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## Systems Engineering Design of an Electronically Interactive Application for Runway Incursion Prevention

Yixuan Cheng

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SYSTEMS ENGINEERING DESIGN OF AN ELECTRONICALLY INTERACTIVE  
APPLICATION FOR RUNWAY INCURSION PREVENTION

by

Yixuan Cheng

A Thesis Submitted to the College of Aviation, School of Graduate Studies,  
in Partial Fulfillment of the Requirements for the Degree of  
Master of Science in Aeronautics

Embry-Riddle Aeronautical University  
Daytona Beach, Florida  
August 2018

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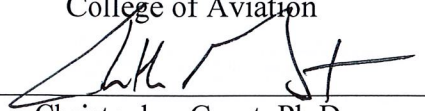
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## Abstract

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Title: SYSTEMS ENGINEERING DESIGN OF AN ELECTRONICALLY  
INTERACTIVE APPLICATION FOR RUNWAY INCURSION  
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Institution: Embry-Riddle Aeronautical University

Degree: Master of Science in Aeronautics

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Runway Incursion is the leading cause of serious incidents or accidents in airports. One of the most common causes of a runway incursion is airport unfamiliarity. Therefore, the researcher designed an electronically interactive application as a practice tool for pilots to utilize during flight preparation. The objective of this application is to enhance airport familiarity to ultimately reduce runway incursion. This application is interactive, affordable, accessible, and mobile device-based. It was designed using the Systems Engineering approach, following Human Factors Engineering principles to make this application user-friendly and to provide optimized human machine interaction. A model-based Systems Engineering software-CORE was utilized to manage the system requirements and provide clear traceability and rationality for each function. A prototype of the interface was developed and evaluated using a heuristic evaluation approach. The experts participating in the evaluation generally agreed that this application would provide an enhanced learning experience of the airport environment during flight preparation rather than studying the FAA airport diagram alone. This project provides a

guideline for Software engineers to program this application expeditiously with the least amount of confusion.

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## **Chapter I**

### **Introduction**

Let's start with a scenario that most of us are familiar with. Can you quickly picture all traffic lights, stop signs, and lane changes of a route that you drive every day? For example, the route from your home to your workplace. Can you also try to picture all traffic lights, stop signs, and lane changes of the route that you are usually being driven as a passenger? Which picture is clearer in your mind?

Can you quickly navigate to a destination in a city that you have driven around previously? Can you quickly navigate to a destination in a city that you have not driven around, but you have read the city map numerous times? Which navigational picture can be established faster in your mind? Imagine that you are required to drive to a destination in an unfamiliar city, and you are given the names of the road that you need to take. If you have been studying the map, how confident are you to find the correct way and make the correct turn to get to the destination exactly on the roads that you are required to take? Will you be confused or will you make mistakes during the drive, especially when traffic is jammed?

Taxiing an airplane in a pilot's home-based airport is very much like us driving from home to our workplace. If the pilot has dynamic hands-on taxiing experience and first-person point of view experience, he or she usually has higher familiarity of the airport surface, compared to the pilot who only has observational experience of taxiing. Taxiing in a new airport is like us trying to navigate in an unfamiliar city. A pilot can study the airport diagram, just like we can study the map. When a pilot lands at a new airport, he or she will be given instructions by the air traffic controller (ATC) to taxi via

specific taxiways to get to the parking location. Will the pilot react faster and more accurately if he or she has studied the static Federal Aviation Administration (FAA) airport diagram numerous times? Or, will the pilot react faster and more accurately, with less confusion, if he or she has dynamic practicing experience of taxiing in this airport?

According to Robson (2008), learning is more effective if it is meaningful, purposeful, and active. Active learning involves participation, interaction, feedback, and should be multi-faceted. Being multi-faceted means employing multiple neurophysiological senses (i.e. sight-visual, hearing-auditory, smell-olfactory, taste-gustatory, and touch-haptic/tactile). Research has shown that humans remember about 20% of what we were told; about 40% of what we hear and see; and about 60% of what we hear, see, and do (Robson, 2008). Studying the FAA diagrams only involves the visual sensation and only requires the user to “see”. There is no doubt that a pilot will study the airport diagram thoroughly in advance. However, unfamiliarity of an airport is an issue that cannot be solved completely by studying the airport diagram alone.

Most of the time there will be additional issues that add more pressure onto pilots when taxiing instructions are given. Pilots may experience conditions such as: the pilot is a new student pilot, the pilot is on his or her first cross-country solo flight, or fatigue is affecting the pilot’s performance, and so forth. In the meantime, other factors may create more difficulties during the taxiing process. For instance, ATC is giving complicated instructions, the traffic is congested on the airport surface, the workload is increased due to low visibility caused by bad weather or darkness, and so on. According to Reason’s (2000) Swiss Cheese Model of system accidents, these factors are the unsafe acts that are distributed as holes in different slices of Swiss cheese. Even the holes can be covered by

another slice of Swiss cheese temporarily; however, any active failures, such as the pilot failing to hold short at an active runway, can instantly line up the holes in different layers of the Swiss cheese and cause an accident. In this case, the accidents that happen on the airport surface usually fall into the category of Runway Incursion (RI).

In order to address the issues mentioned above and reduce RI, the author designed an electronically interactive application for users to taxi around airports. It was designed to be a practice tool to enhance user's familiarity of airports. Airport unfamiliarity was listed as the top three causal factors of RI (Federal Aviation Administration [FAA], n.d.-c). Therefore, the successful implementation of this application can fix one large "hole" in the Swiss Cheese Model that has been causing RI. Ultimately this application will reduce RI caused by unfamiliarity of an airport, thusly increasing airport surface safety.

### **Project Definition**

The FAA's definition of RI is "any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle, or person on the protected area of a surface designated for the landing and takeoff of aircraft" (FAA, 2015a, para. 1). RI is a serious safety concern that can lead to incidents or accidents in aviation (FAA, n.d.-c). Runway safety issues have been on the National Transportation Safety Board (NTSB)'s Most Wanted List to reduce transportation accidents and save lives from 1990 to 2012 (National Transportation Safety Board [NTSB], n.d.-b). According to the FAA data that is valid through July 12, 2018, there was a continuous increase of RI: 1,242 RIs in fiscal year (FY) 2013, 1,264 RIs in FY2014, 1,458 RIs in FY2015, 1,560 RIs in FY2016, and 1746 RIs in FY2017 (FAA, 2018c).

In recent years, the prevention of RI has moved on to a stage that involves automation. There have been many RI prevention systems developed and under development. Due to the nature of complexity of these systems, they are often very expensive to develop. Only airlines, large airports, and aircraft manufacturers can afford to adopt them. Also, most of the systems require the transmission of live traffic and the installation of airport surface sensors to determine real-time aircraft location, which are very complicated to install and implement. Airports such as New Smyrna Beach Municipal Airport and Ormand Beach Municipal Airport that do not operate under Part 139 operations have low commercial traffic and high General Aviation (GA) operations. They may not have the financial sustainability to implement the sensor system. Airports such as Orlando Melbourne International Airport and Daytona Beach International Airport (DAB) that operate under Part 139 operations have a moderate amount of commercial traffic and high volume of GA traffic. They may also not be able to generate enough financial resources to install the sensor system as opposed to the major airports in the world. The current transmitter equipped on GA aircraft does not have the capability to indicate traffic information on an airport surface. In other words, GA pilots must scan the outside environment and rely on ATC to monitor traffic on airport surfaces during taxiing. RI prevention systems for GA has become a niche market. No automated RI prevention system has been designed particularly for GA operations at a relatively low cost. Yet, GA has contributed to a large number of RIs in the past years. RI can be caused by pilots, ATC, or ground operations. The FAA data indicated that 65% of RIs resulted in the deviations of pilots of air carrier aircraft, military aircraft, and GA. GA pilots were responsible for 3/4 of the 65% RIs caused by pilot deviations (FAA, n.d.-c).

According to the FAA (n.d.-c), the common causes of RI are a lack of vigilance or situational awareness (SA), failure to adhere to standard operating procedures (SOP), pilot fatigue, airport unfamiliarity, distractions, bad weather, low visibility, airport construction, nonconformance with ATC instructions, and miscommunication with ATC. Failure to comply with ATC instructions, airport unfamiliarity, and failure to conform with SOP are determined as the top three causal factors of RI (FAA, n.d.-c).

The FAA's suggestions for RI prevention are divided into two parts, which are the preflight planning stage and taxiing stage. During the preflight planning stage, the pilot needs to obtain the Airport/Facility Directory (A/FD), acquire a current airport diagram, and plan a possible taxi route thoroughly in advance. This process usually needs to be done the night before the flight. A pilot should become familiar with the airport layout before performing the flight. On the day of the flight, the pilot needs to attain the Notices to Airmen (NOTAMs), most current weather update, and the Automated Terminal Information Service (ATIS) information. A pilot also needs to contact the weather briefer, in order to collect the most updated information of the departure and landing airports. During the taxiing stage, which includes moving to or from a runway and navigating around the airport, the pilot will be required to carry out clear, terse, and efficient communication with ATC. Based on ATC instructions, the pilot needs to trace or highlight taxi routes before moving the aircraft. When taxiing, the pilot should be alert and remain "heads-up" with continuous scanning of the external environment, pay attention to surface navigation, complete all appropriate checklists, and assure putting the aircraft in the right setting for the right time. When the pilot arrives at the designated point of the runway and receives permission for takeoff, always double confirm the

correct runway by checking the alignment of aircraft heading and runway heading before adding power to take off (FAA, n.d.-c).

Evidently, conforming to the FAA, pilots are expected to study the airport diagram and plan all the possible taxi routes during the preflight preparation. This is the FAA's suggestion for pilots to get familiar with the airport layout. Airlines often provide SOPs and supplemental materials for flight preparation. Some GA pilots coming from flight training institutions may have supplemental materials; however, some may not. Recreational pilots usually do not have supplemental materials unless they obtain them from other resources particularly. Generally speaking, most GA pilots do not have sufficient resources to get familiar with the airport. The preflight preparation can be done more actively and dynamically to increase airport familiarity, instead of relying on reading static FAA airport diagrams solely. A system with easier accessibility is in demand for these pilots. Therefore, the author designed an electronically interactive mobile application for pilots to practice taxiing at the airport they choose. This application should be used as supplemental material to the FAA airport diagram. This application was designed for a pilot who wants to get familiar with a specific airport. It can be used during the pilot's leisure time or during preflight preparation.

The idea of designing this application was initiated based on the observation of flight students at Embry-Riddle Aeronautical University (ERAU). RI is one of the leading concerns for student pilots during their flight training. One of the biggest challenges for students obtaining their private pilot license (i.e. 0 to 50 hrs of flight time) at ERAU is knowing the airport environment including runways, taxiways, hot spots, movement and non-movement area, "hold short" position, airport surface signs,

markings, and lighting. Inexperienced pilots are very susceptible to RIs. It can be very challenging for them to pay attention to the dynamic scenario on the ground while communicating with ATC, as well as, operating the aircraft. Meanwhile there are many experienced pilots who have difficulties taxiing at unfamiliar airports. As a student pilot flying to a nonhome-based airport, he or she may find navigating at the airport is challenging and sometimes confusing. Even experienced pilots, such as student pilots who have more than 50 flight hours, may still find flying into an unfamiliar airport challenging. Unfamiliarity of the airport environment may make pilots at any experience become disoriented, confused with ATC instructions, or delayed in response. As a result, it will increase the possibility of RI. All the pilots including student pilots, instructor pilots, recreational pilots, and commercial pilots are required to study the FAA airport diagram before each flight, especially when flying into new airports. Any form of the airport diagram can only provide pilots a static experience. However, according to Butler, Zaromb, Lyle, and Roediger (2009), dynamic visualizations can provide engaging and influential learning advantages. Accordingly, a more dynamic airport diagram that pilots can practice with will be a good supplemental tool to increase familiarity of airport surface.

In this project, the author designed an electronically interactive application for smartphone or portable tablet users to practice moving to or from a runway or moving about different airports. There are two reasons why the author designed the new system based on a smartphone or portable tablet. First, ERAU has adopted electronic flight bag (EFB) in flight training. Flight students are highly encouraged to use electronic flight bag which is installed on their own iPads. Thusly, this new system can be easily installed



on the iPad already possessed by most flight students. Second, mobile learning has become a popular way of learning over the past decade. Not only can it provide an interactive experience, but it is also becoming a part of everyone's daily activity and lifestyle. A mobile device is no longer just a communication tool. It is a multimedia tool that students access several times a day. Mobile learning is now portable, accessible, and affordable (Dekhane & Tsoi, 2012).

This new application was designed using a systems engineering design approach, based on human factors engineering (HFE) concepts and a comprehensive list of system requirements collected from three sources, which are from the potential users, the author, and the FAA regulations. This application was designed to provide the highest level of usability, functionality and optimal human machine interaction experience. This application provides hands-on experience of taxiing at the selected airport by the user. Users will receive more dynamic practicing experience and which will result in higher familiarity of the airport chosen. Eventually RI caused by unfamiliarity of the airport can be reduced with the implementation of this application.

The primary stakeholders of this application were the ERAU Flight Department and the student pilots who are undertaking flight training in the Flight Department. In the future, the final product can be developed based on this design process. Finally, when the product is released to the general public, GA pilots (i.e. student pilots, instructors, and recreational pilots), commercial pilots, military pilots, airport operation, flight training institutions, airlines, and any personnel who have the intention of generating a basic understanding or familiarization of airports can benefit from using this application.

Overall, GA operators and GA pilots will benefit from this application most significantly and directly. Other aeronautical operators will also benefit more or less.

This electronically interactive application was designed in a similar way as some ATC games or airport and aircraft operation games in the market. To name a few, Airport Manager, Unmatched Air Traffic Control, Airport Madness, Real Airport Truck Duty Simulator 3D, Flight Simulator FlyWings 2014, and Infinite Flight. The interface of the application contains simple yet necessary information of the airport surface. The overall taxiing experience on the application will replicate a real cockpit experience. In this application, users can choose a different time of day and weather settings. Users will receive instructions from simulated ATC and then users can plan the taxi route as per ATC instruction using the FAA airport diagram. The application generates different pre-programmed ATC instructions every time. Therefore, users can choose to practice multiple times on different taxiways and runways. Users can also switch to different airports as long as the airport is included in the application database. It does not require an Internet connection unless a software update is necessary. Users' taxiing experience will no longer be limited to visualizing the FAA airport diagram, instead, they are required to read the FAA airport diagram, follow the simulated ATC instructions, and perform taxiing operation on their mobile devices. Users can obtain engaging hands-on experience of utilizing FAA airport diagrams, locating the correct taxiways and runways, planning an accurate taxi route, reading the airport signs, and conducting taxi procedures correctly.

## **Project Goals and Scope**

The purpose of this project was to design an electronically interactive mobile application. The design process was guided by the systems engineering approach. In order to achieve optimal functionality of the application, the author collected a comprehensive list of user requirements and adopted the commonly used HFE concepts in system design. Heuristic evaluation of the interface was used in the later stage to ensure good usability of the application. The overall goal of the project was to design a new RI prevention system for GA, and affordability, simplicity, and practicality are the top priorities. The application was designed in a user-friendly way. Compared to the existing RI prevention systems, this application aimed to achieve better human machine interactions for the targeted users.

The scope of the project was restricted to reduce only one of the three major causal factors of RI, which is airport unfamiliarity. The project analyzed the RI mishaps, incidents, or accidents caused by airport unfamiliarity. The human factors (HF) theories included in the project were studied for the purpose of system design solely. Even though the application can be adopted in different aviation segments, the author primarily designed the application for GA operators and pilots. Therefore, the user requirements and taxiing procedures for commercial pilots were not analyzed thoroughly.

The author understands the necessity of including all the airports in the United States (U.S.). However, due to the limitations of this project and the massive number of towered and nontowered airports in the U.S., the project is restricted to one airport. It requires extensive time and funding to transform all the airport diagrams into three-dimensional (3D) displays included in the application. Therefore, the interface of the

application as presented in the Result section only included DAB because it is most frequently used by ERAU students.

### **Definitions of Terms**

**FAA Fiscal Year**      FAA fiscal year begins on October 1 of previous year and ends on September 30 of current year. For example, FY2017 began on October 1, 2016, and ended on September 30, 2017.

### **List of Acronyms**

3D	Three-Dimensional
ADS-B	Automatic Dependent Surveillance-Broadcast
A/FD	Airport/Facility Directory
AMASS	Airport Movement Safety System
ASDE-X	Airport Surface Detection Equipment – Model X
ATC	Air Traffic Controller
ATCO	Air Traffic Control Officer
ATIS	Automated Terminal Information Service
CAST	U.S. Commercial Aviation Safety Team
CDTI	Cockpit Display of Traffic Information
CNO	Chino Airport
DAB	Daytona Beach International Airport
EFB	Electronic Flight Bag
ERAU	Embry-Riddle Aeronautical University
ERGL	Elevated Runway Guard Lights

FAA	Federal Aviation Administration
FAROS	Final Approach Runway Occupancy System
FBO	Fixed-Base Operator
FFBD	Functional Flow Block Diagram
FY	Fiscal Year
GA	General Aviation
GBT	Ground-Based Transmitter
GND	Ground Operations
GPS	Global Positioning Systems
HF	Human Factors
HFE	Human Factors Engineering
HNL	Honolulu International Airport
HOQ	House of Quality
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
INCOSE	International Council on Systems Engineering
IRB	Institutional Review Board
KLM	KLM Royal Dutch Airlines
LAHSO	Land and Hold Short Operations
MABS	Mobile Application Based Systems
NextGen	Next Generation Air Transportation System
NOTAMs	Notices to Airmen
NTSB	National Transportation Safety Board

OFZ	Obstruction Free Zone
OI	Operational Incidents
QFD	Quality Function Deployment
RA	Requirements Analysis
RAAS	Runway Awareness and Advisory System
RI	Runway Incursion
RIDA	Runway Incursion Detection Algorithm
RIPDA	Runway incursions Prediction and Detection Algorithms
RIPS	Runway Incursion Prevention System
RWSL	Runway Status Light System
SA	Situational Awareness
SAA	South African Airways
SOP	Standard Operating Procedures
SPSS	Statistical Package for the Social Sciences
SURF-IA	Enhanced Traffic Situational Awareness on the Airport Surface with Indications and Alerts
TIS-B	Traffic Information Service Broadcast
TPMs	Technical Performance Measures
TWR	Tower Control
U.S.	United States
VNY	Van Nuys Airport
VOC	Voice of The Company

## **Chapter II**

### **Review of the Relevant Literature**

#### **Threats of Runway Incursion**

RI is a serious runway safety concern in aviation due to the frequency and the potential fatalities it may cause (FAA, n.d.-c). On February 1, 2017, an IndiGo aircraft had a RI mishap in Indira Gandhi International Airport in New Delhi with a Jet Airway Boeing 737. The Jet Airway B737 was stationed in Taxiway W where the IndiGo aircraft almost entered by mistake. ATC alerted the IndiGo pilot, and the aircraft stopped before entering Taxiway W and had to stay on the runway connecting to Taxiway W, which is Runway 28. This caused a blockage of Runway 28 and led to a massive delay in the airport (“Plane enters wrong runway,” 2017). On February 14, 2017, an AirAsia Airbus A330 failed to hold short at Runway 34R of Narita Airport, Tokyo; causing ATC to instruct a China Airline Airbus A330 to go around during final approach in order to avoid potential collision with the AirAsia A330 (Hradecky, 2017).

On February 3, 2017, a Hawaiian Airlines Boeing 717 and a Cessna were taking off on the intersecting runways in Kahului Airport, Hawaii. The Cessna was taking off without clearance. ATC noticed the conflict and instructed the Cessna to turn left to avoid the B717. The pilot of the B717 noticed the Cessna and turned right to avoid it before ATC alerted the crew (“Hawaiian Airlines jet was,” 2017). On February 13, 2017, a private Aviat A-1C Husky overflew an American Airlines Boeing 737 in Orange County-John Wayne Airport, California. The Aviat A-1C Husky was cleared to land on Runway 20L but mistakenly landed on the parallel Taxiway C. The B737 was taxiing on Taxiway L. Taxiway L is intersecting with Taxiway C. The Aviat A-1C Husky overflew

the B737 at the intersection of two taxiways during final approach (“ASN wikibase occurrence,” 2018).

The above RI mishaps or incidents were just a fraction of the RIs that occurred during February of 2017. According to the FAA (n.d.-c), on average there are three RI mishaps, incidents, or accidents happening at towered airports every day in the U.S. The FAA categorized RI into three categories: air traffic control officer (ATCO) related situations, flight crew related situations, and airside vehicle driver related situations (Mrazova, 2014).

**ATCO related RI.** ATCO related situations are also known as operational incidents (OI) related RI (FAA, n.d.-c). It refers to ATCO’s failure to subsequently check for a correct read-back from the flight crew, or failure to give a clearance to an aircraft correctly. The failure leads to the aircraft taxiing onto a runway while another aircraft is landing on the same runway or the runway is occupied by another aircraft or vehicle (Mrazova, 2014).

In 2010, an RI incident happened at Amsterdam Airport Schiphol involving a Norwegian Boeing 737-300 and a bird control vehicle. The vehicle was cleared to inspect Runway 24, and the B737 was later cleared to take off on the same runway by ATC. The B737 flew over the vehicle closely without noticing it (SKYbrary, 2016c).

In 2011, an RI incident happened at Chicago Midway International Airport involving a Southwest Boeing 737-700 and a Gama Charters Learjet 45. ATC first cleared the Southwest to taxi across an active runway, and then inadvertently cleared the Gama Charters to take off on the same runway. The Learjet overflew the B737 near the crossing point by 62 feet (SKYbrary, 2016e).



In 2014, another RI incident occurred in Port Elizabeth South Africa due to an ATC error. A South African Airways (SAA) Bombardier CRJ 200 made a go around from an approach and failed to maintain safe separation with another SAA Airbus A320 that just took off. The probable cause was that ATC failed to monitor the CRJ 200 and cleared the A320 to take off when the CRJ 200 was on short final to land (SKYbrary, 2016a).

In 2015, an Air France Airbus A320 and a TNT Airways Boeing 737 had a RI in Barcelona Airport in Spain due to an ATC error. The A320 was given a clearance by the Ground Operations Controller (GND) to cross an active runway. However, the B737 was given a clearance by the Tower Controller (TWR) to land on this runway. The A320 noticed the B737 near the crossing point. The pilots stopped and re-confirmed with GND control. As soon as the GND controller corrected the clearance from “cross” instruction to “hold position” instruction, the B737 landed on the same runway (SKYbrary, 2016b).

**Airside vehicle driver related RI.** Driver deviation related situation refers to airside vehicles entering an active runway without ATC clearance (FAA, n.d.-c). In 2010, an Airwork Swearingen SA227 Metroliner flew narrowly over a vehicle at Dunedin International Airport, New Zealand. Both the pilot and the driver did not notice each other until advised after the nearly missed collision. The probable cause of this RI was the vehicle entered the runway without appropriate clearance (SKYbrary, 2016g). On February 3, 2018, a vehicle entered an active runway at London Gatwick Airport where an Aer Lingus A320 was landing on the same runway. The Aer Lingus jet landed safely and the investigation of this serious incident is ongoing (Flynn, 2018).

**Flight crew related RI.** A flight crew related situation is also known as pilot deviation related RI (FAA, n.d.-c). The top three causal factors of RI are all flight crew related. They are: (a) failure to comply with ATC instructions, (b) airport unfamiliarity, and (c) failure to conform with SOP (FAA, n.d.-c).

The worst and deadliest civil aviation airplane crash was in 1977 which involved two Boeing 747s. It was the consequence of RI. A KLM Royal Dutch Airlines (KLM) B747 took off without ATC clearance and collided with a Pan American World Airways (Pan Am) B747 that was taxiing on the same runway. Among all the probable and contributing causes of the collision, pilot deviation from KLM B747 was the active failure of Reason's (2000) Swiss Cheese Model that led to the accident (Air Line Pilots Association [ALPA], n.d.).

Another fatal accident which occurred due to RI on an active runway was the Linate Airport accident that happened on October 8, 2001. A Scandinavian Airlines McDonnell Douglas MD-87 collided with a Cessna Citation CJ2 at Linate Airport, Milan. The Cessna was disorientated in poor weather conditions and entered the active runway by mistake. The MD-87 was taking off from the runway and collided with the Cessna at high speed killing all the people on board both aircrafts and four ground staff (Hradecky, 2005).

Entering the wrong runway occurs frequently regardless of pilots' experience or airport condition. It is extremely hazardous even though sometimes it does not lead to serious consequences. On December 30, 2015, an Easyjet Airbus A319 was cleared to land on Runway 04L but landed erroneously on Runway 04R in Pisa Airport, Italy

(Hradecky, 2015). Runway 04R was closed and used as a taxiway when the incident happened (Richter, 2015). This incident was also a pilot deviation related RI.

Pilot's failure to hold short or check the runway traffic before entering an active runway has also led to numerous RI incidents. On July 2, 2008, an Air Tran Airways Boeing 737 failed to hold short of Runway 34 during arrival taxiing at Seattle-Tacoma International Airport. The B737 crossed Runway 34 while a North West Airlines Airbus A330 was taking-off (SKYbrary, 2016d). The A330 overflew the B737 closely by 425 feet vertically (NTSB, 2008).

Pilot deviation related RI can also happen at a pilot's home base airport. On May 5, 2016, a Korean Air Airbus A330 accidentally taxied onto the wrong taxiway crossing Runway 15R in Seoul Incheon Airport. A Singapore Airline Boeing 777 was cleared for takeoff on Runway 15R. Korean Air taxied past the hold short line, consequently the tower immediately instructed Singapore Airline to cancel the takeoff because Korean Air was taxiing onto the runway (Hradecky, 2016a).

Five months later, on October 11, 2016, another pilot deviation related RI serious incident happened at a pilot's home base airport. Two China Eastern flights almost collided in the airline's main hub, which is Shanghai Hongqiao International Airport in China (China Eastern Airlines, n.d.; Hradecky, 2016b). A China Eastern Airbus A330 was cleared to cross Runway 36L. The A330 turned down the radio and started crossing without further checking with ATC at the hold short line. The ATC erroneously gave a takeoff clearance for a China Eastern Airbus A320 on Runway 36L. The A320 noticed the A330 was on the runway so the crew excessively climbed to avoid the collision. The A320 overflew the A330 at 19 meters vertical separation (Hradecky, 2016b).

Some common mistakes can be concluded from the preceding RI mishaps, incidents, and accidents. These are RIs caused by entering the wrong taxiway because of disorientation or miscommunication with ATC, entering the wrong runway, crossing the runway erroneously, and failing to hold short before entering an active runway. The FAA data shows that lots of RIs relate to GA operation (FAA, n.d.-c). According to the NTSB (n.d.-c), the aviation industry has devoted extensive attention to improve airport surface safety for Part 121 operation; however, recent data showed that GA operation contributed most to the total number of RI. Therefore, the author believes that there is a lack of RI prevention solutions for GA. In the following section, the author reviewed the RI prevention systems that are developed or under development at this moment. After listing the advantages and drawbacks of each system, the author had a better idea to design the best fitted and most needed RI prevention system for GA operation.

### **Runway Incursion Prevention Systems**

The FAA established a Runway Safety Program in 1999 which includes increasing the awareness in aviation personnel and the installation of RI prevention systems (McLean & Monro, 2004). After decades, many RI prevention systems were developed or under development. Some of them are reviewed in the following paragraphs.

In 1991, the FAA published its first Runway Incursion Plan. After three amendments of the plan, the FAA published a Runway Safety Blueprint in 2000. The FAA has never stopped emphasizing the importance of lessening RI to improve runway safety (ALPA, 2007). After the second edition of the blueprint in 2002, the FAA also published the Runway Safety Call to Action Safety Summit in 2007. The phase two of

the Runway Safety Call to Action was convened in 2015 (FAA, 2015b). Additionally, the U.S. Commercial Aviation Safety Team (CAST) completed the most comprehensive study on RI risk to date and produced reports to mitigate RI risk (ALPA, 2007). CAST is a group made up of government, manufacturer, and industry aviation safety experts who cooperate with the FAA closely to improve runway safety (ALPA, 2007). The NTSB has issued numerous runway safety recommendations to FAA based on its investigations (ALPA, 2007). The NTSB listed runway safety as the Most Wanted Transportation Safety Improvement in 2011-2012 (NTSB, n.d.-c). In 2013, the NTSB listed safety of airport surface operation as the Most Wanted Transportation Safety Improvement which included Runway Incursion as well (NTSB, n.d.-a). The outcome of all these actions was the improvement in technologies, training, and procedures to prevent RI. The purpose of the review was to study current RI prevention systems, as well as analyze the limitations and constraints of current systems. Therefore, the author would be able to design a new RI prevention system that meets the GA operation requirements for the purpose of lessening RI more specifically.

**Runway Incursion Prevention System (RIPS).** NASA originally designed the RIPS as a simulator to prevent pilots from getting into RI situations. RIPS integrates different technology into surface communication, navigation, and surveillance systems for flight crews and ATC. Pilots are able to view the application as a head-down display with moving map of taxiways and runways and head-up display with guidance in real time (Jones & Prinzel, 2006). RIPS displayed complex and detailed information. Therefore, the author intended to design an application that is simplified and displays only simple yet necessary information. Users at any experience level can practice at their

own convenience using the application as a mean for an inexpensive practice tool prior to any flight.

**Automatic Dependent Surveillance-Broadcast (ADS-B).** ADS-B is a system that provides two-way communication between a ground-based transmitter (GBT) and electronic equipment in the aircraft. The aircraft transmits a signal that consists of its location, and the ground transmitter then transmits information back to the aircraft, giving the position of other aircraft in the area based on the global positioning systems (GPS) installed (Horowitz & Santos, 2009). This process happens simultaneously during the flight. Pilots are able to gauge the surrounding traffic in midair (FAA, 2006). ERAU's fleet are equipped with the ADS-B to prevent potential air traffic threats in midair (Embry-Riddle Aeronautical University, 2016). In comparison, the application that the author developed prevents traffic conflicts on the airport surface instead of in midair. Also, it does not require transmission of signals in real time.

**Enhanced Traffic Situational Awareness on the Airport Surface with Indications and Alerts (SURF-IA).** SURF-IA is part of the Next Generation Air Transportation System (NextGen) technology that will alert pilots of potentially dangerous runway incursions through a Cockpit Display of Traffic Information (CDTI; Joslin, 2014). Generally speaking, SURF-IA sends alerts based on live traffic information, and pilots need to take action to avoid potential RIs. However, the application designed by the author will not provide alerts, and no live traffic is included.

**Runway Awareness and Advisory System (RAAS).** RAAS is similar to SURF-IA which enhances pilot's situational awareness to reduce the risks of RI and other airport surface accidents. It monitors aircraft movements around the airport by collecting

real-time airport data and the installation of GPS and other onboard sensors on the aircraft (SKYbrary, 2016f). However, the application designed by the author is preventing RI from a different perspective. Also, in order to reduce the complexity, the application does not require any enhancement of aircraft capability.

**Traffic Information Service Broadcast (TIS-B).** TIS-B is a system that reports live traffic on the ground and transmits a signal to the aircraft. The pilot inside the aircraft can then see what activity is happening on the ground through the equipment installed in the aircraft (Schönefeld & Möller, 2012). In comparison, the application designed by the author does not require live traffic data to be transmitted, which means radar surface sensors are not required. Therefore, it is affordable and easy to be installed for GA aircraft if necessary in the future.

**Mobile Application Based Systems (MABS).** MABS is an application installed on mobile devices that requires built-in GPS to determine aircraft position. The limitation of MABS is lacking in the accuracy of aircraft positioning (Schönefeld & Möller, 2012). Schönefeld and Möller (2012) mentioned that MABS was an interesting solution for RIs for GA, but there were many limitations needing improvement. In comparison, the application designed in this project is a mobile application that is not equipped with built-in GPS.

**Other RI prevention systems.** Other RIs avoidance and detection systems, such as Airport Movement Safety System (AMASS), Runway Status Light System (RWSL), Final Approach Runway Occupancy System (FAROS), and Airport Surface Detection Equipment – Model X (ASDE-X), all require installation of airport surface sensors (Singh & Meier, 2004). Runway incursions Prediction and Detection Algorithms

(RIPDA) requires radar transmission for live traffic (Schönefeld & Möller, 2012).

Similarly, China was developing the Runway Incursion Detection Algorithm (RIDA) which detects live traffic and gives alerts to pilots (Wang & Li, 2015). However, in the author's point of view, both airport surface sensors and radar transmission of live traffic are associated with high costs and complexity. In order to make the application affordable and simple, both live traffic and airport surface sensors were excluded from the design.

In the next section, the author reviewed the key elements of airports that pilots would encounter during taxiing including moving to or from a runway and navigating around the airport.

### **Airport Infrastructure**

Proceeding paragraphs reviewed the serious consequences of RI and the limitation of current RI prevention systems that GA can adopt. In this section, the author focused on reviewing the airport infrastructure, which includes airport lightings, signs, runway/taxiway configurations, hold short points, and hot spots. These airport infrastructures and the regulations associated with each airport surface feature were considered in the design process of the application. In the end, a brief review of the airport layout of DAB was included.

All pilots might find it challenging to get familiarized with the airport environment by reviewing the FAA airport diagram alone. Some key elements of the airport environment that pilots need to be familiar with are: (a) runway and taxiway configuration, (b) runway length, (c) expected hold short positions before intersections, and (d) hot spots (FAA, 2012). These four elements vary in different airports.



Meanwhile, pilots also need to understand the airport infrastructure including lightings, signs, and markings. According to the FAA (n.d.-c), airport complexity, close proximity of runway thresholds, joint use of a runway as a taxiway, and any other special design of the airport runway and taxiway layout can easily cause confusion and lead to entering the wrong taxiway or runway.

**Lightings.** Airport lightings are one of many key components to airport surface. These lightings are useful for pilots and other airside vehicle operators to navigate around the airport at night or during severe weather phenomena (FAA, n.d.-b). The main features of airport lightings include runway edge lights, runway centerline lights, taxiway edge lights, and taxiway centerline lights. Runway edge lights, as well as runway centerline lights are illuminated in white on a visual approach runway. Airports with precision approach runway capability, such as Instrument Landing System (ILS), have different lighting configurations. A precision approach runway has white runway edge lights and white runway centerline lights, similar to a visual approach runway. However, the key differences are upon reaching the 2,000 feet of runway remaining point, the runway edge lights of precision approach runway will change to yellow for the remainder of the runway. Additionally, the runway centerline lights will also change to different colors. At the 3,000 feet runway remaining point, the runway centerline lights will alternate between white and red until the 1,000 feet runway remaining point. Finally, they will remain all red for the last 1,000 feet. Runway centerline lights are installed in the pavement, and in some runways these lights are bidirectional (Price & Forrest, 2016).

Taxiway edge lightings are illuminated in blue. In some instances, airports can install blue taxiway edge reflectors to enhance visibility at night or during low visibility

conditions. Taxiway centerline lights are illuminated in green. Lead-in or lead-off taxiway centerline lights are featured in alternating yellow and green lights (Price & Forrest, 2016).

**Signs.** Airport signs are critical navigational aids on airport surface. They are the most basic and traditional indicators on airport surface (FAA, n.d.-a). FAA Advisory Circulars 150/5340-18L (FAA, n.d.-a) provide detailed guidance on the installation and location of signs on runways and taxiways. There are five different types of signs that pilots and airside vehicle operators will see when navigating throughout an airport. These signs include mandatory instruction signs, location signs, direction signs, destination signs, and runway distance remaining signs (FAA, n.d.-a).

***Mandatory instruction signs.*** Mandatory instruction signs are depicted in white lettering and red background. They are used to indicate taxiway/runway intersections, runway/runway intersections, ILS system, critical areas, Obstruction Free Zone (OFZ) boundaries, runway approach areas, and no entry areas. Mandatory instruction signs are the most important signs because they protect a runway, the approach to a runway, or the clear zone for the precision instrument system to work properly (Price & Forrest, 2016).

***Location signs.*** Location signs are depicted in yellow lettering with a black background. They are the references for pilots and airside vehicle operators to locate themselves on runway or taxiway. These signs are vital when pilots and airside vehicle operators report their position to ATC (Price & Forrest, 2016).

***Direction signs.*** Direction signs are depicted in black lettering with yellow background and an arrow. They indicate the direction of taxiways. They also indicate

taxiway exit from a runway, taxiway intersections, and taxiway/runway intersections (Price & Forrest, 2016).

***Destination signs.*** Destination signs point the general direction to a remote location, such as to a fixed-base operators (FBO), terminal, or cargo area. They are depicted in black lettering on a yellow background and always contain an arrow (Price & Forrest, 2016).

***Runway distance remaining signs.*** Runway distance remaining signs are depicted in white numeral inscription on a black background. They are important for pilots during takeoff and landing operations. These signs provide pilot's information of how much runway is available in thousands of feet (Price & Forrest, 2016).

***Markings.*** Markings are another critical navigational aid on airport surface. Markings, as a supplement to airport signs, provide guidance for pilots and airside vehicle operators to locate themselves. Markings indicate hold short position, ILS critical area, taxiway/taxiway hold short position, non-movement area boundary, and enhanced taxiway centerline (FAA, n.d.-a). Airport surface markings and signs are collocated in the same color (FAA, n.d.-a).

***Hold short markings.*** Hold short position marking is a type of marking that indicates an entrance to a runway from a taxiway. They are depicted in two solid yellow lines and two dash yellow lines. The hold short marking is typically located across of the taxiway centerline, within 10 feet of the hold position sign (FAA, n.d.-a). In most cases, pilots will be given a hold short instruction by ATC prior to joining an active runway for takeoff procedure. Additionally, hold short instruction will also be given when a pilot is crossing an active runway from a taxiway (Price & Forrest, 2016).

Another hold short point on a runway is the land and hold short operations (LAHSO) point. LAHSO is commonly used in airports that have intersecting runways. Pilots need to land on the runway and stop prior to the hold short point on the runway. It is because the intersecting runway is being used by another aircraft at the same time (Aircraft Owners and Pilots Association, n.d.). The LAHSO point is painted the same as other hold short points on the airport surface (Price & Forrest, 2016).

***Taxiway/taxiway hold short markings.*** Taxiway/taxiway holding position markings are depicted as a black background with dash yellow lines. Taxiway/taxiway holding position markings indicate an area on a taxiway that aircraft need to hold short upon ATC's instruction prior to joining the intersecting taxiway. One of the main reasons for holding short prior to joining another taxiway is because ATC needs to clear another aircraft that is crossing the intersecting taxiway. The aircraft that receives the hold short instruction has to stop prior to the hold short point so that there is enough room for wingtip clearances of the other aircraft (FAA, n.d.-a).

Many hold short points were established to accommodate wingtip clearances, especially on parallel runways. Figure 1 is the FAA airport diagram of Honolulu International Airport (HNL). RI can easily happen between parallel runway 4L/22R and 4R/22L due to limited space. Because the fleet operating in HNL ranges from Cessnas to the wide-bodied 747, pilots need to be cautious when maneuvering around the parallel runways. Aircraft that stay on the taxiways between the two runways will endanger both runways, because it is taking up the runway safety areas of both. This is extremely dangerous because landing aircraft require wingtip clearance when landing on either runway 4L/22R or 4R/22L (FAA, 2017).

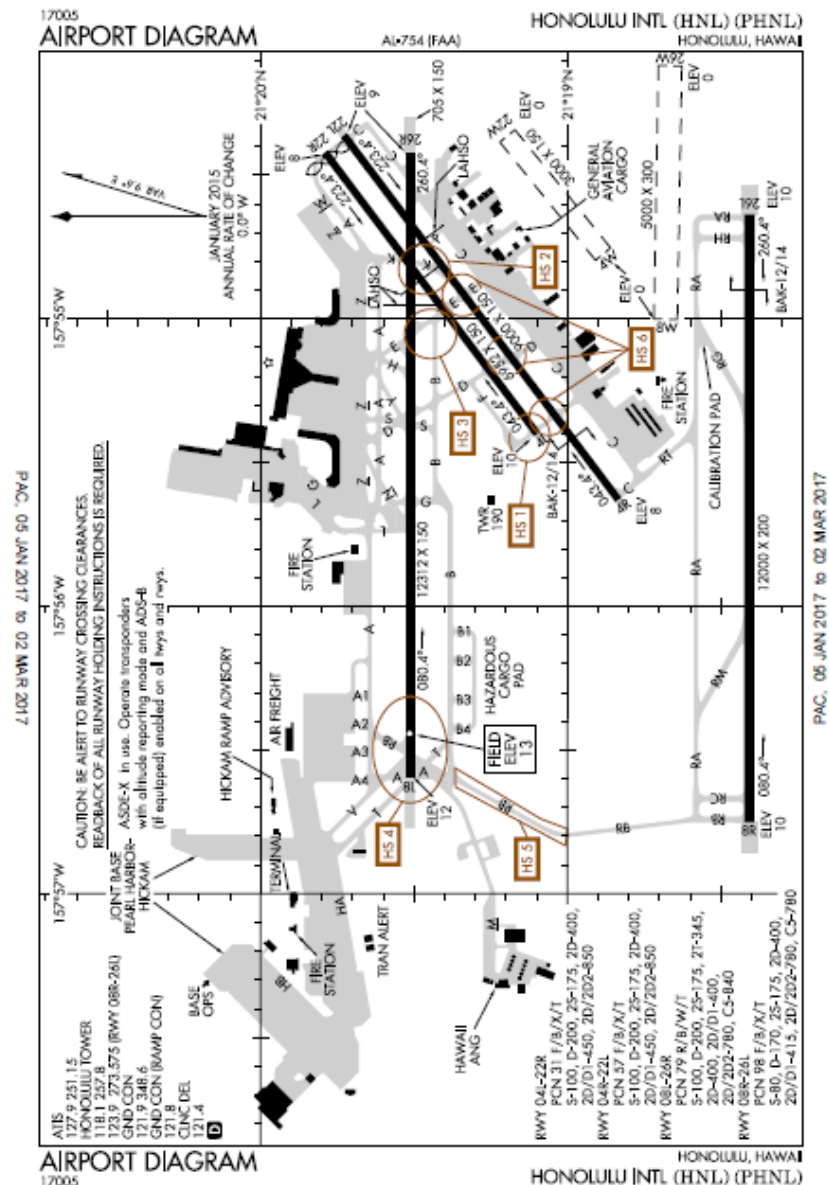


Figure 1. FAA airport diagram of Honolulu International Airport (HNL). Adapted from Terminal Procedures, In *Federal Aviation Administration*, n.d., Retrieved February 20, 2017, from [http://aeronav.faa.gov/d-tp/1808/00754ad.pdf#nameddest=\(HNL\)](http://aeronav.faa.gov/d-tp/1808/00754ad.pdf#nameddest=(HNL)).

**ILS critical area markings.** ILS critical area markings illustrate a designated area on the airport surface that must be clear of aircraft, vehicles, people or any kind of obstructions when a landing aircraft is utilizing the ILS system. They are painted in two

horizontal solid yellow lines with multiple vertical solid yellow lines. The ILS critical area markings look like a horizontally placed ladder on a surface (Price & Forrest, 2016).

***Enhance taxiway centerline markings.*** Enhance taxiway centerline markings are the amplified taxiway centerline markings. They are shown as two yellow dashed lines on each side of the solid yellow line. They help to notify pilots that a hold short point is approaching. The enhancement will begin at the 150 feet point before the hold short point.

Clear airport lightings, signs, and markings are extremely important for pilots during taxi. For example, in Chino Airport (CNO), which is located in San Bernardino County in California, Taxiway L is associated with tricky turns. As shown in Figure 2, when exiting Runway 26L at Taxiway L, if pilots inadvertently make a right turn on Runway 21, they would be at a high risk of entering Runway 26R/8L. The complex intersections on Taxiway L require pilots to stay focused and continually scan the airport signs and markings to determine the correction location.

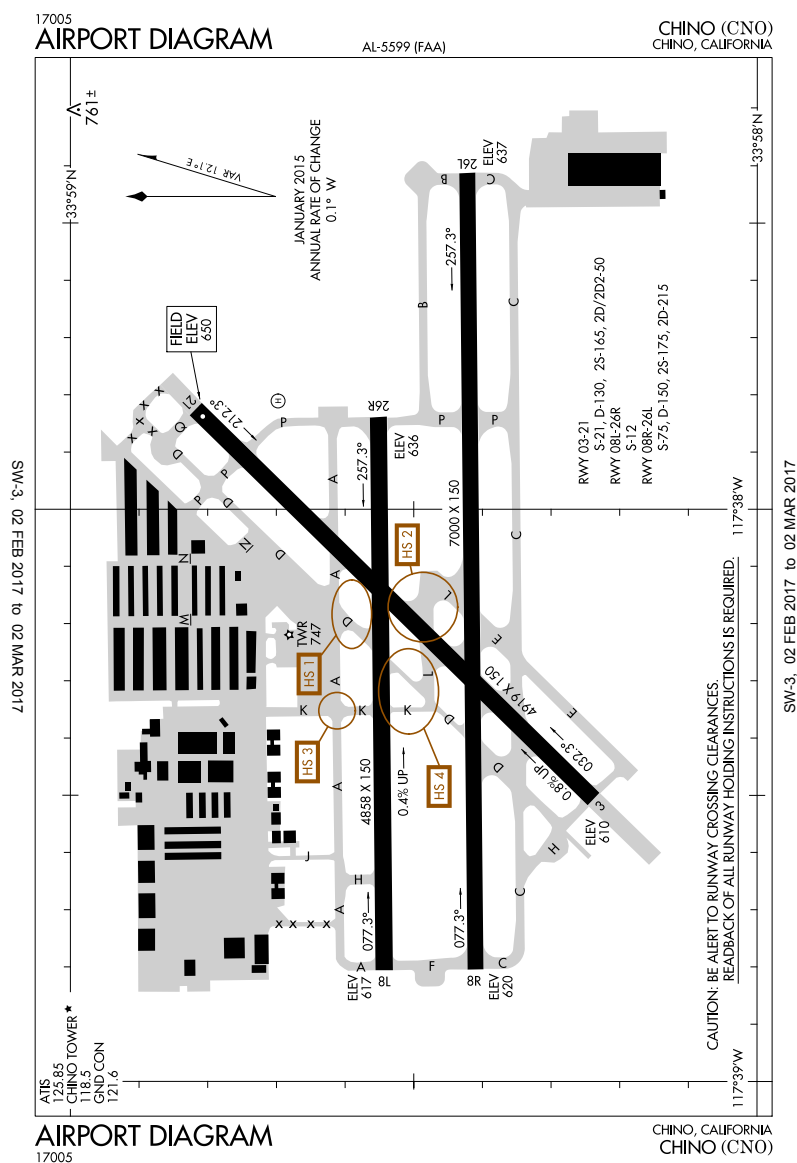


Figure 2. FAA airport diagram of Chino Airport (CNO). Adapted from Terminal Procedures, In *Federal Aviation Administration*, n.d., Retrieved February 20, 2017, from [http://aeronav.faa.gov/d-tpp/1808/05599ad.pdf#nameddest=\(CNO\)](http://aeronav.faa.gov/d-tpp/1808/05599ad.pdf#nameddest=(CNO))

**Runway/taxiway configuration.** Intersecting runways refer to two or more runways that cross or meet within their lengths (Dictionary of aeronautical terms, 2006). The benefits of intersecting runways would be giving the flexibility for pilots to choose

which runway they would like to operate from when the wind does not favor the main runway. Additionally, intersecting runways can increase the runway operation capacity when an airport is running on a simultaneous operation. However, simultaneous operation of intersecting runways increases the risk of RI (SKYbrary, 2018).

Parallel runways are the runways that have parallel centerlines (FAA, n.d.-c). Usually parallel runways have the same runway numbers with L (left) and R (right) to distinguish them (Dictionary of aeronautical terms, 2006). Some airports such as Hartsfield-Jackson Atlanta International Airport have five parallel runways; they are named as Runways 8L/26R, 8R/26L, 9L/27R, 9R/27L, and 10/28 (FAA, n.d.-b). Parallel runways sometimes can put pilots at risk of RI. For example, John Wayne Airport (SNA), located in Orange County in Southern California, is the nation's fiftieth busiest airport. As shown in Figure 3, SNA is an airport that has limited separation between parallel runways. As the result, the hold short line for the parallel runway can appear very suddenly. SNA has three hot spots. Hot spot can be defined as a location on the airport surface, specifically, in the movement area that has a high potential risk of collision or RI (FAA, n.d.-c). As depicted in the airport diagram, at hot spot number three, pilots can easily miss Taxiway C when transitioning from Taxiway A, which put pilots in Taxiway H. Missing the entrance of Taxiway C will easily put pilots at risk of RI for Runway 20L/2R. Also, because of the short length of Runway 20L/2R, pilots sometimes will accidentally enter the parallel taxiway, which is Taxiway C. An incident mentioned in the Literature Review section happened at this airport. The GA pilot was cleared to land on Runway 20L but mistakenly landed on the parallel Taxiway C, overflying an American Airlines Boeing 737 closely ("ASN wikibase occurrence," 2018).



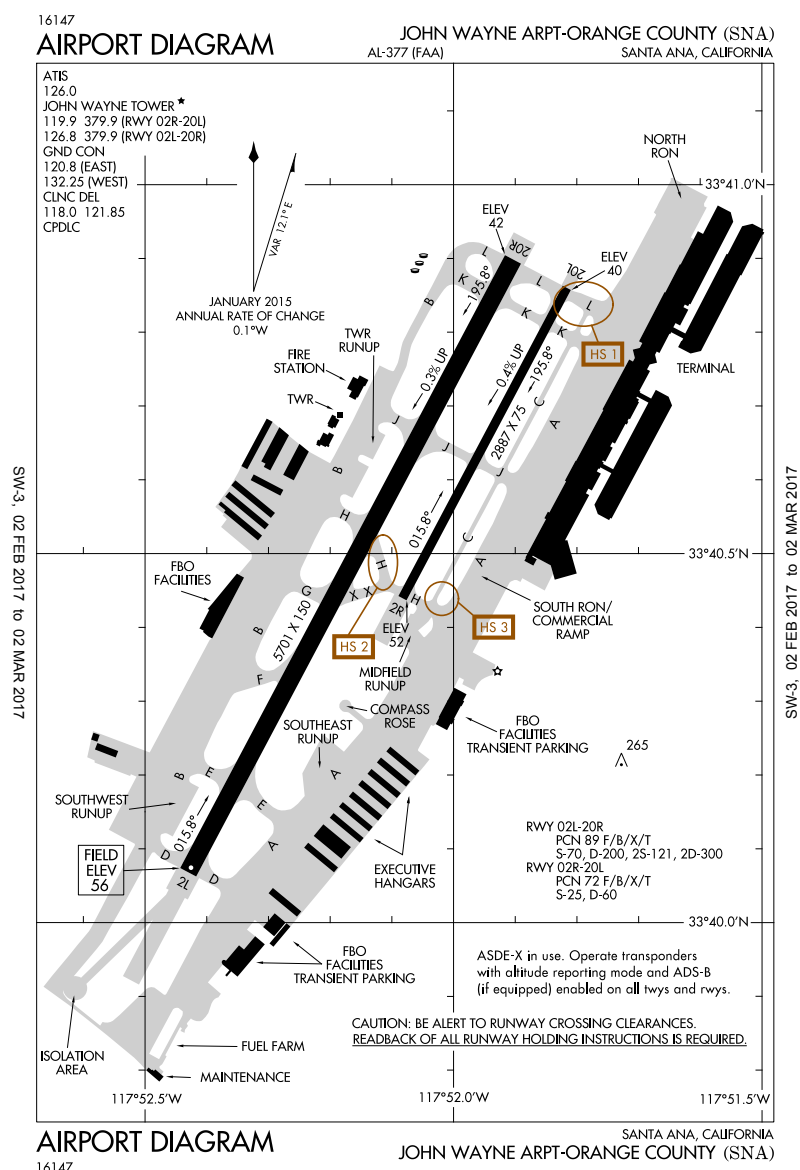


Figure 3. FAA airport diagram of John Wayne Airport (SNA). Adapted from Terminal Procedures, In *Federal Aviation Administration*, n.d., Retrieved February 20, 2017, from [http://aeronav.faa.gov/d-tp/1808/00377ad.pdf#nameddest=\(SNA\)](http://aeronav.faa.gov/d-tp/1808/00377ad.pdf#nameddest=(SNA)).

Van Nuys Airport (VNY) in Los Angeles is one the busiest GA airport in the world. It has a relatively high ratio of RIs caused by GA pilots especially due to pilot deviation. VNY has two parallel runways as indicated in Figure 4. Similar to SNA, with minimal separation between parallel runways, RI is a major threat at VNY. In addition,

Runway 16L/34R at VNY is short in length and parallel to Taxiway B. Pilots often make the mistake thinking that Runway 16L/34R is a taxiway, or accidentally land on Taxiway B thinking that it is a runway.

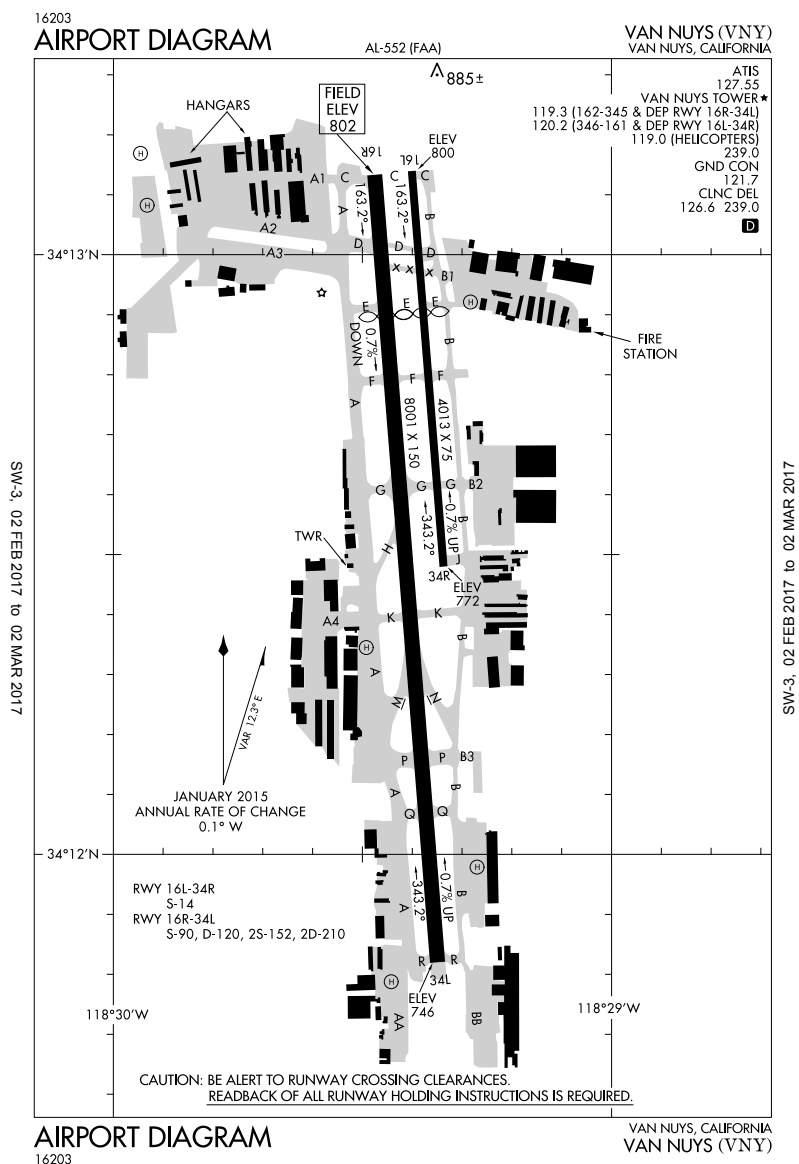


Figure 4. FAA airport diagram of Van Nuys Airport (VNY). Adapted from Terminal Procedures, In *Federal Aviation Administration*, n.d., Retrieved February 20, 2017, from [http://aeronav.faa.gov/d-tpp/1808/00552ad.pdf#nameddest=\(VNY\)](http://aeronav.faa.gov/d-tpp/1808/00552ad.pdf#nameddest=(VNY)).

**Daytona Beach International Airport.** Daytona Beach International Airport (DAB) has three runways. These runways are 7L/25R, 7R/25L, and 16/34. In 2010, DAB had 290,455 aircraft operations with an average of 796 per day. GA operation counted for 97% of the traffic, with 1% airline operation, 2% air taxi operation, and < 1% military operation. As of March 2017, there were 235 aircraft based in DAB. The fleet included 173 single-engine aircraft, 40 multi-engine aircraft, 21 jets, and 1 helicopter. Some of the biggest flight schools in the nation such as, Air America Flight Center, ATP Flight School, Spectrum Flying Club, Daytona Aviation Academy, Dickinson Aviation, Embry-Riddle Aeronautical University, and Phoenix East Aviation are based out of DAB (AirNav, n.d.).

In addition to the busy air traffic in DAB, navigating around the airport surface can always be a challenge to pilots. For example, in DAB, pilots need to pay extra attention when exiting from one of the FBO's ramp. As indicated in Figure 5, when pilots attempt to go to Taxiway P8 via Taxiway P, often times pilots would turn in early and end up in Taxiway M1. This is because the taxiway sign for Taxiway P is located right next to Taxiway M1. Once they make the wrong turn to Taxiway M1, it is impossible to make a U-turn even for a Cessna 172, because Taxiway M1 is a narrower than usual one lane taxiway. Pilots will need to go southbound to enter M2 to exit and restart the taxi from the ramp again.

The primary goal of a system is to provide usability, also known as being user-friendly. Usability is defined by the functionality and presentation of the interface.

Contemporary systems have concentrated primarily on interface presentation and interaction, which have greatly improved usability. On the other hand, functionality has a dominant impact on usability (Kieras, 1990; Rouse, Salas, & Cannon-Bowers, 1992). Functionality somewhat determines what and how tasks are performed by the users. It also presents partially how the users think about the interface. If a system is designed based on the users' conceptual model and its functions are self-understanding, this system's applicability and the aid it provides can tremendously enhance the usability (Hammer, 2010). In order to combine both the functionality and presentation of the interface seamlessly, psychologists first need to study users' mental model, which is how users adapt to and understand things before engineers start designing the system (Kieras, 1990; Rouse et al., 1992).

Even in a most basic human-machine system, human, machine, and environment are the three elements that need to be considered. The human element is consisted of sensation, cognition, and action. The human element needs to be considered for the purpose of enhancing usability. Sensation refers to all the neurophysiological functions of human beings, including visual, auditory, olfactory, gustatory, and haptic/tactile sensation. Cognition refers to human beings' allocation of attention, perception, memory, and decision. Action refers to human beings' muscle activity to conduct discrete controls (e.g. buttons, switches, and pedals), to modify continuous controls, and to speak (Sheridan, 2010). The machine and environment elements consist of physical dimensions, comfort, expected human capacity, reach, strength and performance (Robson, 2008). Apparently, HF needs to be considered in any system design to ensure usability and more. Engineers cannot design a system solely based on engineering

concepts. In the direction of optimal human machine interaction, a systematic approach called HFE was begun in the 1940s. HFE is the engineering discipline that involves both psychologists and engineers' joint effort to study the interactions of human and machine (i.e. organizational and technologic components) interface (Chapanis, as cited in Guastello, 2014). Generally, the term HFE is used interchangeably with HF ergonomics. In present days, HFE is a holistic approach that is incorporated in most systems' development stage with physical, cognitive, social, organizational, and environmental factors considered equally (Chadwick & Jeffcott, 2013; Guastello, 2014). Applying HFE principles when designing user interfaces can improve usability, in another words, make the interface more user-friendly (Wiklund & Kendler, 2013). Also, applying HFE principles as early as possible in the system design process helps to maximally benefit the final product (Wickens, Gordon-Becker, Liu, & Lee, 2004).

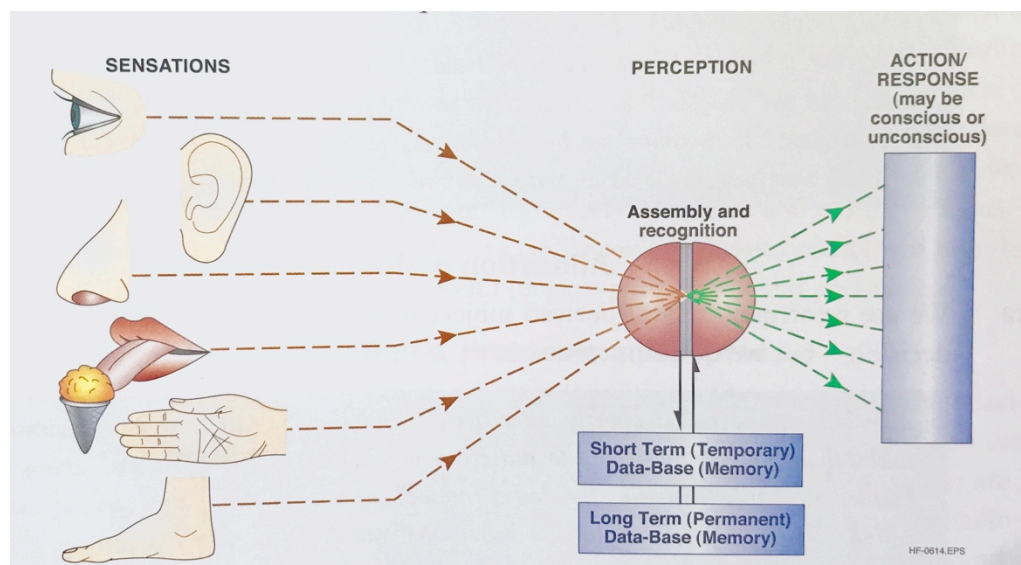
Typically, the designer of a new system needs to review previous published research; consider data compendiums of human capabilities; apply HF design standards of controls, visual and audio display principles, labeling methods, and so forth; and follow HF principles and guidelines. As a result, the designer can effectively involve HFE into system design. In this project, the author adopted Wickens' (2002) multiple resource theory, which integrates human capabilities, human sensations, perception, and cognition. The author also used the 13 principles of display design (Wickens et al., 2004), which includes HF design standards and principles to guide the design process of the new system.

**Multiple resource theory.** Wickens (as cited in Wickens, 2002) introduced the theory of multiple resources that humans could deal with multiple tasks more efficiently

if the tasks are given from different resources (i.e. different human sensory inputs: visual, auditory, haptic/tactual, gustatory, and olfactory). Wickens (2002) cited a study conducted by Parkes and Coleman in 1990 which indicated that drivers reacted to instructions given verbally more successfully than instructions given textually. It was because drivers used their eyes to drive. When the instructions were given textually, drivers needed to use their eyes to read the instruction. When the instructions were given verbally, drivers used other “resources” – ears, to listen to the instruction. This study showed that information given in multiple resources was easier to perceive. Wickens (2002) used this study to further prove that sensor organs such as eyes, ears, nose, taste buds, and receptors in the skin and muscles acted as multiple resources of information processing. Next, the author reviewed the different human sensations in order to decide how the information should be given in the application being designed in order to optimize usability and functionality.

***Sensation.*** An enormous amount of stimulation is perceived by our sensory organs (i.e. eyes, ears, nose, taste buds, and receptors in the skin and muscles) and presented to us as visual (sight), auditory (hearing), olfactory (smell), gustatory (taste), and haptic/tactile (touch) sensations. We detect stimuli and then we make decisions in our mind, which is known as cognition/perceptional; next we respond with actions. For example, the process of providing a meaningful visual image of the environment requires the eyes to capture stimuli (e.g. light and movement), the brain to match the image to previously stored data, and then the brain recognizes or perceives the information. Although the eye is the most important sensor organ for flying, other sensor organs such as ear, skin, and muscular feeling can reinforce or contradict the visual messages.

Additionally, the ear does not only hear auditory messages and interpret them, it also acts as an important balance organ. The ear can sense and perceive messages including which way is up, whether we are accelerating or steady, and whether we are erect. Figure 6 shows the information processing flow of human beings, which is a one-way flow (Robson, 2008).



*Figure 6.* Information processing. Adapted from “Human being pilot: Human factors for aviation professionals,” by D. Robson, 2008, p. 211.

The human brain acts as a central decision-maker, which can only consider one problem at a time. Alternatively, the human brain is only capable of processing one data source detected by one sensation at a time. A common misunderstanding of multi-tasking is that the human brain can process information simultaneously. In fact, our brain is switching attention quickly from one task to another and immediately switches back again. The human brain processes information sequentially, that is starting with the most prior tasks we detect via sensations (Robson, 2008). Therefore, the author should design



the new system to provide information via three resources, which are visual, auditory, and tactile sensations. Applying the multiple resource theory by Wickens will make information easier to perceive. In general, most of the information is provided visually other than ATC instructions. ATC instructions are played through the speaker or headphones from the mobile device. In this application, the author designed the ATC instructions to be displayed visually and played verbally to utilize multiple resources (i.e. visual and auditory). Tactile sensation should also be used to provide warnings. When the users make a mistake while taxiing, the mobile device should vibrate and a red X should appear on the screen to indicate the error message.

***Perception/Cognition.*** After human beings sense the stimuli, we perceive the information and make it meaningful so that we can take the best action. For instance, a group of visual images may become an aircraft heading toward a pilot. The pilot recognizes the danger and takes action to avoid the aircraft. Our sensor organs continuously detect stimuli to aid a constantly updated mental model of the situation. Our brain continually makes sense of what we hear, feel, see, smell, or taste. This process is named perception. Our previous experience and expectation can cause the perceived information to be biased, confused, misled, or inadequate. On the other hand, previous experience and expectations can also lead to faster integration of information into mental models (Robson, 2008).

Sensors such as the visual nerve and the auditory nerve transfer sensed information to the central nervous system (the brain and the spinal cord), where the information is perceived. During this process, the sensed information is stored in a sensory memory for a split second, just enough for us to select which ones to instantly

take care of. It is quickly discarded and displaced by new sensed information unless our brain determines to absorb it and process it. A noteworthy fact is that each sense has its own memory with a different length of retention time. For example, auditory messages last relatively longer in the sensory memory than visual messages. A visual message lasts only about one second; however, an auditory message lasts about five seconds before it fades (Robson, 2008). Consequently, the author should design the new system to have the function to play ATC instructions via speaker, instead of displaying textually only.

After the sensory memory, useful information will be transferred into working memory. Working memory processes the information that we have chosen to attend to and which may be drawn from the long-term memory. The next stage in memory is short-term memory. A typical human brain can hold seven items for 15 seconds in the short-term memory. Shortly it fades away unless we successfully transfer it to long-term memory. A brief ATC instruction to “change frequency to one two eight point five” will remain in short-term memory long enough for pilots to select the frequency. If the pilot delays the action or the ATC instruction contains additional information than the frequency, the pilot will possibly forget the frequency. For this reason, pilots are recommended to write down an ATC route clearance as it is received because human short-term memory will not be able to deal with multiple items in an ATC route clearance, both in terms of numbers of items and also in time of retention of a long auditory message over five seconds (Robson, 2008). As a result, the author aimed to design the application with a function to display the ATC instruction textually on the

screen and remain on the screen until next ATC instruction is generated. In this case, users do not need to write down the information in order to perform taxiing instructions.

**Thirteen principles of display design.** Even though we provide information through different resources (sensations), human limitation stops us from retaining information that contains more than seven items for 15 seconds in the short-term memory in general (Robson, 2008). As a result, organizational structure of display design is widely adopted to aid human perception and information processing. The organizational structure being reviewed in this section is known as 13 principles of display design. Thirteen principles of display design are categorized into four groups: (a) perceptual principles, (b) mental model principles, (c) principles based on attention, and (d) memory principles (Wickens et al., 2004).

The first category, perceptual principles, contains five principles. The first principle is to make displays legible (or audible). Legible or audible displays are fundamental for usable displays. The next four perceptual principles are applied based on the first principle. The second principle is to avoid absolute judgment limits (Wickens et al., 2004). Absolute judgment refers to the successful visual discrimination of two stimuli that are next to each other. When only one stimulus is presented, either human beings have difficulty distinguishing it or they try to compare the stimuli to the mental representations of the other possible stimuli. Absolute judgment is useful but limited to human ability, such as limit in knowledge or working memory. For instance, human beings are capable of discriminating among 11 different color hues. If light blue is used to indicate main water supply and dark blue is used to indicate emergency water supply, we can discriminate the color difference when both colors are visualized, but not when

only one color is visualized (Bainbridge & Dorneich, 2010). Therefore, absolute judgment should be avoided in display design to avoid confusion and errors (Wickens et al., 2004). The third principle is to display information using top-down processing, e.g. a checklist. Top-down processing provides sequential information in accordance with how users expect to perceive the information. The fourth principle is redundancy gain, which refers to the fact a message is more likely to be successfully captured when repeated more than once. This is more effective if the redundant or repeating message is given in alternative forms (e.g. verbal ATC instruction and textual ATC instruction). The fifth principle is to use discriminable elements. In addition, the ratio of discriminable elements to similar elements also determines the level of confusion. For instance, ABP4989 is more similar to ABP4979 than is 89 similar to 79. Similarity causes confusion in visual information, which can be very dangerous; therefore, we should use discriminable elements in displays (Wickens et al., 2004).

The second category, mental model principles, contains the sixth and seventh principles of display design. The sixth principle is the principle of pictorial realism, which is to use look-alike shapes, geometric forms, or close-to-reality symbols or colors to display a variable. For example, a symbol of a thermometer with vertical indications can be used to represent the temperature. The indication of high and low speed should be on a vertical scale. In the design of the application, symbols such as a house can be used to replace the long message of “return to home page”. This can reduce redundancy as well as increase pictorial realism. The seventh principle is the principle that the moving part should be compatible with the users’ mental model. For instance, aircraft should

move upward with increasing altitude, which is compatible to most pilots' mental model (Wickens et al., 2004).

The third category, principles based on attention, contains the eighth, ninth, and 10th principles of display design. The eighth principle is minimizing information access cost in time or effort. Frequently used information should be retrieved from sources that require minimal time and effort to access. The author can apply this principle when designing the interface. For example, the taxiing interface of the new application should only show the aircraft and the airport environment, with some most commonly used navigation features displayed. Displaying the FAA airport diagram can be eliminated. Otherwise it will have too much information to display on a small screen, especially when users open the application in their mobile devices. Including the FAA airport diagram in a different page will not be ideal either. During taxiing, pilots are expected to have the FAA airport diagram accessible at all time. That being said, users will need to constantly switch screens between the aircraft view and the FAA airport diagram view. In addition, the FAA airport diagram is updated very frequently on the FAA website. It will create a problem if the design engineer needs to constantly update the software in order to keep the FAA airport diagram current. Therefore, the best way to simplify the process is to exclude the FAA airport diagram in the application. Users will need to supply their own FAA airport diagram to navigate around the airport and identify their locations while using the application. The ninth principle is proximity compatibility. Sometimes, human beings need to divide their attentions among two or more sources of information, in order to integrate the multiple sources to complete the tasks. In this case, the two or more sources of information are considered as close mental proximity. They

can be displayed closely, in a common color, by configuring them in a pattern or by linking with lines to show close proximity, when integration of divided attention is used. Proximity in display should be used wisely when focused attention is needed. Because close proximity prevents successful discrimination of information, it also leads to confusion in perception especially when we need to focus our attention on one particular item (Wickens et al., 2004). The 10th principle is the principle of multiple resources. This principle was explained in detail in the previous section of Wickens (2002) multiple resource theory.

The fourth category, memory principles, contains the last three principles of display design. The 11th principle is to replace the necessity of using working memory or long-term memory with the knowledge in the world. For example, using a checklist for repeating but important tasks, or display information that needs to be compared simultaneously instead of sequentially. The 12th principle is the principle of predictive aiding. This principle mainly aims to reduce the workload of retaining information in the working memory. We want to be proactive, in other words, we need to predict or anticipate what is going to happen in the near future. For example, when a pilot turns the aircraft, an extended dashed line can be displayed to indicate the upcoming flight path, so that pilot does not need to retain this information in the working memory. The 13th principle is the principle of consistency. For instance, if a series of buttons have “pressed=on,” then the latter buttons cannot be “pressed=off”. The display of elements or symbols should always have a consistent meaning. For instance, red color is generally perceived as stop or warning; therefore, the author should use red color in the new system

to indicate errors instead of using other colors such as green to indicate errors (Wickens et al., 2004).

**Other design principles.** Smith and Mosier (1986) also proposed a similar guideline to organize the display. There are five goals of organizing the display, which are: (a) consistency of data display, (b) efficient information assimilation by the user (i.e. using familiar format, or displaying related information), (c) minimal memory load on the user, (d) compatibility of data display with data entry, and (e) flexibility for user control of data display (Shneiderman & Plaisant, 2005). Nielson (1994s) introduced eight general interface design principles, which are: (a) match between system and real world, (b) consistency and standards of expressing information, (c) visibility of system status to keep users informed, (d) user's freedom in control (i.e. undo, cancel, redo, exit, initiate, avoid), (e) error management (i.e. prevention, recognition, and recovery from error), (f) reduce memory workload, (g) flexibility and efficiency of use, and (h) simplicity and aesthetic integrity. In conclusion, the principles for interface design proposed by different researchers are very similar. In the author's point of view, the 13 principles of display design is the most suitable guideline for the design process of the interface. As a result, the author would adopt this principle to design the new system.

In summary, the author should apply the multiple resource theory by Wickens to give information in multiple resources (i.e. different human sensory inputs: visual, auditory, haptic/tactual, gustatory, and olfactory). The information will be easier to perceive by users (Wickens, 2002). In this application, the author should design the ATC instructions to be displayed visually and played verbally to utilize multiple resources (i.e. visual and auditory). Tactile sensation should be used to provide warnings when the

users make a mistake while taxiing. Next, the author should adopt Robson's (2008) theory of human sensation and memory capability. Although ATC instructions should be displayed visually, there should be a function to disable the display. Lastly, based on the 13 principles of display design (Wickens et al., 2004), the author should use symbols such as "house" to replace long messages and minimize information displayed. The information should be easy to retrieve using the features on the interface. The FAA airport diagram should be not included in the application. Errors should be indicated in alignment with real world, for example, using a red X to indicate "mistake" or "wrong way".

### **Systems Engineering Approach**

**Conceptual design.** When designing a new system using the systems engineering approach, typically there are four steps to follow. The first step is conceptual design, which involves identifying user needs and developing system requirements. The development of a completed list of requirements is critical in this step because it is the foundation of system design. It specifies the rationale and necessity of the design. The requirements should be generated following a general-to-specific process. General requirements can be collected through observation or interview with users. General requirements are the guideline for the initial process of the design (Liu, 2016). First, the requirement collection process would be discussed in the following paragraphs.

In the field of systems engineering, all the requirements of system design fall under the category of system requirements. The system design process is requirement driven (Liu, 2016). System requirements are the technical descriptions of system characteristics. Requirements come from system objectives, which are the needs from



different stakeholders. System designers analyze the system objectives and then translate them into requirement (Nørstebø, 2008). In other words, a system starts with a need; a need is what the system is designed to address or must have (Liu, 2016). Requirement gathering should be the initial process followed by translation process which is requirements analysis (RA). The result of requirement gathering should reflect the constraints of the current system and the requirements for a new system (Roberts, Berry, Isensee, & Mullaly, 1998).

Systems requirements can be categorized into four major categories and some secondary categories. All the requirements overlap with each other under different categories. The first major category is functional requirements. Functional requirements specify the desired functions that a system should provide and what the user should do to carry out this function (Liu, 2016). For example, the new application designed by the author should allocate major operational tasks to the users (e.g. operating the aircraft, perceiving the ATC instructions, identifying the correct way, etc.). Therefore, the goal of the new application is to enhance users' operational experience of taxiing around the airport and increase their level of familiarity. The second major category is performance requirements, which specify how well the system function shall be performed. The third major category is constraint requirements, which specify the limitation of the system. The fourth category is verification requirements that are used to verify whether the system performs well enough. Other categories of system requirements include: (a) requirements originating directly from customers, (b) derived requirements from RA to further refine the originating requirements, (c) design decision requirements from the

designers, (d) end-user requirements, (e) management/business requirements, and (f) maintenance/support requirements (Liu, 2016).

In conclusion, the system requirements of this new application should include the major categories of requirements, the originating requirements from the users which could be gathered by survey, design decision requirements from the author, and management/business requirements which should be collected from the FAA regulations on airports and aircraft operation. After gathering all the system requirements, there should be tests and evaluations throughout the process to generate a more specific list of requirements which can be used for detailed design of a new system. At the end of the conceptual design, the designer should be able to determine the functions of the new system based on the requirements collected (Liu, 2016).

**Preliminary design.** The second step of the systems engineering design process is preliminary design. In this step, a more detailed design of functions and components should be conducted. After identifying the requirements that the new system is aiming to meet, preliminary design translates the requirements to how the system requirements are fulfilled by each system functional component. This translation shows the traceability of how each requirement links to each function (Liu, 2016).

**Detailed design.** The third step of systems engineering design process is detailed design. In this step, a final configuration integrating all the components should be developed and then an evaluation should be conducted to review the new system. In a typical user testing evaluation, usability testing is commonly used. However, heuristic evaluation is another commonly used method to evaluate usability of user interface design. It is due to the fact that implementing usability testing could be expensive and

time consuming when obtaining initial evaluation results. Heuristic evaluation and testing is more cost efficient and can be done in a timely manner (Liu, 2016). Also, heuristic evaluation is the process of a person viewing an interface and making value judgments based on the 10 heuristics of usability, using his or her own common sense or intuition. Therefore, heuristic evaluation can provide a systematic inspection of the interface and provide some useful recommendations for changes (Jones, Failla, & Miller, 2009; Nielsen, 1995b; Shneiderman & Plaisant, 2005).

Nielsen (1995a) provided the following 10 heuristics evaluation criteria of user interface design:

1. Visibility of system status. For example, the author should ask the experts questions like “on a scale of 1 to 10, how would you score the interface of the mobile application, in terms of its ability to always keep pilots informed about what is going on, through appropriate feedback within reasonable time?”

2. Match between system and the real world. For example, the author should ask the experts questions like “on a scale of 1 to 10, how would you score the interface of the mobile application, in terms of its ability to match the real airport dynamic environment during taxiing?” Or “on a scale of 1 to 10, how would you score the interface of the mobile application, in terms of its ability to speak the pilot’s language, with aeronautical words, phrases, and concepts familiar to the pilots?”

3. User control and freedom. For example, the author should ask the experts questions like “on a scale of 1 to 10, how would you score the interface of the mobile application, in terms of its ability to provide users freedom to “cancel”, “undo” or leave the unwanted state without having to go through an extended dialogue?”

4. Consistency and standards. For example, the author should ask the experts questions like “on a scale of 1 to 10, how would you score the interface of the mobile application, in terms of its ability to provide consistent information?” Consistent information can be defined as having the clarity so that users should not have to wonder whether the words, symbols, or indicators used in the mobile application mean the same thing as the FAA airport diagrams, flight control desk, and any other flight supplemental documents?”

5. Error prevention. For example, the author should ask the experts questions like “on a scale of 1 to 10, how would you score the interface of the mobile application, in terms of its ability to provide good error messages, preventing a problem from occurring in the first place?”

6. Recognition rather than recall. For example, the author should ask the experts questions like “on a scale of 1 to 10, how would you score the interface of the mobile application, in terms of its ability to minimize the users’ memory load? Users should not have to remember information from one part of the interface to another.” Or “on a scale of 1 to 10, how would you score the interface of the mobile application, in terms of its ability to provide clear or easily retrievable instructions for the use of the mobile application?”

7. Flexibility and efficiency of use. For example, the author should ask the experts questions like “on a scale of 1 to 10, how would you score the interface of the mobile application, in terms of its flexibility and efficiency of use, for both inexperienced and experienced pilots?”

8. Aesthetic and minimalist design. For example, the author should ask the experts questions like “on a scale of 1 to 10, how would you score the interface of the mobile application, in terms of its ability to allow users to tailor frequent actions such as customizing common shortcuts as they prefer?” Or “on a scale of 1 to 10, how would you score the interface of the mobile application, in terms of its ability to provide only relevant and needed information?” Or “on a scale of 1 to 10, how would you score the aesthetics layout of the interface of the mobile application? It should respect the principles of contrast, repetition, alignment, and proximity.”

9. Help users recognize, diagnose, and recover from errors. For example, the author should ask the experts questions like “on a scale of 1 to 10, how would you score the interface of the mobile application, in terms of its ability to help users recognize, diagnose, and recover from errors? Error messages should be expressed in plain language (no codes). The mobile application should precisely indicate the problem, and constructively suggest a solution.”

10. Help and documentation. For example, the author should ask the experts questions like “on a scale of 1 to 10, how would you score the interface of the mobile application, in terms of its ability to provide help when users require additional information to understand the airport layout?”

Nielsen (1995b) indicated that in order to lower the probability of biased heuristic evaluations, evaluators should work individually, only communicating after completion, including written or recorded reports following the inspection. Heuristic evaluation is a great evaluation process to validate the interface design because one of the best ways to

find mistakes and problems in interfaces is to “use” the interface and look for them (Jones et al., 2009).

**System installation and deployment.** The fourth step of designing a new system using the systems engineering approach is system installation and deployment, operation and maintenance. After the evaluation, the author should finalize all the necessary changes before moving to this step. This final step also includes continuous follow-up evaluation from the users. The engineers will also continuously maintain the system and support any technical issues (Liu, 2016).

### **Summary**

This literature review was structured into five sub-sections. First, the author reviewed the mishaps, incidents, and accidents caused by RI to indicate the severity and frequency of RI. Especially, GA contributed to a significant amount of RIs. Also, airport unfamiliarity was found to be a major type of RI causation. Therefore, the author would develop a new system for GA pilots to reduce RI caused by airport unfamiliarity. Second, the author reviewed the current RI prevention systems and discovered that most systems require transmission of live traffic information and installation of airport surface sensor. Most systems were developed at very high-scale. As a result, it is expensive and difficult to implement those systems in GA operation. This further confirmed the necessity of developing an affordable, accessible, and simple RI prevention system. Third, the author reviewed airport lightings, signs, and markings, runway/taxiway configuration, and DAB layout plan. This review provided the author a comprehensive understanding of the airport elements that should be included in the interface design. Also, this part of the literature review enabled the author to collect the system

requirements from the FAA rules and regulations of operating an aircraft on an airport surface. The reference materials include the FAA Part 139 Airport Certification (FAA, 2018b), Advisory Circulars 150/5300 – 13A, Airport Design (FAA, 2018a), and FAA airport diagrams. Fourth, the author reviewed the multiple resource theory; human sensation, perception, cognition, and memory capability; and 13 principles of display design. These HFE principles guided the author to design a user-friendly application. Fifth, a systems engineering approach would guide the design process of the application. The author would collect user requirements from survey questionnaires, conduct RA, translate each requirement into a function, design the interface, and conduct a heuristic evaluation to validate the design. The design process would be further introduced in the next section, Methodology.

## **Chapter III**

### **Methodology**

#### **Project Statement of Work**

The purpose of this project was to develop a user-friendly, affordable, interactive, and dynamic application for users to practice taxiing using their portable devices anywhere at any time. The taxiing environment will replicate real airport surface and will be designed based on the FAA airport diagrams. This application will be a supplemental material during flight preparation. Pilots who use this application will first study the FAA airport diagram of the airport and next will practice taxiing around the airport using the application while reading the FAA airport diagram. This process is similar to normal flight preparation routine. After the active learning process on the application, the users are believed to have enhanced familiarity of the airport environment that they choose to practice with in comparison to studying the FAA airport diagram alone. Ultimately, this application will help to prevent RIs caused by unfamiliarity of the airport environment. The primary stakeholders of this application are the ERAU flight department and the flight students from ERAU. Therefore, the airport environment of prototype was established based on DAB.

#### **Conceptual Design**

The author adopted the systems engineering approach of designing a new system as the methodology. The first step is conceptual design. In this step, the author first identified system users and system needs (Liu, 2016). As a result, the author collected system requirements from three sources, which were from the potential users, the FAA rules and regulations, and the author's design ideas. The design ideas were collected



based on flight observation and past experience interacting with pilots, analysis of current RI prevention systems, and review of HFE principles. A questionnaire survey approach was used to collect the requirements from the potential users, which are the students at Embry-Riddle Aeronautical University and the employees at DAB. Feasibility analysis and RA were used to filter the requirements. Consequently, a complete list of system requirements was developed in this step.

**System requirements collection.** The author collected the system requirements from three sources, which were from the potential users, the FAA rules and regulations, and the analysis of HFE principles. The primary users of this new application would be the ERAU Flight Department and the student pilots who are undertaking flight training in the Flight Department. DAB was chosen to be the only airport included in the prototype because this is the most frequently used airport by ERAU. Because DAB was used in the initial design, the employees, especially airport operation agents at DAB, would also be considered as the potential users. Thusly, a questionnaire survey was used as the approach to understand user (i.e. ERAU students and DAB employees) expectations/requirements. The overall goal of this requirement collection process was to determine what the system should provide, not how it is constructed (Liu, 2016).

**Design decision requirements.** Design decision requirements were originated from the designer, which was from the author's observation and past experience interacting with pilots, as well as the analysis of current RI prevention systems and HFE principles. The author designed the new application as a supplemental material during flight preparation to enhance airport familiarity. This new application should be interactive, user-friendly, and should provide experience that the FAA airport diagram

does not provide. As a result, the author designed the application with the capability to display the image in the way that was preferred by users. The application also has the options to change weather condition and time of day, display the runway and taxiway in the color that users preferred, and provide users most needed information (e.g. distance indicator and heading indicator). Also, based on the HFE principles, the application would provide critical information through multiple resources (i.e. visual, auditory, and tactile human sensation). Long ATC instructions have the possibility to stress mental workload; therefore, there would be a function to display ATC instructions on screen. This will save users time to write down long ATC instructions. The display of information should be clear, simple, but informative. Some commonly understood symbols can be used to replace redundant information. There also should be attention-catching notifications of errors or successful completion of tasks.

***Management/business requirements.*** In order to collect comprehensive FAA rules and regulations, the author referred to three materials. First, the author referred to the FAA Part 139 Airport Certification to collect requirements of airport configuration (FAA, 2018b) because DAB is under Part 139 operation. The requirements on how to draw the airport environment were collected from Advisory Circulars 150/5300 – 13A, Airport Design (FAA, 2018a). Also, the author studied the FAA airport diagrams to identify the most critical information that would be included in the application. The author also collected improvement requirements based upon the limitation of the FAA airport diagram to shape the design of the application.

***User requirements.*** The author used a survey approach to collect user requirements because a survey is cost-effective and relatively quick for data collection,

especially when using Internet survey tools (Wise, Abbott, Wise, & Wise, 2010). Therefore, the survey tool “Survey Monkey<sup>TM</sup>” was used to distribute survey questionnaires and collect participants’ feedback. This survey was approved by the Institutional Review Board (IRB) of ERAU. All the participants agreed and signed the informed consent before taking the survey. The questionnaire included 37 questions and could be completed in 15 minutes. Participants from group one were the students who are over 18 years old, studying at Embry-Riddle College of Aviation, or undergoing flight training in Embry-Riddle with any flight hours. Participants from group two were the employees at DAB. All the participants self-selected to participate in the survey. In the first section of the survey, basic information about the participants such as age, flight background, and flight experience were collected. In the second section of the survey, the author asked some narrowly designed questions to collect precise personal preference of the application. The answers of these questions were percentage based. For example, participants were asked to rate the importance of two-dimensional or three-dimensional display, color of runway, verbal or textual ATC instruction, options to choose weather condition, display of heading indicator, etc. Each of the questions in the second section would generate an answer of a percentage. The author calculated the average percentage of all the answers for each question. The higher percentage means higher importance. All the questions in section two were ranked based on the average percentage of importance. For example, if the importance of two-dimensional display had a lower percentage result than the importance of three-dimensional display, the author would adopt three-dimensional display in the design. The ranking of the importance of each requirement was also necessary to perform a HOQ analysis, as part of the RA. In the last

survey question, participants were asked to freely contribute any ideas about the design of the new system. The author would incorporate the feasible ideas into the design process as part of the user requirements. Both qualitative and quantitative self-reported data would be collected through the survey questionnaire and used in the RA. No statistical analysis was used to compare the data collected. The sole purpose of this survey was to collect user requirements as well as to score the importance of each requirement. A copy of the IRB approval, consent form, and survey questions is included in Appendix B.

**Feasibility analysis and requirements analysis (RA).** Next, the author analyzed the technical feasibility, economic feasibility, operational feasibility, and legal feasibility of translating each requirement into a function. Some requirements collected from the three sources were not feasible for the author to accomplish, for example, including live traffic information, other aircrafts that are taxiing at the same airport, real-time location of the aircraft, and so forth in the mobile application. These requirements were against the initial design philosophy, which was to design an affordable and simplified practicing tool. The RA process is when the author translated general and vague needs from the users, the designer (i.e. the author of the project), and the FAA regulations into formal requirement statements (Liu, 2016). An example of a formal requirement statement would be that the system shall present the ATC instructions on the screen when required by the user.

One important activity in RA is to perform trade-off studies. Systems engineers need to translate system requirements into technical performance measures (TPMs) so that they can rank the importance of each requirement and perform trade-off studies. One of the commonly used tools is called quality function deployment (QFD). The first user

requirements collection survey provided the ranking of importance of each requirement. The result also indicated the importance level of each requirement on a scale of one to 100. QFD contains three basic techniques, which are the voice of customers, the voice of the company (VOC), and relationship between them, which is termed the house of quality (HOQ). HOQ is a part of the QFD, which uses a planning matrix to connect user requirements and product capabilities, and eventually guides the designer to meet the user requirements optimally. The author used the survey result to conduct a HOQ analysis which indicated the ranking of importance of each requirement. Therefore, in the later design process, the most critical requirement should be prioritized, and the least critical requirement could be eliminated if necessary.

**CORE.** CORE by Vitech Corporation is model-based systems engineering software. It was used in this project to manage the requirements and provide clear traceability and rationality for each function. CORE has been a widely utilized software in the systems engineering community since 1992 (Liu, 2016). The author input all the system requirements into CORE and translated them into functions. This is a crucial process to prepare the requirements for the next step: preliminary design. The permission to use CORE to conduct this project is included in Appendix A.

### **Preliminary Design**

The second step is preliminary design. The result of the conceptual design should be a list of functions that the new system should perform in order to fulfill the analyzed requirements (Liu, 2016). International Council on Systems Engineering [INCOSE] (2012) states that a system function can be performed by multiple system elements including hardware, software, firmware, facilities, personnel, and procedural data.

System users, which is the personnel, may or may not directly perform the function. An intuitive way of functional development should be a decomposition process, which is to always start with the highest hierarchy and then move on to the lower level functions. In the previous step, the author used the systems engineering software, CORE, to translate requirements into functions and show the traceability. In this step, a typical functional analysis was illustrated by functional flow block diagram (FFBD) using CORE 9. The FFBD describes the sequential relationships of functions. It is a necessary procedure in any system design. In the end of this step, the functions that would be included in the application were finalized.

### **Detailed Design**

The third step is detailed design. The result from the conceptual design and preliminary design would be integrated into a final form of the system in the detailed design. In this step, the author designed the interface to include all the functions based on the HFE theories. Once the interface was designed, heuristic evaluation was used in this step to collect opinions of the interface from three to five HF experts and three to five experienced pilots. The heuristic evaluation was conducted in a questionnaire survey approach. In order to compare whether the interface is significantly different from the traditional FAA airport diagram, the author conducted a t-test to compare the mean scores. As a result, the author would be able to find out any significance of the new interface. Based on the experts' comments gathered from the heuristic evaluation, the interface was modified to accommodate some feasible changes. The final interface was displayed in Microsoft PowerPoint to demonstrate the operation of the application designed in this project.

**Interface.** The first step when designing the interface was to consider HFE principles. For example, as reviewed in the Literature Review section, the new system should provide information via visual, auditory, and tactile sensations. Auditory messages last relatively longer in the sensory memory than visual messages. Therefore, ATC instruction would be provided verbally. According to Robson (2008), a typical human brain can hold seven items for 15 seconds in the short-term memory. Therefore, there is a function on the interface to choose textually display ATC instructions. Also, when a user makes a mistake, a tactile warning (i.e. vibration from the portable device) will be given as well as a red X should be displayed. As reviewed in the Literature Review section, 13 principles of display design were used in different ways to guide the design process of the interface. For example, the author used a house symbol to indicate the function “return to home page”. The arrangement of function feature displayed on the screen was thoroughly considered. The frequently used information, such as heading direction and distance remaining, was displayed obviously for users to retrieve the information. The application does not have redundant functions such as showing the FAA airport diagrams. As a result, this will either cause too much information to be displayed on the same page, or constant switch of pages to retrieve information if the FAA airport diagram is displayed on a separate page. The author reviewed the HFE theories and systems engineering theories continuously to accommodate all the feasible system requirements.

The hardware used in the interface design was a computer and the FAA airport diagrams. The software used in the interface design were the Flight Simulator X, CORE, Adobe Photoshop, and Microsoft PowerPoint.

**Heuristic evaluation.** At this stage, the initial interface of this application had been designed. As one of the necessary design processes of a new system, an evaluation of the new system must be conducted (Liu, 2016). The author chose heuristic evaluation as the method to evaluate the interface of the application to identify usability problems of the interface. Heuristic evaluation is an expert-review method that can be performed even when user interfaces are only available in paper form. The designer can explain the interface to the experts, without having them actually use the system to perform a task (Nielsen, 1995b). Heuristic evaluation would be the best approach in this project to provide feedback because the completed system has not yet been developed.

According to Nielsen (1995b), heuristic evaluation will require three to five experts in each category. In principle, more usability problems will be discovered with the increased number of evaluators. Nielsen (1994) concluded from his past project experience that five evaluators would identify about 75% of the usability problems, 10 evaluators would identify roughly 85% of the usability problems, and 15 evaluators would identify close to 90% of the usability problems.

Therefore, the author aimed to reach out to 5 to 10 experts in total, depending on the availability. The experts were chosen from a group of HF experts from ERAU and a group of experienced pilots (over 200 flight hours) from current ERAU students or ERAU alumni. Upon receiving the second IRB approval to conduct the heuristic evaluation, the author sent out the evaluation questions in a questionnaire to the experts who agreed to participate. The survey contains 14 heuristic evaluation questions, one background information question, and two open-ended questions which allow the experts to freely contribute their suggestions of the features of the application.



Next, the author arranged face to face appointments with the experts separately. A presentation was prepared using Microsoft PowerPoint to demonstrate the operation of the application to the experts. In this presentation, the author included nine screenshots of the interface and explained the meaning of the interface and the functions showing on the interface. The dynamic of the interface was achieved by using the hyperlinks of Microsoft PowerPoint. After the experts understood the interface and the functions of the application, the author also provided the experts four FAA format diagrams, which were HNL, CNO, SNA, VNY, and DAB. These five airports all have a high volume of GA traffic. The author explained the FAA airport diagrams to the experts that were confused. Some experts also had questions about heuristic evaluation; therefore, the author clarified the heuristic evaluation method and the meaning of each evaluation question. Next, the experts were given a long period of time to answer the questions. On average, each expert returned the survey result within one month. No communication among the experts was observed.

All these experts scored the interface design based on the 10 basic rules of heuristic evaluation, and then provided comments and a list of potential problems if necessary. Pairwise comparisons are necessary to identify whether the new interface is significantly different from the traditional FAA format airport diagrams in terms of the ability to provide enhanced airport familiarity. Therefore, the author asked the same experts to score the FAA format airport diagrams based on the 10 basic rules of heuristic evaluation, and then provide comments and a list of potential problems if applicable. Both qualitative and quantitative self-reported data were collected through the questionnaire. As the result, two groups of scores were obtained and analyzed

statistically using pairwise comparisons to identify any significant difference. Statistical Package for the Social Sciences (SPSS) was used to run the statistical pairwise t-test analysis.

A copy of the IRB approval, consent form, and survey questions are included in Appendix C. Based on the experts' comments in the heuristic evaluation, the interface was modified to accommodate some feasible changes. The final interface was included in the Result section of this project.

## **Chapter IV**

### **Results**

This chapter includes the results of the user requirements collection survey. Based on the survey result, the author's design ideas gathered from previous studies and observations, and the FAA regulations, a HOQ matrix was developed. The author also used CORE 9 to compile a list of comprehensive system requirements, establish five hierarchy diagrams of the requirements that shows traceability between requirements and functions, and establish nine FFBDs. Next, the statistically analyzed result of the heuristic evaluation was included. Also, the good features of the application, and the potential problem of the FAA airport diagram and the application according to the experts were listed. Lastly, the author presented nine screenshots of the final version of the interface design.

#### **User Requirements Collection**

There were 32 participants in the first user requirements collection survey. The number of participants who had piloted an aircraft before was 21. The number of participants who had never piloted an aircraft before was 11. Question 25 asked the importance of displaying the image with a top-down view (2D), and the result was 66%. Question 26 asked the importance of displaying the image with a first-person point of view (3D), and the result was 78%. Therefore, the author initially designed the display of image with first-person point of view (3D). Due to the limitation of the Flight Simulator X, which is the software used in the interface design, the author designed the display of image from an ownship perspective.

In question 29, 30, and 32, participants rated the importance of verbal ATC instructions was 90%; the importance of textual ATC instructions was 42%; the importance of both verbal and textual ATC instructions was 54%. This result affirmed the design idea and the HFE theories. Therefore, in the default setting, ATC instructions would be played through the speaker or headphone of the mobile device verbally. However, according to the HFE theories reviewed in the Literature Review section, displaying ATC instructions on screen aid short-term memory. The author designed an option for users to activate textual ATC instruction if needed. The users may double tap the screen to display the newest ATC instruction, and double tap again to disable the display.

In question 33 and 34, participants were asked to rate the importance of displaying runway and taxiway in real-life airport surface painting color, as well as the importance of displaying runway and taxiway according to the FAA airport diagram color. The result indicated that displaying both the runway and taxiway in dark grey color to reflect the actual airport environment was more important, which had a score of 86%. The importance of displaying the runway and taxiway in black and light grey to replicate the FAA airport diagram was 57%. As a result, the author designed the color of the runway and taxiway in dark grey. These three sets of questions were the only questions that required the author to identify the alternative options and adopt the more important user requirement in the design process. Questions 25 and 34 were excluded from the user requirement analysis because the alternative questions (i.e. question 26 and 33) had higher importance scores. The result of the questions, except question 25 and 34, was organized based on the percentage of importance and displayed in Table 1.

Table 1

*Percentage of Importance of Each User Requirement*

	Importance
Verbal ATC Instruction	90%
Daytime or Nighttime Setting	87%
Runway and Taxiway in Dark Grey	86%
Heading Indicator	84%
Different Weather Setting	82%
3D Display	78%
Distance Indicator	65%
Verbal and Textual ATC Instruction	54%
ATC Instruction Remains on Screen	50%
Textual ATC Instruction	42%

*Note.* ATC = Air Traffic Controller; 3D = Three-Dimensional.

**House of Quality**

In the HOQ matrix, the customer requirements column and the customer importance column were generated based on the results collected from the first survey. The functional requirements in the horizontal row were generated by the author from studying previous literature and the FAA regulations. The scale of the association level was determined by the author, where nine indicates a strong association, three indicates a medium association, one indicates a weak association, and zero indicates no association. Generally speaking, the association level of each functional requirement to each user requirement is highly debatable within the design team, as well as among the integrators of the entire system on a large scale. This is a critical part of the design process. If all the debates and conflicts can be overcome at this stage, it will save a great amount of time in the end when integrating the final product. In this case, the author was the sole designer for this mobile application; therefore, the level of association of each functional

requirement to each customer requirement was decided based on the author's observation and past experience interacting with pilots, as well as the analysis of current RI prevention systems and HFE principles, previous studies, as well as the FAA regulations.

The result of the HOQ matrix was presented in Figure 7 and 8. According to the HOQ, the most important functions in this new system were shown in Figure 9.

Column #	1	2	3	4	5	6	7
Relative weight							
Customer importance	Home page	Aircraft type setting	Weather condition setting	Time of day setting	Heading direction	Distance indicator	Go straight
7.8 First-person point of view (3D)	9	9	1	1	1	1	9
8.7 Time of the day setting	9	1	3	9	1	1	1
8.2 Weather setting	9	1	9	3	1	1	1
9 Verbal ATC instruction	1	0	0	0	3	3	9
4.2 Textual ATC instruction	0	0	0	0	3	3	3
5 ATC instruction on screen	0	0	0	0	3	3	3
5.4 Verbal and textual ATC instruction	0	0	0	0	3	3	3
8.6 Color (dark grey)	1	0	1	1	1	1	1
6.5 Distance indication	1	1	0	0	3	9	9
8.4 Heading indicator	1	1	0	0	9	3	9
Importance	254.80	102.00	116.30	119.30	199.20	187.80	354.60
% Importance	7%	3%	3%	3%	5%	5%	9%

Figure 7. House of quality part 1.

8	9	10	11	12	13	14	15	16	17	18	19	
Turn left	Turn right	Pause and hold short	Read back ATC instruction	Start to taxi	Go to settings	ATC instruction displayed on screen	Warning of wrong way	Restart the taxi	Taxi completion notice	Return to home page	ATC say again	
9	9	1	0	9	0	0	1	9	1	1	0	Association
1	1	0	0	1	9	0	0	1	0	0	0	Strong 9
1	1	0	0	1	9	0	0	1	0	0	0	Medium 3
9	9	9	9	9	0	9	3	1	3	0	9	Weak 1
3	3	3	3	1	0	9	9	1	1	0	3	None 0
3	3	3	3	1	0	9	9	1	1	0	3	
3	3	3	3	1	0	9	9	1	1	0	3	
1	1	1	0	1	0	0	1	1	0	0	0	
9	9	9	1	9	0	1	9	1	1	0	0	
9	9	9	1	9	0	1	9	1	1	0	0	
354.60	354.60	275.30	139.70	325.40	152.10	227.30	308.90	134.20	64.30	7.80	124.80	
9%	9%	7%	4%	9%	4%	6%	8%	4%	2%	0%	3%	Scale 1-100%

Figure 8. House of quality part 2.



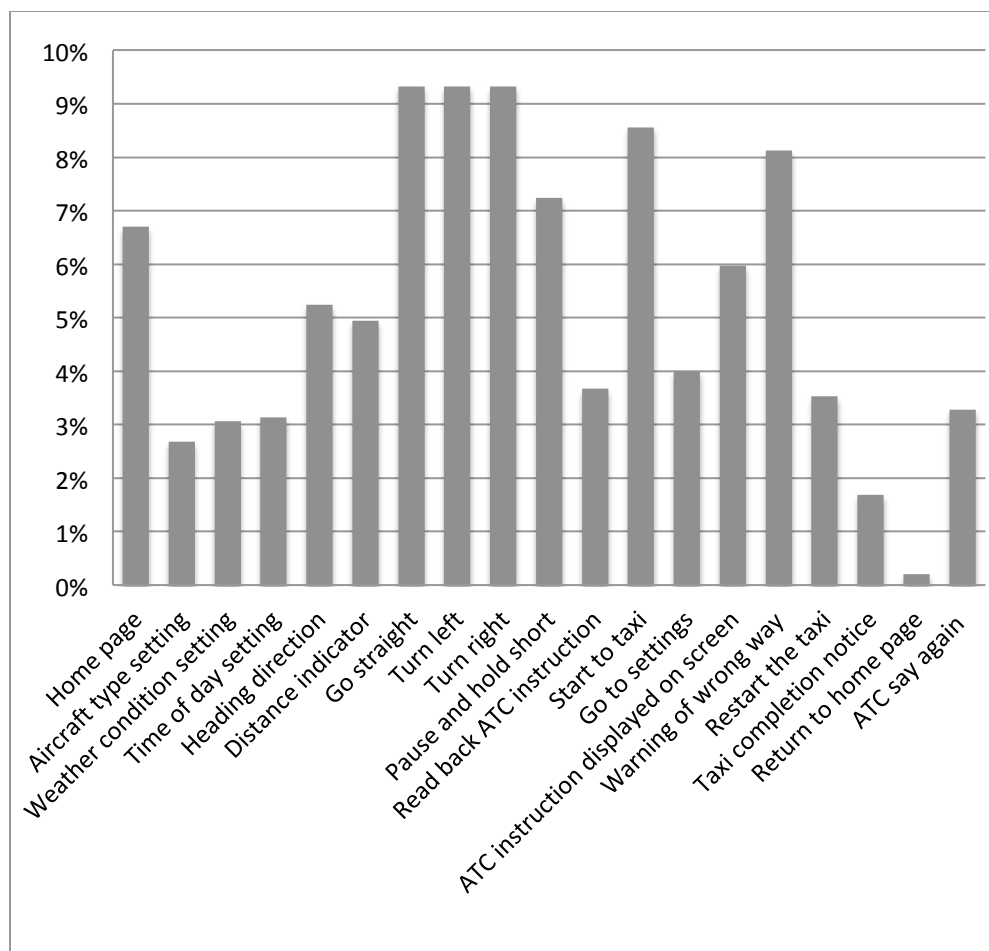


Figure 9. Ranking of importance.

## CORE

The results generated by CORE are presented in the following paragraphs. The results include a list of system requirements, five hierarchy diagrams of the requirements, and nine FFBDs of the functions.

**List of requirements.** The author used CORE 9 to compile all the system requirements, including the requirements collected from the potential users, the FAA rules and regulations, and the author's design ideas based on flight observation and past experience interacting with pilots, analysis of current RI prevention systems, and review

of HFE principles. The system requirements were written in CORE language and listed in Table 2.

Table 2

*List of Requirements*

Class	Number	Element	Description
Requirement	REQ.0	Requirements	
Requirement	REQ.1	Home page	The system shall start with a home page
Requirement	REQ.1.1	Start to taxi	The system shall start to taxi
Requirement	REQ.1.1.1	Display ATC instruction on screen	The system shall display ATC instructions on screen
Requirement	REQ.1.1.2	Distance indicator	The system shall display distance indicator
Requirement	REQ.1.1.3	Go straight	The system shall allow the aircraft to go straight
Requirement	REQ.1.1.4	Heading indicator	The system shall display heading indicator
Requirement	REQ.1.1.5	Hold short	The system shall allow the aircraft to pause and hold short
Requirement	REQ.1.1.5.1	Restart the taxi	The system shall allow the user to restart the taxi
Requirement	REQ.1.1.5.2	Return to home page	The system shall allow the user to return to home page
Requirement	REQ.1.1.5.3	Warning of wrong way	The system shall give warning of wrong way
Requirement	REQ.1.1.5.4	Say again	The system shall allow the user to perform "say again" which is to replay the ATC instruction verbally
Requirement	REQ.1.1.6	Read back	The system shall allow the user to read back ATC instruction
Requirement	REQ.1.1.7	Turn left	The system shall allow the aircraft to turn left
Requirement	REQ.1.1.8	Turn right	The system shall allow the aircraft to turn right

Requirement	REQ.1.1.9	Textual ATC instruction	The system shall display ATC instruction textually on the interface
Requirement	REQ.1.1.1.0	Verbal and textual ATC instruction	The system shall play ATC instruction verbally as well as display ATC instruction textually on the interface simultaneously
Requirement	REQ.1.1.1.1	Verbal ATC instruction	The system shall play ATC instructions verbally
Requirement	REQ.1.2	Go to settings	The system shall allow the user to go to settings
Requirement	REQ.1.2.1	Aircraft type	The user shall be able to choose between Diamond Twin-Star and Cessna 172.
Requirement	REQ.1.2.2	Time of day	The user shall be able to choose the time of day
Requirement	REQ.1.2.3	Weather condition	The user shall be able to choose the weather condition
Requirement	REQ.2	3D display	The system shall display the image with first-person point of view
Requirement	REQ.3	Color of runway	The color of the runway and taxiway shall be in dark grey.
Requirement	REQ.4	Taxiing completion notice	The system shall display taxiing completion notice

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*Note.* REQ = Requirement; ATC = Air Traffic Controller; 3D = Three-Dimensional.

**Hierarchy diagrams.** The results of the hierarchy diagram of the requirements elements can be found in Figure 10 to Figure 14. The hierarchy diagrams presented the hierarchical relationship among system requirements. The highest level of system requirement is refined by the next level. The next level of requirements are further refined by the next lower level. The hierarchy diagram also indicated the traceability of functions. For example, in Figure 10, the home page requirement is the basis of the home page function.

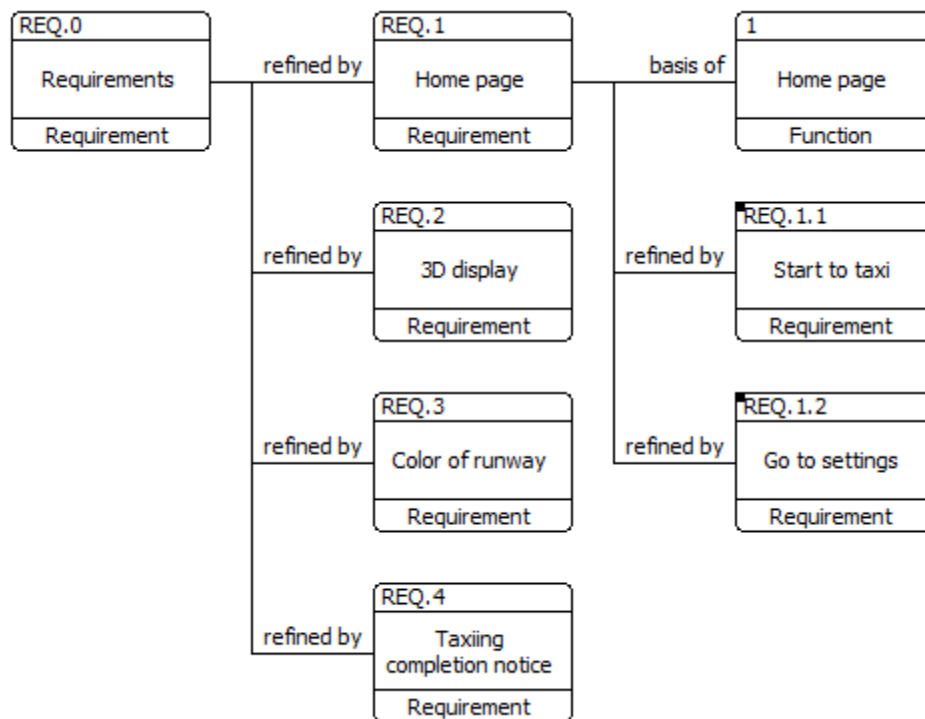


Figure 10. First level of system requirements.

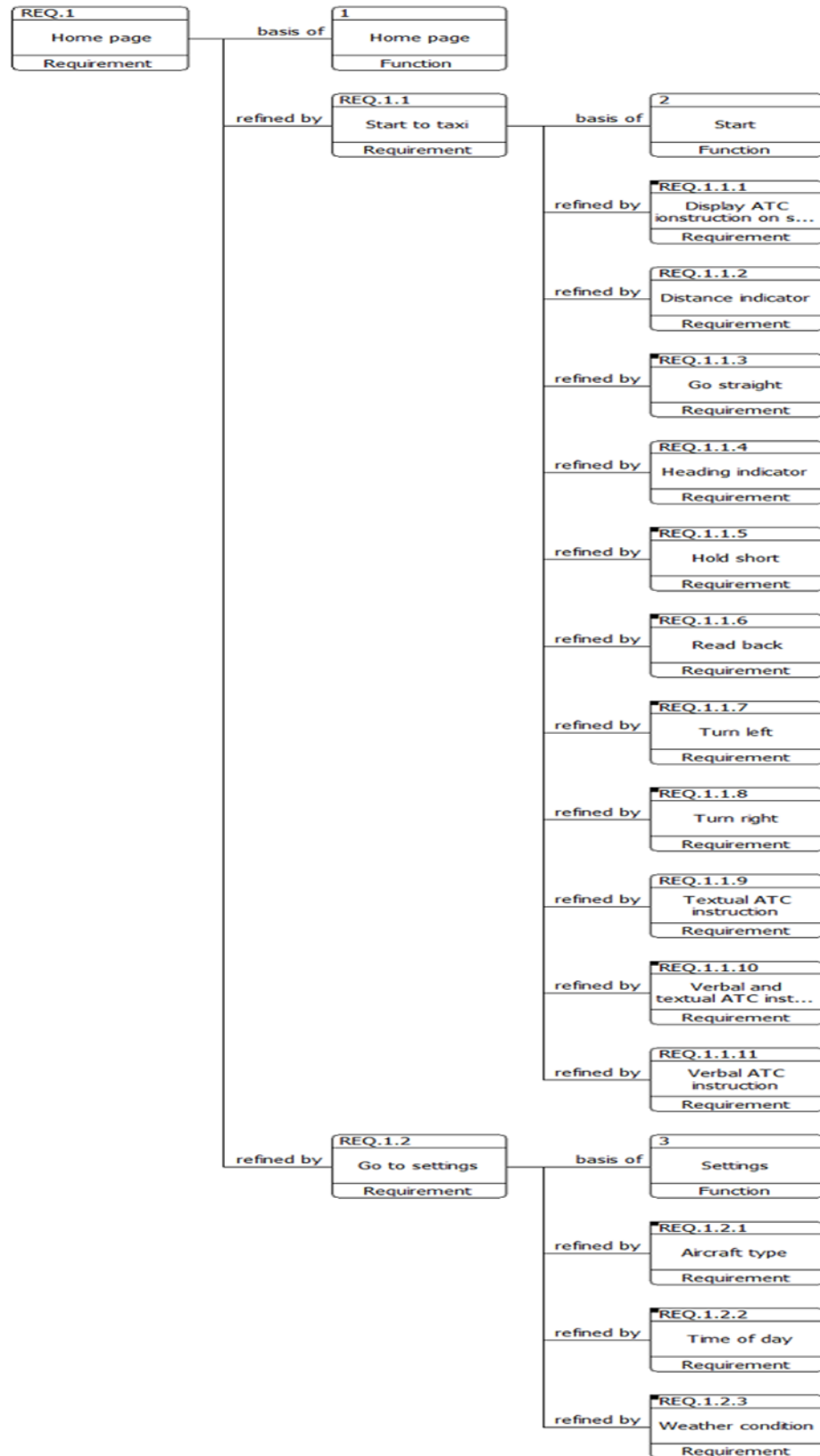


Figure 11. Second level of system requirements.

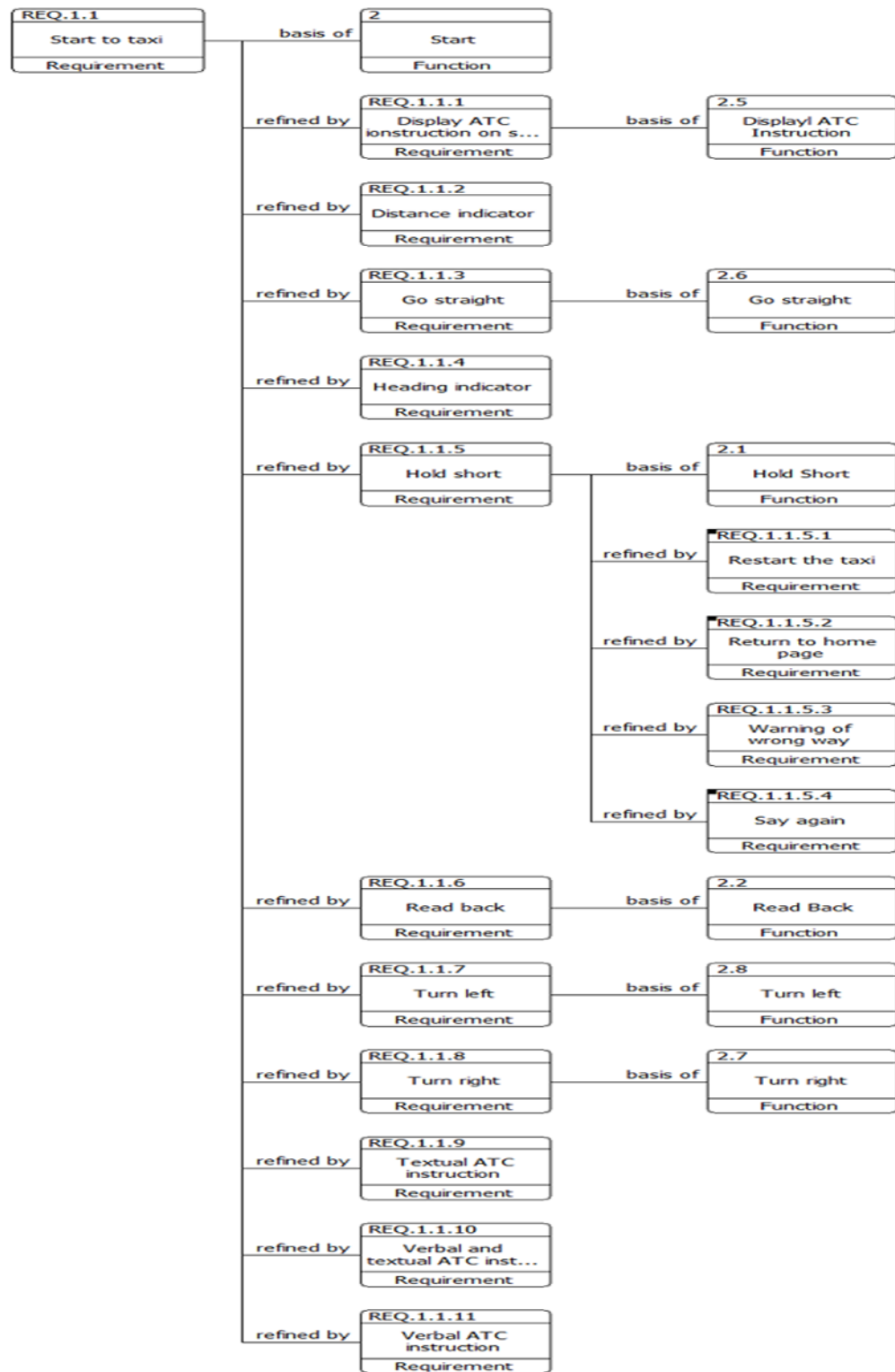


Figure 12. Third level (i.e. level 1.1) of system requirements.

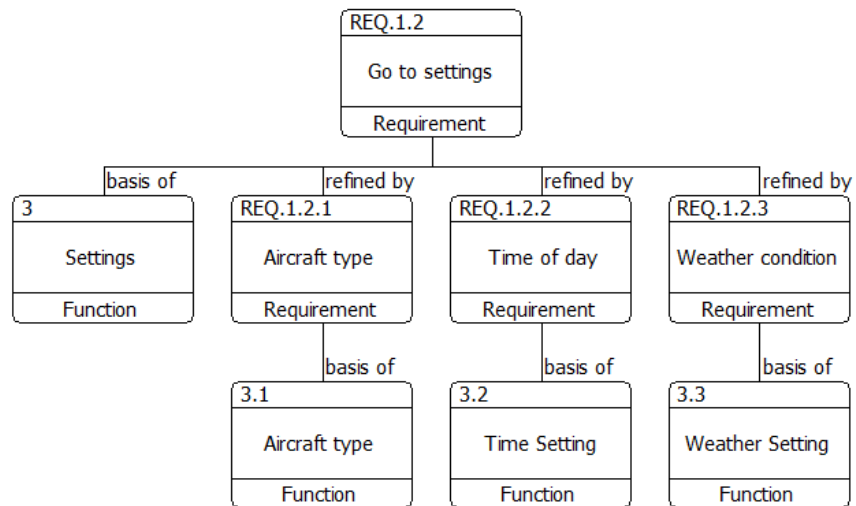


Figure 13. Third level (i.e. level 1.2) of system requirements.

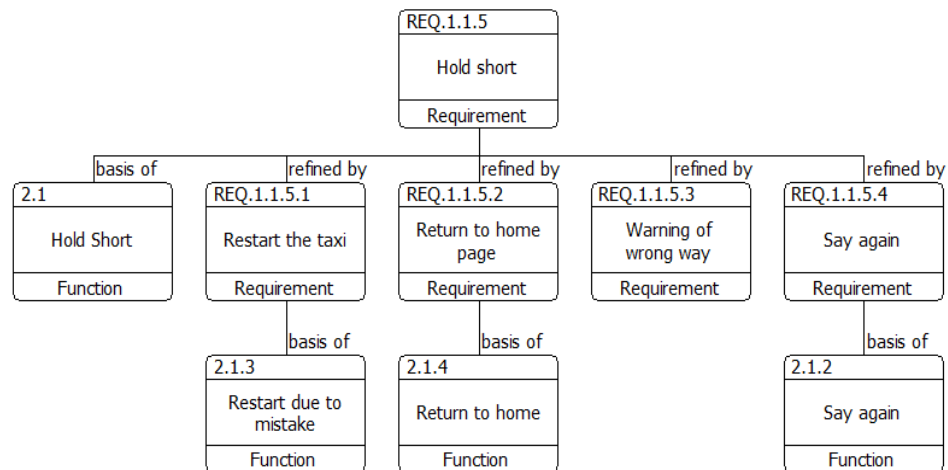


Figure 14. Fourth level of system requirements.

**Functional flow block diagrams (FFBD).** Last part of the result generated by CORE contained nine FFBDs of system function elements. The author translated the requirement elements to function elements and created the FFBDs using CORE 9. The FFBDs of system functions are shown in Figure 15 to Figure 23.

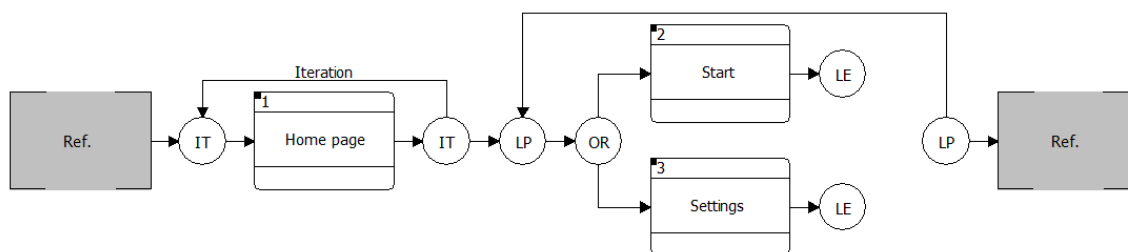


Figure 15. Function 1.0 Home page (FFBD).

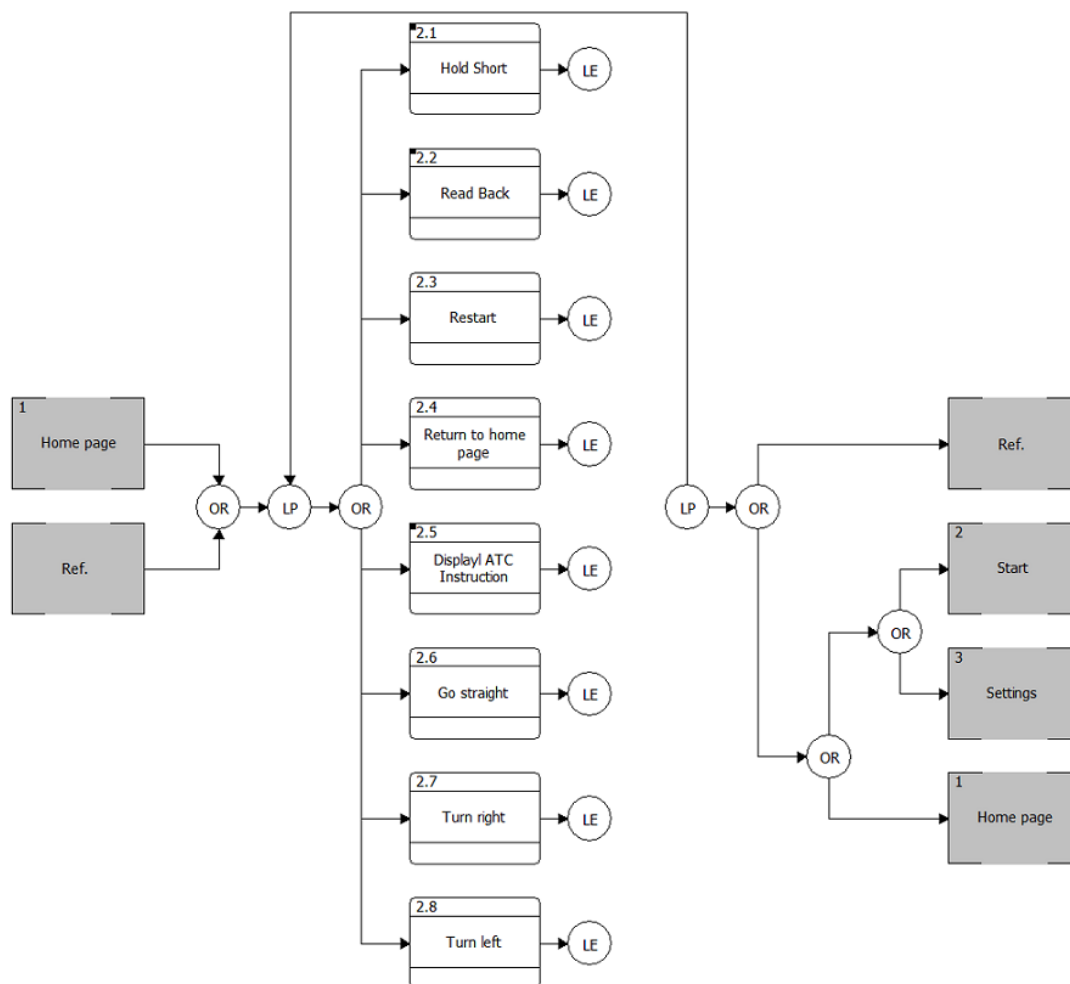


Figure 16. Function 2.0 Start taxiing (FFBD).



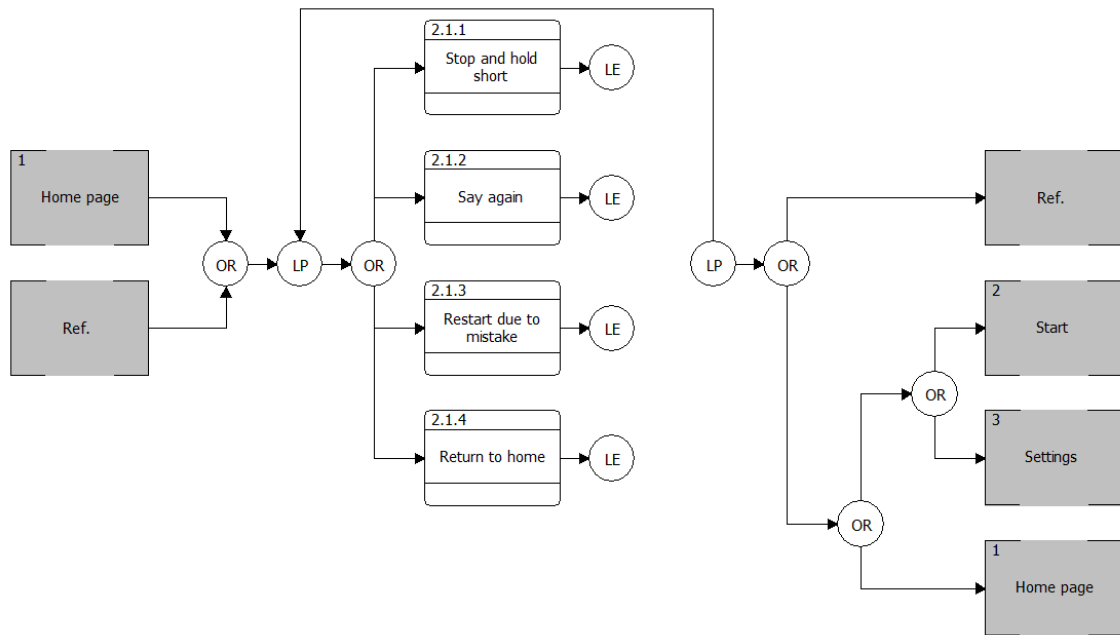


Figure 17. Function 2.1 Hold short (FFBD).

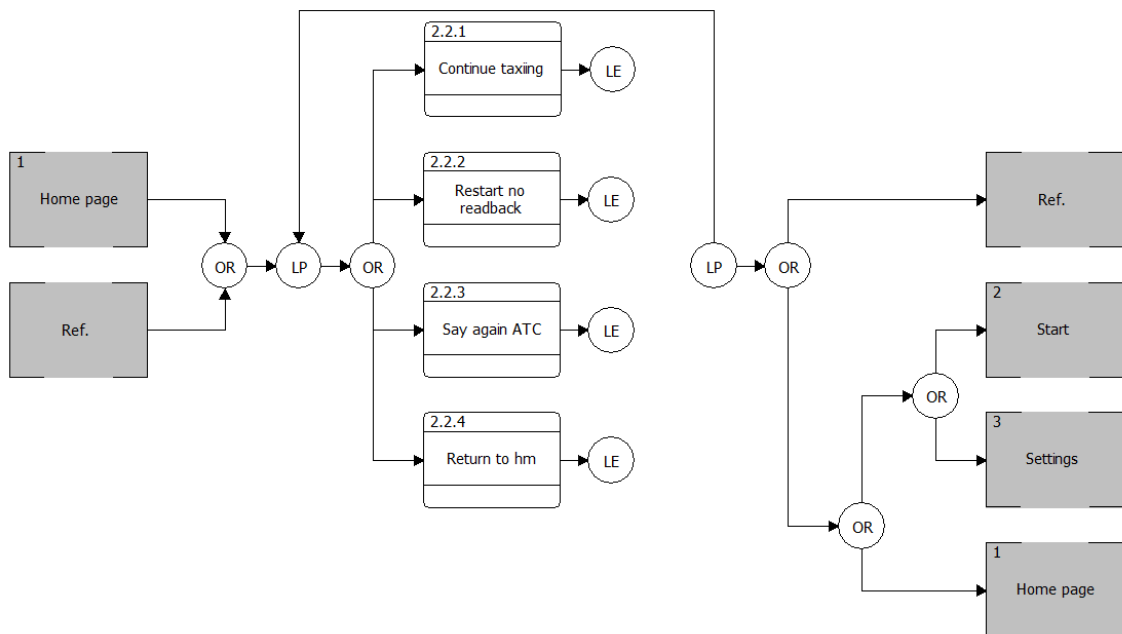


Figure 18. Function 2.2 Read back (FFBD).

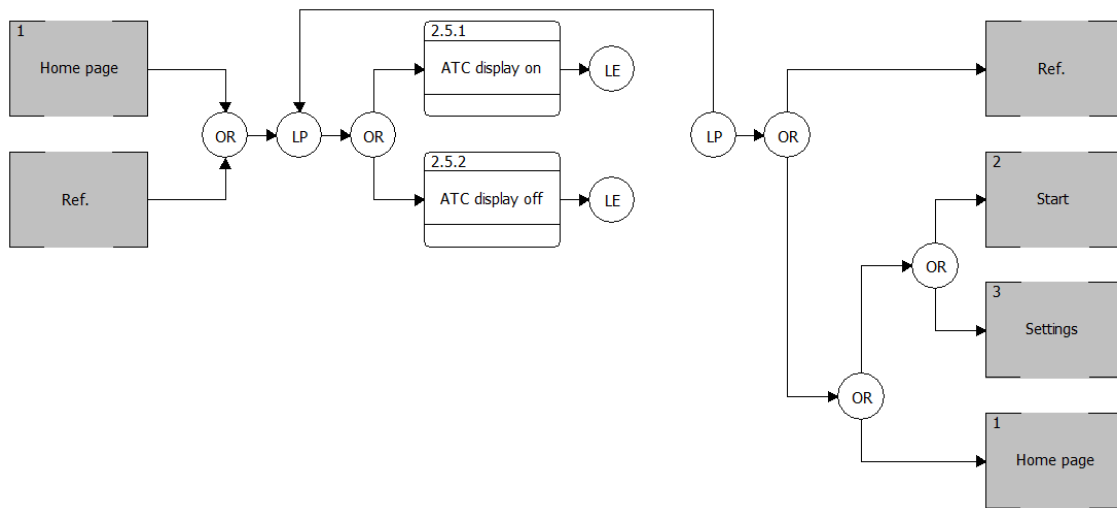


Figure 19. Function 2.5 Display ATC instruction (FFBD).

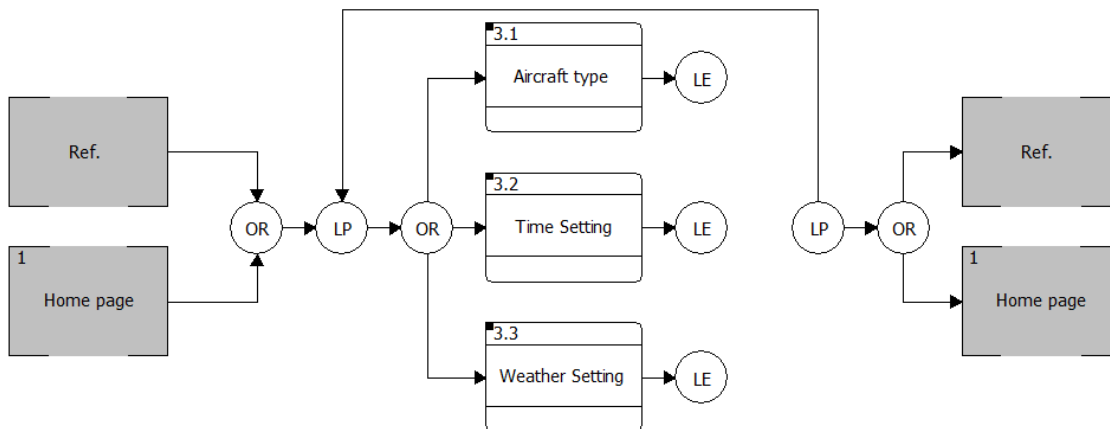


Figure 20. Function 3.0 Settings (FFBD).

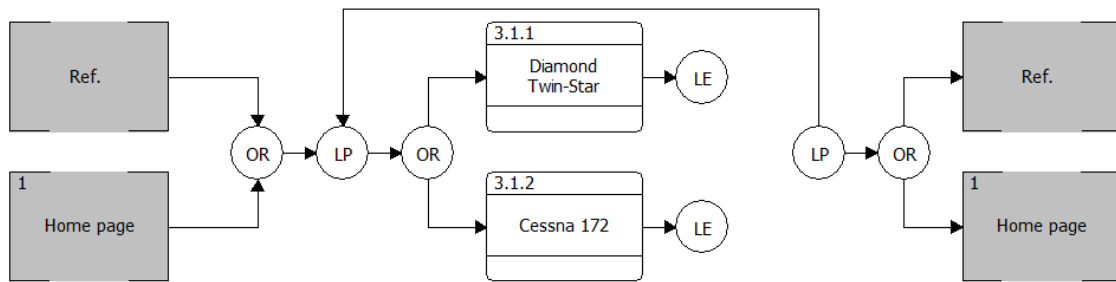


Figure 21. Function 3.1 Aircraft type (FFBD).

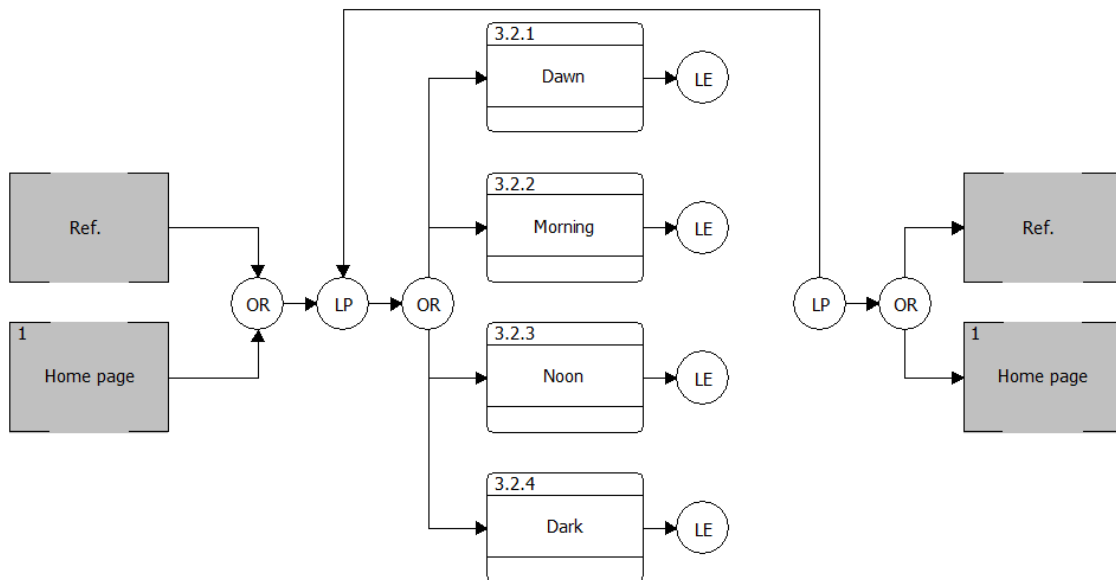


Figure 22. Function 3.2 Time setting (FFBD).

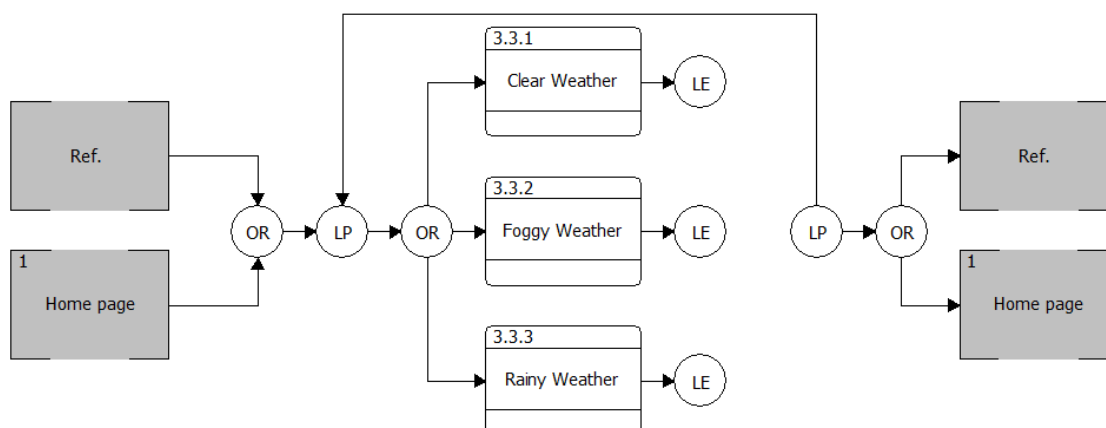


Figure 23. Function 3.3 Weather setting (FFBD).

### Heuristic Evaluation

There were 9 participants conducting the heuristic evaluation. Five of the participants are experienced pilots. Three of the participants are HF experts. One participant is both an experienced pilot and HF expert. In each question of the heuristic evaluation, the participants were asked to score the FAA diagram and the interface of the application. The application was demonstrated using Microsoft PowerPoint to the participants. The initial interface reviewed by the experts can be found in Appendix C under IRB approval of survey 2. There were 14 questions, which provided 14 pairs of comparisons. The author ran 15 pairwise t-tests including a comparison of the sum of the scores for the FAA diagram and the application to compare the overall results of the heuristic evaluation. The results of the t-tests indicated four significant differences in the heuristic evaluation comparison, as well as a significant difference in the overall score comparison.

The FAA airport diagram had a significantly lower score on its ability to match the real airport dynamic environment during taxiing than the application. A pairwise t-test was significant at the alpha level of .05,  $t(8) = -5.77, p < .05$ . The FAA airport diagram had a significantly lower score on its ability to provide good error messages and prevent a problem from occurring in the first place than the application. A pairwise t-test was significant at the alpha level of .05,  $t(8) = -3.88, p < .05$ . The FAA airport diagram had a significantly lower score on the aesthetics of layout that respects the principles of contrast, repetition, alignment, and proximity compared to the application. A pairwise t-test was significant at the alpha level of .05,  $t(8) = -2.8, p < .05$ . The FAA airport diagram had a significantly lower score on its ability to help pilots recognize, diagnose, and recover from error compared to the application. A pairwise t-test was significant at the alpha level of .05,  $t(8) = -4.66, p < .05$ . Overall, the FAA airport diagram had a significantly lower score than the application based on the heuristic evaluation principles. A pairwise t-test was significant at the alpha level of .05,  $t(8) = -3.54, p < .05$ . Table 3 summarized the mean, standard deviation, and significance of all the significant companions.

Table 3

*Significant Results of Heuristic Evaluation*

Pair	Question	Mean	Std. Deviation	Sig. (2-tailed)
Pair 2	FAA Q3	3.67	3	
	APP Q3	9.56	.73	.000
Pair 6	FAA Q7	3.22	3.96	
	APP Q7	8.33	1.8	.005
Pair 12	FAA Q13	6.11	2.8	
	APP Q13	9	1	.023
Pair 13	FAA Q14	3.33	3.35	
	APP Q14	8.11	2.37	.002
Pair 15	FAA	79.11	34.28	
	Overall			
	APP	115.67	13.67	.008
	Overall			

*Note.* FAA = Federal Aviation Administration; APP = Application; Q = Question.

The experts also provided the potential problems that they noticed. The problems are listed in Table 4 and 5. Moreover, the experts provided their opinions on the better design features of the application. These better features include that users can immediately be informed when they make a mistake. The interface reflects the real-world environment. The experts pointed out that the simplicity of deciphering signs and markings, as well as the minimal use of codes make the application easily understood. The options of changing the time of day, choosing different weather conditions, and the use of attention-capturing graphics are a good feature that the application has. Overall, the experts took satisfaction in providing just enough information and directions to avoid clutter, thereby creating a user-friendly and informative environment on demand.

Table 4

*Potential Problems of the FAA Airport Diagram*

List of Problems
Difficult to know the orientation (i.e. North)
Color of runway and taxiway does not reflect actual airport environment
Lack of pilot phrases other than taxiway and runway numbers
Symbols used are deviated from real life
Too much information listed and required to be memorized
Lack of dynamic
Plain display (i.e. 2D, black and white)
No feedback of error
Information is all coded in aviation terms
Not possible to understand without prior knowledge
<i>Note.</i> 2D = Two-Dimensional.

Table 5

*Potential Problems of the Application*

List of Problems
Overly rely on the application especially inexperienced pilots
Lack of alignment with the FAA airport diagram
Inaccurate taxi instructions
Forced to restart the entire taxiing process after making mistakes
Users become complacent with shortcuts used in the application
No views of the entire airport
<i>Note.</i> FAA = Federal Aviation Administration.

**Interface**

The interface was finalized after the heuristic evaluation. The author incorporated many useful suggestions from the comments of each question in the questionnaire into the interface design. The following figures show the home page, setting menu, departure point of taxiing in DAB which is the ERAU ramp, different ATC instruction display,

different weather setting, and time of day setting. Also, the interface when user makes a mistake during taxiing and when user completes the taxiing were also presented.

Figure 24 is the home page the user will see after opening the application. The user can choose to start taxiing with previous settings by clicking start. If this is the first time of use, the application will start the taxiing process with default setting. In the default setting, user will operate a Diamond Twin Star under day time and clear weather condition. Alternatively, user can go to settings to choose the aircraft type, weather condition, and time of day.



*Figure 24.* Home page.

Figure 25 is the setting menu that user will be navigated to after clicking settings in the home page. The options of aircraft types are Diamond Twin Star and Cessna 172.



There are four time of day settings, which are dawn, morning, noon, and dusk. There are three weather settings, which are clear, fog, and rain. Upon completion of choosing the preferred settings, users can navigate back to the home page by clicking the house icon on the right bottom corner.

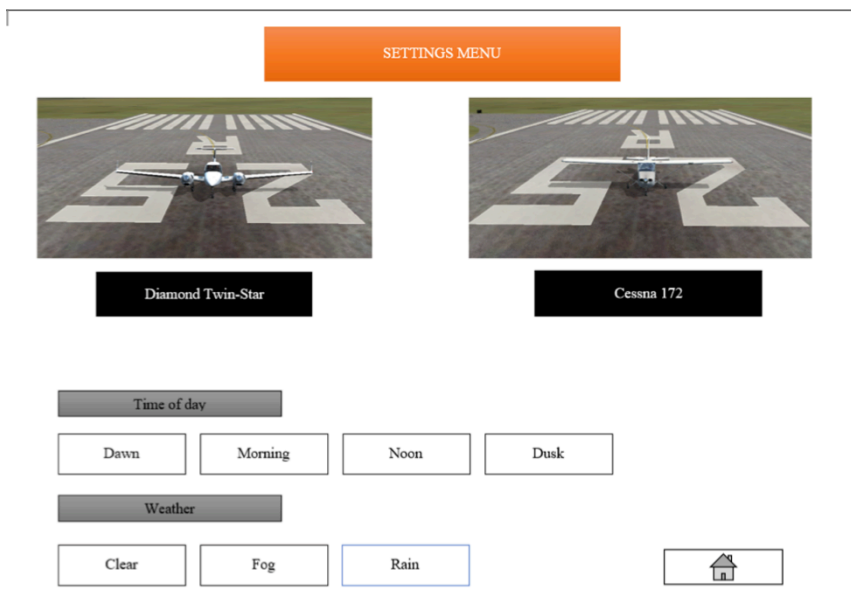
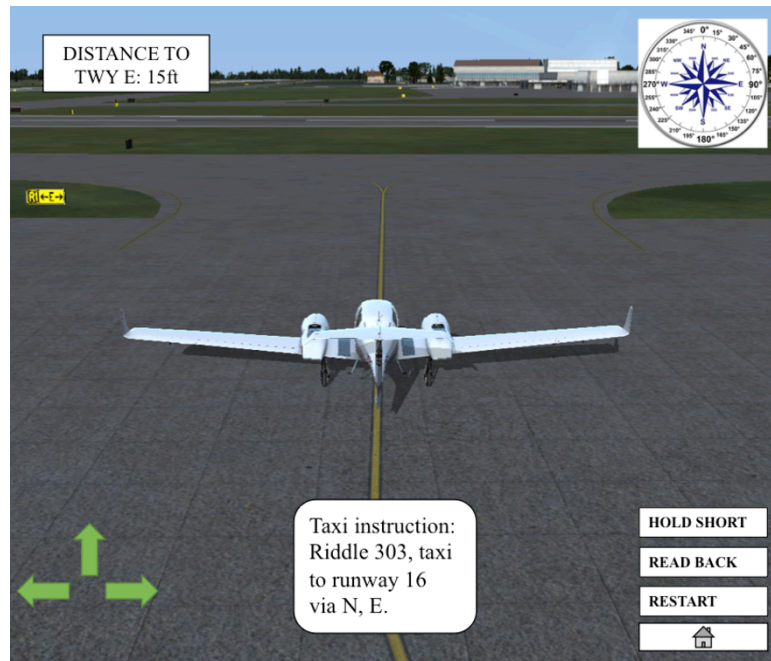


Figure 25. Setting page.

This interface was designed based on DAB airport environment. Therefore, once the taxiing process begins, the screen will display the aircraft chosen stopping at the ERAU ramp, as shown in Figure 26. This is the starting point of the taxiing process. As shown on the screen, there is a distance indicator that presents the distance to the next critical point, such as taxiway intersection, hold short position, runway crossing point, and so on. On the top right corner, there is a heading indicator. This mobile application is a supplemental material for pilots to practice in the airport they choose; therefore, it is essential to use the FAA airport diagram as the primary navigation tool. While operating

the aircraft, the user is expected to use the FAA airport diagram simultaneously to identify the aircraft location. In this case, the heading indicator will be helpful. The screen does not have the function to zoom in and out. However, the view of the aircraft can be turned 360 degrees. This setting replicates the actual taxiing condition in an aircraft. In other words, user will need to read the runway or taxiway numbers and signs, view around the aircraft, and refer to the FAA airport diagram to identify the location correctly.

User can press the green arrows on the bottom left to move the aircraft forward, left, or right. There is no backward arrow because no aircraft have a reverse function in real life. On the bottom right, there are four options including hold short, read back, restart, and home page. Stop at hold short line and wait for ATC instruction to proceed is one of the most important things to practice during taxiing. The application will generate ATC hold short instructions. When the aircraft is approaching the hold short line, the user should stop, press the hold short button, and wait for next ATC instruction to proceed. The read back button should be pressed every time when the application issues a new ATC instruction. The restart button is for user to return to the ramp and restart the taxiing process. The home button is for user to return to the home page.



*Figure 26.* ERAU ramp as the starting point.

In the default setting, ATC instructions will be played verbally. User can double tap the screen to display textual ATC instructions. Next, the instructions will stay on the screen until user double taps the screen again to disable the display. Figure 27 shows the screen when ATC instructions are displayed textually.

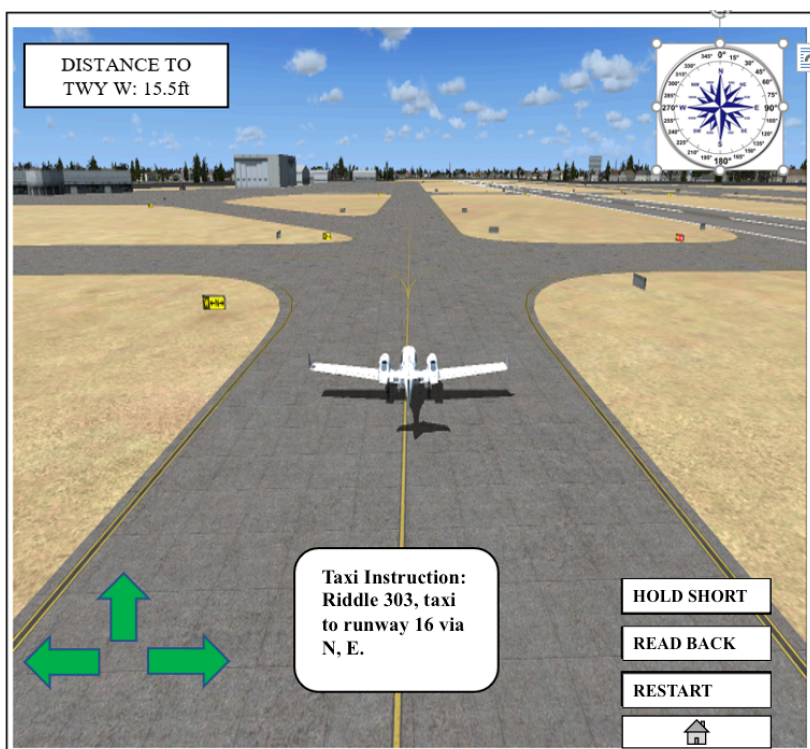


Figure 27. Taxiing screen with ATC instruction displayed.

Figure 28 shows when the ATC instructions are not displayed on screen. Figure 28 also shows that the aircraft is approaching the hold short line. The correct procedures should be to stop the aircraft, press the hold short button, wait for next ATC instruction to proceed, and then move forward to cross the runway.

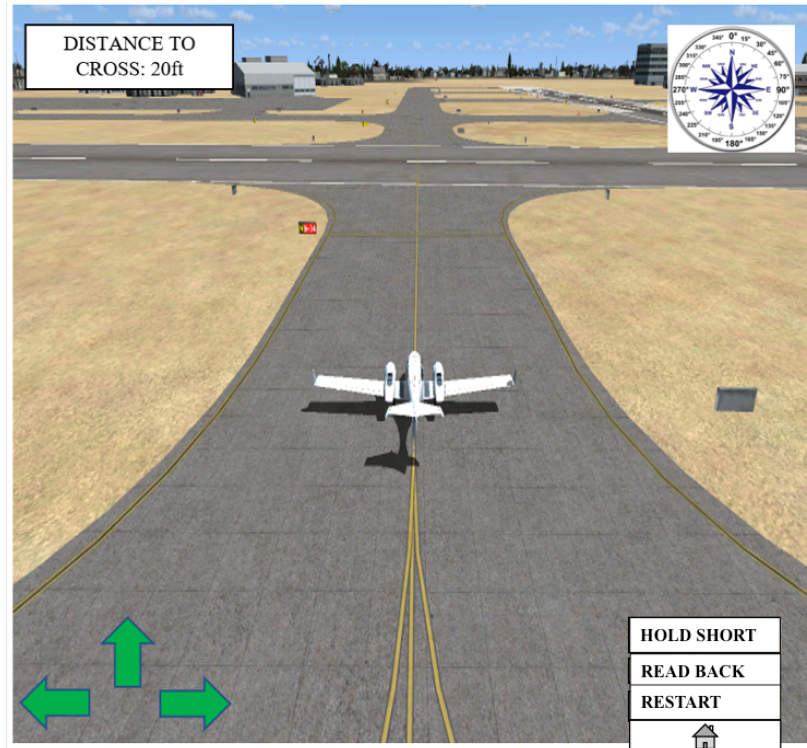


Figure 28. Without ATC instruction displayed and before hold short line.

When the aircraft is operated incorrectly, a red X will display on the screen to indicate the mistake type, as shown in Figure 29. Some common mistakes are crossing the hold short line without stopping, entering the wrong taxiway or runway, or entering the runway without ATC clearance. When the warning is given after the mistake, user will be forced to restart from the ramp or quit the taxiing process and go back to the home page. User can also click the say again button to repeat the ATC instruction. This function allows user to review the mistake and correct it next time.

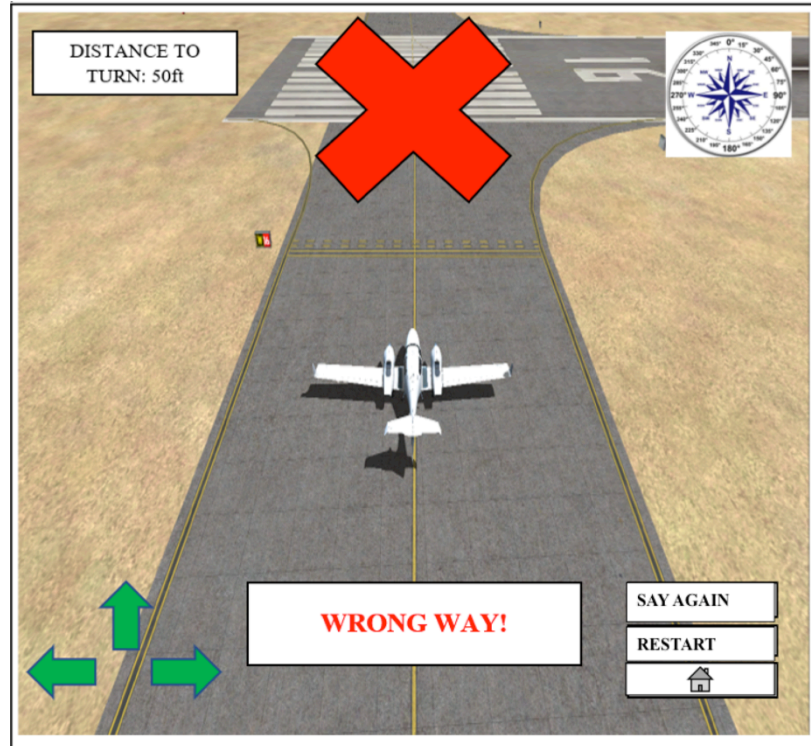


Figure 29. Mistake.

The author also included three screenshots of different time and weather settings. Figure 30 shows the raining weather condition during day time. Figure 31 shows clear weather during night time with airport lightings and signs illuminated. Figure 32 shows a foggy weather condition during day time.



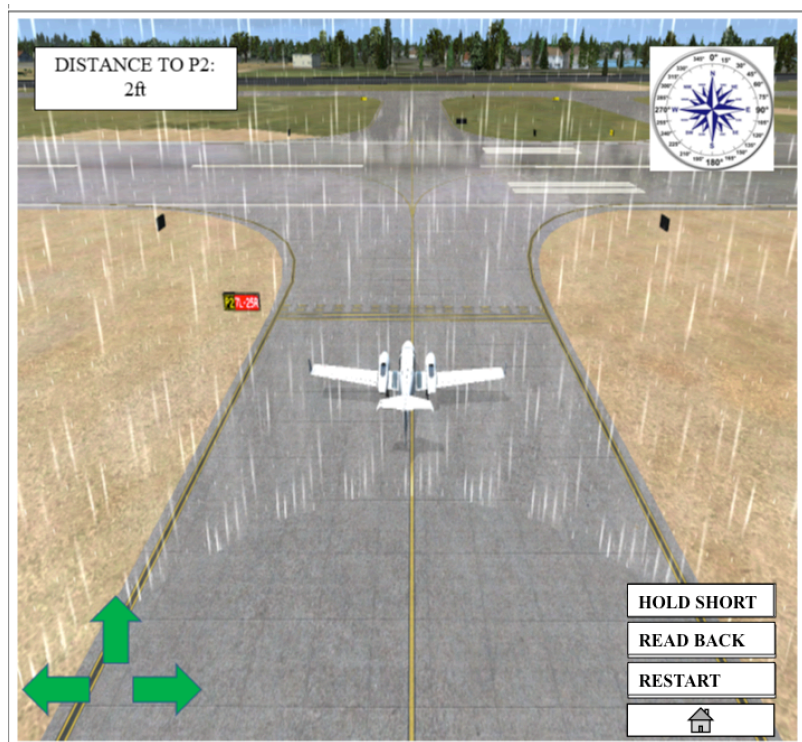


Figure 30. Rain setting.

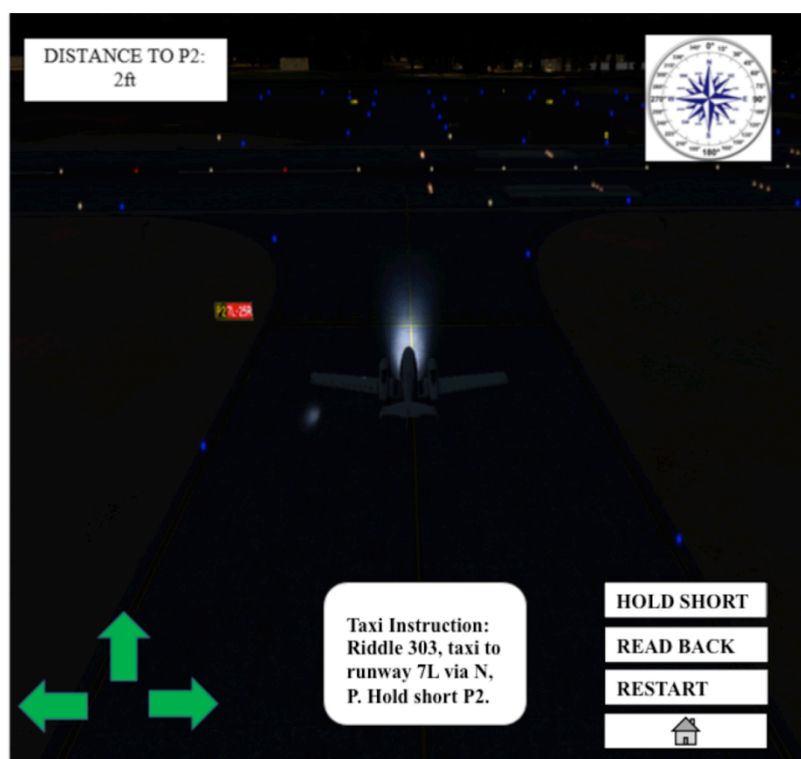
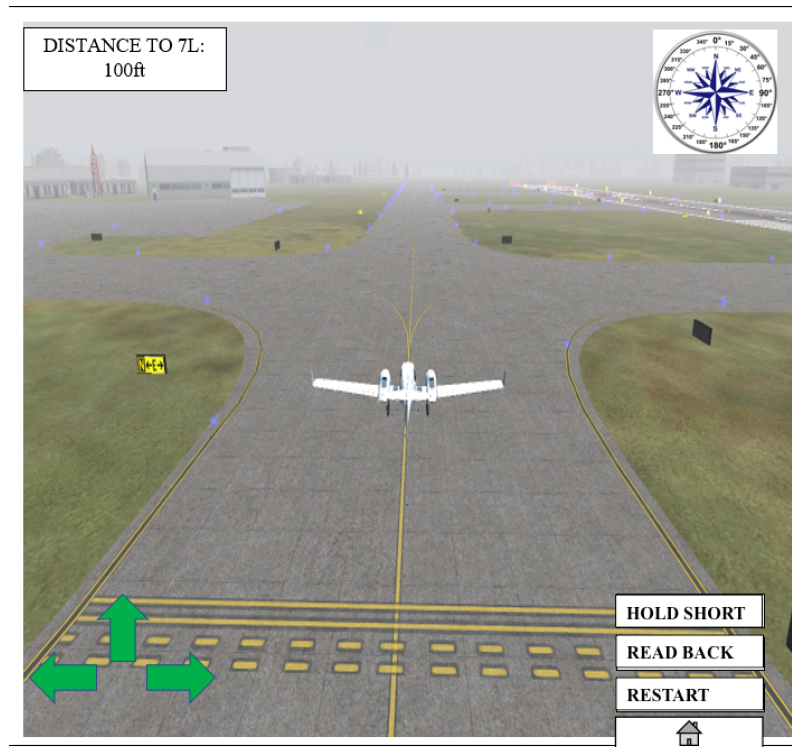


Figure 31. Night setting.



*Figure 32.* Fog setting.

Once the user operates the aircraft to the correct runway without mistakes, a taxi completion page will be displayed, as shown in Figure 33. At this point, the taxiing process is ended. User can click the restart button to go back to the ramp or quit the taxiing process by returning to the home page.



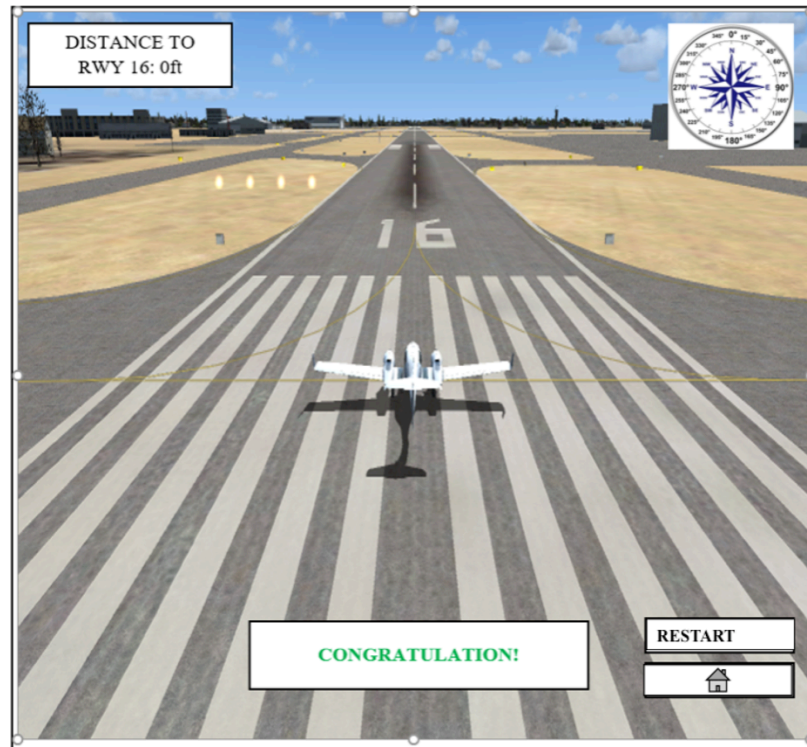


Figure 33. Taxi completion page.

In summary, this chapter provides the results of the user requirements collection survey, a HOQ matrix, a list of comprehensive system requirements, hierarchy diagrams of the requirements, traceability of functions, and FFBDs. Also, this chapter includes the result of the heuristic evaluation. The end product of the entire design process is the interface developed by the author.

## **Chapter V**

### **Discussion, Conclusion, and Recommendations**

#### **Discussion**

The end product of the entire design process is the interface designed by the author. The heuristic evaluation result has shown that the functions of this application, as well as the interface design, were integrative and holistic. Also, the experts participating in the heuristic evaluation generally agreed that the application would be a good practice tool to enhance airport familiarity. The heuristic evaluation was performed strictly following the 10 heuristics criteria of user interface design developed by Nielsen (1995). The experts rated the application designed by the author, and the FAA airport diagrams based on their visibility of system status, abilities to match between system and the real world, user control and freedom, consistency and standards, error prevention, abilities to provide recognition rather than recall, flexibility and efficiency of use, aesthetic and minimalist design, abilities to help users recognize, diagnose, and recover from errors, and abilities to help and documentation. The result indicated that the application has better ability to match between system and the real world. The application provides error prevention. It has enhanced aesthetic and minimalist design. The application also has increased ability to help users recognize, diagnose, and recover from errors. The application overall has preferable reviews than the FAA airport diagrams. Therefore, using the FAA airport diagram along with the application for flight preparation should provide stronger learning experience and increased airport familiarity.

The comments provided by the experts participated in the heuristic evaluation helped the author to improve some deficiencies in the initial interface design. Therefore,

the interface included in the Result section is different from the interface included in Appendix C. The interface as shown in Appendix C was the initial design. It was reviewed by the experts during the heuristic evaluation. The author addressed the suggestions and improved the interface design. The results of the heuristic evaluation have contributed to the final interface design. Also, the experts came up with many beneficial design ideas. The author will accommodate the ideas in the next stage of design. The design ideas in the next stage were further explained in the Recommendations.

The application of HFE during the design process has significantly enhanced the outcome of this project. The interface was able to carry out satisfying human machine interaction. Based on the heuristic evaluation result, not only was this application designed comprehensively to provide simple yet necessary functions for pilots to practice taxiing, but also this application provides a user-friendly operational experience. The HF experts who conducted the heuristic evaluation provided positive comments regarding the interface design, the functional design, and the ease of operation of this application. This desirable outcome was a consequence of adopting HFE in the design process.

Some of the comments and suggestions collected from both surveys were not accommodated in the design process due to the project scope. However, the design idea of this application was clearly stated, critically analyzed, and successfully proven to be practical. The necessity of developing the final product has also been proven. Software engineers can follow this design process to program the application. The result has shown the traceability, the operational method, and the flow direction of each function, thusly, software engineers can program the application with minimal confusion. It is

believed that software engineers will find the FFBDs generated in CORE to be very helpful when programming each function of the application.

The role of systems engineering design in this project is to guide the design process of the application. The Methodology section was structured based the four steps of systems engineering design. The first benefit of following these four steps were to enable the author to identify user needs and develop a list of system requirements following a general-to-specific process. The system requirements were collected from three sources, which were from the users, the designer (i.e. the author of the project), and the FAA regulations. These requirements were very vague and unclear in the beginning. The author followed the feasibility analysis and requirements analysis approach to translate general needs into formal requirement statements. This list of system requirements is the foundation of system design. The author next analyzed the technical feasibility, economic feasibility, operational feasibility and legal feasibility of translating each requirement into a function. The most significant benefit of this step is to specify the rationale of the system. Therefore, the author can obtain a clear understanding of the requirements that should be met and the requirements that exceed the design rationale.

In the next stage of systems engineering design, which is preliminary design, the author translated the system requirements into functions of the application. This process could be confusing and overwhelming without the guide of systems engineering design process. The second benefit of adopting systems engineering design was to show the traceability of each function. In other words, the functions are backed up by the requirements. The functions were designed in a systematic way, with clear evidence to

support why each function is necessary and how each function can fulfill the requirements.

Lastly, the author followed the steps in the third stage of systems engineering design, which is the stage. The author followed the steps to integrate all the system components. In this step, the most significant benefit of using systems engineering design approach was to allow the author discover an optimal way to develop the interface and evaluate the design. The heuristic evaluation result confirmed the feasibility of developing this application and the necessity of programing this application. The author was also benefited greatly from the comments collected from the experts who participated in the heuristic evaluation.

Additionally, a design process guided by systems engineering approach usually can reduce many design problems in the later stage because the designer has incorporated HF, human machine interaction, and system environment into the design process of this complex application, and also because systems engineering approach guided the author to accomplish a requirement driven design process, following the general to specific design principle. The goal of this project was to design an interactive learning tool for pilots to enhance airport familiarity. Systems engineering approach was the best fit to guide the design of this application because system design activities are interactive by nature. It is emphasized that there should not be defined boundaries between design activities because the systems engineering approach requires the designer to view the activities as an interactive entirety.

The result of this project provides a well-structured design process and repetitively polished design ideas, which are reflected on the final version of the

interface. This interface has been explained thoroughly and is ready to be turned into an application by software engineers.

## **Conclusion**

The author believes that the purpose of this project was met successfully. It was intended to develop a user-friendly, affordable, interactive, and dynamic application for users to practice taxiing using their portable devices anywhere and at any time. The author designed the application to strictly follow the purpose of this project.

Some limitations of this project include the limited number of participants in both surveys. In the first user requirement survey, the author was only able to collect 32 responses. In the future, the author hopes to have more time and funding to recruit more participants and conduct more in-depth personal interviews to collect user requirements. Because of the limited number of participants in the first survey, the requirement analysis of the application unavoidably has some nature limitations. Also, due to the constraint of the project scope, some design ideas from the author as well as suggested by the participants from both surveys were not included in the application. The interface was constructed base on the airport infrastructure of DAB. Only one airport was included in the demonstrating interface. Because this project is the design process of the application, therefore, the last step of systems engineering design, which is system installation and deployment, was eliminated from the project.

The author learned from this project that recruiting experts to participate in the heuristic evaluation could be extremely difficult. The author spent over four months to finally collect all the responses. Although the author did not set the high requirements of experts who can participate the heuristic evaluation, but many experts that the author

reached out felt unfamiliar with the heuristic evaluation process and declined to participate in the survey. Also, because heuristic evaluation requires participants to think and provide in-depth analysis, the time and effort associated with the survey had turned down many potential participants.

Also, the author learned that the programming of this application could be very time-consuming. Because it requires the software engineers to transform all the 2D FAA airport diagram into 3D views. Additionally, the potential legal issues of using the FAA airport diagram must be considered if the software designer decides to commercialize the product. Otherwise, the software designer can purchase commercial airport diagrams to implement in the design. Although the costs relate to the purchase could be very pricey.

### **Recommendations**

The prototype that will be built based on current design process should be tested on potential users. The purpose of testing the prototype is identify any usability deficiencies in the early stage before software deployment. Systems engineering design process emphasizes the importance of usability testing and continual improvement of the system. The backward direction of the design process should be expected. In other words, software designer should anticipate that there will be necessary changes of the prototype including functions and interface changes after usability testing.

The more important recommendation to this project is to further expand the functions of this mobile application. In the next stage of the design process, more airports, especially the ones that are commonly used by ERAU, should be added. Also, an Internet connection should be applied not only limited to software updates, but also during normal operation. Many responses from the first survey suggested displaying

other aircraft or airside vehicles on the screen. Although installing a live traffic transmission is not possible at this stage, it is possible to display all the users on the screen with Internet connection. Therefore, aircraft operated by the users will form a realistic traffic environment on an airport surface. Users will have the ability to interact with each other.

In this case, the author suggests expanding the application to include an ATC instruction practice feature. In the home page, users will have options to enter the taxiing process as a pilot or as an ATC. The new feature of entering the taxiing process as an ATC will benefit the users who want to practice issuing ATC instructions. Eventually, there will be two groups of users in the application interacting with each other online. All the ATC instructions that the pilot user group receives will be issued by the ATC user group. Therefore, this application can be adopted more widely and benefit more people. In this case, because the application is becoming more complicated to operate, a tutorial of using the application and technical support page should be included to provide a better experience. Some other recommendations from the author include adding a taxi speed indicator with speeding warning, adding a function to display the FAA diagram in a different page, and showing the entire airport environment in a small screen in the corner with the location of the aircraft.

The author believes that if the current design process is successfully adopted by a software engineer, a user-friendly, affordable and portable practice tool will be created. This practice tool could significantly benefit the GA society. It will become a helpful supplemental material for flight preparation. With this innovative and dynamic way of



studying the airport diagram before conducting a flight, RI caused by airport unfamiliarity especially by GA pilots will be reduced successfully in the near future.

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## **Appendix A**

### **Permission to Conduct Research by CORE**

## Permission to Conduct Research by CORE

Operations @

Welcome to CORE - Embry-Riddle

To: CHENGY5@my.erau.edu, Cc: liu89b@erau.edu, Support

Inbox - Exchange February 9, 2018 at 9:42 AM

Details

0

Yixuan

Thank you for your interest in CORE™ software for the University Program. This message is to confirm your acceptance into the program and assist you in getting started with CORE. We highly recommend that you print this email and keep a copy for future reference.

### Product Information

Key information regarding the license is shown in the table below. The **Serial Number** is the permanent unique identifier for a license. You will need the serial number in order to generate your license request (for Vitech to activate your software.) You'll also need the number when you contact customer support with questions, or if you request license changes.

Serial Number	Software Version	License Type	Maintenance Expiration Date
	CORE Spectrum	University Program	31 August 2018

### Getting Started

**Installation:** We have attached a copy of our installation guide to this email. Please review the guide, and when you are ready to download CORE 9, visit our [Software](#) page to download your product's installer.

**Screencasts:** The support team has created an extensive screencast video library to help you get started – from installation to navigating the software. Visit our [Screencast Library](#) to access the videos.

### Learning More

Vitech is continually expanding its resources libraries to improve user experiences. There are resources for new and practiced users alike on the [Vitech Resource Library](#). In addition, we encourage you to check out our [LinkedIn](#) page where you can connect with other Vitech users and the Vitech team.

### Need Help?

We're here for you! You can reach our support team at 540.951.3999 or email [support@vitechcorp.com](mailto:support@vitechcorp.com). We're available for you from 9 a.m. to 6 p.m. eastern time Monday through Friday.

Regards,

Jonathan R. Charlton

Operations Manager

540.951.3322 x109

[www.vitechcorp.com](http://www.vitechcorp.com) | Blog [community.vitechcorp.com](http://community.vitechcorp.com) | Twitter [@VitechCorp](https://twitter.com/VitechCorp)

Vitech Corporation *Celebrating 25 years of systems engineering excellence*



2270 Kraft Drive, Suite 1600  
Blacksburg, Virginia 24060  
(540) 951-3322 • (540) 951-8222 Fax

### CORE™ / GENESYS™ for Research – Overview and Instructions

Vitech is committed to the advancement of systems engineering – the state of the art and the state of the practice. As part of that commitment, Vitech grants licenses of its CORE and GENESYS systems engineering environments to support industry initiatives and research that further systems engineering.

The Research Program is designed for use by graduate and postgraduate researchers wishing to employ the full versions of Vitech software in support of their doctoral or postdoctoral work. If an applicant is approved, Vitech will provide a single license of the latest commercial version of either CORE or GENESYS (depending upon which is best suited for the researcher and the research) at no charge for use during the project. Advisors may also request a license to oversee the efforts. This program is ideal for researchers who:

1. Have previously used the Vitech solution during their systems engineering coursework, for prior research, or in a commercial environment; and
2. Are working on a project that exceeds the limits (size, schema, reports) of the university edition.

#### Applying for the Research Program

Researchers may apply for the Research Program by completing this application form which includes provision of contact information and a description of the project. Understanding the mental model behind software is important in successfully applying the software in research, so it is key to have prior experience with the Vitech solution or identify an advisor with such experience. If the researcher does not have such a resource, Vitech will attempt to identify an appropriate individual from Vitech or the greater community to support approved research initiatives.

The Research Program constitutes a corporate grant, and as such Vitech is selective in the research it supports. Requests are evaluated based upon the quality of the information provided on the application form.

The completed form should be submitted via email to [universityprogram@vitechcorp.com](mailto:universityprogram@vitechcorp.com). Once Vitech receives the project information sheet, we will follow up via email or phone to discuss the details of the project to ensure that it is suitable. If approved for the program, the researcher(s) and advisor will be required to submit a term license agreement.

#### Upon Project Acceptance

If the project request is approved, Vitech will send license information to the designated individuals for the latest commercial version of the appropriate Vitech software. After installation, the user will be prompted at startup to license the software.

Depending upon the nature of the research proposed and the researcher's experience with the Vitech solution, Vitech may host a demonstration or other kickoff event in support of the effort. Throughout the project, the university program manager will touch base with the researcher periodically to check on project status. The researcher is encouraged to proactively contact Vitech – to share progress updates, to request technical assistance with the software, or to ask for systems engineering guidance.

The schedule information submitted in the application form will be used to determine the expiration date on software grants. Vitech grants licenses in increments of up to one year and renews research licenses annually depending on project length.

[Clear Form](#)

#### Additional Resources

- **Documentation:** Product help is included with the software installation. A guided tour, System Definition Guide, Architecture Definition Guide, and other guides are also provided as part of the software installation. Proper review of this documentation will accelerate learning and improve your effectiveness in leveraging the software.
- **Online Resources:** An overview of the Vitech software and methodology is provided in the resources and support sections of the Vitech website ([www.vitechcorp.com](http://www.vitechcorp.com)). In particular, the video overviews of capabilities and snippets on selected features are valuable for those who have less familiarity with the Vitech software or the latest versions of the Vitech software.
- **Premium Resources:** Secure login to portions of our website are reserved for customers who are current on maintenance. Participants in the Research Program are invited to take advantage of this site. This includes MySupport, premium screencasts and webinars, and priority customer support.

#### Researcher Commitment

The researcher is responsible for submitting an electronic copy of their final report or dissertation to the university program manager along with information regarding any publications or conferences where the project results will be briefed. For multi-year research projects, the researcher will provide a lightweight interim report reflecting project status, use and utility of the software, project plan updates, and any publications or public presentations to date prior to renewal of the license. As a condition of the program, the researcher is responsible for granting permission to Vitech to publicize the use of Vitech software as part of the individual's research.

#### For Additional Information

Donna Long, University Program Manager  
540-951-3322 x113 | [universityprogram@vitechcorp.com](mailto:universityprogram@vitechcorp.com) | [www.vitechcorp.com](http://www.vitechcorp.com)



2370 Kloth Drive, Suite 1600  
Blacksburg, Virginia 24060  
(540) 951-3322 • (540) 951-8222 Fax

### Research Application Form

For Vitech Use:		Date Submitted:	License Expiration:
Project #:			
Support Plan:			
<b>RESEARCHER INFORMATION</b>			
Full name:	YIXUAN CHENG		
University:	EMBRY-RIDDLE AERONAUTICAL UNIVERSITY		
Telephone:		Email:	CHENGYS@MYERAU.EDU
Address:			
Level of Study:	<input checked="" type="checkbox"/> Research <input type="checkbox"/> Doctorate		
Degree Program:	MASTER OF SCIENCE IN AERONAUTICS		
Willing to Provide Final Work Product and Publications, along with associated electronic project file:	<input type="checkbox"/> No. If no, explain: <input checked="" type="checkbox"/> Yes. Type of work product: Thesis		
Previous Experience with Vitech Solution:	<input type="checkbox"/> No <input checked="" type="checkbox"/> Yes. If yes, describe: The researcher has taken a System Engineering course that was instructed based on CORE. The researcher had used CORE to fulfill assignment requirements as part of the course.		
<b>ADVISOR INFORMATION</b>			
Full name:	DAHAI LIU		
University:	EMBRY-RIDDLE AERONAUTICAL UNIVERSITY		
Department:	GRADUATE STUDIES DEPARTMENT		
Telephone:	3862266214	Email:	LIU89B@ERAU.EDU
Address:	600 S CLYDE MORRIS BLVD, DAYTONA BEACH, FL 32114		
Previous Experience with Vitech Solution:	<input type="checkbox"/> No <input checked="" type="checkbox"/> Yes. If yes, describe: Dr. Liu is the instructor of the System Engineering course. He teaches students how to apply CORE into system engineering and evaluate students' performance.		

Effective 1 April 2017

Page 2

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<b>PROJECT INFORMATION</b>	
Start Date:	1/31/2018
Projected Completion Date:	08/30/2018
Research/Dissertation Title:	An Electronically Interactive Mobile Application for Enhanced Airport Familiarization and Runway Incursion Prevention
<b>Synopsis: (Multi-paragraph overview. Please attach your institution-approved project description. At a minimum, this synopsis should include research objectives, timeline, and intended artifacts.)</b> <p><b>Research objectives</b> Runway Incursion (RI), is defined as any incorrect presence of an aircraft, vehicle, or person on an active runway, is the leading cause of serious incidents or accidents in airports. One of the most common causes of RI is airport unfamiliarity. Therefore, the researcher aims to design an electronically interactive mobile application as a practice tool for pilots to utilize during flight preparation. The purpose of this application is to enhance airport familiarity and ultimately reduce runway incursion. This application is designed to be affordable and user-friendly. Thusly, as the objective of this research, a comprehensive list of user requirements will be collected through survey and analyzed in CORE. The final output of each user requirement is expected to be traceable, and clearly presented in a Quality Function Deployment (QFD) to indicate the importance of the requirements. The functionality and usability of the mobile application will be evaluated by experts using Heuristic Evaluation approach.</p> <p><b>Timeline</b> The survey result is expected to be available in the beginning of February. The researcher will need to have access to CORE prior to that in order to establish a brief work plan. The researcher is expecting to develop multiple Functional Flow Block Diagrams (FFBD) and Quality Function Deployment (QFD) by then end of February. During the month of March, the researcher will work with the advisor, Dr. Liu, to improve the design for a better output. By the end of April, the researcher will summarize all the activities being performed in CORE. A draft research paper can be expected in the end of May. The researcher will continue to work with Dr. Liu to finalize the research paper and seek for potential publication during June, July and August.</p> <p><b>Intended artifacts</b> An intended artifact will be a prototype of the electronically interactive mobile application that the researcher devotes to design.</p>	
Journals, Conferences, etc. to which it is expected results will be submitted:	Where: N/A
	When: N/A

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**Appendix B****IRB Approval of Survey One**

## IRB Approval of Survey One

### Embry-Riddle Aeronautical University Application for IRB Approval Exempt Determination

Principle Investigator: Yixuan Cheng

Other Investigators: Dr. Dahai Liu

Role: Student Campus: Daytona Beach College: Aviation/Aeronautics

Project Title: An Electronically Interactive Mobile Application for Enhanced Airport Familiarization and Runway Incursion Prevention

#### Review Board Use Only

Initial Reviewer: Teri Gabriel Date: 02/04/2018 Approval #: 18-090

Exempt: Yes

Dr. Michael Wiggins Michael E. Wiggins, Ed.D. Date: 03/09/2018  
IRB Chair Signature

Digitally signed by Michael E. Wiggins, Ed.D.  
DN: cn=Michael E. Wiggins, Ed.D., o=Embry-Riddle  
Aeronautical University, ou=Aeronautical Science  
Department, email=mwiggins@erau.edu, c=US  
Date: 2018.03.09 14:17:19 -0500

#### Brief Description:

The purpose of this study is to develop a user-friendly and affordable application to prevent runway incursions caused by unfamiliarity of the airport environment. As the goal of the application is to be user-friendly, a completed list of user requirements will be needed. To obtain all the user requirements, the researcher needs to survey Embry-Riddle students and employees at Daytona Beach International Airport to collect their ideas. Thusly, the first survey of this study is to collect user requirements through a survey instrument.

The second part of the study is to 'reach out' to 10-30 experts to 'critique the interface designed by the researchers'. This will be done by a survey.

This research falls under the **exempt** category as per 45 CFR 46.101(b) under:

- ☐ (1) Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies, and research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- ☒ (2) Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met:
- (i) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects;
  - (ii) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the

subjects' financial standing, employability, educational advancement, or reputation.

- ☐ (3) (i) Research involving benign behavioral interventions in conjunction with the collection of information from an adult subject through verbal or written responses (including data entry) or audiovisual recording if the subject prospectively agrees to the intervention and information collection and at least one of the following criteria is met:
- (A) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects;
- (B) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation.
- ☐ (4) Secondary research for which consent is not required: Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met:
- (i) The identifiable private information or identifiable biospecimens are publicly available;
- (ii) Information, which may include information about biospecimens, is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained directly or through identifiers linked to the subjects, the investigator does not contact the subjects, and the investigator will not re-identify subjects.
- ☐ (6) Taste and food quality evaluation and consumer acceptance studies:
- (i) If wholesome foods without additives are consumed, or
- (ii) If a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration or approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture.

An exempt research project does not require ongoing review by the IRB, unless the project is amended in such a way that it no longer meets the exemption criteria.

## 2. Design, Procedures, Materials and Methods: Describe the details of the procedure to be used and the type of data that will be collected.

The researcher has designed a survey that collects participants' general preference of the new application. First, the researcher aims to collect some basic information about the participants such as age, flight background, and flight experience. Second, the researcher listed some narrowly designed questions to collect precise personal preference, such as color of runway, verbal instruction or textual ATC instruction, weather condition, heading indicator. The last question allows participants to freely contribute any ideas about the design of the new application.

The survey will be distributed via an online survey link (Survey Monkey, the link is: <https://www.surveymonkey.com/r/7H9WQWC>) through 1. Embry-Riddle flight department flight administration office, 2. Embry-Riddle College of Aviation administration office, and 3. Daytona Beach International Airport administration office. Students study in College of Aviation, and/or conducting flight training in Embry-Riddle flight department will receive a link to participate through Survey Monkey. The researcher will contact the administration office of Daytona Beach International Airport office and ask them to forward the survey link to their employees at the airport.

Both qualitative and quantitative self-reported data will be collected through the survey and used in analysis.

Recruitment email with the survey link that the researcher is providing to Embry-Riddle flight department flight administration office / Embry-Riddle College of Aviation administration office:

My name is Yixuan Cheng. I am a graduate student from Master of Science in Aeronautics. I am currently conducting my thesis study, which is to design a user-friendly and affordable mobile application to prevent Runway Incursions caused by airport unfamiliarity. This application will be a practice tool for pilots to use on their portable devices to practice taxiing. After obtaining hands-on experience of taxiing in the airport, pilots will have better familiarity of the airport environment. Consequently, this application will help to prevent RIs caused by unfamiliarity of the airport environment. The goal of the application is to be user-friendly and to provide a better human-machine interaction experience.

As the researcher, I am aiming to collect a completed list of user requirements for me to design the interface and the functions of the application. Therefore, could you please help me to forward the survey link: <https://www.surveymonkey.com/r/7H9WQWC> to the students? This survey will take about 15 minutes to complete. Your help is appreciated.

Should you have any questions please feel free to contact me at [chengy5@my.erau.edu](mailto:chengy5@my.erau.edu).

Again, the survey link is <https://www.surveymonkey.com/r/7H9WQWC> and it will take only a few minutes to complete. Your help is very appreciated.

Recruitment email with the survey link that the researcher is providing to Daytona Beach International Airport administration office:

My name is Yixuan Cheng. I am studying Master of Science in Aeronautics in Embry - Riddle Aeronautical University. I am currently conducting my thesis study, which is to design a user-friendly and affordable mobile application to prevent Runway Incursions caused by airport unfamiliarity. This application will be a practice tool for pilots to use on their portable devices to practice taxiing. After obtaining hands-on experience of taxiing in the airport, pilots will have better familiarity of the airport environment.

As the researcher, I am aiming to collect a completed list of user requirements for me to design the interface and the functions of the application. Since this application is for airport taxiing practicing purpose, I highly believe that both pilots' and airport operator's ideas and opinions matter equally. Therefore, I would like to ask for your assistance, to forward the survey link <https://www.surveymonkey.com/r/7H9WQWC> to your fellow workers. This survey will take about 15 minutes to complete. This survey will provide me a great help to design the mobile application, and benefit the overall aviation community eventually.

Should you have any questions please feel free to contact me at [chengy5@my.erau.edu](mailto:chengy5@my.erau.edu). Your help is very appreciated.

Again, the survey link is <https://www.surveymonkey.com/r/7H9WQWC> and it will take only a few minutes to complete. Thank you very much for your participation.

## Human Subject Protocol Application

Campus:	Daytona Beach	College:	COA
Other Institution Name & Address:			
Applicant:	yixuan cheng	Degree Level:	Master
ERAU ID:	2399990	ERAU Affiliation:	Student
Project Title:	An Electronically Interactive Mobile Application for Enhanced Airport Familiarization and Runway Incursion Prevention		
Principal Investigator:	Yixuan Cheng		
Other Investigators:	Research advisor: Dr. Dahal Liu		
Submission Date:	04/18/2017	Beginning Date:	02/10/2018
Expected End Date:	08/31/2018		
Type of Project:	Survey		
Type of Funding Support (if any):	No		

### Questions:

- Background and Purpose: Briefly describe the background and purpose of the research.

Runway Incursion (RI) is the leading cause of serious incidents or accidents in aviation. The prevention of RI has moved on to a stage which involves automation. There have been many RI prevention systems developed and under development. Due to the nature of complexity of these systems, they are expensive and only large corporations, such as airlines, airports and aircraft manufacturers can afford to adopt them. No RI prevention systems are designed particularly at a relatively lower cost for General Aviation (GA). Yet, GA has an increasing number of RI in the past years.

Therefore, the purpose of this study is to develop a user-friendly and affordable mobile application to prevent RIs. This application will be a practice tool for pilots to use on their portable devices to practice taxiing. After getting some hands-on experience of taxiing in the airport, pilots will have better familiarity of the airport environment. Therefore, this application will help to prevent RIs caused by unfamiliarity of the airport environment. As the goal of the application is to be user-friendly, a completed list of user requirements will be required to design the interface and the functions of the application. To obtain all the user requirements, the researcher needs to survey the students at Embry-Riddle Aeronautical University and the employees at Daytona Beach International Airport to collect their ideas. Thusly, this survey is to collect user requirements for the design of the application.

1 embryriddle.edu

- Measures and Observations: What measures or observations will be taken in the study?

All the data that will be used in this study will be self-reported data from the survey. No actual observations of the participants of the survey will be conducted. In the first survey, participants' personal information (i.e., age) will be collected and scores towards the importance of each user requirement will be measured through survey. There will also be open-ended questions to collect participants' own ideas of user requirements.

- If any questionnaires, tests, or other instruments are used, provide a brief description.

The survey contains 37 questions and will be completed in 15 minutes. ?

- Risks and Benefits: Describe any potential risks to the dignity, rights, health or welfare of the human subjects. Assess the potential benefits to be gained by the subjects as well as to society in general as a result of this project. Briefly assess the risk-benefit ratio.

RISKS: There is a minor risk that the participant's personal information can be obtained and known by the researcher since emails are used. The risks of participating in this study are minimal, no more than everyday life.

BENEFITS: The participants will not be benefited from participating the survey directly. However, once the user requirements are collected from the survey, and the application is developed, all the students in Embry-Riddle and other General Aviation pilots will be benefited. The participants of the survey will be benefited indirectly in the end.

- Informed Consent: Describe the procedures you will use to obtain informed consent of the subjects and the debrief/feedback that will be provided to participants. See Informed Consent Guidelines for more information on Informed Consent requirements.

An informed consent page will appear prior to respondents being able to begin the survey. This form utilizes all the elements required by the ERAU IRB. Respondents will be asked to read the form and if they agree with its contents and if they agree to participate. For the online survey (the first survey), they will select "OK" which links to the beginning of the survey. Alternatively, if the respondent does not wish to participate, they are asked to close their browser window to exit. See the informed consent document as an attachment of this application.

- Anonymity: Will participant information be anonymous (not even the researcher can match data with names), confidential (Names or any other identifying demographics can be matched, but only members of the research team will have access to that information. Publication of the data will not include any identifying information.), or public (Names and data will be matched and individuals outside of the research team will have either direct or indirect access. Publication of the data will allow either directly or indirectly, identification of the participants)?

Anonymous

- Justify the classification and describe how privacy will be ensured/protected.

The informed consent will have the following statement, and these procedures will be followed: "Your individual information will be protected in all data resulting from this study. Your responses to this survey will be anonymous. No personal information will be collected other than basic demographic descriptors. There will be no questions that are used to identify individual identifications". Due to the potential construction of email addresses, there is the potential for names of individuals to be recognizable to the researcher. The IP addresses of the respondents will not be captured by Survey Monkey. All data will be preserved within the password protected Survey Monkey account and, once downloaded onto the researcher's password protected computer, will be deleted from Survey Monkey. Publication of the data will be in summary format only. No one other than the researcher will have access to any of the responses.

2 embryriddle.edu

3 embryriddle.edu

7. Privacy: Describe the safeguards (including confidentiality safeguards) you will use to minimize the risks. Indicate what will happen to data collected from participants that choose to "opt out" during the research process. If video/audio recordings are part of the research, please describe how that data will be stored or destroyed.

Participation in this study is completely voluntary. The participants may stop or withdraw from the study at any time or refuse to answer any particular question without it being held against to. If the participant does not wish to continue, their data will be discarded and not used in the analysis. The decision of whether or not to participate will have no effect on participants' current or future connection with anyone at Embry-Riddle Aeronautical University-Daytona Beach. Participants will be identified using only participant numbers in the data file, not by name, and that no participant names will be collected or recorded. The researcher will not be able to know participants' identities because there will be no questions that can be used to identify individual participants.

8. Participant Population and Recruitment Procedures: Who will be recruited to be participants and how will they be recruited. Note that participants must be at least 18 years of age to participate. Participants under 18 years of age much have a parent or guardian sign the informed consent document.

Participants group 1: Student who are over 18 years old, studying at Embry-Riddle College of Aviation or undergoing flight training in Embry-Riddle with any flight hours.  
Participants group 2: Employees at Daytona Beach International Airport.  
The survey questions will be available through SurveyMonkey. The researcher will distribute the link to the online survey to flight students through flight department; to non-flight students through the administration office of each program in College of Aviation; and to employees at Daytona Beach International Airport through the administration office of the airport. They will self-select to participate.

9. Economic Considerations: Are participants going to be paid for their participation?

No

9b. If yes, describe your policy for dealing with participants who 1) Show up for research, but refuse informed consent; 2) Start but fail to complete research.

10. Time: Approximately how much time will be required of each participant?

It will take participant's 15 minutes to complete the survey.

By submitting this application, you are signing that the Principal Investigator and any other investigators certify the following:

1. The information in this application is accurate and complete
2. All procedures performed during this project will be conducted by individuals legally and responsibly entitled to do so
3. We will comply with all federal, state, and institutional policies and procedures to protect human subjects in research
4. We will assure that the consent process and research procedures as described herein are followed with every participant in the research
5. That any significant systematic deviation from the submitted protocol (for example, a change in the principal investigator, sponsorship, research purposes, participant recruitment procedures, research methodology, risks and benefits, or consent procedures) will be submitted to the IRB for approval prior to its implementation
6. We will promptly report any adverse events to the IRB

Electronic Signature:

yixuan cheng

embryriddle.edu

From: H  
To: chengy5@my.erau.edu  
Date: 2/6/2018 3:55 PM  
Subject: Re: Survey Forwarding

Hi Yixuan,

Yes I will certainly forward the survey to my colleagues in Daytona Beach International Airport once the survey is approved and posted online. Thank you.

Best,  
[redacted]

Daytona Beach International Airport  
700 Catalina Dr., Suite 300  
Daytona Beach, FL 32114

>>> "Cheng, Yixuan" <CHENGY5@my.erau.edu> 2/6/2018 2:23 PM >>>  
Good afternoon

My name is Yixuan Cheng. I'm also a student from MSA as you are. I'm currently conducting my thesis study, which is to design a mobile application for runway incursion prevention. In order to design this application, I will need to survey the potential users of this application to obtain their user requirements. I believe that the opinions from the airport operation side is very critical to the design process. Thusly, I am writing this email to ask if you could kindly forward the link of the survey to your fellow workers. It is completely voluntary to participate the survey, and all the information will be anonymous. It will take about 15 minutes to complete all the questions. If possible, I will send you the link once the survey is approved by IRB. Thank you in advance for your help.

Best regards,  
Yixuan Cheng  
Master of Science in Aeronautics  
College of Aviation  
Embry-Riddle Aeronautical University  
Daytona Beach, FL 32114  
Phone: (917)743-2919  
Email: chengy5@my.erau.edu

# AGREEMENT TO PARTICIPATE IN User Requirements Collection for the Design of an Electronically Interactive Mobile Application for Enhanced Airport Familiarization and Runway Incursion Prevention

STUDY LEADERSHIP. I am asking you to take part in a research project that is led by Yixuan Cheng, a graduate student at Embry-Riddle Aeronautical University – Daytona Beach.

PURPOSE. The purpose of this study is to collect comprehensive user requirements from pilots and non-pilots with aviation background. The user requirements collected will be integrated into the design process of an electronically interactive application that can be used on any portable devices. This application is designed as an accessible and affordable tool for pilots to practice taxiing anywhere at any time. Ultimately, users of this application will gain familiarity of the airports after practicing.

ELIGIBILITY. To be in this study, you must be 18 years or older.

PARTICIPATION. During the study, you will be asked to complete an online survey about your personal information: age, native language and flight experience. You will complete questions that determine your preference of the functions, interface, and information given from the application. Your experiences about electronic flight bag and tablet-based aviation games will also be collected.

RISKS OF PARTICIPATION. The risks of participating in this study are minimal, no more than everyday life.

BENEFITS OF PARTICIPATION. I do not expect the study to benefit you personally. However, your participation will help us design a user-friendly and affordable tool to practice taxiing around airports. Ultimately it will benefit the entire aviation community.

COMPENSATION. There is no compensation for participating in this study.

VOLUNTARY PARTICIPATION. Your participation in this study is completely voluntary. You may stop or withdraw from the study at any time or refuse to answer any particular question without it being held against you. When participants choose to quit the survey, data will be discarded and not used in the analysis. Your decision on whether or not to participate will have no effect on your current or future connection with anyone at Embry-Riddle Aeronautical University– Daytona Beach.

RESPONDENT PRIVACY. Your individual information will be protected in all data resulting from this study. Your responses to this survey will be confidential. No personal information will be collected other than basic demographic descriptors in the survey. In order to protect the confidentiality of your responses, I will keep your responses within the password protected

Survey Monkey account and, once downloaded onto the researcher's password protected computer, will be deleted from Survey Monkey. Publication of the data will be in summary format only. No one other than the researcher will have access to any of the responses

FURTHER INFORMATION. If you have any questions or would like additional information about this study, please contact Yixuan Cheng, chengy5@my.erau.edu or (917)-743-2919.

The ERAU Institutional Review Board (IRB) has approved this project. You may contact the ERAU IRB with any questions or issues at (386) 226-7179 or teri.gabriel@erau.edu. ERAU's IRB is registered with the Department of Health & Human Services – Number – IORG0004370.

CONSENT. By clicking the "OK" entry below means that you understand the information on this page, eligible to participate, and voluntarily agree to participate. If you do not wish to participate in this research, you are free to exit out of this page. If you are ineligible to participate in this research, you must exit out of this page.



Survey of User Requirements Collection for the Design of an Electronically Interactive Mobile Application for Enhanced Airport Familiarization and Runway Incursion Prevention

- 1) How old are you?
  - a) 18-20
  - b) 21-25
  - c) 26-30
  - d) 31-40
  - e) 41-50
  - f) 51-60
  - g) 61 or older
- 2) Is English your native language?
  - a) Yes
  - b) No
- 3) Have you ever piloted an aircraft before?
  - a) Yes
  - b) No
- 4) What is your level of flight experience?
  - a) 0-49 flight hours
  - b) 50-99 flight hours
  - c) 100-199 flight hours
  - d) 200+ flight hours
- 5) What is the highest certificate / ratings do you currently hold?
  - a) Student Pilot Certificate
  - b) Private Pilot
  - c) Instrument Rated
  - d) Commercial Pilot
  - e) CFI / CFI / MEI
- 6) Have you flown within the last 90 days?
  - a) Yes
  - b) No
- 7) How many years have you been flying?
  - a) Less than one year
  - b) 1-3 years
  - c) 4-6 years
  - d) 7+ years
- 8) Where did you do your flight training?
  - a) Embry-Riddle Aeronautical University
  - b) Florida based flight school
  - c) Outside of Florida
- 9) How many times have you approximately departed/landed in Daytona Beach International Airport (DAB)?
  - a) 0-49 times
  - b) 50-99 times
  - c) 100-199 times
- d) 200+ times
- e) N/A, never taxi in DAB
- 14) During the taxiing phase, do you often feel confused with the taxi instructions given by Air Traffic Controller (ATC) when operating in an airport that you have NEVER operated in?
  - a) Yes
  - b) Sometimes, but I can manage
  - c) Not at all
- 15) During the taxiing phase, do you often feel confused with taxi instructions given by Air Traffic Controller (ATC) when operating in an airport that you have operated in TWO or LESS times?
  - a) Yes
  - b) Sometimes, but I can manage
  - c) Not at all
- 16) How often would you consider asking for progressive taxi instructions in an unfamiliar airport?
  - a) Almost always – just to be safe
  - b) Likely
  - c) Never because it sounds unprofessional
- 17) Imagine that tomorrow is the day where you will have your first cross-country solo flight to Key West. Your destination airport is Florida Keys Marathon Airport (MTH). Since this is your first cross-country solo flight, we assume that you're not very familiar with the airport layout of Florida Keys Marathon Airport (MTH). Do you agree that reviewing the FAA format airport diagram is a good way to gain airport familiarization in this case?
  - a) Yes
  - b) No
- 18) In the same scenario, do you agree that studying the FAA format airport diagram of Florida Keys Marathon Airport (MTH) does NOT give you comprehensive awareness of the airport layout including taxiways, runways, hot spot, intersections, and Fixed Base Operation?
  - a) Yes
  - b) Maybe
  - c) No
- 19) In the same scenario, do you agree that there could be something better than a FAA format airport diagram of Florida Keys Marathon Airport (MTH) for you to study as part of your pre-flight routine, in order for you to become familiar with the Florida Keys Marathon Airport (MTH) layout?
  - a) Yes
  - b) Maybe
  - c) No
- 20) For an airport that you are not or less familiar with, do you think a taxiing practice software/application based on FAA format airport diagram will help you gain familiarization?
  - a) Yes
  - b) Maybe
  - c) No
- 21) Do you think hands-on experience, such as practicing with a taxiing software/application on your mobile device, will help you to perform when operating in a new airport?
  - a) Yes
  - b) Maybe

- d) 200+ times
- 10) Please rate your confidence in ability to execute taxiing instructions in Daytona Beach International Airport (DAB) on a scale of 1 to 10, where 1 means "Not confident at all" and 10 means "Very Confident".

1 ————— 5 ————— 10

- 11) Have you ever noticed the circled service road in the below diagram in Daytona Beach International Airport (DAB), or not?
  - a) Yes
  - b) No



- 12) If you answered YES to Question 11, how did you notice this service road in Daytona Beach International Airport (DAB)? If you answered NO to Question 11, please skip this question and continue to Question 13.
  - a) I noticed during taxiing and it never confused me.
  - b) I know this intersection because I almost made the wrong turn.
  - c) I made the wrong turn before.
  - d) I know this intersection because my instructor and/or other people have pointed that out for me.
  - e) I know someone had made a mistake on this turn, and I learnt from his/her mistake.
  - f) Other (Please specify)
- 13) How many times have you ever felt confused with taxi instructions given by Air Traffic Controller (ATC) when taxiing in Daytona Beach International Airport (DAB)?
  - a) Never felt confused
  - b) 1 to 3 times
  - c) 4 to 6 times

- c) No
- 22) How familiar are you with electronic flight bag?
  - a) Extremely familiar
  - b) Very familiar
  - c) Somewhat familiar
  - d) Not so familiar
  - e) Not at all familiar
- 23) Do you use your electronic flight bag for as part of your pre-flight routine before each flight?
  - a) Yes
  - b) Sometimes
  - c) No
- 24) Have you played any of the following tablet-based games?
  - a) Airport Manager
  - b) Unmatched Air Traffic Control
  - c) Airport Madness
  - d) Real Airport Truck Duty Simulator 3D
  - e) Flight Simulator FlyWings 2014
  - f) Infinite Flight
  - g) Other games (Please specify)
  - h) Never
- 25) Imagine there is a new game that lets you taxi in any airports you choose was just released. In this game, the airports replicate real life airport diagrams and airport surfaces. First you choose the airport you would like to play on. Second, an artificial ATC will give you taxi instructions to get you to a certain location in the airport from your current location. Third, based on the airport diagram available, you can move the aircraft adherence to ATC's instructions. The overall goal is to comply with ATC instructions while navigating around the airport safely and correctly. If you are given a new game as such, how important to you that the image should be displayed with a top-down view (2D)?
 

Not important at all ————— Very important
- 26) If you are given a new game as described in Question 25, how important to you that the image should be displayed with a first-person point of view (3D)?
 

Not important at all ————— Very important
- 27) If you are given a new game as described in Question 25, how important to you that the users should be able to choose the time setting between Daytime or Nighttime while taxiing?
 

Not important at all ————— Very important
- 28) If you are given a new game as described in Question 25, how important to you that the users should be able to choose the weather condition (i.e. sunny, cloudy, rainy, foggy, or snowy) while taxiing?
 

Not important at all ————— Very important
- 29) If you are given a new game as described in Question 25, how important to you that the ATC instructions should be given verbally (played through the speaker or headphone of your mobile device (phone or tablet)?
 

Not important at all ————— Very important



- 30) If you are given a new game as described in Question 25, how important to you that the ATC instructions should be given textually (displayed on the screen)?  
Not important at all -----Very important
- 31) If the ATC instructions are displayed on the screen, how important to you that the instructions should remain on the screen, so that you can follow the instructions easily?  
Not important at all -----Very important
- 32) If you are given a new game as described in Question 25, how important to you that the ATC instructions should be given both verbally and textually?  
Not important at all -----Very important
- 33) If you are given a new game as described in Question 25, how important to you that the color of runway and taxiway in daytime should both be in dark grey, in order to replicate the real life airport surface painting?



- Not important at all -----Very important
- 34) If you are given a new game as described in Question 25, how important to you that the color of runway and taxiway in daytime should replicate the FAA format airport diagram color? That is, black color for runway and light grey color for taxiway.



- Not important at all -----Very important
- 35) If you are given a new game as described in Question 25, how important to you that there should be a distance indication alert before turns and hold short lines?

- Not important at all -----Very important
- 36) If you are given a new game as described in Question 25, how important to you that there should be a heading indicator?  
Not important at all -----Very important
- 37) If you are given the opportunity to add more functions to this new game, in order to provide better taxiing experience, what will you add (Please specify in detail)?

## **Appendix C**

### **IRB Approval of Survey Two**

## IRB Approval of Survey Two

### Embry-Riddle Aeronautical University Application for IRB Approval Exempt Determination

Principle Investigator: Yixuan Cheng

Other Investigators: Dr. Dahai Liu

Role: Student Campus: Daytona Beach College: Aviation/Aeronautics

Project Title: Stage Two Study of an Electronically Interactive Mobile Application for Enhanced Airport Familiarization and Runway Incursion Prevention

#### Review Board Use Only

Initial Reviewer: Teri Gabriel Date: 03/09/2018 Approval #: 18-116

Exempt: Yes

Dr. Michael Wiggins

**Michael E. Wiggins,**  
**Ed.D.**

IRB Chair Signature

Digitally signed by Michael E. Wiggins, Ed.D.  
DN: cn=Michael E. Wiggins, Ed.D., o=Embry-Riddle  
Aeronautical University, ou=Aeronautical Science  
Department, email=wigginsm@erau.edu, c=US  
Date: 2018.03.19 08:20:04 -0400

Date: 03/19/2018

#### Brief Description:

The purpose of this study is to conduct heuristic evaluations of the FAA format airport diagram and the interface of an electronically interactive mobile application for airport taxiing. The study will use a survey.

This research falls under the **exempt** category as per 45 CFR 46.101(b) under:

- ☐ (1) Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies, and research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- ☒ (2) Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met:
- (i) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects;
  - (ii) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the

subjects' financial standing, employability, educational advancement, or reputation.

- ☐ (3) (i) Research involving benign behavioral interventions in conjunction with the collection of information from an adult subject through verbal or written responses (including data entry) or audiovisual recording if the subject prospectively agrees to the intervention and information collection and at least one of the following criteria is met:  
(A) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects;  
(B) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation.
- ☐ (4) Secondary research for which consent is not required: Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met:  
(i) The identifiable private information or identifiable biospecimens are publicly available;  
(ii) Information, which may include information about biospecimens, is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained directly or through identifiers linked to the subjects, the investigator does not contact the subjects, and the investigator will not re-identify subjects.
- ☐ (6) Taste and food quality evaluation and consumer acceptance studies:  
(i) If wholesome foods without additives are consumed, or  
(ii) If a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration or approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture.

An exempt research project does not require ongoing review by the IRB, unless the project is amended in such a way that it no longer meets the exemption criteria.

Human Subject Protocol Application

Campus:	Daytona Beach	College:	COA
Other Institution Name & Address:			
Applicant:	Yixuan Cheng	Degree Level:	Master
ERAU ID:	2399990	ERAU Affiliation:	Student
Project Title:	Stage Two Study of an Electronically Interactive Mobile Application for Enhanced Airport Familiarization and Runway Incursion Prevention		
Principal Investigator:	Yixuan Cheng		
Other Investigators:	Research advisor: Dr. Dahai Liu		
Submission Date: 03/06/2018			
Beginning Date:	03/16/2018	Expected End Date:	
Type of Project:	Survey		
Type of Funding Support (if any):	No		

Questions:

1. Background and Purpose: Briefly describe the background and purpose of the research.

This research study intends to develop a new mobile application. Pilots at any experience can use this mobile application as a practice tool to improve their familiarity in selected airports. The goal of this mobile application is to enhance pilot's airport familiarity. With enhanced familiarity, runway incursions will be reduced. At this stage, the interface of this mobile application has been designed based on Human Factors Engineering concepts. As one of the necessary designing processes of a new system, an evaluation of the new system has to be conducted. The researcher chose Heuristic Evaluation as the method to evaluate the interface of the new system. Heuristic evaluation is an expert-review method. According to Nielsen (1990), heuristic evaluation will require 3-5 experts in each category. Thusly, the researcher will try to reach out to 10-30 experts depending on availability. The experts will be chosen from a group of Human Factors experts and a group of senior pilots (over 200 flight hours). All these experts will score the interface designed based on the ten basic rules of heuristic evaluation, and then provide comments if they have any. In order to conduct a t-test to compare whether the new interface is significantly better than the traditional FAA format airport diagrams, the researcher will also ask the same experts to score the FAA format airport diagrams based the ten basic rules of heuristic evaluation, and then provide comments if they have any. As a result, the researcher will obtain two groups of scores, and then will be able to conduct statistical analysis to find out any significance of the new interface.

2. Design, Procedures, Materials and Methods: Describe the details of the procedure to be used and the type of data that will be collected.

The survey is a list of questions that the experts (Human Factors researchers/professors and senior pilots who have over 200 flight hours) will give scores and comments if applicable. Both qualitative and quantitative self-reported data will be collected through the survey and used in analysis. The researcher will provide the experts four FAA format diagrams, which are Van Nuys Airport in Los Angeles, Honolulu International Airport, Chino Airport in California, and Daytona Beach International Airport. The researcher will also provide the experts nine screenshots of the interface of the mobile application. The researcher will ask the experts to score, provide comment for both FAA airport diagram and the interface. In the end, the researcher will ask the experts to freely contribute their suggestions in terms of the features and accessibility of the mobile application. The purpose of the survey is to evaluate the interface, compare the score of the traditional FAA airport diagram and the newly designed interface, and collect some further suggestions. Based on the score, the researcher will conduct a t-test and determine whether the new interface score is significantly higher than the FAA diagram. The survey will be distributed via the researcher's school email. The researcher will contact 5-15 Human Factors experts and 5-15 senior pilots and ask them to participate in the survey. The researcher will search on the Embry-Riddle faculty list to find professors that have Human Factors background and email them the survey. The researcher will ask 5-15 senior pilots that she knows in person whether or not they would like to participate in the survey. If they do, the researcher will email them the survey. The 5-15 senior pilots that the researcher knows in person are either an Embry-Riddle student or an Embry-Riddle alumni.

Recruitment email that the researcher will send to the experts:

My name is Yixuan Cheng. I am a graduate student from Master of Science in Aeronautics. I am currently conducting my thesis study, which is to design a user-friendly and affordable mobile application to prevent Runway Incursions caused by airport unfamiliarity. This application will be a practice tool for pilots to use on their portable devices to practice taxiing. After obtaining hands-on experience of taxiing in the airport, pilots will have better familiarity of the airport environment. Consequently, this application will help to prevent Ris caused by unfamiliarity of the airport environment.

I have designed the interface of this mobile application and adopting Heuristic Evaluation method as the evaluation method of this new system. In this email, I have enclosed four FAA format airport diagrams, and nine screenshots of the interface that I designed. I would like to ask you to score and give any feedback and comments in the survey that I have provided in the email. Please feel free to contact me should you have any questions regarding the survey, the interface, or anything else that you are unsure of. I will be more than happy to clarify. This survey will take about 30 minutes to complete. Your help is greatly appreciated.

Should you have any questions please feel free to contact me at chengy5@my.erau.edu.

Recruitment email that the researcher will send to the pilots:

Hello,

I am currently conducting my thesis study, which is to design a user-friendly and affordable mobile application to prevent Runway Incursions caused by airport unfamiliarity. This application will be a practice tool for pilots to use on their portable devices to practice taxiing. After obtaining hands-on experience of taxiing in the airport, pilots will have better familiarity of the airport environment. Consequently, this application will help to prevent Ris caused by unfamiliarity of the airport environment.

I have designed the interface of this mobile application and adopting Heuristic Evaluation method as the evaluation method of this new system. In this email, I have enclosed four FAA format airport diagram, and nine screenshots of the interface that I designed. I would like to ask you to score and provide any comments in the survey I provide in the email. Please feel free to contact me should you have any questions regarding the survey, the interface, or anything else that you are unsure of. I will be more than happy to clarify. This survey will take about 30 minutes to complete. Your help is greatly appreciated.

Should you have any questions please feel free to contact me.

3. Measures and Observations: What measures or observations will be taken in the study?

All the data that will be used in this study will be self-reported data from the survey. No actual observations of the participants of the survey will be conducted. The participants will be asked whether they are Human Factors experts or Experienced Pilots. No other personal information will be collected. There will be open-ended questions to collect participants' own ideas of the interface.

3b. If any questionnaires, tests, or other instruments are used, provide a brief description.

The survey contains 17 questions and will be completed in 30 minutes.

4. Risks and Benefits: Describe any potential risks to the dignity, rights, health or welfare of the human subjects. Assess the potential benefits to be gained by the subjects as well as to society in general as a result of this project. Briefly assess the risk-benefit ratio.

RISKS: Since emails are used there is a risk that the participant's personal information can be obtained and known by the researcher. This is a minor risk. Other than this, the risk of participating in this study is minimal, no more than everyday life.

BENEFITS: The participants will not be benefited from participating in the survey directly. However, if the application is successfully launched, all the students in Embry-Riddle and other GA pilots will be benefited. The participants of the survey will be benefited indirectly in the end.

5. Informed Consent: Describe the procedures you will use to obtain informed consent of the subjects and the debrief/feedback that will be provided to participants. See Informed Consent Guidelines for more information on Informed Consent requirements.

The first page of the survey is the consent form and respondents will read the consent first to make sure they understand the form. If the respondents do not wish to do the survey, they can leave the page blank. If the respondents do not wish to continue the survey, they can quit at anytime without penalty and the data will be discarded and will not be used in the analysis. The respondents can skip any questions they want during the process without penalty.

6. Anonymity: Will participant information be anonymous (not even the researcher can match data with names), confidential (Names or any other identifying demographics can be matched, but only members of the research team will have access to that information. Publication of the data will not include any identifying information), or public (Names and data will be matched and individuals outside of the research team will have either direct or indirect access. Publication of the data will allow either directly or indirectly, identification of the participants.)?

Confidential

6b. Justify the classification and describe how privacy will be ensured/protected.

The informed consent will have the following statement, and these procedures will be followed: "Your individual information will be protected in all data resulting from this study. Your responses to this survey will be anonymous. No personal information will be collected other than whether you are a Human Factors Expert or an Experienced Pilot. There will be no questions that are used to identify individual identifications". Due to the potential construction of email addresses, there is the potential for names of individuals to be recognizable to the researcher. Therefore the level of privacy of this study will be confidential. In order to protect the anonymity of the responses, the researcher will keep the responses in a password-protected file on a password-protected computer. No one other than the researcher will have access to any of the responses. Publication of the data will be in summary format only.

7. Privacy: Describe the safeguards (including confidentiality safeguards) you will use to minimize the risks. Indicate what will happen to data collected from participants that choose to "opt out" during the research process. If video/audio recordings are part of the research, please describe how that data will be stored or destroyed.

Participation in this study is completely voluntary. The participants may stop or withdraw from the study at any time or refuse to answer any particular question without it being held against them. If the participant does not wish to continue, their data will be discarded and will not be used in the analysis. If the participants choose to discontinue during the research process, their data will be discarded and will not be used in the analysis. The decision of whether or not to participate will have no effect on participants' current or future connection with anyone at Embry-Riddle Aeronautical University Daytona Beach. Participants will be identified using only participant numbers in the data file, not by name, and that no participant names will be collected or recorded.

8. Participant Population and Recruitment Procedures: Who will be recruited to be participants and how will they be recruited. Note that participants must be at least 18 years of age to participate. Participants under 18 years of age must have a parent or guardian sign the informed consent document.

Participants group 1: Human factors professors from Embry-Riddle  
Participants group 2: Senior pilots (with more than 200 flight hours) from Embry-Riddle or Embry-Riddle alumni.  
The survey will be distributed via the researcher's school email. The researcher will contact 5-15 Human Factors experts and 5-15 senior pilots and ask them to participate in the survey. The researcher will search on the Embry-Riddle faculty list to find professors that have Human Factors background and email them the survey. The researcher will ask 5-15 senior pilots that she knows in person whether or not they would like to participate in the survey. If they agree to participate, the researcher will email the survey to the participant. The 5-15 senior pilots that the researcher knows in person are either an Embry-Riddle student or Embry-Riddle alumni.

9. Economic Considerations: Are participants going to be paid for their participation?

No

9b. If yes, describe your policy for dealing with participants who 1) Show up for research, but refuse informed consent; 2) Start but fail to complete research.

10. Time: Approximately how much time will be required of each participant?

It will take participant's 30 minutes to complete the survey.

By submitting this application, you are signing that the Principal Investigator and any other investigators certify the following:

1. The information in this application is accurate and complete
2. All procedures performed during this project will be conducted by individuals legally and responsibly entitled to do so
3. We will comply with all federal, state, and institutional policies and procedures to protect human subjects in research
4. We will assure that the consent process and research procedures as described herein are followed with every participant in the research
5. That any significant systematic deviation from the submitted protocol (for example, a change in the principal investigator, sponsorship, research purposes, participant recruitment procedures, research methodology, risks and benefits, or consent procedures) will be submitted to the IRB for approval prior to its implementation
6. We will promptly report any adverse events to the IRB

Electronic Signature:

Yixuan Cheng

AGREEMENT TO PARTICIPATE IN

Stage Two Study of an Electronically Interactive Mobile Application for Enhanced Airport Familiarization and Runway Incursion Prevention

Heuristic Evaluation of the FAA Format Airport Diagram and the Interface of an Electronically Interactive Mobile Application for Airport Taxing Practice

STUDY LEADERSHIP. I am asking you to take part in a research project that is led by Yixuan Cheng, a graduate student at Embry-Riddle Aeronautical University – Daytona Beach.

PURPOSE. The purpose of this study is to conduct heuristic evaluations of the FAA format airport diagram and the interface of an electronically interactive mobile application for airport taxing. This application is designed as an accessible and affordable tool for pilots to practice taxing anywhere at any time. Ultimately, users of this application will have familiarity of the airports after practicing. Thusly, this heuristic evaluation is designed to evaluate whether the interface of this application can provide consistency, usability, and human machine interaction compared to the traditional FAA format airport diagram.

ELIGIBILITY. To be in this study, you must be 18 years or older.

PARTICIPATION. During the study, you will be asked to complete a survey. Your research background will be asked. You will complete 17 questions. The questions are constructed based on the 10 Usability Heuristics for User Interface Design (Nielsen, 1995). You will be asked to score the FAA format airport diagram and the interface of the mobile application, as well as provide commands if applicable. You will also be asked two open-ended questions to obtain any suggestions you may have to the mobile application.

RISKS OF PARTICIPATION. Since emails are used there is a risk that the participant's personal information can be obtained and known by the researcher. This is a minor risk. Other than this, the risk of participating in this study is minimal, no more than everyday life.

BENEFITS OF PARTICIPATION. I do not expect the study to benefit you personally. However, your participation will help us design a user-friendly and affordable tool to practice taxing around airports. Ultimately it will benefit the entire aviation community.

COMPENSATION. There is no compensation for participating in this study.

VOLUNTARY PARTICIPATION. Your participation in this study is completely voluntary. You may stop or withdraw from the study at any time or refuse to answer any particular question without it being held against you. When participants choose to quit the survey, data will be discarded and not used in the analysis. Your decision on whether or not to participate will have no effect on your current or future connection with anyone at Embry-Riddle Aeronautical University – Daytona Beach.

RESPONDENT PRIVACY. Your individual information will be protected in all data resulting from this study. Your responses to this survey will be confidential. Your consent form and survey will be stored in two separate folders, so that your personal information cannot be linked to your answers. No personal information will be collected other than whether you are a Human Factors Expert or an Experienced Pilot. There will be no questions that are used to identify individual identifications. In order to protect the confidentiality of your responses, I will keep your responses in a password-protected file on a password-protected computer. No one other than the researcher will have access to any of the responses.

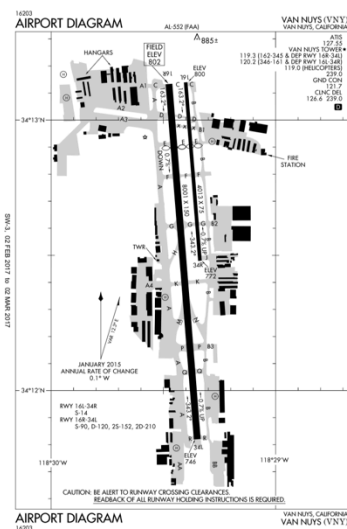
FURTHER INFORMATION. If you have any questions or would like additional information about this study, please contact Yixuan Cheng, chengy5@my.erau.edu or (917)-743-2919.

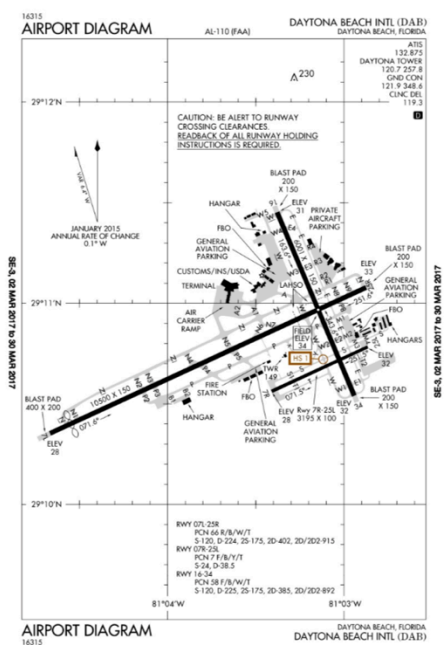
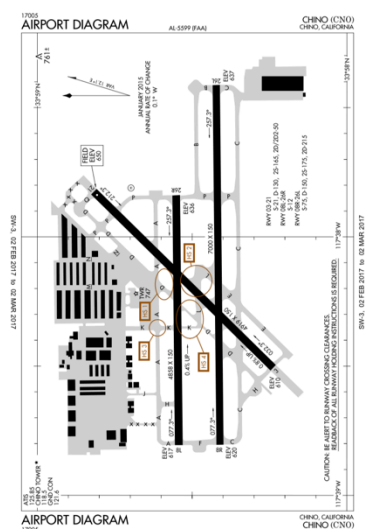
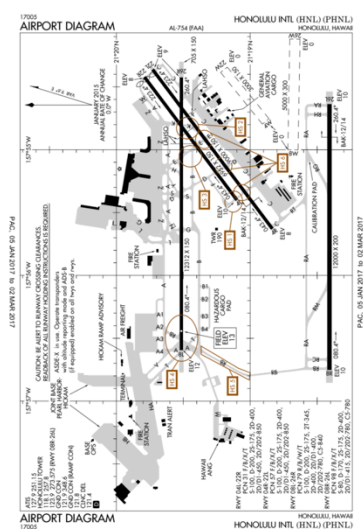
The ERAU Institutional Review Board (IRB) has approved this project. You may contact the ERAU IRB with any questions or issues at (386) 226-7179 or teri.gabriel@erau.edu. ERAU's IRB is registered with the Department of Health & Human Services – Number – IORG0004370.

CONSENT. Your signature below means that you understand the information on this form, that someone has answered any and all questions you may have about this study, and you voluntarily agree to participate in it. Please make a copy of this form for your records. A copy of this form can also be requested from Yixuan Cheng.

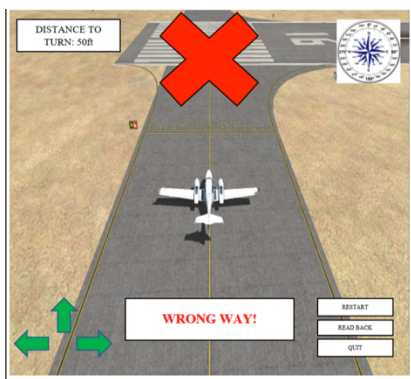
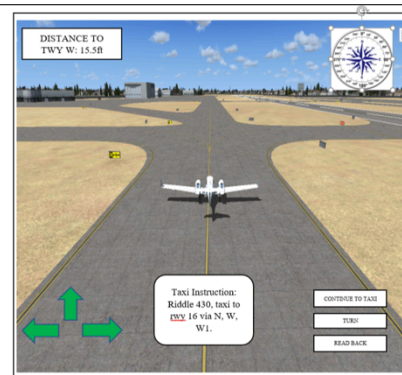
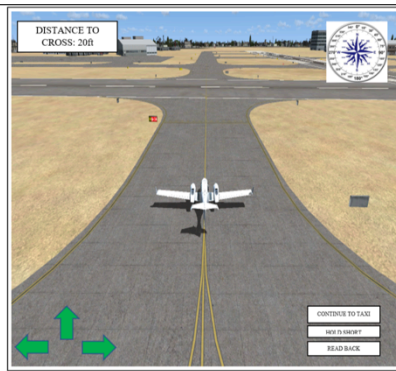
Signature of Participant \_\_\_\_\_ Date \_\_\_\_\_

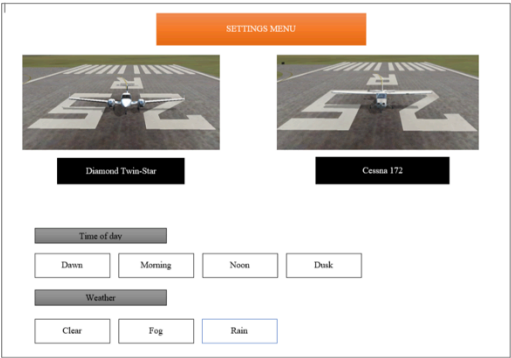
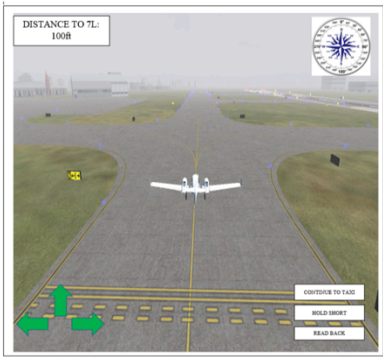
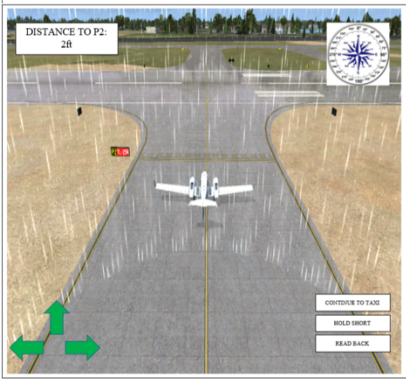
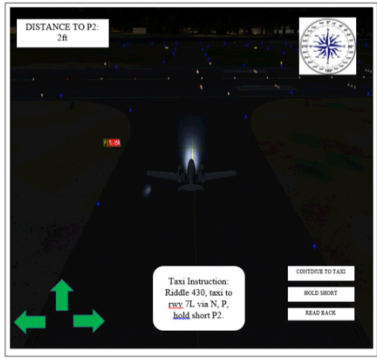
Printed Name of Participant \_\_\_\_\_













*Heuristic Evaluation of a FAA Format Airport Diagram and the Interface of an Electronically Interactive Mobile Application for Airport Taxiing Practice*

## Introduction

### THE FAA FORMAT AIRPORT DIAGRAM

The FAA format airport diagram is the most important resource for pilots to review airport layout before each flight. Pilots expect themselves to establish a certain level of familiarization of the airport after reviewing the FAA airport diagram. The FAA airport diagram should provide a comprehensive understanding of the taxiways, runways, hot spots, hold short position and all the other information that is critical for pilots to navigate around the airport. Along with the Air Traffic Controller's instructions and other supplemental documents provided from the flight school/airline/aircraft charter, pilots should be able to taxi around the airport without any mistakes. The researcher will provide four FAA airport diagrams for you to review.

### THE ELECTRONICALLY INTERACTIVE MOBILE APPLICATION

The electronically interactive mobile application to practice taxiing around the airport is a brand new system designed by the researcher using System Engineering approach. This dynamic mobile application is replicating the airport layout based on the FAA airport diagram. In addition, there is an artificial Air Traffic Controller (ATC) that gives taxiing instructions to the users. Thusly, users can follow the ATC instructions to navigate around the airport using artificial aircraft displayed on the interface. Instead of studying a motionless airport diagram, users have the opportunity to obtain hands-on experience of taxiing. As a result, users will become familiar with the airport environment. In the meantime, other user groups of the mobile application can be 1. leisure players who want to have a realistic feeling of taxiing around the airport; 2. researchers who want to study taxiing behaviors; 3. flight schools that want to provide a supplemental flight preparation resource for their students; 4. airport operations, occasional pilots, or anyone who wants to obtain certain level of understandings of airport environment. Therefore, the design goal of this mobile application is to provide a practice tool to taxi around the airport of choice that is interactive, user-friendly, accessible, easy-to-use, affordable, and portable. The researcher will provide nine screenshots of the interface of the mobile application for you to review.

1) Which category best describes you?

- a) Human Factors experts
- b) Experienced pilots
- c) Both

2) On a scale of 1 to 10, how would you score the FAA format airport diagram / the mobile application, in terms of their ability to always keep pilots informed about what is going on, through appropriate feedback within reasonable time?

	Score (1-10)	Potential Problems
FAA Airport Diagram		
Mobile Application		

3) On a scale of 1 to 10, how would you score the FAA format airport diagram / the mobile application, in terms of their ability to match the real airport dynamic environmental during taxiing?

	Score (1-10)	Potential Problems
FAA Airport Diagram		
Mobile Application		

4) On a scale of 1 to 10, how would you score the FAA format airport diagram / the mobile application, in terms of their ability to speak the pilot's language, with aeronautical words, phrases and concepts familiar to the pilots?

	Score (1-10)	Potential Problems
FAA Airport Diagram		
Mobile Application		

5) On a scale of 1 to 10, how would you score the FAA format airport diagram / the mobile application, in terms of their ability to provide pilots freedom to "cancel", "undo" or leave the unwanted state without having to go through an extended dialogue.

	Score (1-10)	Potential Problems
FAA Airport Diagram		
Mobile Application		

6) On a scale of 1 to 10, how would you score the FAA format airport diagram / the mobile application, in terms of their ability to provide consistent information? Consistent information can be defined as having the clarity so that pilots should not have to wonder whether the words, symbols, indicators used in the FAA format diagram or the mobile application mean the same thing as other airport diagrams, flight control desk and any other flight supplemental documents.

	Score (1-10)	Potential Problems
FAA Airport Diagram		
Mobile Application		

7) On a scale of 1 to 10, how would you score the FAA format airport diagram / the mobile application, in terms of their ability to provide good error messages, prevent a problem from occurring in the first place?

	Score (1-10)	Potential Problems
FAA Airport Diagram		
Mobile Application		

8) On a scale of 1 to 10, how would you score the FAA format airport diagram / the mobile application, in terms of their ability to minimize the pilots' memory load? Pilots should not have to remember information from one part of the diagram to another.

	Score (1-10)	Potential Problems
FAA Airport Diagram		
Mobile Application		

9) On a scale of 1 to 10, how would you score the FAA format airport diagram / the mobile application, in terms of their ability to provide clear or easily retrievable instructions for the use of the diagram?

	Score (1-10)	Potential Problems
FAA Airport Diagram		
Mobile Application		

10) On a scale of 1 to 10, how would you score the FAA format airport diagram / the mobile application, in terms of their flexibility and efficiency of use, for both inexperienced and experienced pilots?

	Score (1-10)	Potential Problems
FAA Airport Diagram		
Mobile Application		

11) On a scale of 1 to 10, how would you score the FAA format airport diagram / the mobile application, in terms of their ability to allow pilots to tailor frequent actions such as customizing common shortcuts as they prefer.

	Score (1-10)	Potential Problems
FAA Airport Diagram		
Mobile Application		

12) On a scale of 1 to 10, how would you score the FAA format airport diagram / the mobile application, in terms of their ability to provide only relevant and needed information?

	Score (1-10)	Potential Problems
FAA Airport Diagram		
Mobile Application		

13) On a scale of 1 to 10, how would you score the aesthetics layout of the FAA format airport diagram / the mobile application? It should respect the principles of contrast, repetition, alignment, and proximity.

	Score (1-10)	Potential Problems
FAA Airport Diagram		
Mobile Application		

14) On a scale of 1 to 10, how would you score the FAA format airport diagram / the mobile application, in terms of their ability to help pilots recognize, diagnose, and recover from errors? Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

	Score (1-10)	Potential Problems
FAA Airport Diagram		
Mobile Application		

15) On a scale of 1 to 10, how would you score the FAA format airport diagram / the mobile application, in terms of their ability to provide help when pilots require additional information to understand the airport layout?

	Score (1-10)	Potential Problems
FAA Airport Diagram		
Mobile Application		

16) What design features on this mobile application do you like about?

17) Can you think of a way to make this application more accessible or user-friendly?