Design of a Procedure Analysis Tool (PAT) for an Affordable Human Factors Certification Process of Aviation Devices

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1. Statement of Work

1.1 Scope
This statement of work (SOW) defines the effort required for the design, engineering development, and test of a prototype for the Design of a Model Based Human Factors Tool in FAA Certification. It includes associated program management, human factors engineering, and logistic support planning requirements.

1.2 Background
The Design of a Model Based Human Factors Tool in FAA Certification has been initiated to design, develop, produce, and deploy an improved certification process that will fulfill the requirements specified in the Advisory Circular. This system will replace the current paper based certification process with an automated simulation that will accurately predict and provide proof if the device is to be certified.

1.3 Applicable Documents
The documents used in this project listed in this section are invoked and tailored to meet the needs of the planned procurement within the requirements section.

1.4 Standards
- Standard Operating Procedure for RJ100
- Advisory Circular 25.1302
- Federal Aviation Regulation

1.5 Other Documents
- Means of Compliance regarding FAR 25.1302
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- Policy Impacts of Implementing NextGen Research
- Joint Planning & Development Office Strategic Decision and Policy Model
- Human Factors Design Guidelines for Multifunction Displays
- The Multimodal Evaluation Model
- Human Performance Consequences of Stages and Levels of Automation: An integrated Meta-Analysis
- Brain Monitoring May Improve Pilots, Controllers

1.6 Requirements
Only the minimal needs are written within this SOW. The following headings breakdown into more detail what the requirements of the project will entail.

1.7 General
The developer shall design and execute this system that shall meet the requirements in accordance with the Advisory Circular 25.1302 and the tasks written in the standard operating procedure expressed for the RJ100.

1.8 Systems Engineering
The developer shall implement a systems engineering management process. The necessary tasks to be performed shall be requirements analysis, functional analysis and allocation, and synthesis for the design of the system. A transportation of the requirements shall be completed that will address systems design, development, fabrication, test and evaluation, operational deployment, logistical support, personnel training, and final disposal.
1.9 **Systems Analysis**
The developer shall conduct a trade-off analysis and cost-effective analysis to ensure that a thorough and comprehensive set of options and alternatives is considered for the design will all aspects of system life cycle considered. The detail of the analysis will include cost, schedule, performance, and risk impacts.

1.10 **Software Design**
Software development shall be integrated within the systems engineering efforts.

The software used will consist of excel, xml, and java.

1.11 **Program Management**
The project shall include the following:

- Program Planning
- Financial Management
- Data Management
- Risk Assessment and Mitigation
- Life Cycle Cost Analysis and Control
- Schedule Development
- And other management area(s)
2.0 Introduction

2.1 Overview

Equipment on airliners must be certified by FAA to ensure compliance with safety standards designed to minimize design-related flight crew errors. This process is currently accomplished by both inspection and Human-In-The-Loop (HitL) testing – a time-consuming and costly process. A recent Federal Aviation Regulation (FAR) 25.1302 newly requires the analysis of all tasks increasing certification costs beyond current staffing, budget and timelines. The Procedure Analysis Tool (PAT) described in this paper is a decision support tool designed for use by inspectors performing the certification test to meet the FAR25.1302 requirements. The PAT simulates the performance of human operators performing a task on the device under evaluation and may be used as a screening tool to identify tasks that warrant HitL testing, allowing for evaluation within reasonable time and budget.

The PAT calculates the percentage of pilots that perform the procedure in excess of an allowed threshold representing the Probability of Failure to Complete PFtoC the procedure. Procedures with long right tails are flagged for full HitL testing. PAT was demonstrated on 15 Swiss European airlines Standard Operating Procedures (SOP) to evaluate the Multifunction Control Display Unit (MCDU). Three procedures resulted in a PFtoC above the threshold, and were therefore flagged for HitL testing. This preliminary analysis highlights the importance of semantic cues to recognize emerging mission situations, which have the greatest effect on the final time distribution. Entering the 15 procedures into the tool took 5.1 hours and 11.56 seconds average runtime. Analysis of
the human factors certification process shows that the PAT reduces the evaluation time by 70% per function.

There is an ever-increasing amount of passengers needing to fly each year. The FAA stated that from the year 1995 until 2030, the projected amount of passengers would increase from 580 million to 1.2 billion. With the increase of passengers, there is also an increase of the number of daily flights. These daily flight statistics are expected to double within the same timespan from 30,000 to 60,000. Side by side with the increase of passenger and daily flights, the infrastructure of the U.S. air transportation technology is aging. Because of aging technology, there is an increase of flight delays and cancellations, an increase of maintenance costs, all while safety remains stagnant. Businesses and government have recognized these problems and have been working on a new legislation called NextGEN. NextGEN is a government program that will transform ground navigation into satellite-based navigation.

According to the United States Department of Transportation – U.S. Air Carrier Traffic Statistic, current flight capacity is somewhat constant and flight demand is increasing. Looking at the linear fit of following graphs, it can be noticed there is a positive increasing linear fit for flight demand and a nearly flat linear fit for the flight capacity.
The total passenger revenues miles show the increasing past and projected revenues from the years 1993 to 2020. This is an indication towards the increasing demand for flights. Available seat miles show the capacity for total flights each year, which is nearly constant.

According to the Joint Planning and Development Office (JPDO), they plan to bring NextGEN online by 2025. The goal of NextGEN is to significantly increase the safety, security, capacity, efficiency, and environmental compatibility of air
transportation operations, and by doing so to improve the overall economic well-being. NextGEN is expected to cost roughly $40 billion dollars. While the cost of this program seems steep, the projected money it will save through the next decade will exceed 123 billion dollars. To compare, 123 billion dollars equates to 400 new NextGEN equipped jumbo jets.

NextGEN is a modernization program will inspire technology to grow and demand more devices. These devices will have implementation portfolios that will include operational improvements. The nine-implementation portfolios being considered 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
6. Collaborative Air Traffic Management
7. Automation Support for Separation Management
8. On Demand NAS Information
9. Environment and Energy

If a Performance Based Navigation Portfolio were to be improved, the manufacturer would create an improvement concerning the PBNs: OI 103209 – Increase Capacity and Efficiency Using Area Navigation and Required Navigation Performance. From there, new devices would be made for aircraft containing PBN equipment. This is just one example of an Operational Improvement that is being taken into account. There are
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numerous projected Operational Improvements expected for the next 15 years. Overall, the number of OIs needing certification is projected to peak from the years 2010 to 2018.

Each OI is associated with its set of Research Actions. 3.5 years is the associated amount of time to certify per Research Action. This means there is approximately 1.75 years delegated to each OI with 2 to 3 devices needing certification per OI. There lies a problem in the year 2014, 60 OIs are expected to take an unreasonable 100 years to complete.

In 2003 Boeing published statistics indicating that there were 139 commercial jet aircraft accidents world-wide between 1993 and 2002 [1]. In 67% of these, flight crew error was cited as a major factor by the investigating authority [1]. These statistics remain consistent across accident categories that have been recently examined [1]. Along with the previous statistic, it has been noted that cognitive demand imposed on the pilot during
flight is due to the complexity of the environment. This second statistic gives similar percentages for the main cause of accidents:

- 56% errors due to Flight Crew
- 17% errors due to Aircraft
- 13% errors due to Weather
- 6% errors due to Miscellaneous
- 4% errors due to Maintenance
- 4% errors due to Airport or Air Traffic Control

Among the factors identified to have contributed to these accidents is design [1]. Such an analysis led FAA to take measures to address the design and certification of transport category flight decks [1]. As a result, and in a harmonization effort with the European authorities, FAA issued in 2013 a Federal Aviation Regulation (FAR) 25.1302 relating to airworthiness standards on installed systems and equipment for use by the flight crew [2]. The Federal Aviation Regulation complements existing regulations to ensure the design reduces or avoids crew errors and directly addresses crew capabilities and limitations of task performances.

The proposed requirements in § 25.1302 augment regulations with more explicit requirements for design attributes related to managing and avoiding flight crew error [3]. This regulation collects all human factors regulations in one FAR and adds to the lower-level (ergonomic) human factors that “the applicant1 must show that […] flightcrew […] can safely perform all of the procedures associated with the systems' and equipment's

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1 The FAA works closely with device manufacturers (known as “applicants”) to perform the tests and evaluations that show that the devices meets the performance standards in the FARs.
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intended functions” [4]. Although this regulation improves the process, it increases certification cost and time budgets beyond current capacity.

Unlike the other characteristics of device performance, such as temperature range, vibration, mean-time-between failures, etc. that are specified by the performance standards in the FAR and evaluated for airworthiness, the human factors regulations have historically been made open-ended [5]. First, the human factors regulations are found buried in FARs for specific types of devices (e.g. displays, flight controls) [5]. Second, the rules focus on low level human factors issues such as the salience of displays in sunlight, the tactile feel of adjacent knobs, and the ergonomics of input device placement relative to pilot seating position [5]. These rules do not specify performance standards related to procedure performance [5].

The complementary Advisory Circular (AC) 25.1302 provides guidelines for the Methods of Compliance (MOC) with FAR25.1302 [4]. C 25.1302 is the guidance for the design and methods of compliance for the installed equipment on airplanes to minimize errors by the crew and enable crew to detect and manage errors. Breaking down further, AC 25.1302 (b) supports the crew in planning and decision-making, reduces errors by making design requirements. Lastly, AC 25.1302 (b-2) enforces accessible and usable control and information by flight crew in a manner consistent with urgency, frequency and task duration, which focus on human factor.
The AC 25.1302 provides six guidelines for the certification process:

- Provide device for certification
- Evaluate systems, components, and features vs. crew tasks
- Identify degrees of novelty, complexity, and integration
- Determine the applicability of requirements to systems, components, features and aspects of the design that require substantiation
- Selecting appropriate means of compliance
- Provide human factors testing

For the first four guidelines stated above, the applicant should provide the device to be certified based on the regulations of standard operating procedures. All flight crew members have a positive contribution to the safety of the flight because of their ability to assess continuously changing conditions. During these conditions, they are expected to make reasoned decisions. Although, even healthy and well trained flight-crew members make errors. Thus, design and approval of design of any equipment intended for flight
crew members use from their normally seated position on their flight deck in both normal and non-normal (emergency) conditions. Flight-crew members are trained to use all the installed equipment that meets the specified requirements for operation of the air system vehicle.

The applicant must show that all installed equipment individually and in combination with other systems and equipment are designed in a way that allow all flight-crew members to perform their task safely while operating the airplane. Design of equipment has its own specific features, such as: degrees of complexity, novelty, and integration. Complexity is a number of elements that the flightcrew are expected to use. For instance, any flightcrew member should know the exact number of control models of a knob, if it were to have more than one. Novelty is considering if a new design would affect and change flight crew members’ performance. Integration is the interaction between flight crew members and systems. All the characteristics of equipment should be identified, documented, and provided by applicant for flight crew members’ usage. For instance, each individual control, information, buttons, colors, and feedbacks should be identified, provided, unambiguous, and accessible for flight crew members to manage errors if any were to occur.

In this project, the last two steps of the process are what is studied. These two steps include Providing Appropriate Means of Compliance and Provide Human Factors Testing. Means of Compliance is a method to test and evaluate the device. It includes a statement of similarity, overall safety in detail, and analysis of the device. The types of testing include:

- Mock-up Testing
• On the Bench Testing
• Laboratory Testing
• Simulator Testing or Human in the Loop Testing
• Aircraft Testing
• Inspector Testing

In the last step of the process, the FAA Human Factors Inspector or the Designated Engineering Representative working for a device manufacturer would choose one of the above methods of testing to evaluate a device based upon its Standard Operating Procedures. Then, based upon their evaluation, they will send its approval or rejection.

Since FAR25.1302 focuses on task performance, the tasks are drawn from the Standard Operating Procedures (SOP). These are a set of instructions that document how to perform routine and emergency activities to ensure safety, consistency, and quality. These Standard Operating Procedures tell the pilots how to travel from point A to point B in an aircraft; they describe the duties of the flightcrew and specify limitations, normal procedures, and abnormal procedures. Standard Operating Procedures can be found in company manuals as well as training manuals including Computer Based Training (CBT). For this project, Swiss European airlines SOPs on the Multi-Function Display Unit (MCDU) were used to test case the proposed tool. The entire SOP included roughly 104 procedures, 642 tasks, and 1,263 subtasks. These SOPs are vital as a checklist for the pilot every time they fly the aircraft.

To demonstrate how SOPs will be used, take the example of the Initial Approach Procedure. While performing this procedure, pilots may be required to perform a hold at
the present position. The Hold at Present Position is a task within the Initial Approach Procedure. This task is composed of 4 subtasks that include:

1. Press HOLD
2. Press 6R
3. Review the default holding patterns and revise when necessary
4. Press EXEC to activate holding patterns

Further task decomposition is organized using a sequential model of operator actions to complete a task called the Task Specification Language (TSL). The model captures both the decision-making actions as well as the physical actions such as a button push.

Predictions are based on the salience of the cue to prompt to the next operator action. The Operators Actions are configured into a framework with 6 steps:

1. OA1 – *Identify the Task*: This is the decision making step where the user must recognize the need to perform a certain task
2. OA2 – *Select Function*: This is the decision making step to determine which feature or function of the automation should be used. This is known as mapping the task to the specific function
3. OA3 – *Access Function*: This is the physical action to display the correct window, wizard etc.
4. OA4 – *Enter Data or Function*: This is the physical action to enter the data or select the required options
5. OA5 – *Confirm and Verify*: The pilot must now verify that the entry is correct
6. OA6 – *Monitor*: The pilot must monitor the aircrafts trajectory and changing state as per the entries for the task entered.
Predictions are based on the salience of the cue to prompt the next operator action [6].

The main benefits of this model include clear and orderly decompositions of the tasks to allow for Operator Actions to be timed and means to measure a decomposed task.

The Procedure Analysis Tool (PAT) being proposed performs the human factors assessment based on one metric: time. A device with good human factors engineering simply enables safe performance of tasks within a certain threshold of time. The PAT simulates pilot performance time on the device under evaluation. The output of PAT is a frequency distribution showing the number of pilots versus Time to Complete (TTC) one procedure [6]. The percentage of pilots performing the procedure in excess of an allowed threshold represents the Probability of Failure to Complete (PFtoC) the procedure. Procedures with long right tails [7], as shown in Figure 1 below, are flagged for HitL testing.

The diagram in Figure 2 below is a generic TSL example portraying basic the interactions within the cockpit where the agents involved in the procedure performance are represented by lifelines and can:

1. Be a number of devices including the specific device to be certified
2. Be one or two operators (pilots) that depend on a certain task
3. Be relevant to the outside world

The TSL steps are shown in red.
The arrows represent the information circulating between the agents including the operator’s cognitive actions represented by recursive arrows. The arrows progress in a sequential fashion from top to bottom to show time progression. The *Identify task/procedure* is first triggered by semantic cues from the device and/or the outside world, followed by a memory item retrieval leading to the *Select Function* guiding the operator to look in the relevant area of the cockpit/device. One or multiple (k) visual cues are presented to the operator which in turn triggers the *Access* step. The operator then *Enters* the required data causing a display change in the device represented by a semantic cue prompting the *Confirm*, after which semantic cues either from the device, or the outside world, or both enable the *Monitor* step. The TSL steps are expanded and modeled as Operator Actions (OA) in the PAT.
The OAs are then categorized into pre-defined Operator Action Categories (OAC) and assigned to a statistical distribution of time to complete the operation. "After that, the compilation of all OA times is performed to compute the total procedure time."
2.2 Stakeholder Analysis

Today, the U.S. Federal Aviation Administration (FAA) is responsible for licensing pilots, aircraft maintenance technicians, aircraft, and airports. Since safety and protection of any aviation danger is a primary and essential factor in human life, FAA becomes the main stakeholder that provides safety and certification of it. There is a European organization called European Aviation Safety Administration (EASA) that gives approval for the design components to aviation manufacturer- an entity that builds aircrafts. They also work with organizations out of European Union like FAA. The diagram below shows the relations between all the stakeholders.

When an aircraft is built, human factor specialist (inspector) who works for FAA would check every single instrument and element in the cockpit design by aviation manufacturer that are approved by EASA. This examination will be accomplished by “Human Factor Certification Tool”. After all, the inspector will report the safety to FAA to support the certification. The FAA will certify the aircraft. Manufacturer Designated Engineering Representatives (DER) push aviation manufacturer to keep safety of certification, also aviation manufacturer wants to sell their devices and get the safety approve even if there are errors out there with any instrument. On the other side, DERs must report the safety to FAA inspector to approve the technical data and give certification.[4]

When an aircraft is certified, flight test pilots will test the aircraft to provide approval for safety information to FAA. Hence, FAA gives certification license to the actual pilot who will operate the aircraft. FAA employs the air traffic controllers who give tasks to pilot for operation, and provide air traffic control information to the airport.
However, they are going to be regulated by foreign regulatory authorities.[5] All these processes are happening for a very important demand of increasing safety from passengers who expect the congress to provide all needs for FAA to do their job.

2.2.1 Stakeholders Tension

Stakeholder conflicts arise when the needs of some stakeholder group comprise the expectations of others. There are two tensions between stakeholders:

1. Manufacturer DERs vs. Aviation Manufacturer: aviation manufacturer builds the aircrafts, and manufacturer DERs would inspect that air system vehicle. Aviation manufacturer want DERs to certify their devices and designs; even though, if still there are errors. On the other side, DERs want the manufacturer to consider the required safety for the certification.
2. Manufacturer DERs vs. Human Factor Specialist (Inspector): when DERs inspect the safety of any aircraft, they send a report to FAA inspector because eventually FAA needs to give certification. If there are errors with aircrafts, then DERs can not send the report to inspectors. Thus, they might ignore the errors existing or not certify the aircraft for the manufacturer.

2.2.2 Win-Win Analysis

Win-Win analysis is defined as solving policy problems by finding solutions that exceed the best initial expectation of all major groups. The “Human Factor Certification Tool” would save time in inspecting the aircraft. Moreover, it reduces the errors and increases the accuracy of work which helps to mitigate all rework. In win-win analysis, DERs would be eliminated from the stakeholders because by using Human Factor Certification Tool all work can be done by FAA inspectors once. In this way, aviation manufacturer saves time and money while building aircraft, and DERs are not pushed to work on the certification with some existing errors. As a result, FAA inspectors would inspect the safety of the aircraft and report it to FAA for certification.
3.0 Statement of Need

Since aviation safety is an important and essential factor in human life, the Federal Aviation Administration became the first main stakeholder to provide safety by enforcing laws. FAA endeavors to provide and purvey a hundred percent reliable and available aviation system. Aviation manufacturer is an entity that builds aircrafts and gives out the devices to the market. They have their own inspectors to check the safety of their devices before they are sent to the market. These inspectors are called Designated Engineering Representatives who report the safety of the devices and aircrafts to FAA inspectors to get the approval for the certification. Time, cost, and labor are the resource constraints of both stakeholders, since FAA and Aviation Manufacturer have their inspector to test and evaluate the devices, and they pay those inspectors regarding the labor hours they put in the third stakeholder is passengers who take the flights. They want to have a safe, reliable, available, and cheap flight to travel and in this context they expect the congress to highlight the rules and laws that support the safety of people and to reject any law that is against the aviation safety and security.

All people in the entire world are looking and trying to get benefit of the business they doing just for themselves. It is very rare that people work to the serve other people purely. FAA takes the responsibility of aviation safety; however, aviation manufacturer just builds the aircrafts and ask the DERs to report the safety of those devices. So, they do not take the human factor errors and risks into account after final aircraft assembly. Their main goal is to give the devices out into the market and receive the benefit out of it, which mean that they minimal the importance of human life. Thus, all stakeholders involved in this system are required to put all their efforts to provide safe flights devoid and free from any human factor risks. Having a system evaluated and reduced in human
factor errors can make more satisfied customers if they also provide flights with low rate of price.
4.0 Operational Concept

4.1 Vision Statement

Our group aims to create a solution (system) that will accurately aide in certifying new devices proposed to be placed in an airplane cockpit. This system will test the device using the new Human Factors guidelines proposed in the Federal Aviation Regulation, FAR 25.1302, the Advisory Circular 25.1302, and the specific airline Standard Operating Procedures. Our device will provide a simulation and will test the tool to see if it fails to complete the task at hand. If so, our system will provide what percentage of the tool tested fails and which particular tasks or functions it fails and/or what percentage of tasks need to be reviewed for Human in the Loop testing. However, if all tasks were able to be completed our system will provide proof that it can be passed for certification.

This Procedure Analysis Tool will address the tension created by the current method. As this tool is implanted, the Designated Engineering Representative will be able to give objective evidence to the FAA and their boss, the device manufacturer. This will rid the problem of subjectivity as well as provide for a time and cost efficient means of compliance.

The Designated Engineering Representative (DER) will input the Standard Operating Procedures (SOP) for the airplane that their device wishes to be inputted. From there, they will run our tool and receive reliable and objective results that will alert them if the tool can be passed, if it fails, or if only certain tasks need to be sent for review during the Human in the Loop type testing.

4.2 Requirements:

4.2.1 Mission Requirements
The main PAT mission requirements are:
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MR.1 The PAT shall enable compliance with the FAR 25.1302 requirements.

MR.2 The PAT shall reduce the post FAR25.1302 certification cost by at least 65%.

MR.3 The PAT shall remove the stakeholder tensions between the FAA, the Applicant, and the DER.

4.2.2 Originating Requirements

- Input/output: Tool shall use inputs of SOP, OAC, OA and sensitivity analysis parameters from the user to output frequency distribution of procedure time completion.

- External Interface: Tool shall utilize Cognition, Perception and Motor Skills

- Cost: Tool shall reduce the current certification cost by 65%

- Schedule: Tool shall be able to collect revenue by the turn of 5th fiscal year.

- Performance: Tool shall be available to use most of the time and shall report without error 95% of the time.

- Observance: Qualification data shall be acquired from SOP and Operator Action Category defined in the tool.

- Verification Plan: Tool shall be verified against small experiments dealt with cognition, perception and motor skills.

- Validation Plan: Tool results shall be evaluated against experiment data and data acquired from literature review.

4.2.3 Technology Requirements

The main Technology Requirements are as follows:

TR1. The PAT shall use a Graphical User Interface to enable user input and tool
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output display.

TR2. The PAT shall use a Database to store Operator Performance data.

TR3. The PAT shall accept up to 600 procedures for decomposition.

TR4. The PAT shall use a lookup function to map the OA to their statistical distributions.

TR5. The PAT shall use an algorithm to generate random numbers and sum them into total procedure time.

TR6. The PAT shall use Monte Carlo Simulation to simulate 500 operators performing the SOP procedure.

4.2.4 Functional Requirements
The main Functional Requirements are as follows:

FR1. Provide Interface

FR1.1 Provide Application on Computer

FR1.1.1 System Shuts down and Returns to Home Screen

FR1.2 Provide Display of Result Output

FR1.2.1 Create Report from Displayed Output

FR2. Provide Information of Needed Input

FR2.1 Input Standard Operating Procedures

FR2.1.1 Receive Input: Procedures

FR2.1.2 Receive Input: Tasks

FR2.2 Store Data input into the Tool

FR3. Process Input and Output
FR3.1 Identify Keywords input into the tool
FR.3.2 Allow Accessibility to TSL functions
FR3.3 Request Manual Input for Remaining SOPs
FR3.4 Process Data

FR3.4.1 Check to see if the device Passes or Fails
FR3.4.1.1 Display what percentage Passed
FR3.4.1.2 Display what percentage needs to be sent for testing in Human in the Loop Testing
FR3.4.1.3 Display which tasks Failed

4.3 Operational Scenarios

The main purpose of PAT is to make flights safer and more reliable by inspecting the aircrafts in a short time and evaluating all the functions. Federal Aviation Administration and Aviation Manufacturer are the two main customers and stakeholders that will use PAT the most. Aviation Manufacturer is an entity that builds aircraft and devices. Currently they have their designated engineering representatives to certify the device before having the devices out in the market. They must be certain about the way device functions and operates. Since it is a very time consuming method to take to evaluate the device the company would use PAT to test all the functions within the cockpit in a shorter time and get a more reliable result. PAT would help the manufacture to save cost and time in producing aircrafts. Moreover they minimize the rate of reproducing and fixing the devices after first assembly.
FAA can be one of the main customers of PAT to provide aviation safety. Since FAA enforces laws to have safety for passengers, they can use PAT to evaluate all functions involved with human factor errors. In this way PAT can be used by FAA to evaluate aviation manufacturer work and make sure that the device is reliable and safe to operate. If both stakeholders use PAT, the rate of human factor error will be reduced to zero percent.

Passengers are the tertiary stakeholder and they want to travel safe. They do not have any direct contact with PAT, but the usage of PAT by other stakeholders can give this opportunity to passengers to resolve their needs.

**Process Modeled:**

The Sequence Diagram above inputs Standard Operating Procedures, Operators Actions, and respective Operator Action Categories. The tool has an Operator Performance Model database that uses human perception, cognition, and motor skills. The tool will output the time it takes to complete the task as well as the probability of failure to complete the task.
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If the task has a higher probability to complete the task, the tool will suggest X amount of tasks to be sent to the Human in the Loop Testing.

To reiterate:

**Inputs:** SOPs with a database of Operator Performance Model expressed in statistical distributions of time to complete an action in seconds.

**Outputs:** Frequency distribution of the number of pilots plotted against the time to complete the task along with the Probability of Failure to Complete the procedure.
4.4 Objectives Hierarchy
Below states the high level objectives for the proposed Procedure Analysis Tool.

O.1 Minimize Operational Costs (w=16%)
   O.1.1 Minimize Installation Costs
   O.1.2 Minimize Maintenance Costs (System Costs)

O.2 Optimize Performance (w=26%)
   O.2.1 Maximize Availability of PAT tool
   O.2.2 Maximize Maintainability
   O.2.3 Maximize Reliability of Procedure Analysis Tool

O.3 Maximize Compliance with FAR 25.1302 (w=58%)

Developer preference, Analytical hierarchy process and normalizing techniques were used to come up with the weighting factors. Maximizing the compliance with FAR 25.1302 is currently carrying the highest weight because it is the core of our tool objectives.

Types of Objectives:

1. Fundamental Objectives are essential to the systems purpose. In this project, the fundamental objectives are:
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- Provide Awareness of the tasks that have failed
- Minimize time to perform certification by 68%
- Reduce cost to perform certification by 65%
- Provide Awareness of Results by supplying a notification of whether a task passes or fails

2. Means Objectives help achieve the fundamental objectives. Derived requirements are based upon the means objectives. In this project, the means objectives are:

- Maximize availability of Procedure Analysis Tool by providing function on a computer
- Provide Updates if any change occurs to software
- Detection of Device of Failures must Report Errors within 95%
- Detection must report within 5% of Marginal Error
4.5 Problem Statements

The demand for device certification is projected to peak in the years 2013-2018. An ever-increasing gap exists between the number of available human factor inspectors and the number of new devices that need to be certified, yet the current method used during the certification process is very inefficient, time consuming, and cost prohibitive. The change that has made this certification process is due to the new regulation put into place. The following sections show the derivation the time and cost before FAR 25.1302 regulation was enacted and the current means of compliance regarding, FAR 25.1302.

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<th>Symbol</th>
<th>Definition</th>
<th>Value [Units]</th>
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<tbody>
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<td>n</td>
<td>Number of Runs to complete experiment</td>
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<td>$t_i$</td>
<td>Time to Inspect Function</td>
<td>10 min/1 function × 1 hour/60 min=0.1667 hours per function</td>
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<td>Time to Set up Experiment</td>
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### Design of A PAT for an Affordable Aviation Human Factors Certification Process

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<tr>
<th>$w_P$</th>
<th>Wage of 2 Pilots per Simulation</th>
<th>$$250$hour</th>
</tr>
</thead>
</table>

**Cost and Time of PRE FAR 25.1302**

\[
T_{\text{INSP}}(x) = t_i \times x = 0.1667x
\]

\[
T_{\text{HITL}}(x) = n(t_{SE} + t_{CE})x = 4.6x
\]

\[
T_{\text{Alt1}} = T_{\text{INSP}}(x) + T_{\text{HITL}}(x) = 4.7667x
\]

\[
C_{\text{INSP}}(x) = w_i \times T_{\text{INSP}} = 33x
\]

\[
C_{\text{HITL}}(x) = n((w_i \times t_{SE}) + ((w_P + w_i) \times t_{CE}))x = 1600x
\]

\[
C_{\text{ALT1}}(x) = C_{\text{INSP}}(x) + C_{\text{HITL}}(x) = 1633x
\]

For a device being tested that consists of 600 tasks, the Inspectors and Human in the Loop testers would only need to analyze a small number of tasks. In this example, the inspectors and testers process 30 tasks. Therefore, 30 was input into the formulas shown above.

**Inspection Cost:** $500

**Inspection Time:** 5 hours

**Human in the Loop Testing Cost:** $14,000

**Human in the Loop Testing Time:** 80 hours

Total cost and time for PRE FAR 25.1302 = $14,500 and 85 hours
Cost and Time of POST FAR 25.1302

\[ T_{\text{INS}}(x) = t_i \times x = 0.1667x \]

\[ T_{\text{HITL}}(x) = n(t_{SE} + t_{CE})x = 4.6x \]

\[ T_{\text{ALT1}} = T_{\text{INS}}(x) + T_{\text{HITL}}(x) = 4.7667x \]

\[ C_{\text{INS}}(x) = w_i \times T_{\text{INS}} = 33x \]

\[ C_{\text{HITL}}(x) = n((w_i \times t_{SE}) + ((w_P + w_i) \times t_{CE}))x = 1600x \]

\[ C_{\text{ALT1}}(x) = C_{\text{INS}}(x) + C_{\text{HITL}}(x) = 1633x \]

Assuming the same device of 600 is to be tested, the current process now has a mandated regulation stating all functions and tasks must be tested. This increases the cost and time of the certification process dramatically.

With all 600 functions tested:

Inspection Cost: $10,000

Inspection Time: 100 hours

Human in the Loop Testing Cost: $979,000

Human in the Loop Testing Time: 1600 hours

Total cost and time for PRE FAR 25.1302 = $989,000 and 1700 hours

Additionally, the evaluation process is ineffective. Currently, the airworthiness certification process is solely paper based and is manually computed. No tool exists to
automate the process; however, if the tool existed, then it would be able to reduce time and energy. The certification process includes four different phases where the design and performance assessment phases require the most time and are separately conducted. Currently, no cockpit interaction has been integrated into the certification process. For example, crew-crew interactions, crew-automation interaction, crew-out of the window interaction, crew-Air Traffic Control (ATC) interactions are not evaluated during the certification process. These problems can be seen in the table below. Along with each problem is the listed solution that the Procedure Analysis Tool proposed will solve.

<table>
<thead>
<tr>
<th>Problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stakeholders tension created the DER who is both employed by the applicant and must report to the FAA inspector during the certification process</td>
</tr>
<tr>
<td>Lack of cockpit interaction in the current certification process</td>
</tr>
<tr>
<td>Current means of compliance are subjective</td>
</tr>
<tr>
<td>Time Consuming and Expensive</td>
</tr>
</tbody>
</table>
4.6 Proposed Solution

The solution proposes a Procedure Analysis Tool that will simulate the operation procedures within the cockpit. The use of this tool will solve the four main problems stated above, relieve stakeholder tensions, and provide for a more efficient use of the inspector’s time.

Proposed Concept of Operations

The proposed solution is a Procedure Analysis Tool (PAT) for the use by the designated engineering representative. This tool will substitute the current certification evaluation process (i.e. Inspection, and HitL on all tasks) with the inspection testing accompanied by PAT on all tasks and then dedicate HitL testing to only procedures with high probability of failure to complete. The PAT simulates flightcrew performance and keeps track of their timing while executing procedures on a device enabling affordable automation for task/usability analysis. The automated evaluation is significantly faster and cheaper. It also eliminates stakeholders’ tensions by providing rapid, yet objective means of analysis.

Also, in addition to enabling compliance with the requirement to analyze all tasks, it enables implementation of accessible and usable control and information by the flight crew in a manner consistent with (1) urgency; as a result of defining a threshold for the PFtoC, (2) frequency; as a result of modeling OACs with various frequency levels (rare, moderate, and routine), and (3) task duration; as represented by the TTC the procedure. A high level idea of the PAT concept of operations is illustrated in the Figure 3 below where the DER evaluates a proposed system design (device) and its allotted airline SOP using a combination of TSL and operator performance model that includes a database of
OAC and their related statistical distributions to generate time-on-procedure distributions for each procedure.

The procedure analysis tool will save the cost of the human factors certification process by 65%. This can be seen in the cost and time derivations for the proposed process that includes this procedure analysis tool. This can be seen in the formulas solved below:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
<th>Value [Units]</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>Number of Runs to complete experiment</td>
<td>20</td>
</tr>
<tr>
<td>$t_i$</td>
<td>Time to Inspect Function</td>
<td>10 min/1 function × 1 hour/60 min=0.1667 hours per function</td>
</tr>
<tr>
<td>$t_{SE}$</td>
<td>Time to Set up Experiment</td>
<td>3 hours/30 functions=0.1 hours per function</td>
</tr>
<tr>
<td>$t_{CE}$</td>
<td>Time to Complete Experiment</td>
<td>4 hours/30 functions=0.13 hours per function</td>
</tr>
</tbody>
</table>
Design of A PAT for an Affordable Aviation Human Factors Certification Process

<table>
<thead>
<tr>
<th>$t_{SF}$</th>
<th>Time to Set up Function</th>
<th>1.5 hours per function</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{RS}$</td>
<td>Time to Run Simulation</td>
<td>13.68 seconds/1 hour × 1 hour/3600 seconds = 0.0038 hours/function</td>
</tr>
<tr>
<td>$w_i$</td>
<td>Wage of Inspector</td>
<td>$200/hr</td>
</tr>
<tr>
<td>$w_P$</td>
<td>Wage of 2 Pilots per Simulation</td>
<td>$250/hr</td>
</tr>
</tbody>
</table>

Cost and Time of POST FAR 25.1302

\[
T_{INSP}(x) = t_i \cdot x = 0.1667x
\]

\[
T_{HITL}(x) = n(t_{SE} + t_{CE})x = 4.6x
\]

\[
T_{PAT}(x) = (t_{SF} + t_{RS})x = 1.5038x
\]

\[
C_{INSP}(x) = w_i \cdot T_{INSP} = 33x
\]

\[
C_{HITL}(x) = n((w_i \cdot t_{SE}) + ((w_P + w_i) \cdot t_{CE}))x = 1600x
\]

\[
C_{PAT}(x) = w_i (t_{SF} + t_{RS})x = 300x
\]

\[
T(x) = T_{INSP}(x) + T_{PAT} + 10\% T_{HITL}(x) = 2.1x
\]

\[
C(x) = C_{INSP} + C_{PAT} + 10\% C_{HITL} = 490x
\]

Assuming the same device of 600 is to be tested, the new process will cost $490 per function tested.

Cost of POST FAR 25.1302 with PAT: $294,000

In Summary:
This new tool will provide an automated evaluation and only send the functions that have a probability of failure to complete to the HitL testing. This will be significantly faster and cheaper throughout the entire process. This process will also eliminate stakeholders’ tensions by providing rapid, yet objective means of analysis. Lastly, it will enable implementation of accessible and usable control and information consistent with (1) urgency, (2) frequency, and (3) task duration.
4.7 Functional Architecture

The highest-level functional decomposition is shown in the hierarchical decomposition in the figure below: The super system is composed of the user and the system; that is the Designated Engineering Representative (DER) and the Procedure Analysis Tool (PAT).

This hierarchy provides the high level idea of the Human Computer Interaction (HCI) involved in evaluating the procedure/function. The following diagram is an IDEF0 where the functional architecture works as follows: the DER decomposes the procedures into OA and categorizes them OAC. The PAT then maps each OA to its statistical distribution. When the DER finishes adding new OAs, the PAT sums up all the OA times after which it performs Monte Carlo simulation. The PAT displays a first stage output displaying a frequency distribution of number of pilots performing the previously decomposed procedure against the time to perform the procedure. At which point the DER inputs threshold for failure to complete the procedure along with the allowable Probability of Failure to Complete (PFtoC). The PAT processes the comparison and
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displays results which are in this case whether the procedure has passed or failed the test (i.e., it is a pass if the PFToC procedure is below the allowable PFToC set by the DER).

A second set of analysis that the PAT can provide is option to perform Sensitivity Analysis (SA). The DER selects option to perform SA and inputs SA parameters. The PAT shows results.

A second level decomposition of the Perform DER Duties and Provide PAT Services functions is shown below:

I. Perform DER Duties:
The functional decomposition is shown below with the Perform DER Duties as
the first level function decomposed into 7 functions. They are:

F2.1 Decompose Task
F2.2 Categorize OA
F2.3 Perform Request for Monte Carlo Simulation
F2.4 Provide Acceptable PFtoC
F2.5 Perform Request for Sensitivity Analysis
F2.6 Input Parameters for Sensitivity Analysis

The IDEF0 diagram linked to this decomposition is shown below where the DER uses the
Standard Operating procedures and performs a decomposition of the procedure. The OAs
are the output of the F2.1 Decompose task function and will be later used as an input to
the PAT (this will be shown and explained on the next functional decomposition). Once
the OAs are created the PAT provides a pre-set selection of OAC to the DER from which
he or she will select the category the OA falls under. This process is shown by the F2.2
function Categorize OA. Here as well, the output to this function will be used as in input...
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to the PAT for further processing. The next function is F.2.3 Perform a request for a Monte Carlo Simulation. When the DER is done performing the decomposition, the PAT should have compiled the first task time and shown it in the user interface. At this point the DER requests for a Monte Carlo simulation to replicate the task time 500 times and record the timing of each iteration. This function also includes the request for the resulting statistical distribution. The next function is F2.4 Provide Threshold for Fail/Pass where the PAT prompts for this user input by showing the final distribution to give an idea of a threshold within possible bounds. At this point the DER inputs the requested threshold for Probability of Failure to Complete the Task. The two remaining functions are for the Sensitivity Analysis where the PAT gives the option of performing the sensitivity analysis with question. The DER replies yes or No. if the reply is yes, this means that the output of this function is the request for sensitivity analysis. The sensitivity analysis involves changing the parameters of the statistical distributions associated with the OACs. That is what is performed by the last functions F2.6. Input parameters for sensitivity analysis.
II. Provide PAT Services:

The functional decomposition of this function is as follows:

F1.1 Provide Interface for Input/Output

F1.2 Provide Operator Action Categories

F1.3 Generate Random numbers

F1.4 Sum up OA times into task time

F1.5 Request threshold for PFtoC task and Acceptable PFtoC

F1.6 Display PFtoC and results of Fail/Pass

F1.7 Provide option to perform Sensitivity Analysis

F1.8 Show results of Sensitivity Analysis
F.1 Provide PAT Services

F1.1 Provide Interface for Input/Output
F1.2 Provide Operator Action Categories
F1.3 Generate Random Numbers
F1.4 Sum up OA times into task time
F1.5 Request threshold for PPtoC task and Acceptable PPtoC
F1.76 Provide option to perform Sensitivity Analysis

Design of A PAT for an Affordable Aviation Human Factors Certification Process
4.8 Physical Architecture

The physical architecture of the system is composed of the Procedure Analysis Tool and the user (i.e., the DER). The PAT is composed of three components, they are (1) the Graphical User Interface (GUI) for the user input output display, (2) the Processing Unit that performs the calculation of task times and the Monte Carlo simulation, and (3) the Operator Performance Model that stores the operator action categories and their relating statistical distributions.
4.9 Mathematical Models and Assumptions

We designed experiments for each operator action category. The result of the experiments contributed to 4 different distributions. These are explained below.

Lognormal Distribution

Variable time to complete the task $t'$ is log-normally distributed if $\log (t')$ has a normal distribution. Skewed distributions are particularly common when mean values are low, variances large, and values cannot be negative. Skewed distributions best fit log normal distributions. Hence, the data set that had more skewed distribution, they were denoted as log-normally distributed. The lognormal distribution is a 2-parameter distribution. The probability density function of $t'$ for this distribution is calculated by:

$$f(t') = \frac{1}{\sigma' \sqrt{2\pi}} e^{-\frac{1}{2} \left(\frac{t'-\mu'}{\sigma'}\right)^2}$$

Where:

$t'$ = values are the time-to-complete the task

$\mu'$ = mean of the time-to-complete the task

$\sigma'$ = standard deviation of the time-to-complete the task

The mean of the lognormal distribution is calculated as follows:

$$\mu = e^{\mu' + \frac{1}{2} \sigma'^2}$$

The standard deviation of the lognormal distribution is calculated as follows:

$$\sigma_T = \sqrt{\left(e^{2\mu'} + \sigma'^2\right) \left(e^{\sigma'^2} - 1\right)}$$

Normal Distribution

---


Normal (or Gaussian) distribution is a continuous probability distribution — a function that tells the probability that any real observation will fall between any two real limits or real numbers, as the curve approaches zero on either side. Normal distribution is useful for our experiments because of the central limit theorem, which allows, independently drawn mean of many random variables from the same distribution to be distributed approximately normally, irrespective of the form of the original distribution. For variable time to complete the task $x$, the probability density function of $x$ for this distribution is calculated by:

$$f(x, \mu, \sigma) = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Where:

$\mu$ = mean of the time-to-complete task

$\sigma$ = standard deviation of the time-to-complete the task

**Triangular Distribution**

A triangular distribution is a continuous probability distribution with a probability density function shaped like a triangle. It is defined by three values: the minimum value $a$, the maximum value $b$, and the peak value $c$. For our experiments, it was useful to use triangular distribution because we can often estimate the maximum and minimum values, and the most likely outcome, of the time-to-complete tasks even if we are lacking the mean and standard deviation of the data set.

The formula that we used for the probability density function is:

---


Exponential Distribution

We decided to use exponential distribution for its memory less properties and its capability to estimate time between events in Poisson process.

The probability density function (pdf) of an exponential distribution is\(^\text{6}\)

\[
f(x; \lambda) = \begin{cases} 
\lambda e^{-\lambda x} & x \geq 0, \\
0 & x < 0.
\end{cases}
\]

Where:

\(\lambda = \text{rate parameter of the distribution}\)

Mean and variance of an exponentially distributed random variable X with rate parameter \(\lambda\) is given by:

\[
E[X] = \frac{1}{\lambda}
\]

\[
\text{Var}[X] = \frac{1}{\lambda^2}
\]

For example, to calculate the mean and standard deviation of the working memory lognormal distribution we used the following equations:

\[
f(t') = \frac{1}{\sigma' \sqrt{2\pi}} e^{-\frac{1}{2} \left( \frac{t' - \mu'}{\sigma'} \right)^2}
\]

……………………………(1)

\[
\mu = e^{\mu' + \frac{1}{2} \sigma'^2} \sigma_T = \sqrt{\left( e^{2\mu' + \sigma'^2} \right) \left( e^{\sigma'^2} - 1 \right)}
\]

……………………………(2)

Where:

\[
t' = \text{each data point for time-to-complete the task}
\]

\[
\mu' = 0.737
\]

\[
\sigma' = 1.21
\]

0.737 for 1.21 were found by plugging in the sample mean of 4.58 and standard deviation of 6.54 to the pdf of the distribution equation (1) for each point and taking the mean and standard deviation of all the data. After plugging 0.737 and 1.21 back into the equation (2), we found that the mean time is 4.37 and the standard deviation is 7.43.

**4.9.1 Operator Action Category Statistical Distributions Elicitation:**

There are 17 OACs in total (shown in Table 1). Each OAC is accompanied by a statistical distribution. The statistical distributions and their parameters were either taken from literature review (ex: Visual Cue N~ (0.62, 0.11) (Cao, 2013)), or produced by designing experiments using GMU students as subjects. For example, the “Working
Memory Item Retrieval” OAC was performed between a time keeper and the subject as follows:

1. Time keeper reads out loud all of the steps of a task. Example the “Hold at Present Position” Task
2. Time keeper immediately starts stopwatch for 50 seconds allowing subject to remember what was read
3. Time keeper asks question related to the above mentioned task, and immediately starts stopwatch until subject answers correctly. The recorded time is labeled $T_{tot}$. Note: The timer is kept running if the subject answers the question incorrectly.
4. Once the correct answer is obtained, subject speaks out the answer again while time keeper records timing of voicing out the answer. This time is labeled $T_{ans}$
5. Repeat steps 2 to 4 five times using a new question
6. For each question, compute the working memory item retrieval time ($T_{WM}$) by subtracting the answer time from the total time as follow:
   \[ T_{WM} = T_{tot} - T_{ans} \] (1)
7. Record and analyze data for fit.

This experiment was performed by 5 subjects for 2 tasks with 5 questions each resulting in 50 data points. In this case, the distribution was found to fit a lognormal type according to the analysis (Limpert, 2001) of the mean, variance, and skeweness of the sample. The resulting distribution is Log (0.737, 1.21).

4.9.2 Design of Experiment
Each experiment was executed 10 times with 2 participants each time. Sample size:5

Operator Action Flight control Manipulation (hand)
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Participant 1:
1. Start the time when finish dictating and continue until Participant 2 gets it right
2. Repeat it for 10 times for each task
3. Tabulate them in excel

Participant 2:
1. T1 Switch on autopilot and autothrottle
2. T2 Steer the aircraft laterally(left and right) with the nose wheel steering
Figure 1: Normal Distribution with mean of 2.57 and standard deviation of 0.651

Flight control Manipulation (feet)

Participate 1:

- Start the time when finish dictating and continue until Participant 2 gets it right
- Repeat it for 10 times for each task
- Tabulate them in excel

Participant 2:

- Apply brake (located at the toe of the pedal)
Figure 2: Lognormal Distribution with a mean of 1.12 and Standard Deviation of 0.231

Thrust levers manipulation

Participant 1:

- Start the time when you finish dictating and continue until Participant 2 gets it right
- Repeat it for 10 times for each task
- Tabulate them in excel

Participant 2:

- Set Thrust lever to fuel off.
- Press the TOGA buttons and advancing the thrust levers to the GA MAX
Figure 3: Triangular Distribution with the minimum value 1.12, the maximum value 2.09, and the peak value 1.58

**Long term procedural memory item retrieval**

Participant 1:

- Start the time when finish dictating and don’t stop until Heather gets it right
- Repeat it for 10 times for each task
- Tabulate them in excel
- Have the planning a holding pattern at a waypoint (till step 4) from pilots guide (pg 9-20) ready
- Participant 2 will memorize the guide. Experiment is scheduled to be on after 4 days from memorization
Planning a holding pattern at a waypoint in the flight plan

1. Press HOLD.

Planning a holding pattern at a waypoint in the flight plan (Cont)

2. Press the line select key for the waypoint where the aircraft should enter the holding pattern. This copies the waypoint identifier to the scratchpad.

3. Press 6L to move the waypoint identifier in the scratchpad to the HOLD AT field.
Planning a **holding pattern at a waypoint in the flight plan** (Cont)

4. Press a line select key to move the holding pattern identifier from the scratchpad to the flight plan. The **hold** fix is entered in the flight plan before the selected waypoint, a route discontinuity is entered after the hold fix, and the RTE HOLD page automatically displays.

---

Participant 2:

- Memorize planning a holding pattern at a waypoint from pilots guide (pg 9-20) 4 days before the experiment.
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Figure 4: Lognormal Distribution with mean of 1.21 and Standard Deviation of 2.1

2.1

Working memory item retrieval

Participant 1:

- Start the time when finish dictating and continue until Participant 2 gets it right
- Dictate the following only once
  - Press **HOLD**
  - Press **6R**
  - Review the default
  - Press **EXEC** to activate holding patterns
- After 51 seconds interval
  - Ask what comes after pressing 6R key?
  - Ask what comes before pressing EXEC?
- Repeat it for 10 times
- Tabulate them in excel

Participant 2:

Follow Participant 1.
Figure 5: Lognormal Distribution with mean of 4.37 and Standard Deviation of 7.43

TSL select

Participant 1:

- Turn on the program/Flight display (FMS)
- Explain to Participant 2 the procedure for change speed schedule for climb (6-16 pilots guide)
- Make Participant 2 do the change speed schedule for climb (6-16 pilots guide)
- Start the time when finish dictating and continue until Participant 2 gets it right
- Repeat it for 10 times for each task
- Tabulate them in excel
Participant 2:

Follow Participant 1
Figure 6: Triangular Distribution with the minimum value 7.5, the maximum value 12, and the peak value 17.5

<table>
<thead>
<tr>
<th>Operator Action Category (OAC)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>button push</td>
<td>Normal(0.3, 0.01)</td>
</tr>
<tr>
<td>decision (TSL Id)</td>
<td>Normal(0.5, 0.002)</td>
</tr>
<tr>
<td>decision/choice</td>
<td>Lognormal(2, 1)</td>
</tr>
<tr>
<td>flight controls manipulation (feet)</td>
<td>Normal(2.31, 0.651)</td>
</tr>
<tr>
<td>flight controls manipulation (hands)</td>
<td>Lognormal(1.12, 0.231)</td>
</tr>
<tr>
<td>listen to audio (ATC Clearance, Aural Warning)</td>
<td>exponential (1, 0.1)</td>
</tr>
<tr>
<td>long term memory item retrieval</td>
<td>Lognormal(1.3, 2.1)</td>
</tr>
<tr>
<td>MCC callout</td>
<td>Normal(2, 1)</td>
</tr>
<tr>
<td>MCC readback</td>
<td>Normal(1.5, 0.2)</td>
</tr>
<tr>
<td>Talk to ATC (including Readback)</td>
<td>exponential (0.9, 0.1)</td>
</tr>
<tr>
<td>thrust levers manipulation</td>
<td>Triangular(0.1, 2, 3.5)</td>
</tr>
<tr>
<td>TSL Select</td>
<td>Normal(0.1, 0.002)</td>
</tr>
<tr>
<td>visual check</td>
<td>Normal (1, 0.5)</td>
</tr>
<tr>
<td>visual cue: Routine</td>
<td>Normal(0.632, 0.011)</td>
</tr>
<tr>
<td>visual cue: Moderate frequency</td>
<td>Normal(1, 0.02)</td>
</tr>
<tr>
<td>visual cue: Rare frequency</td>
<td>Normal(1.632, 0.03)</td>
</tr>
<tr>
<td>working memory item retrieval</td>
<td>Lognormal(0.737, 1.21)</td>
</tr>
</tbody>
</table>
4.9.3 Random Number Generation

The generation of the random number per OAC statistical distribution was performed based on the inverse function and the Linear Congruential (LCG) methods (Banks, Carson II, Nelson, & Nicol, 2009).

4.9.4 Sequential Variables Process

The Operator Actions (OA) are modeled in series and their sum is illustrated by the chart below demonstrating a simplified version of a task composed of 3 OAs.

The principles mentioned above are implemented in the below algorithm as follow:

1. carry out any initializations required.
2. while i < 500
3. {
4.    initialize Procedure time PT
5.    user input ← OA and OAC
6.    read in the OAC for the OA in sequence.
7.    generate next random number as per OAC.
8  add the number to the accumulated sum PT.
9        i++
10  }
11  identify the type of distribution.
12  evaluate the average.
13  evaluate the standard deviation.
14  user input ← Threshold of probability of failure to complete.
15  calculate the probability of failure to complete the task.

4.10 Results - Case-Study of 15 SOP Procedures
For the preliminary analysis, a pool of 15 procedures was defined for the MCDU. In an effort to make this first sample a representative one, procedures were drawn from across all phases of flight. For example, the Initialize Position procedure would be performed during the Pushback/Taxi/Take-off phase. The selection of procedures per phase of flight is as follows: 4 Procedures for Flight Planning, 3 for each of the Pushback/Taxi/Take-off, and Domestic/Oceanic Cruise, 4 for Descent/Final Approach phases, and 1 Procedure for the Taxi and Arrival phase.

Each Procedure was (1) decomposed, (2) analyzed for OAC weight, (3) analyzed for statistical distribution fit and (4) analyzed for PFtoC the Procedure.

An example task description for the Initialize Position task is shown in Figure 7. This procedure totaled 55 operator actions. The OACs weights were as follows: (47.27%) “Visual cue”, (16.36%) “Long-term memory item retrieval”, (12.73%) “Decision/Choice”, (10.91%) “Button Push” and (5.45%) “Working-Memory Item
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Retrieval” while (1.82%) of the procedure is either “TSL Procedure Identification”, “Decision/Choice”, “TSL Selection”, or “Visual Check”.

The *Initialize Position* output distribution best fitted a Lognormal distribution with parameters 50 + LOGN (166, 238), and the PFtoCT was computed to be 1.6%.

With a maximum allowable PFtoC of 2.5% the procedure was estimated to have passed the certification evaluation.
4.11 Method of Analysis

I. Overview:

The PAT models perceptual, cognitive, and motor skills time performances to simulate pilot operations in the cockpit environment. The input to the PAT is a detailed description of the tasks from the SOP and/or the CBT. The PAT combines SOPs with a database of Operator Performance Model 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 along with the PFtoC the procedure. Figure 4 shows a model for the tool with input, output, and where the Operator Performance Model database comes into play.

![Process Modeled by PAT Diagram]

**FIGURE 7 - PROCESS MODELED BY PAT**

The process is seven steps. The DER performs steps 1 and 5 while the rest is accomplished by the PAT as follows:

1. Decompose procedure into Operator Actions (OA) and categorize into OAC.
2. Associate with Operator Performance Database (OPD).
3. Simulate task operation.
4. Request threshold for allowable time window and acceptable PFtoC from user.
5. Execute user input as required.
6. Calculate PFtoC for the procedure to determine if device functions require further HitL testing.

7. Perform a Sensitivity Analysis to identify OAC with highest impact.

   Step one is performed using an interaction diagram (see Figure 6). Each OA falls under an Operator Action Category (OAC) associated with a statistical distribution as shown in Table 1. After the identification of the OAC for each OA, random numbers are generated according to their statistical distributions before being aggregated to a procedure time. This operation is performed 500 times using a Monte Carlo simulation to result in a distribution as shown in Figure 1.

II. Mathematical Models/Algorithms

4.11.1 Initialize Position:

An example task description for the “Initialize Position” task is shown in Figure 6. This procedure totaled 55 operator actions. The OACs weights were as follows: (47.27%) “Routine visual cue”, (16.36%) “Long-term memory item retrieval”, (12.73%) “Decision/Choice of button”, (10.91%) “Button push” and (5.45%) “Working memory item retrieval” while (1.82%) of the procedure is either “TSL Procedure Identification”, “Listen to Audio”, “TSL Selection”, or “Visual Check”.

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<table>
<thead>
<tr>
<th>OAC for Initialize Position</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>button push</td>
<td>11.32%</td>
</tr>
<tr>
<td>decision (TSL Id)</td>
<td>1.89%</td>
</tr>
<tr>
<td>decision/choice</td>
<td>13.21%</td>
</tr>
<tr>
<td>listen to ATC Clearance</td>
<td>1.89%</td>
</tr>
<tr>
<td>long term memory item</td>
<td></td>
</tr>
<tr>
<td>retrieval</td>
<td>15.09%</td>
</tr>
<tr>
<td>TSL Select</td>
<td>1.89%</td>
</tr>
<tr>
<td>visual check</td>
<td>1.89%</td>
</tr>
</tbody>
</table>
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<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>visual cue</td>
<td>47.17%</td>
</tr>
<tr>
<td>working memory item</td>
<td></td>
</tr>
<tr>
<td>retrieval</td>
<td>5.66%</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>

The “Initialize Position” output distribution best fitted a Lognormal distribution with parameters 50 + LOGN (166, 238), and the PFtoCT was computed to be 1.6%. With a maximum allowable PFtoC of 2.5% the procedure was estimated to have passed the certification evaluation. A screenshot of the task decomposition is shown in figure, a table summarizing the OAC contribution to the overall task is shown in figure. As well, the distribution showing a right tail along with the PFtoC is shown in figure.

| PFtoC | 1.6% | Pass |

Enter Runway Extension:
The results of the decomposition yielded 18 operator actions. The percentage of the OAC to the overall procedure are: 41% for visual cue, 35% long term memory retrieval, almost 6% button push, decision TSL, and listen to audio as shown on the table below.

<table>
<thead>
<tr>
<th>Row Labels</th>
<th>Count of random number</th>
</tr>
</thead>
<tbody>
<tr>
<td>button push</td>
<td>5.88%</td>
</tr>
<tr>
<td>decision (TSL Id)</td>
<td>5.88%</td>
</tr>
<tr>
<td>listen to audio (ATC Clearance, Aural Warning)</td>
<td>5.88%</td>
</tr>
<tr>
<td>long term memory item retrieval</td>
<td>35.29%</td>
</tr>
<tr>
<td>TSL Select</td>
<td>5.88%</td>
</tr>
<tr>
<td>visual cue: Routine</td>
<td>41.18%</td>
</tr>
</tbody>
</table>

Running the Monte Carlo distribution resulted in the distribution shown on figure below. And the probability of failure to complete the task is 2.4% making the procedure pass the test.
Change Turn Direction and Speed

This task involves a change in the HOLD setting after they were entered. The operator changes the speed information as well as the turn direction in addition to the inbound track information. The decomposition (shown in figure) of this task resulted in 28 operator actions of which 39% are visual cues, 36% are long term memory retrievals, 14% button pushes, and 3.57% working memory items retrievals and decision (TSL ID).

<table>
<thead>
<tr>
<th>Row Labels</th>
<th>Count of random number</th>
</tr>
</thead>
<tbody>
<tr>
<td>button push</td>
<td>14.29%</td>
</tr>
<tr>
<td>decision (TSL Id)</td>
<td>3.57%</td>
</tr>
<tr>
<td>long term memory item retrieval</td>
<td>35.71%</td>
</tr>
<tr>
<td>TSL Select</td>
<td>3.57%</td>
</tr>
<tr>
<td>visual cue: Rare frequency</td>
<td>39.29%</td>
</tr>
<tr>
<td>working memory item retrieval</td>
<td>3.57%</td>
</tr>
</tbody>
</table>
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| Grand Total | 100.00% |
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The resulting distribution is shown below with PFtoC of 0.8% making the procedure pass the certification evaluation test.

![Frequency Chart]

| PFtoC | 0.80% |

**4.11.2 Select Speed Restriction:**

The select speed restriction is a task that is performed when the navigation Flightplan or ATC request for it. The decomposition of this task resulted in 25 Operator Actions as shown on the diagram in figure below. The Operator Action Categories proportions are: 28% moderate frequency visual cue, 20% routine visual cue, 24% long term memory item retrieval, 12% button push, and 4% either a decision, a choice of button, a listen to audio, or a TSL Select.

<table>
<thead>
<tr>
<th>Row Labels</th>
<th>Count of random number</th>
</tr>
</thead>
<tbody>
<tr>
<td>button push</td>
<td>12.00%</td>
</tr>
<tr>
<td>decision (TSL Id)</td>
<td>4.00%</td>
</tr>
<tr>
<td>Task</td>
<td>Percentage</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>decision/choice</td>
<td>4.00%</td>
</tr>
<tr>
<td>listen to audio (ATC Clearance, Aural Warning)</td>
<td>4.00%</td>
</tr>
<tr>
<td>long term memory item retrieval</td>
<td>24.00%</td>
</tr>
<tr>
<td>TSL Select</td>
<td>4.00%</td>
</tr>
<tr>
<td>visual cue: Moderate frequency</td>
<td>28.00%</td>
</tr>
<tr>
<td>visual cue: Routine</td>
<td>20.00%</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>
The resulting distribution and the PFtoc of 2.4% are shown on figure below:
This task has passed the certification test for a threshold at 3 std from mean and acceptable PFtoC of 2.5%.

4.11.3 Enter Hold Exit Time:

This procedure is performed when setting up the HOLD parameters settings. The decomposition yielded 28 Operator Actions and the categories percentages were as follows: 50% visual cues, 25% long term memory retrieval, 7% either button push or working memory retrieval, and 3.75% TSL Id, decision/choice, or TSL Select.

<table>
<thead>
<tr>
<th>Row Labels</th>
<th>Count of random</th>
</tr>
</thead>
<tbody>
<tr>
<td>button push</td>
<td>7.14%</td>
</tr>
<tr>
<td>decision (TSL Id)</td>
<td>3.57%</td>
</tr>
<tr>
<td>decision/choice</td>
<td>3.57%</td>
</tr>
<tr>
<td>long term memory item</td>
<td>25.00%</td>
</tr>
</tbody>
</table>
Design of A PAT for an Affordable Aviation Human Factors Certification Process

retrieval

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>TSL Select</td>
<td>3.57%</td>
</tr>
<tr>
<td>visual cue: Routine</td>
<td>50.00%</td>
</tr>
<tr>
<td>working memory item retrieval</td>
<td>7.14%</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>
The probability of failure to complete the task was 2.4% resulting in the task passing the evaluation test.

4.11.4 Check Climb and Cruise VNAV Setting:

The decomposition of this task resulted in 28 Operator actions as shown on figure the OAC percentages are shown on table below

<table>
<thead>
<tr>
<th>Row Labels</th>
<th>Count of random number</th>
</tr>
</thead>
<tbody>
<tr>
<td>button push</td>
<td>12.00%</td>
</tr>
<tr>
<td>decision (TSL Id)</td>
<td>4.00%</td>
</tr>
<tr>
<td>decision/choice</td>
<td>4.00%</td>
</tr>
<tr>
<td>listen to audio (ATC Clearance, Aural Warning)</td>
<td>4.00%</td>
</tr>
<tr>
<td>long term memory item retrieval</td>
<td>24.00%</td>
</tr>
</tbody>
</table>
Design of A PAT for an Affordable Aviation Human Factors Certification Process

<table>
<thead>
<tr>
<th>TSL Select</th>
<th>4.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>visual cue: Moderate frequency</td>
<td>28.00%</td>
</tr>
<tr>
<td>visual cue: Routine</td>
<td>20.00%</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>
Select Arrival Procedure:

This procedure may be performed during the initial approach phase where the pilots input the intended arrival information. The decomposition of this task resulted in 47 Operator
Design of A PAT for an Affordable Aviation Human Factors Certification Process

Actions and their contribution to the procedure by percentage is 61% visual cue, 13% button push, 11% decision/choice, 9% long term memory item retrieval, and 2% TSL Id, listen to audio, or TSL Select as shown on the table below:

<table>
<thead>
<tr>
<th>Row Labels</th>
<th>Count of random number</th>
</tr>
</thead>
<tbody>
<tr>
<td>button push</td>
<td>12.77%</td>
</tr>
<tr>
<td>decision (TSL Id)</td>
<td>2.13%</td>
</tr>
<tr>
<td>decision/choice</td>
<td>10.64%</td>
</tr>
<tr>
<td>listen to audio (ATC Clearance, Aural Warning)</td>
<td>2.13%</td>
</tr>
<tr>
<td>long term memory item retrieval</td>
<td>8.51%</td>
</tr>
<tr>
<td>TSL Select</td>
<td>2.13%</td>
</tr>
<tr>
<td>visual cue: Routine</td>
<td>61.70%</td>
</tr>
</tbody>
</table>

**Grand Total** | 100.00%

The resulting PFtoC is 4.8% resulting in the failure of the procedure to pass the certification test.
Design of A PAT for an Affordable Aviation Human Factors Certification Process

PFtoC 4.80%
Design of A PAT for an Affordable Aviation Human Factors Certification Process
4.11.5 *Change speed and altitude of a non-active waypoint*: 

This task happens when the pilot for some reason (ATC instruction or change of navigation pan) need to change the setting of a waypoint that is not active in the current conduct of the flight. This task resulted in 33 operator actions and the percentages are as follow:

<table>
<thead>
<tr>
<th>Row Labels</th>
<th>Count of random number</th>
</tr>
</thead>
<tbody>
<tr>
<td>button push</td>
<td>15.15%</td>
</tr>
<tr>
<td>decision (TSL Id)</td>
<td>3.03%</td>
</tr>
<tr>
<td>decision/choice</td>
<td>3.03%</td>
</tr>
<tr>
<td>listen to audio (ATC Clearance, Aural Warning)</td>
<td>3.03%</td>
</tr>
<tr>
<td>long term memory item retrieval</td>
<td>12.12%</td>
</tr>
<tr>
<td>TSL Select</td>
<td>3.03%</td>
</tr>
<tr>
<td>visual cue: Moderate frequency</td>
<td>30.30%</td>
</tr>
<tr>
<td>visual cue: Routine</td>
<td>21.21%</td>
</tr>
<tr>
<td>working memory item retrieval</td>
<td>9.09%</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>

The PFtoC the task and the distributions are shown in the figure below with the probability of failure to complete the task of 1.4%
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| PFtoC | 1.4% |

Select a Preset Company Flightplan:
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Before the aircraft departs the origin airport, the pilots must enter a Flightplan. This specific procedure is for a preset company Flightplan that is usually stored in the aircraft Flight Management System. This task resulted in 48 operator actions and the categories involved in the task are:

<table>
<thead>
<tr>
<th>Row Labels</th>
<th>Count of random number</th>
</tr>
</thead>
<tbody>
<tr>
<td>button push</td>
<td>14.29%</td>
</tr>
<tr>
<td>decision (TSL Id)</td>
<td>2.04%</td>
</tr>
<tr>
<td>decision/choice</td>
<td>10.20%</td>
</tr>
<tr>
<td>listen to ATC Clearance</td>
<td>2.04%</td>
</tr>
<tr>
<td>long term memory item retrieval</td>
<td>18.37%</td>
</tr>
<tr>
<td>Readback to ATC</td>
<td>2.04%</td>
</tr>
<tr>
<td>TSL Select</td>
<td>2.04%</td>
</tr>
<tr>
<td>visual check</td>
<td>2.04%</td>
</tr>
<tr>
<td>visual cue</td>
<td>40.82%</td>
</tr>
<tr>
<td>working memory item retrieval</td>
<td>6.12%</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>

The probability of failure to complete the task is 2.6% failing the certification test. The resulting distribution is shown on the figure below:
4.12 Verification and Validation

Web browser search:

1. Open Google Chrome
2. Type RJ100 in search box and hit search
4. Report the max takeoff weight and payload

Task Breakdown for the experiment:

Id Task – cues for new task the task is identified from when the time keeper in the experiment asks the subject to make a search. It’s analogous to the listen to ATC (ATC gives clearance, and pilots know what to do).

Estimate the time between explanation and understanding of the task.

Select Function – cues to map task to function [find the browser icon]

Here the function to select (mentally) is the ‘search’ feature (Google) no visual cues are involved so far. it’s all cognitive.

Access – cues to get to input device [click the browser icon](1 through 3 are visual cues, 4 is access, 5 is enter)

1. Visual cue: browser explorer
2. Visual cue: browser chrome
3. Visual cue: browser Firefox
4. Choice/decision: browser chrome
5. Button push: click on chrome icon.
Now the same cycle goes for selecting the right icon and so on, until reaching the “search” button that includes all the visual cues and the button pushes (in addition to some working and long term memory as required).

- Entry – cues to select/enter information [same as above]
- Confirm/Verify – cues to confirm/verify [see the browser]
- Visual cue: page display change
- Monitor and Recognize Anomalies – cues register time to open the browser, is it slow?
- Visual cue: search contains the word “RJ100”

<table>
<thead>
<tr>
<th>sequence</th>
<th>entity performing</th>
<th>OAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>listen to instruction</td>
<td>listen to audio (ATC Clearance, Aural Warning)</td>
<td></td>
</tr>
<tr>
<td>memory item retrieval</td>
<td>long term memory item</td>
<td></td>
</tr>
<tr>
<td>identify task</td>
<td>decision (TSL Id)</td>
<td></td>
</tr>
<tr>
<td>memory item retrieval</td>
<td>long term memory item</td>
<td></td>
</tr>
<tr>
<td>select function (search item in google in chrome)</td>
<td>TSL Select</td>
<td></td>
</tr>
<tr>
<td>see chrome icon on the computer interface</td>
<td>visual cue: Routine</td>
<td></td>
</tr>
<tr>
<td>see explorer icons on the computer interface</td>
<td>visual cue: Routine</td>
<td></td>
</tr>
<tr>
<td>select chrome or explorer</td>
<td>decision/choice</td>
<td></td>
</tr>
<tr>
<td>see search box</td>
<td>visual cue: Routine</td>
<td></td>
</tr>
<tr>
<td>select the search box</td>
<td>decision/choice</td>
<td></td>
</tr>
<tr>
<td>type “RJ100”</td>
<td>button push</td>
<td></td>
</tr>
<tr>
<td>type “RJ100”</td>
<td>button push</td>
<td></td>
</tr>
<tr>
<td>type “RJ100”</td>
<td>button push</td>
<td></td>
</tr>
<tr>
<td>type “RJ100”</td>
<td>button push</td>
<td></td>
</tr>
<tr>
<td>type “RJ100”</td>
<td>button push</td>
<td></td>
</tr>
<tr>
<td>type “RJ100”</td>
<td>button push</td>
<td></td>
</tr>
<tr>
<td>type “RJ100”</td>
<td>button push</td>
<td></td>
</tr>
<tr>
<td>click the url</td>
<td>button push</td>
<td></td>
</tr>
<tr>
<td>search results come back</td>
<td>visual cue: Routine</td>
<td></td>
</tr>
<tr>
<td>press alphanumeric keys</td>
<td>flightcrew action</td>
<td>button push</td>
</tr>
</tbody>
</table>

**Figure 8: Task Breakdown for the experiment**

**Distribution Analysis for the time to complete the task for the experiment:**
The experiment yielded a bell curve where cognition was not used. Sample size of 7 with 3 trials for each subject resulted in 21 data points to be plotted. We found that 50% of values are less than the mean and 50% are greater than the mean. Result showed that 68% of values are found to be within 1 standard deviation of the mean. 95% of values are found to be within 2 standard deviations of the mean and 99.7% of values are found to be within 3 standard deviations of the mean.

**Figure 9: Normal Distribution with mean of 1.06 and Standard Deviation of 0.43**

Our next experiment used cognition in the activities where participants had to memorize the sequence of steps. Sample size of 8 with 2 trials on each subject resulted in a total of 16 data point that was plotted in the diagram below. The experiment yielded a lognormal pattern of dispersion skewed to the right. According to peer reviewed journal “Dispersion of Response Times Reveals Cognitive Dynamics”, cognitive tasks are associated with a lognormal dispersion and a positive pattern of skew. Our result justifies the result of the experiment shown below.
Figure 10: Lognormal Distribution with mean of 2.93 and Standard Deviation of 1.04
5.0 Business Case

5.1 Business Models

The current certification process is very time consuming and costly. The Procedure Analysis Tool (PAT) is designed to save businesses money throughout the Human Factors Certification Process. There are three ways for a business to acquire the software being offered. Below states the three business models:

1. A La Carte Model

   This model will allow businesses to experiment with our product before they buy into either the License Model or Purchase Model. It will also allow smaller businesses to save money by paying for a device with less tasks and only paying for the functions they test. The payment per function for this model is $250. For a device with 30 tasks, the A La Carte model will amount to $7,500. This model allows for businesses to test an unlimited amount of functions.

2. License Model

   This model will have a unit price of $200,000 in the first year to acquire the software. Each year after there will be a recurrent annual fee of $75,000. This fee will include a subscription fee to keep the software as well as a software update cost to get the most up-to-date software available. This model allows for businesses to test an unlimited amount of functions.

3. Purchase Model
This model will have a unit price of $500,000. This is a one-time cost that will allow businesses to test an unlimited amount of functions. Each year thereafter, there will be a recurrent fee of $50,000 to update the software.

### 5.2 Prospective Market Opportunity

The market analysis identified several potential buyers that would be interested in investing in this tool being offered. Among which include: Honeywell, Thales, Airbus, Bombardier Aerospace, GAMA, Embraer, FAA, Garmin, Boeing, Rockwell/Collins, Avidyne, Smiths, and G.E. The expected number of units sold is estimated to be between 107 to 209 units.

<table>
<thead>
<tr>
<th>Company</th>
<th>Lower Sales Range (units)</th>
<th>Upper Sales Range (units)</th>
<th>Mean (units)</th>
<th>Standard Deviation (units)</th>
<th>Variance (units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honeywell</td>
<td>10</td>
<td>20</td>
<td>15</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>BOEING</td>
<td>20</td>
<td>50</td>
<td>35</td>
<td>15</td>
<td>225</td>
</tr>
<tr>
<td>THALES</td>
<td>10</td>
<td>20</td>
<td>15</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>AIRBUS</td>
<td>15</td>
<td>30</td>
<td>22.5</td>
<td>7.5</td>
<td>56.25</td>
</tr>
<tr>
<td>ROCKWELL/COLLINS</td>
<td>10</td>
<td>20</td>
<td>15</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>BOMBARDIER</td>
<td>10</td>
<td>20</td>
<td>15</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>GAMA</td>
<td>5</td>
<td>10</td>
<td>7.5</td>
<td>2.5</td>
<td>6.25</td>
</tr>
<tr>
<td>EMBRAER</td>
<td>15</td>
<td>30</td>
<td>22.5</td>
<td>7.5</td>
<td>56.25</td>
</tr>
<tr>
<td>AVI Dyne</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Total Mean: 161.5  
Total Standard Deviation: 21.16

The above chart calculates the mean, standard deviation, and variance for different companies. The total mean of expected units to be sold is 161.5. The expected sales range is between 140 and 183.
5.3 Acquisition of Customers:
We have modeled the market acquisition in two phases of five years each. The first phase is a result of targeted marketing (read the thing!)

The second phase was modeled using random number generation as per a uniformly distributed distribution with the intervals shown below. For each business model, we have taken into consideration new customers, shift to other business model, and lost customers.

Phase 1:

<table>
<thead>
<tr>
<th>Year 1</th>
<th>1 new “A La Carte” customer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 2</td>
<td>2 new “A La Carte” customers</td>
</tr>
<tr>
<td></td>
<td>1 customer shift to “License” Model</td>
</tr>
<tr>
<td>Year 3</td>
<td>1 new “A La Carte” customer</td>
</tr>
<tr>
<td></td>
<td>2 customers shift to “License” Model</td>
</tr>
<tr>
<td>Year 4</td>
<td>7 new customers use “License” Model</td>
</tr>
<tr>
<td>Year 5</td>
<td>1 customer shifts to “Purchase” Model</td>
</tr>
</tbody>
</table>

Phase 2:

Following 5 years – Radom numbers generated per following uniformly distributed Intervals as follows:

A la Carte

New: between (0, 3)

Shift to License: between (1, 2)
*Lost customer: between \((0, 1)\)

**License Purchase**

New between \((0, 7)\)

Shift to Application: between \((0, 2)\)

*Lost customer: between \((0, 2)\)

**Application Purchase**

New: between \((0, 1)\)

*Lost: customer 0

### 5.4 Market Penetration per Business Model

The projection of the market acquisition for the first five years are shown on this chart and they include the three business models.

![Market Penetration Chart](chart)

### 5.5 Annual Costs

The costs are slit into startup costs and recurrent costs as follows:

**Startup Costs**
• Software development: $250,000
• Marketing, sales, business management: $250,000

Recurrent Costs:

• $250,000 scales with consulting business and product support services growth

5.6 Profit Streams

The summary of the cumulative costs, revenue, profits, and Return on Investment (ROI) are shown on the table and chart below:

<table>
<thead>
<tr>
<th>Time</th>
<th>Cumm. Revenue</th>
<th>Cumm. Cost</th>
<th>Profit</th>
<th>ROI</th>
</tr>
</thead>
<tbody>
<tr>
<td>year0</td>
<td>$</td>
<td>- $</td>
<td>500,000</td>
<td>(500,000)</td>
</tr>
<tr>
<td>year1</td>
<td>$50,000</td>
<td>$750,000</td>
<td>$700,000</td>
<td>-193%</td>
</tr>
<tr>
<td>year2</td>
<td>$350,000</td>
<td>$1,000,000</td>
<td>$(650,000)</td>
<td>-165%</td>
</tr>
<tr>
<td>year3</td>
<td>$875,000</td>
<td>$1,250,000</td>
<td>$(375,000)</td>
<td>-130%</td>
</tr>
<tr>
<td>year4</td>
<td>$2,550,000</td>
<td>$1,500,000</td>
<td>$1,050,000</td>
<td>-30%</td>
</tr>
<tr>
<td>year5</td>
<td>$3,850,000</td>
<td>$1,750,000</td>
<td>$2,100,000</td>
<td>20%</td>
</tr>
</tbody>
</table>

At end of year 5, ROI is 20% and the Breakeven point is forecasted to occur after year 4.
6.0 Management Plan and Report

Description: This management plan is details the responsibilities of each group member, group assessment, a timeline of tasks, budget, and work breakdown structure.

Work Breakdown Structure

The work breakdown structure was separated into five categories. Each category was then broken into subtasks. The five categories were Management and Research, Context Analysis, Concept of Operations, Results, and Documentation.

- Management and Research section, planning, budgeting, risk analysis, time sheets, and weekly accomplishment summaries had to be completed.
- Context Analysis section, a context, problem statement, need statement, and stakeholder analysis was completed.
Design of A PAT for an Affordable Aviation Human Factors Certification Process

- Concept of Operations included Requirements, System Alternatives, Modeling and Simulation was completed.
- The results section included the analysis, conclusion, and recommendations.
- Documentation includes deliverable preparation, poster, paper, and conference preparations.

6.1 Project Timeline
The project began September 1, 2014. Below depicts the project plan that was completed in Microsoft project.

<table>
<thead>
<tr>
<th>Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research/Gather data</td>
<td>19 days</td>
<td>9/1/14 8:00 AM</td>
<td>9/19/14 4:00 PM</td>
<td></td>
</tr>
<tr>
<td>Design a Single Pilot Cockpit for</td>
<td>1.875 days</td>
<td>9/1/14 8:00 AM</td>
<td>9/2/14 4:00 PM</td>
<td></td>
</tr>
<tr>
<td>Advisory Circular</td>
<td>8 days</td>
<td>9/3/14 8:00 AM</td>
<td>9/12/14 5:00 PM</td>
<td>2</td>
</tr>
<tr>
<td>Contact/Meet Sponsor</td>
<td>0 days</td>
<td>9/12/14 4:00 PM</td>
<td>9/12/14 4:00 PM</td>
<td>3.5</td>
</tr>
<tr>
<td>Aircraft Operating Manual RJ100</td>
<td>8 days</td>
<td>9/3/14 8:00 AM</td>
<td>9/12/14 5:00 PM</td>
<td>2</td>
</tr>
<tr>
<td>Technique for Means of Compliance</td>
<td>5 days</td>
<td>9/1/14 8:00 AM</td>
<td>9/5/14 5:00 PM</td>
<td></td>
</tr>
<tr>
<td>Statistical modelling of networked</td>
<td>1.875 days</td>
<td>9/6/14 8:00 AM</td>
<td>9/9/14 4:00 PM</td>
<td>6</td>
</tr>
<tr>
<td>Human Factors Design Guidelines</td>
<td>1.875 days</td>
<td>9/10/14 8:00 AM</td>
<td>9/11/14 4:00 PM</td>
<td>7</td>
</tr>
<tr>
<td>Multimodal Evaluation Module: De</td>
<td>1 day</td>
<td>9/12/14 6:00 AM</td>
<td>9/12/14 5:00 PM</td>
<td>8</td>
</tr>
<tr>
<td>Human Performance Consequence</td>
<td>0.875 days</td>
<td>9/13/14 8:00 AM</td>
<td>9/15/14 5:00 PM</td>
<td>9</td>
</tr>
<tr>
<td>Policy Impacts of Implementing Nex</td>
<td>1.875 days</td>
<td>9/16/14 8:00 AM</td>
<td>9/17/14 5:00 PM</td>
<td>10</td>
</tr>
<tr>
<td>Joint Planning &amp; Development Office</td>
<td>1.875 days</td>
<td>9/18/14 8:00 AM</td>
<td>9/19/14 5:00 PM</td>
<td>11</td>
</tr>
<tr>
<td>Brain Monitoring May Improve Pilot</td>
<td>0 days</td>
<td>9/19/14 4:00 PM</td>
<td>9/19/14 4:00 PM</td>
<td>12</td>
</tr>
<tr>
<td>Gather Statistics</td>
<td>10 days</td>
<td>9/1/14 8:00 AM</td>
<td>9/12/14 5:00 PM</td>
<td></td>
</tr>
</tbody>
</table>

The project was broken into deadlines. The first deadline was Briefing 1, on September 22, 2014. The preparation to this point began with research and gathering data. After reading last year’s project, the group read the new legislation that the entire project is based from: Advisory Circular and the aircraft operation manual from the RJ100. This began our critical path to when the first meeting with the sponsor occurred. Meanwhile, the group defined the project scope, listed the initial stakeholders, created a preliminary budget, identified preliminary alternatives and revised.
For the next deliverable, the group will work on mission, system, functional, and derived requirements. The concept of operation will be stated as well as a statement of work will be written. Research and revisions will be completed by the next deadline on October 13, 2014.

For Briefing 3 on October 28, 2014 the design of the experiment must be completed. The initial coding and tool selection will be completed. The creation of a mathematical design and initial results will be compiled. The risks of the experiment will analyze and preliminary results will be calculated.
Next, the finalization of results will be compiled. This will entail finalizing the problem/need statement, the requirements, the context analysis, the earned value analysis, the final stakeholder analysis and the system alternatives. With much revision and preparation we will be ready for the Dry Run briefing due on November 17, 2014.

For the preparation of the end of the semester, final slides, final report, conference paper, poster, presentation slides will be either drafted or completed by December 3, 2014. After the final exam on December 3, 2014, winter break work will occur until January 19, 2015. Winter break work will entail the necessary revisions of the simulation, analysis, design of experiment, and analysis of results. Once the semester begins again, the team will gather questions about revisions and meet with the sponsor by February 2, 2015.
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Two days will be given to writing an abstract and submitting to the instructor and then preparing for Briefing 1 on February 9, 2015. Also due February 9, 2015 is the SEIDS extended abstract.

Preparing for Briefing 2 will last for 12 days. Briefing 2 will occur on February 23, 2015. Midterm preparation and preparation to meet with sponsor will occur for a couple weeks until the Midterm exam that is on March 4, 2015.

To finalize our project for Mason, we will prepare for the Dry Run Final Presentation that will occur on March 24, 2014. The Final Presentation, Final Report, Final Conference Paper, Final Poster, and Final Youtube Video will be completed by April 20, 2015. Preparation for the Conferences will be completed for the weeks until the their dates.
6.2 Budget

Wage/hour for team = $45

GMU Overhead = 2.13

Total Hourly Rate = $95.74

If the team were to work 60 hours a week for 34 weeks, the total of the project would come to $195,309.60. Evidently, these weeks will not have equal work, but an average of 60 weeks were taken. Other weeks will have more or less due to different class requirements.

6.3 Project Management Plan

<table>
<thead>
<tr>
<th>Team Members Name</th>
<th>Contribution to Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heather Johnson</td>
<td>Context, Requirements, Business Case, Project Management, Final Paper, Final Poster, PowerPoint Slides</td>
</tr>
<tr>
<td>Houda Kerkoub</td>
<td>Final Paper, Simulation, Conference Papers</td>
</tr>
<tr>
<td>Shaida Latifi</td>
<td>Context, Stakeholders, Reliability</td>
</tr>
<tr>
<td>Mumtahiba Mahmoud</td>
<td>Problem/Solution, Design of Experiment (Human Factors), Method of Analysis</td>
</tr>
<tr>
<td>Alexis Nittoli</td>
<td>Context, PowerPoint Slides, Transfer of Files for Simulation, Requirements</td>
</tr>
</tbody>
</table>
Risk was calculated under three main areas. In this project, the team calculated the main risk areas and the likelihood, severity, and detectability to recognize if failures were to occur.

### 7.1 Business Uncertainty

a. *Market Size is too small* – The severity of this risk would be almost detrimental to the company. The likelihood of this occurring is almost minimal and the detectability of this risk is 50/50.

b. *Market Size is not growing* – The severity of this risk is not as bad for the company, but as before, the likelihood of this occurring is also almost minimal. The detectability of this risk is 50/50.

c. *Regulatory trends are not aligned with the service or product* – The severity of this risk is great, and the likelihood of occurring is 50/50.

### 7.2 Operational Risks

d. *Not able to deliver service in time* - The severity of this is 50/50. The likelihood of occurring the detection is minimal.
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e. **Staff Issues** – The severity, likelihood of occurring, and Detectability of this risk is 50/50 each.

### 7.3 Financial Model Uncertainties

g. **Recession** – The severity of this risk occurring is roughly 70%, the likelihood of occurring is 50/50 and the detectability of the risk is 60%.

The two main risks this team faces is the regulatory trends that may not be aligned with the service or product and if a recession were to occur.

### 8.0 Conclusions and Recommendations

The analysis of 30 functions is known to take four hours and to be replicated with 20 different set of crew totaling 80 hours for the analysis of 30 tasks. This project analyzed a total of 15 tasks in about 12 hours. The pre-FAR time to analyses 15 tasks is 40 hours if a proportion exercise if accomplished. Therefore, analysis of the human factors certification process shows that the PAT reduces the evaluation time by 70% per function (i.e. the time taken was 12 hours as opposed to 40, that is a reduction to 30% of the initial time) and consequently solves the problem imposed by FAR25.1302. The PAT was demonstrated to work on 15 Procedures on the MCDU device.

Evaluating the 15 procedures with PAT took 12:47 hr. entry time, 11.56 sec. average runtime, and analysis showed that PFtoC ranged between 0.4% and 2.6%. Also, 3 over 15 procedures (20%) were flagged for HitL testing. The Visual Cue category gathered the greatest OAC percentage which highlights the importance of semantic cues
to recognizing emerging mission situations and prompting the next step of the procedure process.

Recommendations include

1- to take a closer look at the cognitive OACs and analyze how they impact the overall task time using the sensitivity analysis enabled by this tool. Also, the simulation assumes the visual cues are modeled in series, and more work is recommended about how to model parallel visual cues that are within the human field of vision.

2- Use the sensitivity analysis on all the operator action categories and analyze the threshold at which the PToF fails or passes.

9.0 Special Thanks
We would like to give a special thanks to the people that have helped us through this semester including, Dr. Sherry, Mr. George Blaha, Dr. Donohue, Dr. Laskey, Dr. Berg, Dr. Adelman, Dr. Costa, Siamak Khaledi, Kunal Sarkhel, and David Hughes.

10.0 References


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