LEARNING LESSONS FROM INCIDENTS TO IMPROVE RUNWAY SAFETY: WHAT HELPS CONTROLLERS CREATE INFORMATION-RICH REPORTS THAT IMPROVE OUR KNOWLEDGE OF RUNWAY INCURSIONS AND THEIR CAUSES?

by

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Dedicated to my grandparents, parents, and all my teachers

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The views expressed in this paper are those of the authors and do not necessarily reflect those of the FAA. The information in this research does not constitute FAA Flight Standards or FAA Aircraft Certification policy.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AIDS	Accident Incident Data System
ASDE-X	Airport Surface Detection Equipment, Model X
ASIAS	Aviation Safety Information Analysis and Sharing
ASRS	Aviation Safety Reporting System
ATCS	Air Traffic Control Specialist
ATIS	Automated Terminal Information Service
ATM	Air Traffic Manager
ATO	Air Traffic Organization
ATSAP	Air Traffic Safety Action Program
CEDAR	Comprehensive Electronic Data Analysis and Reporting
CIC	Controller in Charge
FAA	Federal Aviation Administration
ICAO	International Civil Aviation Organization
ICV	Internal Compliance Validation
MOR	Mandatory Occurrence Report
NTSB	National Transportation Safety Board
OI	Operational Incident
PD	Pilot Deviation
QA	Quality Assurance
QAQC	Quality Assurance and Quality Control
REL	Runway Entrance Light
RI	Runway Incursion
ROC	Regional Operations Center
RWSL	Runway Status Light
THL	Takeoff Hold Light
VPD	Vehicle/Pedestrian Deviation

ABSTRACT

A runway incursion occurs when an aircraft, ground vehicle, or a pedestrian is present on a runway when they were not supposed to be there. Runway incursions are a decades-old and continuing problem. The runway incursion between two Boeing 747s at Tenerife airport in 1977 is still the worst accident in aviation history. Despite the aviation community's efforts to mitigate runway incursions, the number of incursions has not decreased. Though most of the runway incursions that occur today are near-misses or incidents, and do not result in injuries or aircraft damage, we cannot count on fortune to prevent another deadly accident.

While the COVID-19 crisis has slowed air traffic, the industry is optimistic about recovery and return to the growth in air traffic we have seen over the past decade. With this growth comes the potential for more runway incursions. Therefore, we must develop better ways of preventing incursions. Runway incursion incidents are one way to learn more about how we can prevent similar incidents in the future and reduce the probability of serious accidents. Unfortunately, most incident reports lack detailed information on the causes of runway incursions. In the United States, trained investigators at the National Transportation Safety Board investigate aviation accidents, but not most incidents, including incursions. Air traffic controllers on duty at the time of incursion report the incident to the FAA. While most controller reports explain what happened, they often do not explain why the incident happened. We need deeper insight into why incidents occur so that we can develop more effective measures to reduce incursions.

After controllers submit their incident reports, reviewers at the FAA go through the controller-generated reports and determine the need for further investigation. They may contact the controllers for more information or talk to the pilots involved. This research considers one aspect of the reporting process — the reporting form. The research hypothesis is that an alternative reporting form that asks detailed questions and guides the controller to look deeper into an incident can provide more details on human error and causes of these errors than the current form, which does not necessarily prompt controllers to gather all the details of the incident.

The design of the alternative reporting form is based on the theoretical framework of expert systems. Expert systems, which provide tailored questions and guidance to medical doctors and others, have proven useful in other fields. The resulting alternative tool aims to guide controllers into answering three major questions: what happened (which aircraft were where, and when), how

it happened (e.g., controller gave the wrong instruction), and why it happened (e.g., controller was fatigued).

To investigate how controllers interact with different reporting formats and what helps them or detracts them from creating useful reports, the research experiment involved controllers reporting two hypothetical runway incursions either using the alternative reporting tool or an online survey based on the current FAA form. The experiment used surveys, think-aloud protocols, observations, and interviews to collect data on what controllers included in their reports and how controllers generated these reports. The findings helped compare the type of information we get from the two reporting formats, and how the reporting formats affected the quality of the incident reports.

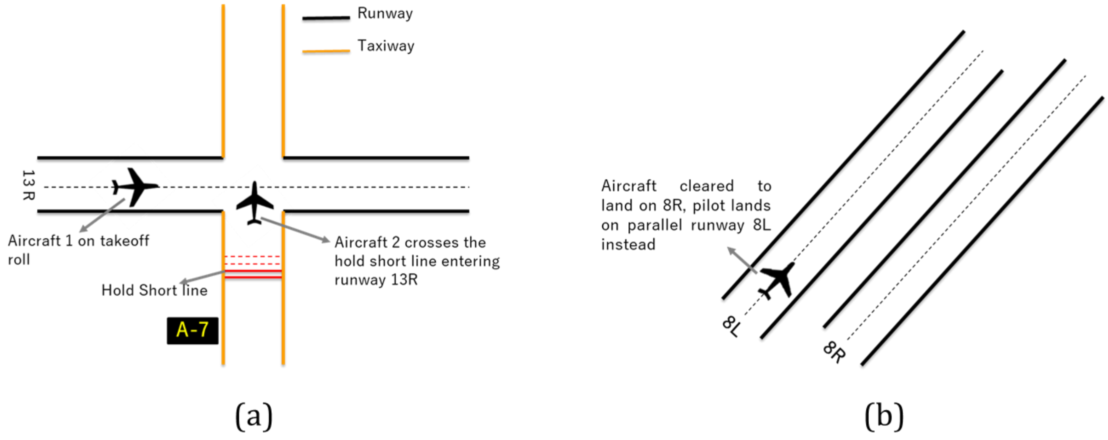
Overall, the alternative tool-generated reports provided more information than the online survey based on the current FAA form. Each controller who participated in the experiment approached preparing an incident report differently and different factors motivated them to specify details of the incident. While the format of the alternative reporting form helped one controller talk to the pilot and learn more about why the pilot made an error, the format did not have the same impact on another controller.

This research identifies ways of helping controllers prepare more useful reports. This research may help the FAA improve data collection. More useful reports in the future can help the aviation community identify the cause of human errors leading to incursions, and develop more effective mitigation strategies, ultimately saving lives.

1. INTRODUCTION

The increase in number of runway incursions over the last five years presents a threat to runway safety. The runway incursion that occurred between two Boeing 747s about 40 years ago at Tenerife is still the most deadly accident in aviation history. The FAA defines a runway incursion (RI) as the incorrect presence of an aircraft, vehicle, or person on the protected area of the airport surface designated for the landing and takeoff of aircraft (FAA, n.d.-b). The FAA limits this definition to incursions occurring at towered airports, likely because data is easier to obtain from airports with formalized control and safety structures (Thomas, 2002). At non-towered airports, runway transgressions occur when an aircraft, vehicle, or pedestrian enters an active runway, irrespective of whether a loss of separation from another aircraft occurs (ASRS, 2003).

Figure 1 shows two examples of runway incursions. Figure 1(a) shows a more serious runway incursion than Figure 1(b). In Figure 1(a), if Aircraft 1 is unable to abort takeoff, the chances of a collision are high. In Figure 1(b), there may be no serious consequences to the pilot's incorrect landing if there are no other aircraft in the vicinity.



(a) (b)

Figure 1. Two examples of runway incursion incidents: (a) the incursion occurs because Aircraft 2 entered onto the active runway, (b) the incursion occurs because the aircraft landed on a runway other than the authorized one.

Runway incursions are a decades-old and continuing problem. In 1983, a runway collision between two commercial airliners in Madrid, Spain, killed ninety-two people (Burns, 1983). In 1990, a Boeing 727 collided with a DC-9 in Detroit, Michigan, resulting in eight deaths and twenty-one injuries (Walsh & McAllister, 1990). In 1991, thirty-four people were fatally injured when a Boeing 737 landed and collided with a commuter aircraft on a runway at Los Angeles International Airport (NTSB, 1991). In 2000, a Boeing 747 took off from a closed runway in Taiwan, killing eighty-two people when it collided with ground equipment (Thomas, 2002).

On average, at least four runway incursions occur each day in the United States (FAA, n.d.- c). This number only represents the reported incursions at towered airports. It is highly likely that many incidents go unreported because the controllers or pilots do not realize that a runway incursion has occurred. While most of these incursions do not result in injuries or damage, given different circumstances, they could have been serious accidents. (Barnett et al., 2000) conducted a study in 2000 where they predicted that given the frequency of runway incursions, there is a potential of a catastrophic runway collision that could kill 700–800 people and seriously injure 200 others by 2022. While the decline in air traffic due to COVID-19 may have rendered these predictions incorrect in the short term, we can expect that as traffic returns to its previous levels, the risk of incursions will also return.

The FAA has implemented several measures to reduce runway incursions, such as raising awareness and improving training. For example, the FAA has mandated twice yearly recurrent runway safety training for air traffic controllers. The FAA also works with pilot associations to design training material that raises awareness about current runway safety issues (FAA, 2018a).

The FAA is improving infrastructure through better signage, markings, and lightings. For example, the FAA developed Runway Status Lights (RWSL) to reduce the severity and number of incursions. RWSL comprises of Runway Entrance Lights (RELs) and Takeoff Hold Lights (THLs) and does not interfere with other airport operations. At present, twenty airports in the U.S. are operating with this technology (FAA, 2020).

The FAA is also implementing systems that enhance surface movement detection to increase the situational awareness of pilots and controllers (FAA, n.d.-a). For example, about thirty-five major airports in the U.S. have or will receive ASDE-X. Airport Surface Detection Equipment, Model X (ASDE-X) provides detailed coverage of runways and taxiways. Air traffic controllers can use the displayed information to track aircraft movement and spot potential conflicts, especially when visibility is poor (FAA, 2010a). However, despite these and other efforts, the number of runway incursions has not abated as intended (COVID-19 downturn excepted).

Analysis of historic accident and incident data shows that human error contributes significantly to runway incursions. The FAA classifies the source of a runway incursion as controller error, or an error on the part of a pilot, vehicle driver, or pedestrian. While historic data can help us identify the types of errors humans make, researchers are still not fully aware of the specific causes of such human errors in each case (Beasley, 2017). Like other aviation incidents, runway incursion incidents are not generally investigated with the same rigor or detail as accidents, partly because they tend not to evoke the same images of danger or disasters (Madsen et al., 2016). In one of the NTSB's forums on runway safety issues, members of the board emphasized the importance of more human factors-related data, and how this data is critical to prevent runway incursions (Werfelman, 2017). Understanding what human errors lead to runway incursions, and why humans make these errors, can help the FAA and the aviation community allocate resources to prevent such errors (Torres et al., 2011).

Researchers have analyzed past runway incursion accidents and incidents including those recorded in four publicly accessible databases: (1) the National Transportation Safety Board's (NTSB) Aviation Accidents and Incidents database, (2) NASA's Aviation Safety Reporting System (ASRS), (3) the FAA's Accident and Incident Data System (AIDS), and (4) the FAA Office of Runway Safety's RWS database. These researchers pointed out that the incident reports in the RWS database do not often provide information on why the runway incursion occurred. Despite the RWS database having a significantly higher number of incident reports than other databases, these reports were the least helpful in analyzing the underlying causes of runway incursions. For example, pilot error is cited in a majority of incursions recorded in the RWS database, but only a handful of reports explain why the pilot erred. These less rigorous or less detailed reports are a missed opportunity for learning. Learning from incidents plays a major role in improving safety, and researchers have stated the need for enhanced data collection (Beasley, 2017; JSAT, 2000).

In the United States, runway incursion accidents and selected runway incursion incidents are investigated by trained investigators, and recorded in the NTSB database. Most accident reports in the NTSB database are well structured, providing a general description of the accident, findings of the investigators, and recommendations to improve aviation safety (Sarsfield et al., 2000). The quality of commercial aviation accident investigations is a major reason for the significant improvement in aviation safety over the past half-century (Oster et al., 2013). The information gained from these investigations has improved safety by highlighting what went wrong in the past and what needs to be done to prevent similar accidents in the future.

Given that runway incursions are mostly non-serious incidents or near-misses, they do not generally get the attention of the trained investigators at the NTSB. At towered airports in the United States, air traffic controllers on duty at the time of incursion are required to report the incursion to the FAA Office of Runway Safety's RWS database. The controllers fill out a reporting form, in which they describe what happened during the incursion. Based on this narrative, the reviewers at the FAA decide whether to investigate the incident further. The controllers who report these incidents, unlike the investigators at the NTSB, may not have the training or resources to conduct in-depth investigations and report all the underlying contributing factors.

The reporting process starts with the air traffic controller filling out an FAA reporting form, also known as a Mandatory Occurrence Report (MOR). The form first asks general information such as the date and time of the occurrence, the role of the controller at the time of occurrence, and whether the occurrence is a significant occurrence. Then the form has different sections asking questions pertaining to a particular type of occurrence. For example, in the section on 'Surface Separation' MOR, the form asks where the loss of separation occurred, which entities (aircraft, vehicle, or pedestrian) were involved and details of those entities. These questions are objective in the manner that they only ask for identifiable information of the aircraft, vehicle, or pedestrian involved. Finally, the form has an open-ended question asking the controller to describe the incident in their own words. This open-ended question may not prompt them to look deeper into the incident. Improving the reporting form may be one way to improve the quality of reports. In my research, I aim to answer the following questions:

- Does the format of the reporting form affect the quality of air traffic controller-generated runway incursion incident reports?
- How do controllers interact with different reporting formats and what perspectives do they have while reporting a runway incursion incident?

I created an alternate reporting tool that asks air traffic controllers specific questions to help identify human error and its contributing factors. The reporting tool is based on the concept of expert systems, which are computer-based systems that provide tailored questions and guidance to non-expert users in a domain. To answer my research questions, I designed an experiment where air traffic controllers reported two hypothetical runway incursion incidents either using my reporting tool or an online form based on the FAA reporting form.

This document is laid out as follows: Chapter 2 presents the literature review, Chapter 3 assesses the current reporting system and discusses the weaknesses in the controller-generated runway incursion incident reports. Chapter 4 describes the process of designing the alternative reporting form. Chapter 5 lays out the experiment design, Chapter 6 discusses the results of the experiment, and Chapter 7 concludes the research and lays out the future work.

2. LITERATURE REVIEW

Investigations of accidents have contributed significantly to improving aviation safety. With runway incursions mostly being near-misses or incidents rather than catastrophic accidents, the aviation community must focus on proactively learning from these incidents. This Chapter describes previous work on analyzing causes of runway incursions, why learning from incidents is important, and what systems can help novice users such as air traffic controllers investigate runway incursion incidents.

2.1 Human error in past RI accidents and incidents

One of the reasons for the increase in number of runway incursions is that the aviation community does not fully understand the causes of human error that led to the incursion. Analysis of historic accident and incident data shows the types of human error that lead to runway incursions.

Bellantoni & Kodis (1981) examined 166 runway incursions recorded in the NTSB and ASRS databases[1]. 47% of the incursions were due to controller error, 35% were due to pilot error, 13% were due to controller or pilot error, and 5% were due to other factors such as equipment or airport layout. 82% of controller errors involved controllers issuing conflicting clearances. Pilots most frequently (50%) erred by proceeding without a clearance. Other errors include pilots being lost or disoriented, not following instructions, or not seeing and avoiding other traffic.

In 1986, the NTSB conducted special investigations on 26 runway incursions (NTSB, 1986). Although not necessarily statistically representative, the NTSB argued that the factors involved in these 26 incursions were indicative of causal factors in other incidents. Staffing issues, specifically the absence of supervisors to monitor and assist other controllers, contributed to controller error. Other issues included lack of coordination between the ground and local control, forgetfulness, boredom, and inadequate scanning of runways. Some of the incursions could have been avoided if the pilot paid more attention to radio communications, used proper radio phraseology, or scanned the runway before entering.

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[1] The 166 runway incursions include incursions recorded in the NTSB database between January 1, 1964 and December 31, 1978, and in the ASRS database between July 1, 1976 and June 30, 1978.

Difiore et al. (2006) analyzed 300 ASRS reports of airport surface movement events at the 34 busiest airports in the United States, submitted by pilots between May 2001 and August 2002. 35% of the analyzed reports involved the pilot crossing the hold short line without authorization. In 40% of these cases, the pilot inadvertently crossed the hold short line without realizing they were doing so.

Cardosi et al. (2010) analyzed incursions between 2000 and 2002 and pointed out some of the errors made by air traffic controllers, pilots, and vehicle drivers. They found that memory lapses, for example, forgetting about an airplane, were a common error among air traffic controllers. Some of the common errors that pilots made were incorrect readback of instructions and not being aware of their position or the surrounding area. Vehicle drivers most often erred by not contacting the ATC before moving onto a controlled surface.

Torres et al. (2011) examined 300 runway incursion reports recorded in the ASRS and the NTSB database. They performed analyses to support their hypothesis that there is a significant statistical relationship between human factor errors and runway incursions. They found that 34% of the reports cited lack of situational awareness, 27% of the reports cited miscommunication, and 16% of the reports cited distraction as a contributing factor.

2.2 Learning from RI incidents

Researchers who used the RWS database to understand runway incursions stated that the incident reports were not helpful in their analysis of determining the root causes. For example, the Commercial Aviation Safety Team (CAST) and the General Aviation Joint Steering Committee (GAJSC) formed a Runway Incursion Joint Analysis team (RI JSAT) to review and analyze runway incursion accidents and incidents to develop strategies that may reduce the potential of runway incursions. The team of researchers used these reports to develop event sequences and determine root causes. Out of the 21 pilot deviations in their dataset, they had to discard nine, since these reports did not contain enough information to develop event sequences. Of the remaining twelve, they had to additionally depend on the team's collective experience to describe what happened. They could not find any useful information in the reports on vehicle or pedestrian deviation (JSAT, 2000). (Cistone, 2014) used the HFACS (Human Factors Analysis and Classification System) framework to find root causes of past runway incursions and pointed out that the RWS reports did not contain enough information to perform this analysis. (Cardosi et al.,

2010) analyzed past runway incursion incidents and stated that the incident reports rarely included information as to why these errors occurred.

While it is fortunate that runway incursions today are mostly near-misses or incidents, they are also a missed opportunity for learning because trained investigators do not generally investigate these incidents. The ‘common cause hypothesis’ suggests that the causes of incidents are almost identical to those for an accidents, and a thorough investigation of incidents can prevent catastrophic accidents. Ideally, the aviation community should focus on learning lessons from these ‘low-stakes’ incidents to improve safety in the same way it used ‘high-stakes’ accidents in the past (Griffin et al., 2016).

Dekker (2014) describes two views of human error. The first view, also known as the ‘bad apple theory’, states that the inherent unreliability of human operators introduces failures in the system. This theory assumes that complex systems are intrinsically safe and need to be protected from ‘bad apples’ or unreliable human operators. The second view, or the new view, states that complex systems are not intrinsically safe and that the human operators have to create safety while working towards achieving the system’s goals. Investigating incidents in the new view where human error is the starting point of an investigation rather than the conclusion, can help the aviation community identify and address causes of runway incursions.

2.3 Expert Systems for RI Incident Reporting

Aviation accident investigation is a complex task that requires investigators to have a high level of technical skill and knowledge in the domain (Nixon et al., 2018). Furthermore, investigating causes of human error is generally not an easy task as the analysis techniques used for human factors investigation are less refined than for those to investigate, for example, a mechanical failure (Wiegmann et al., 2003). Not surprisingly, air traffic controllers who report runway incursion incidents and may not be trained investigators do not necessarily know how to gather all the details of the incident.

Trained investigators at the NTSB typically interview personnel involved in the accident or incident or any witnesses. The investigators are trained to ask questions that will help them identify the root causes of the accident or incident. Air traffic controllers may not necessarily know where to begin the investigation. Research on computer-based procedures for data collection aims to develop software programs that can replace the trained interviewer, in our case an investigator

(Saris, 1991). These programs select and display frames or scripts based on the input from the user. For example, the program might ask the air traffic controller to input the phase of flight of the aircraft at the time of the incident. Based on the controller's input, it asks questions pertaining to that specific phase of flight. Computer-based interviewing techniques can ensure that specific sets of questions are always asked in specific situations (Johnson, 2002). The requirements of such a computer-based program are that it asks appropriate questions, displays answer categories and instructions, store responses, and branch to the next question based on the entered responses (Saris, 1991).

Developing such programs for incident reporting requires knowledge from experts who can go beyond just identifying human error to identifying causes of these errors. Expert systems, a type of knowledge-based systems, are systems that can offer expertise to novices in a domain to solve specific problems (Lucas et al., 1991). Industries in multiple domains have used expert systems for system design, monitoring and fault diagnosis (Puppe, 1993). Expert systems may help air traffic controllers draw on the expertise of trained investigators to look deeper into an incident and create information-rich reports. Expert systems consist of three main components: (1) knowledge base, (2) inference engine, or a set of rules that represent the knowledge base, and (3) the graphical user interface. The knowledge base contains all the knowledge and facts about the expert system domain. The inference engine executes actions based on the user's input that fulfills specific conditions. The user interacts with the interface, answers questions that start the logical process of the inference engine (Liebowitz, 1995; Ozden et al., 2016).

In my research, I use the theoretical concept of expert systems to create a computer-based program, i.e., an alternative reporting tool, to help controllers look deeper into an incident and consider creating information-rich reports we can learn from. The knowledge base for the alternative reporting tool consists of elements of a good incident report, characteristics of runway incursions, and lessons learned from past accident and incident data. The inference engine for the reporting tool is a set of decision trees and questions based on runway operations and

Various industries that have developed approaches to help investigate and report accidents and incidents in safety critical systems. The Royal Society for the Prevention of Accidents in the U.K. highlights some underlying principles that are useful to understand and follow when investigating an incident. The society suggests that the investigator must gather data that can answer the *what* and the *why*. The *what* encompasses the sequence of events leading up to the incident and the errors or violations that occurred leading to the incident. The *why* identifies the underlying causes for each error and violation. To analyze *why* the incident occurred, they suggest using accident models such as AcciMap, fish-bone diagrams, or fault tree analysis (RoSPA, 2015).

In the mining industry, Colin (2017) suggests reconstructing the incident, and then conducting a back analysis to learn the reasons the incident occurred. They summarized the reasons into three categories: (1) direct causes, or what prompted the incident, (2) indirect causes, or what events contributed to the direct cause of the incident, and (3) root causes, or what safety measures would have prevented the incident from occurring.

In the health care industry, Mahajan (2010) lists the elements of an investigative process. The author suggests that interviews with key staff members after an incident should aim to determine what happened in terms of chronology of the events, how it happened in terms of important acts or omissions made by the staff, and finally elicit why these acts or omissions occurred.

In the aviation industry, investigators at the NTSB use the Aviation Investigation Manual – Major Team Investigations as a guide in collecting evidence, holding public hearings, and preparing the final report for an accident. While the manual provides some technical information related to investigative activities, it primarily focuses on procedural or administrative guidance. The manual refers investigators to the ICAO Manual of Aircraft Accident Investigation for technical information and illustrations of investigative techniques (NTSB, 2002). The manual has four parts: organization and planning, procedures and checklists, investigation, and reporting. The part on investigation provides guidance on investigating aspects such as aircraft operating environment, aircraft structures, or aircraft systems. The aspect most applicable to our framework is investigating human factors. Figure 2 shows the seven-step process for investigating human factors. The data gathered through this process is consistent with the guidelines from other industries described in this section. The primary focus remains on creating a sequence of events, identifying errors, and finding the causes of these errors.

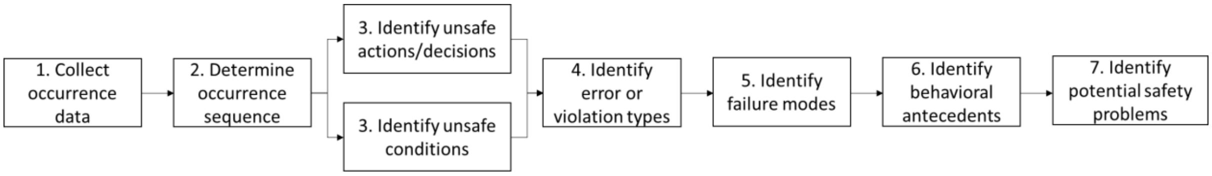

Figure 2. Process for investigating human factors-related data in accidents and incidents. Adapted from ICAO's Manual of Aircraft Accident Investigation.

To identify the characteristics of runway incursions and lessons learned from past accidents and incident, I assessed the current reporting system. I analyzed narratives of runway incursion accidents and incidents from three databases to identify how and why incursions occur. I also identified the weaknesses in the current incident report which motivated the design of the reporting tool. Section 3 gathers information for the knowledge base of the alternative reporting tool and Section 4 describes the questions and logical processes that form the inference engine. Section 4 also describes the user interface.

3. ASSESSMENT OF THE CURRENT REPORTING SYSTEM

Runway incursion incidents and accidents are investigated by different groups and recorded in several different databases. The NTSB investigates all runway incursion accidents and major incidents and records them in the NTSB database. FAA Inspectors also investigate some aviation accidents, as well as incidents that are not investigated by the NTSB, and record them in the Accident/Incident Data System (AIDS). Since 2001, the FAA has been recording runway incursion incidents in the RWS database. Air traffic controllers are responsible for reporting incidents to the FAA. The FAA reviews these reports and records the runway incursion incidents in the RWS database. Based on the information provided in these reports, investigators at the FAA or the NTSB might consider investigating the incident further (Cistone, 2014). Although the number of incursions has been increasing each year (until the COVID-19 air traffic downturn), the severity of most of these incursions is not high. Consequently, trained investigators at the NTSB or the FAA do not generally investigate these incidents. Table 1 shows the sources of data in these three databases.

Table 1. Some of the publicly available databases that contain records runway incursion accident and incident data (GAO, 2010). The FAA implemented the RWS database in 2001 to record all runway incursion incidents at towered airports.

Database	Source of Data	Data collected
National Transportation Safety Board Aviation Accident and Incident Database **(NTSB)**	NTSB Investigators	Aviation accidents and major incidents
Accident/Incident Data System **(AIDS)**	FAA Inspectors	Some aviation accidents and those incidents not investigated by the NTSB
FAA Runway Safety Office’s Runway Incursions **(RWS)**	Air Traffic Controllers	Runway incursion incidents

Researchers in other industries identified factors that affected incident reporting in their domain. For example, research in the healthcare industry focusing on how doctors and nurses report incident and their attitudes towards incident reporting resulted in strategies to improving incident reporting (Kinsgton et al., 2004). Clarke (1998) investigated factors affecting incident reporting among train drivers. In the aviation industry, there is limited literature on how controllers complete the reporting process for runway incursion incidents, or their attitudes towards the process and forms. That work is summarized here. Cistone (2014) gives a high-level view of the review and entry process of incident reports in the RWS database, but we still lack a deeper understanding of the reporting process with sufficient detail to explain the lack of details in the incident reports. In this chapter, I describe the current runway incursion incident reporting system and the role of the air traffic controller in this system. I then compare a sample of reports from the RWS database to investigator-generated reports from the NTSB and AIDS database and identify weaknesses in the controller-generated reports

3.1 Reporting System for the RWS Database

Figure 3 shows the reporting system for the RWS database.

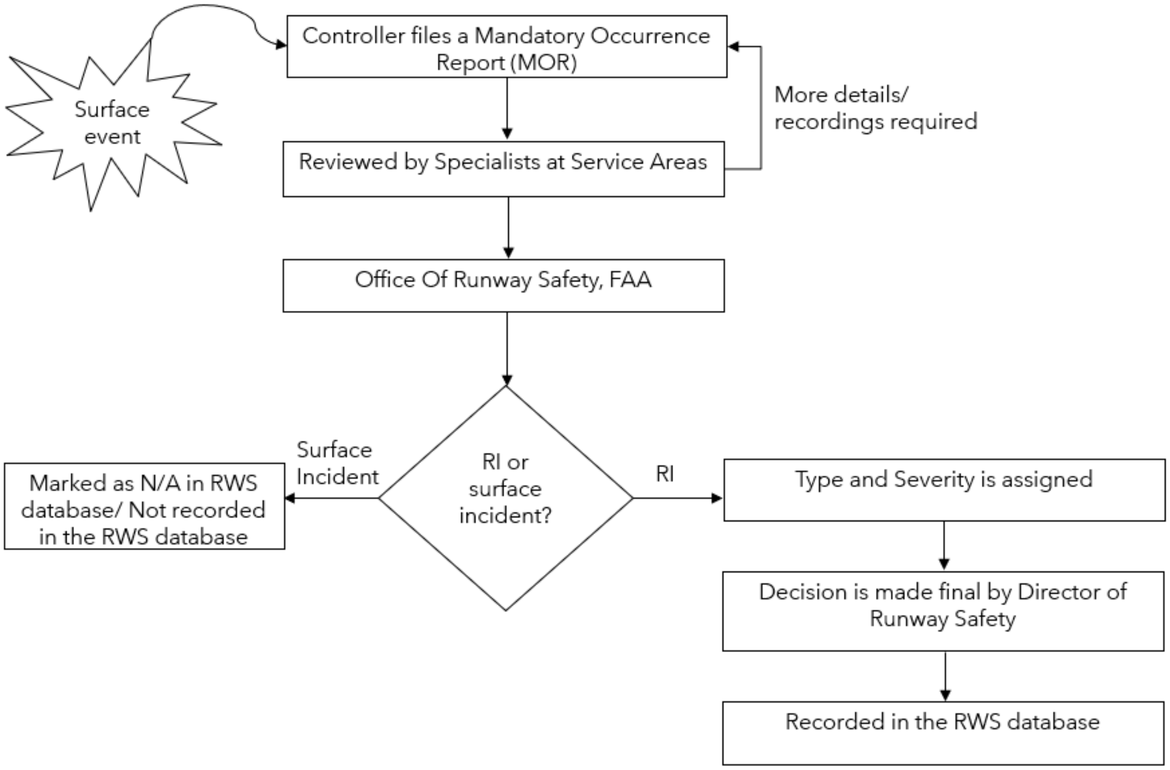

Figure 3. The flow chart shows the reporting system for the RWS database. In case of a surface event, the controller fills out an MOR, which specialists then review. After the FAA assigns a source of the incursion and a severity category, the incident reports get recorded in the RWS database.

When a runway incursion occurs at a towered airport, the air traffic controller on duty must report the incident to the FAA. The controller fills out a Mandatory Occurrence Report (MOR), which concerned FAA authorities, such as the Air Traffic Organization (ATO), then review and determine whether there is a need for a deeper investigation. Then, the Office of Runway Safety reviews the report and classifies it as a surface incident or a runway incursion. For example, a collision on the runway would be a runway incursion, but a collision on the ramp would be a surface incident. At the end of the process, in case of a runway incursion, it is classified as an operational error, pilot deviation, or vehicle-pedestrian deviation as described in Table 2. Surface events are recorded in the FAA Incident Database, along with all other incidents.

Table 2. The FAA's classification of the sources of runway incursions and an example for each (FAA, n.d.-b).

Source of RI	**Description**	**Example**
Operational Incident	Incidents due to the action of the ATC	ATC clearing an aircraft to land on a closed runway
Pilot Deviations	Action of a pilot which violates any FAA regulation	Pilot of a taxiing aircraft crossing a runway without clearance
Vehicle/Pedestrian Deviations	Vehicles or pedestrians entering into a movement area without clearance from ATC	A ground vehicle enters onto an active runway without contacting the ATC

The Director of Runway Safety confirms the source of the incursion and finalizes the severity ranking (see Table 3). This preliminary determination and classification of surface incidents is made final after 90 days, unless the incident requires a second review, in which case the Office of Runway Safety may collect more information about the incident, such as recorded tapes of communication between the pilot and controller.

Table 3. Runway incursion severity categories and their description. The FAA follows certain criteria to categorize incursions in one of these severity categories (FAA, 2010b).

Category	Description
A	A serious incident in which a collision was narrowly avoided.
B	An incident in which separation decreases and there is a significant potential for collision, which may result in a time-critical corrective/evasive response to avoid a collision.
C	An incident characterized by ample time and/or distance to avoid a collision.
D	An incident that meets the definition of a runway incursion such as an incorrect presence of a single-vehicle/person/aircraft on the protected area of a surface designated for the landing and take-off of aircraft but with no immediate safety consequences.
E	An incident in which insufficient or conflicting evidence of the event precludes assigning another category.

In my research, I focus on the air traffic controller and their role in the reporting process. To identify opportunities for improvement in the reporting system, I interviewed air traffic controllers to gain insight into their role in the reporting process. I asked them to identify what forms they use for reporting incursions, their experiences using the form, and their opinions on it. Additionally, I asked controllers how they view incident reporting and the factors they consider while reporting the incidents.

3.2 Interviews with Air Traffic Controllers[2]

I developed a semi-structured interview with a list of 17 questions (see Appendix A). The questions focus on three areas: (1) what kinds of forms controllers use; (2) what happens after the controllers submit the reporting form, that is, who reviews or investigates the incident; and (3) the controllers' experience using the form, and their opinions on it. The semi-structured format allowed the controllers to be more descriptive in their responses and allowed me to ask follow-up questions. After obtaining approval from Purdue University's Institutional Review Board (IRB), I requested permission from three airports in Indiana to talk to their controllers. I received written confirmation from one of these airports and interviewed four controllers in person. The controllers I interviewed were in positions where they were either in charge of reporting events or in managerial positions where they reviewed the reporting of events or assisted in the investigation of events. I interviewed each controller in person and each interview lasted for about an hour. I

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[2] This section is based on our paper "Understanding Current Ways of Reporting Runway Incursion Incidents at Towered Airports" presented at the 20th International Symposium on Aviation Psychology (ISAP) in 2019.

took notes while talking to the controllers and did not record any identifiable information. The controllers were very descriptive in their responses and were happy to share their knowledge of incident reporting with me.

This subsection describes the process of filling out and submitting a Mandatory Occurrence Report (MOR), and the controllers' view on incident reporting and the reporting form. The FAA lays out the reporting requirements and controllers across the country use the same reporting forms. As a result, I do not suspect any significant changes in controllers' description of the reporting process itself if I were to interview more controllers. Opinions on its value may differ however. While all the controllers I interviewed considered incident reporting to be an essential tool to improve safety, other controllers might think differently. Similarly, controllers other than the four I interviewed, might have varied opinions on the current reporting form.

3.2.1 Submitting an MOR

The controller in charge (CIC) and the Air Traffic Manager (ATM) at one of our airports gave us an insight into the process for submitting an MOR. Overall, the details that the controllers provided on the process conform to the FAA guidelines. Controllers fill out a Mandatory Occurrence Report (MOR) using an online tool called CEDAR (Comprehensive Electronic Data Analysis and Reporting) to provide details of the incident. The FAA's guidelines mention that if controllers do not have access to CEDAR, they can fill out the FAA Form 7210-13, available online as a PDF, instead, and mail or fax the completed form to the FAA (FAA, 2012).

One of the controllers provided us with a flowchart that shows the steps involved in submitting an MOR. Figure 4 shows a re-creation of this flowchart. There are essentially three important aspects to filling out an MOR: (1) determining whether the event was significant, (2) selecting the type of MOR, and (3) specifying more details in case of a pilot deviation.

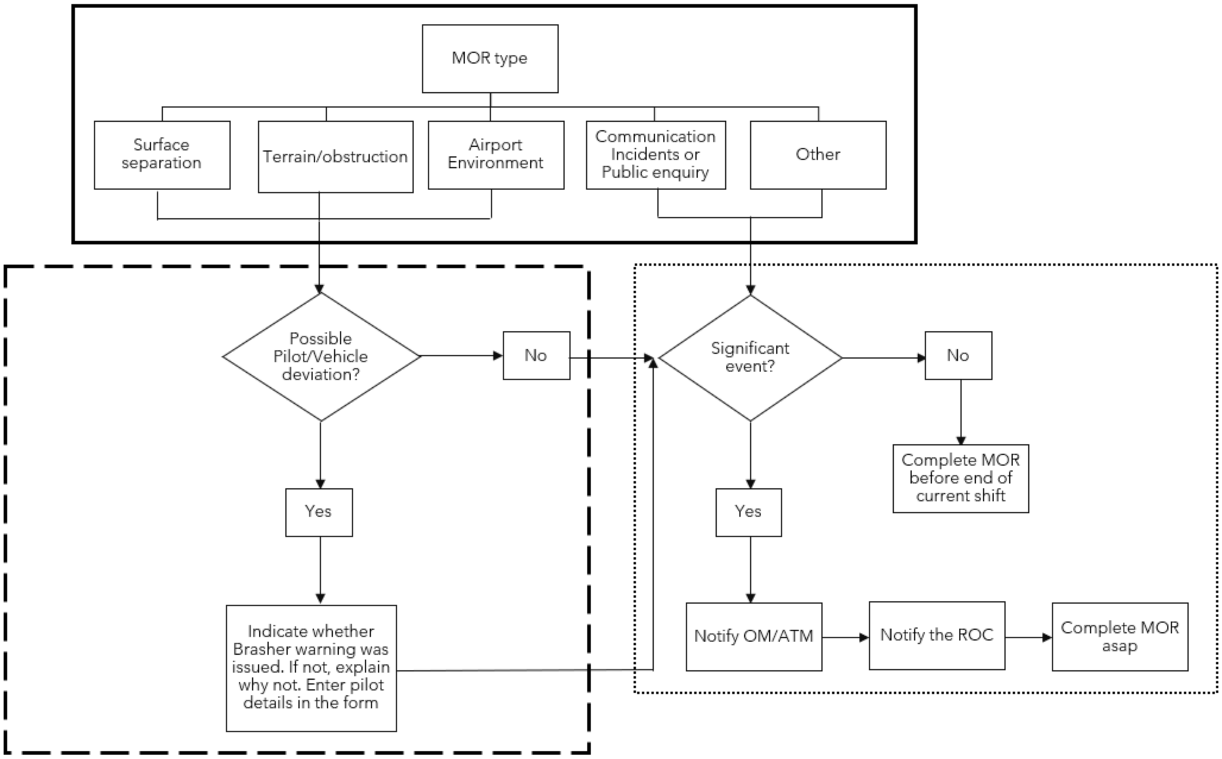


Figure 4. A re-created version of the Event Reporting Flow Chart. One of the controllers I interviewed printed out the original chart for me. The three boxes show three important aspects to filling out an MOR: (1) determining whether the event was significant, (2) selecting the type of MOR, and (3) specifying more details in case of a pilot deviation.

Question four on the form asks the controller to indicate whether the event was significant. The FAA gives a list of potentially significant events, such as security incidents, or when the separation between aircraft is less than 33% of the FAA separation standard. This list of events is not all-inclusive, and the FAA guidelines suggest that each situation should be considered based on individual circumstances. In case of a significant event, controllers must immediately report significant events to the CIC or their manager (ATM). The ATM will then inform the Regional Operations Center (ROC). ROCs are strategically placed across the United States and coordinate issues and programs that involve multiple FAA departments. The CIC mentioned that in case of a significant event, they would be calling a lot of people in managerial positions to notify them of the incident and answering a lot of questions related to the incident. The controller may fill out the form right away, make a note of the event and fill out the form later, or call another controller to take over while they fill out the form. In case of a significant event, the controller must report the incident using an MOR within an hour of the event. If the event is not significant, the controllers must complete the MOR before the end of their current shift. This timeline conforms to the FAA guidelines on MORs.

The next step involves determining the type of occurrence for which the controller is filing a report. For example, the MOR could be for a surface or airborne loss of separation. The details that the form asks the controllers for depends on the type of MOR they select. The online form has a drop-down menu with types of MOR. Table 4 lists the types of MORs in the form and their description.

Table 4. Types of MORs and their description (FAA, 2012)

Type of MOR	Description
Airborne loss of separation	Any suspected loss of radar separation involving instrument flight rules (IFR) aircraft, or visual flight rules (VFR) aircraft in Class B and C airspace, Terminal Radar Service Area (TSRA), or practice VFR approaches. Any suspected loss of separation involving formation flights or non-radar standards.
Terrain/Obstruction	Any suspected loss of separation between an aircraft and terrain or obstacles that the air traffic services provider deems to affect the safety of the flight.
Surface loss of separation	Any ground surveillance alert indicating loss of separation or any suspected loss of separation between an aircraft and another aircraft, or vehicle, or a pedestrian.
Airspace/Altitude/Route/Speed anomaly	Any instance in which an aircraft deviates from the expected airspace, altitude, routing, airspeed, or without a point-out or hand-off. Any instance where an aircraft operates at an altitude, routing, or airspeed that the air traffic services provider deems to affect the safety of the flight. Any instance where an aircraft enters a special use airspace without coordination or authorization.
Communication	Any instance in which there was no communication with an aircraft or communication was not maintained as expected/maintained.
Inquiry	Any concern expressed by external sources regarding loss of separation with an aircraft, either airborne or surface, including near midair collision notifications from a flight crew.
Emergency	Any instance involving hazards such as medical emergencies, equipment malfunction, bird strike, pilot disorientation, hijacking, or bomb threat.
Airport environment	Any runway incursion or runway excursion.

Next, the controllers reporting the incident need to consider whether it was a possible pilot or vehicle deviation. Sometimes, the controller may talk to the pilots involved to find out their side of the story. In case of a pilot deviation, the controllers must give details of the pilot such as their name and their license number for further investigation and specify whether a Brasher Warning was issued to the pilot. A Brasher warning is issued to the flight crew instructing them to make a note of the occurrence and collect their thoughts for future coordination with Flight Standards regarding enforcement actions or operator training (FAA, 2012). If the controller did not issue this warning, they need to explain why they did not.

In the end, the form asks the controller to provide a brief summary of the incident. It suggests the controller to provide enough information for the Quality Assurance department to understand what happened.

3.2.2 After Submitting an MOR

Figure 5 shows an overview of what happens after the controller submits the MOR. The ATM explained that controllers submit the MOR to the service center (East, West, or Central) under which the airport falls. The department of Quality Assurance and Quality Control (QAQC) reviews the MORs and may contact the ATM for more details. They may ask for recordings of the communication between the pilot and the ATCS, interview the CIC, speak to the pilot, or ask the NTSB or third parties to get involved in the investigation. QAQC analyzes the reports to find trends or common contributing factors to events. They may issue an Internal Compliance Validation (ICV) to the ATM, recommending steps to reduce the frequency of unsafe events. The department of QAQC also does random checks to ensure that events are reported. For example, they may review ATSAP reports or pilot-submitted reports to check if a specific event is missing an MOR. In such cases, the controller could lose their job for not reporting the event.

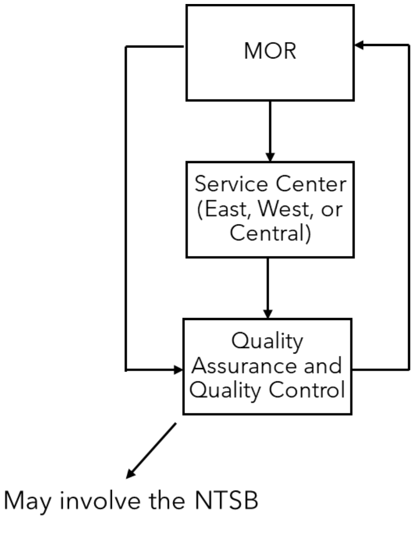


Figure 5. Overview of the process after submitting an MOR. The Service Centers and Quality Assurance and Quality Control (QAQC) review the reports and may contact the controller for more details. Based on the incident, the QAQC might involve the NTSB to look deeper into the incident.

3.2.3 Controllers’ Views on Incident Reporting

All the controllers agreed that incident reporting is important to maintain and improve aviation safety. They feel that reporting incidents will help prevent similar incidents from occurring in the future. They are of the view that reporting incidents may be the only way to become aware of unsafe events at small airports that do not have the equipment to track and record surface movements. In their opinion, the change in aviation’s safety culture with an emphasis on fixing systemic issues rather than punishing the culprit has motivated them to report incidents. They feel proud of reporting incidents, and thus, contributing to safer runways.

The controllers in managerial positions always supported the FAA in further investigations of an incident and followed the procedures. The biggest factor they consider in reporting is the significance of the event. Not surprisingly, they are more invested if the incident is significant and will look deeper into the underlying causes.

3.2.4 Controllers’ Views on The Reporting Form

One of the controllers stated that the MORs often help identify *what* happened, while the Air Traffic Safety Action Program (ATSAP) reports usually help to identify *why* it happened. ATSAP is a non-punitive program that encourages controllers to report incidents. The controllers felt that ATSAP has helped develop a strong safety culture among controllers. One of them said that ATSAP reports are often more detailed than MORs—one of the reasons being that the ATSAP form probes the controllers by asking additional related questions. The simple format of the MOR form may not necessarily encourage controllers to look deeper into the causes — something they are willing to do when asked more detailed questions.

By referring to the ATSAP reports, the personnel investigating the incident not only understand the incident better but can also identify any cases of under-reporting. For example, if the report submitted by the pilots is vague or the pilot’s account contradicts the controller’s, the investigators can contact the involved personnel to get more clarity on the event and raise awareness of such issues.

The controllers said that the list is quite extensive in terms of types of occurrences, and that the terminology used in the form is easy to understand. One of the controllers stated that non-significant events are quick and easy to report.

The controllers had varied opinions on the online MOR form. One said that the online form was better than the previously used paper form because it asks only those questions that pertain to the specific type of MOR selected. Another controller said that the form was user-friendly and easy to fill out. While these two controllers said that they do not dislike anything specific about the form, another controller said that the questions the form asks are too basic. They pointed out that the form lacks objectivity because it asks the controller to describe the incident in their own words. The controller said that with an open-ended question, the person filling out the form uses their discretion in reporting the details of the incident. This person may choose not to report certain facts if they think they are not significant enough. Additionally, the controllers filling out the form may be under time pressure, or busy at work, and hence may only report the bare minimum.

3.3 Evaluating RI Reports from the RWS Database

In this section, I analyze the runway incursion reports in the NTSB database, the AIDS database, and the RWS database to investigate what the controller-generated reports might be lacking in relation to investigator-generated reports. Since my research focuses on incident reporting at towered airports, I only analyzed past runway incursions that occurred at towered airports. Reports in all three databases include a narrative of some form describing the incursion. I analyze these narratives using a common coding system based on the elements a good accident or incident report should have. In this section, I describe my process of retrieving runway incursion data from the three databases, analysis of these reports, and the weaknesses in controller-generated incident reports.

3.3.1 Retrieving data from databases

In this section, I present my process of retrieving data from the NTSB, AIDS, and RWS databases. I was a part of *PEGASAS Project 20: General Aviation Runway Incursion* funded by the FAA. Our tasks involved analysis of runway incursions at towered airports involving at least one GA (Part 91) aircraft recorded in the NTSB and AIDS databases. We reported early aspects of this work in our final project report to the FAA, parts of which are repeated here (FAA, 2018b). The work here expands that analysis to include all runway incursions that occurred at towered airports —those that involved as well as those that did not involve a GA aircraft.

The NTSB uses a coding system to code its findings. To filter data from the NTSB database, I created a list of applicable codes, read the narratives of events that fell under the code, and used the FAA's definition to filter out the runway incursions. The AIDS database, unlike the NTSB database, has no coding structure for the causal factors. The AIDS search form has different ways of filtering data including filtering incidents based on the phase of flight of the aircraft involved and based on keywords that may be present in the narrative. I searched through the database using keywords and phases of flight applicable to runway incursions to filter reports. The RWS database contains runway incursions as well as some events that the FAA has not yet classified as incursions. The database also contains some events that are not runway incursions but are still recorded in the database. Some of these events include unauthorized movements on taxiways or runway excursions, where the aircraft veers off from the runway or overruns the runway. The FAA assigns each runway incursion a severity code (A, B, C, or D) and the search options in the database make it easy to filter the runway incursions from the non-classified events.

NTSB database

The NTSB (National Transportation Safety Board) Aviation Safety Database, managed by the National Transportation Safety Board, is the most comprehensive civil aircraft mishap database available. Trained NTSB investigators investigate accidents and selected incidents to find the causes or probable causes of these events. Analysts at the NTSB headquarters review and verify the reports submitted by the investigators. Senior management at the NTSB makes the final determination of findings and causes before they are recorded in the database (Murphy & Levendoski, 1989). Based on their findings, the NTSB makes recommendations to avoid similar accidents in the future. The database contains records of all commercial and general aviation accidents and selected incidents that took place in the United States since 1962. The database does not include accidents or incidents that involve military or public use (e.g., police planes, search-and-rescue planes) aircraft. The NTSB also investigates some accidents outside the United States; in such cases, while an entry is made in the database, the NTSB does not release the final report.

The NTSB database is publicly available from NTSB's official website. The NTSB database is an Access file with various tables, each providing specific details about the accident or incident. For instance, the 'Aircraft' table gives information about the involved aircraft's make and model, FAR part, airframe hours or any damage that was caused to it. Each accident or incident can be identified by a unique 14-digit event ID. The event ID is the common field across the various tables and is used to search for details across the database.

The NTSB uses a coding system to describe the findings from investigating accidents and incidents. The NTSB's coding manual describes the codes used in the database to describe the sequence of events in each accident or incident (NTSB Coding Manual, 1998). The NTSB changed its coding system in 2008. The coding manual describes the pre-2008 coding system, but there is no coding manual available for the new coding system. While the post-2008 coding system uses a code 'XXX320: Runway Incursion veh/AC/person' to designate a runway incursion, there is no specific code for runway incursions in the pre-2008 coding system. Thus, the post-2008 data, and the code 'XXX320', were a good starting point to retrieve runway incursion data. (Cistone, 2014) analyzed the NTSB database for data on airport surface deviations and formed a list of occurrence codes and phases of flight codes (in both the coding systems) that could be used to filter surface deviations. I used a subset of these codes to filter out runway incursions. For example, while Cistone (2014) considered codes that describe collision of aircraft with an object, or a collision between two aircraft at the ramp area, I excluded such codes because the FAA's definition of runway incursion does not involve collision with object, or collision on a surface other than one designated for takeoff or landing. Tables 5-9 show the complete list of occurrence and phase of flight codes I used for the pre-2008 and post-2008 coding systems.

Table 5. Occurrence codes used to filter events in the NTSB's Pre-2008 coding system, and their description.

Code Number	Description
100	Abrupt Maneuver
220	In flight collision with object
271	Collision between aircraft (other than mid air)
280	Near collision between aircraft
310	On ground/water collision with object
430	Miscellaneous/other

Table 6. Phases of flight codes used to filter events in the NTSB's Pre-2008 coding system, and their description.

Code Number	Description
510	Taxi
512	Taxi – to takeoff
513	Taxi – from landing
520	Takeoff
521	Takeoff – roll/run
523	Takeoff – aborted
570	Landing
571	Landing – flare/touchdown
572	Landing – roll
573	Landing – aborted

Table 7. Modifier codes used to filter events in the NTSB's Pre-2008 coding system, and their description.

Code Number	Description
2520	Vehicle
2502	Aircraft moving on ground
2513	Other person

Table 8. Event codes used to filter events in the NTSB's Post-2008 coding system, and their description.

Code Number	Description
XXX320	Runway Incursion veh/AC/person
XXX070	Airport Occurrence
XXX100	Air Traffic Event
XXX200	Ground Collision
XXX260	Near mid air Collision
XXX270	Abrupt Maneuver
XXX490	Collision during takeoff/landing
XXX900	Miscellaneous/ Other

Table 9. Phases of flight codes used to filter events in the NTSB's Post-2008 coding system, and their description.

Code Number	Description
250XXX	Taxi
251XXX	Taxi to Runway
252XXX	Taxi into position
253XXX	Taxi – From runway
300XXX	Takeoff
301XXX	Takeoff – Aborted
550XXX	Landing
551XXX	Landing Flare/Touchdown
552XXX	Landing - Roll

Figure 6 shows the process of filtering accidents and incidents recorded using the pre-2008 coding system to find runway incursions that occurred at towered airports. The number in red indicates the number of events at each stage.

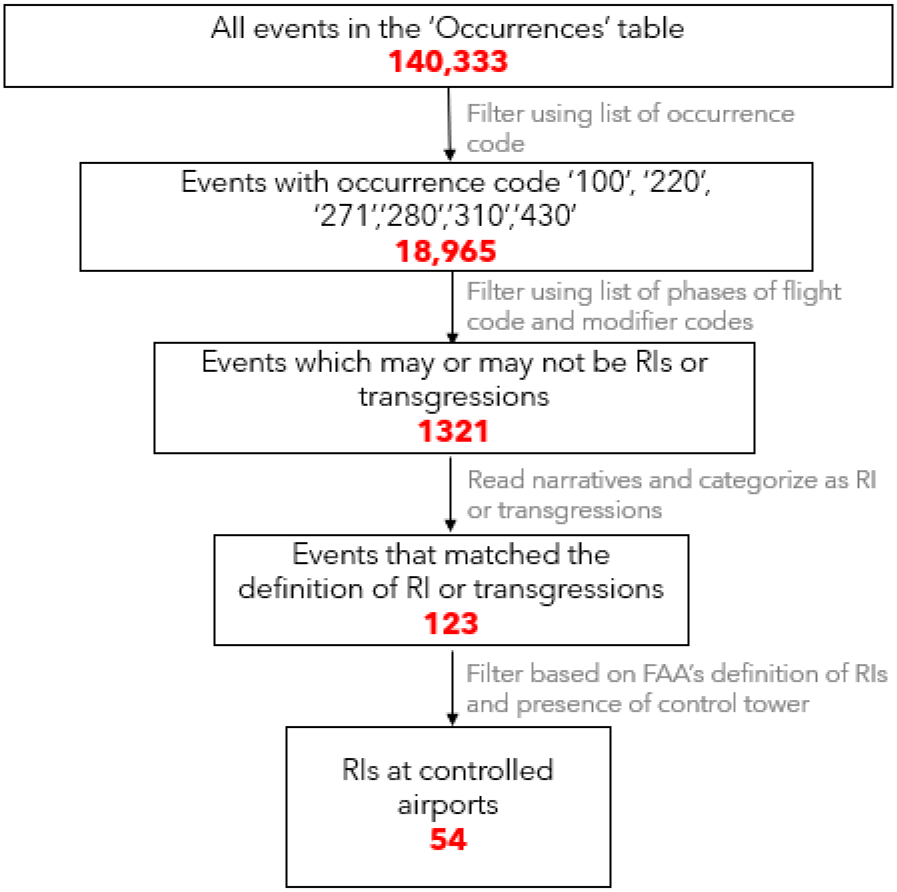


Figure 6. Process to filter RIs in the NTSB database in the pre-2008 coding system. At the end, I had a set of 54 runway incursions that occurred at towered airports.

In the Pre-2008 coding system, the ‘Occurrences’ table gives information of the type of event and the phase of flight. First, I filtered down the 140,333 events in the pre-2008 coding system to 18,965 based on the list of occurrence codes. Then I filtered these events based on the phase of flight code. For events under the code ‘220: in flight collision with object’ and ‘310: on ground/water collision with object’, I filtered the events using the modifier codes for vehicle, aircraft, and person. These modifier codes specify that the collision occurred either with a vehicle, aircraft or other person, which is in line with the FAA definition of runway incursion. Thus, I had a set of 1321 events that could be runway incursions that occurred at towered and non-towered airports.

I read the narratives of each of these 1321 events to determine if they were runway incursions or transgressions. Out of these 1321 events, I found that at least 123 events matched the definition of a runway incursion or transgression. The database does not specify whether the airport where the event occurred was towered or not. Therefore, we used the ‘Events’ table and the ‘Aircraft’ tables to find the airport name or airport ID to find the location. Then we searched these airports at www.airnav.com to determine whether they were towered or not. As a result, I found 54 runway incursions that occurred at towered airports.

Figure 7 shows the process of filtering accidents and incidents recorded using the post-2008 coding system to find runway incursions that occurred at towered airports. To begin, I considered the ‘Events_Sequence’ table in the database. This table gives the occurrence code. The occurrence code identifies *what* happened, and the phase of flight. Next, I filtered all the events in the ‘Events_Sequence’ table using the list of ‘eventsoe_no’ that describes the type of occurrence (e.g., ‘320’ describes runway incursion, ‘070’ describes airport occurrence). As a result of the filtering, I had 1606 events. Next, I kept all events under the ‘eventsoe_no’ except for occurrence code ‘XXX270: Abrupt maneuver’ and ‘XXX900: Miscellaneous/other’. For events with these codes, I checked the phase of flight code and only kept those events that occurred in a phase of flight relevant to runway incursions. Table 9 shows the complete list of phases of flight codes I used in this stage. Thus, the number 1063 in the third stage represents all the events for the codes ‘XXX320/070/100/200/260/490’ and filtered events for the codes ‘XXX270/900’. However, this filtering does not guarantee that all events are runway incursions. For example, the code ‘XXX200’ which stands for ‘ground collision’, includes events where a collision occurred between two aircraft on a taxiway. To identify which events are runway incursions, I read the narratives of each of these reports. Thus, I found at least 43 events that matched the definition of RI or transgressions. Then I searched the airports on which these 43 events occurred, on www.airnav.com to determine whether they were towered or not. As a result, I found 17 runway incursions that occurred at towered airports.

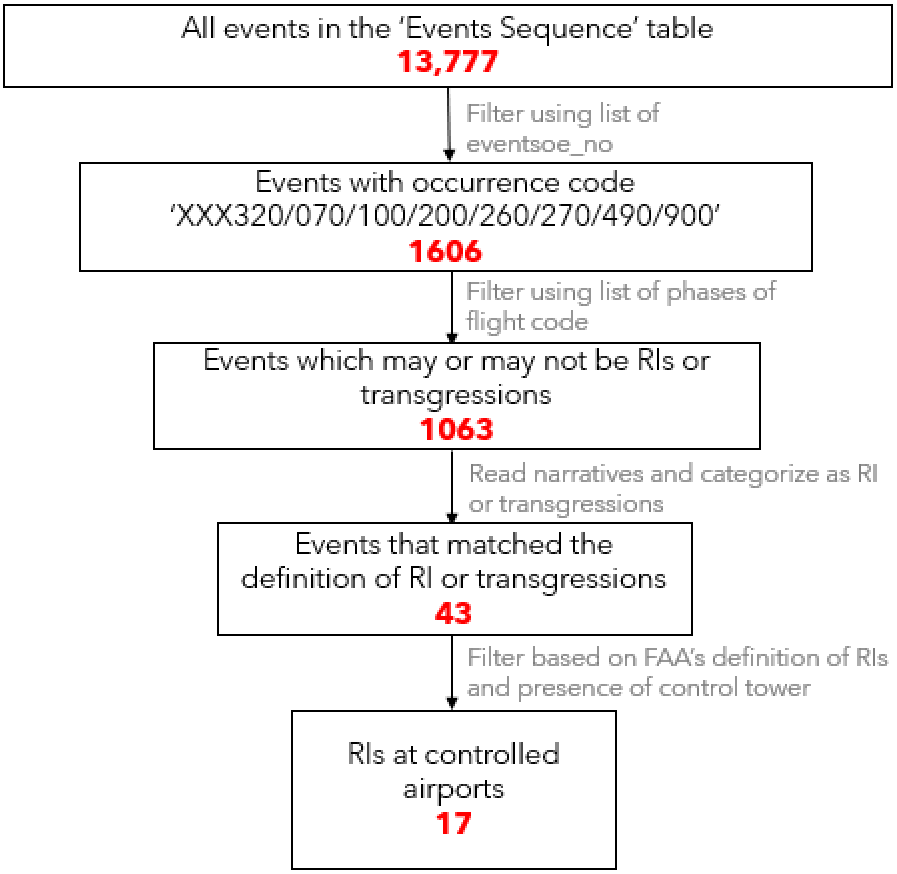


Figure 7. Process to filter RIs in the NTSB database in the post-2008 coding system. At the end, I had a set of 17 runway incursions that occurred at towered airports.

In total, I found 71 runway incursion accidents and incidents recorded in the NTSB database that occurred at towered airports. While I considered events recorded till 2017, I did not find any RI events before 1983 or between 2011 and 2017. Note that since 2011 there have been at least 10,000 incursions that did not warrant NTSB investigation (FAA, n.d.- c).

AIDS database

The FAA Accident and Incident Data System (AIDS) database contains records of incidents in all categories of civil aviation. The incidents in the database are those events that do not meet the aircraft damage or personal injury criteria described by NTSB's definition of an accident. A separate report is issued for each aircraft involved in the incident. The AIDS database contains more than 100,000 records of incidents from 1978 onward (Nazeri, 2007). The database is publicly available from the FAA's Aviation Safety Information Analysis and Sharing (ASIAS) website. The website provides an AIDS search form to search for events based on narratives, report number, event date, event location, operations of aircraft, or aircraft details such as aircraft make and model. Unlike the NTSB database, the AIDS database does not have a coding system to describe the incidents. To narrow my search space, I filtered reports by focusing only on those phases of flight that pertain to runway incursions. I also used keywords such as 'runway incursion', 'incursion', or 'failed to hold short' to search for narratives that could potentially describe a runway incursion.

I first filtered the database by focusing only on those phases of flight that pertain to runway incursions. The database does not provide a formal definition of the terms it uses to describe the various flight phases. I used the phases of flight related to taxi, takeoff, and landing. Table 10 shows the list of phases of flight I used to narrow our search, and the number of incidents in each. The number of incidents may vary based on when you are searching. The database may get updated with new events. This analysis ended in August 2017.

Table 10. The phases of flight related to runway incursions that I used to filter the incidents in the AIDS Database. The table also shows the number of incidents corresponding to each phase of flight.

Phase of flight	Number of incidents
Final approach	3946
Go round	451
Ground taxi (other airplane)	7665
Landing	642
Landing-approach	741
Landing-rollout	1481
Landing-touchdown	2599
Operations on ground from landing	334
Operations on ground to takeoff	27
Other ground operations	1726
Other (specify)	260
Roll out (fixed wing)	16224
Takeoff	113
Takeoff-ground roll	2970
Takeoff-aborted	14
Takeoff-climb out	677
Takeoff-departure	391
Takeoff-rotation	197
Taxi	8637
TO-aborted (fixed wing)	1773
TO-initial climb	2826
Touch and go landing	1545
Unknown	330
Total	**55,569**

The next step in filtering the data involved using keywords to search the narratives. I used keywords that describe a runway incursion to find potential incursions. I also used keywords that do not necessarily describe a runway incursion to eliminate those incidents. Table 11 shows the list of both sets of keywords.

Table 11. The set of keywords I used to filter runway incursions and the set of keywords I used to eliminate other incidents in the AIDS Database.

Keywords applicable to RIs	Keywords not applicable to RIs
Runway incursion	Deer
Incursion	Directional control
Crossed runway	Flat tire
Crossed the runway	Flipped over
Crossed a runway	Gear collapsed
Taxied onto runway	Gear down
Taxied onto the runway	Gear retracted
Taxied onto a runway	Gear up
Across runway	Instead of flaps
Across the runway	Nose gear collapsed
Across a runway	Nosed over
Misunderstood	Overran
Without clearance	Ran off runway
Without ATC clearance	Ran off
Without ATCT clearance	Retracted flaps
Entered runway	Retracted gear
Entered the runway	Snowbank
Entered a runway	Struck a runway light
Exited runway	Tire went flat
Exited the runway	Veered off
Exited a runway	Veered
Taxied on runway	
Taxied on the runway	
Taxied on a runway	
Active runway	
Hold short	
Failed to hold short	
Hold line	
Closed runway	
Pulled	
Wrong runway	
Opposite direction	
Another aircraft	
Avoid hitting	
Vehicle	
Pedestrian	

These keywords were most helpful when considering the phases of flights listed in Table 12. For other phases of flight, I read all the narratives and classified them as runway incursions or transgressions. After reading the reports, I found 398 runway incursion reports in total. It is possible that we missed some RIs, but my structured approach to identifying RIs makes the likely number of missed RIs very low.

Table 12. The keywords in Table 11 were most useful then the aircraft involved in the incident were in a phase of flight that involved some form of taxiing.

Phase of flight for which the keywords were most applicable
Ground taxi (other airplane)
Landing-rollout
Operations on ground from landing
Operations on ground to takeoff
Other ground operations
Roll out (fixed wing)
Takeoff-ground roll
Taxi

Then, I found the airport IDs where the incursion occurred using www.airnav.com. Using the airport name, city, and state that was available in the database, I found the airport ID and subsequently whether there was a control tower present or not. I read the narratives of the reports for which the location of the incident was missing to infer whether it was towered or not. For example, for report number 19860627058349I, the airport name was not specified in the database, but the narrative mentioned that the ATCS instructed the pilot to taxi into position and hold. Thus, I inferred that the airport was towered at that time.

As a result, I identified 298 reports that were for incursions at towered airports. As mentioned earlier, the database publishes a report for each aircraft involved in the incident. I looked for reports with the same date and location and from the narratives cross-checked whether the reports are for the same incident. In such cases, the database specifies in the general information whether the aircraft was the first or second aircraft involved in the incident. I treated reports pertaining to the same incident as one. Thus, I found 293 incidents that occurred at towered airports.

Using the event date and location, I found that three out of the 293 incidents are already recorded in the NTSB database. Table 13 shows the three events which are present in the NTSB database. I excluded these three events from my analysis of the AIDS database.

Table 13. AIDS Report Number and the NTSB Numbers of reports that correspond to the same runway incursion. I excluded these three events from my analysis of the AIDS database.

AIDS Report Number	NTSB Number
19841008076759I	FTW85IA011
19841008076819I	
20010727020211I	CHI01IA248
20000121040559I	CHI00IA062

In total, I found 290 runway incursion incidents from the AIDS database. Most of these incursions occurred between 1978 and 2001. This database does not have many incursions post 2001 probably because the FAA created the RWS database in 2001, and runway incursions post 2001 were mainly recorded in the RWS database.

RWS database

The number of reported incursions increased significantly from 2007 to 2008. During this period, the FAA adopted ICAO's (International Civil Aviation Organization) definition of runway incursions. As a result of this change, the FAA now considers an incorrect presence of an aircraft without a conflict with another vehicle or pedestrian as a runway incursion rather than a surface incident. Additionally, the implementation of ATSAP (Air Traffic Safety Action Program) in 2008 may have increased reporting (GAO, 2010). Therefore, to ensure that I analyze a consistent set of incursions, I consider only incidents from 2009 to 2018. I downloaded data from the database twice, once on October 18 2019, and then again on December 4 2019. The FAA may make changes to the severity level or the source of the incident. As a result, some data fields changed when I downloaded the data the second time. The analysis described here is based on the data I downloaded on December 4 2019.

Next, I only considered incidents that the FAA classified as an operational incident, pilot deviation, or vehicle/pedestrian deviation as opposed to 'other' and 'unknown'. Of the 16,031 incidents, I discarded 2,790 incidents to only focus on those that the FAA assigned a severity category to. As a result, I had a total of 13,241 incidents to sample from.

I analyzed all the reports in severity categories A and B. For the Category C and Category D reports, I calculated the representative sample size using a confidence level of 95% and a margin of error of 5% as they are commonly used values. As a result, I randomly sampled 360 reports from the 5575 Category C reports, and 366 reports from the 7541 Category D reports.

The FAA assigns a source to each report in the database. The three sources of incursions are: (1) operational incidents (OIs), (2) pilot deviations (PDs), and (3) vehicle or pedestrian deviations (VPDs). I calculated the proportions of OIs, PDs, and VPDs in the 5575 Category C reports and the 7541 Category D reports. I used these proportions to determine the number of OIs, PDs, and VPDs in my sampled 360 Category C reports and 366 Category D reports. In other words, my sample proportion and population proportion were equal. Table 14 shows the number of reports I analyzed in each category.

Table 14. Total number of RWS runway incursion reports in each severity category, and the number of reports I sampled and analyzed.

Severity category	Number of incidents	Number of reports analyzed
A	63	63
B	62	62
C	5575	360 (136 OIs + 184 PDs + 40 VPDs)
D	7541	366 (19 OIs + 262 PDs + 85 VPDs)
Total	**13,241**	**851**

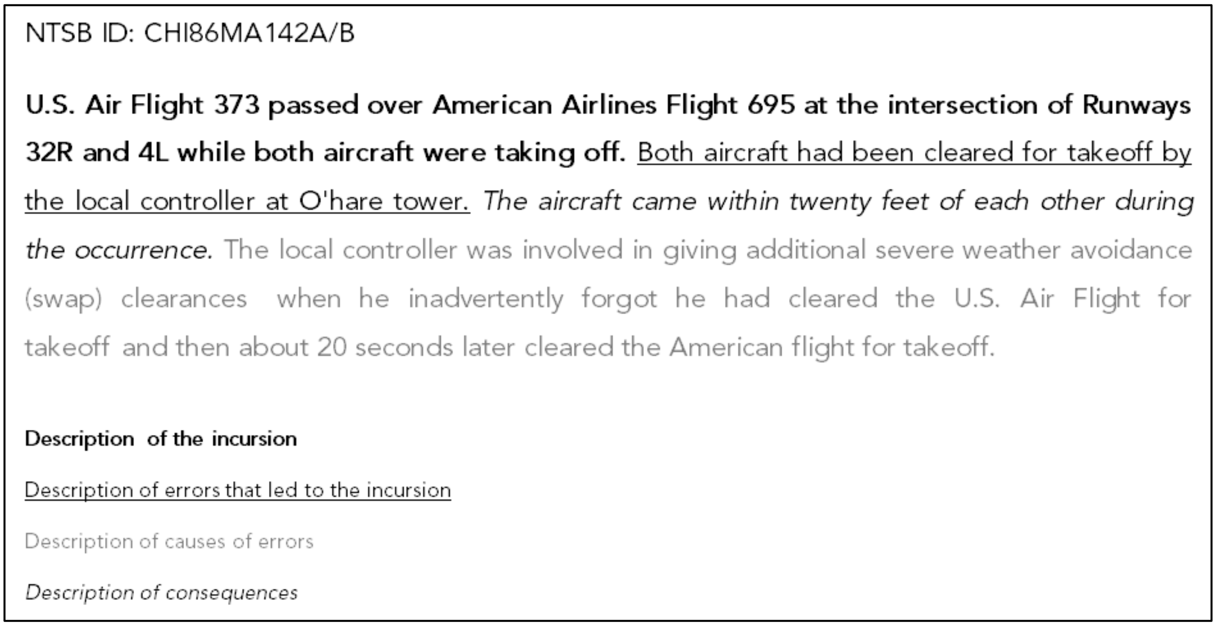
3.3.2 Narrative Analysis of Runway Incursion Reports

As indicated earlier, reports in all three databases included a narrative of some form describing the incursion. I performed analysis of this text information to find what data is available from these reports. I needed a common coding system to code all the reports so that I could find the difference in information obtained from reports recorded in the three databases. The coding system is based on elements that a good incident or accident report usually has (described in Section 2.3).

In conclusion, a framework for incident investigation includes a sequence of events explaining *what* happened, the errors that led to the incident explaining *how* the events occurred, and finally *why* these errors occurred. Based on this framework, I coded information in the narratives that pertained to one of the following categories:

1. A description of the incursion. For example, whether the aircraft landed on a closed runway, entered onto an active runway, or took off from a wrong runway (different runway than what the controller had assigned).
2. A description of errors that led to the incident. For example, the pilot had an incorrect readback but the ATCS failed to correct it.
3. A description of why the human element in the incursion made an error. For example, the pilot could not see the hold short line because the lines were faded.
4. A description of consequences of the incursion and what, if any, evasive actions led to minimizing the severity of the incursion. For example, the pilot aborted takeoff when they saw another aircraft cross the runway ahead of them.

Figure 8 shows an example of coding a report from the NTSB database.



NTSB ID: CHI86MA142A/B

U.S. Air Flight 373 passed over American Airlines Flight 695 at the intersection of Runways 32R and 4L while both aircraft were taking off. Both aircraft had been cleared for takeoff by the local controller at O'hare tower. *The aircraft came within twenty feet of each other during the occurrence.* The local controller was involved in giving additional severe weather avoidance (swap) clearances when he inadvertently forgot he had cleared the U.S. Air Flight for takeoff and then about 20 seconds later cleared the American flight for takeoff.

Description of the incursion

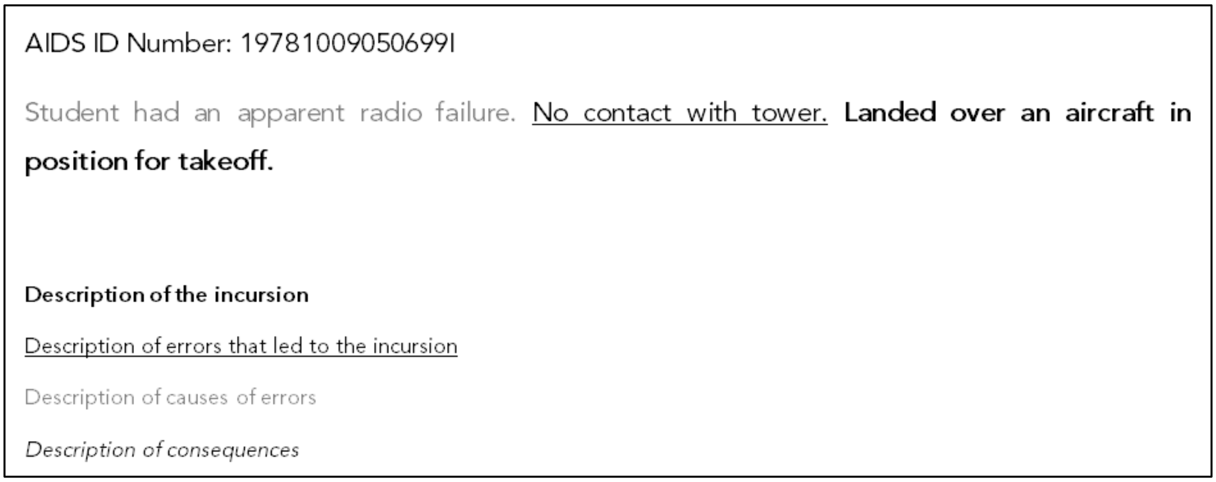
Description of errors that led to the incursion

Description of causes of errors

Description of consequences

Figure 8. An example of coding a report from the NTSB database.

Figure 9 shows an example of coding a report from the AIDS database.



AIDS ID Number: 19781009050699I

Student had an apparent radio failure. No contact with tower. **Landed over an aircraft in position for takeoff.**

Description of the incursion

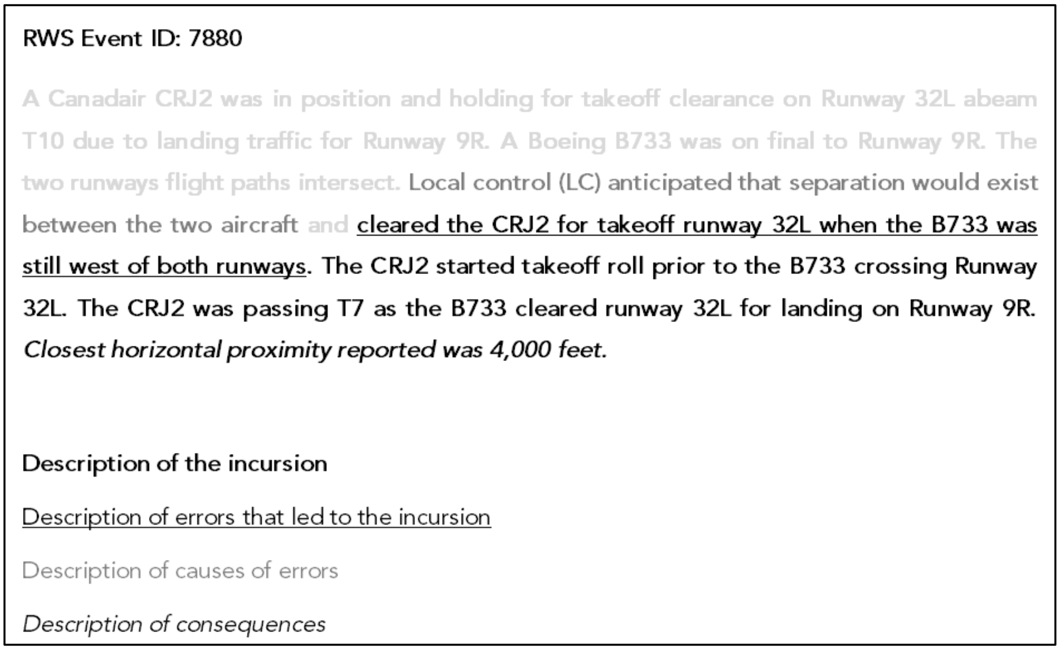
Description of errors that led to the incursion

Description of causes of errors

Description of consequences

Figure 9. An example of coding a report from the AIDS database.

Figure 10 shows an example of coding a report from the RWS database. Many reports in the RWS database have detailed explanations of what happened after the incursion. Some reports also contain separation between the two aircraft as does the following report.



RWS Event ID: 7880

A Canadair CRJ2 was in position and holding for takeoff clearance on Runway 32L abeam T10 due to landing traffic for Runway 9R. A Boeing B733 was on final to Runway 9R. The two runways flight paths intersect. Local control (LC) anticipated that separation would exist between the two aircraft and cleared the CRJ2 for takeoff runway 32L when the B733 was still west of both runways. The CRJ2 started takeoff roll prior to the B733 crossing Runway 32L. The CRJ2 was passing T7 as the B733 cleared runway 32L for landing on Runway 9R. *Closest horizontal proximity reported was 4,000 feet.*

Description of the incursion

Description of errors that led to the incursion

Description of causes of errors

Description of consequences

Figure 10. An example of coding a report from the RWS database. This report does not specify the reasons for pilot crossing the runway.

3.3.3 Weakness in controller-generated reports

Table 15 shows the number of reports in each of the three databases that contained information coded as one of the four main categories. Since there is no way to determine how many instances of each category should the narratives have, I counted the presence of each category in the narrative. For example, if the report mentioned at least one reason as to why the pilot made an error, I counted presence of category 3 as 1, else it was 0. It is possible that I may have missed coding some information but counting the presence and not each factor reduces the impact of any counting errors.

Table 15. Percentage of reports in each database that had information coded as Category 1 (description of the incursion), Category 2 (description of the communication or instructions issued), Category 3 (description of why the human element in the incursion made an error), and Category 4 (description of what happened after the incursion)

	Category 1	Category 2	Category 3	Category 4
NTSB	100%	99%	85%	79%
AIDS	100%	84%	30%	41%
RWS	100%	89%	28%	49%

i. Few reports explain why the incursion occurred

Not surprisingly, most of the NTSB reports explain why the incursion occurred. One of the reasons the AIDS database lacks in describing why the incursion occurred may be that investigators do not investigate accidents and incidents with the same rigor. While accidents encourage industries to take action to improve safety, incidents, which are comparatively less serious but occur more frequently than accidents, usually do not present as strong a case for stakeholders to take immediate action (Greenwell, 2003).

As Table 5 shows, only 28% of the RWS reports state at least one cause that describes *why* the incursion occurred.

ii. All the contributing factors may not be reported

Most human errors result from limitations in the overall system in which the operators work. As a result, a runway incursion often occurs due to a combination of contributing factors. Cistone and researchers at John A. Volpe National Transportation Systems Center are of the view that the controller may choose to report only a subset of contributing factors that caused the incident (Cistone, 2014; Volpe, 2016).

The investigators at the NTSB during their interviews ask questions that probe the controller or the pilot to think deeper about why the incident occurred. For example, in one incident (NTSB Number: OPS06IA008A/B), the controller issued conflicting instructions that led to a loss of separation between two aircraft. The investigators asked the controller to describe what happened. They then asked him whether he had any idea as to why the incident happened. The controller responded by saying that he diverted from his main task of preventing collisions to thinking about the efficient use of runways and airspaces. The investigators asked him other questions such as staffing issues, visibility from the tower, whether the controller was fatigued or stressed, and the noise level in the tower. As a result of these questions, the investigators found multiple contributing factors. They found that there was a lack of supervision in the tower, the controller usually worked standing up because it was difficult to see the runways from his position in the tower, and the lack of teamwork in the tower bothered him.

The RWS reports lack such details. For example, in cases where the controller issued conflicting instructions, they don’t go beyond stating that the controller was distracted or forgot about an aircraft.

iii. Many reports contain perspectives of one party only

One of the reasons the RWS reports are limited in their content is because the reports may involve the perspectives of one party only (Cistone, 2014). The controller filing these reports may not be aware of contributing factors that led to pilot error, hence lacking the pilots' perspective (Volpe, 2016). For example, an incident in the RWS database (Event ID: 11795), involved the controller clearing an aircraft to land on a closed runway because they did not receive a notification on the runway closure. The report does not mention any factors that may have led to the pilot landing on the closed runway. The FAA classifies this incident as an operational incident.

In contrast, the NTSB interviews the pilots, controllers, or any other witnesses to complete their report. In an incident from the NTSB database (NTSB ID: OPS08IA009), like the one mentioned above, the controller cleared the pilot to land on a closed runway. The controller had not updated the Automated Terminal Information Service (ATIS) to reflect the runway closure. They did not inform the approach controller about the runway closure as required. Even though the controller issued a wrong clearance, it's the pilot's responsibility to ensure safety of the flight. In this incident, there were no runway closure markings at the approach end and the runway lights were on. The runway did not appear to be closed, which may have contributed to the pilot landing on the closed runway.

Additionally, the RWS reports are subjected to the biases of the air traffic controller. They may not report factors that they don't deem to be important. In contrast, the NTSB is an independent organization, and the reports can be assumed to be complete and less subject to biases (Nazeri et al., 2008).

iv. Analysis depends on the level of detail provided by the controller

The Volpe researchers found that communication errors were the top causes of incursions in their dataset. They state that a probable reason could be that the controller who is involved in the incident files the report. They are in radio contact with the pilot or the vehicle driver and can provide more insight into the communication (Volpe, 2016). In my analysis, I also found that 89% of the reports contained a description of the communication between the controller and pilot or vehicle driver. These descriptions included information on what instructions the controller issued, whether the readback was correct, and whether an incorrect readback was corrected.

The Volpe researchers found that issues in markings and signage contributed the least to runway incursions. These may be attributed to the fact that the controllers may be unaware of such issues as illustrated in the previous examples. The researchers point out that their analysis depends on the information provided by the controllers (Volpe, 2016). As a result, communication errors as the top cause of runway incursions may not necessarily be true. It could just be a result of controllers citing it more often than other issues.

3.4 Rationale for an Alternative Reporting Form

In my research, I focus on one aspect of the reporting process—the reporting form. The reporting process starts with the controller filling out a reporting form. The content of the form, to some extent, motivates the need for a further investigation into the incident. The lack of details in these reports may become a missed opportunity for learning from these incidents. Better information in the form may help the FAA authorities in their investigation and develop effective preventive measures.

4. ALTERNATIVE REPORTING TOOL

Chapter 2 pointed out weaknesses in the reports from the RWS database, highlighted what air traffic controllers think of the current form, and described three categories of data required in an incident report. Keeping in mind that air traffic controllers may not be trained investigators, the aim of the alternative reporting tool is to guide air traffic controllers in a step-by-step manner through their incident investigation and create information-rich incident reports.

The goal of the alternative reporting tool is to create reports that describe the three categories of data required in an incident report: (1) a description of what happened, (2) a description of errors that led to the incursion, and (3) a description of causes of these errors.

The alternative reporting tool is based on the concept of expert systems. Experts in a domain add a knowledge base to the expert systems, which non-expert users then use for decision making. Expert systems are advantageous when an expert is too expensive, or to reduce unintentional biases of the non-expert user.

Like expert systems, the reporting tool consists of three components: (1) a knowledge base, (2) a set of rules, and (3) an interface. The knowledge base consists of a set of human errors that may lead to incursions, as well as their causes, which I identified from analyzing past runway incursion accidents and incidents (see Section 2.3.2). The next step in designing the expert systems-based reporting tool is to represent the knowledge base using a set of rules, that is, as a set of conditions that relate statements of facts to one another (Buchanan & Duda, 1983). The set of rules or conditions in the case of my reporting tool are a set of tailored questions. The responses to these questions describe the incursion scenario, identify the human errors that led to runway incursions, and causes of these errors. They also determine the depth of the investigation. For example, if the pilot’s readback was incorrect, the reporting tool asks the reporter to specify the errors in the readback and whether the controller communicating with the pilot corrected the pilot’s readback. The tool then asks the reporter to identify factors that may have contributed to the pilot reading the instructions back incorrectly and factors that contributed to the controller not correcting the pilot’s incorrect readback.

This chapter details the design of the tool. This chapter is primarily based on the work previously published in two conference proceedings: (1) ‘Archetypal Models of Runway Incursions’ presented at the 17th AIAA AVIATION Conference in 2017, and (2) ‘Narrative

Analysis of Runway Incursion Reports in the National Transportation Safety Board Database to Identify Contributing Human Errors and its Causes' presented at the 64th Annual Meeting of the Human Factors and Ergonomics Society in 2020.

A runway incursion may involve one or more aircraft, vehicles, or pedestrians. For this research, I consider only incursions between two aircraft, and exclude incursions involving ground vehicles or pedestrians, or more than two aircraft. Throughout this chapter, I refer to a hypothetical incursion that occurred between two aircraft, Aircraft 1 and Aircraft 2. The incursion occurred at a notional towered airport with two intersecting runways—runway 17-35 and runway 4-22 as shown in Figure 11. In this incursion, Aircraft 1 entered onto Runway 17/35 at Taxiway C1 without authorization. Aircraft 2 was rolling out after landing on Runway 17 when Aircraft 1 entered the active runway behind Aircraft 2. Aircraft 1 was taxiing to Runway 22 for departure.

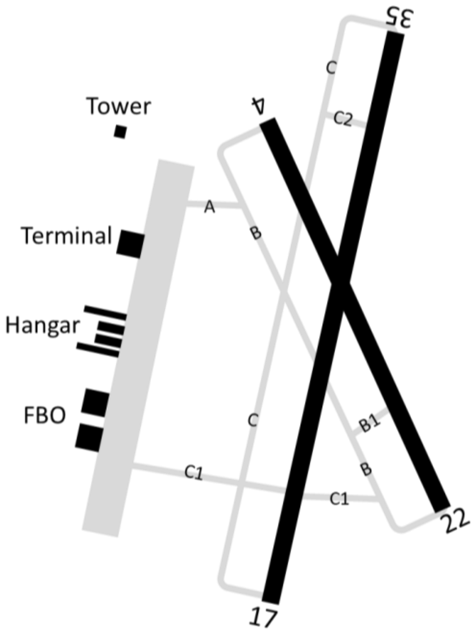


Figure 11. Runway diagram for the notional airport at which the hypothetical incident occurred. The towered airport has two intersecting runways.

4.1 Questions to Identify the Incursion Scenario[3]

The alternative reporting tool asks a list of questions to determine *what* happened. The tool uses the responses to these questions to create a sequence of events describing the incident. The responses to these questions in the tool identify:

- the airport at which the incident occurred
- the location on the airport where the incident occurred
- entities involved in the incident
- what these entities were doing at the time of incident

Runway incursions occur in a limited number of ways. An incursion can occur due to two reasons: (1) an aircraft's entry or exit into a wrong area, and (2) an aircraft's wrong entry into or wrong exit from an area (Singh & Meier, 2004).

In a runway incursion involving two aircraft, at least one aircraft is incorrectly present on a runway. The conflicting aircraft can be taking off, landing on, or taxiing on the same runway. Given an airport configuration, it is possible to create a finite set of geometries that depict the location of the aircraft involved at the time of incursion. To illustrate the geometries, consider Runway 17/35 at the notional airport. The aircraft involved can either use a single runway, be at an intersection with another runway, or be at an intersection with a taxiway.

Figure 12 shows the two possible geometries for an aircraft that is using Runway 17/35 based on the direction in which the aircraft is headed. Geometry GS1 is when the aircraft is using Runway 17, and GS1' is when the aircraft is headed in the opposite direction or using Runway 35. The colored line extending down the runway and beyond indicates that the aircraft could be present anywhere on the runway, approaching the runway for landing, or climbing out of the runway. Later in this section, I list questions that will determine a more specific location of the aircraft on the runway.

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[3] This section on generating the archetypal scenario at the time of incursion and the sequence of events leading up to the incident draws from our paper, 'Archetypal Models of Runway Incursions', AIAA AVIATION 17th Aviation Technology, Integration, and Operations Conference, AIAA Paper 2017-4392, Denver, Colorado, June 2017.

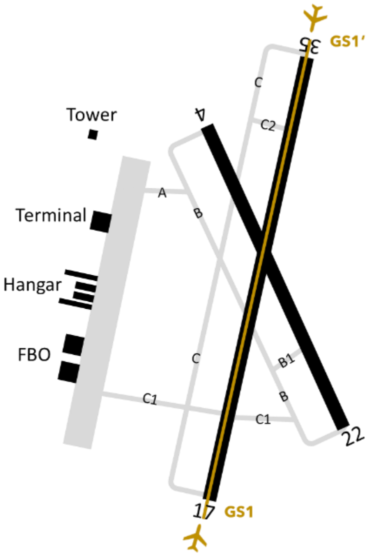

Figure 12. Possible geometries based on where the aircraft is headed while using Runway 17/35. The aircraft can be present anywhere on the runway, approaching the runway, or climbing out of the runway. G: Geometry; S: Single runway; 1/1': different directions of movement

Figure 13 shows the possible geometries for an aircraft present at the intersection of the runway of incursion with another runway. Geometries GRE1 and GRE1' represent the two ways in which the aircraft can be entering the intersection at the time of incursion. Geometries GRL1 and GRL1' represent the two ways in which the aircraft can be leaving the intersection at the time of incursion.

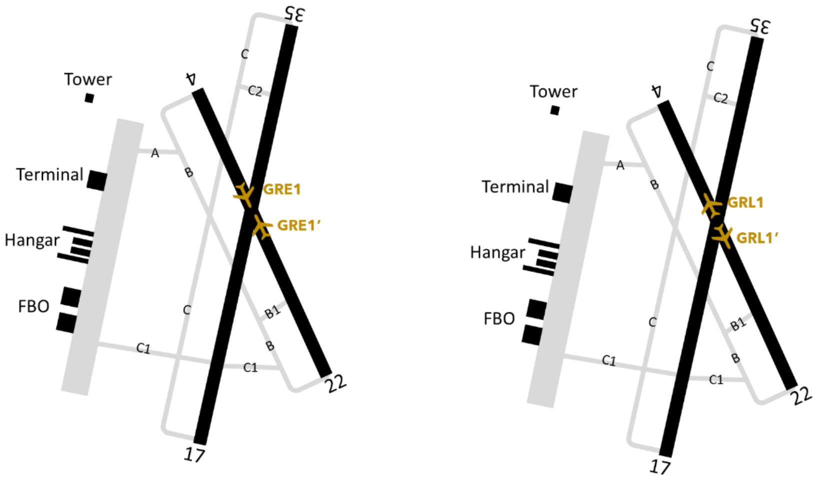

Figure 13. Possible geometries if the aircraft present on a runway intersecting with the runway of incursion (Runway 17/35). G: Geometry; R: Runway intersection; E/L: Entering or Leaving the intersection; 1/1': different directions of movement

Figure 14 shows the possible geometries for an aircraft present on the intersection of the runway of incursion and a taxiway, at the time of incursion. The geometry depends on which intersecting taxiway the aircraft was present on, and whether it was entering or leaving the intersection.

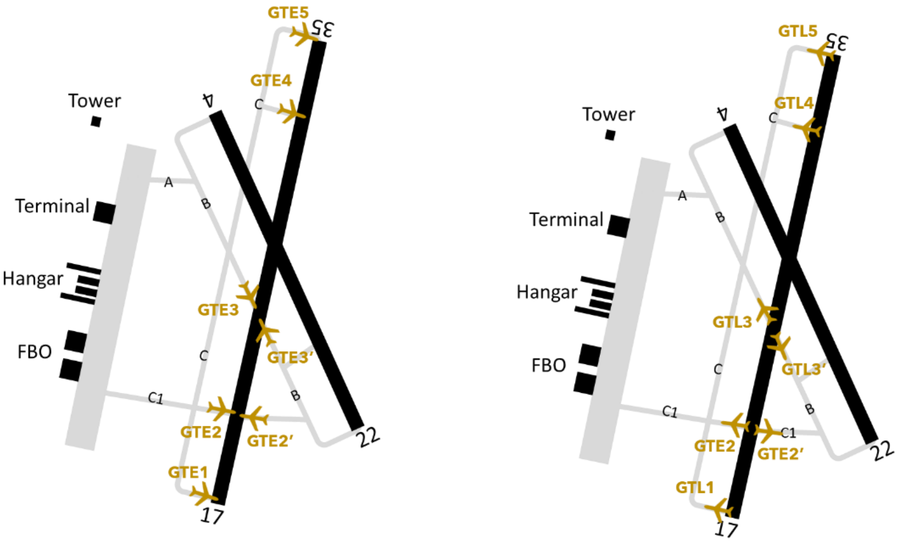

Figure 14. Possible geometries if the aircraft present on a taxiway intersecting with the runway of incursion (Runway 17/35). G: Geometry; T: Taxiway intersection; E/L: Entering or Leaving the intersection; X/X': different directions of movement

Similarly, a finite set of geometries represents the possible ways an aircraft can be incorrectly present on Runway 4/22. The reporting tool uses a series of tailored questions to determine the archetypal RI scenario that shows where the involved aircraft were present at the time of incursion. This archetypal RI scenario and the phases of flight the aircraft were in at the time of incursion, lay the foundation to determine the sequence of events that preceded the incursion.

Figure 15 shows the steps involved in determining the archetypal RI scenario. The reporting tool first asks the user (air traffic controller reporting the incursion) to specify the airport at which the incursion occurred as input to customize the geometries for the specific airport. For our hypothetical incident, it is the notional towered airport.

In Step 2, the reporting tool asks the user to select the runway of incursion. The runway of incursion is the runway on which an aircraft was incorrectly present. If the airport has only one runway, then that runway is the runway of incursion. Since the notional airport has two runways, the user must select out of the two options: Runway 17/35 or Runway 4/22. In the hypothetical incursion, the runway of incursion is Runway 17/35 because Aircraft 1 was incorrectly present on this runway.

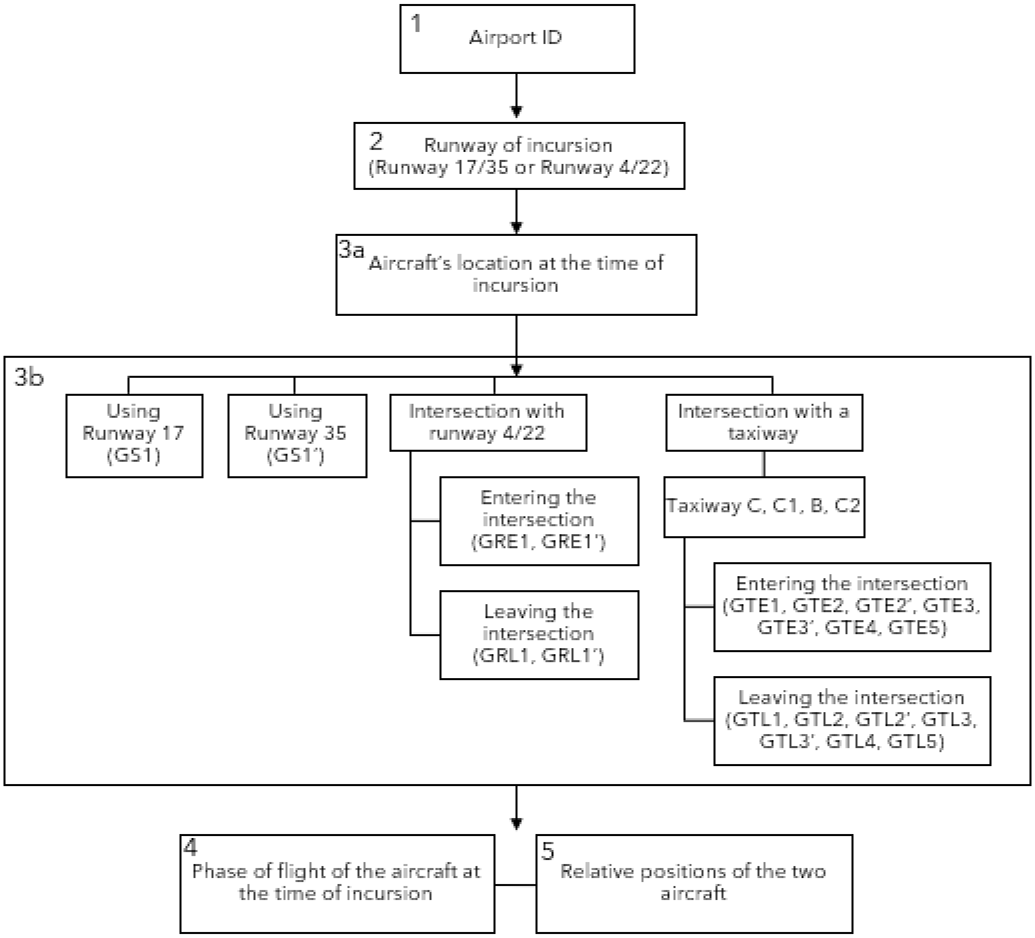

Figure 15. Steps involved in determining the archetypal RI scenario. The options for runway of incursion and aircraft's location at the time of incursion are based on the hypothetical incident at the notional airport.

In Step 3, the reporting tool asks the user tailored questions to determine the location of the two aircraft at the airport at the time of incursion. In the hypothetical incident, since Aircraft 2 was rolling out after landing on Runway 17, the geometry for Aircraft 2 is GS1.

If the user specifies that the aircraft was at the intersection with Runway 4/22, the reporting tool asks an additional question where the user selects the direction of movement of the aircraft, thus narrowing down on a specific geometry. If the user specifies that the aircraft was present at the intersection with a taxiway, the reporting tool asks the user to indicate which taxiway's intersection the aircraft was present on. Then the reporting tool asks the user to specify the direction of movement. In the hypothetical incident, Aircraft 1 was present at the intersection of Runway 17/35 and a taxiway. Based on the narrative, Aircraft 1 was entering Runway 17/35 from taxiway C1, narrowing down its geometry to GTE2 (Figure 14).

In the final steps, the reporting tool asks the user to specify the phase of flight the aircraft were in at the time of incursion, and their position relative to one another. While the geometry for Aircraft 1 fixes its location on the runway, Aircraft 2 could be present anywhere on Runway 17. For example, Aircraft 2 could either be *in front of*, or *behind* Aircraft 1. Figure 16 shows an approximate location for Aircraft 2 on the runway given that in the hypothetical incident, Aircraft 1 entered Runway 17 behind Aircraft 2.

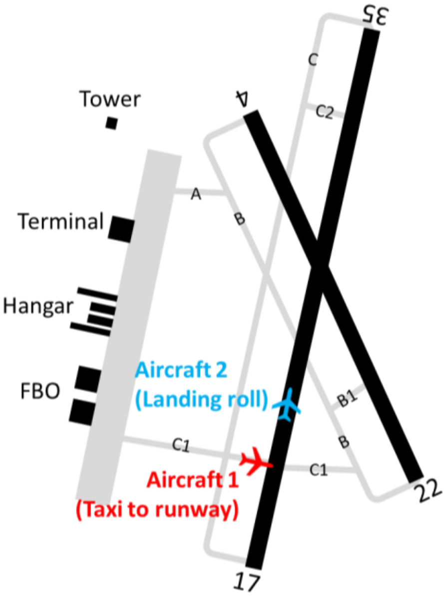

Figure 16. The archetypal scenario at the time of the hypothetical incursion. Aircraft 1 entered Runway 17/35 conflicting with Aircraft 2 that was rolling out after landing on the same runway.

The phases of flight describe what the aircraft were doing at the time of incursion. Table 16 lists and defines the possible phases for an aircraft that is involved in a runway incursion. In the hypothetical incident, at the time of incursion, Aircraft 1 was in 'taxi to runway' and Aircraft 2 was in 'landing roll out' phase of flight.

Table 16. Definitions of different phases of flight an aircraft involved in a runway incursion can be in (ECCAIRS Aviation, n.d.)

Phase of Flight	Definition
Taxi to runway	Commences when the aircraft begins to move under its own power leaving the gate, ramp, apron, or parking area, and terminates upon reaching the runway.
Taxi into position	From entering the runway until reaching the take-off position.
Taxi from runway	Begins upon exiting the landing runway and terminates upon arrival at the gate, ramp, apron, or parking area, when the aircraft ceases to move under its own power.
Takeoff roll	The phase of flight from the application of take-off power, through rotation up to 35 feet [12 m] above runway end elevation or until gear-up selection, whichever comes first.
Aborted takeoff	The phase of flight in which any attempt is made to terminate a takeoff between the application of take-off power, through rotation and up to 35 feet [or 12 meters] above the elevation of the runway end (from the point where the decision to abort has been taken until the aircraft begins to taxi from the runway).
Initial climb	From the end of the takeoff roll run sub-phase to the first prescribed power reduction, or until reaching 1000 feet above runway elevation or the VFR pattern, whichever comes first.
Approach	The phase of flight from the outer marker to the to the point of transition from nose-low to nose-high attitude immediately prior to the flare above the runway [IFR]; or [VFR] from 1000 feet (300 meters) above the runway end elevation or from the point of VFR pattern entry to the flare above the runway.
Landing flare/touchdown	The phase of flight from the point of transition from nose-low to nose-up attitude, just before landing, until touchdown.
Landing roll	The phase of flight from touchdown until the aircraft exits the landing runway or comes to a stop, whichever occurs first.

At the end of the process shown in Figure 15, we have the archetypal scenario at the time of incursion showing where the aircraft were, and what they were doing. These archetypes only approximate the location of the aircraft at the time of incursion. They do not necessarily represent the distance between the two aircraft.

To identify the sequence of events preceding the incursion scenario, I backtrack the positions of the aircraft to estimate where they were before the incursion. A general rule of thumb I use is to trace the aircraft positions to events where the phase of flight changed. Since every movement at runways and taxiways of towered airports must be authorized by the ATC, these events may have resulted in the RI due to the pilot not following a correct ATC instruction, proceeding without instruction, or due to the ATC giving a wrong instruction.

Figures 17 (a) and 17 (b) show the logical sequence of phases of flight I use to backtrack the positions of the aircraft depending on whether the aircraft intends to take off from a runway or land on it.

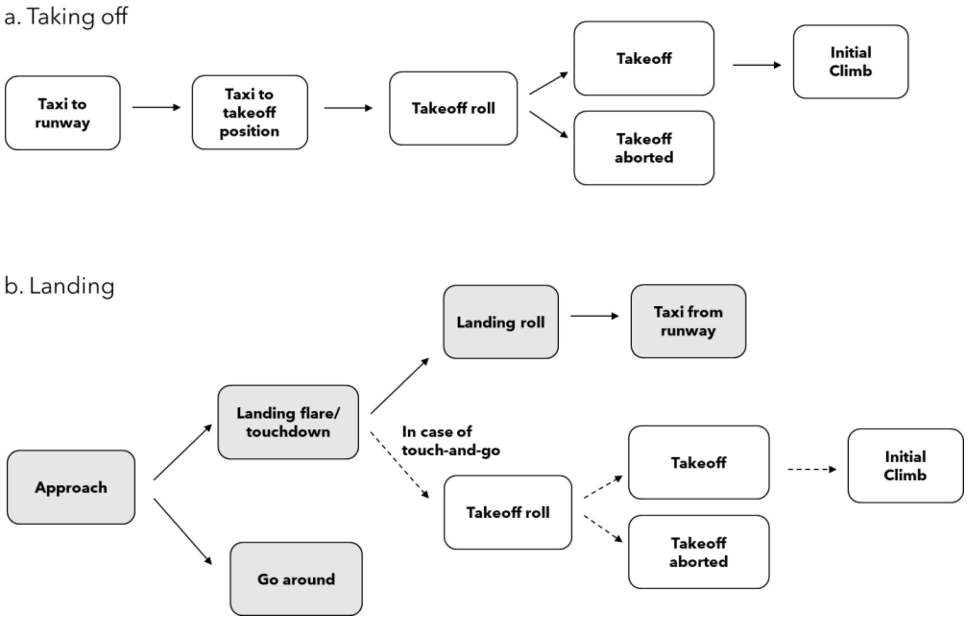

Figure 17. Sequence of phases of flight for aircraft taking off or landing. In case of landing, there is a possibility for touch-and-go. This sequence is shown by dashed arrows. (Bhargava and Marais, 2017)

Figure 18 shows a sequence of snapshots estimating the locations of the aircraft before and during the incursion. Note that the sequence represented here is an estimation of the actual incident and is not meant to represent the precise positions of the aircraft at each moment in time. Precise positions are generally only available for airports with systems that can track surface movement of aircraft and vehicles (Bhargava and Marais, 2017).

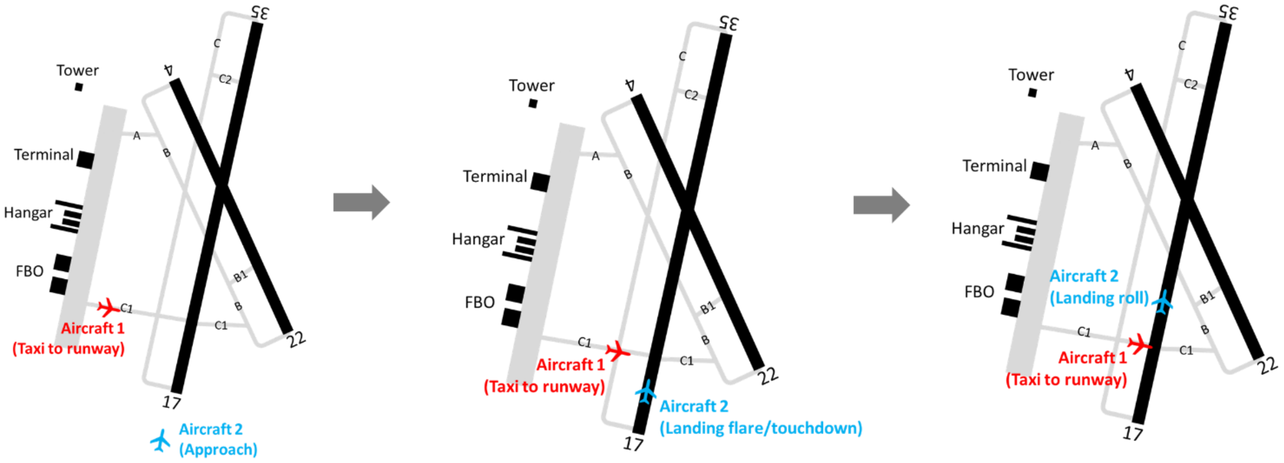

Figure 18. Backtracking the positions of the aircraft using the scenario at the time of incursion and the sequence of phases of flight, we can estimate the sequence of events leading up to the incursion.

4.2 Questions to Identify Errors That Led to the Incursion[4]

Previous research stated that human error is a major contributor of runway incursions. Human error occurs when human actions lead to negative consequences or fail to achieve the desired outcome (Kanki, 2018). One way to detect human errors is to define the overall goal, list the actions humans need to take to achieve that goal and identify the deviations in actions that led to the failure to achieve the desired outcome. Task analysis, a human error analysis technique that breaks down how operators interact with the system and with other personnel, can be used to identify what has gone wrong in the system from the human action point of view (Doytchev and Szwillus, 2009).

Here, I use task analysis to break down the overall goal of avoiding conflict on the runway into controller and pilot/vehicle driver subtasks. At towered airports, i.e., airports with an operating control tower, aircraft movement on runways and taxiways must typically be approved by the controller. Unauthorized movements on the runway are also runway incursions. For example, the pilot lands on a runway without establishing any prior communication with the control tower at that airport. These cases require investigation into why the pilot did not communicate with the control tower, and alternative ways in which the runway incursion could have been prevented. For

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[4] The task analysis described in this section is derived from our paper, 'Narrative Analysis of Runway Incursion Reports in the National Transportation Safety Board Database to Identify Contributing Human Errors and its Causes', 64th International Annual Meeting, Human Factors and Ergonomics Society, 2020.

example, the controller could have noticed the aircraft's unauthorized entry into the airspace and attempted to contact the pilot.

In cases where there was two-way communication between the controller and the pilot, the readback-hearback task loop ensures that the pilot has the correct set of instructions, and that the pilot intends to follow the instructions. Pilot readback is the pilot's repetition of the instructions back to the controller. Controller hearback is when the controller is listening to the pilot's readback and making sure the pilot has the correct set of instructions. Runway incursions can occur when the controller or pilot does not perform their tasks or performs them inaccurately.

Figure 19 shows the readback-hearback task loop. The controller must transmit a correct and complete set of instructions and transmit this set to the correct pilot. The pilot must read the instructions back correctly and completely. The purpose of the readback is to ensure that the pilot heard the instructions correctly. The controller must pay attention to the pilot's readback, and correct the pilot if the readback is wrong. The hearback allows the controller to correct the pilot if they have a wrong set of instructions, and also allows the controller to catch any errors in the instructions.

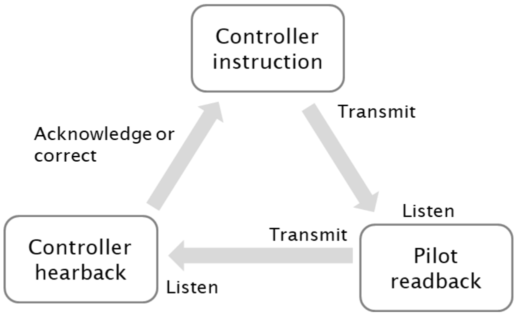


Figure 19. Controller-pilot communication loop that aims to ensure the pilot has the correct set of instructions. (FSF, 2000).

Once the pilot and the controller have ensured that the pilot has the correct set of instructions, the next task for the pilot is to ensure that the controller's instructions are safe to follow, or else request amendments (FAA, 2017). Finally, the pilot must follow these instructions.

Using task analysis to systematically detect errors can improve the process of incident investigation. The list of subtasks acts like a checklist of potential errors the air traffic controller reporting an incident should look for in the incident. Though the FAA categorizes the sources of runway incursions as an operational incident or a pilot deviation, it is possible that the incursion was a result of both controller and pilot error. For example, consider a scenario where the controller issued the pilot of Aircraft 1 to hold short of a runway. The pilot did not read back the hold short instructions and the controller did not catch the error. Subsequently, the pilot assumed that they were cleared to cross the runway and entered onto it conflicting with another aircraft on the same runway. Although this incident is a pilot deviation, the controller contributed to the incident too by not paying attention to the pilot's readback and making sure the pilot had the right set of instructions. Thus, tasks analysis not only detects the errors that may have led to the incursion, but also points out the flaws in the system that led those errors to propagate.

The remainder of this chapter details the questions the alternative reporting tool asks to detect the errors that led to the runway incursion. I use decision trees to identify whether the controller and the pilot were successful in performing the tasks that lead to the overall goal of preventing a runway incursion.

4.2.1 Initial Investigation Page

The questions on the 'Initial Investigation' page of the website aim to determine whether there was any communication between the controller and the pilot, whether the controller issued a correct instruction, and whether the pilot followed the instructions. Figure 20 shows the decision tree to identify major sources of error and the pages that follows.

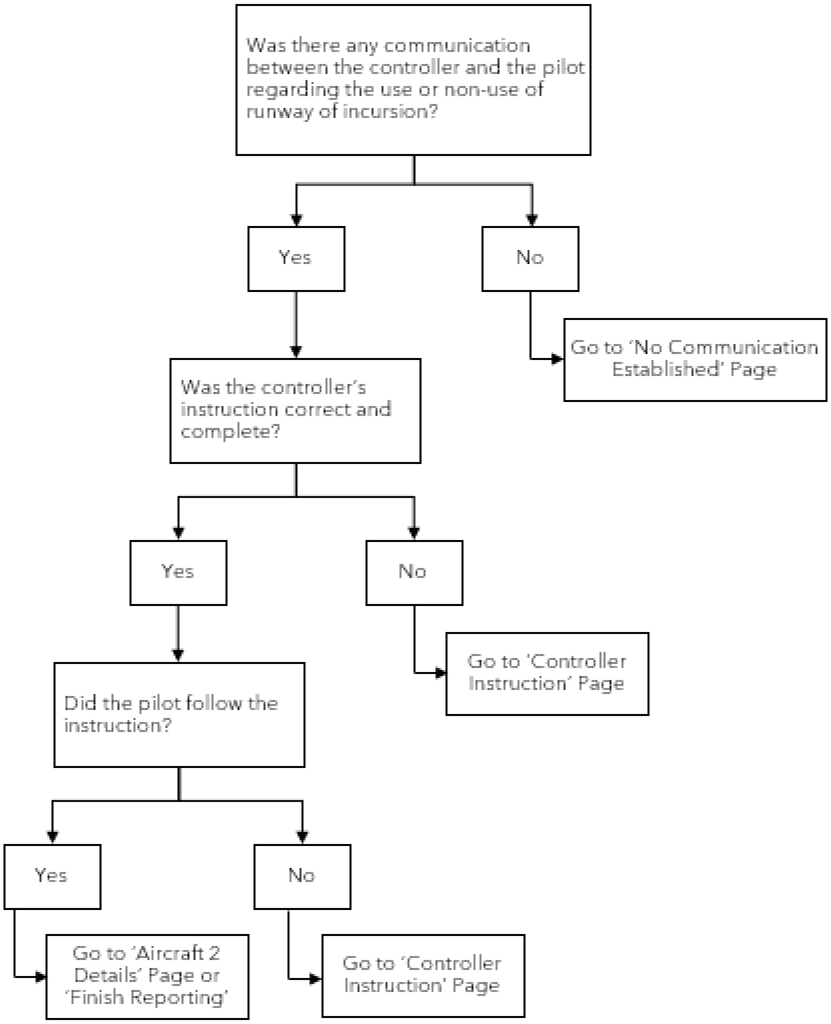


Figure 20. Set of questions on the 'Initial Investigation' page. This page identifies the major sources of errors and determines the depth for further investigation.

The reporting tool first asks whether there was any communication between the controller and the pilot regarding the use or non-use of the runway of incursion. For example, the controller cleared an aircraft to land on, take off from, or taxi on the runway of incursion. Additionally, the controller may issue an instruction to hold short of the runway of incursion. Examples where there was no communication between the controller and pilot include pilot landing on a runway without a landing clearance, or the pilot accepting a clearance for another aircraft.

If there was no communication between the controller and the pilot, the reporting tool goes to the 'No Communication Established' page. Section 3.2.6 details the questions on this page.

If there was communication between the controller and the pilot, the tool asks whether the controller's instruction was correct and complete. An instruction is correct and complete if it conforms to the FAA's prescribed air traffic control procedures and phraseology as laid out in Order JO 7110.65Y. If the answer to this question is no, then the tool goes to the 'Controller Instruction' page. If the controller's instruction was correct and complete, the tool asks whether the pilot followed the instruction. If the pilot did not follow the instruction, the tool goes to the 'Controller Instruction' page as well. If the pilot followed the instruction, the tool assumes that there were no errors involved with the aircraft, and moves to the other aircraft involved in the incursion to check for errors or goes to the end of the reporting form (if the controller finished reporting details for both aircraft). Figure 21 shows the different pages following the 'Controller Instruction' page. The following subsections discuss each of these pages.

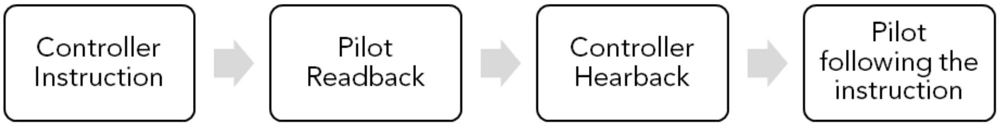


Figure 21. If there was any communication between, the tool asks detailed questions to identify whether the controller and the pilot performed the subtasks required to achieve runway safety correctly.

4.2.2 Controller Instruction Page

Figure 22 shows the decision tree to identify the error in the controller's instructions. While the tool auto-populates the choice for Q1 based on the Initial Investigation, this section goes in step deeper into identifying whether there were any issues in transmitting the instruction to the pilot and what those issues were. For example, another pilot had "stepped on" (i.e., started talking to the controller on the same frequency) the transmission leading to partial transmission of instruction to the pilot it was intended for.

If the controller's instruction was correct and complete, the tool goes to the 'Pilot Readback' page. If the controller's instruction was not correct or complete, the tool detects the error and asks the controller to enter the specific errors in the instruction before moving to the 'Pilot Readback' page. For example, the error in the controller's instruction could be that the controller issued a landing clearance for a closed runway.

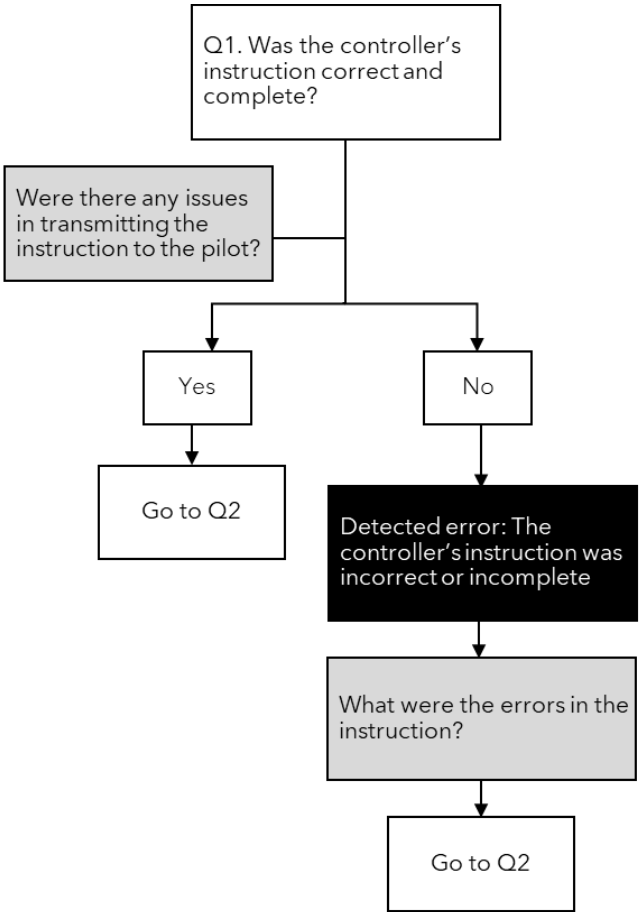


Figure 22. Questions on the 'Controller Instruction' page. This part detects any error related to the controller's instruction and any issues in transmitting the instruction to the pilot.

4.2.3 Pilot Readback Page

There are two aspects to this part of the investigation. One pertains to the pilot listening to the controller's instruction, and the second pertains to the pilot's readback. Figure 23 shows how the tool detects the error that the pilot did not or could not hear the controller's instruction. An example of the pilot not listening to the controller's instruction or missing a part of it could be that the transmission was garbled, or another pilot stepped on the transmission. If the pilot had issues listening to the instruction, the tool detects the error and asks the controller to enter the specific issues the pilot had. The controller may not necessarily know the pilot's side, and so they have the option to choose 'Unknown'. For questions related to the pilot readback, the tool does suggest the controller talk to the pilot to get their perspective.

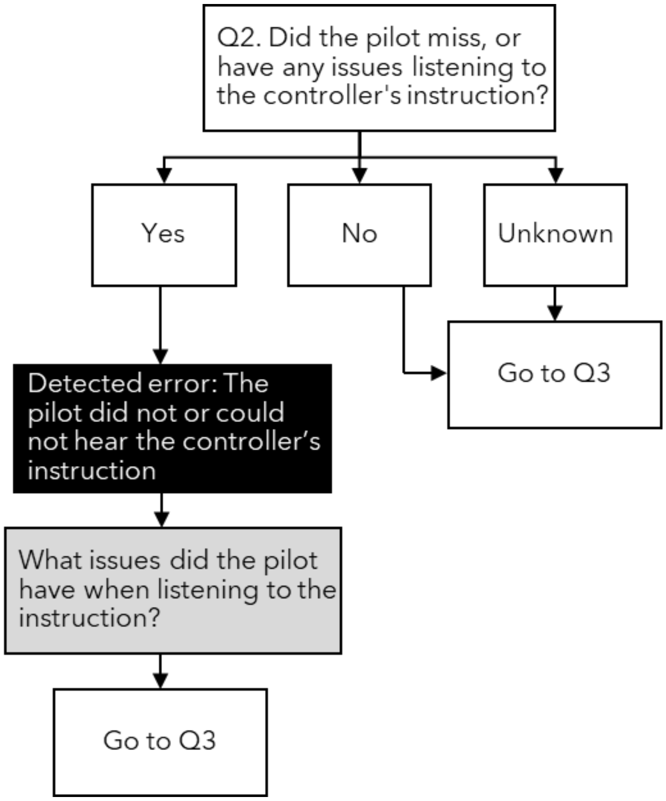


Figure 23. Questions on the ‘Pilot Readback’ page. The first question on this page identifies whether the pilot had any issues listening to the controller’s instructions.

Figure 24 shows the set of questions to detect errors pertaining to pilot's readback.

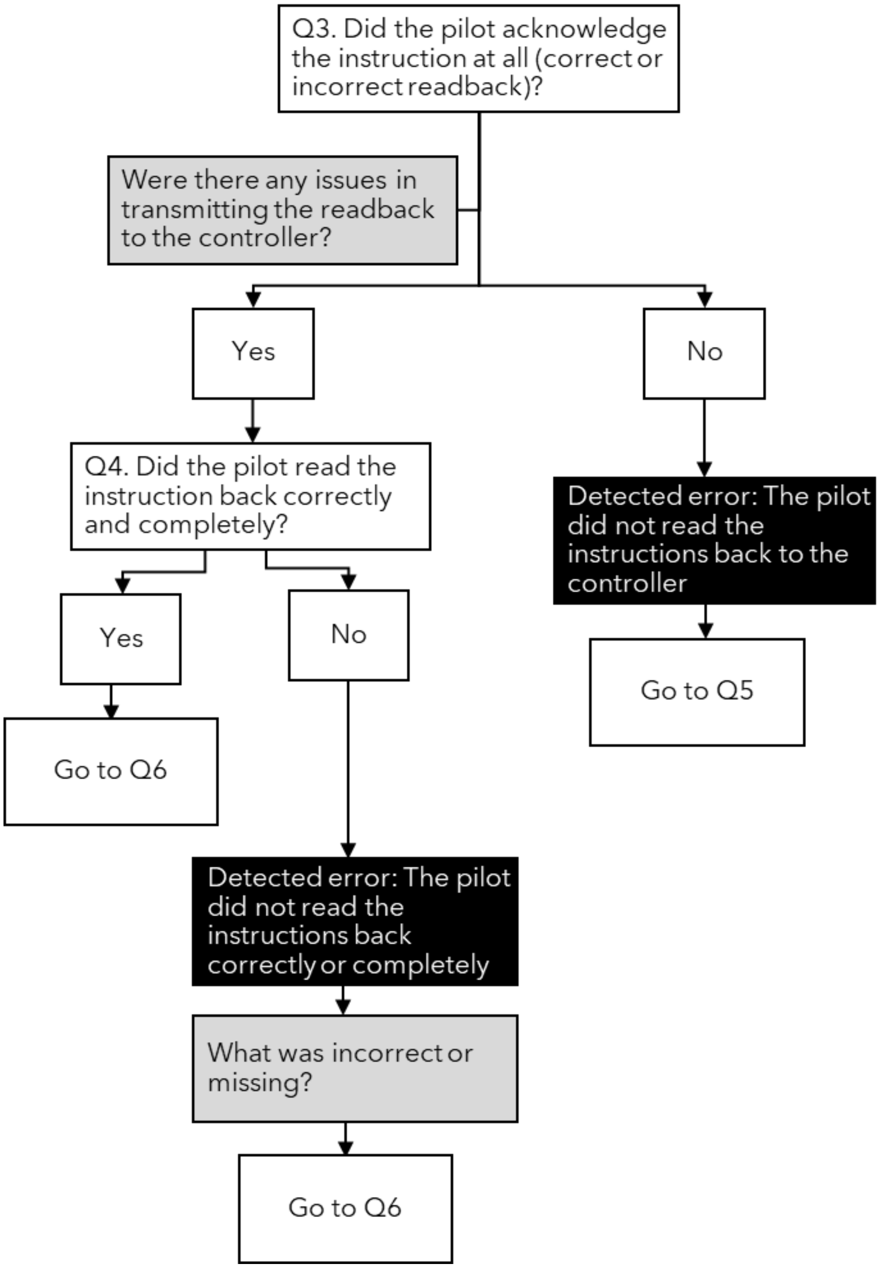


Figure 24. The next set of questions on the 'Pilot Readback' page identify whether the pilot read the instructions back to the controller. If the pilot read back the instructions, the tool asks whether the readback was correct and complete.

The tool first asks whether the pilot acknowledged that they received the instruction irrespective of the accuracy of the readback. If the pilot did not, then the tool detects that error and moves to Q5 as shown in Figure 25. If the pilot acknowledged the instructions, the tool asks whether the pilot had any issues transmitting the readback to the controller. Additionally, the tool asks whether the readback was correct and complete. If it was, the tool goes to Q6 (see Figure 26). If the readback was incorrect or incomplete, the tool detects the error and asks the controller to specify what errors the pilot made in the readback. Then, it moves to Q5.

4.2.4 Controller Hearback Page

Controller hearback is an opportunity for the controllers to identify any errors in their initial instructions and correct them. Based on the responses to the questions on pilot's readback, there are two possibilities. The tool shows Q5 as shown in Figure 25 if the pilot did not acknowledge the instructions at all. Here, the tool asks whether the controller asked the pilot to read the instructions back. If they did not, the tool detects the error and moves to the next stage page. If they did, it loops back to Q4.

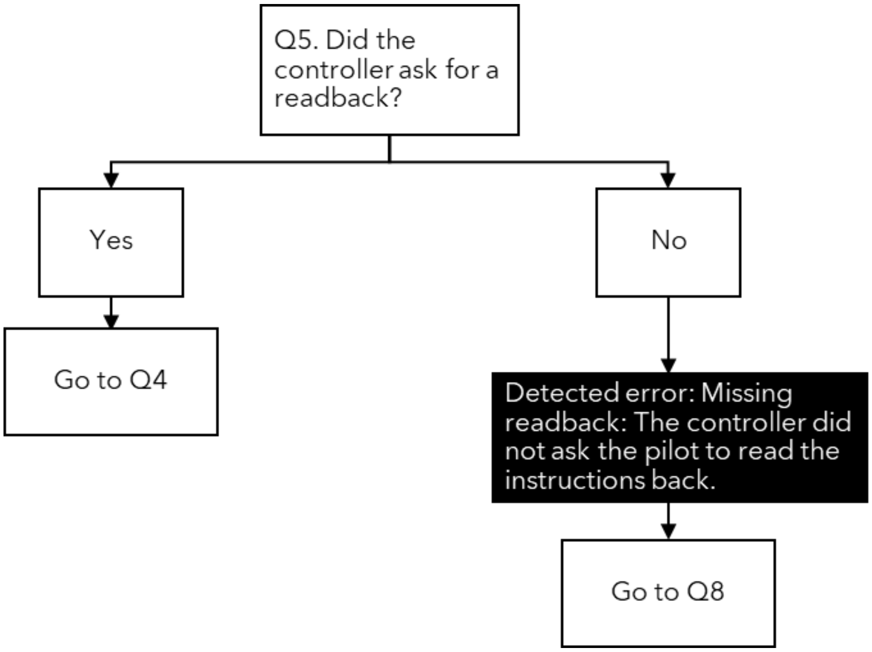


Figure 25. Questions on the 'Controller Hearback' page. If the pilot did not read the instructions back to the controller, the tool asks whether the controller asked the pilot for a readback.

Figure 26 shows the decision trees when the pilot does read the instructions back. If the pilot read back correctly and completely, the tool only asks whether the controller had any issues listening to the readback. For example, the controller's radios were faulty. If they did, the tool detects the error and asks the controller to specify the issues.

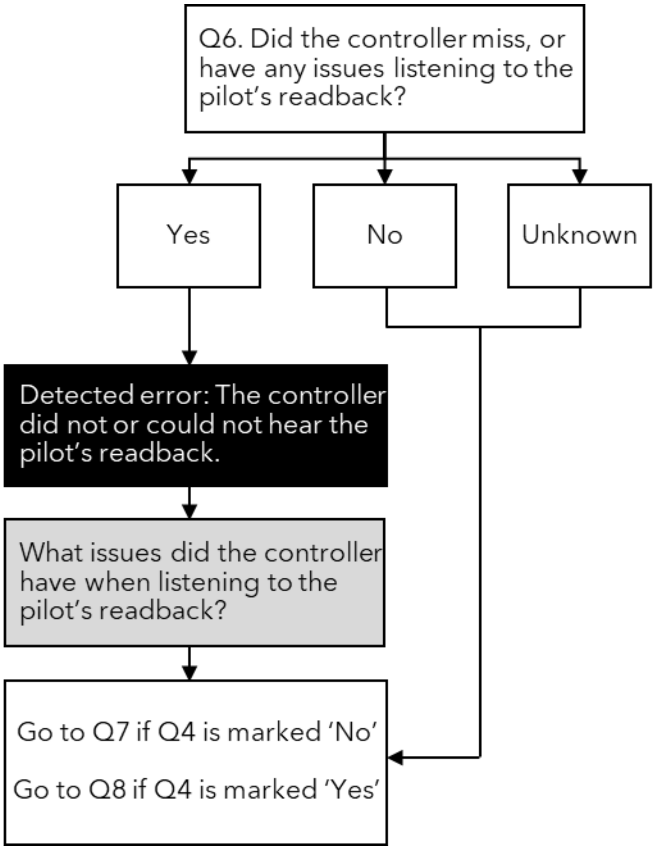


Figure 26. Questions on the 'Controller Hearback' page. If the pilot read the instructions back to the controller, the tool asks whether the controller had any issues listening to the readback.

If the pilot's readback was incorrect or incomplete, the tool asks whether the controller corrected the pilot's readback in addition to Q6. If the controller corrected the readback, it loops back to Q4, and if not, the tool detects the error that the controller did not correct the pilot's readback.

4.2.5 Pilot Following the Instruction Page

On this page, the tool first asks the controller whether the pilot ensured the instruction was safe to follow. Since ultimately it is the pilot's responsibility to ensure the safety of the flight, the pilot must make sure the runway is safe to operate on and clear of any conflicts. Figure 27 shows the flow of questions on this page. If the pilot ensured the safety of the flight, the tool detects the error that despite that, the pilot got involved in the runway incursion. This error helps identify contributing factors such as lack of runway closure markings leading the pilot to land on a closed runway that appeared ‘normal’ to the pilot. If the pilot did not ensure that the instruction was safe to follow, the tool detects this error. The controller may not know whether the pilot ensured the instruction was safe to follow, and so they can select the ‘unknown’ option. The tool suggests that the controller talk to the pilot to get their side of the story.

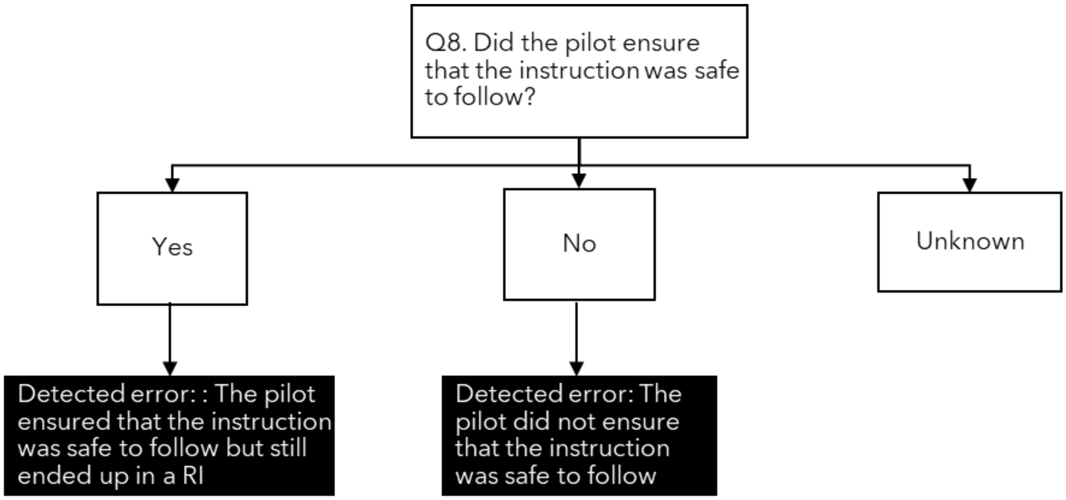


Figure 27. Questions on the ‘Pilot following the instruction’ page. Here, the tool asks whether the pilot ensured the instruction was safe to follow. For example, the pilot scanned the runways before entering onto it.

Finally, the tool asks whether the pilot followed the instructions, shown in Figure 28. If the pilot did not, the tool detects the error and asks the controller to enter the specific errors the pilot made.

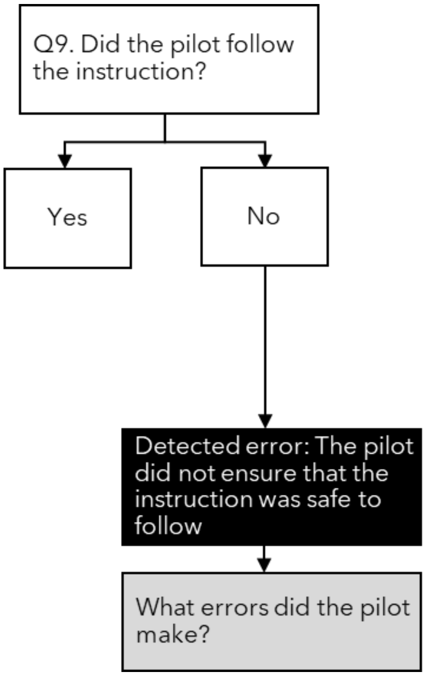


Figure 28. Questions on the ‘Pilot following the instruction’ page. Here, the tool asks whether the pilot followed the instructions, and if they did not, what errors they made.

The tool can detect a total of ten types of errors based on the controller’s responses to Questions 1 through 9. Since these questions are based on the typical sequence of all the tasks controllers and pilots perform to ensure safety on the runways, this set of ten potential types of errors is complete. The tool then shows the controller the types of errors they identified and asks them to specify contributing factors for each error. If a controller using the tool feels that these questions do not capture all the types of errors that led to the incursion, they can add their own in a ‘Summary’ section at the end of the reporting tool.

4.2.6 No Communication Established Page

Figure 29 shows the set of questions on this page. Here, the reporting tool asks what errors the pilot made, and why the pilot did not communicate with the controller. It also asks whether the controller observed the unauthorized aircraft movement and attempted to contact the pilot to ask them what the pilot’s intentions were.

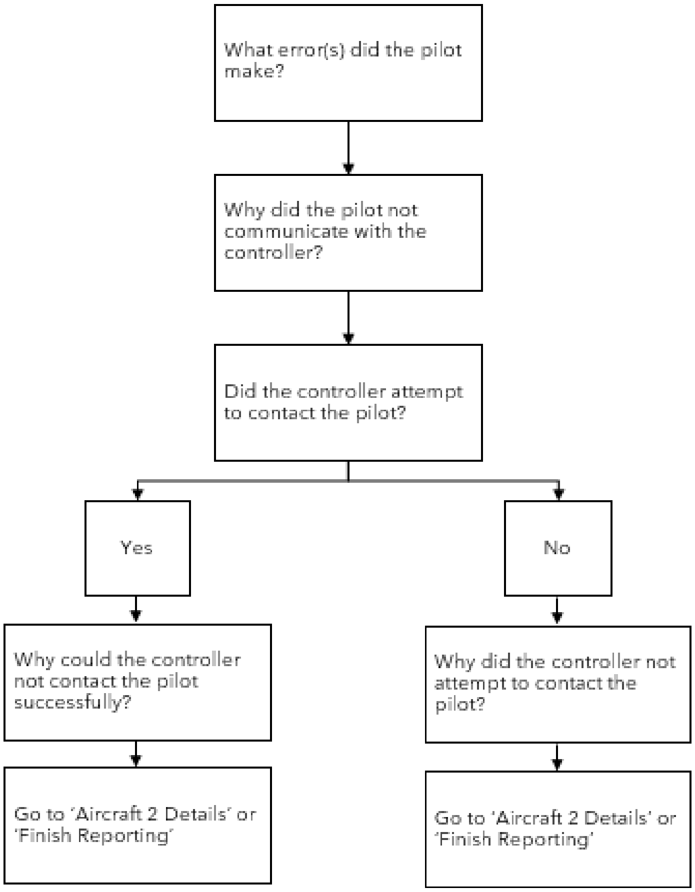


Figure 29. Questions on the 'No Communication Established' page.

4.3 Questions to Identify Contributing Factors

For each identified error, the tool asks the controller to specify factors that contributed to that error. These contributing causes explain *why* the errors occurred. To help controllers answer this question, or be aware of the possible underlying causes, the reporting tool provides a list of options. In the instructions, the tool mentions that the list of contributing factors is not exhaustive, and that the controller is not limited to choosing from the listed options. Additionally, the tool allows the controller to modify factors they selected from the list or add their own.

From the narrative analysis of the databases, I have a list of sentences that describe *why* errors that lead to incursions may occur. I used these factors to create the list of options, which is a two-step process: (1) based on the narratives, map the factors to the errors, and (2) categorize the causes into meaningful categories so the controller can easily navigate to the correct option instead of having to search through a long list of possible answers.

To illustrate the mapping of factors to the identified errors, consider a runway incursion (NSTB ID: FTW95IA126A/B) that happened when the controller cleared an aircraft to land on a runway and seven seconds later cleared another aircraft to taxi onto the same runway and hold for takeoff. As a result, the landing aircraft was only 35 feet above the aircraft holding in position. Thus, the error was that the controller issued incorrect or incomplete instructions. The contributing factors that the report mentioned included the controller getting uncomfortable minutes before the incident, the supervisor failing to recognize that the controller needed a break, and the controller's workload being heavy.

In another runway incursion, (NTSB ID: OPS09IA001A/B), the pilot did not follow the controller's instruction to hold short of a runway. The report mentioned that some of the contributing factors were that there were no hold short markings for the intersecting runway.

For the error, *the pilot did not read the instructions back to the controller or read the instructions back incorrectly*, the narratives mentioned only one contributing factor. See references, (Wilson, 2016) and (Monan, n.d.), for the remaining twelve contributing factors.

Table 17 shows the number of contributing factors for each type of error the tool can detect. Appendix B gives the complete list of options for each error the tool can detect.

Table 17. Total number of contributing factors for each type of error the tool can detect. This list of factors is from the analysis of runway incursion accident and incident data. This list is non-exhaustive; the tool gives controllers an option to add their own factors if needed.

Error	Number of contributing factors
The controller’s instruction was incorrect or incomplete	97
The pilot did not or could not listen to the controller’s instructions	9
The pilot did not read the instruction back to the controller	13
The pilot did not read the instruction back to the controller correctly	13
The controller did not or could not hear the pilot's readback	8
The controller did not correct the pilot's incorrect readback of the instruction	7
Missing readback: the controller did not ask the pilot to read the instruction back	7
The pilot did not scan runways to make sure the instruction was safe to follow	4
The pilot ensured that the instruction was safe to follow but still ended up in an incursion	21
The pilot did not follow the controller's instruction	77

4.4 Interface Design

The tool is a web-based interactive tool, see https://engineering.purdue.edu/VRSS_RItool. I created the tool using HTML, CSS, PHP, and JavaScript. The tool consists of a series of pages pertaining to different aspects of incident reporting — describing what happened, detecting errors that led to the incursion, and specifying contributing factors that led to the incursion. Figure 30 shows the flow of these pages in the tool.

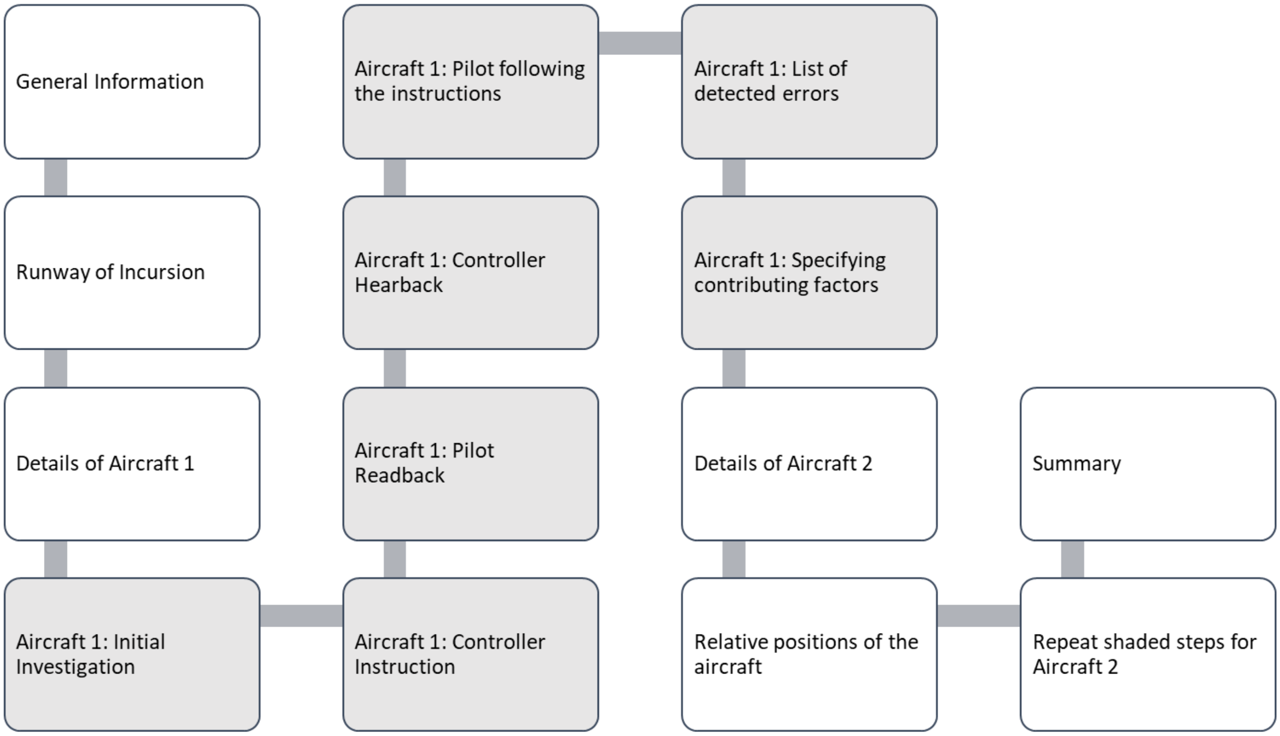


Figure 30. The flow of different pages in the alternative reporting tool if there was communication between the controller and the pilot.

The controllers can navigate back and forth between these pages and change their responses if they wished to. Other than the questions on when and where the incursion occurred, and information of the aircraft involved, the controllers can skip any questions they did not know the answer to or did not wish to provide an answer to. At the end, the tool provides a summary of the responses the controller enters. At this point, while the controller cannot go back in the tool and change any responses, the summary has editable fields for the controller to make any changes before they submit the report.

See Appendix D for questions in the reporting tool and Appendix E for the different features of the tool.

5. EXPERIMENTAL SETUP

The questions in the alternative reporting tool aim to provide controllers with a checklist of details they should consider reporting. The questions also aim to encourage controllers to look deeper into an incident. Following is a list of expected outcomes the alternative reporting tool aimed to achieve:

1. Help controllers describe what happened in detail.
2. Generate incident reports that provide information on not only human error but also causes of human error.
3. Help controllers identify all potential errors that may have led to the incident rather than viewing the incident as an operational or pilot deviation.
4. Prompt controllers to talk to the pilots involved in the incident to include the pilot's perspectives in their report.
5. Provide controllers guidance on what questions to ask the pilots involved in the incident to gain insight into factors that may have contributed to the incident.

I designed an experiment to investigate whether the alternative reporting tool achieves these outcomes. Additionally, the experiment investigates the extent to which the alternative reporting tool affects the quality of incident reports, or the controllers' ability to create information-rich reports. For example, did a question on the alternative reporting tool motivate the controller to talk to the pilot or was it something they would do regardless of the format of the reporting form?

Controllers today generally use the online tool CEDAR to report runway incursion incidents. The FAA requires controllers to fill out a paper/PDF form — Form 7210-13 when they don't have online access. Since CEDAR is only accessible to air traffic controllers, I created a Qualtrics survey based on the FAA Form 7210-13. I used the Qualtrics survey to compare how controllers interact with different reporting formats.

I conducted an experiment with air traffic controllers where each participating controller reported two hypothetical incidents using either the alternative reporting tool or an online form based on the FAA Form 7210-13. The controllers either reported Incident 1 first and then Incident 2 or vice-versa. This chapter describes the various steps leading up to the experiment, the study procedures I followed to conduct the experiment, and the types of data I collected through this experiment.

5.1 Hypothetical runway incursion incident videos

The two hypothetical incursions occurred at the Seattle International Airport (KSEA). Figure 31 shows the official airport diagram of KSEA from the FAA. Both incursions involved two aircraft — a Cessna 172 and a Piper Warrior II. In Incident 1, the Cessna 172 (Tail number: VRSS1) failed to hold short of Runway 16L at taxiway Echo as instructed and conflicted with the Piper Warrior II (Tail number: VRSS2) that was rolling out after landing on the same runway. In Incident 2, the Piper Warrior II (Tail number: VRSS3) failed to hold short of Runway 16 L on taxiway Foxtrot while taxiing after landing on Runway 16 C. As a result, the aircraft conflicted with the Cessna 172 (Tail number: VRSS4) that was on its takeoff roll on Runway 16 L. The positions of the aircraft and taxiing instructions are hypothetical and do not necessarily represent actual practices at KSEA.

Figure 32 shows the view of runways an air traffic controller working in the KSEA tower would see. I used this image as the background for my videos. I created animations that showed the aircraft movements on the runways and taxiways visible from the tower. The aircraft in the animation are not to scale, and their speeds in the animation are not proportional to the speeds of the actual aircraft. For the audio, I wrote a script that laid out the communication between the controller and the pilots at the time of the incident. See Appendix C for the scripts. I used a text-to-speech converter to create the audio file for the animation. I also added an audio file containing background noises in an air traffic control tower. A controller working in the control tower would be accustomed to hearing some background noise. For additional sound effects, I added the sound of the mic keying in and out at the start and end of each conversation.

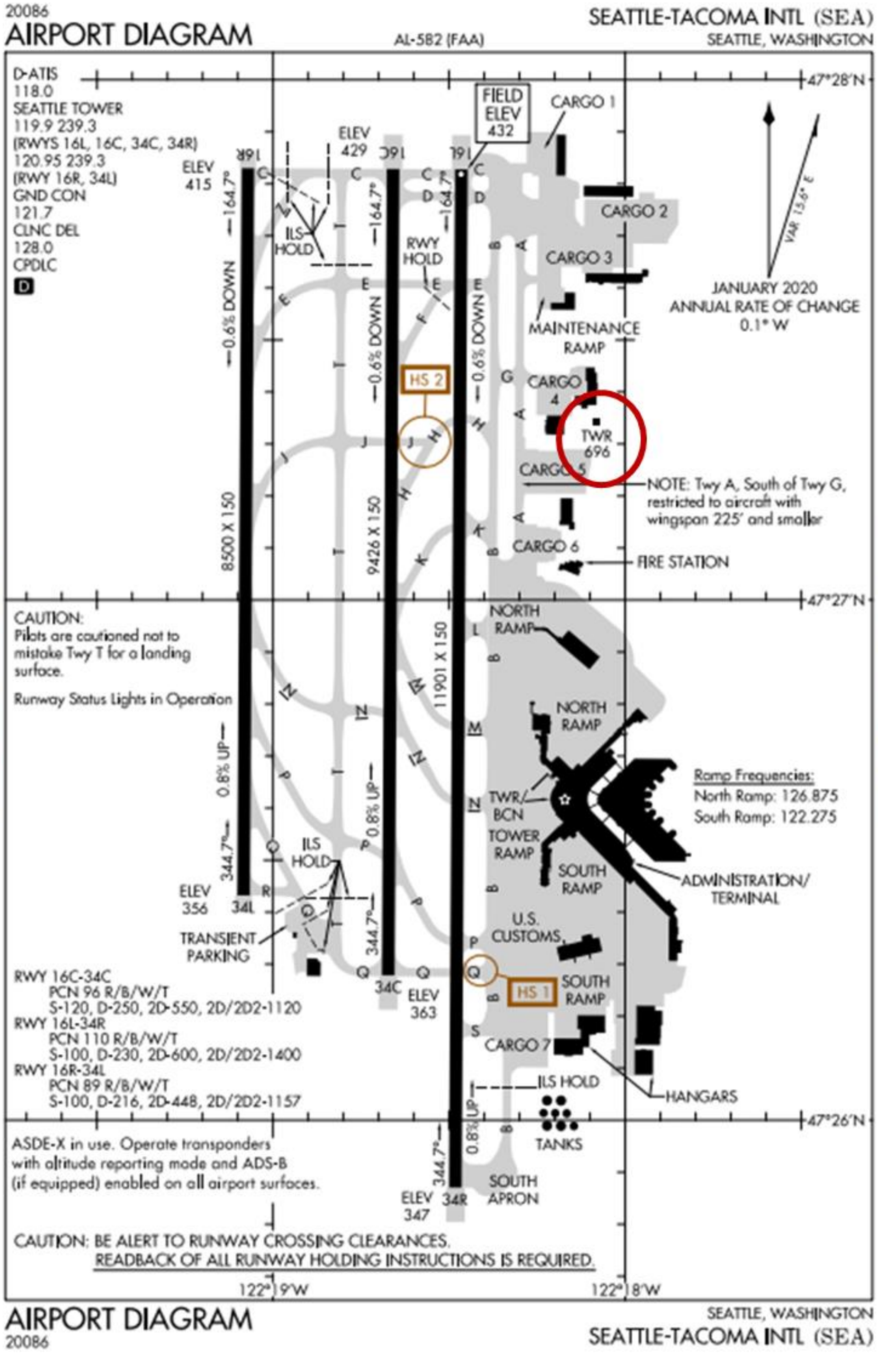


Figure 31. The FAA-published airport diagram of KSEA. Both hypothetical incidents occurred on Runway 16 L. The red circle marks the location of the control tower at the airport.

Figure 32. View of runways from the tower (Source: X-plane 11 Simulator)

5.2 Reporting context for the controllers

Since the controllers participating in the experiment may not have had experience working at KSEA, I provided them with some background information on the airport, control tower at the time of incursion, aircraft involved in the hypothetical incident, and the weather. The controllers had access to this information throughout the experiment. Appendix F contains the details on the background information I provided for each incident.

During the experiment, the controller reporting the hypothetical incursions could choose to talk to the pilots involved to hear the pilots' side of the story and report any important factors from it. They could ask them questions to identify what factors contributed to the incursion. Study personnel played the role of the pilots involved in the two hypothetical incursions. I created fictional background stories describing how and why each "pilot" got involved in the incursion. See Appendix G for these background stories.

In real-life reporting, controllers have access to recordings of their conversations with the pilot. The controller may need to listen to these tapes to answer questions on the reporting form. I used the incident videos to create an audio-only file that played the conversation between the controller and the pilot in the hypothetical incursions.

5.3 Study Procedures

I conducted the experiment over a video call where I asked controllers to share their screen or browser window, but not their face (i.e., I asked them to disable their camera). I recorded the call to have a record of how they fill out the form and so that I didn't lose any verbal cues.

There were at least two observers present during each call. The study personnel playing the role of the pilot involved in the incursion were on standby and only joined the call when the controller asked to talk to them. After getting the controller's verbal consent to participate in the study, I started recording the call and started the experiment by going over the logistics. I shared my screen and showed them the reporting form they would be using and where they could find additional information they may need while filling out the form. I informed them that similar to a real-life incident, they could only view the hypothetical incident video once, and they could request to talk to the pilots involved or listen to the audio tapes at any point during the reporting process. I also encouraged controllers to think aloud as they interacted with the form and reminded them when they fell silent while interacting with the form.

After going over the logistics, I shared the link to the reporting form with the controllers and gave them time to go over the background information, if needed, to familiarize themselves with the setup for the hypothetical incidents. Once the controllers said they were ready, I played one of the two incident videos while sharing my screen. In other words, the controllers did not have links to the incident videos. After watching the video, the controllers shared their screen displaying the reporting form and reported the incident. Refer to Appendix D for the questions in each of the reporting forms. None of the questions on the reporting forms asked for any identifiable or demographic information.

While reporting, if the controller asked to listen to the audio tapes, I shared the links to the audio-only files with them so they could play it on their end whenever they wished to. If the controller asked to talk to the pilot involved, I let the pilot, who was on standby, into the call. After reporting one incident, when the controller indicated they were ready for the next one, I played the other incident video at my end and followed the same set of procedures.

After the controllers finished reporting, I conducted a voluntary short debrief session with them where I asked some open-ended questions about the forms and recorded any other feedback they may have. Refer to Appendix D for the list of questions I had for the debrief session.

5.4 Data Collection

After getting approval for this study from Purdue University's Institutional Review Board (IRB), we reached out to personal contacts or contacts via social media who connected us to potential participants. We then reached out to the potential participants via email describing the experiment and requesting their participation. Seven controllers participated in our study. They were either currently working at an FAA control tower in the United States or had retired from working at one.

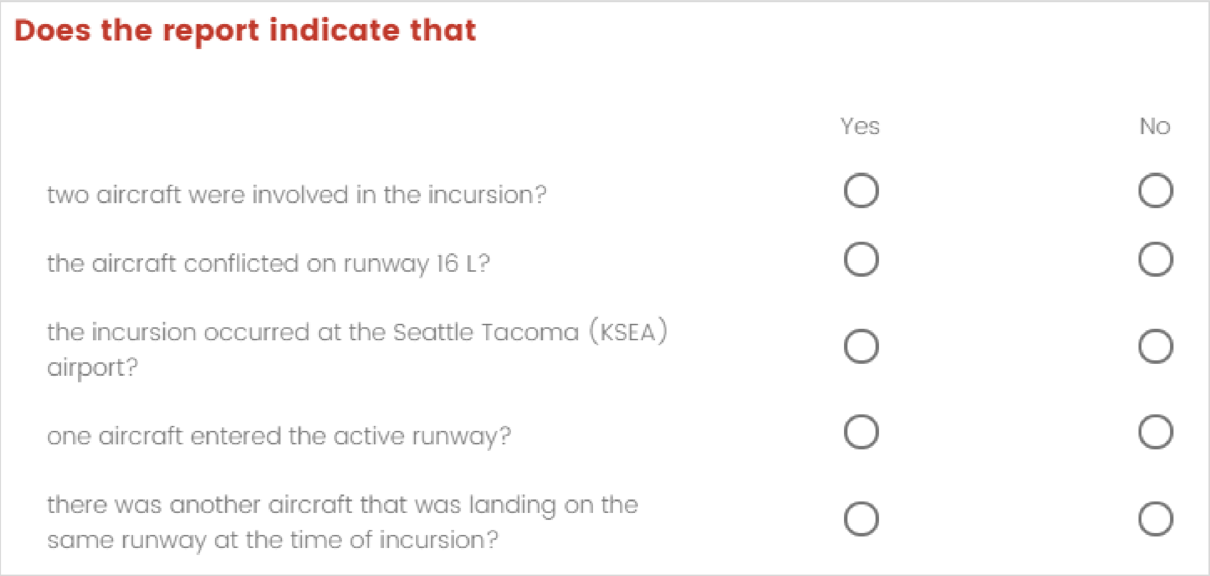
On average, each call lasted for approximately 70 minutes, with the shortest call being 45 minutes and the longest call being 83 minutes. All the controllers participated in the voluntary debrief session. Since the format of the debrief session was that of a semi-structured interview, I asked follow-up questions based on controllers' responses in addition to the questions I had prepared before. At the end of each call, I had the following types of data

- Incident report or the responses the controllers entered in the forms
- A video showing how the controllers interacted with the form, for example, how did they navigate through the pages or which buttons did they click.
- The audio component of the form that contains the think-aloud protocols and the conversations during the debrief session.

5.5 Rubric to evaluate the content in each incident report

Based on the incident videos, I created a rubric to evaluate the controller generated reports. Appendix H contains the full rubric. The purpose of the rubric was to identify what information we get from the two reporting formats and how the controllers reported that information. The rubric was not intended to point out any flaws in the report. My goal was to identify whether there was something in the form that prompted controllers to give a specific piece of information or whether they would have done so irrespective of the format of the form.

Figure 33 shows the rubric items for the first category of information, the description of the incident for Incident 1. The only change in the rubric for Incident 2 is that the last item asks whether the report indicated that there was another aircraft on takeoff roll on the same runway at the time of incursion. For the reports to describe the incident completely the controllers must specify the airport at which the incursion occurred, the location on the airport where the incursion occurred, who was involved in the incursion (for example, two aircraft or an aircraft and a ground vehicle), and what were they doing at the time of incursion.

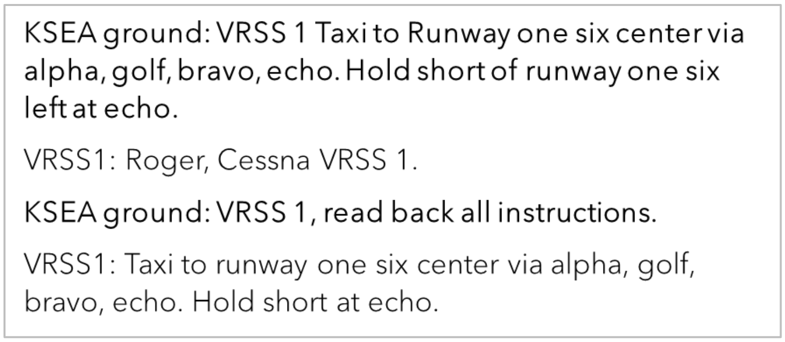


Does the report indicate that

	Yes	No
two aircraft were involved in the incursion?	○	○
the aircraft conflicted on runway 16 L?	○	○
the incursion occurred at the Seattle Tacoma (KSEA) airport?	○	○
one aircraft entered the active runway?	○	○
there was another aircraft that was landing on the same runway at the time of incursion?	○	○

Figure 33. Rubric items to evaluate how well the reports described the incident. Both incidents occurred on Runway 16L at the KSEA Airport and involved one aircraft crossing entering onto the active runway. For Incident 2, the last item asks whether the report indicated that another aircraft was on takeoff roll on the same runway at the time of incursion.

I used the script I wrote for the hypothetical incident video to generate the error part of the rubric. Figure 34 shows a snippet of the script I wrote for the conversation between Seattle Ground and the VRSS 1 pilot. In this snippet, the errors are that the pilot responded with ‘Roger’ on the first readback, missed the call sign and which runway to hold short of in the second readback.



KSEA ground: VRSS 1 Taxi to Runway one six center via alpha, golf, bravo, echo. Hold short of runway one six left at echo.

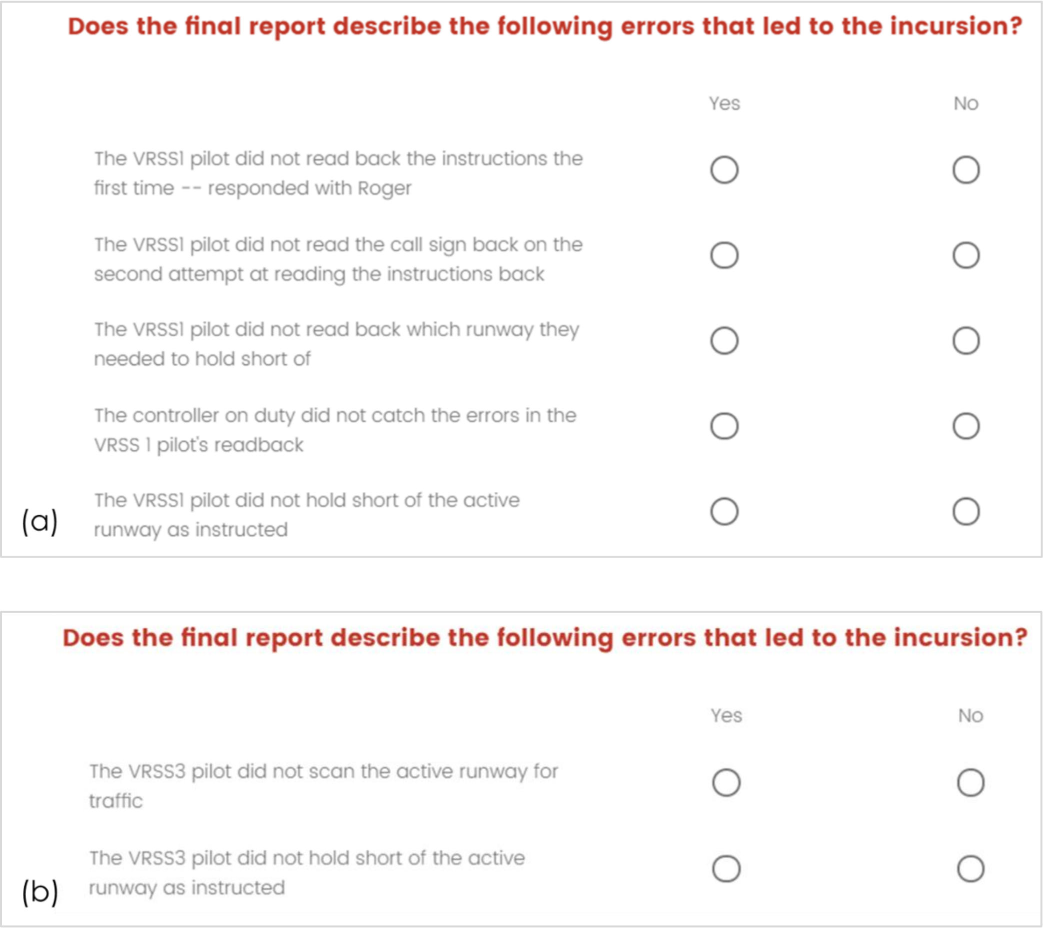
VRSS1: Roger, Cessna VRSS 1.

KSEA ground: VRSS 1, read back all instructions.

VRSS1: Taxi to runway one six center via alpha, golf, bravo, echo. Hold short at echo.

Figure 34. A snippet of the script I wrote for the communication between KSEA ground and VRSS 1 pilot. The snippet shows multiple errors in the pilot's readback.

Figures 35(a) and 35(b) show the rubric for this category of information for Incident 1 and Incident 2 respectively.



Does the final report describe the following errors that led to the incursion?

	Yes	No
The VRSS1 pilot did not read back the instructions the first time -- responded with Roger	○	○
The VRSS1 pilot did not read the call sign back on the second attempt at reading the instructions back	○	○
The VRSS1 pilot did not read back which runway they needed to hold short of	○	○
The controller on duty did not catch the errors in the VRSS 1 pilot's readback	○	○
The VRSS1 pilot did not hold short of the active runway as instructed	○	○

(a)

Does the final report describe the following errors that led to the incursion?

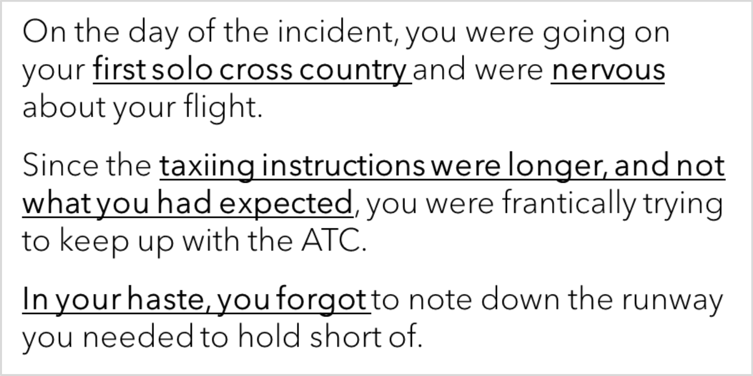
	Yes	No
The VRSS3 pilot did not scan the active runway for traffic	○	○
The VRSS3 pilot did not hold short of the active runway as instructed	○	○

(b)

Figure 35. Rubric items to evaluate whether the reports specified that particular error. 35(a) corresponds to errors in Incident 1 and 35(b) corresponds to errors in Incident 2. Though both incidents were pilot deviations, the errors that contributed to the incursion were more than just the pilot entering onto the active runway.

For Incident 1, the rubric includes errors in the pilot readback and the controller not catching the error. The purpose of these errors was to identify what helps controllers report errors in addition to just reporting the most evident error of pilot crossing the hold short line. For Incident 2, one of the errors was that the pilot did not scan the runway before entering onto it. The purpose of this error was to identify whether controllers consider asking the pilot this question, and if they do, what prompts them.

For the items on the rubric to evaluate the contributing factors, I used the background story I wrote for the pilots in the hypothetical incidents. Figure 36 shows a snippet of the story I wrote for the VRSS 1 pilot. In this snippet, the factors that contributed to the incursion are that the pilot was nervous, the flight was their first solo cross-country flight, the taxiing instructions were longer than what they had expected, and the pilot forgot to note down the runway they needed to hold short of.



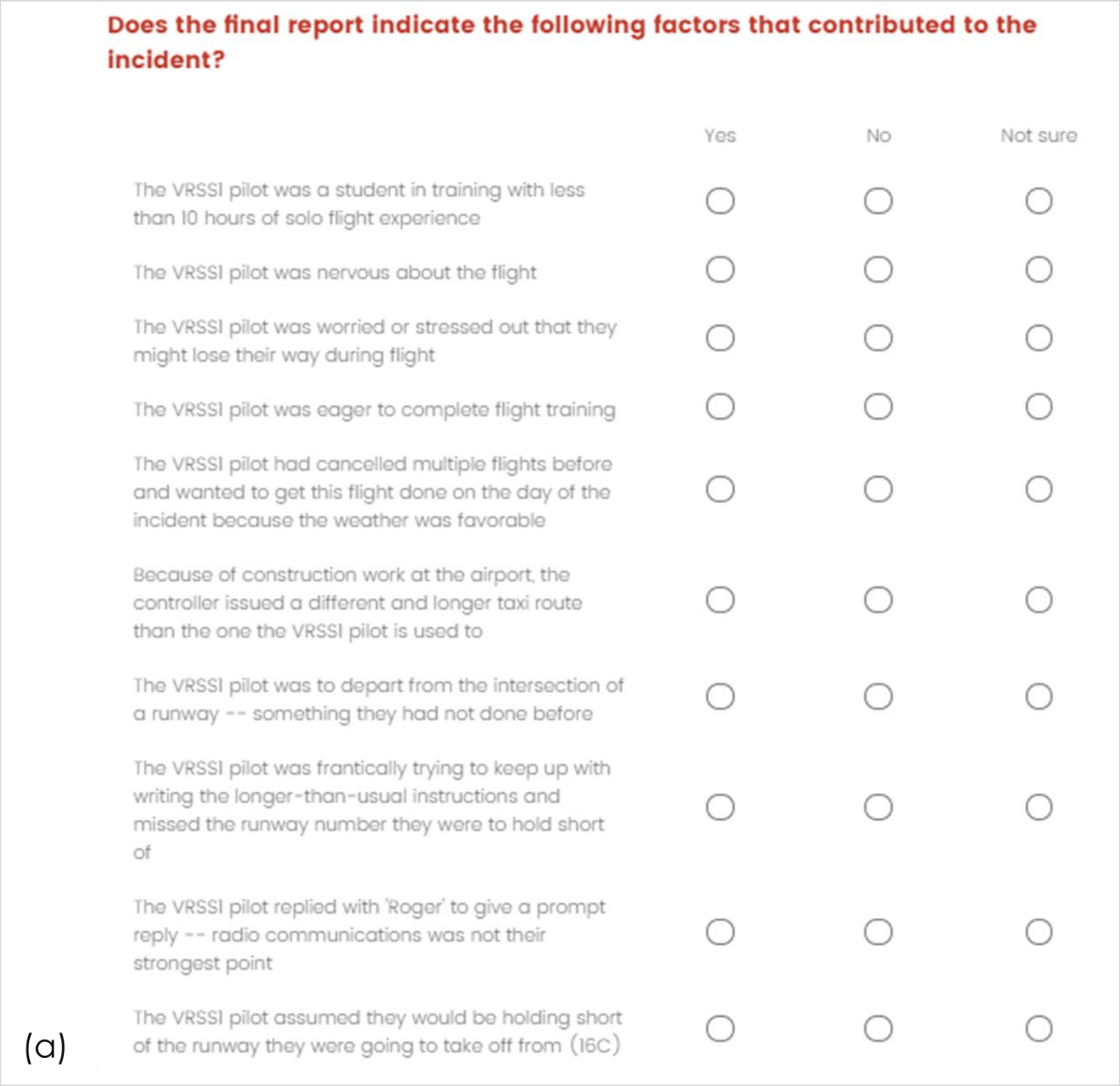
On the day of the incident, you were going on your first solo cross country and were nervous about your flight.

Since the taxiing instructions were longer, and not what you had expected, you were frantically trying to keep up with the ATC.

In your haste, you forgot to note down the runway you needed to hold short of.

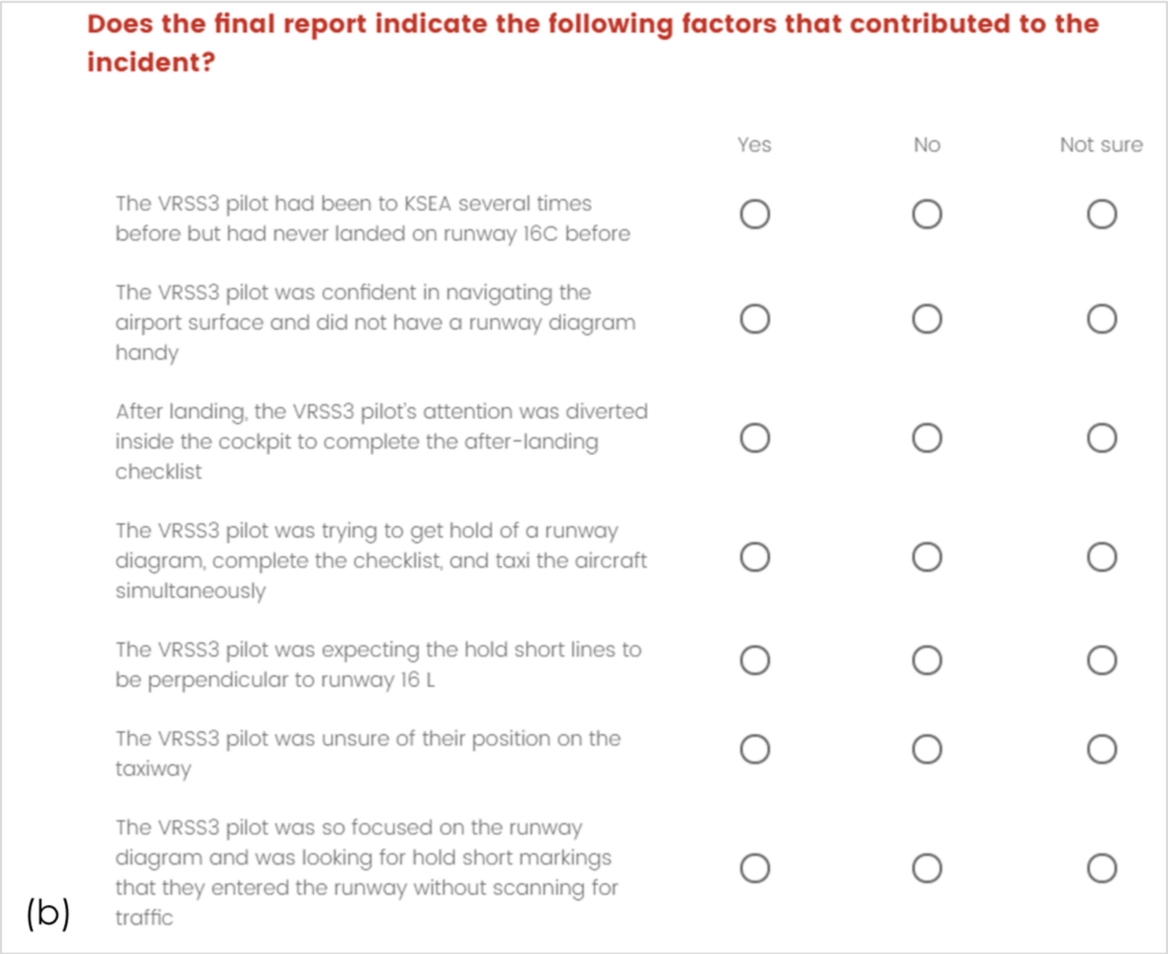
Figure 36.Snippet of the background story I wrote for the VRSS 1 pilot. The underlined text shows some of the factors that contributed to the pilot error.

Figures 37(a) and 37(b) show rubric items for this category.



Does the final report indicate the following factors that contributed to the incident?

	Yes	No	Not sure
The VRSSI pilot was a student in training with less than 10 hours of solo flight experience	○	○	○
The VRSSI pilot was nervous about the flight	○	○	○
The VRSSI pilot was worried or stressed out that they might lose their way during flight	○	○	○
The VRSSI pilot was eager to complete flight training	○	○	○
The VRSSI pilot had cancelled multiple flights before and wanted to get this flight done on the day of the incident because the weather was favorable	○	○	○
Because of construction work at the airport, the controller issued a different and longer taxi route than the one the VRSSI pilot is used to	○	○	○
The VRSSI pilot was to depart from the intersection of a runway -- something they had not done before	○	○	○
The VRSSI pilot was frantically trying to keep up with writing the longer-than-usual instructions and missed the runway number they were to hold short of	○	○	○
The VRSSI pilot replied with 'Roger' to give a prompt reply -- radio communications was not their strongest point	○	○	○
The VRSSI pilot assumed they would be holding short of the runway they were going to take off from (16C)	○	○	○



Does the final report indicate the following factors that contributed to the incident?

	Yes	No	Not sure
The VRSS3 pilot had been to KSEA several times before but had never landed on runway 16C before	○	○	○
The VRSS3 pilot was confident in navigating the airport surface and did not have a runway diagram handy	○	○	○
After landing, the VRSS3 pilot's attention was diverted inside the cockpit to complete the after-landing checklist	○	○	○
The VRSS3 pilot was trying to get hold of a runway diagram, complete the checklist, and taxi the aircraft simultaneously	○	○	○
The VRSS3 pilot was expecting the hold short lines to be perpendicular to runway 16 L	○	○	○
The VRSS3 pilot was unsure of their position on the taxiway	○	○	○
The VRSS3 pilot was so focused on the runway diagram and was looking for hold short markings that they entered the runway without scanning for traffic	○	○	○

(b)

Figure 37. Rubric items to evaluate whether the reports specified a particular contributing factor. 37(a) corresponds to contributing factors for Incident 1 and 37(b) corresponds to contributing factors for Incident 2. These factors are based on the background story laying out how and why the pilots got involved in the incursion.

6. RESULTS AND DISCUSSION

Seven active or retired air traffic controllers participated in the experiment. Each controller reported both hypothetical incidents using either the alternative reporting tool, which I will refer to as the *website*, or the online form based on the FAA Form 7210-13, which I will refer to as the *survey*. Table 18 shows the controller codes for each controller who participated in the experiment, the reporting format they used, and the order in which they reported the hypothetical incidents. For example, ATCS (Air Traffic Control Specialist) 1 reported Incident 1 first and then Incident 2 using the website. ATCS 2 reported Incident 2 first and then Incident 1 using the survey.

Table 18. Air traffic controllers who participated in the experiment reported two hypothetical incidents either using the alternative reporting tool or an online form based on the FAA Form 7210-13. They either reported Incident 1 first or Incident 2. Each ATCS used the same form to report both incidents.

	Incident 1 + Incident 2	**Incident 2 + Incident 1**
Alternative reporting tool (Website)	ATCS 1, ATCS 5	ATCS 2, ATCS 6
Online form based on FAA Form 7210-13 (Survey)	ATCS 3, ATCS 7	ATCS 4

At the end of the experiment, I had a total of fourteen incident reports. Eight of these reports are website-generated and the remaining six are survey-generated. The incident reports contain the data controllers entered in the reporting forms. Recording the video call generated two major files: (1) the video file showing the controller’s screen as they reported the incidents, thought out loud, and the debrief session, and (2) a file that contains only the audio component of the call. I used an online software tool to automatically transcribe the audio. Each transcription consists of two parts — the transcribed think-aloud protocols and the transcribed debrief session. After transcribing the audio, I deleted the audio component from the recoded video, that is, I created a soundless version of the video. Purdue University’s IRB approved these steps to protect the identity of the participants.

Each observer referred to the incident report that contained the responses controllers entered in the form, the transcription of the audio, and the soundless video to evaluate the fourteen controller-generated reports against the rubric described in Section 5.5. The observers used the responses controllers entered in the form to indicate the presence or absence of details listed in the rubric. For any additional details, the observers performed content analysis on the transcription audio of the file to find out how and why controllers reported that additional information. This content analysis was deductive in nature as the observers had a preestablished plan for searching through data based on their set goal (Hsieh & Shannon, 2005). To analyze the content from the open-ended questions I asked in the debrief sessions, I used the inductive method for analyzing content, where I found themes and patterns after reading the transcriptions.

This chapter is laid out as follows. After summarizing the results in Section 6.1, Section 6.2 of the chapter focuses on the controllers' interactions with the pilots involved — the factors affecting the controllers' decision to talk or not talk to the pilot and what the conversations were. This section also describes factors affecting the controllers' decision to listen to the audio-only file of the incident. Section 6.3 describes the controllers' interactions with the different reporting formats and how controllers reported details of the incident. This section also highlights the usability issues with the reporting formats that the controllers pointed out. Finally, Section 6.4 discusses the implications of the results on the expected outcomes of the website, controllers' opinions on the two reporting formats, and controllers' views on the future of reporting.

6.1 Summary of results

The website-generated reports provided more information on types of errors that led to the incursion and the factors that contributed to the incursion than the survey-generated reports. The reasons for including or not including certain details in the reports also varied across the seven controllers. There was no one way in which the controllers interacted with either the website or the survey. There were differences in why controllers decided to talk or not talk to the pilot, the conversations they had with the pilots, and why they decided to listen or not listen to the audio-only files.

While two controllers spoke to the pilot before they started reporting the incidents, one controller spoke to the pilot once when they landed on the website page that asked them to specify factors that contributed to pilot errors, and one controller asked the pilot multiple questions as they were identifying factors that contributed to pilot errors. While one controller spoke to the pilot before the incident because generally, they get the pilots' statements before submitting the report, another controller stated that as a controller, it is not their job to talk to the pilots and investigate the incident. They said that the controller's job is only to describe *what* happened. The controller said investigating the *why* is up to the NTSB or the FAA.

Controllers had different approaches to creating their incident reports. One controller said they wanted to create a 'big picture' for Quality Assurance (QA) of what had happened and said that the QA would listen to the audiotapes and investigate the incident further as needed. Another controller listened to the tapes multiple times making sure they had an accurate set of details on the conversation between the pilot and the controller because they viewed the incident report as a 'legal document'.

6.2 Controllers' interactions with the pilots involved in the incident and the audio-only file of the incident videos

Table 19 shows whether the controller talked to the pilot or listened to the audio-only files of the incidents. The first column shows the controller code and the second column shows which form they used. The next two columns show the data for the two incidents. The grey shaded cells indicate which incident they reported first. For example, ATCS 1 reported Incident 1 first, and ATCS 3 reported Incident 2 first.

The first column under each incident indicates whether the controller listened to the audio-only file of the incident. The audio-only files are analogous to the recordings of the conversations between the controller and the pilot in a real-life scenario. The second column for each incident shows whether the controller spoke to the pilot who crossed the hold short line, that is, the pilot who was incorrectly present on the runway. The third column shows whether the controller spoke to the other pilot — the one that wasn't incorrectly present on the runway. This section looks deeper into each of these interactions.

Table 19. The checkmarks in the table indicate that the controller listened to the audio-only file or spoke to the pilot involved while reporting the incident. The crosses indicate that the controller did not listen to the audio file or speak to the pilot involved while reporting the incident.

Controller Code	**Form Used**	**Incident 1**			**Incident 2**		
		Listened to the audio-only file	Spoke to VRSS 1 pilot	Spoke to VRSS 2 Pilot	Listened to the audio-only file	Spoke to VRSS 3 pilot	Spoke to VRSS 4 Pilot
ATCS 1	Website	✓	✓	✗	✓	✓	✗
ATCS 3	Website	✓	✗	✗	✓	✗	✗
ATCS 5	Website	✗	✗	✗	✗	✓	✓
ATCS 7	Website	✓	✓	✗	✓	✓	✗
ATCS 2	Survey	✗	✗	✗	✗	✗	✗
ATCS 4	Survey	✓	✗	✗	✓	✗	✗
ATCS 6	Survey	✗	✗	✗	✗	✗	✓

6.2.1 Factors affecting the controllers' decision to talk or not talk to the pilots involved in the incidents

Overall, four controllers (ATCS 1, ATCS 5, ATCS 7, ATCS 6) spoke to the pilots at least once during the experiment. Three controllers (ATCS 3, ATCS 2, and ATCS 4) did not talk to the pilots while reporting either incident. Each controller had a different motivation to talk to the pilots involved in the incidents. ATCS 5 and ATCS 6 were the only controllers who spoke to the pilot who did not cross the hold short line, that is, the pilot who was not incorrectly present on the runway. They were also the only controllers whose decision to talk to the pilots changed between the two incidents. Both ATCS 5 and ATCS 6 reported Incident 1 first. While reporting this incident, they did not talk to the pilots involved, but talked to them when they reported the second incident.

Previous Experience

ATCS 5 spoke to both pilots after they watched the incident video and before opening the reporting form. ATCS 5 said that they spoke to both pilots involved in Incident 2 because in a real-life scenario they generally get the pilots' side of the story before submitting the report. In the case of Incident 1, even though ATCS 5 mentioned they should have spoken to the pilot before reporting, they went ahead and submitted the report. In the debrief session, ATCS 5 stated that they did not have a specific reason for not talking to the pilots in Incident 1. They stated that they "*didn't really know the rules of the game*", i.e., they did not know the "rules" of the experiment.

ATCS 4 reported the incidents using the survey. During the debrief session, they said that they did not consider talking to the pilot, based on their previous experience of reporting incidents. They said that for pilot deviations, they would type out the transcript of the conversation between the controller and the pilot, and it would be the supervisor's responsibility to talk to the pilot. They acknowledged that they could have spoken to the pilot since that resource was available, but they didn't tap into it based on their previous ways of reporting pilot deviations.

Questions on the website to detect errors

For questions such as 'Did the pilot miss, or have any issues listening to the controller's instructions?' and 'Did the pilot ensure that the instruction was safe to follow?', a controller wouldn't generally know the answer unless they talked to the pilot. These questions motivated only ATCS 7 to talk to the pilot while reporting Incident 1. The other controllers who answered these questions either guessed a response or marked 'unknown' without talking to the pilot. One of the controllers who marked 'unknown' for these questions said that they have no way of knowing this information. The instructions for these questions on the website stated that controllers could request to talk to the pilot. These instructions did not prompt the controllers to talk to the pilot because the controllers skipped reading the instructions.

Questions on the website to identify contributing factors

When the website asked ATCS 1 to specify contributing factors for the pilot-related errors they had identified, they went through the list of options and stated that as a controller they wouldn't know which factors applied. ATCS 1 said that they generally do not interact with the pilots other than warning them of the pilot deviation. ATCS 1 said that they are not the "*police of the sky*" and so do not get into detailed discussions with the pilot. However, for the purpose of the experiment, they spoke to the pilot of VRSS 1.

Questions to identify contributing factors also prompted ATCS 7 to talk to the pilots. When they clicked to specify factors for the error *the pilot did not follow the controller's instructions*, they went through some of the options before stating that they would not know which factors were applicable unless they spoke to the pilot. They requested to talk to the pilots and asked the pilot multiple questions until they had gone through all the options and confirmed with the pilot whether that option was an applicable contributing factor.

The questions did not motivate ATCS 3 to talk to the pilots. When the website asked them to specify factors that contributed to the identified pilot errors, they went through the list of options and kept thinking out loud that they didn't know whether any of those factors applied and that they would not possibly know that information. During the debrief session they said that they forgot that talking to the pilot was an option because it is not something they usually think of as an option. They said that as a controller is it is not their job to talk to the pilots — it is up to the NTSB or the FAA to investigate the pilot deviation. They further stated that even if they talked to the pilots, they couldn't "*speak for them*" indicating they could not give an accurate account of events on behalf of the pilots.

Details of the incident

ATCS 6 did not specify a particular reason for not talking to the pilots in Incident 1. They spoke to the pilot of VRSS 4 after they saw the incident video and before they started reporting. ATCS 6 mentioned that while reporting Incident 2, they only spoke to the pilot of VRSS 4 (the aircraft that was not incorrectly present on the runway) to reconfirm with the pilot their own understanding of what had happened. In the debrief session, ATCS 6 also mentioned that they did not want to talk to any pilot involved in the incident because "*at the end of the day, there's a very emotionally charged situation and everybody [is] shook up*".

ATCS 2 focused on providing details that would help Quality Assurance (QA) understand what happened. They said that it would then be up to QA to look deeper into the incident and talk to the pilots if necessary.

6.2.2 Conversations with the pilot

Similar to the motivation to talk to the pilot, the conversations the controllers had with the pilots were unique. While some controllers asked the pilots detailed questions, some only asked for a general overview.

Conversations before reporting the incident

After the incident video played, ATCS 5 vocalized the instructions they would give to both pilots in these cases. They said they would issue takeoff instructions to the VRSS 4 pilot and taxiing instructions to the VRSS 3 pilot. They would also give the VRSS 3 a phone number to call within the next hour of the current phone call.

When they spoke to the VRSS 3 pilot, ATCS 5 asked the pilot to explain what caused them to enter the active runway. After the pilot explained their reasons, ATCS 5 paraphrased what the pilot had stated and confirmed with the pilot the reasons for them entering onto the runway. They said they would be reporting the incidents, and then FSDO might get in touch with them for further actions. Flight Standards District Offices are regional offices of the FAA. Their responsibilities include certification of airmen and aircraft, accident reporting and investigation, and enforcing the FAA rules and regulations. They ended the conversation by asking the pilot to stay safe and hoped that the pilot doesn’t get involved in such incidents in the future.

When ATCS 5 spoke to the VRSS 4 pilot, they briefed the pilot about the steps the tower would take following the incident. Then they asked the VRSS 4 pilot to describe what the pilot believed happened. After the VRSS 4 gave their account, ATCS 5 asked if the VRSS4 pilot aborted takeoff because the controller’s instruction to abort takeoff alerted the pilot or whether they started aborting on their own. Finally, ATCS 5 asked the VRSS 4 pilot whether anyone was injured in the aircraft.

ATCS 6 was the only controller who reported the incidents using the survey and also spoke to the pilot involved in the incident. They only spoke to the VRSS 4 pilot and did so before they started reporting. ATCS 6 asked the VRSS 4 pilot whether they understood why they had instructed the pilot to abort their takeoff. ATCS 6 then confirmed with the pilot that the VRSS 3 pilot had indeed crossed the hold short line to make sure ATCS 6 had the right recollection of events.

Conversations while reporting the incident

ATCS 1 and ATCS 7 spoke to the pilot while reporting the incident. While ATCS 1 asked for a general overview of the incident, ATCS 7 asked more specific questions.

When ATCS 1 spoke to the VRSS 1 pilot, they asked the VRSS 1 pilot whether any factors distracted the pilot or whether the pilot had any issues asking ATCS 1 clarification questions along the taxi route. ATCS 1 did not ask the VRSS 1 pilot any follow-up questions. When reporting Incident 2, ATCS 1 asked to talk to the VRSS 3 pilot. They notified the VRSS 3 pilot that they were filling out paperwork to report the incident and asked the VRSS 3 pilot to paint them a picture of what was going on in the cockpit at the time of incursion. ATCS 1 asked one follow-up question and then thanked the pilot for the information.

When the VRSS 3 pilot joined the call, ATCS 7 asked them if they were a single piloted aircraft to make sure that none of the factors related to crew resource management applied. Then ATCS 7 asked the VRSS 3 pilot about ten questions, all of which stemmed from the contributing factors they saw as options. For example, "*Are you a student pilot?*", "*Did you have any expectation that the ATC would correct you if you were on the wrong route?"*, or "*Did you consider yourself disoriented once you landed and began your taxi?*".

While reporting Incident 1, ATCS 7 first spoke to the VRSS 1 pilot to ask them whether they had any issues listening to the controller's instructions because ATCS 7 could not be completely sure of their response without talking to the pilot. Then, ATCS 7 also asked the VRSS 1 pilot whether they checked the runway was clear before entering onto it. When specifying the contributing factors, ATCS 7 asked the VRSS 1 pilot a total of four questions based on the options they saw.

6.2.3 Factors affecting the controllers' decision to listen to the audio-only file of the incidents

Overall, four controllers (ATCS 1, ATCS 3, ATCS 7, and ATCS 4) referred to the audio-only file of the incidents while reporting. ATCS 1, ATCS 3, and ATCS 7 reported the incidents using the website and referred to the audio-only files while answering questions aimed to detect errors that may have led to the incursion. For example, *What instructions did the controller give Aircraft 1?* or *What was incorrect or missing in the readback? If the pilot took multiple attempts to read the instruction back correctly and completely, please list out all the errors the pilot made.*

ATCS 4 reported the incidents using the survey and listened to the audio-only file multiple times while describing what had happened. They said that the report could help FSDO decide the appropriate penalty for the pilot. For example, ATCS 4 said the pilot deviation in Incident 1 could be the VRSS 1 pilot's 'third strike' and the pilot may face serious consequences. In such cases, if the incident report is well detailed, FSDO may notice that while the pilot's readback was incorrect, the controller made an error too by not correcting the readback. Thus, more detailed reporting could reduce the severity of consequences the pilot might face. ATCS 4 viewed the report as a legal document and hence their goal was to type up the entire conversation between the controller and the pilot verbatim.

ATCS 6 called in via their phone and shared their phone's screen while reporting the incident. As they were submitting their report, they mentioned that if their interface was a little better, they would listen to the audio-only files to make sure they described the incident accurately. ATCS 6 said they would amend their report if Quality Assurance (the department that reviews the incident reports) listens to the tapes and gets back to the controller asking them about details they may have missed.

6.3 Controllers' interactions with the different reporting formats

Similar to the interactions with the pilots and the audio-only files, controllers interacted differently with the two reporting formats. This section compares the information obtained from the two forms and investigates how and why the controller reported a specific piece of information. This section shows the inter-rater reliability in three ways: (1) the raw data itself — the number of observers that agreed on the presence or absence of each rubric item in each report, (2) the percentage agreement between observers, and (3) the AC_1 statistic to account for any agreement by chance. See Appendix I for details on measures of inter-rater reliability.

The tables in this section use this notation to show observer agreement on the presence or absence of a rubric item in the report:

✓	All four observers agreed that the rubric item was specified in the report.
✓̳	Three out of the four observers that the rubric item was specified in the report.
✗	All four observers agreed that the rubric item was not specified in the report.
✗̳	Three out of observers agreed that the rubric item was not specified in the report.
–	There was a tie between the observers, or there was no clear majority.

Wongpakaran et al. (2013) summarized the benchmark values proposed by different researchers for the AC_1 statistic.

Table 20. Level of agreement corresponding to different ranges of $\boldsymbol{\kappa}$ and AC_1 statistic as proposed by different researchers.

Landis and Koch	Altman	Fleiss
<0: Poor		
0.00 to 0.20: Slight agreement	<0.20: Poor agreement	
0.21 to 0.40: Fair agreement	0.21 to 0.40: Fair agreement	<0.40: Poor agreement
0.41 to 0.60: Moderate agreement	0.41 to 0.60: Moderate agreement	0.40 to 0.75: Intermediate to good agreement
0.61 to 0.80: Substantial agreement	0.61 to 0.80: Good agreement	
0.81 to 1.00: Almost perfect agreement	0.81 to 1.00: Very good agreement	>0.75: Excellent agreement

6.3.1 Factors affecting the controllers' description of the incident

All fourteen reports, irrespective of the reporting format, described the incident completely. Table 21 shows which rubric item for the description of incident the reports specified. The table also shows the two measures of inter-rater reliability between the four observers in indicating whether the reports specified a particular rubric item for the description of the incident.

Table 21. Evaluation of how well the controller-generated reports described the incident. See section 6.3.1 for the legend.

Controller Code	Form Used	Incident 1					Incident 2				
		Two aircraft were involved in the incursion	The aircraft conflicted on Runway 16L	The incursion occurred at KSEA	One aircraft entered the active runway	Another aircraft was on landing roll on the same	Two aircraft were involved in the incursion	The aircraft conflicted on Runway 16L	The incursion occurred at KSEA	One aircraft entered the active runway	Another aircraft was on takeoff roll on the same
	IRR (%)	100	100	100	92.857	100	100	100	100	92.857	57.143
	AC_1 statistic	1	1	1	0.904	1	1	1	1	0.904	0.291
ATCS 1	Website	✓	✓	✓	✓	✓	✓	✓	✓	✓	$\underline{\underline{\checkmark}}$
ATCS 3	Website	✓	✓	✓	✓	✓	✓	✓	✓	✓	$\underline{\underline{\checkmark}}$
ATCS 5	Website	✓	✓	✓	✓	✓	✓	✓	✓	✓	$\underline{\underline{\checkmark}}$
ATCS 7	Website	✓	✓	✓	✓	✓	✓	✓	✓	✓	$\underline{\underline{\checkmark}}$
ATCS 2	Survey	✓	✓	✓	$\underline{\underline{\checkmark}}$	✓	✓	✓	✓	$\underline{\underline{\checkmark}}$	✓
ATCS 4	Survey	✓	✓	✓	✓	✓	✓	✓	✓	✓	$\underline{\underline{\checkmark}}$
ATCS 6	Survey	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

All observers indicated that all reports specified that the incursion involved two aircraft and occurred on Runway 16L at the KSEA airport. Both forms specifically asked which airport the incident occurred at and the location at the airport where the incursion occurred. I designed the website for incursions involving two aircraft and so it was apparent that the incursions involved two aircraft. The survey specifically asks who was involved in the incursion. The options for this question are two aircraft, aircraft and a vehicle, and aircraft and a pedestrian.

All reports indicated that one aircraft entered the active runway. One out of the four observers indicated that none of the ATCS 2-generated reports specified that one aircraft entered the active runway. All reports also indicated that the other aircraft was on the active runway. One of the four observers indicated that five of the Incident 2 reports did not specify that another aircraft was on takeoff roll on the active runway leading to a low estimate of agreement. These reports mentioned only ‘rolling out’ without specifying ‘landing roll’ or ‘takeoff roll’, resulting in the observer indicating that this detail was missing.

6.3.2 Factors affecting the controllers' description of errors leading to the incident

Overall, the website-generated reports provided more information on errors. Table 22 shows which errors on the rubric the controller specified in their report and the two measures of inter-rater reliability between the four observers.

Table 22. Errors that the controllers specified in their reports and the corresponding inter-rater reliability. See section 6.3.1 for the legend.

Controller Code	Form Used	Incident 1					Incident 2	
		VRSS 1 pilot responded with roger on the first readback	VRSS 1 pilot did not specify the call sign in the second readback	VRSS 1 pilot did not specify runway to hold short of in the second	The controller did not catch the errors in the pilot readback	VRSS 1 pilot did not hold short of runway	VRSS 3 pilot did not scan runways before entering	VRSS 3 pilot did not hold short of runway
	IRR (%)	92.857	78.571	80.952	78.571	90.476	92.857	85.714
	AC1 statistic	0.870	0.696	0.654	0.611	0.865	0.904	0.798
ATCS 1	Website	✓	✗	✗	✗̳	✓	✗	✓
ATCS 3	Website	✓	✗̳	✓	✓̳	✓	✗	✓
ATCS 5	Website	✗	✗	✗	✗	✓	✗̳	✓
ATCS 7	Website	✓̳	✓̳	–	✓̳	✓	✓	✓
ATCS 2	Survey	✗	✗	✗	✗	–	✗	✓̳
ATCS 4	Survey	✓	✗̳	✓	✓	✓	✗	✓̳
ATCS 6	Survey	✗	✗	–	✗	✓	✗	✓

Structured questions to detect errors

One of the reasons that ATCS 5, ATCS 2, ATCS 6 specified the fewest errors is that they did not respond to the questions structured based on task analysis to identify the errors. The survey did not specifically ask whether the pilot's readback was correct or ask them to specify the errors in the pilot's readback. Even though ATCS 5 used the website, they did not see these questions either. For the question: *Was there any communication between the controller and the pilot regarding the use or non-use of Runway 16L?*, ATCS 5 selected ‘No’ and hence the website showed them the ‘No Communication Established’ page (See Section 3.2.6).

Reference to the audio-only file

Another factor that contributed to ATCS 5, ATCS 2, and ATCS 6 not specifying most errors is that they did not refer to the audio-only file while reporting the incidents. In the debrief session, ATCS 2 mentioned that both incidents were clearly pilot deviations where the controller was not at fault. However, later in the session they realized the controller may have been at fault too by not correcting the pilot’s incorrect readback. ATCS 2 said that they would have to listen to the audio-only file to confirm the errors that led to the incursion.

ATCS 4, despite using the survey and not having access to the structured questions, specified most of the errors. In their case, listening to the audio-only file contributed significantly to them specifying errors. For Incident 1, while ATCS 4 did not explicitly state that the pilot did not mention the call sign in the second readback, their report contains the exact readback of the pilot where the call sign is missing.

ATCS 1, ATCS 3, and ATCS 7 listened to the audio-only file while reporting errors in the pilot’s readback. While all of them identified that the pilot did not read back the instructions on the first attempt, i.e., only responded with ‘Roger’, only one controller identified that the pilot did not state the aircraft’s call sign in the second readback. Only two controllers specified that the pilot missed the runway they were supposed to hold short of in their second readback. In fact, ATCS 1 specified that the pilot’s second readback was accurate with hold short instructions. Three controllers specified that the controller did not catch the error in the pilot’s readback or correct the pilot’s incorrect readback. ATCS 3 specified one error that was not on the rubric: the controller did not or could not hear the pilot’s readback. ATCS 3 did not state a reason for specifying this error, but they had listened to the audio-only files while answering questions pertaining to pilot readback.

Talking to the pilot

ATCS 7 was the only controller who spoke to the pilot while specifying errors for Incident 1. While reporting Incident 1, they asked the VRSS 1 pilot whether the pilot had issues listening to the instruction or whether the pilot had scanned the runways before entering. ATCS 7 was initially unsure of their responses and hence requested to talk to the VRSS 1 pilot.

None of the other controllers spoke to the pilot while reporting errors for Incident 2. ATCS 7's Incident 2 report was the only report that indicated that the VRSS 3 pilot did not scan the active runway before entering onto it. It may be difficult for the controllers to identify whether the pilot scanned the runway before entering onto it or whether the pilot had any issues listening to the instruction without talking to the pilot. For instance, one of the controllers kept mentioning that they did not know that information or there was no way for them to know whether the pilot scanned the runways or had issues listening to the instruction. ATCS 4 did not specify that the pilot did not scan the runways before entering because they did not talk to the pilot and this information is not apparent in the audio-only files.

Personal experience

ATCS 1 specified three errors that were not on the rubric. One of them was that the pilot (VRSS1) did not scan runways to make sure the instruction was safe to follow. For this error, ATCS 1 assumed that since the pilot crossed the hold short line, it was obvious they did not scan the runways for conflicting traffic. They noted from their own experience that pilots must always scan runways before crossing.

ATCS 1 and ATCS 7 specified one error in their Incident 2 reports that was not on the rubric based on how they issue instructions in the real world. According to both of them, the controller's instruction was incorrect and incomplete but in different contexts. ATCS 1 specified that the controller's instruction to VRSS 3 was incomplete because the controller missed stating the point at which VRSS 3 should hold short in their instruction. ATCS 7 specified that the controller's instruction to VRSS 4 was incomplete because the controller did not state that the other aircraft would be holding short of Runway 16L.

6.3.3 Factors affecting the controllers’ description of contributing factors to the incident

Table 23 shows the total number of errors and contributing factors controllers specified in their reports. None of the survey-generated reports specified any contributing factors. There were inconsistencies in the number of specified contributing factors among controllers who used the website. For example, ATCS 1 specified 18 contributing factors for Incident 1 whereas ATCS 3 only specified three. This section highlights possible reasons why none of the survey-generated reports specified any contributing factors and the reasons behind the highly skewed distribution of contributing factors among the four controllers who used the website.

Table 23. Total number of errors and their contributing factors controllers specified for each incident.

Controller Code	**Form Used**	**Incident 1**		**Incident 2**	
		Number of specified errors	Number of specified contributing factors	Number of specified errors	Number of specified contributing factors
ATCS 1	Website	5	18	3	23
ATCS 3	Website	4	3	1	0
ATCS 5	Website	1	2	2	4
ATCS 7	Website	4	14	3	17
ATCS 2	Survey	1	0	1	0
ATCS 4	Survey	4	0	1	0
ATCS 6	Survey	2	0	1	0

Table 24 shows whether the Incident 1 reports specified the contributing factors on the rubric. Table 25 shows whether the Incident 2 reports specified the contributing factors on the rubric.

Table 24. Contributing factors that the controllers specified in their Incident 1 reports and the corresponding inter-rater reliability. See Section 6.3.1 for the legend.

Controller Code	**Form Used**	**Incident 1**									
		VRSS 1 pilot was a student pilot with less than 10 hours of solo flight experience	VRSS 1 pilot was nervous about the flight	VRSS 1 was stressed they may lose their way during the flight	VRSS 1 was eager to complete flight training	VRSS 1 was determined not to cancel this flight	Because of construction, the controller issued a longer taxi route than usual	VRSS 1 pilot had never done an intersection departure before	VRSS 1 was frantically trying to keep up with instructions and missed parts of it	VRSS 1 replied with Roger to give a prompt reply	VRSS 1 pilot assumed they would be holding short of Runway 16 c
	IRR (%)	92.857	88.095	92.857	100	100	78.571	80.952	78.571	83.333	85.714
	AC_1 Statistic	0.925	0.898	0.927	1	1	0.766	0.795	0.776	0.825	0.848
ATCS 1	Website	✓̳	–	✗	✗	✗	✗̳	–	–	–	✓̳
ATCS 3	Website	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
ATCS 5	Website	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗̳
ATCS 7	Website	✓	✓	✗̳	✗	✗	✗̳	✗̳	–	✗̳	✓
ATCS 2	Survey	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
ATCS 4	Survey	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
ATCS 6	Survey	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗

Table 25. Contributing factors that the controllers specified in their Incident 2 reports and the corresponding inter-rater reliability. See Section 6.3.1 for the legend.

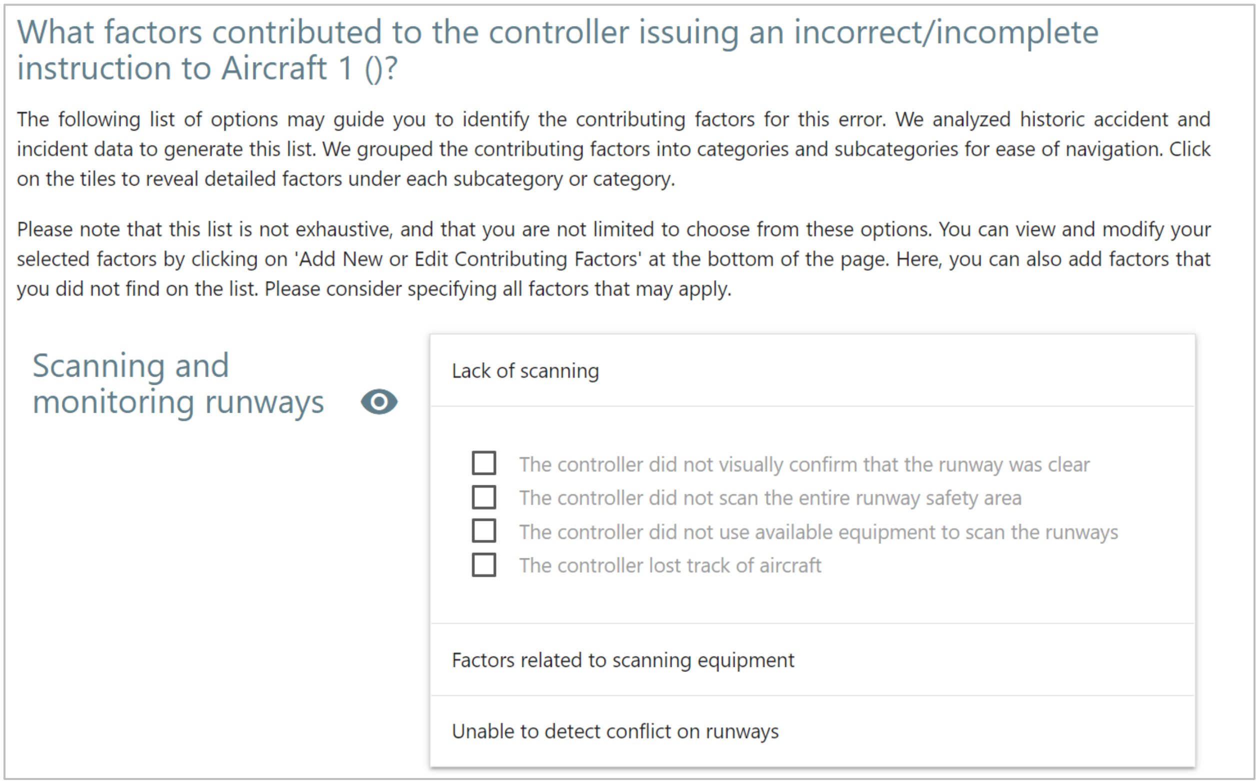
Controller Code	Form Used	Incident 2						
		VRSS 3 pilot had never used Runway 16 C before	VRSS 3 pilot did not have a runway diagram handy	VRSS 3 pilot was focused on completing the after-landing checklist	VRSS 3 pilot was trying to find a runway diagram, complete the checklist, and taxi	VRSS 3 pilot was expecting the hold short lines to be perpendicular to Runway 16L	VRSS 3 pilot was unsure of their position on the taxiway	VRSS 3 was focused more on the runway diagram than outside the aircraft
	IRR (%)	85.714	76.190	92.857	90.476	92.857	83.333	85.714
	AC_1 Statistic	0.842	0.744	0.924	0.902	0.926	0.819	0.850
ATCS 1	Website	✓̳	✓̳	✗	✗	✗	✓	✗̳
ATCS 3	Website	✗	✗	✗	✗	✗	✗	✗
ATCS 5	Website	✓	✗̳	✓	✗	✗	–	✗
ATCS 7	Website	✓̳	–	✗̳	–	✓	✓	✗̳
ATCS 2	Survey	✗	✗	✗	✗	✗	✗	✗
ATCS 4	Survey	✗	✗	✗	✗	✗	✗	✗
ATCS 6	Survey	✗	✗	✗	✗	✗	✗	✗

Questions that ask controllers to specify the contributing factors

One major difference between the two reporting formats is that for each error the website detected, it asked the controllers to specify the factors that contributed to that error. The survey does not ask such specific questions that may prompt the controllers to specify contributing factors. The lack of these questions may have contributed to ATCS 2, ATCS 4, and ATCS 6 who used the survey to not report any contributing factors. They did not specify any additional factors, i.e., those not on the rubric, either.

While questions to identify contributing factors helped ATCS 1, ATCS 5, and ATCS 7 report factors for pilot error, they did not have any effect on ATCS 3's description of contributing factors. As stated earlier, ATCS 3 went through the options for the factors for pilot errors and did not select any saying they didn't know what caused the pilot to make an error. For Incident 1, they selected one factor from the list and added one on their own. Both of these factors were not on the rubric.

In addition to asking the controllers to specify factors for detected errors, the website also gave them a list of options. I created the list of options by analyzing past accidents and incidents. I sorted the factors into categories and subcategories to make it easy for the controllers to navigate. Figure 38 shows an example of the interface for these options.



What factors contributed to the controller issuing an incorrect/incomplete instruction to Aircraft 1 ()?

The following list of options may guide you to identify the contributing factors for this error. We analyzed historic accident and incident data to generate this list. We grouped the contributing factors into categories and subcategories for ease of navigation. Click on the tiles to reveal detailed factors under each subcategory or category.

Please note that this list is not exhaustive, and that you are not limited to choose from these options. You can view and modify your selected factors by clicking on 'Add New or Edit Contributing Factors' at the bottom of the page. Here, you can also add factors that you did not find on the list. Please consider specifying all factors that may apply.

☐ The controller did not visually confirm that the runway was clear
☐ The controller did not scan the entire runway safety area
☐ The controller did not use available equipment to scan the runways
☐ The controller lost track of aircraft

Figure 38. A snippet from the website showing how the website presented the categories and subcategories of contributing factors to the controllers.

Figure 38 also shows the instructions for these types of questions. Even though the instructions mentioned that the list is not exhaustive, and the controllers could modify or add their own, the controllers did not choose to do so. Except for ATCS 3 who added their own response while reporting Incident 1, none of the controllers clicked on the 'Add New or Edit Contributing Factors' button.

The categorization of options did not prove to be very helpful because the controllers most often clicked on each and read through each option. Given that in some cases, there could be as many as 97 options, it took controllers a long time to report the incident. The list of options also contributed to controllers specifying many factors that were not necessarily explicitly stated by the pilots, and more likely based on the controllers' biases.

Conversations with the pilot

For Incident 1, ATCS 1 specified a total of 18 factors, two of which were on the rubric and which the pilot mentioned. ATCS 1 did not specify two factors that the pilot explicitly stated. ATCS 1 not asking the VRSS 1 pilot detailed questions may have contributed to the VRSS 1 pilot not getting a chance to mention all the factors on the rubric. For Incident 2, ATCS 1 specified a total of 23 factors, three of which were on the rubric. ACTS 1 did not specify one factor that the VRSS 3 explicitly stated in their conversation.

For Incident 1, ATCS 7 specified a total of 17 contributing factors. The VRSS 1 pilot explicitly mentioned two factors that ATCS 7 specified in their report. For Incident 2, ATCS 7 specified a total of 23 contributing factors. The VRSS 3 pilot explicitly mentioned six factors, all of which ATCS 7 specified in their report.

Controllers' own perspectives

For Incident 1, ATCS 1 specified 16 factors that were based on their own interpretation of what the pilot stated, or their own idea of why the pilot made an error. For example, ATCS 1 specified that '*the pilot assumed the ATC would correct them if they were on the wrong route'*. While the pilot did not indicate that this factor contributed, ATCS 1 said that student pilots generally have that assumption. Another example is that ATCS 1 specified that '*the pilot was not very familiar with the airport*' because the VRSS 1 pilot said they were on their first solo cross country. ATCS 1 doubted that VRSS 1 would be a student pilot based at KSEA.

For Incident 2, ATCS 1 specified 8 factors that contributed to the controller not issuing a correct or complete instruction. The rubric did not list this error and hence none of these 8 factors corresponding to controller's error in the instruction were on the rubric. ATCS 2 specified 12 factors that were primarily based on their assumptions or inferences after talking to the pilot.

For Incident 1, ATCS 7 specified 12 factors that were based on their own inferences. For Incident 2, ATCS 7 specified 7 factors that contributed to the controller not issuing a correct or complete instruction. The rubric did not list this error and hence none of these 7 factors were on the rubric.

6.4 Discussion

Chapter 4 laid out five expected outcomes for the website. This section discusses the implications of the findings on the expected outcomes. In the debrief session, I asked controllers their opinions on the form they used and whether they had any feedback or suggestions to improve the reporting forms. This section also discusses responses the controllers gave to these questions.

6.4.1 Implications of the results on the expected outcomes

Expected Outcome 1

The website helped controllers describe what happened in detail. The website achieved this outcome in that all the website-generated reports described the incident in detail. While the survey did not guide the controllers as much as the website did to describe the incident, all survey-generated reports also described the incident in detail. Neither the controllers who used the website nor the ones who used the survey mentioned any specific features of the two formats that guided them better to describe all the details of the incident. Thus, there were no significant advantages of the website over the survey.

Expected Outcome 2

The second outcome the website aimed to achieve was that the website-generated reports provide information on not only human error but also causes of human error. The major difference in the format of the two forms is that the website explicitly asks the controller to specify factors for each human error they identified whereas the survey does not. The highly skewed distribution of contributing factors among the controllers who used the website indicate that the format of the website alone is not sufficient to prompt the controller to report all causes of human error. Such differences in how different reporters view an incident is a continuing concern in many incident reporting systems (Johnson, 2000). Johnson (2002) and Saris (1991) suggest that allowing reporters to select contributing factors from an approved taxonomy can help reduce these differences. The researchers were of the view that guiding reporters through a causal analysis by forcing them to consider a wide range of contributing factors, including human error, can reduce the individual reporter's biases.

This structure did not reduce inter-reporter biases in my experiment. The website provided controllers with a list of options, grouped into meaningful categories and subcategories, that may have contributed to the error. One disadvantage of these options was that they led to controllers selecting many options that did not necessarily apply to the incident. Moreover, controllers only selecting factors from the list of factors, which is non-exhaustive, and not adding any new factors, may not be productive in improving our understanding of why incursions occur. While it is not possible to completely eliminate these biases, standardized training in human factors and reporting incidents can help reduce some of these biases.

Expected Outcome 3

The third expected outcome of the website is that the format of the website helps controllers identify all potential errors that may have led to the incident. The format of the form does affect the number and types of errors specified in the report. Overall, the website-generated reports specified more errors than the survey-generated reports. Additionally, more website-generated reports specified controller-related errors than the survey-generated reports.

The two primary factors that helped the controllers report errors are: (1) the specific questions on the website based on task analysis to detect errors that may have led to the incursion, and (2) controllers referring to the audio-only files while reporting. ATCS 1's Incident 1 report was an exception in this case as neither the specific questions on the website nor listening to the audio-only files helped them identify all the errors in the pilot's readback. ATCS 2's and ATCS 5's Incident 1 reports showed that an absence of specific questions that aim to detect errors and controllers not referring to the audio-only files leads to a lot of missing information on the errors. ATCS 4's Incident 1 report showed that typing the exact conversation that took place between the controller and the pilot by constantly referring to the audio-only files can also point out most errors that led to the incursion. ATCS 7's Incident 2 report is an indicator that talking to the pilot can help identify pilot errors such as *the pilot did not scan the active runway before entering onto it*, which the controller may not be aware of otherwise. The controller also may not deduce these errors from listening to the audio-only files because the pilot does not explicitly say over the radios whether they checked the runways for conflict.

Thus, the website's structured way of asking questions combined with listening to the audio-only files and talking to the pilot can help controllers identify more errors that may have led to the incursion. The combination of these three practices may remove the emphasis on categorizing an incursion as *either* an operational incident *or* a pilot error and identify flaws in the interactions between the controller and the pilot.

Since the incidents involved only two aircraft, pilot-related errors and controller-related errors were the two types of errors that could have contributed to the incursion. Five website-generated reports specified controller-related errors while one survey-generated report specified controller-related errors. While ATCS 3's responses to the questions on the website detected that the controller did not hear the pilot's readback or correct the incorrect readback, they felt strongly about reporting the controller error. They said, "*maybe the controller is going to get thrown under the bus because this [pilot] can't say, 'hold short Runway [16L]'* ".

Expected Outcome 4

The fourth expected outcome is that the website prompts controllers to talk to the pilots involved in the incident to include the pilot's perspectives in their report. The questions on the website prompted the controllers to talk to the pilots involved in the incident. When controllers realized that they did not know the response to a question related to pilot error, they spoke to the pilot to get the pilot's perspective of the incident. In two cases where the controllers spoke to the pilot before reporting the incident, the format of the form did not have any effect on the controller's decision to talk to the pilot. While the analysis shows that getting the pilots' side of the story can provide information-rich reports, controllers were skeptical that they would actively seek out the pilot's perspective in a real-world scenario.

Expected Outcome 5

The fifth expected outcome of the website is that the website provides controllers guidance on what questions to ask the pilots involved in the incident to gain insight into factors that may have contributed to the incident. The website achieved this outcome only in the case of ATCS 1 and ATCS 7 where the controller based their conversation with the pilot on the questions and information they saw on the website.

6.4.2 Controllers' opinions on the two reporting formats

Controllers who used the website stated that it was thorough, interactive, and user-friendly. They said that the structured way of asking questions helped them dive deep. The questions made them look back at the incident and try to recall the details. They said that the website was well-designed keeping in mind how controllers report incidents — where they may listen to the audio-only files to report the details and make revisions as needed. Controllers appreciated the summary at the end (See Appendix E), especially the visual aid. They liked how the visual aid showed a step-by-step progression of events leading up to the incursion. They pointed out that while the visual aids in the summary were helpful in *what* happened, they couldn't refer to anything to make sure the errors and causes were accurate before submitting the report. In the context of submitting the form, one of the controllers stated that it "*kind of seems a little final*". When controllers report incidents in the real world, they reserve the right to change their statement at a future date, an option that was missing on the website.

In terms of improving the website, they said that the question that asks them to specify the FAR part of the aircraft involved may be unnecessary as the controller would not know that, and it doesn't make any difference to how they would report. The question that asked whether there was any communication between the controller and the pilot, confused some controllers at first. Though the website explained the question further in the 'Help' window, controllers did not click on the button. They said there is room for improvement in making that question clearer.

Through the debrief sessions, one apparent advantage of the survey over the website was that the survey was short. Controllers who used the survey mentioned it was general, intuitive, simple, and straightforward. One of them said that controllers don't like filling out paperwork and hence they liked the survey because it was short. Controllers who used the website pointed out that the form was too long to fill out right away. Since the controller has until the end of their shift to submit the report, they would not have enough time to gather all the information in that timeframe.

6.4.3 Controllers' views on the future of incident reporting

The controllers feel that incident reporting is important and looking into human factors-related data is essential to improve aviation safety. In the past, analysis of reports led to changes in phraseology and runway configurations, and hence controllers believe that it is important to collect every bit of data possible. They said that while reporting is essential, it is also crucial that the aviation community pays attention to these reports, finds patterns in causation, and prevents them before waiting for a significant accident to fix the issues.

The controllers stated that any future reporting forms must aim at making it easy for controllers to report details of the incidents. The form should be intuitive, clear, straightforward, and have checklists so it easy for controllers to write their reports. One of the controllers said that the reporting system is not "*one size fits all*". They said that it is impractical to think of one reporting system that is going to "*reflect the tapestry of the National Airspace System*". For example, reporting an error caused by a student pilot who has much less experience compared to a commercial pilot will look different. While the student pilot may get off with a warning, the commercial pilot may face more severe consequences.

A few aspects of data collection that controllers emphasized were that it may be useful to collect information on the pilot's training and experience. One of the controllers suggested that tapping into the impressions the controllers form while talking to the pilot might be one of the areas to explore. They said that based on the time the pilot takes to key in their mic, the time pilots take to formulate their requests, or the time pilots take to respond to instructions, are all indicators of a pilot's ability or experience. The controllers may sense fatigue, hypoxia, or whether the pilot is under the influence of alcohol from their conversations with the pilot.

In terms of talking to the pilots to gain their perspective of the incident, overall, the controllers had conflicting opinions. Some controllers said that a controller is never going to be responsible to investigate the pilots' side of the story. They said it is not the controllers' job to find out *why* the incident happened, and controllers are not trained to investigate incidents.

While controllers acknowledged the benefits of including the pilots' perspectives in their report, they said that the timeframe within which the FAA requires them to submit the report is not enough to contact the pilot and gather more information. Some controllers do not feel comfortable writing up a pilot for an error. Their policy is "*no blood, no foul*". They said that a pilot's attitude after the incident affects the actions the controllers might take. For instance, if the pilot is confrontational, the controller may reflect that in their report to elevate any course of action against the pilot.

Considering the future of incident reporting, one controller thinks that it would be beneficial for the pilots and controllers to converse after an incident as any further investigation would have a lot more information to build off of. In contrast, one controller thinks that there is not much value in controllers talking to the pilots after an incident. The controller said that it would be difficult for either of them to be objective, and the controller and pilot involved in the incident would end up blaming one another.

7. CONCLUSION AND FUTURE WORK

7.1 Conclusion

To answer my two research questions, I conducted an experiment with air traffic controllers where they reported two hypothetical incidents using either the alternative reporting tool (website) or an online form based on the FAA Form 7210-13 (survey). While I designed the tool for incursions involving two aircraft, the tool can be modified to account for incursions involving one aircraft, an aircraft and a ground vehicle, and an aircraft and a pedestrian. In case of incursions involving one aircraft, the tool would eliminate the sections on Aircraft 2. For incursions involving a ground vehicle, since vehicle drivers also maintain two-way communication with controllers, investigations around errors pertaining to the ground vehicle would replace Aircraft 2. Incursions involving a pedestrian are rare and tool would ask fewer questions to identify errors and causes of those errors.

The experiment used three qualitative methods to collect data: (1) think-aloud protocols, (2) interviews, and (3) observations. The results from the experiment answered my two research questions.

i. Does the format of the reporting form affect the quality of air traffic controller-generated runway incursion incident reports?

The format of the reporting form does not affect the description of the incident. All the incident reports, irrespective of the reporting format described the incident completely. They all specified when and where the incident occurred, that there were two aircraft involved, and what the aircraft were doing at the time of incursion.

The format of the reporting form does affect the number and types of errors that controllers report. The website-generated reports specified more errors than the survey-generated reports. The presence of more controller-related errors in the website-generated reports suggests that the format nudged controllers to consider other causes for ‘pilot deviation’ in addition to pilot error.

The format of the reporting form also affects the number of reported contributing factors. The major difference in the reporting formats that affected reporting of contributing factors was that the website specifically asked the controllers to specify factors and gave them a list of options.

While the survey-generated reports did not specify any contributing factors, the website-generated reports specified 81 factors across the four controllers who used the website to fill out the two incidents. The number of contributing factors each controller specified individually depended on their interaction with the reporting format. The format of the website caused the controllers to go through the options and specify factors they thought contributed, or talk to the pilot. In one case, the format did not change the controller's decision to not look deeper into the incident.

ii. How do controllers interact with different reporting formats and what perspectives they have while reporting a runway incursion incident?

Changing the reporting form is one potential way to improve incident reporting. Expert systems used for incident reporting need to account for different ways controllers interact with the form and their perspectives while reporting a runway incursion.

Controllers said that they found the website's structured way of asking questions useful. These questions helped them dive deeper and use the resources available to them to gather accurate information for their reports. Moving forward, controllers suggested that a reporting form must aim at making reporting easy, for instance, by providing a checklist of things the controller must look into.

While the checklist, or the structured way of asking questions, helped controllers identify errors, the questions that aimed to identify the causes of the errors were not always helpful. In contrast to what other researchers hypothesized, guiding controllers through causal analysis and giving them a wide range of contributing factors to choose from did not help reduce individual biases or necessarily prompt them to look deeper into the incident. Expert systems for incident reporting, especially those focused on identifying human factors-related data, need to consider the complexity of human factors investigation. Investigating human factors is subject to biases, reporters' willingness to investigate further, and how reporters perceive the evidence found (Wiegmann et al., 2003). While the reporting form can ask questions or suggest ways controllers can report all the details of the incident, it is up to the controller to gather all the information and interpret it.

Though controllers agreed that the pilot's perspective is important in the incident reports, they also said that they do not usually get a chance to talk to the pilots involved, and sometimes seeking out the pilot makes it difficult for them to conform to the reporting requirements. Some controllers found it useful to talk to the pilots during the incident and suggest that in a real-world too, controllers should be able to have detailed conversations with the pilots involved. Some controllers, however, do not think talking to the pilot after an incident would be useful because even if they did, the controllers would not be able to present the pilot's views in their report. Furthermore, the controllers and pilots might end up in arguments, trying to blame one another for the incident.

Controllers' mindsets also played a role in the quality of reports they created. Some controllers think they are not trained to conduct investigations, or that it is not their job. They said they don't feel the need to follow up with the pilot after an incident because they trust the FAA and other enforcement agencies to look into it. One controller treated the incident report as a 'legal document' and therefore focused on making sure that their account of what happened was accurate. While they did not report the causes of errors, they specified most of the errors that led to the hypothetical incursions in the experiment.

Johnson (2000) states that people are more likely to report incidents if they feel their contributions is helping their work environment become a better place. As controllers pointed out, incident reports are sometimes the only notifications of unsafe events and so, the aviation community must not lose an opportunity to improve the quality of these reports. The controllers feel a sense of pride while reporting incidents as they feel they are contributing to aviation safety. Their interest and cooperation to improve safety is encouraging to researchers. In the words of one of the controllers, "*we are happy to help those who are willing to help us*."

7.2 Future work

Controllers usually use CEDAR, which is an online reporting tool, and only fill out the PDF/paper version of the FAA Form 7210-13 when they cannot access CEDAR. While some of the controllers whom I interviewed mentioned that CEDAR is just an online version of the Form 7210-13, some talked about additional questions on CEDAR. At present, only air traffic controllers have access to CEDAR, and outsiders such as researchers, do not have access to the form. If accessing the questions on CEDAR becomes possible, it would be useful to compare the alternative reporting tool to CEDAR.

The FAA released a new version of Form 7210-13 in October 2020. I used the 2012 version of the form in my experiment. At the time of designing and conducting my experiment, the FAA website showed the 2012 version as being 'active'. It is unclear whether air traffic controllers have switched to the newer version of the form or whether the FAA has made any updates to CEDAR as a result of this new form. The FAA's repository of forms still indicate that the 2012 version is in use. Moreover, some of the controllers I spoke to were unaware of the new form. The new form asks for more details in case of a pilot deviation than the old form. Specifically, the new form asks whether a Brasher warning was issued, and if not, then why not. Additionally, it also provides a text box asking controllers to specify and factors contributing to the incident. In this case, it would also be useful to compare the alternative tool with the 2020 version of the form, and also perhaps compare the 2012 and the 2020 versions of the form.

My experiment highlighted some factors that may aid or detract controllers from creating information-rich reports. For example, controllers who listened to the audio-only files, and controllers who used the website, reported most of the errors that led to the incursion. Future work can include conducting experiments with more participants to explore statistically significant correlations between these factors and the information contained in the reports.

One of my findings was that many contributing factors that controllers specified were based on their understanding of the incident or their interpretation of the pilot's account, and not necessarily what the pilot stated. Moreover, the controllers barely modified the factors to make them specific to the incident or added their own. The list of contributing factors that the alternative reporting tool provided may have caused them to recognize factors rather than recall what the pilot mentioned. Future work can experiment with different ways of asking controllers to specify factors and investigate their effects on the outcomes. For example, instead of giving controllers a list to choose from, the form gives a few examples of contributing factors and provides controllers a text box to enter their responses.

While my data did not show any differences in how controllers interact with the reporting formats while reporting an incident they thought was significant versus an incident they thought was not, this lack of difference may not always exist. It may be beneficial to study the effects of the severity of the incident on the reports the controllers generate. For example, comparing reports for an incident similar to the ones I created for my experiment with those for an incident where an aircraft crosses the hold short line with no other aircraft in its vicinity. This study may be useful since every incident, irrespective of its severity, can be a learning lesson and thus, it is important that we collect information-rich data for non-severe incidents too.

One of the controllers suggested tapping into verbal cues such as time taken by the pilot to formulate their request, or if they sound off-nominal on the radios to act as warnings or indicators of potential unsafe events. A study on correlations between these verbal cues and flight safety can be beneficial especially in the general aviation community. There is a possibility that general aviation pilots flying without an instructor or under their own supervision may misjudge their fitness to fly, in which case, an added level of safety checks by controllers may help.

Parallel work of investigating other aspects of reporting such as how Quality Assurance reviews the reports or their criteria to investigate an incident further, and ways to combine perspectives of controllers and pilots involved in an incursion may also contribute to the aviation community's need to improve data collection. EUROCONTROL developed TOKAI (Toolkit for ATM Occurrence Investigation) as a tool to support incident investigations and to manage the safety data collected. It combines different aspects of data collection, management, and analysis in one application. It also allows users such as chief investigators to suggest recommendations at any point during the investigation. The application is also capable of generating certain statistics based on the events stored in its database (Patriarca et al., 2018). Future work can explore the usefulness of such applications in United States' National Airspace System.

APPENDIX A. LIST OF QUESTIONS FOR SEMI-STRUCTURED INTERVIEWS WITH AIR TRAFFIC CONTROLLERS

List of questions for the semi-structured interviews with air traffic controllers to understand the current ways of reporting runway incursion incidents.

1. Have you reported a runway incursion incident to the FAA?
2. Does the process of reporting a RI change depending on which airspace the airport is in? For example, is the process different if the runway incursion occurred at KLAF as opposed to KORD?
3. What forms do you use to report runway incursions?
4. How often/How many times have you filled out this form?
5. How long does it take you to fill out a form?
6. Given a runway incursion, how much time do you have to submit the report?
7. To whom do you submit the form? or Who reviews the form once you submit it?
8. Do the reviewers often contact you for further investigation, if so, what kind of incidents are investigated further?
9. Given an incursion, are you more likely to fill it right away, or possibly later?
10. Do you often talk to pilots/other people to learn more about the incident before reporting it?
11. Do you receive any training on filling out the form?
12. What do you like about the reporting form?
13. According to you, do any terms on the form need more clarification/explanation?
14. What is the most frustrating part of the form?
15. Do you think the form is enough, if not, what might you add?
16. Do you think the form is too extensive, if yes, what might you subtract?
17. Do you think the reporting is useful?

APPENDIX B. LIST OF CONTRIBUTING FACTORS FOR EACH TYPE OF ERROR THE TOOL CAN DETECT

Error: The controller's instruction was incorrect or incomplete

Category	Subcategory	Contributing Factor
Scanning and monitoring runways	Lack of scanning	The controller did not visually confirm that the runway was clear
		The controller did not scan the entire runway safety area
		The controller did not use available equipment to scan the runways
		The controller lost track of aircraft
	Factors related to scanning equipment	The tower did not have a ground surveillance system
		The ground surveillance system did not alert the controller of the potential conflict
		Flaw in system design: Surveillance system did not display the necessary information
		Software issues with the surveillance system
	Unable to detect conflict on runways	Obstructions in the tower blocked the controller's view of runways and taxiways
		Weather conditions reduced visibility of runways from the tower
		It was difficult to see entire movement area from working location in the tower
		The runway appeared to be clear to the controller while scanning
		It was difficult to spot the aircraft as its color blended with the surroundings
		Night conditions: The controller lost track of the aircraft in the lights
		Night conditions: Lack of lights on the aircraft
		Night conditions: Intensity of runway lights obstructed the view of aircraft
		Night conditions: Lights from highway nearby interfered with seeing the aircraft

Category	Subcategory	Contributing Factor
Working environment	Workload	Heavy traffic at the airport
		Moderate to heavy traffic at the airport
		The controller was busy with other tasks at hand
		The controller's workload was heavy
		The controller was working two positions
		The controller was working overtime
	Supervision/Assistance from other controllers	Lack of supervisory personnel in the tower
		Supervisor was not paying attention to runway operations
		Lack of help from the supervisor or co-workers
		Supervisor did not notice the controller was overloaded
		The controller asked the supervisor for a much needed break but did not get one
	Working conditions in the tower	Noise in the tower made it difficult for the controller to focus
		Indifference of co-workers distracted the controller
		Lack of teamwork in the control tower
		Non-ergonomic working area reduced the controller's performance
	Staffing in the tower	Other controllers were on break
		The controller voluntarily took more responsibilities
		The tower was inadequately staffed
		The staffing requirements in the tower were inadequate
		Extra set of eyes might have helped detect the conflict
Training and experience	Insufficient training	The controller did not have sufficient training at night
		The controller had never been to the airport at night prior to incident
		The controller was not aware of airport geometry
		The controller was not aware of lack of signage on the movement areas
		The controller's training did not include tour of hotspots
		The controller was accustomed to follow modified/incorrect procedures
		The controller was not trained to use memory joggers
	Insufficient experience	The controller's training was in progress
		The controller was not yet qualified to perform the task they were assigned
		The controller has a record of previous operational errors
		General light traffic at the airport did not provide enough learning experience to the controller
		The controller was getting used to new procedures but they were not second nature to the controller yet

Category	Subcategory	Contributing Factor
Psychological factors	Assumption/Expectation	The controller assumed the aircraft's position on the movement area
		The controller believed the aircraft was taken out of landing/takeoff sequence
		The controller assumed the pilot of the conflicting aircraft had stopped/was holding short
		The controller thought the runway was clear
	Poor judgement	The controller misjudged the separation between aircraft
		The controller misjudged the speed of taxiing aircraft
		The controller placed the aircraft in a position it was not ready for
		The controller estimated the separation between aircraft based on pilot's incorrect report
		The controller tried to expedite takeoffs to avoid delays
	Omission of tasks	The controller did not notice the flight strip was marked for an intersection departure
		The controller did not correlate the aircraft to the aircraft sequence
		The controller did not verify aircraft's position
	Lapse of memory	The controller forgot about a clearance given earlier
		The controller forgot about the aircraft
		The controller forgot that the runway was occupied by another aircraft/vehicle
		The controller forgot to turn over the flight strips
	Distraction	The controller was focused on another aircraft
		The controller was distracted by personal issues
		The controller was distracted by other tasks at hand
	Misidentification/Misinterpretation	The controller misidentified one aircraft for another
		The controller was mistaken about aircraft sequencing
		The controller misidentified one aircraft for another
		The controller was unsure of the aircraft's position
	Complacency	Routine operations led to complacency
		Light traffic led to complacency

Category	Subcategory	Contributing Factor
Procedures	Changes and waivers	Changes in procedures for unknown reasons
		Waivers in procedures - risk mitigation strategies not provided
		Controllers were in the process of changing landing and takeoff runways
		Procedures allowed controllers to use their own judgement to pass control of the runway intersection rather than using Runway Intersection Coordination Device
	Did not follow procedures	The controller did not relay information to other centers as required
		The controller did not follow procedures on phraseology
		The controller did not use available memory aids
		The controller did not place the flight progress strips correctly before handing it over to another controller
	Insufficient procedures	There were no procedures in place on the use of memory joggers
		There were no procedures in place on sequencing flight strips
		The definition/limits on aircraft taxi speed was not clear
		The authorities did not require controllers to request read back entire requests from vehicle operators - may result in unnecessary exchanges on radio
		Authorities allowed controllers to perform tasks they were not yet qualified for under certain conditions
		Airport design and layout did not meet RSA dimensions
		The procedures did not account for inadequate runway safety area dimensions
Communication with other controllers	Miscommunication or no communication between controllers	Miscommunication between controllers
		The controller did not coordinate with other controllers
		The controller did not have complete/correct information from other controllers
		Local and Ground controllers worked separately and could not hear what was transmitted on others' frequency
		The controller did not relay the required information to other controllers
Nearby/ Conflicting aircraft related issues		Conflicting/nearby aircraft was taxiing slower than normal
		Conflicting/nearby aircraft entered the airspace without authorization
		Conflicting/nearby aircraft flying was slow

Error: The pilot did not or could not listen to the controller's instructions

Category	Contributing Factor
Crew Resource Management	The pilot depended on their co-pilot to handle communications
	The First Officer was busy flying the airplane and missed the transmission
Inaudible instruction	There was noise and commotion on the runway
	The runway assignment was not audible
Psychological factors	The pilot thought they were authorized to operate on runway
	Language was an issue with the pilot
	The pilot was distracted by activities in the cockpit
Radio issues	The pilot had a problem tuning into the tower frequency
	The pilot's radio volume was turned down

Errors: The pilot did not read the instruction back to the controller and The pilot did not read the instruction back to the controller correctly

Category	Contributing Factor
Aviation language related factors	The pilot's Aviation English Language was not proficient
	The ATC used non-standard and/or ambiguous phraseology
	Regional differences: Some phrases are interpreted differently by foreign/non-local pilots
Crew resource management	Only one pilot (in a crew of two) was listening to the ATC frequency
Psychological factors	The pilot confused the call sign with another aircraft they fly that has a similar call sign
	Pilot's slip of mind or tongue
	The pilot 's mindset was pre-programmed for a specific instruction
	Expectancy: The pilot heard what they wanted to hear
	The pilot assumed their silence was their acceptance of the instruction
	The pilot did not ask ATC to verify the instruction
	The pilot read back a 'best guess' hoping ATC would catch the error
	The pilot misunderstood the controller's instructions
Tasks at hand	Pilot was too busy with other tasks to acknowledge the instruction

Error: The controller did not or could not hear the pilot's readback

Category	Contributing Factor
Workload	Heavy traffic at the airport
	Moderate to heavy traffic at the airport
	The controller was busy with other tasks at hand
Working conditions in the tower	Noise in the tower made it difficult for the controller to focus
	Indifference of co-workers distracted the controller
	Lack of teamwork in the control tower
	Non-ergonomic working area reduced the controller's performance
Equipment	The controller's radios were faulty

Errors: The controller did not correct the pilot's incorrect readback of the instruction and Missing readback: the controller did not ask the pilot to read the instruction back

Category	Contributing Factor
Psychological factors	The controller misunderstood the pilot's taxiing intentions
	The controller did not realize that two aircraft had accepted the clearance
	Aircraft involved had similar sounding aircraft call signs which confused the controller
	Foreign pilots with heavy accents made it difficult for the controller to understand the readback
Radio issues	The controller could not contact the pilot because the pilot had radio issues
Tasks at hand	The controller was busy communicating with another controller
	The controller was busy coordinating runway changes

Error: The pilot did not scan runways to make sure the instruction was safe to follow

Category	Contributing Factor
Assumption/Expectation	The pilot did not attach any significance to transmissions involving the active runway
Crew resource management	The pilot was focused on taxiing/flying the aircraft
	The First Officer was paying attention to duties in the cockpit
	The pilot relied on co-pilot to get data from advisories

Error: The pilot ensured that the instruction was safe to follow but still ended up in an incursion

Category	Contributing Factor
Psychological factors	The pilot thought conflicting aircraft was holding position when it was actually on takeoff roll
	The pilot misidentified conflicting aircraft as a static object on the runway
Crew resource management	The pilot expressed concerns of being on the wrong route to the First Officer who affirmed they were on the right taxiway/runway
	Both, the pilot and the First Officer confirmed that the runway was clear
Help from ATC	The pilots tried to contact the controller but did not get any response from them
	The pilot did not advise the controller they had trouble finding the runway/taxiway
	The pilot expressed their confusion regarding the instruction but the controller affirmed that the instruction was correct
	ATC suggested the unknown target (conflicting aircraft) could be false — event was not visible from the tower
Indications of closed runway	Closed runway's lights were on
	Closed runway looked normal
	Xs were not erected on the closed rwy
	Unlighted construction cones on closed runway
	NOTAMS did not specify the opposite runway was closed. For example, it said runway 1L closed and did not specify 19R
Runway/Conflicting traffic was not visible	Taxiways and runways are aligned in such a way that the pilot cannot see the runway before entering
	Insufficient aircraft navigation lights on conflicting traffic
	Crown in the runway obstructed view of the opposite end
	Nose had not been lowered from landing altitude
	Reduced visibility due to IFR conditions
	Blowing snow obstructed view of the conflicting aircraft
	Pilot's windows were fogged
	LAHSO lights made it difficult to see the conflicting aircraft

Error: The pilot did not follow the controller's instruction

Category	Subcategory	Contributing Factor
Aircraft related factors	Aircraft equipment	The aircraft's nose wheel was not equipped with taxiing light
		The aircraft had electrical problems
		The aircraft had radio problems
		The aircraft's brakes failed
		The pilot stopped on runway due to an open door
	Flight related factors	The aircraft's speed was high to hold short in time
		The aircraft was heavy and the landing distance was longer than usual
		Night conditions: pilot carried extra altitude and landed further than usual
Crew resource management		The First Officer's attention was devoted in the cockpit to complete the checklist items
		The First Officer was busy flying the airplane and missed the transmission
Environment related factors	Adverse weather conditions	The temperature in the cockpit was very cold
		Blowing snow/wind blew over the runway sign
	Reduced visibility	Reduced visibility due to blowing snow
		Reduced visibility due to glare from the sun
		Reduced visibility due to high brightness of runway or taxiway lights
		Reduced visibility due to de-icing fluid on the aircraft windows
		Brightness of runway/taxiway lights obscured view of signs
		Reduced visibility due to ground fog
	Nearby aircraft	Reduced visibility due to jet blast from departing aircraft
		Taxiing aircraft in front blocked the forward progress of the pilot leading to them not being clear of the runway
		The pilot entered the active runway to make room for another aircraft
Availability/ Use of information		ATIS did not mention of use of ATC-assigned runway
		Runway diagram did not show location of hold short lines
		Pilot did not use runway diagram or taxi chart to improve situational awareness
		Pilot did not check the NOTAMS

Category	Subcategory	Contributing Factor
Psychological factors	Disorientation/Situational awareness	The pilot was disoriented
		The pilot could not determine their position
		The pilot did not realize they were on the runway
		Other activities at the airport disoriented the pilot
		The pilot could not find the runway/taxiway
		The pilot lost their situational awareness
		The pilot was confused about the assigned taxiing route
	Expectation/Assumption	The pilot assumed which runway they would use
		The pilot assumed they were on the correct path
		The pilot thought they were cleared to operate on the runway
		The pilot thought the runway assigned to them was closed and avoided using it
		The pilot slowed down expecting to hear hold short instructions
		The pilot expected the hold short lines to be perpendicular to the runway when they were not
		The pilot assumed it was not required to hold short of an in-active runway
		The pilot assumed they were instructed to taxi into position and hold
		The pilot assumed the ATC would correct them if they were on the wrong route
	Misidentification/ Misinterpretation	The pilot misunderstood the controller's instructions
		The pilot misidentified the runway
		The pilot mistook runway for taxiway
	Distraction	The pilot was distracted talking to the passengers
		The pilot's attention was diverted from outside the aircraft
	Mental/Physical health conditions	The pilot was fatigued
		The pilot had mental health issues
		The pilot was nervous
		The pilot was under the influence of alcohol

Category	Subcategory	Contributing Factor
Runway markings, lighting, and signage	Markings	Markings were old and faded
		Lack of hold short markings for the runway intersection
		Hold short lines for two runways converged at the same taxiway
		Lack of markings or signs to indicate a runway
		The intersection of runways was poorly marked
	Lighting	Runway/taxiway was not lit at the time of incursion
		Runway/taxiway was lined with reflectors of the wrong color
		Runway/taxiway lights were out of service
		Runway/taxiway lights were decommissioned
	Blocked view of markings/lightings/signage	Sign for taxiway was facing one direction: was only visible from the opposite runway
		Hold short lines were not visible because of salt on the taxiway
		Hold short lines were not visible because the aircraft was a tail-dragger
		Hold short lines were obscured by snow or other objects
		Blowing snow/wind blew over runway sign
Communication related factors		The pilot was on the wrong frequency
		Language was a problem with the pilot
		The pilot lost communication with the tower
		The pilot did not understand the reference to a hold short line
		The pilot was very confused — missed multiple corrections from the ATC
Training/Experience		The pilot had not used the taxiway or runway before
		Student pilot with less solo experience
		The pilot had insufficient experience at controlled airports
		The pilot was not very familiar with the airport
		The pilot had difficulty navigating on the airport
		The pilot did not have a valid piloting license
		The pilot did not have a valid medical certificate
		The pilot was not aware of the procedures for calling the tower

APPENDIX C. SCRIPT FOR COMMUNICATION BETWEEN THE CONTROLLER AND THE PILOTS INVOLVED IN THE HYPOTHETICAL INCURSION

For Incident 1

VRSS2 Pilot: Seattle tower, Warrior VRSS 2, 5 miles north, in bound for a full stop.

KSEA Tower: Warrior VRSS 2, report 3 miles north, straight in for Runway 16L.

VRSS2 Pilot: Report 3 miles north, straight in for Runway 16L, VRSS 2.

VRSS1 Pilot: Seattle ground, Cessna VRSS 1 at Cargo 3 ready to taxi with information Delta.

KSEA ground: VRSS 1 Taxi to Runway 16C via alpha, golf, bravo, echo. Hold short of Runway 16L at echo.

VRSS1 Pilot: Roger, Cessna VRSS 1.

KSEA ground: VRSS 1, read back all instructions.

VRSS1 Pilot: Taxi to Runway 16C via alpha, golf, bravo, echo. Hold short at echo.

VRSS2 Pilot: Seattle tower, Warrior VRSS 2, 3 miles north.

KSEA Tower: Warrior VRSS 2, runway one six left cleared to land, traffic holding short.

VRSS2 Pilot: Cleared to land Runway 16L, VRSS2.

KSEA ground: VRSS 1, Stop immediately!

For Incident 2

KSEA Tower: VRSS 3, runway one six center cleared to land

VRSS3 Pilot: Cleared to land, runway one six center, VRSS 3.

KSEA Tower: VRSS 3, exit runway at foxtrot, hold short of runway one six left for departing traffic, contact ground.

VRSS3 Pilot: Exit runway at foxtrot, hold short of runway one six left, contact ground, VRSS 3.

VRSS4 Pilot: Seattle tower, VRSS 4 holding short of runway one six left, ready for departure

KSEA Tower: VRSS 4, runway one six left cleared for takeoff, traffic will be holding short

VRSS4 Pilot: Runway one six left, cleared for takeoff, VRSS 4.

KSEA Tower: VRSS 4, abort takeoff!

APPENDIX D. LIST OF QUESTIONS IN THE TWO REPORTING FORMATS

List of Questions in the alternative reporting tool

General Information

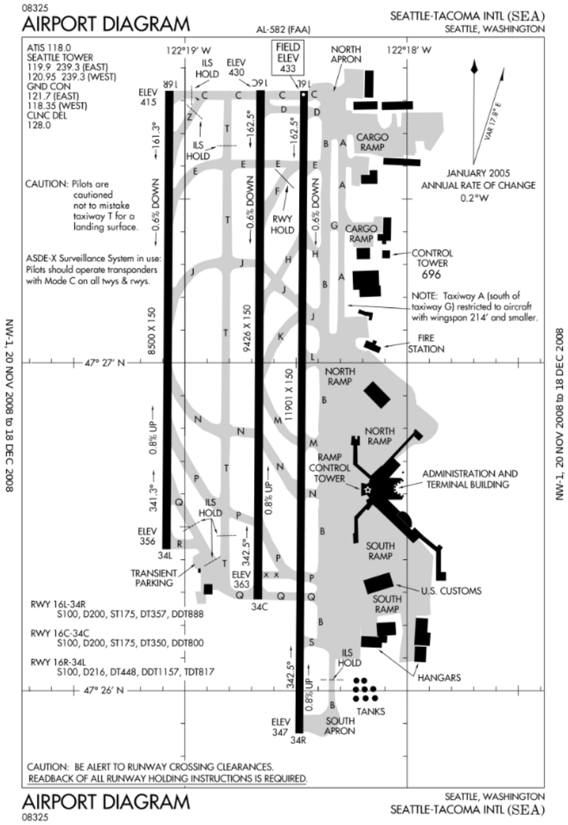
Please enter the general details of the incursion.

1. Four letter airport ID ____________________________________
2. Date of incursion ___________________________
3. Time of incursion ____
4. The role that best fits your position at the time of the incident.
    - o Controller providing services
    - o Front line manager
    - o Internal facility reviewer
    - o Controller in charge
    - o External facility referral
    - o Other

Runway of Incursion

5. On the airport diagram, please click on the runway on which the incursion occurred.

You selected ___________________________



CAUTION: Pilots are cautioned not to mistake taxiway T for a landing surface.

ASDE-X Surveillance System in use: Pilots should operate transponders with Mode C on all twys & rwys.

JANUARY 2005
ANNUAL RATE OF CHANGE
0.2°W

NOTE: Taxiway A (south of taxiway G) restricted to aircraft with wingspan 214′ and smaller.

RWY 16L-34R
S100, D200, ST175, DT357, DDT888

RWY 16C-34C
S100, D200, ST175, DT350, DDT800

RWY 16R-34L
S100, D216, DT448, DDT1157, TDT817

CAUTION: BE ALERT TO RUNWAY CROSSING CLEARANCES.
READBACK OF ALL RUNWAY HOLDING INSTRUCTIONS IS REQUIRED.

Q6 to Q49 repeat for Aircraft 2.

Details of Aircraft 1

Please enter the details of Aircraft 1. You can designate any one of the two aircraft involved as Aircraft 1. The subsequent questions will refer to Aircraft 1 by the tail number you enter here.

6. Aircraft tail number ____________________________________
7. Aircraft make and model ___________________________

8. Select FAR Part:

○ Part 91: General Aviation

○ Part 103: Ultralight

○ Part 105: Parachute jumping

○ Part 121: Air carrier

○ Part 125: 20+ Pax, 6000+lbs

○ Part 129: Foreign

○ Part 135: Air taxi and commuter

○ Part 137: Agricultural

○ Part 141: Pilot schools

Options for Q9 are based on which runway is selected in Q5

9. Please select the location of Aircraft 1 at the time of incursion.

○ On Runway 16 L/C/R

○ On Runway 34 R/C/L

○ At the intersection of Runway 16L-34R/16C-34C/16R-34L and a taxiway

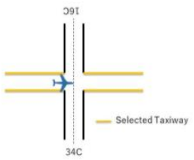
Display Q10 and Q11 if 'At intersection of Runway and a taxiway' is selected in Q10
Options for Q10 and 11 are based on which runway is selected in Q6. The complete list is below.

10. Please select the intersecting taxiway on which Aircraft 1 was present at the time of incursion.

○ C
○ D
○ E
○ P
○ Q
○ S
○ B
○ F
○ J
○ L
○ K
○ M
○ N
○ H

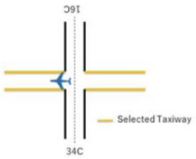
11. Please select the direction of Aircraft 1's movement.

○



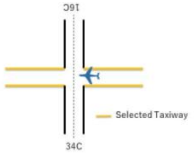
Entering the runway from the left

○



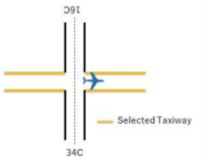
Exiting the runway to the left

○



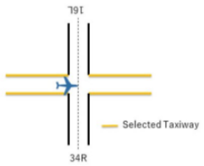
Entering the runway from the right

○



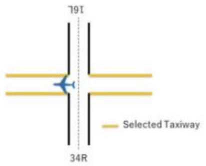
Exiting the runway to the right

○



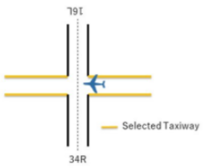
Entering the runway from the left

○



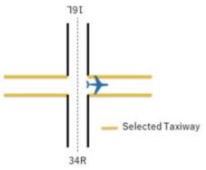
Exiting the runway to the left

○



Entering the runway from the right

○



Exiting the runway to the right

12. Please select the phase of flight Aircraft 1 was in, at the time of incursion. (Click on help for the definitions)

Taxi

- ○ Taxi to runway
- ○ Taxi into position
- ○ Taxi from runway

Takeoff

- ○ Takeoff roll
- ○ Aborted takeoff
- ○ Initial climb

Landing

- ○ Approach
- ○ Landing flare/touchdown
- ○ Landing roll
- ○ Go around

Initial Investigation

Please answer the questions with respect to Aircraft 1.

13. Was there any communication between the controller and the pilot regarding the use, or non-use of Runway?

- ○ Yes
- ○ No

If 'Yes' go to Q14. If 'No' go to Q36

14. Was the controller's instruction correct and complete?

- ○ Yes
- ○ No

If 'Yes' go to Q15. If 'No' go to Q16

15. Did the pilot follow the instruction?

○ Yes

○ No

If 'Yes' repeat Q6 to Q49 for Aircraft 2. If 'No' go to Q16

Controller Instruction

Please answer the questions with respect to the instruction given to Aircraft 1. You can request to listen to the communication audio at any point.

16. What instruction did the controller give Aircraft 1?
E.g., taxi to runway 16C via Alpha Charlie, hold short of runway 16L.

17. Was the controller's instruction correct and complete?

○ Yes

○ No

If 'Yes' go to Q19. If 'No' go to Q18

18. Please list the error(s) in the instruction.
E.g., the controller cleared aircraft to land on a closed runway

19. Were there any issues in transmitting the instruction to Aircraft 1?

○ Yes

○ No

If 'Yes' go to Q20. If 'No' go to Q21

20. Please list the issue(s) in transmitting the instruction.
E.g., the controller had faulty radios

Pilot readback

Please answer the questions with respect to Aircraft 1 pilot's readback. You can request to listen to the communication audio or talk to the pilot at any point.

21. Did the pilot of Aircraft 1 miss, or have any issues listening to the controller's instruction?

○ Yes

○ No

If 'Yes' go to Q22. If 'No' go to Q23

22. Please list the issue(s) the pilot of Aircraft 1 had listening to the instruction.

E.g., another pilot stepped on the transmission

23. Did the pilot of Aircraft 1 acknowledge the instruction at all (correct or incorrect readback)? If the controller asked the pilot multiple times to read back the instructions before the pilot eventually did, please select 'Yes'.

○ Yes

○ No

If 'Yes' go to Q24. If 'No' go to Q31

24. Did the pilot read the instruction back correctly and completely? If the pilot took multiple attempts to read the instruction back correctly and completely, please select 'No'.

○ Yes

○ No

If 'Yes' go to Q26. If 'No' go to Q25

25. What was incorrect or missing in the readback? If the pilot took multiple attempts to read the instruction back correctly and completely, please list out all the errors the pilot made.

E.g., pilot did not read the hold short instruction back

26. Were there any issues in transmitting the readback to the controller?

○ Yes

○ No

○ Unknown

If 'Yes' go to Q27. If 'No' or 'Unknown' go to Q28

27. Please list the issue(s) in transmitting the readback to the controller.
E.g., transmission was garbled

Controller Hearback

Please answer the questions with respect to the controller listening to the readback from the pilot of Aircraft 1. You can request to listen to the communication audio at any point.

28. Did the controller miss, or have any issues listening to the pilot's readback(s)?

○ Yes

○ No

If 'Yes' go to Q29

29. What issues did the controller have in listening to the pilot readback?
E.g., another pilot stepped on the transmission

Display Q30 if the answer to Q24 is 'No'

30. Did the controller correct the pilot's incorrect readback(s) until the final readback was correct and complete?

○ Yes

○ No

Display Q31 if the answer to Q23 is 'No'

31. Did the controller ask for a readback?

○ Yes

○ No

Pilot following the instruction

Please answer the questions with respect to Aircraft 1. You can request to listen to the communication audio or talk to the pilot at any point.

32. Did the pilot of Aircraft 1 ensure that the instruction was safe to follow?
E.g., the pilot checked whether the runway was clear before entering onto it

○ Yes

○ No

○ Unknown

33. Did the pilot of Aircraft 1 follow the instruction?

○ Yes

○ No

Display Q34 if the answer to Q33 is 'No'

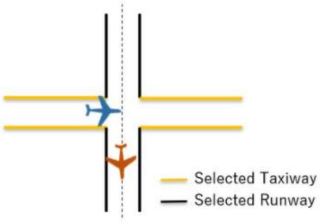
34. What error(s) did the pilot of Aircraft 1 make?
E.g., pilot did not hold short as instructed

Relative positions of the aircraft

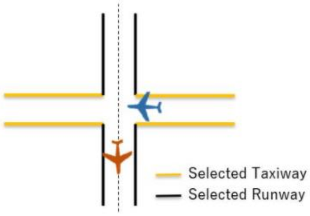
Options for Q35 depend on the response to Q11. The entire set of options is shown below.

35. Please select the illustration that best approximates the relative positions of the two aircraft involved in the incursion.

○



○



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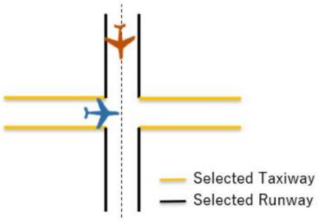
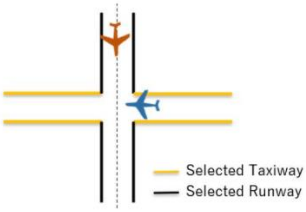
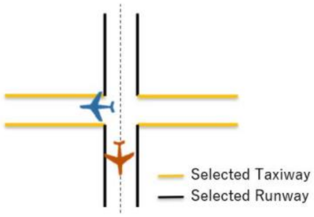


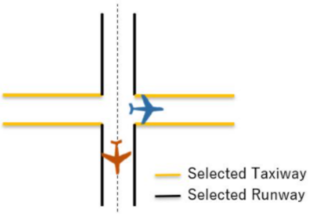
○



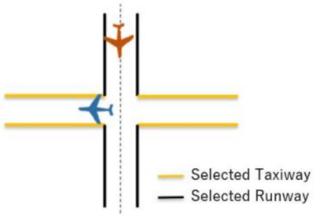
○



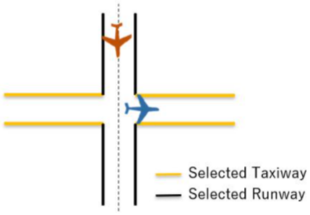
○



○



○



No communication established

36. What error(s) did the pilot of Aircraft 1 (a) make?

☐ The pilot landed on a runway without contacting the tower
☐ The pilot took off from a runway without contacting the tower
☐ The pilot entered a runway without contacting the tower
☐ The pilot accepted a clearance for another aircraft
☐ Other: ____

37. Why did the pilot not communicate with the controller?

☐ The pilot thought the tower was closed
☐ The pilot was on the wrong radio frequency
☐ The pilot's radios failed
☐ The aircraft lost its electrical power
☐ Other: _______________________________________

38. Did the controller attempt to contact the pilot?

○ Yes

○ No

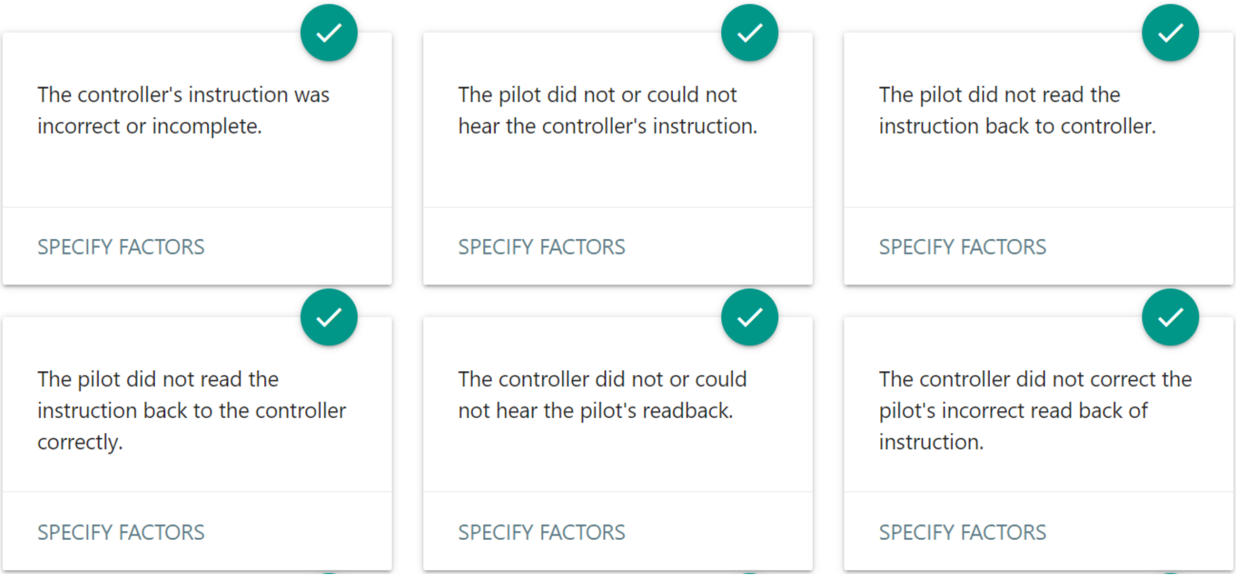
If 'Yes' go to Q39. If 'No' go to Q40

39. Why could the controller not contact the pilot successfully?

40. Why did the controller not attempt to contact the pilot?

List of detected errors

41. Based on your responses, we detected the following errors that led to the incursion. You can go back to the previous questions to change your responses if you think an error was incorrectly detected or if an error was not detected. Click on the 'SPECIFY FACTORS' to specify the contributing factors for that error. Please consider reporting factors for each detected error before proceeding to Details of Aircraft 2.



The controller's instruction was incorrect or incomplete.

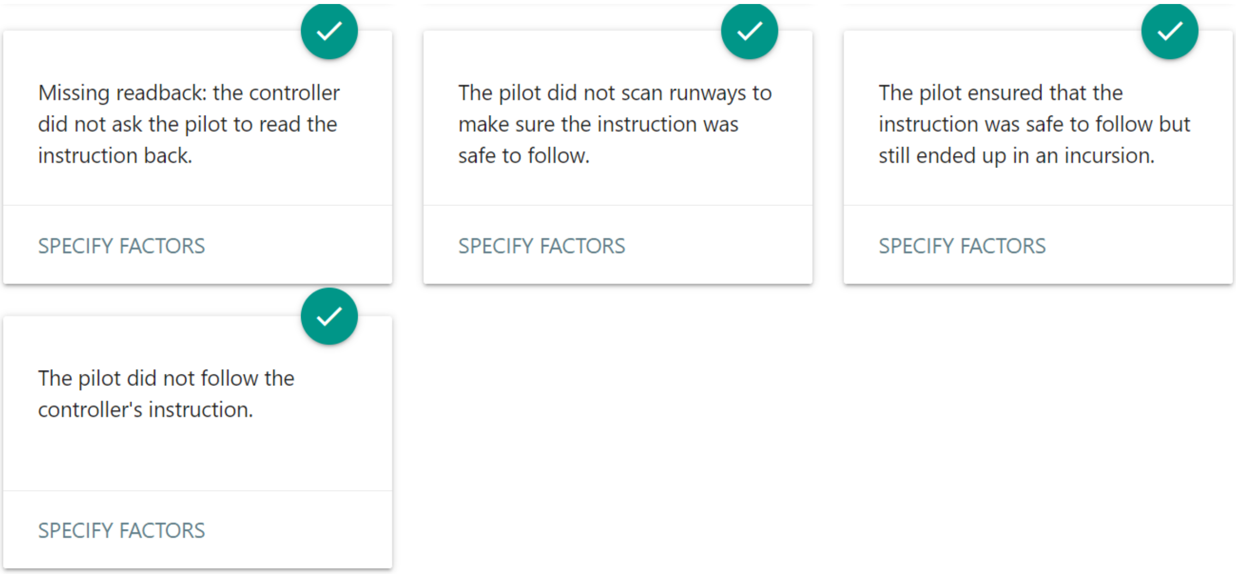
The pilot did not or could not hear the controller's instruction.

The pilot did not read the instruction back to controller.

The pilot did not read the instruction back to the controller correctly.

The controller did not or could not hear the pilot's readback.

The controller did not correct the pilot's incorrect read back of instruction.



Missing readback: the controller did not ask the pilot to read the instruction back.

The pilot did not scan runways to make sure the instruction was safe to follow.

The pilot ensured that the instruction was safe to follow but still ended up in an incursion.

The pilot did not follow the controller's instruction.

Specifying contributing factors

Display Q42 to Q49 based on the error for which the participant chooses to specify contributing factors. See Appendix B for the answer options for each of these questions.

Instructions for Q42-Q49

The following list of options may guide you to identify the contributing factors for this error. We analyzed historic accident and incident data to generate this list. We grouped the contributing factors into categories and subcategories for ease of navigation. Click on the tiles to reveal detailed factors under each subcategory or category.

Please note that this list is not exhaustive, and that you are not limited to choose from these options. You can view and modify your selected factors by clicking on 'Add New or Edit Contributing Factors' at the bottom of the page. Here, you can also add factors that you did not find on the list. Please consider specifying all factors that may apply.

42. What factors contributed to the controller issuing an incorrect/incomplete instruction to Aircraft 1?
43. What factors contributed to the pilot of Aircraft 1 failing to hear the controller's instruction?
44. What factors contributed to the pilot of Aircraft 1 failing to read the instruction back or reading it back incorrectly?
45. What factors contributed to the controller failing to hear the readback from the pilot of Aircraft 1?
46. What factors contributed to the controller not asking for a readback or correcting an incorrect readback from the pilot of Aircraft 1?
47. Why did the pilot of Aircraft 1 not check for conflicts on the runway before operating on it?
48. Even though the pilot of Aircraft 1 checked the surrounding area for conflicts, what contributed to them getting involved in the incursion?
49. What factors contributed to the pilot of Aircraft 1 not following the controller's instruction?

Consequences of the incursion

50. Please describe what happened after the incursion. For instance: did any pilot involved, or the controller take any action to reduce the risk of a collision? What was the estimated separation between the aircraft involved? Were there any injuries or damage?

List of questions in the online survey based on the FAA Form 7210-13

SECTION A
Complete for ALL MORs

- ○ Reporting FAC ID ______________________________________
- ○ Date UTC (dd/mm/yyyy) _____________________________
- ○ Time UTC ____

Significant occurrence?

- ○ Yes
- ○ No

MOR reported by:

- ○ Controller providing services
- ○ FLM
- ○ Internal Facility Review
- ○ CIC
- ○ Aircraft Owner/Operator
- ○ Electronically Detected
- ○ External Facility Referral
- ○ Hotline (describe in summary)
- ○ Other (describe in summary)

Select the type(s) of MORs you are reporting:

- ☐ Airborne separation
- ☐ Terrain/Obstruction
- ☐ Surface separation
- ☐ Airspace/Altitude/Route/Speed
- ☐ Communication
- ☐ Inquiry
- ☐ Emergency
- ☐ Airport Environment

Display This Section:
If Select the type(s) of MORs you are reporting: = Airborne separation

SECTION B - AIRBORNE SEPARATION MORs

B1. MOR type - suspected airborne loss involving:

- ○ IFR aircraft
- ○ VFR aircraft (in Class B or practice VFR approach)
- ○ Formation flights
- ○ Non-radar
- ○ Other suspected loss (describe in summary)

B2. Aircraft #1 information:

○ Aircraft ID (1) ____

○ Aircraft type/suffix (2) ____

○ IFR/VFR (3) ____

○ Facility communicating with A/C (4)

____

○ Position communicating with A/C (5)

____

○ Frequency (6) ____

Formation flight

○ No

○ Non-standard

○ Standard

○ Trailing A/C beacon ____

TCAS RA

○ Yes

○ No

B2. Aircraft #2 information:

○ Aircraft ID ____

○ Aircraft type/suffix ____

○ IFR/VFR ____

○ Facility communicating with A/C

____

○ Position communicating with A/C

____

○ Frequency ____

Formation flight

○ No

○ Non-standard

○ Standard

○ Trailing A/C beacon ____

TCAS RA

○ Yes

○ No

B3. Required separation

○ Vertical (in ft) (1) ____

○ Lateral (in ft) (2) ____

B4. Observed separation

○ Vertical (in ft) (1) ____

○ Lateral (in ft) (2) ____

B5. Airspace Class:

○ A

○ B

○ C

○ Other (describe in summary)

Display This Section:
If Select the type(s) of MORs you are reporting: = Terrain/Obstruction

SECTION C - TERRAIN/OBSTRUCTION MORs

C1. MOR Type - Improper/unexpected operation of aircraft near terrain/obstruction involving:

○ MVA

○ MIA

○ MEA

○ MOCA

○ MCA

○ MRA

○ Other (describe in summary)

C2. Aircraft Information

○ Aircraft ID ______________________________

○ Aircraft type/suffix ______________________________

○ IFR/VFR ______________________________

○ Facility communicating with A/C

____

○ Position communicating with A/C

____

○ Frequency ______________________________

C3. Occurrence location:
(Describe where the occurrence occurred in relation to a navigational aid or fix, for example, VOR, intersection, or localizer)

____

○ C4. Required altitude ______________________________

○ C5. Observed altitude (only include if provided by the person reporting)

____

Display This Section:
If Select the type(s) of MORs you are reporting: = Surface separation

SECTION D - SURFACE SEPARATION MORs

D1. MOR type - suspected surface loss involving:

- ○ Two aircraft
- ○ Aircraft and vehicle
- ○ Aircraft and pedestrian
- ○ Ground surveillance alert between two aircraft
- ○ Ground surveillance alert between aircraft/vehicle

D2. Occurrence Location:
(Describe where on the airport surface the occurrence occurred)

____

D3. Aircraft #1 information:

- ○ Aircraft ID ____
- ○ Aircraft Type/Suffix ____
- ○ Facility communicating with AC
____
- ○ Position communicating with AC
____
- ○ Frequency ____

D4. Other involved aircraft/vehicle/pedestrian information (complete the appropriate section)D4.

D4a. Aircraft

○ Aircraft ID ____

○ Aircraft Type/Suffix ____

○ Facility communicating with A/C

____

○ Position communicating with A/C

____

○ Frequency ____

D4b. Vehicle

Vehicle type:

○ Airport operator (2)

○ FAA (3)

○ Tug (4)

○ Tug with aircraft (5)

○ Contractor (6)

○ A/C not for flight (7)

○ Other (describe in summary) (8)

○ Vehicle ID ____

○ Facility communicating with the vehicle

____

○ Position communicating with the vehicle

____

○ Frequency ____

D4c. Pedestrian

Pedestrian name (if known):

____

Display This Section:
If Select the type(s) of MORs you are reporting: = Airspace/Altitude/Route/Speed

SECTION E - AIRSPACE/ALTITUDE/ROUTE/SPEED MORs

E1. Aircraft information:

- ○ Aircraft ID (1) ____
- ○ Aircraft type/suffix (2) ____
- ○ IFR/VFR (3) ____
- ○ Facility communicating with A/C (4) ____
- ○ Position communicating with A/C (5) ____
- ○ Frequency (6) ____

E2. MOR type - aircraft entered airspace other than expected/intended and alternate actions were taken by ATC or the flight crew. (Complete this sub-section as applicable)

Airspace entered:

- ○ Facility (1) ____
- ○ Position (2) ____

Foreign facility deviation:

- ○ Yes
- ○ No

Action taken by:

- ○ ATC
- ○ Flight crew

E2. MOR type - aircraft operated at altitude/route/speed other than expected/intended. (Complete this sub-section as applicable)

Unexpected/unintended:

- ☐ Altitude
- ☐ Route
- ☐ Airspeed

TCAS RA:

- ○ Yes
- ○ No

Foreign facility deviation:

- ○ Yes
- ○ No

Spillout:

- ○ Yes
- ○ No

E2. MOR type - aircraft conducted visual/contact approach or operated SVFR below weather minima. (Complete this sub-section as applicable)

Aircraft operation/procedure:

☐ Visual approach
☐ Contact approach
☐ SVFR

METAR observation:

____

Display This Section:
If Select the type(s) of MORs you are reporting: = Communication

SECTION F - COMMUNICATION MORs

F1. MOR type - Aircraft communication not:

○ Established as expected/intended and ATC/flight crew actions or ATC notifications required

○ Maintained as expected/intended and ATC/flight crew actions or ATC notifications required

Last contact:

○ Facility ID ____

○ Position ____

○ Frequency ____

F2. Resulting actions:

☐ Alternative action by ATC
☐ Alternative action by flight crew
☐ Additional notification by ATC
☐ Landing without clearance

F3. Aircraft information

○ Aircraft ID ____

○ Aircraft type/suffix ____

○ IFR/VFR ____

○ Facility communicating with AC

____

○ Position communication with AC

____

○ Frequency ____

Display This Section:
If Select the type(s) of MORs you are reporting: = Inquiry

SECTION G - INQUIRY MORs

G1. MOR type - Public inquiry:
Any expression of concern or inquiry, by any external entity, that is made by email, telephone, radio, etc., concerning the proximity or operation of an aircraft, either airborne or on the surface.

G2. Airborne occurrence:

○ Yes

○ No

○ G3. Reporting source ____

○ G4. Contact number ____

G5. Aircraft information:

○ Aircraft ID ____

○ Aircraft type/suffix ____

○ IFR/VFR ____

○ Facility communicating with A/C

____

○ Position communicating with A/C

____

○ Frequency ____

Display This Section:
If Select the type(s) of MORs you are reporting: = Emergency

SECTION H - EMERGENCY MORs

H1. MOR type - in-flight emergency conditions involving:

○ Medical emergency

○ Avionics/instrument malfunction

○ Disoriented

○ VFR in/on top IFR conditions

○ Mechanical malfunction

○ Fuel quantity

○ Bird strike

○ Other (describe in summary)

H1a. Aircraft information:

○ Aircraft ID ____

○ Aircraft type/suffix ____

○ Facility communicating with A/C

____

○ Position communicating with A/C

____

○ Frequency ____

H1b. Malfunctioning equipment component:
(only complete for mechanical MORs)

____

H1c. Passenger or crew condition:
(only complete for medical MORs)

____

H1d. Route information:

○ Departed ____

○ Destination ____

○ Diverted to ____

H2. MOR type - in-flight security conditions involving:

○ Laser light illumination

○ Hijack

○ Bomb threat

H2a. Aircraft information:

○ Aircraft ID ____

○ Aircraft type/suffix ____

○ Facility communicating with A/C

____

○ Position communicating with A/C

____

○ Frequency ____

H2b. Nearest major city:
(only complete for laser light illuminations)

____

H2c. Route information:

○ Departed ____

○ Destination ____

○ Diverted to ____

○ Altitude ____

○ Location (lat/long or fix/radial distance)

____

○ Time DEN notified (UTC) ____

Display This Section:
If Select the type(s) of MORs you are reporting: = Airport Environment

SECTION I - AIRPORT ENVIRONMENT MORs

I1. MOR Type - airport environment MORs involving aircraft on the airport surface:

☐ Aircraft on movement area/runway safety area other than expected/intended

☐ Canceled takeoff clearance/ flight crew aborted takeoff after crossing hold-short line

☐ Aircraft unintentionally maneuvered off runway or taxiway

☐ Aircraft within ILS protected area other than expected/intended

Other aircraft within one-mile of landing threshold?

○ Yes

○ No

Other aircraft on final approach:

○ ID ____

○ Type/Suffix ____

I1a. Occurrence location:
(Describe where on the airport surface the occurrence occurred)

____

I1b. Aircraft information:

○ Aircraft ID ____

○ Aircraft type/suffix ____

○ Facility communicating with A/C

____

○ Position communicating with A/C

____

○ Frequency ____

I2. MOR Type - airport environment MORs involving aircraft landing/departing/on low-approach:

○ Aircraft landed/departed or attempted to land/depart runway/surface other than expected/intended

○ Aircraft landed/departed or executed low approach to closed runway (or closed portion of thereof)

○ Turbojet go-around within 1/2 mile of arrival threshold (non-flight training)

I2a. Occurrence location:
(Describe where on the airport surface the occurrence occurred)

____

I2b. Aircraft information:

○ Aircraft ID ____

○ Aircraft type/suffix ____

○ Facility communicating with A/C
____

○ Position communicating with A/C
____

○ Frequency ____

I3. MOR Type - airport environment MORs involving vehicles on airport surface:

○ Vehicle on movement area/runway safety area other than expected/intended

○ Vehicle within ILS protected area other than expected/intended

Aircraft within one-mile of landing threshold?

○ Yes

○ No

Aircraft on final approach:

- ○ Aircraft ID ____
- ○ Type/Suffix ____

I3a. Occurrence location:
(Describe where on the airport surface the occurrence occurred)

____

I3b. Vehicle type:

- ○ Airport operator
- ○ FAA
- ○ Tug
- ○ Contractor
- ○ A/C not for flight
- ○ Tug with aircraft
- ○ Other (describe in summary)

Vehicle information:

- ○ Vehicle ID ____
- ○ Facility communicating with A/C ____
- ○ Position communicating with A/C ____
- ○ Frequency ____

I4. MOR type - airport movement MOR involving pedestrian on the airport surface: Pedestrian on movement area/runway safety area other than expected/intended.

Aircraft within one-mile of landing threshold?

○ Yes

○ No

I4a. Occurrence location:
(Describe where on the airport surface the occurrence occurred)

____

I4b. Pedestrian name (if known):

____

SECTION J - SUMMARY
Complete for ALL MORs

Provide a brief summary for all MORs in this section that will provide enough information for QA to understand what occurred. Include information about items that require additional information in the specific MOR you are reporting.

____
____
____

Are you sure you want to submit your responses? Once you click 'Next', the survey will end, and you will not be able to change your responses.

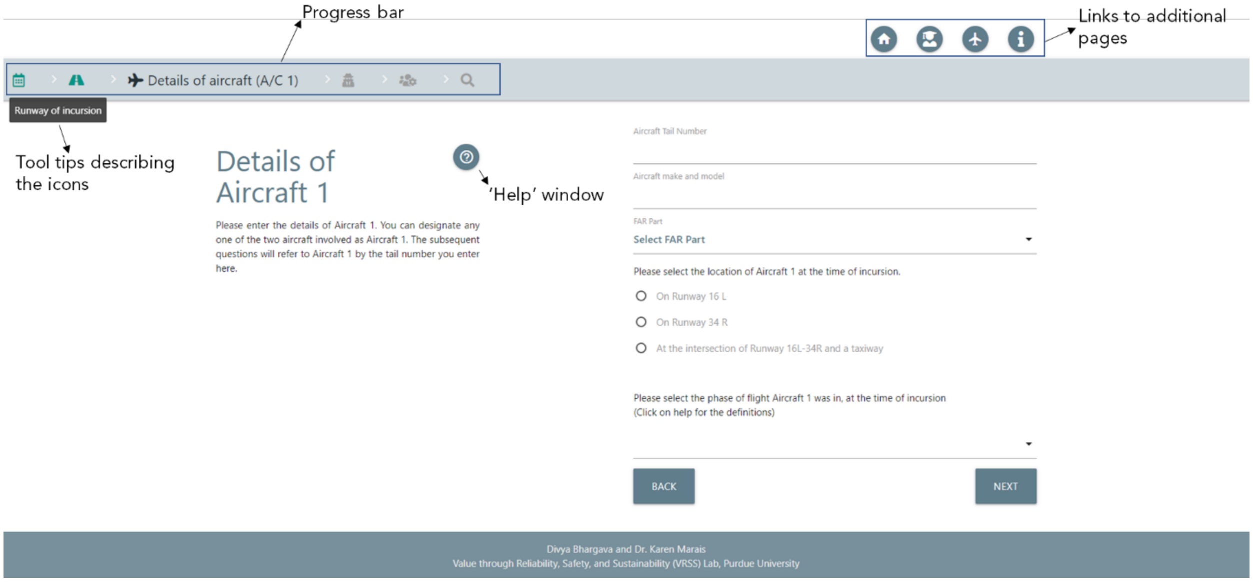
List of questions for the debrief session

1. Does the reporting tool fit in with the reporting requirements air traffic controllers have?
2. What motivated you to talk to the pilot or listen to the communication audio? OR
   Why did you not consider talking to the pilot or listening to the communication audio?
3. Case specific questions: for example, I noticed you were confused about [a specific question], can you tell me more about what happened there? OR, I saw you clicked on the help button for [a specific question], did the help information clarify your confusion?
4. Were the terms used in the questions/options familiar to you?
5. Did you think you had control over the reporting tool – in case you made a mistake, could you easily fix it?
6. Did you think that the reporting tool was consistent in terms of terminology used, structure and formatting?
7. What was your overall opinion on the aesthetics and design of the reporting tool?
8. Finally, do you have any other suggestions or feedback to improve the reporting tool?

APPENDIX E. DIFFERENT FEATURES OF THE TOOL

Layout of different pages in the tool

The following image shows the general layout of most pages on the website. The progress bar shows the user where in the reporting process they are. There are links to additional pages — the Home page, About the research page, About the experiment page, and background information page. The icons have tool tips to describe what the icons represent. Some pages have links to 'Help' windows to give more context to certain terms or questions on the page.



Details of Aircraft 1

Please enter the details of Aircraft 1. You can designate any one of the two aircraft involved as Aircraft 1. The subsequent questions will refer to Aircraft 1 by the tail number you enter here.

Aircraft Tail Number

Aircraft make and model

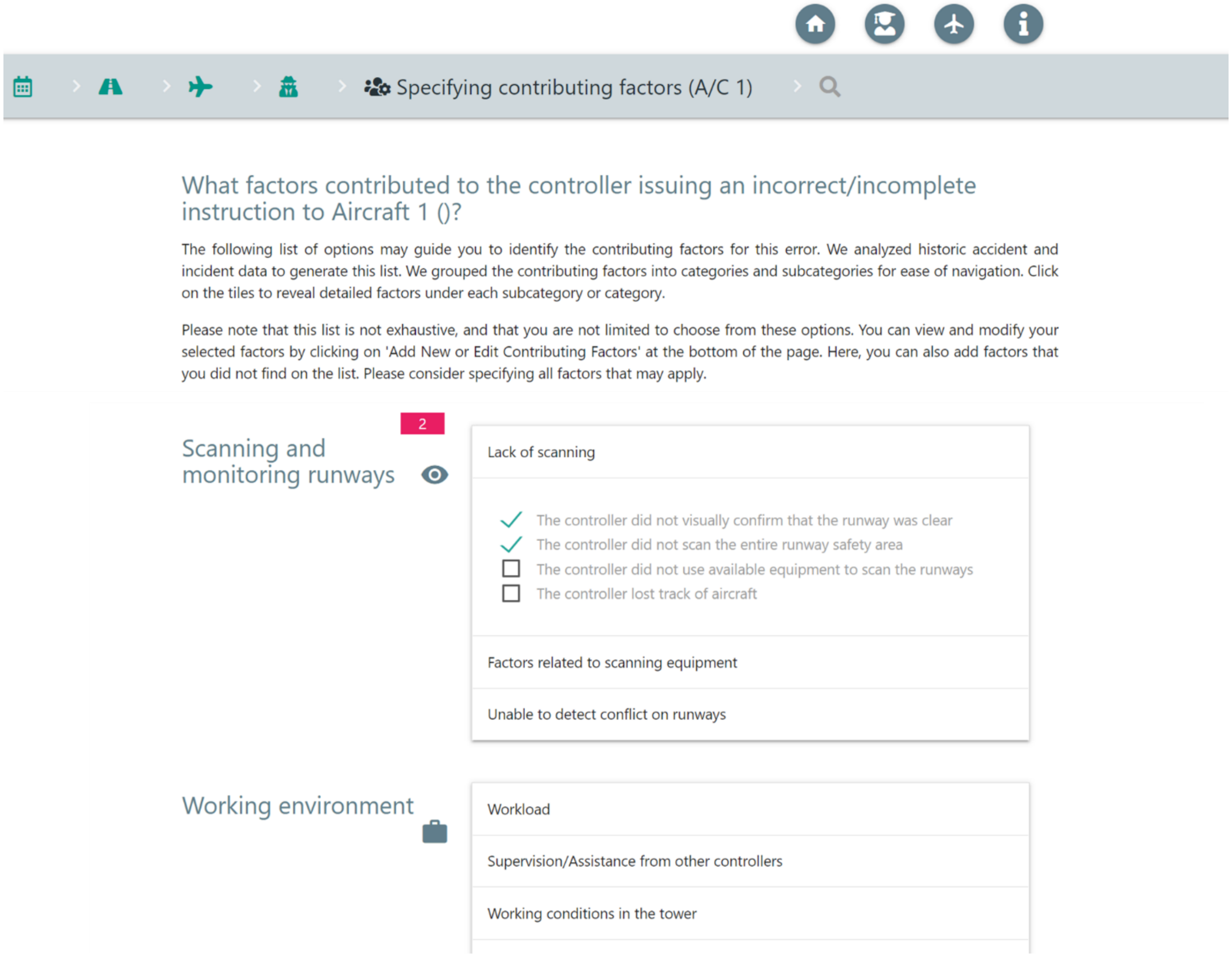
FAR Part
Select FAR Part

Please select the location of Aircraft 1 at the time of incursion.
○ On Runway 16 L
○ On Runway 34 R
○ At the intersection of Runway 16L-34R and a taxiway

Please select the phase of flight Aircraft 1 was in, at the time of incursion
(Click on help for the definitions)

Divya Bhargava and Dr. Karen Marais
Value through Reliability, Safety, and Sustainability (VRSS) Lab, Purdue University

The following image shows an example of the pages that ask the user to specify the contributing factors. The tool uses accordions, or vertically stacked tabs that users can click to show or hide subcategories of contributing factors. The red box shows the user the number of contributing factors they selected in each category. This information maybe useful if they decided to return to this page to edit their selected responses.



What factors contributed to the controller issuing an incorrect/incomplete instruction to Aircraft 1 ()?

The following list of options may guide you to identify the contributing factors for this error. We analyzed historic accident and incident data to generate this list. We grouped the contributing factors into categories and subcategories for ease of navigation. Click on the tiles to reveal detailed factors under each subcategory or category.

Please note that this list is not exhaustive, and that you are not limited to choose from these options. You can view and modify your selected factors by clicking on 'Add New or Edit Contributing Factors' at the bottom of the page. Here, you can also add factors that you did not find on the list. Please consider specifying all factors that may apply.

Scanning and monitoring runways 2

Lack of scanning

✓ The controller did not visually confirm that the runway was clear
✓ The controller did not scan the entire runway safety area
☐ The controller did not use available equipment to scan the runways
☐ The controller lost track of aircraft

Factors related to scanning equipment

Unable to detect conflict on runways

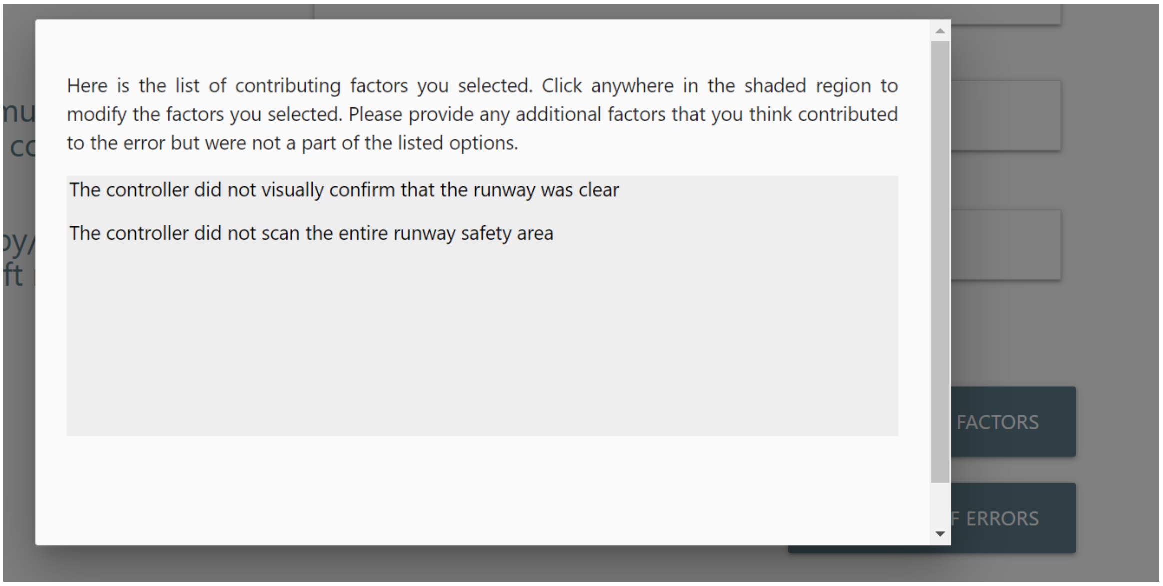
Working environment

Workload

Supervision/Assistance from other controllers

Working conditions in the tower

The users also have an option to edit their selected factors or add their own. When they click on the ‘Add New or Edit Contributing Factors’, they see the following window. The factors they selected show up in an editable text box.

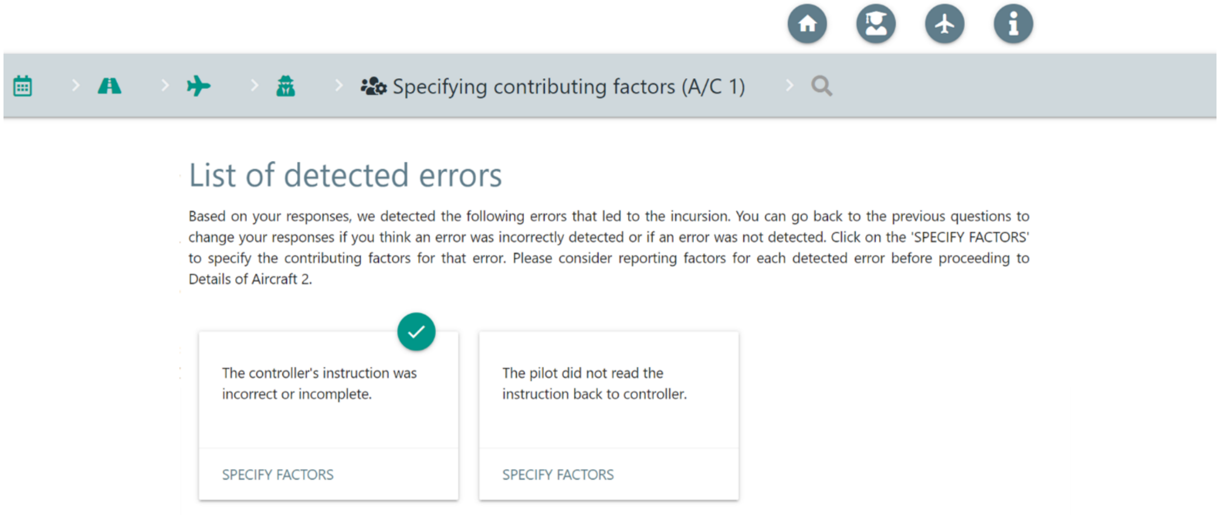


Here is the list of contributing factors you selected. Click anywhere in the shaded region to modify the factors you selected. Please provide any additional factors that you think contributed to the error but were not a part of the listed options.

The controller did not visually confirm that the runway was clear

The controller did not scan the entire runway safety area

The following image shows the ‘List of detected errors’ page. All the errors too detects show up as individual cards. The cards contain a link the user can click on to go to the page that asks them to specify factors for that error. After the user specifies the factors, they come back to this page to report factors for the next error. The green checkmark notifies the user that they have specified factors for that error.



List of detected errors

Based on your responses, we detected the following errors that led to the incursion. You can go back to the previous questions to change your responses if you think an error was incorrectly detected or if an error was not detected. Click on the 'SPECIFY FACTORS' to specify the contributing factors for that error. Please consider reporting factors for each detected error before proceeding to Details of Aircraft 2.

The controller's instruction was incorrect or incomplete.

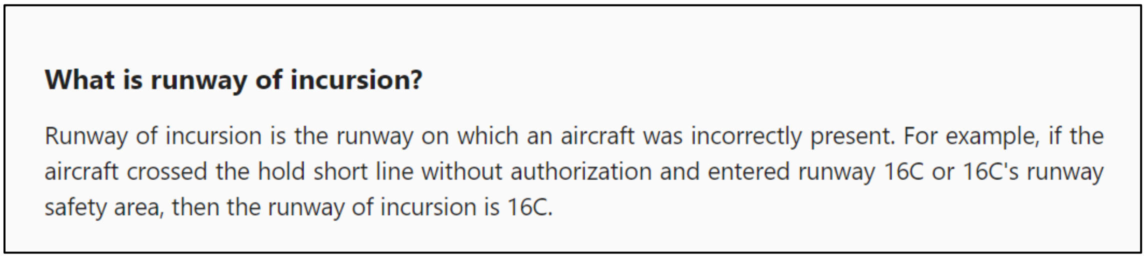
SPECIFY FACTORS

The pilot did not read the instruction back to controller.

SPECIFY FACTORS

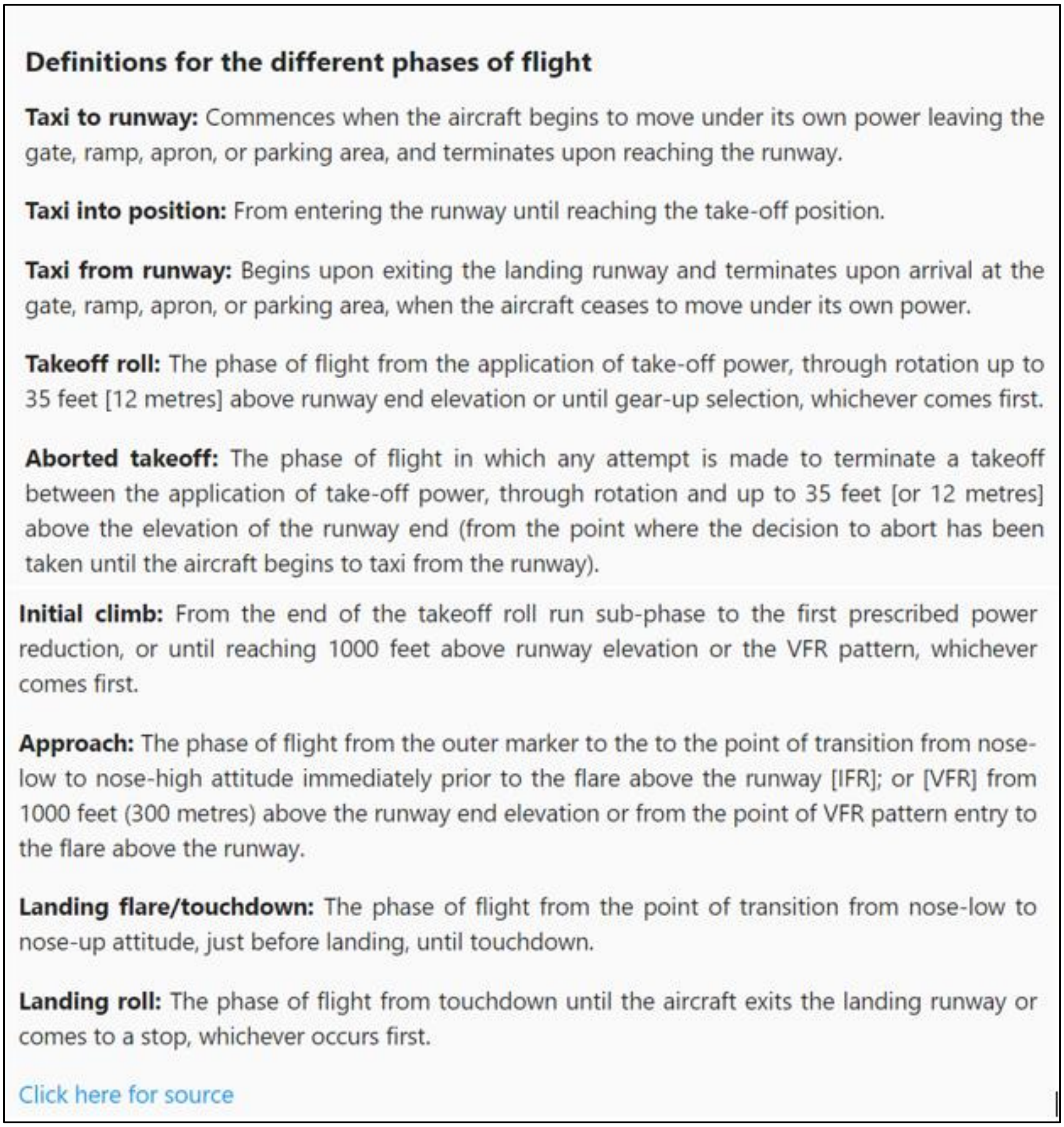
‘Help’ windows

Some questions on the website have a ‘Help’ button explaining the context of the question.



What is runway of incursion?

Runway of incursion is the runway on which an aircraft was incorrectly present. For example, if the aircraft crossed the hold short line without authorization and entered runway 16C or 16C's runway safety area, then the runway of incursion is 16C.



Definitions for the different phases of flight

Taxi to runway: Commences when the aircraft begins to move under its own power leaving the gate, ramp, apron, or parking area, and terminates upon reaching the runway.

Taxi into position: From entering the runway until reaching the take-off position.

Taxi from runway: Begins upon exiting the landing runway and terminates upon arrival at the gate, ramp, apron, or parking area, when the aircraft ceases to move under its own power.

Takeoff roll: The phase of flight from the application of take-off power, through rotation up to 35 feet [12 metres] above runway end elevation or until gear-up selection, whichever comes first.

Aborted takeoff: The phase of flight in which any attempt is made to terminate a takeoff between the application of take-off power, through rotation and up to 35 feet [or 12 metres] above the elevation of the runway end (from the point where the decision to abort has been taken until the aircraft begins to taxi from the runway).

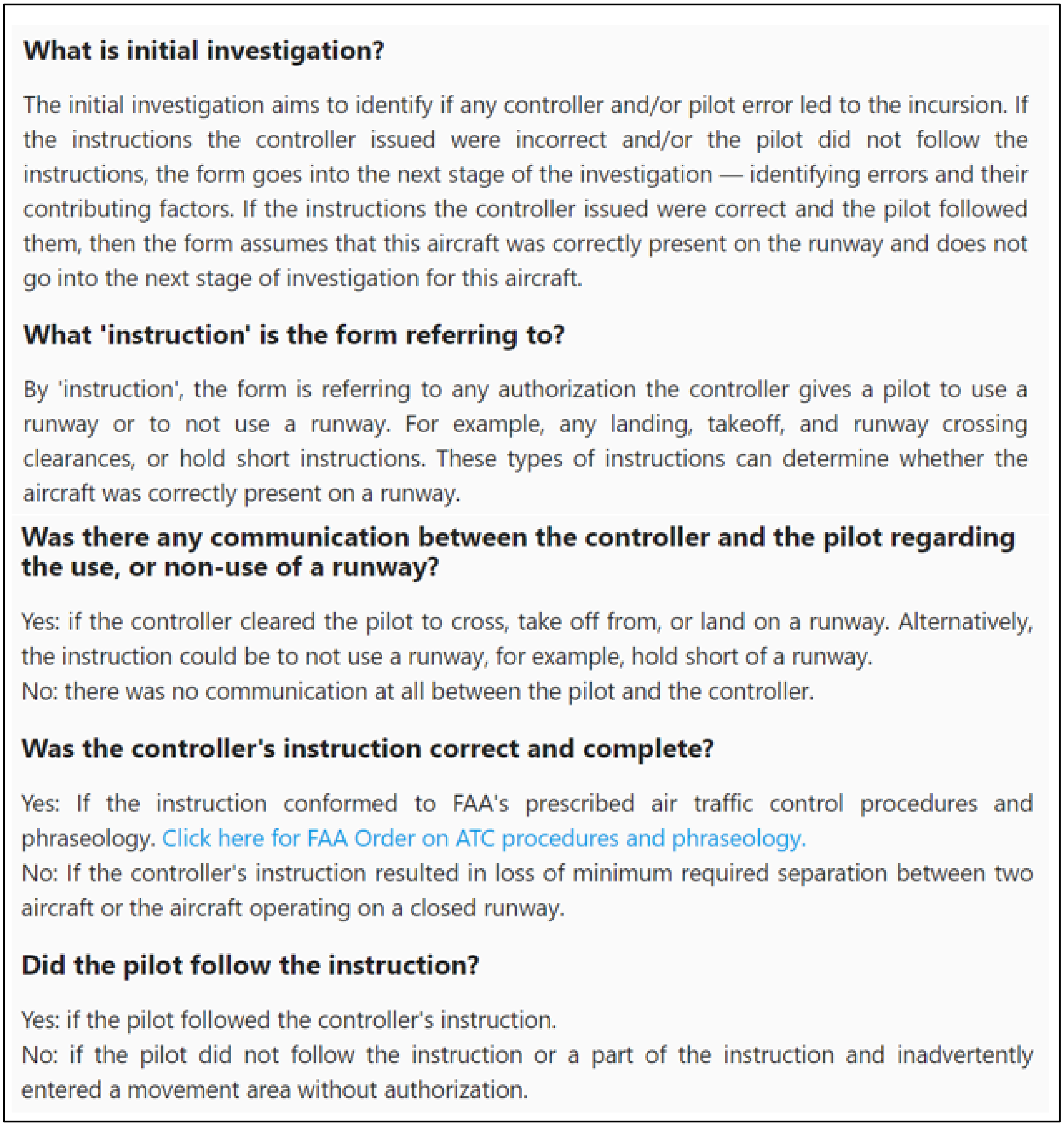
Initial climb: From the end of the takeoff roll run sub-phase to the first prescribed power reduction, or until reaching 1000 feet above runway elevation or the VFR pattern, whichever comes first.

Approach: The phase of flight from the outer marker to the to the point of transition from nose-low to nose-high attitude immediately prior to the flare above the runway [IFR]; or [VFR] from 1000 feet (300 metres) above the runway end elevation or from the point of VFR pattern entry to the flare above the runway.

Landing flare/touchdown: The phase of flight from the point of transition from nose-low to nose-up attitude, just before landing, until touchdown.

Landing roll: The phase of flight from touchdown until the aircraft exits the landing runway or comes to a stop, whichever occurs first.

Click here for source



What is initial investigation?

The initial investigation aims to identify if any controller and/or pilot error led to the incursion. If the instructions the controller issued were incorrect and/or the pilot did not follow the instructions, the form goes into the next stage of the investigation — identifying errors and their contributing factors. If the instructions the controller issued were correct and the pilot followed them, then the form assumes that this aircraft was correctly present on the runway and does not go into the next stage of investigation for this aircraft.

What 'instruction' is the form referring to?

By 'instruction', the form is referring to any authorization the controller gives a pilot to use a runway or to not use a runway. For example, any landing, takeoff, and runway crossing clearances, or hold short instructions. These types of instructions can determine whether the aircraft was correctly present on a runway.

Was there any communication between the controller and the pilot regarding the use, or non-use of a runway?

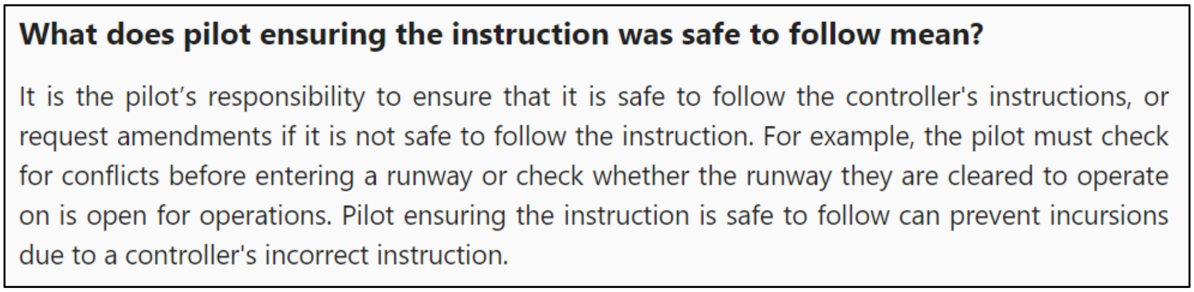
Yes: if the controller cleared the pilot to cross, take off from, or land on a runway. Alternatively, the instruction could be to not use a runway, for example, hold short of a runway.
No: there was no communication at all between the pilot and the controller.

Was the controller's instruction correct and complete?

Yes: If the instruction conformed to FAA's prescribed air traffic control procedures and phraseology. Click here for FAA Order on ATC procedures and phraseology.
No: If the controller's instruction resulted in loss of minimum required separation between two aircraft or the aircraft operating on a closed runway.

Did the pilot follow the instruction?

Yes: if the pilot followed the controller's instruction.
No: if the pilot did not follow the instruction or a part of the instruction and inadvertently entered a movement area without authorization.

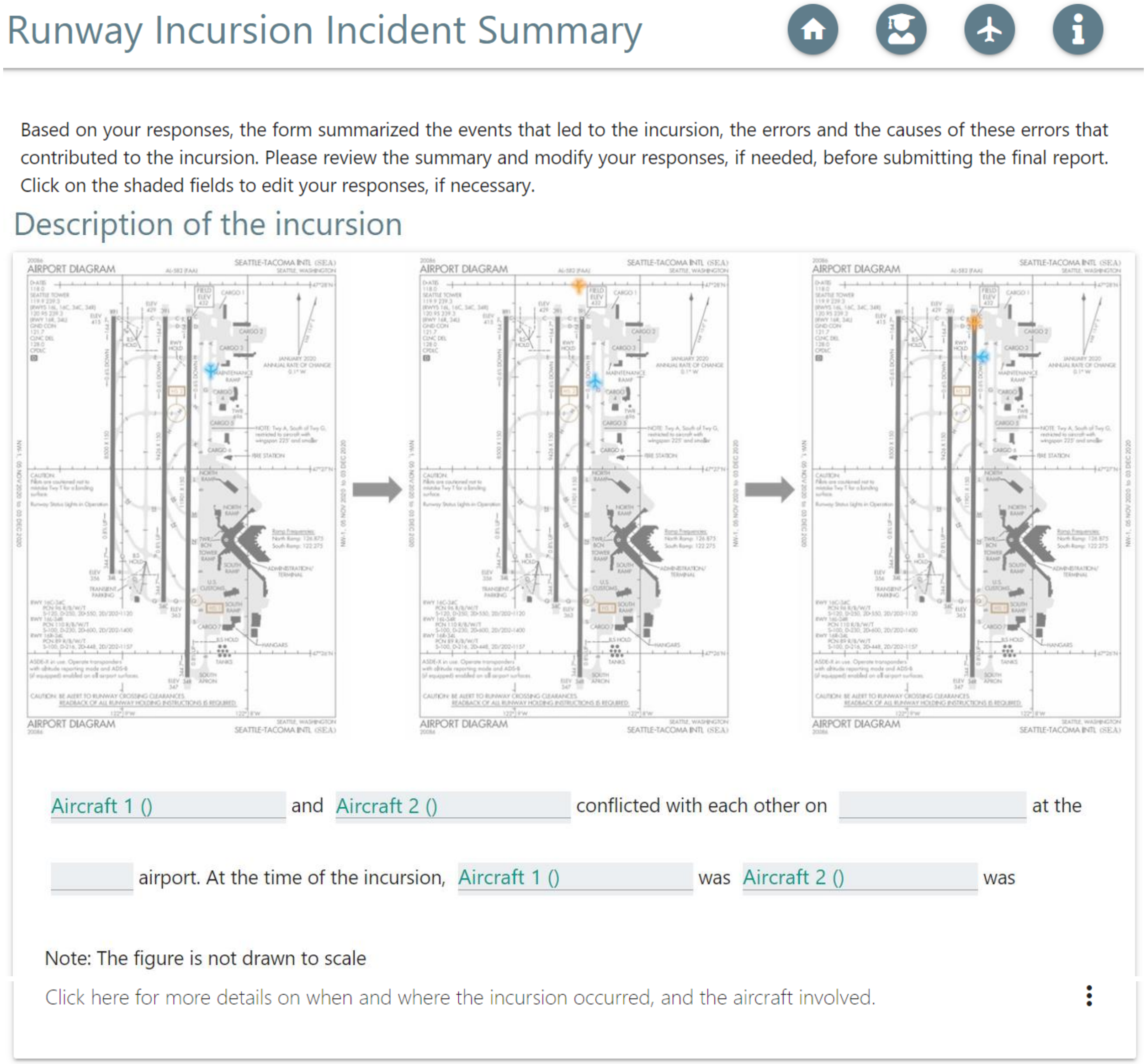


What does pilot ensuring the instruction was safe to follow mean?

It is the pilot’s responsibility to ensure that it is safe to follow the controller's instructions, or request amendments if it is not safe to follow the instruction. For example, the pilot must check for conflicts before entering a runway or check whether the runway they are cleared to operate on is open for operations. Pilot ensuring the instruction is safe to follow can prevent incursions due to a controller's incorrect instruction.

Summary page at the end of reporting

Before the final submission, the tool shows the controllers a summary of responses they entered for any final edits.



Runway Incursion Incident Summary

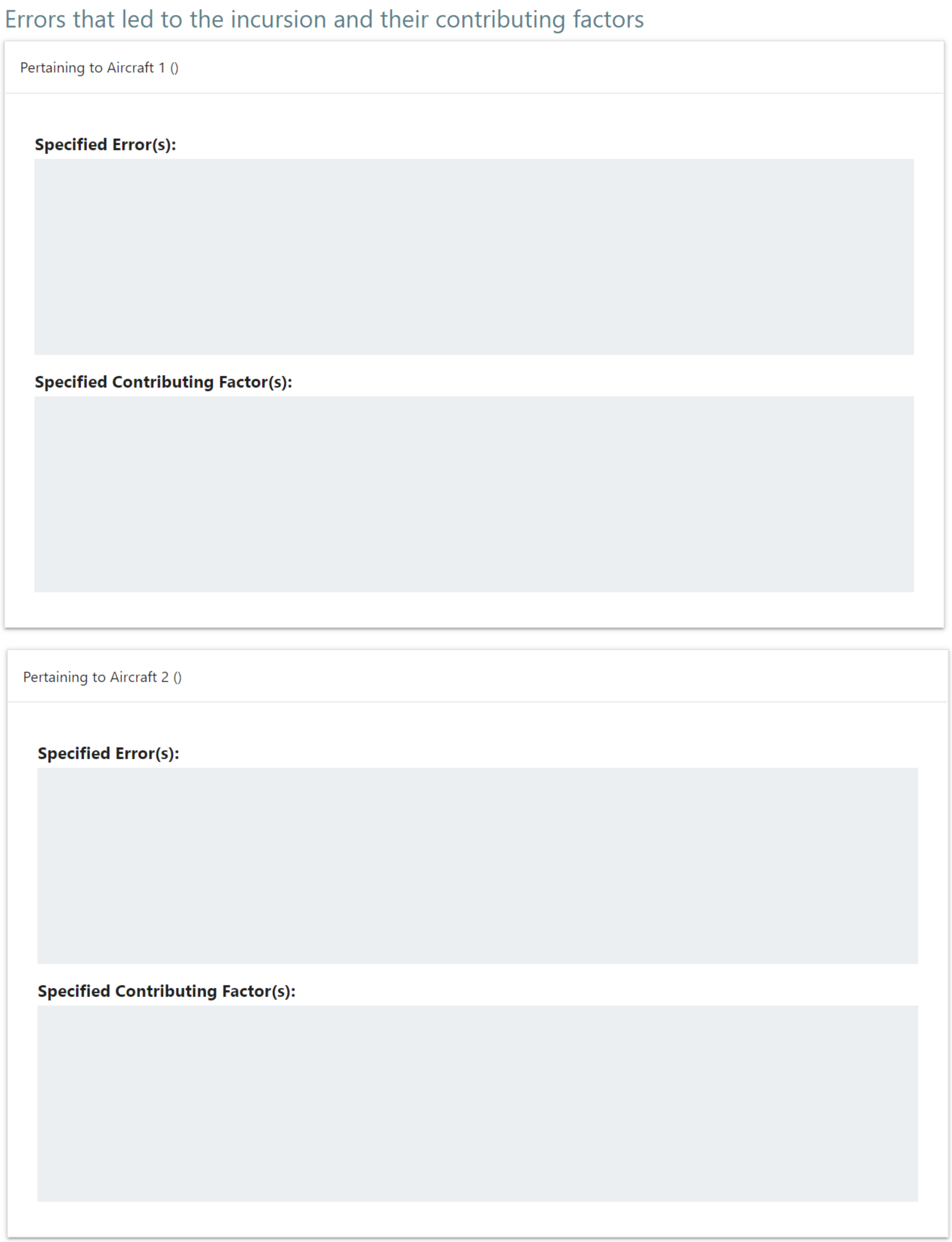
Based on your responses, the form summarized the events that led to the incursion, the errors and the causes of these errors that contributed to the incursion. Please review the summary and modify your responses, if needed, before submitting the final report. Click on the shaded fields to edit your responses, if necessary.

Description of the incursion

Aircraft 1 () and Aircraft 2 () conflicted with each other on ______ at the ______ airport. At the time of the incursion, Aircraft 1 () was Aircraft 2 () was

Note: The figure is not drawn to scale

Click here for more details on when and where the incursion occurred, and the aircraft involved.



Errors that led to the incursion and their contributing factors

Pertaining to Aircraft 1 ()

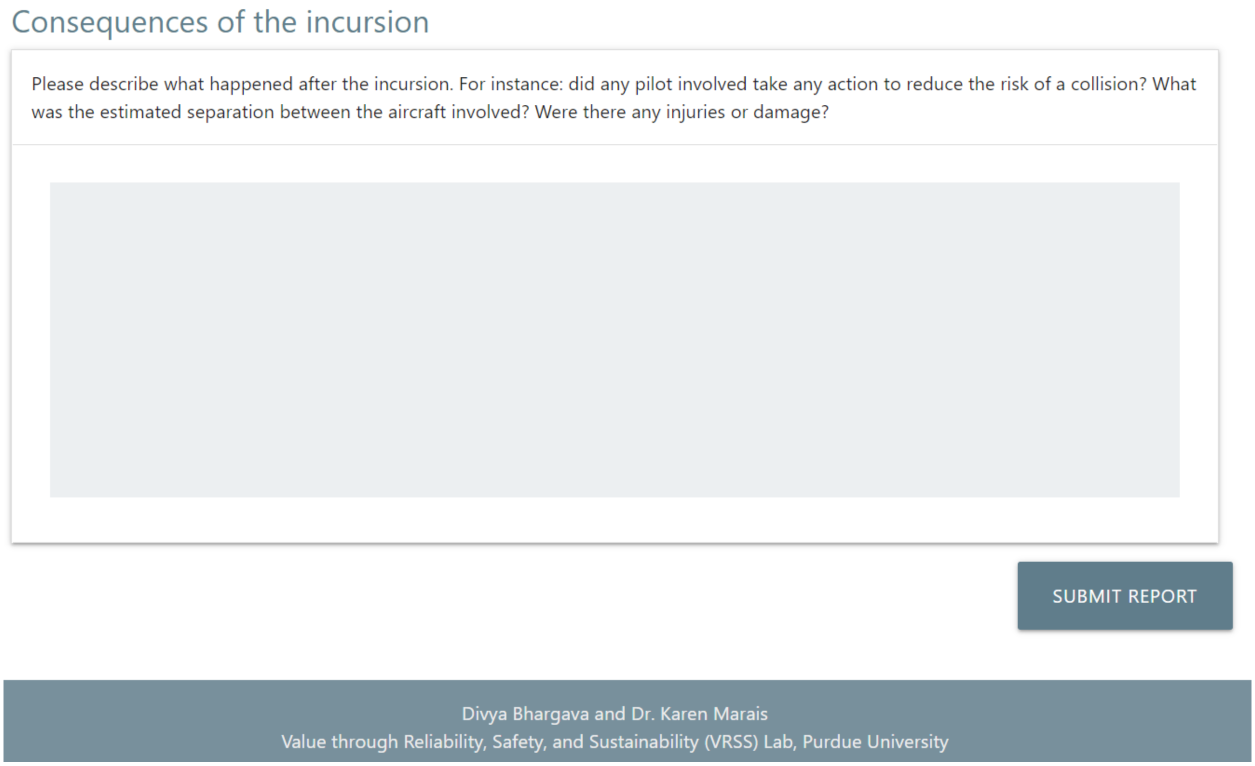
Specified Error(s):

Specified Contributing Factor(s):

Pertaining to Aircraft 2 ()

Specified Error(s):

Specified Contributing Factor(s):



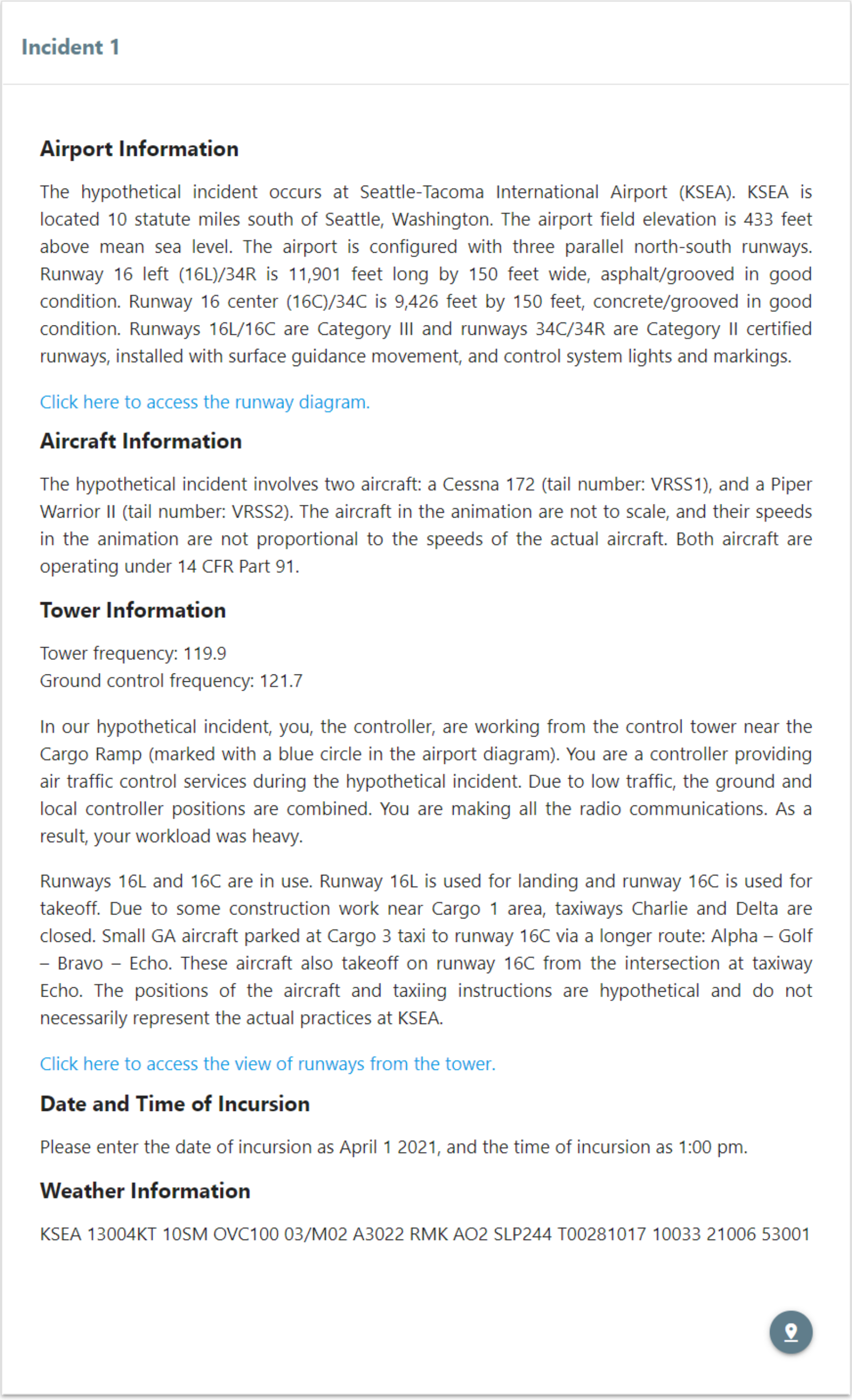
Consequences of the incursion

Please describe what happened after the incursion. For instance: did any pilot involved take any action to reduce the risk of a collision? What was the estimated separation between the aircraft involved? Were there any injuries or damage?

Divya Bhargava and Dr. Karen Marais
Value through Reliability, Safety, and Sustainability (VRSS) Lab, Purdue University

APPENDIX F. BACKGROUND INFORMATION FOR CONTROLLERS

Background information for Incident 1



Incident 1

Airport Information

The hypothetical incident occurs at Seattle-Tacoma International Airport (KSEA). KSEA is located 10 statute miles south of Seattle, Washington. The airport field elevation is 433 feet above mean sea level. The airport is configured with three parallel north-south runways. Runway 16 left (16L)/34R is 11,901 feet long by 150 feet wide, asphalt/grooved in good condition. Runway 16 center (16C)/34C is 9,426 feet by 150 feet, concrete/grooved in good condition. Runways 16L/16C are Category III and runways 34C/34R are Category II certified runways, installed with surface guidance movement, and control system lights and markings.

Click here to access the runway diagram.

Aircraft Information

The hypothetical incident involves two aircraft: a Cessna 172 (tail number: VRSS1), and a Piper Warrior II (tail number: VRSS2). The aircraft in the animation are not to scale, and their speeds in the animation are not proportional to the speeds of the actual aircraft. Both aircraft are operating under 14 CFR Part 91.

Tower Information

Tower frequency: 119.9
Ground control frequency: 121.7

In our hypothetical incident, you, the controller, are working from the control tower near the Cargo Ramp (marked with a blue circle in the airport diagram). You are a controller providing air traffic control services during the hypothetical incident. Due to low traffic, the ground and local controller positions are combined. You are making all the radio communications. As a result, your workload was heavy.

Runways 16L and 16C are in use. Runway 16L is used for landing and runway 16C is used for takeoff. Due to some construction work near Cargo 1 area, taxiways Charlie and Delta are closed. Small GA aircraft parked at Cargo 3 taxi to runway 16C via a longer route: Alpha – Golf – Bravo – Echo. These aircraft also takeoff on runway 16C from the intersection at taxiway Echo. The positions of the aircraft and taxiing instructions are hypothetical and do not necessarily represent the actual practices at KSEA.

Click here to access the view of runways from the tower.

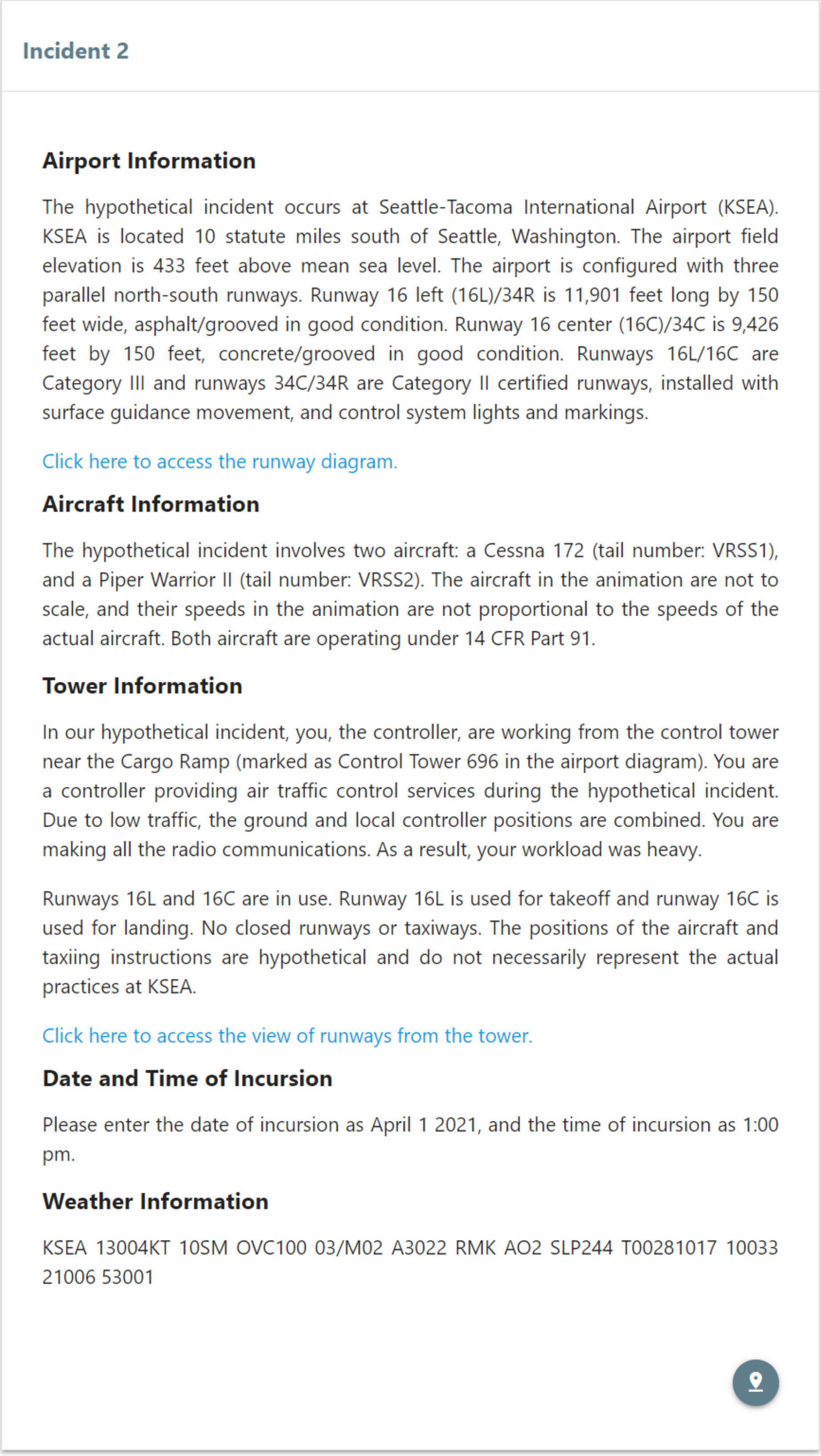
Date and Time of Incursion

Please enter the date of incursion as April 1 2021, and the time of incursion as 1:00 pm.

Weather Information

KSEA 13004KT 10SM OVC100 03/M02 A3022 RMK AO2 SLP244 T00281017 10033 21006 53001

Background information for Incident 2



Incident 2

Airport Information

The hypothetical incident occurs at Seattle-Tacoma International Airport (KSEA). KSEA is located 10 statute miles south of Seattle, Washington. The airport field elevation is 433 feet above mean sea level. The airport is configured with three parallel north-south runways. Runway 16 left (16L)/34R is 11,901 feet long by 150 feet wide, asphalt/grooved in good condition. Runway 16 center (16C)/34C is 9,426 feet by 150 feet, concrete/grooved in good condition. Runways 16L/16C are Category III and runways 34C/34R are Category II certified runways, installed with surface guidance movement, and control system lights and markings.

Click here to access the runway diagram.

Aircraft Information

The hypothetical incident involves two aircraft: a Cessna 172 (tail number: VRSS1), and a Piper Warrior II (tail number: VRSS2). The aircraft in the animation are not to scale, and their speeds in the animation are not proportional to the speeds of the actual aircraft. Both aircraft are operating under 14 CFR Part 91.

Tower Information

In our hypothetical incident, you, the controller, are working from the control tower near the Cargo Ramp (marked as Control Tower 696 in the airport diagram). You are a controller providing air traffic control services during the hypothetical incident. Due to low traffic, the ground and local controller positions are combined. You are making all the radio communications. As a result, your workload was heavy.

Runways 16L and 16C are in use. Runway 16L is used for takeoff and runway 16C is used for landing. No closed runways or taxiways. The positions of the aircraft and taxiing instructions are hypothetical and do not necessarily represent the actual practices at KSEA.

Click here to access the view of runways from the tower.

Date and Time of Incursion

Please enter the date of incursion as April 1 2021, and the time of incursion as 1:00 pm.

Weather Information

KSEA 13004KT 10SM OVC100 03/M02 A3022 RMK AO2 SLP244 T00281017 10033 21006 53001

APPENDIX G. BACKGROUND STORIES FOR PILOTS IN THE HYPOTHETICAL INCIDENTS

Background story for the VRSS 1 pilot

You are a student pilot with 35 hours of flight time logged with instructor and 3 hours of flight time logged solo. Throughout your flight training so far, you and your instructor have been working hard on your radio communications. There have been multiple incidents in the past where you took too long to reply to the ATC. Your instructor told you to reply promptly and read back all the instructions. They also suggested you write the instructions down as the ATC is issuing them, so that you can avoid mistakes in the read back.

On the day of the incident, you were going on your first solo cross country and were nervous about your flight. The night before, as you were planning your flight, your friend told you about a pilot they knew who lost his way on their first solo cross country. This incident added to your stress levels. You have been waiting long to complete your flight training and have cancelled multiple flights due to reasons such as bad weather, midterms, or aircraft being in maintenance. On the day of the incident, all the stars aligned correctly, and you wanted to make the most of this opportunity and get your cross country done.

On the day of the incident, you followed your instructor's guidelines and were writing taxiing instructions as the ATC was issuing them. Because of some maintenance work on the south end of the airport, the ATC issued a longer taxiing route than your usual taxiing route to runway 16 C. Also, due to this maintenance work, the ATC issued an intersection departure from runway 16 C at Echo instead of the runway end. Since the taxiing instructions were longer, and not what you had expected, you were frantically trying to keep up with the ATC. You were busy scribbling away and responded to the ATC with 'Roger' remembering that your instructor asked you to reply promptly to the ATC. In your haste, you forgot to note down the runway you needed to hold short of. When the ATC asked you to read back all the instructions, you read back the instructions correctly but missed out on the runway number you needed to hold short of because you did not have that written down.

The controller did not amend your readback. You took your runway diagram out as you started taxiing. You kept looking down at your chart and looked outside to make sure you were on the right route. As you turned on Echo, you looked down at your instructions that said you needed to hold short at Echo. You looked at your runway diagram and assumed you would be holding short of your takeoff runway, Runway 16 C for your run-up, and not Runway 16 L. As a result, you crossed the hold short line. You immediately realized your mistake and stopped.

Background story for the VRSS 2 pilot

You are a licensed Commercial Pilot with 350 hours of flight time logged. On the day of the incident, you were flying into Seattle to visit a friend. It was your first time landing at the KSEA airport. You did your research on the airport and found that there have been multiple cases of wrong surface landings at the airport—where the pilot mistook the parallel taxiway as a runway. As a result, you were more careful than usual and focused all your attention on the runway. You were not aware of the traffic holding short at the intersection of the runway you 16 L and taxiway Echo. As you got closer to the runway, all your attention was on landing the airplane and you did not see the traffic in the runway safety area. Only after you rolled past the intersection did you realize the traffic had crossed the hold short line.

Background story for the VRSS 3 pilot

You are a licensed Commercial Pilot with 500 hours of flight time logged. You have flown into KSEA several times before but have always landed on Runway 16 L or 16 R. You are confident in navigating on the airport surface and so did not have a runway diagram handy. On the day of the incident, the ATC instructed you to land on Runway 16 C. It was the first time you were landing on this runway. As you were exiting on taxiway F, the controller instructed you to hold short of Runway 16 L at F for departing traffic. You repeated the instructions correctly. Then, your attention was diverted inside the cockpit to complete the items on the after-landing checklist and trying to get hold of an airport diagram. You were expecting the hold short lines to be perpendicular to runway 16 L (which they are not). You accidentally crossed the hold short line. You had forgotten about the departing traffic, and realized your mistake when the ATC instructed the conflicting aircraft to abort takeoff.

Background story for the VRSS 4 pilot

You are a licensed Private Pilot with 54 hours of flight time logged. You are currently training for your IFR rating. On the day of the incident, you were flying to a nearby airport. You were on the tower frequency and heard that the ATC cleared a Warrior to land on the parallel runway. You were also aware that the Warrior was supposed to hold short of your runway. You started your takeoff roll. You were shifting your focus between the runway centerline and your airspeed indicator. As you approached the intersection with taxiway Echo, you remembered hearing about the Warrior on the local frequency and look for it. You realized that the Warrior was close to the runway edge and was not going to stop. You immediately applied the brakes and came to a stop before you reached the intersection.

APPENDIX H. RUBRIC TO EVALUATE CONTROLLER-GENERATED REPORTS

Air traffic controllers who participated in our study reported hypothetical runway incursions using either the Qualtrics survey based on the current FAA form or the alternate reporting form (the website we created). We did this experiment over a video call during which the participants were sharing their screen and 'thinking out loud' as they reported the incident. Our goal is to evaluate how well their reports described what happened, the errors that led to the incursion, and the factors contributing to these errors. The following questionnaire guides you through a structured evaluation of the incident reports created by these two forms.

Please enter your name:

____

Please enter the incident report number:

____

Which incident's final report are you evaluating?

○ Incident 1 (VRSS1 + VRSS2)

○ Incident 2 (VRSS3 + VRSS4)

Which reporting form generated the final incident report you are evaluating?

○ Qualtrics survey based on the FAA form

○ The alternate reporting form (the website)

SECTION 1: WHAT HAPPENED?

Display This Question:If Which incident's final report are you evaluating? = Incident 1 (VRSS1 + VRSS2)

Does the report indicate that

	Yes	No
two aircraft were involved in the incursion?	○	○
the aircraft conflicted on runway 16 L?	○	○
the incursion occurred at the Seattle Tacoma (KSEA) airport?	○	○
one aircraft entered the active runway?	○	○
there was another aircraft that was landing on the same runway at the time of incursion?	○	○

Display This Question:If Which incident's final report are you evaluating? = Incident 2 (VRSS3 + VRSS4)

Does the report indicate that

	Yes	No
two aircraft were involved in the incursion?	○	○
the aircraft conflicted on runway 16 L?	○	○
the incursion occurred at the Seattle Tacoma (KSEA) airport?	○	○
one aircraft entered the active runway without authorization?	○	○
there was another aircraft on takeoff roll on the same runway at the time of incursion?	○	○

SECTION 2: ERRORS LEADING UP TO THE INCURSION

Display This Question:If Which incident's final report are you evaluating? = Incident 1 (VRSS1 + VRSS2)

Does the final report describe the following errors that led to the incursion?

	Yes	No
The VRSS1 pilot did not read back the instructions the first time -- responded with Roger	○	○
The VRSS1 pilot did not read the call sign back on the second attempt at reading the instructions back	○	○
The VRSS1 pilot did not read back which runway they needed to hold short of	○	○
The controller on duty did not catch the errors in the VRSS 1 pilot's readback	○	○
The VRSS1 pilot did not hold short of the active runway as instructed	○	○

Display This Question:If Which incident's final report are you evaluating? = Incident 2 (VRSS3 + VRSS4)

Does the final report describe the following errors that led to the incursion?

	Yes	No
The VRSS3 pilot did not scan the active runway for traffic	○	○
The VRSS3 pilot did not hold short of the active runway as instructed	○	○

Please select any additional errors that the incident report described but are not on the list above.

☐ The controller’s instruction was incorrect or incomplete
☐ The pilot did not or could not hear the controller’s instruction
☐ The pilot did not read the instruction back to the controller at all
☐ The pilot did not read the instruction back to the controller correctly
☐ The controller did not or could not hear the pilot’s readback
☐ The controller did not correct the pilot's incorrect read back of instruction
☐ Missing readback: the controller did not ask the pilot to read the instruction back
☐ The pilot did not scan runways to make sure the instruction was safe to follow
☐ The pilot ensured that the instruction was safe to follow but still ended up in an incursion
☐ Other (Please specify) ____
☐ Other (Please specify) ____

- ☐ Other (Please specify) ____
- ☐ Other (Please specify) ____
- ☐ Other (Please specify) ____

For each additional error you indicated, describe how the controller identified these errors. What was their source of information and their reasoning (if given)?

The controller's instruction was incorrect or incomplete

____

The pilot did not or could not hear the controller's instruction

____

The pilot did not read the instruction back to the controller at all

____

The pilot did not read the instruction back to the controller correctly

____

The controller did not or could not hear the pilot's readback

____

The controller did not correct the pilot's incorrect read back of instruction

____

Missing readback: the controller did not ask the pilot to read the instruction back

____

The pilot did not scan runways to make sure the instruction was safe to follow

____

The pilot ensured that the instruction was safe to follow but still ended up in an incursion

____

Additional Entries

____

SECTION 3: CONTRIBUTING FACTORS

Display This Question:If Which incident's final report are you evaluating? = Incident 1 (VRSS1 + VRSS2)

Does the final report indicate the following factors that contributed to the incident?

	Yes	No	Not sure
The VRSS1 pilot was a student in training with less than 10 hours of solo flight experience	○	○	○
The VRSS1 pilot was nervous about the flight	○	○	○
The VRSS1 pilot was worried or stressed out that they might lose their way during flight	○	○	○
The VRSS1 pilot was eager to complete flight training	○	○	○
The VRSS1 pilot had cancelled multiple flights before and wanted to get this flight done on the day of the incident because the weather was favorable	○	○	○
Because of construction work at the airport, the controller issued a different and longer taxi route than the one the VRSS1 pilot is used to	○	○	○
The VRSS1 pilot was to depart from the intersection of a runway -- something they had not done before	○	○	○
The VRSS1 pilot was frantically trying to keep up with writing the longer-than-usual instructions and missed the runway number they were to hold short of	○	○	○
The VRSS1 pilot replied with 'Roger' to give a prompt reply -- radio communications was not their strongest point	○	○	○
The VRSS1 pilot assumed they would be holding short of the runway they were going to take off from (16C)	○	○	○

Display This Question:If Which incident's final report are you evaluating? = Incident 2 (VRSS3 + VRSS4)

Does the final report indicate the following factors that contributed to the incident?

	Yes	No	Not sure
The VRSS3 pilot had been to KSEA several times before but had never landed on runway 16C before	○	○	○
The VRSS3 pilot was confident in navigating the airport surface and did not have a runway diagram handy	○	○	○
After landing, the VRSS3 pilot's attention was diverted inside the cockpit to complete the after-landing checklist	○	○	○
The VRSS3 pilot was trying to get hold of a runway diagram, complete the checklist, and taxi the aircraft simultaneously	○	○	○
The VRSS3 pilot was expecting the hold short lines to be perpendicular to runway 16 L	○	○	○
The VRSS3 pilot was unsure of their position on the taxiway	○	○	○
The VRSS3 pilot was so focused on the runway diagram and was looking for hold short markings that they entered the runway without scanning for traffic	○	○	○

Please enter any additional contributing factors that the final report described but are not on the list above.

____

For each additional contributing factor you indicated, describe how the controller identified these factors. What was their source of information and their reasoning (if given)?

____

Here is the list of contributing factors you indicated that the incident report describes. Please select the most appropriate option(s) that give insight into how and why the controller specified these factors.

The options in the list are based on previous responses. For each contributing factor that the observers indicated the report described, the observers selected one or more of the following:

- ☐ Selected from the listed options
- ☐ Selected from the listed options and then modified
- ☐ Did not select from the options -- added it on their own
- ☐ Reported after it came up in the conversation with the pilot
- ☐ Did not talk to the pilot -- took a guess

Here is the list of contributing factors you indicated that the incident report does not describe. Please select the most appropriate option(s) that give insight into why the controller did not specify these factors.

The options in the list are based on previous responses. For each contributing factor that the observers indicated the report did not describe, the observers selected one or more of the following:

- ☐ The controller could not find it listed in the options
- ☐ The factor did not come up in the conversation with the pilot
- ☐ The factor came up in the conversation but the controller chose not to report it

ADDITIONAL QUESTIONS

Did the controller talk to the pilot to learn more about the errors the pilot made and what caused those errors?

○ Yes

○ No

Display This Question: If Did the controller talk to the pilot to learn more about the errors the pilot made and what cause... = Yes

What questions did the controller ask the pilot? Specify any follow-up questions the controller asked the pilot as well.

Display This Question: If Did the controller talk to the pilot to learn more about the errors the pilot made and what cause... = Yes

At what point did the controller talk to the pilot?

○ As soon as they landed on a page that asked about errors the pilot made or causes of those errors

○ After they went through the answer options and realized talking to the pilot may help

○ Other ____

Please enter any additional comments/observations you have that you could not indicate in the questionnaire.

____

Are you sure you want to submit your responses? Once you click 'Next', you will reach the end of the survey and will not be able to go back and edit your responses.

APPENDIX I. INTER-RATER RELIABILITY

Four observers evaluated the content in each of the fourteen controller-generated incident reports and used the transcription and the soundless video to identify how and why the controllers reported a piece of information. I was one of the observers; the remaining three were undergraduate students who were enrolled in a course for 1 academic credit. Each observer evaluated the reports independent of the other against a rubric based on the incident video and the background information. The observers evaluated how well the incident reports describe the incidents, and listed the errors that may have led to the incursion and the factors that contributed to those errors.

While there are different methods to calculate inter-rater reliability between observers, the percentage agreement method is the simplest and most basic. It gives a percentage rating of the number of times observers agree in their evaluation of subjects. The major drawback of the percentage method is that it doesn't account for agreement due to chance, i.e., it doesn't account for the probability of observers providing random ratings (Belur et al., 2021). The π-statistic and more recently, Cohen's κ-statistic, are more widely used by researchers as an estimate of inter-rater reliability (Gwet, 2008). There is a lot of controversy among researchers on the credibility of the κ-statistic. One of the issues with Cohen's κ-statistic is that it can show no agreement among raters even if the observed agreement is high (Eugenio and Glass, 2004). Gwet (2002) proposed a more robust alternative statistic, called the AC_1 statistic to account for any agreement due to chance. Wongpakaran et al. (2013) compared the two statistics and concluded that the AC_1 statistic is a more stable estimate of inter-rater reliability.

In my analysis, since the observers base their evaluation on the incident report, the transcribed audio, and the soundless video, the probability of all four observers randomly selecting the presence or absence of a rubric item in the report is low. The AC_1 statistic to measure the inter-rater reliability between the four observers (Viswanathan and Berkman, 2011) is:

$$AC_1 = \frac{p_a - p_{e\gamma}}{1 - p_{e\gamma}}$$

Where $p_a$is the overall agreement probability including agreement by chance or not by chance and $p_{e\gamma}$ is the chance-agreement probability.

$$p_a = \frac{1}{n}\sum_{i=1}^{n}\left\{\sum_{q=1}^{Q}\frac{r_{iq}(r_{iq}-1)}{r(r-1)}\right\}$$

$$p_{e\gamma} = \frac{1}{Q-1}\sum_{q=1}^{Q}\pi_q(1-\pi_q)$$

$$\pi_q = \frac{1}{n}\sum_{i=1}^{n}\frac{r_{iq}}{r}$$

Where,

n: total number of reports evaluated for a specific rubric item

Q: number of categories in the rating scale

r: total number of observers

r_{iq}: number of observers who classified the i^{th}report into the q^{th} category

π_q: probability that an observer classifies a study in category q

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