build Human Factors Database

A. *Scope*

The tool involves a Human Factors Metrics database that contains Operator's Actions Categories (OAC) – finite actions to decompose the tasks. This database is produced by a combination of literature review and experiments. The experiments' objective is to produce statistical distributions of time for Operator's Actions Categories. For example, button push timing is normally distributed with a mean of 0.3 and standard deviation of 0.001[12].The experiments attempt to

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generate the same types of distributions for the remaining OACs.

Communication with Air Traffic Control (ATC) was taken as an example to demonstrate experiments performed for the elicitation of statistical distributions

B. *ATC comminication Experiment Inputs*

The inputs to this experiment are 48 Air Traffic Control (ATC) communication voiced by 5 team members while being timed.

C. *ATC Communication Outputs*

The time to verbalize the ATC message as a function of number of words in a sentence (shown in Figure 5) is the output to this experiment. A regression was then performed to obtain the type of distribution and its characteristics. Results are shown for Pilot Communication as an example on Figure 6. The R^2 value for Pilot communication was found to be $R^2 = 0.4$ and $R^2 = 0.7$ for ATC communication.

Figure 5 - Pilot Communication Experiment Output

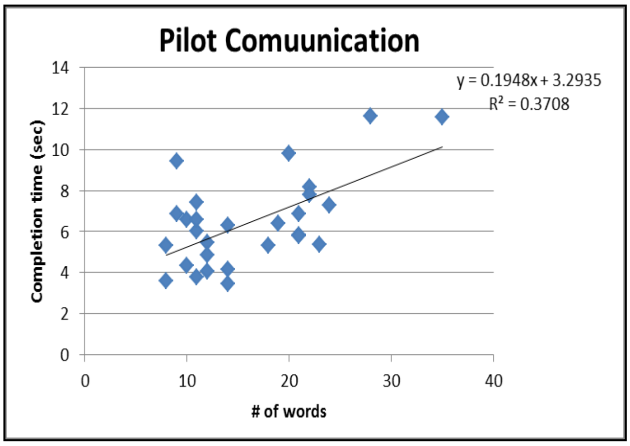
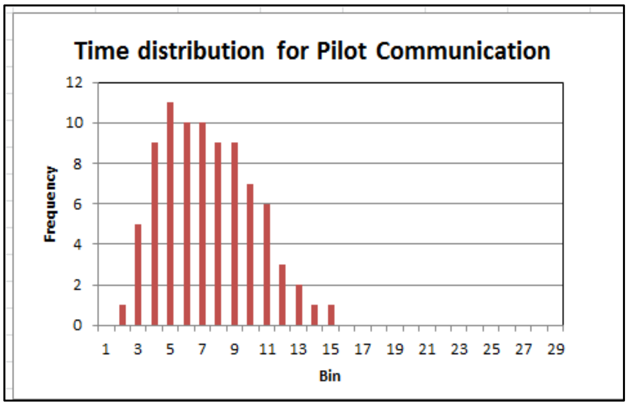


Figure 6 - Pilot Communication Distribution Elicitation



The type of distribution was found to be Lognormal (8.5, 4.2) with a mean of 8.5 and standard deviation of 4.2

VI. PROTOTYPE

The tool is projected to work in three steps as follows:

1. Decompose procedure into OA and associate with Human Factors metrics.
2. Simulate task operation.
3. Calculate probability to complete the task to determine Failed/Passed devices.

Step one is performed using a sequence diagram. To demonstrate this, the Hold at Present Position task involving 4 subtasks was decomposed into 15 OA. Each OA falls under an Operator Action Category (OAC) associated with a statistical distribution similar to the one shown in Figure 6. After the identification of the OAC for each OA, random numbers were generated according to their statistical distributions before being aggregated into a task time. This operation was performed 500 times using a Monte Carlo simulation to result in a distribution as shown below.

Figure 7 - Results of Hold at Present Position Task Simulation

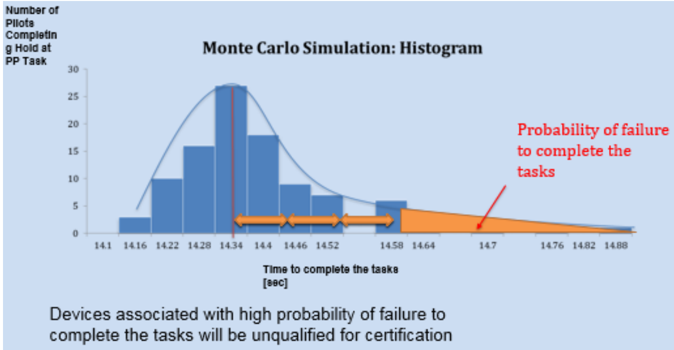


Figure 7 above shows the result of running the prototype on Hold at Present Position task. The region for failure to complete the Task is shown to lie at 3 standard deviations right of the mean to match a 99.7% confidence interval. Decision on what is the acceptable probability of failure to complete the task is still in progress.

VII. BUSINESS CASE

The current certification process is very time consuming and costly. This is because 70% of the process is used for human in the loop and simulator testing. The other 30% is inspection and bench testing. The cost regarding the current means of compliance is as follows:

Cost of Inspector = $Cinsp = \$100\ per\ hour * 1750\ hours = \$175{,}000\ per\ OI$

Cost of human in the loop= $[(25\ pilots * \$75\ per\ hour) + \$100\ per\ hour] * 300\ hours\ of\ testing = \$590{,}000\ per\ OI$

These two equations are calculated by figuring the cost of the inspector testing and the human in the loop testing. The cost of the inspector is decided by the wage of the inspector multiplied by the number of labor hours spent on the OI. The cost of the human in the loop testing comes from the number of pilots testing the device, multiplied by the number of hours the pilots work, multiplied by the number of total hours of testing. There is also an additional cost of the wage of inspector who is watching the pilots test the device. This inspector is paid hourly and works the entire amount of hours of testing. The total amount of cost per OI in the current

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certification process totals almost $470,000. This is calculated by plugging the results from the formulas above into:
$Current\ MOC = (.3 * Cinsp) + (.7 * Chitl) = (.3 * 175{,}000) + (.7 * 592{,}000) = \$470{,}00.$
Evaluation of the business case is in progress and further results will be shown in subsequent reports.

VIII. Future Work

Future work includes:
1- The completion of identification of OACs using the RJ100 SOPs, along with the identification of the statistical distributions relating to the OACs.
2- Find other areas of applications of the tool. They include:
a. A manufacturer version of the PAT.
b. Pilot training.
c. Other transportation fields and nuclear plants

IX. Acknowledgements

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