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Applying Human Error Framework To Explore Prevention Strategies For Wrong Surface Events

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APPLYING HUMAN ERROR FRAMEWORK TO EXPLORE PREVENTION STRATEGIES FOR WRONG SURFACE EVENTS

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Abstract

Wrong surface events are a serious and ongoing risk to aviation safety in the United States National Airspace System. A wrong surface event occurs when an aircraft lands, departs or attempts to land or depart from a surface other than the intended landing or takeoff, also including aircraft landing at the wrong airport. This research examined the contextual factors that contributed to human error ultimately leading to wrong surface events, assessed the efficacy of technology that can be used to prevent, and aviation professional's awareness of wrong surface events in order to determine prevention strategies that can reduce occurrences in the NAS. Four NTSB reports were reviewed to identify context that influences a pilot's actions in wrong surface events. Next, flight deck and air traffic control tower based technologies were examined for their ability to detect and alert the conditions in the four event reports. Finally, eleven aviation professionals were interviewed to assess their awareness and knowledge of risks, strategies, historical events, and terminology related to wrong surface events. The results identified numerous recurring contextual factors in wrong surface events. While technology intended to prevent wrong surface events is improving, numerous shortfalls were identified that inhibit the system's ability to effectively prevent such occurrences. Additionally, results showed an overall lack of awareness among pilots and a pilot training department of wrong surface events and their associated risks, suggesting that efforts to prevent wrong surface events through training are ineffective. The results give opportunities for human error mitigation strategies to be employed to reduce occurrences of wrong surface events.

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Dedicated to Reginald Jackson Jr., the greatest friend I could ask for, so that his name and memory are forever kept and held at the place we first crossed paths: the University of North Dakota. This thesis is symbolic of Reggie's life, which taught us that while things won't always be easy, they will be important, valuable, and cherished. May this serve as a reminder to all who knew him that the adversity we face and the challenges we seek to overcome are really just an opportunity to make an impact, inspire others, and leave a lasting legacy. Be more like Reggie. Forever a friend.

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Acronyms

ADS-B – Automatic Dependent Surveillance Broadcast

ASDE-X – Airport Surface Detection Equipment Model X

ASSC – Airport Surface Surveillance Capability

ATCT – Airport Traffic Control Tower

ATIS – Automatic Terminal Information Service

ATP – Airline Transport Pilot

CFI – Certified Flight Instructor

FAA – Federal Aviation Administration

FOIA – Freedom of Information Act

NAS – National Airspace System (specifically, in the United States)

NOTAM – Notice to Air Missions (formerly Notice to Airmen)

NTSB – National Transportation Safety Board

PAPI – Precision Approach Path Indicator

SBS – Surveillance Broadcast Service

SMGR – Surface Movement Ground Radar

STARS – Standard Terminal Automation Replacement System

SURF-IA - Enhanced Traffic Situational Awareness on the Surface with Indications and Alerts

VASI – Visual Approach Slope Indicator

Terms and Definitions

Multilateration – The process of determining a transponder's location in two (or three) dimensions by solving for the mathematical intersection of multiple hyperbolas (or hyperboloids) based on the time difference between the transponder's signal receipt at multiple sensors.

Plan continuation – A human error concept that involves a cognitive fixation of sticking to the original plan despite cues that may indicate the need for a change of plans.

Priming – A human error concept in which a person may have a subconscious expectation bias to certain condition based on prior experience and act on that expectation.

Chapter I: Introduction

In July 2017, a wrong surface event at San Francisco International Airport nearly resulted in the deadliest aviation accident in history. According one member of the NTSB (2018), “over 1000 people were at imminent risk of serious injury or death” (p. 74) after an Air Canada Airbus A320 mistakenly attempted to land on a parallel taxiway instead of the assigned runway, overflying two Boeing 787s, a Boeing 737, and an Airbus A340. The A320’s landing gear came within an estimated 10-20 feet of striking the tail of the A340 on the taxiway (National Transportation Safety Board, 2018). Many highly publicized incidents and accidents have been wrong surface events, including the crash of Comair 5191 as well as multiple cases of aircraft landing at the wrong airport being highlighted by news media, suggesting an ongoing threat to aviation safety (Hartwig, 2020; Riley et al., 2014).

According to the FAA (2021a), “wrong surface operations are a serious and continuing issue at airports throughout the National Airspace System” (0:05). A wrong surface event occurs when an aircraft lands or departs, or tries to land or depart, on the wrong runway, on a taxiway or when an aircraft lands at the wrong airport (Federal Aviation Administration, 2018d). Wrong surface events can be further broken down into wrong surface departures, attempted wrong surface departures, wrong surface landings, wrong surface approaches, and wrong airport landings. The FAA is examining contributing factors and identify correlations in wrong surface events in recent years with increased focus following the incident in San Francisco in 2017.

Problem Statement

The risks that wrong surface events pose to the safety of the traveling public demonstrate a need to understand why wrong surface events continue to persist in the National Airspace System, how they’re being addressed, and whether current strategies are effective at addressing them. Since not much is known about wrong surface events specifically and little research and information exists compared to other types of aviation safety incidents, this research explores human error contribution, the impacts and efficacy of technological systems, and the impacts and efficacy of current training, education, and procedures that could be identified relating to wrong surface events. A review of literature was conducted on various subjects to provide a foundation for the qualitative analysis of human error contribution as it pertains to wrong surface events. This is a necessary first step because “safety efforts cannot be systematically refocused until a thorough understanding of the nature of human factors in aviation accidents is realized” (Wiegmann & Shappell, 2003, p. 16). Accordingly, an examination of human factors and error is rooted in qualitative research methods. Observations, documents, interviews, surveys, visual materials, articles, and books are all forms of data used in qualitative data production.

Human error framework has not largely been applied to the examination of wrong surface events to validate or aid in the development of prevention strategies. Due to this, it’s beneficial to apply the broad concepts rather than apply a specific model of human error classification. To examine wrong surface events, there is a need to explore the relationship between the actions taken by the pilots and air traffic controllers and the context of the events that lead to wrong surface events. Furthermore, there is a need to examine and understand current prevention strategies and assess the impact of these strategies to determine if they effectively target human error contributing to wrong surface approaches.

Wrong surface events can be classified as a form of human error based since there is a deviation from the intention to land on the correct surface (Reason, 2008). Human error occurs when there is a deviation from the current intention or path towards a goal (Reason, 2008).

Purpose of the Study

To understand why wrong surface events continue to occur, historical events will be analyzed by applying existing human error framework to better understand how the context of an event influences pilots' actions and contributes to the occurrences of wrong surface events. To understand the impact that recent technological improvements have had on the interruption of wrong surface events, a review of literature on current flight deck and air traffic control tower-based technology will be conducted to understand the functionality and assess capability of these systems to interrupt wrong surface events, applying the understanding gained from the analysis of historical events. Finally, this research will interview pilots, air traffic control specialists, and pilot training staff to understand how training, education, and procedures target human error and assess how effective these methods are at creating awareness of the phenomenon to aid in the potential interruption of wrong surface events.

Research Questions

In order to address the purpose of this study the following research questions are posed:

1. What context can be identified to help explain the actions of pilots that contribute to wrong surface events?
2. What impact have flight deck and air traffic control tower-based technological solutions made on wrong surface events? How effective are these solutions at aiding in detection and prevention?
3. What impact does current training, education, and procedural requirements and recommendations have among pilots and air traffic controllers in aiding detection and

interruption wrong surface events? How effective is this at creating awareness and preventing human error contributing to wrong surface events?

Limitations of Current Information on Wrong Surface Events

Wrong surface events have been examined in an extremely limited manner both qualitatively and quantitively. Challenges associated with the overwhelming lack of publicly availably academic research and aviation safety data make research difficult. The FAA has concentrated primarily on the contributing factors and has done little work to determine the root cause of why pilots continue to land and depart surfaces other than intended. Inconsistencies in event classification stem the lack of consistent definitions and terms as well as a fragmented attempt to apply existing human error knowledge. Since many forms of human error classification exist, it can be challenging to organize, understand, and apply.

Single Source Information

The primary source for information on wrong surface events is the FAA, who shares findings in various forms, most often in YouTube videos, FAASafetyTeam Notices on faasafety.gov, or in various other public press forums (Federal Aviation Administration, 2018a, 2018b, 2018d, 2020a, 2021b). It can be presumed that this is to educate a mass audience and not targeted or intended for use in research; therefore it must be easily digestible by the average viewer. The FAA does not publicly share or explain their methods for collecting, sorting, and classifying data. There is no way to independently validate the FAA's claims without the knowledge of how they organize or extrapolate their data source, a failure of the scientific method of research.

Little publicly available academic or peer reviewed research exists on wrong surface events at airports, with the exception of wrong airport landings. The FAA continues to be one of the only existing sources for information on wrong surface events. Multiple requests to collaborate in this research topic and obtain data were sent to the FAA Office of Runway Safety and National Air Traffic Controllers Association Runway Safety Committee in October 2020 and March 2021, receiving no response. Any quantitative analysis of wrong surface event data is nearly impossible without the involvement and willing collaboration with the FAA.

Ease of Access to Data

The FAA's repository of data and information on wrong surface events is not available to the public through any reasonable means. This data is available internally to the FAA's Air Traffic Organization and is sometimes published by the National Air Traffic Controllers Association, the air traffic control labor union in the United States. It's unclear why the FAA isn't more forthcoming with raw data and information related to wrong surface events.

Various challenges are associated with Freedom of Information Act (FOIA) Requests as a means to obtain data or information related to Wrong Surface Events. Requests for information by a private person that involve the gathering of an extensive amount of data are often cost-prohibitive. Portions of a FOIA request filed for information on FAA technology intended to detect and alert to wrong surface events were exempt from being publicly released. The FAA stated that the records are being withheld in their entirety under a FOIA exemption which "protects trade secrets obtained from a person or entity that is privileged or confidential" (S. Walters, personal communication, July 8, 2022, para. 3). In this instance, the information was submitted by Saab Sensis Corporation, the federal government contractor who developed ASDE-X for the FAA. As such, the equipment developed, despite being used by the federal government, is considered to be protected trade secrets. In potential research related to FAA technology such as the ASDE-X and ASSC, it's likely that important contextual information necessary would be withheld from disclosure. This heavily limits any academic research and scrutiny of the equipment that is not sanctioned by the US Government. Although the FAA claims that wrong surface events continue to be a topic of focus, data, and information gatekeeping on the part of the continue to be a challenge in the advancement of aviation safety.

Classification Limitations

Classifying and defining wrong surface events and the human error context surrounding them is the most drastic limitation hindering current and future academic research. According to Wiegmann (2003), "databases that house human error data are often poorly organized and lack any consistent or meaningful structure" (p. 16). Many studies focus on more reliable contextual information, such as the weather conditions, rather than the underlying human error that was the root cause (Wiegmann & Shappell, 2003). Existing research on wrong airport landings is limited by a poorly organized, inconsistent structure leading to differing classifications of wrong surface events as runway incursions or other inconsistent terminology such as taxiway overflight, geographic disorientation, and attempted takeoff from wrong runway (Antuano & Mohler, 1988; National Transportation Safety Board, 2007, 2018). For example, the FAA (2021b) claims that complex airspace, frequency congestion, distractions, and lack of familiarity with the area can lead a loss of situational awareness where the pilot mistakenly identifies the wrong airport without delving into greater detail as to the root cause of the loss of situational awareness like many human error authors suggest (Dekker, 2006; Reason, 2008; Wiegmann & Shappell, 2003). The aviation industry has only recently made improvements in using congruent terms when referring to wrong surface events however most historical events have not been reclassified and re-examined under the newly separated terms.

Although the FAA has effectively been able to explain the intentions and the possible or likely outcomes of wrong surface events, the context of the error is typically event-dependent and specific (Federal Aviation Administration, 2018a, 2018d, 2020a, 2021b). Importantly, the contributing factors the FAA has identified relate to the action or context but don't examine the actions or context, or explain the root cause of the event, and thus fail to properly address human error mitigations or prevention strategies. As a result, the examination of wrong surface events has been limited in scope and prevention strategies have not been examined in their totality within the framework of existing human error framework. No research was found that attempts to define, classify, apply, and further understand the human error as it applies to wrong surface events.

Due to the history of inconsistent classification and naming conventions of wrong surface events, an interpretive approach to existing information of such phenomenon is necessary to lay a framework for future research and understanding of human error in wrong surface events. Though much work has been done by the FAA to examine trends and predictors in wrong surface events, it's faced little to no scrutiny or validation of the trends identified. Unilateral acceptance of the FAA's conclusions, recommendations, and prevention strategies without scrutiny is not in the interest of aviation safety, or public safety. It is necessary to further investigate wrong surface events in settings independently of the FAA.

Applying Similar Research

Attempting to apply similar research is a challenge. Runway incursions have the most similarities to wrong surface events, but key differences exist in event characteristics. Most notably, wrong surface events include the transitionary period of an aircraft in flight and an aircraft being on the ground, both during takeoff and landing. Runway incursions differ from this in that they are the incorrect presence within a defined, predicable, and measurable geographic boundary on the ground. Research on runway incursion prevention systems, surface movement ground radar, and similar systems is limited to surface operations related primarily to the taxiing of aircraft and movement of ground vehicles. Most current research fails to examine the use of these systems beyond the scope of ground operations. Since all wrong surface events involve an airborne phase of flight and in many cases a phase where the aircraft is on the ground, this transitionary period where errors leading to wrong surface events have largely not been accounted for in the development or use of these systems. Some exceptions exist, however. The FAA has upgraded most ASDE-X and ASSC with a Taxiway Arrival Prediction Enhancement, intended to detect and alert to aircraft that are lined up with a taxiway instead of a runway.

Current Prevention Strategies are Ineffective

The efficacy of wrong surface event prevention strategies has been minimally studied. Technological tools and increasing awareness through procedures or training are the two most prevalent prevention strategies identified. Technological solutions function by detecting and alerting pilots or air traffic controllers to misalignments. It’s widely accepted that training creates awareness and, in this case, educate pilots and air traffic controllers on the risk factors identified by the FAA that are associated with wrong surface events. The two categories of technological solutions are flight deck-based detection and alerting systems and air traffic control tower based detection and alerting systems. In addition to the technological solution, the FAA has various information campaigns in the form of FAASafety Team Notices and YouTube videos sharing information to pilots. In some cases, the FAA publishes videos that focus on specific airports, identifying the risks and hazards associated with that airport.

Chapter II: Literature Review

Qualitative research seeks to test a theory or understand a phenomenon or behavior through a conceptual framework examining the issues, settings, and people involved and the theories, beliefs and prior research findings (Maxwell, 2013). Components of qualitative research are often reconsidered or modified during the study as a response to developments or changes.

Due to the limitations on the topic, grounded theory was used to explore the phenomenon of wrong surface events. Grounded theory is a qualitative framework in which theory is develop through repeated interaction with data and information (Maxwell, 2013). The development of this grounded theory occurred over time through the examination of literature and data on wrong surface events, and the application of human error framework to wrong surface events. Grounded theory was used to establish the relationship between existing human error research and existing information of wrong surface events (Federal Aviation Administration, 2018d; Maxwell, 2013; Reason, 2008). The intent to narrow in on a specific topic of research in wrong surface events began with an assessment of available wrong surface event data and facts while attempting to garner a deeper level of understanding of the phenomenon. The development of research questions to test hypotheses surrounding the context, contributing factors, existing prevention strategies applicable to wrong surface events was only completed after repeated interactions with existing literature, event reports from the NTSB, and limited data and information from the FAA on the phenomenon. Recognizing the limitations that existed in this information, the methodology was adapted to a qualitative approach aimed at examining the phenomenon of wrong surface events in general how human error contributes to the event to suggest targeted prevention strategies.

According to Glesne (2016), "phenomenological research is an in-depth inquiry into a topic with a small number of homogenous participants" (p. 290) and examines the experience and perception of each participant to understand similarities and differences. This type of research is particularly important and applicable to examining human error in wrong surface events since the phenomenon itself occurs to pilots and can only be corrected by pilots after the detection of the error.

Human Error Background

Human error is commonly defined as intended actions which are not correctly executed (Isaac, 1999). Reason (2008) acknowledges that there is no universally accepted definition of human error but it's generally accepted "that it involves some type of deviation" (p. 29). Though Reason (2008) describes many different ways human error can be classified, examining the four basic elements of an error is often the most practical place to start. Those four elements are the intention, the action, the outcome, and the context (Reason, 2008). Errors occur in an error chain where a number of preconditions, hazards, latent conditions and unsafe acts occur in a sequence or chain, slipping through safeguards and ultimately lead to an accident (Dekker, 2002, 2006; Ebermann & Scheiderer, 2013; Reason, 1997, 2008; Wiegmann & Shappell, 2003).

Within complex sociotechnical systems, human error is the dominant contributor to accidents and safety compromising incidents (Dekker, 2006; Stanton et al., 2006). Research supports claims from Dekker (2006) and Stanton et al. (2006) within aviation specifically, where around 70% of all accidents are attributed to human error (Ebermann & Scheiderer, 2013; Isaac, 1999; Li et al., 2002; Wiegmann & Shappell, 2003).

Dekker (2002, 2006) challenges the idea of when human error is cited as a cause of an incident or accident, framing it as a theory of human error in which failures within complex systems are unexpected and due to inherently unreliable and erratic behavior from humans and that percentages fail to consider the complex interactions between humans and the systems they interface with. Instead, Dekker (2006) asserts that human error is not a cause of a failure, but rather an effect or symptom of deeper trouble and that it's "systematically connected to the features of people's tools, tasks, and operating environments" (p. 15). Examining human error and human error contribution under this framework fails to determine the context and root cause of the error that contributed to the actions and outcome of a given event (Dekker, 2006; Reason, 2008).

Effective human error research requires the careful assessment of the human actions and context surrounding a given event in order to understand the root cause, rather than attribute blame to a person rather than the person's interaction with a poorly designed system or method (Dekker, 2002, 2006; Reason, 2008). This view of human error attempts to account for human's retrospective, proximal, counterfactual, and judgmental reactions to failures to gain a deeper understanding of the human behavior within the context of the event (Dekker, 2002; Reason, 2008). Human error research should account for the "individual human's unique way of processing information" and "his or her attitudes, motivations, and cultural perspective" (Isaac, 1999, p. 14).

Analyzing and Predicting Human Error

Multiple different models exist for analyzing and predicting human error. The SHELL model exists to explain the relationship between Software, Hardware, Environment and Liveware (Ebermann & Scheiderer, 2013; Isaac, 1999). Software refers to the guidelines, procedures, and information necessary for the human to process. Hardware is the physical displays, systems, and controls that a human physically interacts with or manipulates. Environment refers to the natural environment the human is placed in, including the surroundings, geographic features, and climatic conditions. Liveware refers to the human beings involved. The two Ls in the SHELL naming convention refer to the Liveware-Liveware interactions that occur between two humans. The definitions are well agreed upon within human error research (Ebermann & Scheiderer, 2013; Isaac, 1999; Wiegmann & Shappell, 2003). The SHELL model's ideas and framework aid in the effective analysis of human error, as it allows for the inclusion of the context and perspective of the human involved to understand, rather than blame.

Stanton et al. (2006) developed a methodology specifically for assessing human error on the part of flight crews in the flight deck: the Human Error Template (HET). The HET methodology uses an external error mode taxonomy that was developed from a review of existing human error identification methods and an evaluation of incidences of design-induced pilot error (Stanton et al., 2006). This specific analysis applies and validates elements of the SHELL model to the examination of aviation human error. Stanton et al. (2006) found that multiple methods of human error prediction e.g., the use of multiple human error prediction tools, results in the most accurate method for predicting human error, supporting the idea that human error analysis is complex and should be done using multiple comprehensive methods.

Mitigating Human Error

Proposing a mitigation strategy to human error, by nature, implies a prediction that it will result in a certain effect on human behavior (Dekker, 2002). It's widely accepted that human error can't entirely be prevented, but rather reduced (Ebermann & Scheiderer, 2013; Isaac, 1999;

Reason, 2008). Mitigating human error is best accomplished by systems and organizations that are resilient through a wide variety of principles, policies, procedures, and practices (Reason, 2008). Strategies as they apply to aviation include new procedures, training, regulations, technology, managerial commitment. Specific practices to mitigate human error often involve the use of technology (both hardware and software) to detect and alert to certain conditions where errors are prevalent and training and education of operators to recognize dynamic risks and employ prevention strategies (Dekker, 2006; Ebermann & Scheiderer, 2013; Kirwan et al., 2005; Reason, 2008). In aviation specifically, active alerting human-machine interfaces are known to be effective in alerting pilots and air traffic controllers to hazards (Dekker, 2006; Ebermann & Scheiderer, 2013; Joslin, 2014; Lancaster et al., 2010; Reason, 1997; Schönefeld & Moller, 2012; Vernaleken et al., 2006, 2007).

Wrong Surface Events

Since wrong surface events occur when an aircraft lands or departs, or tries to land or depart, on the wrong runway or on a taxiway or when an aircraft lands at the wrong airport, they can be further broken down into (a) wrong surface departures, (b) attempted wrong surface departures, (c) wrong surface landings, (d) wrong surface approaches, and (e) wrong airport landings (Federal Aviation Administration, 2018d). While there is currently no regulatory requirement that pilots be trained on wrong surface events specifically, the FAA suggests multiple resources for training and education related to wrong surface events (Federal Aviation Administration, 2023b).

The FAA creates awareness tools through press releases, FAASafetyTeam (FAAST) Notices, and more recently, through videos published to YouTube about wrong surface operations or refenced in their video series *From the Flight Deck* where video clips are shown from the point of view of the pilot, overlaid with a voiceover discussion about the specific risks related to a certain airport or in general (Federal Aviation Administration, 2020a, 2021a, 2021b).

Wrong Surface Departures and Attempted Departures

The FAA describes that most commonly, wrong surface departures occur when a pilot departs the runway in the wrong direction, from a taxiway intersection (Federal Aviation Administration, 2020a). An event of this type occurred at Chicago O'Hare International Airport in 2022, where a Delta Airbus A220 cleared for takeoff on runway 10L mistakenly turned right onto the runway from an intersection taxiway instead of left and lined up for 28R. The tower controller who issued the takeoff clearance notice the crew's error and corrected them, allowing them to turn around on the runway and depart in the correct direction (Georgilidakis, 2022; You can see ATC, 2022). Another common wrong surface departure event occurs in intersecting runway configurations when the runways intersect near the threshold and the pilot lines up with the wrong runway entirely (Federal Aviation Administration, 2007; National Transportation Safety Board, 2007). Distractions, communication errors between pilots and air traffic controllers, and misinterpreting runway signs have all been factors attributed to wrong surface departures (Federal Aviation Administration, 2020a).

According to the FAA (2020a), risks associated with wrong surface departures are traffic conflicts with aircraft on approach, aircraft holding in position for departure, or aircraft on a different runway, resulting in a near-miss or collision. Additionally, the departing aircraft may have insufficient runway remaining to get airborne (Federal Aviation Administration, 2020a). The FAA (2020a) explains that feeling rushed, lack of preparation when reaching the hold-short line, and the lack of visual cues, which may be during times with decreased traffic where other aircraft operating in the correct direction all may contribute to the occurrence of a wrong direction intersection takeoff.

The FAA (2020a) has provided several recommendations to prevent wrong surface departures, which include but are not limited to:

- setting the heading bug or course needle to the assigned runway heading prior to taxi;
- conducting checklist items and planning when stationary;
- ensure that pre-takeoff checklist items are complete prior to reaching the hold-short point;
- be ready for departure prior to contacting the tower;
- eliminate distractions to clearly understand the takeoff clearance issued by the tower;
- actively listen;
- do not confuse instructions for turns after departure with a turn on the runway;
- ensure readbacks of takeoff clearances include the intersection the pilot is located at;
- understand runway signage such that the location of the runway number corresponds with the location of the runway threshold (an intersection sign displaying “18L-36R” indicates the runway 18L threshold is to the left and turning right onto the runway would line up with 18L);
- check for traffic;
- check the directional gyro or course needle *and* wet compass prior to takeoff to verify the correct alignment; and
- ask ATC to clarify if there is any doubt.

Wrong Surface Landings and Approaches

As of 2018, wrong surface landings were occurring at a rate of approximately one every other day (Federal Aviation Administration, 2018b). Wrong surface landings and approaches have occurred even after the pilot has readback the correct runway (Federal Aviation Administration, 2021a). In 80% of wrong surface landings, the pilot has readback the correct runway but still landed on the wrong surface (Federal Aviation Administration, 2018a)

The FAA (2018b) states that airport geometry (i.e. the layout of runways and taxiways at an airport) is a common precursor to wrong surface landings and that “parallel or offset parallel runway configurations contribute to more wrong surface landings than any other configuration” (Federal Aviation Administration, 2018b). Furthermore, airport configurations in which one parallel runway is larger than the other and runways that are closely spaced together have been noted as causal factors (Federal Aviation Administration, 2021a). According to the FAA (2018a), parallel runways account for 75% of all wrong surface landings and parallel runways with offset thresholds account for 50% of all wrong surface landings. The FAA suggests that airport geometric factors (i.e., airport design) plays a role in the prevalence of these events (Federal Aviation Administration, 2021a). In other cases, parallel full-length taxiways can also be mistaken for runways, as in the case of Air Canada 759 (Federal Aviation Administration, 2021a; National Transportation Safety Board, 2018).

The FAA believes the cause of these events may be a perception error, that the pilot lines up for the first runway that they see, the first runway they see, or the closest runway, mistaking it as the intended landing runway (Federal Aviation Administration, 2021a). Additionally, the FAA states that pilots may experience expectation bias at airports which they are based out of or frequently fly into when they are cleared to land or for an approach to a runway other than the runway they expect (Federal Aviation Administration, 2021a). This claim is supported by the NTSB's (2018) findings in the Taxiway Overflight of Air Canada 759.

Wrong surface events occur on different surfaces that are not intended for landing such as a parallel taxiway, and even a nearby road or nearby airport with a similar runway configuration (Federal Aviation Administration, 2021a).

In addition to airport geometry, the FAA attributes wrong surface approaches and landings to confusion after a change in runway assignment or expectation bias among locally based pilots who are accustomed to landing on the same runway repeatedly (Federal Aviation Administration, 2021a). The appearance of pavement material (i.e., concrete versus asphalt) can also contribute to pilot confusion and misidentification of the landing surface (Federal Aviation Administration, 2021a).

FAA (Federal Aviation Administration, 2018a) recommendations for preventing wrong surface landings and approaches includes:

- use onboard navigation aids such as the localizer, ILS, or GPS to verify alignment;
- know what runway lights and approach light are on the runway a pilot might encounter;
- if the runways have visual glide path information know which side the VASI or PAPI is located;
- always include callsign and assigned landing runway when reading back a landing clearance;
- actively listen (i.e., hear and clearly understand the actual runway on which the controller has cleared the pilot to land);
- avoid distractions; and

- always have an airfield diagram out for reference.

Wrong Airport Landings

Wrong airport landings have been classified by the FAA as a form of wrong surface event (Federal Aviation Administration, 2021b). The FAA (2021b) states that wrong airport landings occur among pilots operating under both Visual Flight Rules (VFR) and Instrument Flight Rules (IFR). Large metro areas often have several airports in close proximity to each other with similarly numbered or aligned runways due to the consistent prevailing wind across the region. Similarly, airports located along the final approach course on an instrument approach procedure have been mistaken as the airport of intended landing.

The FAA (2021b) has found that complex airspace, frequency congestion, distractions, and lack of familiarity with the area can lead a pilot to lose situational awareness and mistakenly land or make an approach to the wrong airport. The outcome of a wrong airport landing can be severe, including a pilot landing on a shorter than expected runway, a possible conflict or collision between aircraft operating at the airport or in surrounding airspace.

Antuano and Mohler (1988) describe and examine pilot error resulting in wrong airport landings saying “when a crew errs and performs an approach to the wrong airport, whether or not a landing is actually made, the crew has experienced ‘geographic disorientation’” (p. 1). The authors classify this type of wrong surface event as the context that causes error that caused it, rather than as a wrong airport landing, as the term wrong surface event was not used at the time. The errors described by Antuano and Mohler (1988) are among some of the same that the FAA has identified and described in recent educational videos and press releases (Federal Aviation Administration, 2021b). Antuano and Mohler (1988) identified thirty four examples of wrong airport wrong surface approaches and wrong surface landings in twenty years leading up to 1988, in data and factual information about the flights including intending destination and actual airport of landing, aircraft type, pilot age, pilot certification level, total flight time, total flight time in type, prevailing weather conditions, and runway dimensions. Antuano and Mohler (1988) establish the prevalence and awareness of wrong surface approaches and wrong surface landings as far back as 1966 as indiscriminate of pilot skill, aircraft type, location, weather conditions, and limited airport geometry. Jin and Lo (2017) also found no correlation between wrong airport landings and pilot age or experience.

FAA (2021b) recommendations include for prevention of wrong airport landings include but are not limited to:

- checking the sectional chart for airports in close proximity, paying close attention to runway configurations;
- note geographical features such as the proximity to the city or town, or nearby rivers, highways, or visual reporting points in the context of the expected visual perspective;
- check airport diagrams;
- be familiar with the airport's layout and relationship to other ground features such as taxiway and buildings and the orientation to the final approach course;
- understand runway lighting, approach lighting, and visual glideslope indicators;
- use the most precise navigational aids available, such as GPS, localizers, and VOR radials;
- do not make assumptions based on what can be observed outside;
- use all available tools to assist in identifying the correct airport;
- maintain vigilance when landing at airports at night or in close proximity;

- confirm the geographical features identified in preflight match the expected visual picture;
- do not report the airport in sight or decide the airport identified is the correct airport unless certain that the correct airport has been identified.

The FAA suggests that if an air traffic controller uses the phraseology "Not in sight, runway (##) cleared to land," (Federal Aviation Administration, 2021b, 4:06) that the pilot may be at the wrong airport.

Runway Incursions

The FAA defines a runway incursion as "any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle, or person on the protected area of a surface designated for the landing and take off of aircraft" (Federal Aviation Administration, 2020b, Runway Incursions section). The FAA classifies the cause runway incursions by type and severity. The type of runway incursion event is classified as either a Pilot Deviation, an Operational Error, or a Vehicle/Pedestrian Deviation. The severity is classified as Category A through D, Category A being the most severe. Standard classifications of event type and severity make research on runway incursions more effective. An international standard definition of runway incursions, and defined boundaries of runway safety areas allow for more effective research as well.

Runway incursions have been heavily researched, including systems designed to alert pilots and air traffic controllers. Existing bodies of research have focused on runway incursion prevention, developing theories of runway incursions based on existing ICAO definitions, and discussing and assessing the efficacy of existing runway incursions prevention systems (Cardosi, 2001; Schönefeld & Moller, 2012; Young & Jones, 2001).

Cardosi (2001) examined reports from the FAA, NTSB, and human error of air traffic controllers and pilots in runway incursion events and found that "controller errors were predominately attributable to a lapse in controller memory, an error in judgment of separation, failure to ensure that the runway was clear, and inadequate coordination between controllers" (Abstract section). While pilot data lacked objectivity, "pilot errors were subjectively attributed to inadequate airport signage and markings and errors in communication between pilots and controllers" (Cardosi, 2001, Abstract section). Schönefeld and Moller (2012) similarly stated that reducing operational errors by air traffic controllers can be achieved by removing humans from the loop as much as possible, however, this is not entirely practical or feasible in the current state of aviation.

Airport Signage and Markings

Airport Signage and Markings are mandated in Title 14 of US Code of Federal Regulations, Part 139. Requirements are detailed in Advisory Circulars 150/5340-1, *Standards for Airport Markings,* and 150/5340-18 *Standards for Airport Sign Systems*. This creates a uniform way of marking and lighting various surfaces at a commercial service airport including runways and taxiways, improving safety and efficiency (Federal Aviation Administration, 2022c). It's generally accepted that airport signage and marking are intended to create a consistent means for wayfinding around an airfield and designed to enhance pilot's situational awareness to prevent runway incursions and other surface safety incidents.

Airport Geometry

Research has established that airport geometry has an effect on surface events at airports but has been limited primarily to surface runway incursions. Johnson et al. (2016) examined the

30 busiest airports in the US with intersecting runways and the 30 busiest airports in the US without intersecting runways Johnson et al. (2016), “found a significant difference between the proportion of incursions per 100,000 operations for airports with intersecting runways” (p. 19) and those without. Researchers analyzed the 36 busiest airports by enplanements for five additional variables related to airport geometry in statistical models: the number of runway intersections per runway, the number of crossing-taxiway intersections per runway, the number of highspeed taxiway intersections per runway, the number of right-angle taxiway intersections per runway, and the number of runways (Johnson et al., 2016). Johnson (2016) found that the number of runway incursions per 100,000 operations is greater at airports with intersecting runways than at airports without intersecting runways. Johnson et al. (2016) recommends further research be done with larger sample sizes of US and international airports, other geometric factors such as distance between intersections, width of taxiways, or airport hotspots. The FAA has developed procedural and separation standards based on airport geometric factors like distance between centerlines for aircraft conducting simultaneous dependent and simultaneous independent approaches (Federal Aviation Administration, 2022d). The airport geometric variables in Johnson et al.’s (2016) research are limited in applicability to wrong surface events as intersecting surfaces have not been identified or described as being a factor in wrong surface events as if focuses on specific airport geometric factors in runway incursions only. These airport geometric factors differ from the factors identified by the FAA (Federal Aviation Administration, 2018a, 2018b, 2018d, 2020a, 2021a, 2021b) in wrong surface events suggesting that runway incursion literature may be largely inapplicable to wrong surface events.

Parallel Runways.

Airport capacity in any airspace system is limited by the use of available runways (Berge et al., 2006). Numerous bodies of research exist around the construction, use, and improvement in safety and efficiency as it relates to parallel runways and the redesign and construction of parallel runways at major airport in the United States. Researchers note that parallel runways are being constructed at new and existing hub airports (Liang et al., 2018). Liang (2018) further explains that the construction and use of multiple runways provides for increased capacity, the largest increase being with parallel runways. This is supported by Bazargan et al. (2002), who found that a parallel runway configuration offered the maximum increase capacity over diagonal runway configurations in a study on the simulated expansion of Philadelphia International Airport. It could be theorized that these new parallel runways may have inadvertently contributed to an increase in wrong surface events, especially if there are multiple parallel runways requiring different numbering (e.g., 18L, 18R, 17L, 17R) although research has not established that.

Surface Safety Systems

Schönefeld and Moller's (2012) review of surface safety systems provides background on the existing technology meant to prevent runway incursions by enhancing situational awareness of either pilots or air traffic controllers. The authors define runway incursion avoidance as "the ability of a flight crew to avoid inadvertently entering an active runway" (Schönefeld & Moller, 2012, p. 35). Schönefeld and Moller (2012) assert that and current studies on this topic agree that "situational awareness is a key to runway incursion avoidance and the safe handling of runway incursions" (p. 35). This claim is supported by Young and Jones (2001).

Flight Deck-Based Systems

Numerous flight deck-based technologies exist to aid in alerting pilots of surface safety incidents like runway incursions. One such technology, known as Enhanced Traffic Situational Awareness on the Surface with Indications and Alerts (SURF-IA), attempts to mitigate runway incursions with a display in the flight deck meant to enhance pilots' situational awareness (Joslin, 2014). The system functions by predicting conflicts by comparing the aircraft's speed and track to traffic data fed to it by ADS-B (Joslin, 2014; Lancaster et al., 2010). Alerts are issued if the predicted time to conflict falls below a certain time parameter, in most cases approximately 30 seconds for a caution alert and 15 seconds for a warning alert (Joslin, 2014; Lancaster et al., 2010). Flight deck-based surface movement and surface safety systems function in similar ways, tracking the aircraft's movement and using predictive safety logic to detect and alert to potential conflicts between aircraft (Joslin, 2014; Lancaster et al., 2010; Vernaleken et al., 2006, 2007).

Joslin (2014) researched the efficacy of SURF-IA alerting using previously existing metrics and classification systems to determine the impact of the new technology on existing severity classifications. In the article, Joslin (2014) specifically researched "the effectiveness and benefits of the SURF-IA model for providing alerts to reduce the occurrence of PD (pilot deviation) type serious (Category A or B) runway incursion incidents" (p. 3). Two raters examined video reenactments of Category A and B runway incursions and determined whether or not SURF-IA alerting would have been triggered based on the design specifications and standards of the technology (Joslin, 2014). While the study determined SURF-IA would be effective at detecting and alerting to approximately two thirds of serious runway incursions, the raters determined that the remaining one third of incidents examined alerts would not trigger an alert (Joslin, 2014).

Notably, one such case is that the technology would not alert to a situation in which a single aircraft departed from the wrong runway, establishing that as of 2014, some technology would not detect and alert to an attempted wrong surface departure (Joslin, 2014). It can be assumed that similar alerting technology did not exist to alert to wrong surface departures, attempted wrong surface departures and many other wrong surface events. These assumptions are supported by several NTSB Incident and Accident reports examined later in this thesis (National Transportation Safety Board, 2007, 2010, 2017, 2018).

At the time of Joslin's (2014) research, SURF-IA was not yet certified for use on aircraft. Flight deck based alerting technologies have been found to facilitate faster conflict detection and decision making during certain runway incursion scenarios, but system design parameters suppress alerts in other cases (Lancaster et al., 2010). Most research done on flight deck-based detection and alerting systems such as only applies to runway incursions although these technologies have been improved, applied, and adapted to alert to a misalignment with a runway or taxiway both in the air and on the ground (Joslin, 2014; Lancaster et al., 2010; National Transportation Safety Board, 2018; Vernaleken et al., 2006, 2007).

Air Traffic Control Tower-Based Systems

Tools available to enhance situational awareness include Surface Movement Ground Radar (SMGR), a generic term for a system installed in many air traffic control towers and utilized by air traffic controllers to enhance situational awareness of aircraft and vehicles moving on the ground (Schönefeld & Moller, 2012). SMGR displays a map of the airport and tracks moving targets on the surface of that airport. In many cases SMGR systems have advanced safety logic software to predict possible surface incidents and alert air traffic controllers in the tower cab. This is intended to prevent surface incidents that result from operational errors and assist in the detection and prevent of surface incidents that result from pilot deviations (Landry et al., 2013; Schönefeld & Moller, 2012) Generally, SMGR is fed from several sources of data including surface movement radar, airport surveillance radar, multilateration, Mode S radar, and ADS-B (Schönefeld & Moller, 2012). These systems are particularly advantageous in low visibility weather conditions and at night, where aircraft and vehicles may be harder to see (Schönefeld & Moller, 2012). Despite the increasing use in automation such as ASDE-X and ASSC, these systems are not expected to completely resolve runway incursions (Ludwig, 2007). SMGR systems only provide conflict detection and alerts, not conflict resolution (Vaddi et al., 2011). Research on conflict resolution capabilities has limited effectiveness. Vaddi et al. (2011) examined SMGR systems for conflict resolution but only to reduce conflicts on taxiways and runways by slowing or stopping aircraft, cancelling clearances, replanning aircraft movements, and issuing advisories. This differs from conflict alerts since the SMGR is providing predictive metering of aircraft movements, rather than alerting to an imminent hazard that requires immediate action to resolve.

ASDE-X and ASSC

ASDE-X is the primary SMGR system in the United States and is installed at 35 air traffic control towers throughout the country, shown in Table 1 (Federal Aviation Administration, 2022c). The system was developed to reduce category A and B runway incursions (Federal Aviation Administration, 2022b). ASSC is a similar system with more advanced features and functionality (Federal Aviation Administration, 2021d). A total of 43

ATCT facilities were equipped with ASDE-X or ASSC and as of October 2022, 41 of those facilities had received the Taxiway Arrival Predication Enhancement (see Table 1). As of January 2023, ASSC is operational at 8 airports in the United States with plans to install a new system at Joint Base Andrews (ADW) (Federal Aviation Administration, 2023a). Of the 43 ATCT's equipped with ASDE-X or ASSC, 29 are known as Core 30 Airports. According the US Department of Transportation Office of Inspector General (2014), the FAA defines Core 30 airports as the 29 large hub airports and Memphis International Airport and to have the most air traffic. The only Core 30 ATCT without an ASDE-X or ASSC is Tampa International Airport (TPA). All ATCT's with ASDE-X or ASSC, including the remaining 14 ATCTs, are ASPM-77 airports, a subset of airports the FAA uses for air traffic management operational and performance tracking. ATCT facilities with these SMGR systems tend to be the busiest airports in the NAS.

Table 1

List of FAA ATCTs Equipped with ASDE-X or ASSC

FAA Facility Code	ASDE-X or ASSC	Equipped with Taxiway Arrival Prediction
ATL*	ASDE-X	Yes
ANC	ASSC	Yes
BDL	ASDE-X	Yes
BOS*	ASDE-X	Yes
BWI*	ASDE-X	Yes
CLE	ASSC	Yes
CLT*	ASDE-X	Yes
CVG	ASSC	Yes
DCA*	ASDE-X	Yes
DEN*	ASDE-X	Yes
DFW*	ASDE-X	Yes
DTW*	ASDE-X	Yes
EWR*	ASDE-X	No
FLL*	ASDE-X	Yes
HNL*	ASDE-X	Yes
HOU	ASDE-X	Yes
IAD*	ASDE-X	Yes
IAH*	ASDE-X	Yes
JFK*	ASDE-X	Yes
LAS*	ASDE-X	Yes
LAX*	ASDE-X	Yes
LGA*	ASDE-X	Yes
MCI	ASSC	Yes
MCO*	ASDE-X	Yes
MDW*	ASDE-X	Yes
MEM*	ASDE-X	Yes
MIA*	ASDE-X	Yes
MKE	ASDE-X	Yes
MSP*	ASDE-X	Yes
MSY	ASSC	Yes
ORD*	ASDE-X	Yes
PDX	ASSC	Yes
PHL*	ASDE-X	Yes
PHX*	ASDE-X	Yes
PIT	ASSC	Yes
PVD	ASDE-X	Yes
SAN*	ASDE-X	Yes
SDF	ASDE-X	Yes
SEA*	ASDE-X	Yes

FAA Facility Code	ASDE-X or ASSC	Equipped with Taxiway Arrival Prediction
SFO*	ASSC	Yes
SLC*	ASDE-X	Yes
SNA	ASDE-X	No
STL	ASDE-X	Yes

Note. *Denotes Core 30 Airport. Adapted from "FOIA 2022-06437 Response Part 1 of 3, Part 2 of 3 and Part 3 of 3" by Shelia Walters 2022, "Airport Surface Detection Equipment, Model X (ASDE-X)" by the Federal Aviation Administration, 2022, and "ADS-B Airport Surface Surveillance Capability (ASSC)" by the Federal Aviation Administration, 2023. In the public domain.

When ASDE-X was developed, it utilized safety logic software that was initially only designed for "surface trajectory prediction based conflict detection and resolution" (Landry et al., 2013, Introduction section). The FAA (2018d) asserts that ASDE-X is one of the most important runway-safety technologies. ASDE-X enables air traffic controllers to detect potential runway conflicts by providing detailed coverage of movement on runways and taxiways. At some US airports, ASDE-X safety logic data is processed and used to control additional situational awareness tools such as Runway Status Lights (RWSL), which illuminate in specific places and patterns to indicate the imminent presence of an aircraft or vehicle crossing a runway to an aircraft in the takeoff position or on final approach based on predictions from the safety logic system (Federal Aviation Administration, 2022; Schönefeld & Moller, 2012). RWSLs also illuminate to indicate the presence of an aircraft immediately on final approach or on takeoff roll to aircraft or vehicles at hold points along the runway (Schönefeld & Moller, 2012). RWSLs serve as a situational awareness tool for pilots and vehicle operators and cannot be manually controlled by air traffic controllers.

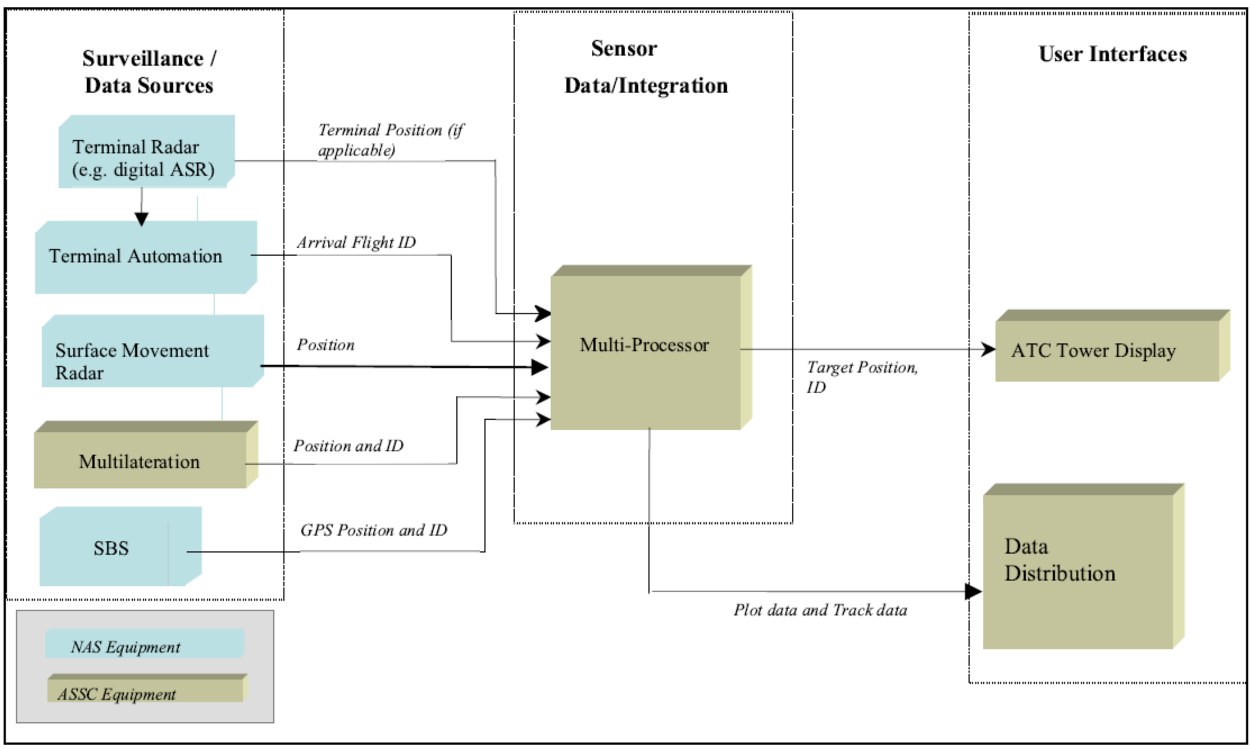
Technology that has been developed for the prevention of runway incursions has allowed for cross-compatibility in the prevention of wrong surface events as well. In September 2017 the FAA began assessing an updated software feature of the ASDE-X's safety logic system intended to detect and alert air traffic controllers when aircraft are lined up for taxiways called Taxiway Arrival Prediction (Federal Aviation Administration, 2018d). Prior to the development of this update ASDE-X's safety logic programming only issued alerts when parameters included a runway in a potential conflict and had to ensure the update did not degrade the system's ability to issue runway alerts (Federal Aviation Administration, 2018d). The FAA performed live flight checks of the Taxiway Arrival Prediction enhancement in various scenarios to ensure it alerted properly and did not produce false alerts such as when an aircraft turns later than expected onto the final approach course. The FAA stated that the system functioned as intended and as of 2018 planned on assessing all ASDE-X and ASSC systems for their viability to review the enhancement (Federal Aviation Administration, 2018d).

ASSC Specifications

The National Airspace System Subsystem Level Specification for Surveillance Broadcast Services Program: Airport Surface Surveillance Capability was obtained through a Freedom of Information Act Request. It details the Airport Surface Surveillance Capability System's performance requirements including (a) multilaterating on transponder equipped aircraft and vehicles, (b) interfacing with Surveillance Broadcast Services (SBS) for ADS-B services for both UAT (Universal Access Transceiver) and 1090-ES data links, (c) providing visual and aural warnings to alert controllers of potential runway collisions, and (d) display/process SBS-only targets without multilateration, (e) providing data to other NAS systems such as Runway Status Lights System; (f) distributing data to non-NAS users. Additional site specific options are (a) the capability for monitoring closely spaced parallel approaches by providing an additional interface to STARS configured to provide multilaterated data, (b) the capability to track targets without any SBS support, and (c) the capability to track targets using only SBS support. Figure 1 shows how these subsystems interface with each other (Federal Aviation Administration, 2021d). This document contains key information on how ASSC functions and provides insight into how ASDE-X similarly functions.

Figure 1

ASSC Functional Diagram



Note. From "National Airspace System Subsystem Level Specification for Surveillance Broadcast Services Program: Airport Surface Surveillance Capability," by the Federal Aviation Administration, 2021. In the public domain.

The ASSC system utilizes safety logic processing to detect and notify air traffic controllers of a number of potential collision scenarios performs safety logic updates once per second, meaning that the system is capable of issuing safety logic alerts on the display system to air traffic controllers every second. A safety logic alert issues an aural and visual warning on the ATC Tower Display when one of the collision situations in Table 2 is detected.

When an ASDE-X or ASSC system generates a safety logic alert, air traffic controllers are required to visually assess the situation an information presented on the ASDE-X or ASSC display then take one of the following actions under the given condition: (a) When an arrival aircraft (still airborne, prior to the landing threshold) activates a warning alert, the controller must issue go–around instructions. (Exception: Alerts involving known formation flights, as they cross the landing threshold, may be disregarded if all other factors are acceptable.), (b) When an arrival aircraft activates a warning alert to a taxiway, the controller must issue go–around instructions, (c) When two arrival aircraft, or an arrival aircraft and a departing aircraft activate an alert, the controller will issue go–around instructions or take appropriate action to ensure intersecting runway separation is maintained, (d) For other safety logic system alerts, issue instructions/clearances based on good judgment and evaluation of the situation at hand (Federal Aviation Administration, 2022d).

Table 2

ASSC Safety Alert Logic Collision Situations

Group I Critical Collision Situations	
Arrival chasing a departure	Lander chasing a lander
Arrival chasing a lander	Lander chasing a taxi
Arrival chasing a taxi	Lander head-on taxi
Arrival chasing departure abort	Lander with a stopped (track of) target
Arrival head-on departure	Arrival head on-abort
Arrival head-on lander	Departure chasing abort
Arrival head-on taxi	Departure head-on abort
Arrival on closed surface	Lander chasing abort
Arrival with a stopped (track of) target	Lander head-on abort
Departure chasing a departure	Departure converging with a taxiway taxi
Departure chasing a taxi	Arrival converging with a taxiway taxi
Departure head-on departure	Lander converging with a taxiway taxi
Departure head-on lander	Departure on a closed runway
Departure head-on taxi	Lander on a closed runway
Departure with a stopped (track of) target	Arrival to a taxiway
Lander chasing a departure	Lander to a taxiway

Group II Essential Collision Situations	
Arrival vs arrival on intersecting taxiway	Departure vs departure on intersecting runway
Arrival vs departure abort on intersecting runway	Departure vs departure abort on intersecting runway
Arrival vs departure on intersection runway	Departure vs lander on intersecting runway
Arrival vs lander on intersecting runway	Lander vs lander on intersecting runway
Arrival vs taxi on intersecting runway	Lander vs abort on intersecting runway
Departure vs taxi on intersecting runway	Lander vs taxi on intersecting runway

Note. Adapted from "National Airspace System Subsystem Level Specification for Surveillance Broadcast Services Program: Airport Surface Surveillance Capability," by the Federal Aviation Administration, 2021. In the public domain.

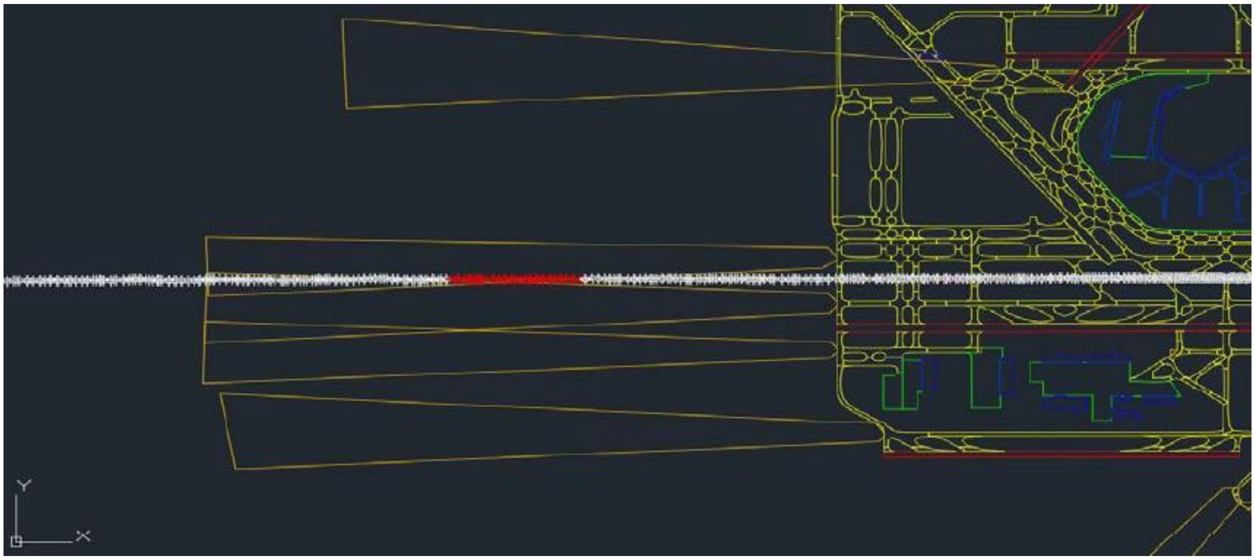
Taxiway Arrival Prediction System Reports

Prior to installation of the Taxiway Arrival Prediction Enhancement, each facility had to have alert polygons drawn into the software to create alert areas at each applicable taxiway. The FAA required simulation based testing of the system at each facility it to ensure the ASDE-X or ASSC system effectively alerted without generating nuisance alerts (Federal Aviation Administration, 2018c, 2019, 2021c, 2022a). These reports were obtained for all applicable airports listed in Table 1 through a FOIA request. Generally the simulation based testing involved running radar recordings of 30 days of traffic at that particular airport to ensure the alert polygons did not produce false alerts, although some testing used longer timeframes. In some cases this meant that seasonal weather factors affected takeoff and landing directions an airport, thereby impacting runway usage (Federal Aviation Administration, 2018e).

FAA Technical Operations would then assess the data for any alerts that the software would have issued to determine if the alert was a nuisance or false alert and if any action should be taken to either adjust the given taxiway arrival region (see Figures 2 and 3) or add an aircraft type to a filter list. This was most common in cases where helicopters were involved and were landing on taxiway intentionally or making an approach to land in a manner that a fixed wing aircraft couldn't (see Figure 4) (Federal Aviation Administration, 2021c).

Figure 2

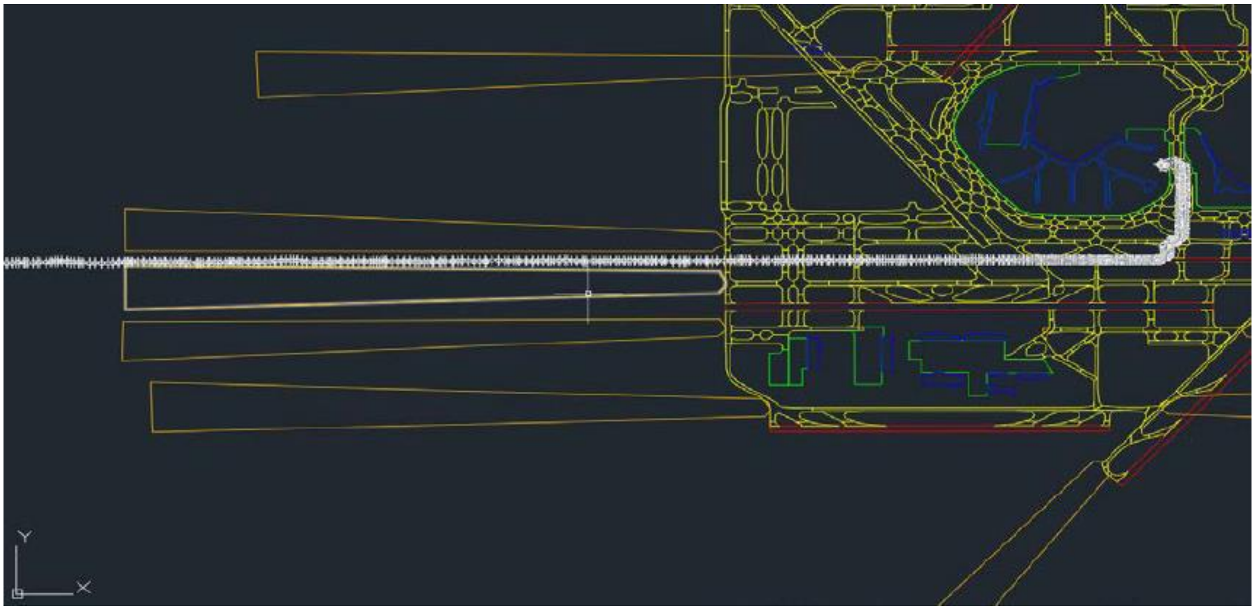
ASDE-X Nuisance Alert at ORD



Note. Aircraft's flight path in white generated a false alert (in red) to Taxiway Arrival Region for N in orange at ORD. The aircraft was not line up with taxiway N and landed safely on runway 10L. Obtained from a FIOA Request. From "ASDE-X Taxiway Arrival Prediction: Implementation at Chicago O'Hare International Airport," by the Federal Aviation Administration, 2019. In the public domain.

Figure 3

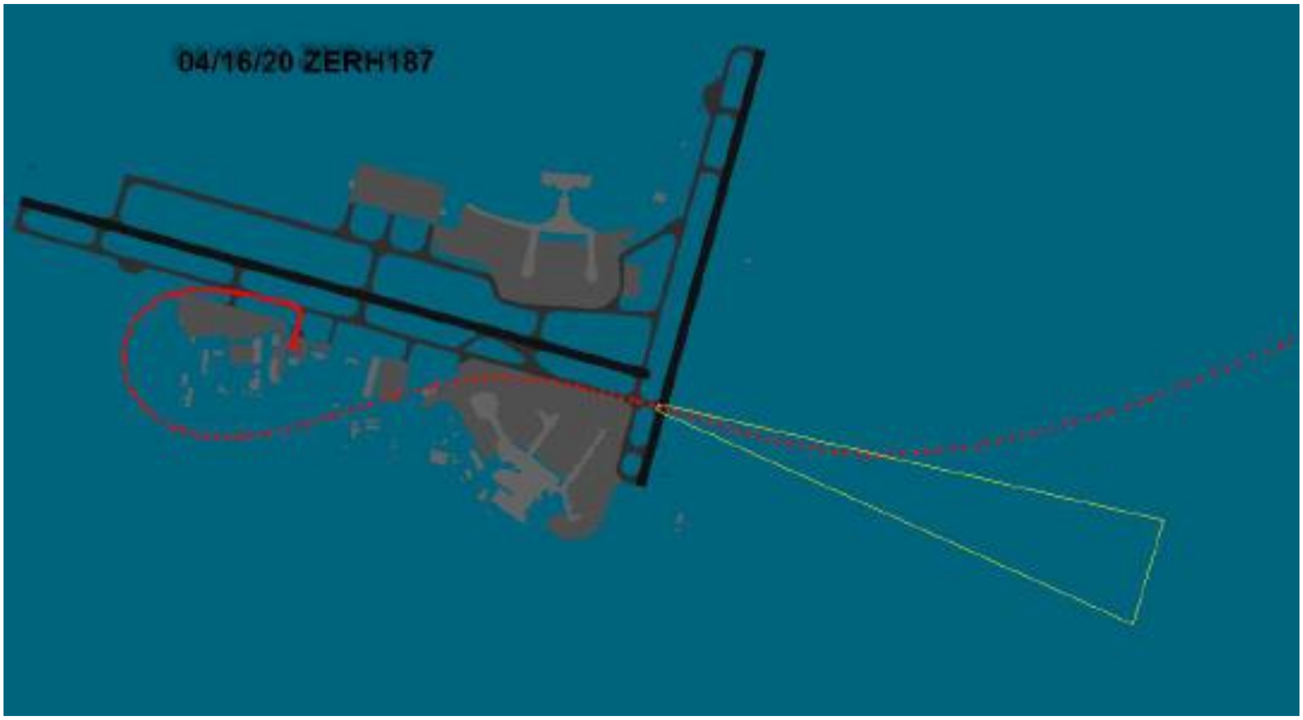
ASDE-X Nuisance Alert Resolution by Adjusting Taxiway Arrival Region



Note. This is the same aircraft and flightpath as in Figure 2. Adjusting the Taxiway Arrival Region for Taxiway N in orange (second from the top) at ORD by trimming the bottom (south side) of the region resolved the nuisance alert. From "ASDE-X Taxiway Arrival Prediction: Implementation at Chicago O'Hare International Airport," by the Federal Aviation Administration, 2019. In the public domain.

Figure 4

Helicopter Making an Approach to Land at Louis Armstrong International Airport



Note. Helicopter circling to land generated a false Taxiway Arrival Prediction alert to taxiway E at MSY. The alert was resolved by adding a helicopter aircraft type filter to the ASSC system's filter list. Obtained via FOIA request. From "ASSC Taxiway Arrival Predictions: Implementation at Louis Armstrong International Airport," by the Federal Aviation Administration, 2021. In the public domain.

Following the simulation testing, the software enhancement was installed on site at the air traffic control tower with the alerting function disabled so as not to interrupt traffic while the system was still being assessed. The enhancement was then assessed post-installation, generally for a period of at least 30 days. Some reports provided by the FAA did not include post-installation reports. One example of this was the ASDE-X Taxiway Arrival Prediction Report from Houston-George Bush Intercontinental Airport (IAH), dated September 10^{th}, 2019, with the report stating that the on-site installation would occur two weeks later on September 24^{th}. It is unclear why this report did not contain post-installation assessment of the upgrade despite it being completed two years before the report was obtained through the FOIA request (Federal Aviation Administration, 2019). This resulted in incomplete records when reviewing these reports.

As of October 2021, the FAA's Press Office reported that the Taxiway Arrival Prediction had resulted in more than 20 saves in which a wrong surface landing on a taxiway was detected, an alert was issued, and the event was prevented (E. Ngai, personal communication, October 26, 2021).

Accident and Incident Reports of Wrong Surface Events

Four accident and incident reports involving wrong surface events were collected and reviewed involving different types of wrong surface events. These event reports from the National Transportation Safety Board were reviewed in detail as part of this literature review and later used to answer Research Question 1. These include the accident report of Comair 5191, and the incident reports of Delta 60, Delta 2845, and Air Canada 759. A review and analysis of incident and accident reports is important to understanding the details of different types of wrong surface events.

Comair 5191

On August 27^{th}, 2006, at approximately 6:06 AM Eastern Daylight Time, a Bombardier CL-600-2B19 commercial regional jet operating Comair Flight 5191 mistakenly lined up and attempted to depart from runway 26 instead of runway 22 at Lexington/Blue Grass Airport

(LEX) in Lexington, Kentucky. The aircraft crashed attempting to take off and was destroyed from impact forces and the post-crash fire. The accident resulted in the fatalities of all 47 passengers, the captain, and flight attendant. The first officer was the only person on board who survived the crash but sustained serious traumatic injuries. Night visual meteorological conditions prevailed at the time of the accident (National Transportation Safety Board, 2007).

The cockpit voice recorder of the accident aircraft began recording at 5:36 AM Eastern Daylight Time, when the two pilot crew were conducting standard preflight preparations. Prior to taxiing, the crew briefed a departure from runway 22 and information from the flight data recorder indicated the heading bug had been set to 227°, corresponding to the magnetic heading of runway 22. The flight crew acknowledged the taxi instructions issued by the controller and began taxing from the ramp down taxiway A (see Figure 5). During the taxi, the NTSB (2007) notes that the crew began having a conversation not pertinent to the safety of flight, during which time two other aircraft depart runway 22 without incident. As Comair 5191 began its takeoff roll, the crew can be heard on the cockpit voice recorder mentioning the lack of runway lights. The crew had a discussion during the takeoff briefing about the runway end identifier lights to runway 4/22 being out of service, with the first officer mentioning other lights being out of service around the airfield when he had arrived at LEX in an inbound flight.

Airport Geometry.

At the time, runway 22 was 7,003 feet long and 150 feet wide and was equipped with high intensity runway lights. Runway 26 was 3,501 feet long with a usable width of 75 feet due to deteriorating pavement conditions on the runway edge (National Transportation Safety Board, 2007). The layout of the airport at the time of the accident is depicted in Figure 5.

Figure 5

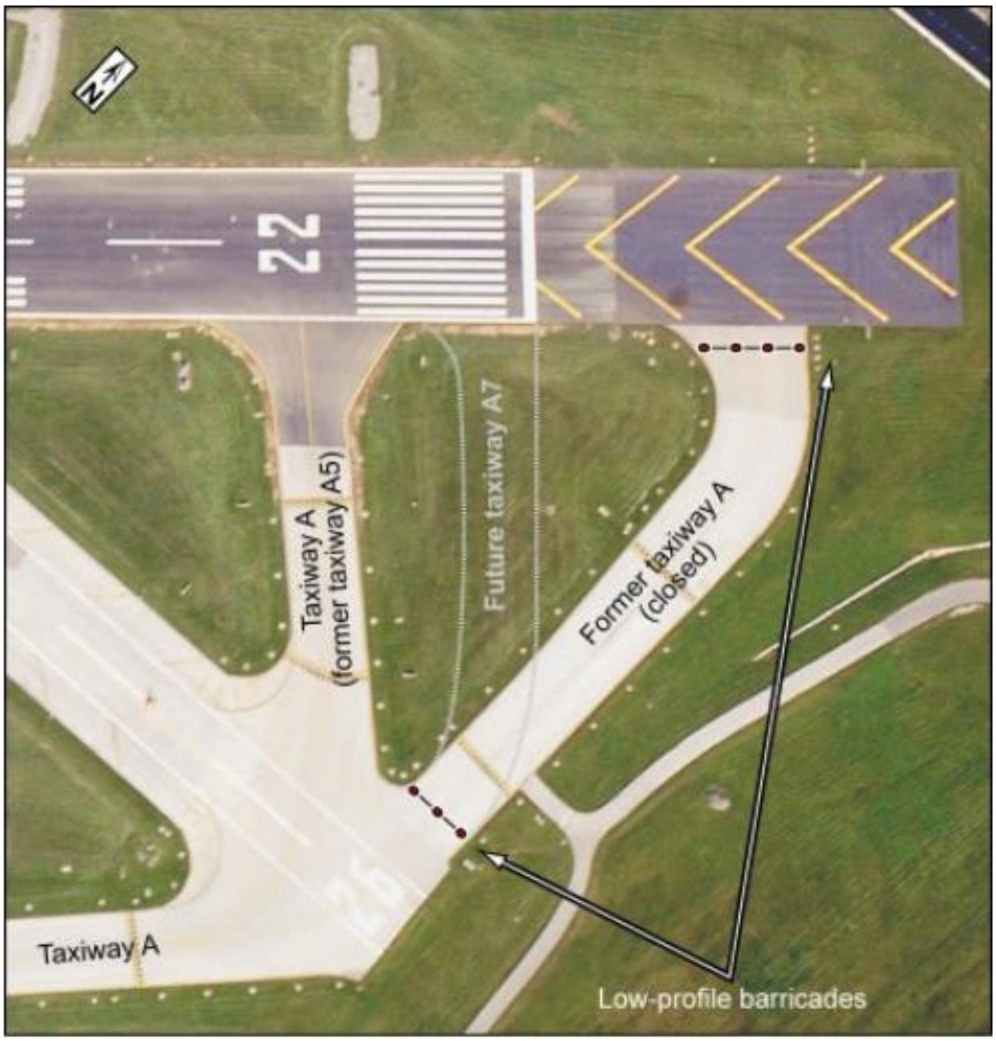
Lexington/Blue Grass Airport Layout

Note. Image provided to the NTSB by the Lexington, Kentucky Police Department showing the airport layout at the time of the accident. From "Attempted Takeoff From Wrong Runway Comair Flight 5191," by National Transportation Safety Board, (https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR0705.pdf#search=ComAir%205191) In the public domain.

The taxiways near the runway 22 and 26 thresholds were undergoing a multiyear construction project that involved the planned demolition of taxiway A in Figure 6 (labeled A7 in Figure 7). As a result, taxiway A was closed and marked with low profile barricades. Figure 7 shows the airport diagram available from the FAA at the time of the accident, which notably does not accurately reflect the layout of the airport seen in Figure 5. LEX's runway 22 and taxiways, including all construction, were in compliance with Title 14 CFR Part 139 standards required for airports conducting air carrier operations at the time of the incident.

Figure 6

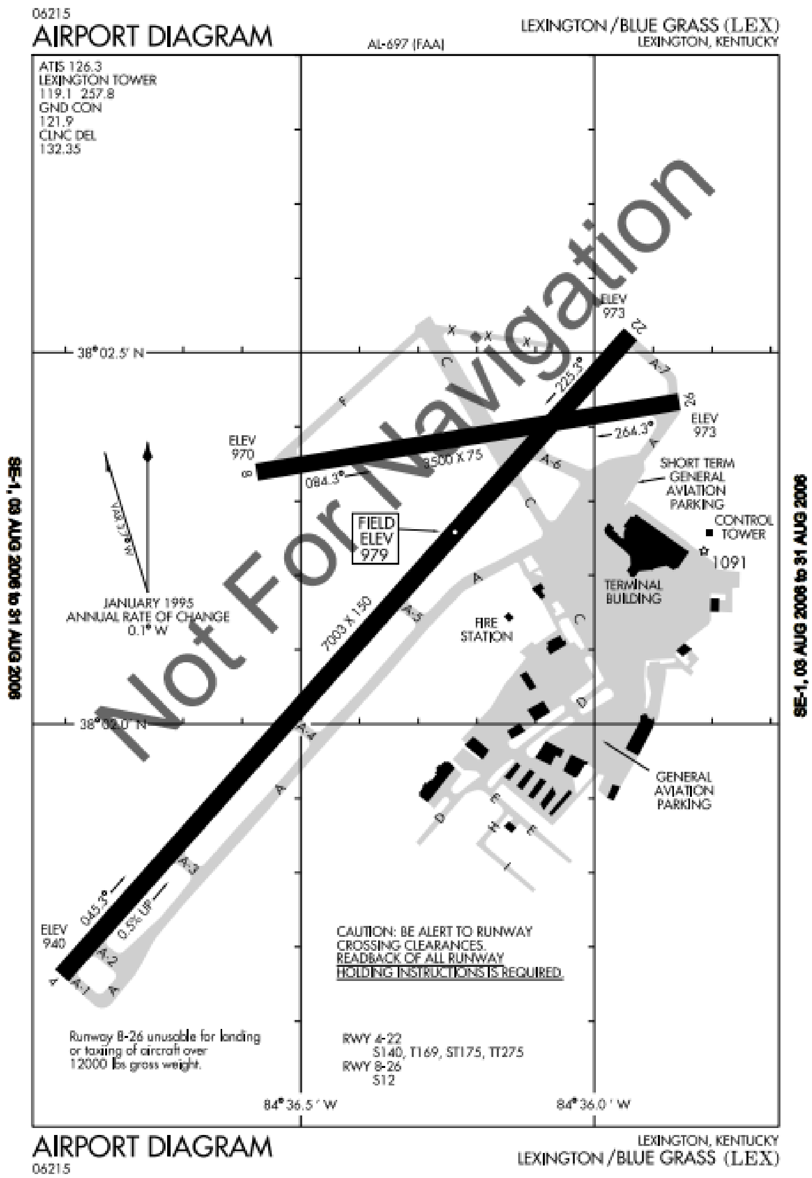
Lexington/Blue Grass Airport Layout and Planned Construction



Note. Image from 2006 showing the runway 22 and 26 thresholds and associated taxiway geometry with future taxiway A7 superimposed in gray. From "Attempted Takeoff From Wrong Runway Comair Flight 5191," by National Transportation Safety Board, (https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR0705.pdf#search=ComAir%205191). In the public domain.

Figure 7

Lexington/Blue Grass Airport Diagram



Note. Airport diagram depicting LEX at the time of the accident (August 2006) that does not accurately depict the taxiways near the runways 22 and 26 thresholds. From "Attempted Takeoff From Wrong Runway Comair Flight 5191," by National Transportation Safety Board (https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR0705.pdf#search=ComAir%205191). In the public domain.

Air Traffic Control.

At the time of the accident, one air traffic controller was on duty in the Lexington (LEX) Airport Traffic Control Tower. The controller was performing combined positions in the tower cab (Clearance Delivery, Flight Data, Local Control, Ground Control), Terminal Radar Approach Control (Approach/Departure and Radar Data). Combining positions is common during late night and early morning shifts, such as at 6:06 AM local time, when the accident occurred (National Transportation Safety Board, 2007).

Transcripts of the air traffic control communications between Comair 5191 and LEX Tower indicate the controller issued instructions for Comair 5191 to "taxi to runway 22" (p. 150) but did not provide a specific taxi route. When crew indicated they were ready for takeoff, the controller instructed Comair 5191 to "fly runway heading, cleared for takeoff" (p. 155). The crew replied, "runway heading, cleared for takeoff" (p.155). Neither the controller nor the flight crew stated the runway number in the clearance. After issuing the takeoff clearance, the controller turned away from viewing the airfield to perform another task. According to the report, the controller stated "that it might have been possible for him to detect the accident airplane was on the wrong runway if he had been looking out the tower cab window" (National Transportation Safety Board, 2007, p. 98). The tower was not equipped with a ground radar system (National Transportation Safety Board, 2007). In post-accident observations, the NTSB (2007) noted it was difficult to determine an aircraft's alignment with runway 22 versus runway 26 during nighttime conditions from the control tower.

Related Incidents at LEX.

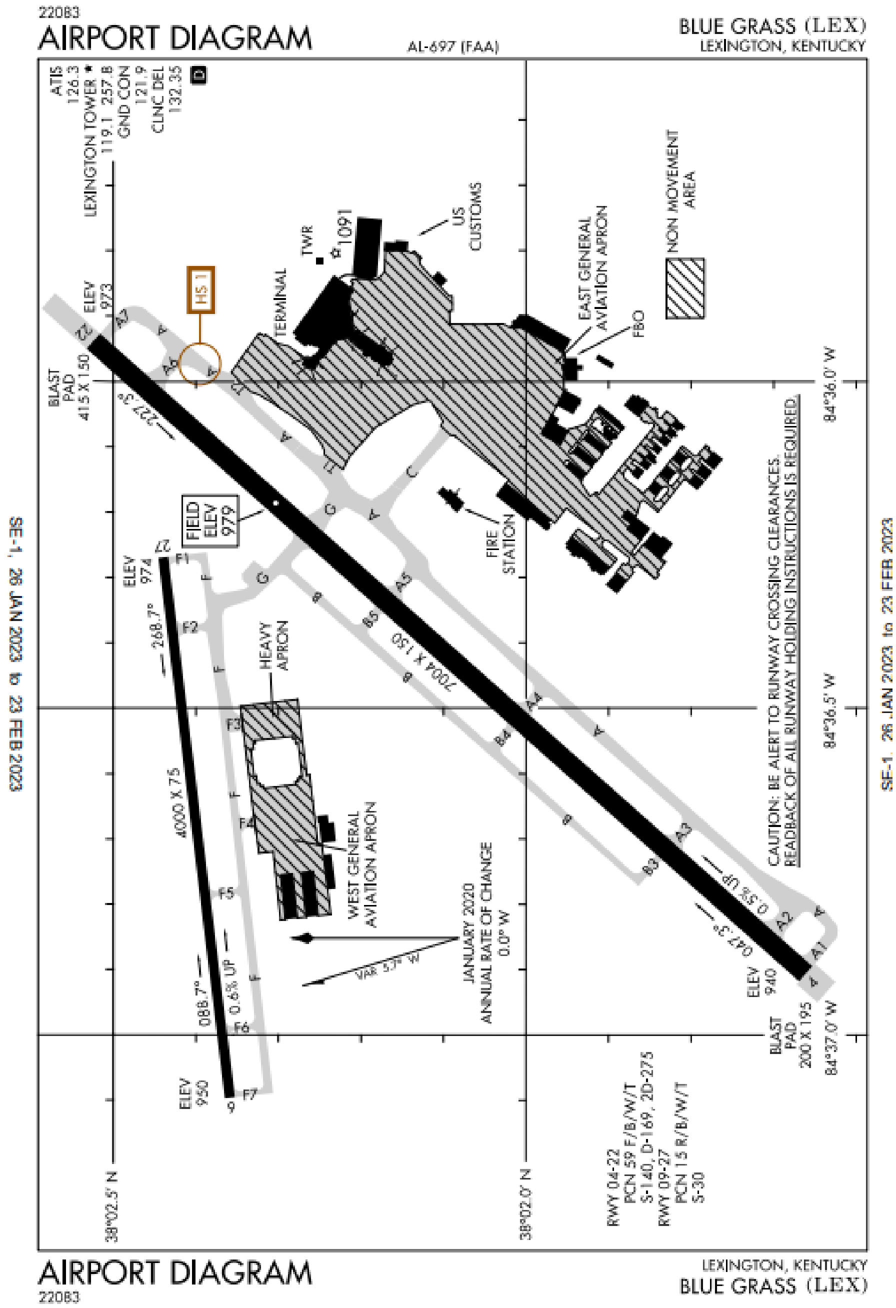
Following the Comair 5191 accident, two similar incidents were noted in the report that occurred at LEX, both during night visual meteorological conditions. One in which a tower controller believed the pilot of a Piper Archer mistakenly lined up for runway 26 instead of runway 22, like Comair 5191 did. The pilot reported that he performed a run up prior to reaching the hold short line for runway 22 and was apparently performing a run up on runway 26. After the aircraft taxied forward and called the tower to receive takeoff clearance, the tower informed the pilot he was mistakenly aligned with runway 26 instead of the correctly assigned runway 22. However, the pilot reported that at no time was he aligned with runway 26 (National Transportation Safety Board, 2007).

In another incident, a Learjet 45 was instructed to taxi to runway 22 and cleared for takeoff prior to reaching runway 26. The captain of the Learjet taxied across the hold short line for runway 26 but did not find the taxiway leading to runway 22 where he expected to find it. The NTSB (2007) noted that the taxiway leading to runway "required a wider left turn than a straight-ahead path to the runway" (p. 28). The crash of Comair 5191 and subsequent similar incidents suggest pilot and air traffic controller confusion related to the airport geometry of the runway 22 and 26 thresholds and the taxiway A7 linking the two.

Since the Comair 5191 crash and other events, LEX has undergone major reconstruction to relocate runway 27 (formerly runway 26), disconnecting the taxiway linking the two runway thresholds and creating a parallel taxiway joining the threshold to runway 22 at a right angle. The current airport layout as of February 2023 is depicted in Figure 8.

Figure 8

Current Lexington/Blue Grass Airport Diagram



Note. Airport Diagram of LEX dated February 2023. From Federal Aviation Administration Airport Diagrams (https://aeronav.faa.gov/d-tpp/2301/00697ad.pdf#nameddest=(LEX)). In the public domain.

Disposition.

In the final report, the NTSB determined the probable cause of the accidents was "the flight crewmembers' failure to use available cues and aids to identify the airplane's location on the airport surface during taxi and their failure to cross-check and verify that the airplane was on the correct runway before takeoff" (National Transportation Safety Board, 2007, p. 105). The NTSB issued a recommendation to the FAA to require aircraft operators to install moving map displays in the cockpit or an automatic system designed to alert pilots when a takeoff is attempted from a runway or taxiway that is not the intended departure surface (National Transportation Safety Board, 2007).

Similar Incidents at Other Airports.

The NTSB's final report on Comair 5191 details similar accidents and incidents involving wrong runway departures. In two separate incidents in January and March of 1989 at Houston-Hobby Airport (HOU), two air carrier aircraft departed runway 17 instead of runway 12R, which was closed for construction, striking barriers, with each continuing to their destination without incident. The FAA and HOU airport authority issued NOTAMs and instructions regarding the runway 17 closure and posted additional guidance signs. The threshold for runways 17 and 12R at HOU are in close proximity to one another, similar to the runways at LEX in 2006. The NTSB classified the issuance of the NOTAMs as an acceptable action.

On December 23rd, 1983, an accident involving Korean Air Lines flight 84 and South Central Air flight 59, the NTSB determined the Korean Air Lines airplane was on the wrong runway and the flight crew could have detected this had they verified the compass heading with the runway heading. Accordingly, the NTSB issued a recommendation that 14 CFR Part 121 and

135 carriers be required to include a compass verification with the assigned runway heading as a normal procedure in their operations manuals (National Transportation Safety Board, 2007). The FAA reported that most Part 121 and Part 135 air carriers included this and subsequently issued directives for the air carriers to include a compass crosschecking procedure to ensure the heading indicator matches the assigned runway(National Transportation Safety Board, 2007).

On October 31st, 2000, a Singapore Airlines Boeing 747 crashed after an attempted takeoff from the wrong runway, killing 83 of the 179 occupants. Taiwan's Aviation Safety Council determined that the pilots did not properly review the taxi route, didn't verify the airplanes position on the active runway prior to takeoff as required company manuals, and the crew ultimately lost situational awareness (National Transportation Safety Board, 2007).

On October 30th, 2006, an Alaska Airlines 737 departed runway 34R instead of 34C at Seattle-Tacoma International Airport. The captain of the flight stated that the Automatic Terminal Information Service (ATIS) broadcast indicated that runway 34R was being used for departures and that the ground controller instructed the crew to follow a 757 to runway 34R. The tower controller instructed the aircraft to line up on runway 34C and correctly readback the instruction, but the captain was still expecting to depart 34R. The crew received a takeoff clearance for 34C but departed 34R. The local controller stated that he noticed the aircraft departing the wrong runway but determined it was safer to let the aircraft depart due to the current traffic conditions. The aircraft departed uneventfully, and the controller informed the crew after takeoff they had departed the wrong runway.

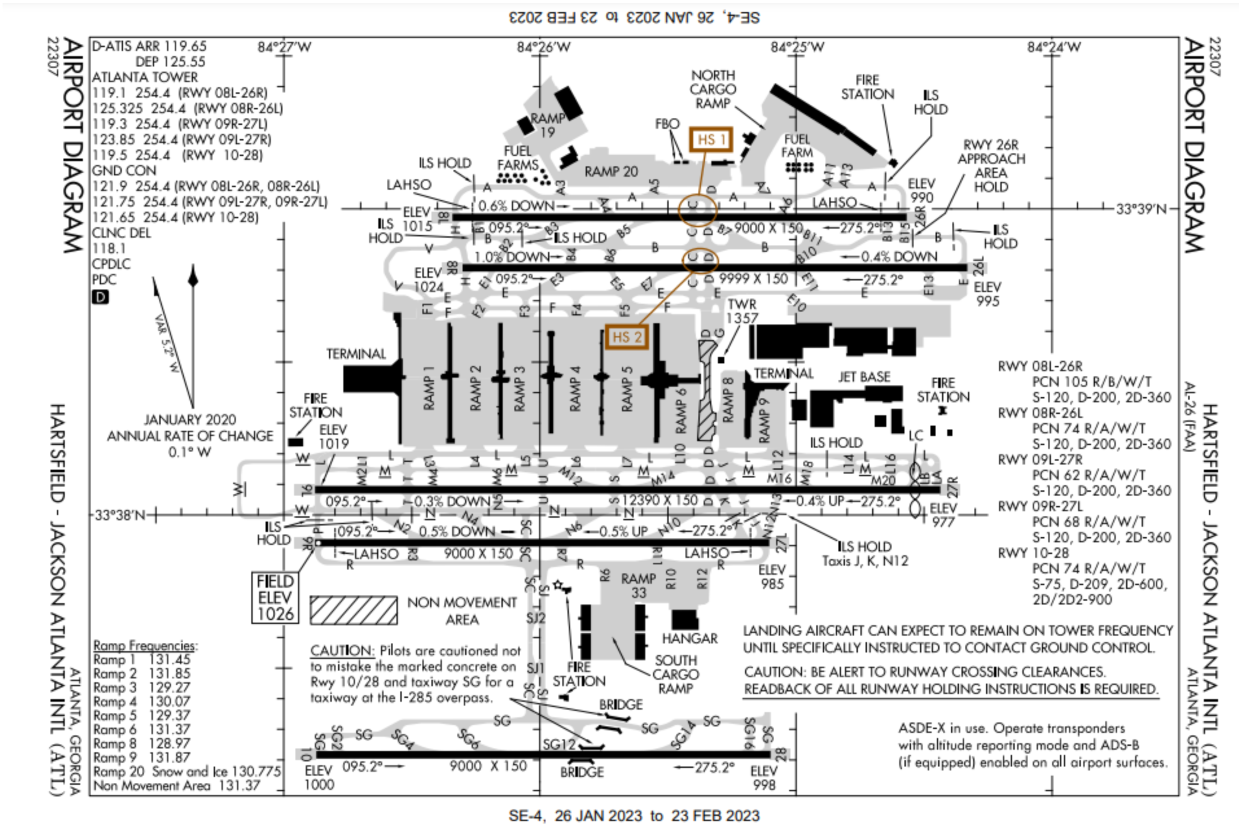
On April 18th, 2007, a United Airlines Airbus A320 attempted to depart runway 27, which was closed at the time, instead of runway 30 at Miami International Airport during night visual meteorological conditions. The captain of the flight reported that he verified the correct runway sign while on a parallel taxiway to runway 30. A slight bend in the taxiway caused the aircraft to be parallel to runway 27 instead of 30 and when the aircraft lined up on the incorrect runway 27, the captain believed it to be runway 30. Prior to takeoff, the aircraft's nosewheel illuminated a truck on runway 27 and the crew corrected the error, taxiing to runway 30 and departing without further incident (National Transportation Safety Board, 2007).

Delta 60 Taxiway Landing

On October 19th, 2009, at 6:05 AM Eastern Daylight Time, a Delta Air Lines Boeing 767-332ER operating Delta Air Lines Flight 60 from Rio de Janeiro, Brazil to Atlanta Hartsfield Jackson landed on taxiway M in Atlanta (ATL) after being cleared to land on runway 27R (see Figure 9) (National Transportation Safety Board, 2010).

Figure 9

Atlanta Hartsfield Jackson International Airport Diagram



Note. Airport Diagram of ATL dated February 2023. This airport diagram may not be an accurate layout of the airport at the time of the incident. From Federal Aviation Administration Airport Diagrams (https://aeronav.faa.gov/d-tpp/2302/00026ad.pdf#nameddest=(ATL)). In the public domain.

The flight deck crew consisted of three pilots: a check airman, a captain who was receiving special qualification experience from the check airman and a first officer. During the flight one of the crew members became ill, leaving the two remaining crew members to conduct the flight without the customary break period. After notifying the company's dispatcher as required, the flight crew elected to continue the flight. The notification of the dispatcher was the only guidance provided for such situation (National Transportation Safety Board, 2010).

Upon descending into ATL, the crew prepared for and briefed a landing on runway 27L. On initial contact with Atlanta Approach control, the crew was given the first runway change to 26R. The crew then briefed runway 26R but was subsequently informed of a second runway change back to runway 27L as initially planned. As the crew was communicating with the tower and the aircraft was near the outer marker for 26R, the tower offered a third runway change to runway 27R, which the crew accepted and was ultimately cleared to land on (National Transportation Safety Board, 2010). According to the NTSB (2010), after being cleared to land on 27R, the captain stated, “the flight was lined up on approach to runway 27L and when the flight was cleared to land on 27R he maneuvered for the side step and lined up on ‘the next brightest set of lights’ he saw” (pp. 3-4). The captain saw “bright edge lights and centerline lights” (National Transportation Safety Board, 2010, p. 4) and thought he had the runway in sight. The flight crew inadvertently landed on taxiway M, which the NTSB notes was a parallel taxiway approximately 200 feet north of 27R.

Airport Geometry.

Atlanta-Hartsfield International Airport has 5 parallel runways in an east-west configuration. Runways 8R/26L and 8L/26R are north of the airline terminal ramp, runways 9L/27R and 9R/27L are south of the terminal ramp, and runway 10/28 is south of 9R/27L and a south cargo ramp. The NTSB (2010) details the dimensions of 27R as “11,890 foot-long, 150 foot-wide grooved concrete runway equipped with high intensity runway edge lights, and centerline lights” (p. 6) as well as a precision approach path indicator on the right side of the runway. At the time of the incident, taxiway M was a 75 foot-wide concrete taxiway with blue edge lights and green centerline lights, located to the north of runway 27R or the right side from the perspective of the flight crew.

As part of the investigation, the investigators conducted an observational study at ATL in collaboration with Airport Operations personnel, Atlanta Air Traffic Control tower personnel and utilized a Delta Air Lines crew and aircraft to examine the airport lighting and visual cues when making an approach to runway 27L, followed by a sidestep maneuver to runway 27R. Investigators sought to demonstrate the event in similar environmental conditions as the day of the incident. The NTSB (2010) found that the lit yellow taxiway signs and portions of the edge and centerline lighting were much brighter than the runway lights to 27R, giving it the appearance of runway lighting.

Air Traffic Control.

During the observational study, NTSB investigators observed flight tests from the tower cab's local control south position. Investigators were able to visually acquire the aircraft's landing lights out the window throughout the approach, noting that it was challenging to determine the alignment of the aircraft since it blended in with the city lights behind it, and the angle of the local control position relative to the runway threshold (National Transportation Safety Board, 2010).

Disposition.

Ultimately, the NTSB (National Transportation Safety Board, 2010) determined that the probable cause of the incident was the flight crew's failure to identify the correct landing surface due to fatigue. Contributing factors were identified as: the flight crew's decision to accept a late runway change, the unavailability of the approach lighting system, and Instrument Landings

System (ILS) for the intended runway and the combination of numerous taxiway signs and intermixing of lighting technologies on the taxiway.

As a result of this incident, the NTSB recommended the FAA expand ASDE-X capabilities to detect and alert to potential taxiway landings. The FAA responded by saying “the ability to accurately predict that an aircraft is arriving to a taxiway is not possible without significant degradation in performance, timeliness, and accuracy of safety logic alerts for the more likely event of an aircraft arriving to a closed or occupied runway” (National Transportation Safety Board, 2018, p. 62).

The NTSB’s determined probable cause of the incident does little to address the root cause. For example, stating that the cause was “the flight crew’s failure to identify the correct landing surface” (p. 2) is simply a description of the event and finding that the probable cause of the incident was the incident itself adds little value to the body of knowledge on any aviation incident or accident. Since this was an incident report rather than an accident report, it does little to determine what can be implemented to solve the problem. The report had to be read in its entirely to identify other factors were prominent and potentially contributed to the incident.

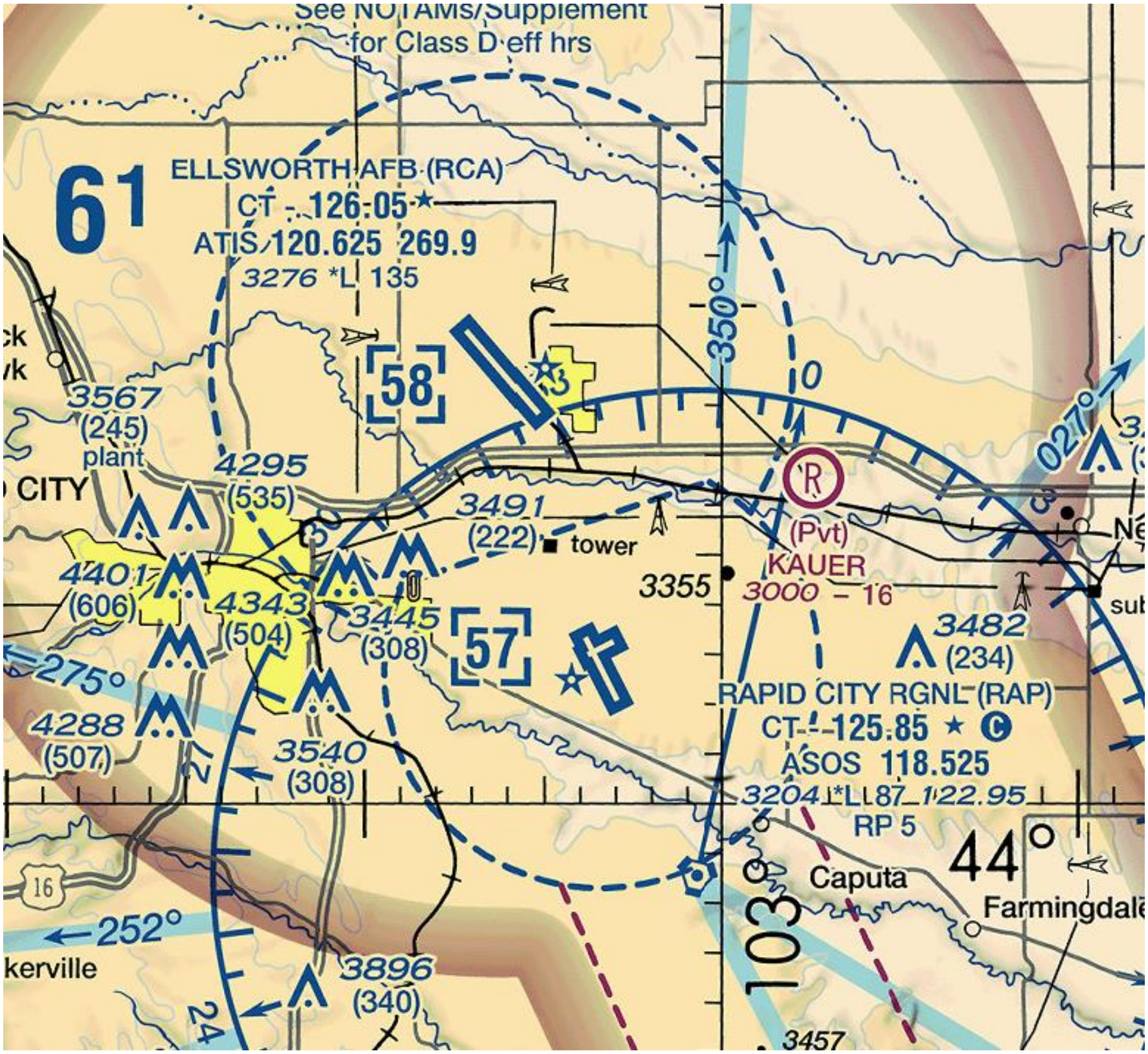
Delta 2845 Wrong Airport Landing

On July 7th, 2016, at 8:40 PM Mountain Daylight Time, an Airbus A320 operating Delta Air Lines flight 2845 to Rapid City Regional Airport (RAP) in South Dakota mistakenly landed on runway 13 at Ellsworth Air Force Base (RCA). At the time of the incident, the weather at Rapid City Regional Airport indicated clear skies and ten miles of visibly with light winds from 170 degrees (National Transportation Safety Board, 2017).

The crew planned and briefed an approach and landing to runway 32 at RAP initially, but following a change in wind, runway 14 became the active landing runway. The crew reported this was not a significant change as they had also prepared for an approach and landing to runway 14. Early in the initial approach to the Rapid City area (see Figure 10), the crew discussed that they needed to descend more rapidly, implying the aircraft was high as it entered a downwind leg to a visual approach to runway 4. Shortly after turning to the instructed heading of 300 to enter the downwind leg, the captain called the airport in sight to the first officer (National Transportation Safety Board, 2017).

Figure 10

Sectional Chart of Rapid City South Dakota Airspace



Note. FAA Sectional Chart of the airspace around RAP and RCA. From *SkyVector,* 2023 (https://skyvector.com/). Reprinted with permission.

The NTSB (2017) report speculates that the captain had actually observed Ellsworth Air Force Base and misidentified it as Rapid City Regional Airport due to the fact that the Air Force

Base was located at 10 o'clock relative to the aircraft's position, while Rapid City Regional Airport was located at 8 o'clock relative to the aircraft's position and six nautical miles apart.

The approach controller issued a base leg turn; however, the crew requested an extended downwind leg to allow more time to descend. Approximately two and a half minutes after the captain advised the first officer he had the airport in sight, the crew accepted a base leg turn as the aircraft descended through 5,800 feet MSL and advised the approach controller they had the airport in sight. At this time the aircraft was 5.5 miles north of Ellsworth Air Force Base and 12 miles north of Rapid City Regional Airport (National Transportation Safety Board, 2017). The NTSB (2017) notes this altitude and position of the aircraft at this point in the approach was consistent with published instrument glide paths to runway 14 at RAP but would be unusually steep for a landing at RCA. The approach controller cleared Delta 2845 for a visual approach to runway 14 at RAP and advised the crew to "use caution for Ellsworth Air Force Base located six miles northwest of Rapid City Regional" (National Transportation Safety Board, 2017, p. 1).

The first officer acknowledged the clearance and verbally asked the captain if he had the correct airport in sight, to which the captain replied, "I hope I do" (National Transportation Safety Board, 2017, p. 4). Following this, the captain selected a radial directly to the final approach course at the final approach fix (ZUDIM) and armed the approach. The ZUDIM waypoint is located 1.2 miles southwest of Ellsworth Air Force Base. The first officer reported after the incident that he recalled the aircraft on the correct navigation path displayed on the aircraft's navigation display. After this, the aircraft passed through the final approach course for runway 14 at RAP, leveling off at 4,900 feet MSL (National Transportation Safety Board, 2017).

The crew asked the approach controller if they should contact the tower and were subsequently instructed to contact Rapid City tower. The aircraft was five miles north of RCA and 11 miles north of RAP, the airport of intended landing and notably, according to the NTSB, positioned near the final approach courses to both runway 13 at RCA and runway 14 at RAP. At this time, the captain disconnected the autopilot and instructed the first officer to clear the flight director display. The aircraft began a rapid descent from 4,600 feet three miles from the threshold of runway 13 at Ellsworth Air Force Base, 1,400 feet below. The captain later said he did not see the Precision Approach Path Indicator lights, but still was focused on the visual approach. On a 1.5 mile final to runway 13 at RCA, the captain verbally confirmed the approach was stable. The aircraft was eight miles from RAP, where the aircraft was supposed to land. While the aircraft was descending at approximately 1,200 feet per minute, the captain made a comment indicating it was a poorly performed or unusual approach. The captain set the thrust levers to idle as the crew reported they both realized they were landing at RCA instead of RAP but elected to land anyway, believing it to be the safest course of action at that time. After exiting the runway the crew informed Rapid City tower that they had mistakenly landed at Ellsworth Air Force Base (National Transportation Safety Board, 2017).

The captain had approximately 25,800 hours, 2,980 hours in the A320 type aircraft. The first officer had approximately 7,600 hours, 2,324 hours in the A320. Neither flight crewmember had records of accidents, incidents, or enforcement actions with the FAA. The NTSB also notes according to Delta Air Lines records, the Capitan had flown once previously into Rapid City Regional Airport a year and half prior, while the first officer had never flown into RAP or RCA as a pilot (National Transportation Safety Board, 2017).

Air Traffic Control.

The approach controller noted that the aircraft seemed high and fast as it entered the downwind leg of the visual approach to runway 14. At the time, the aircraft was nine miles abeam RAP, the intended airport of landing, at 12,000 feet MSL, or 8,800 feet above the field elevation. On a call between the approach controller at Ellsworth Air Force Base and the tower controller at Rapid City Regional Airport, the tower controller noted that he was watching the aircraft on the tower radar display but was recording traffic count information at the time the aircraft landed. The report provided no further information about air traffic control. Without further information, it's difficult to speculate whether the approach controller was monitoring the aircraft's progress on the visual approach or whether the RCA tower controller was monitoring the airspace they were responsible for (National Transportation Safety Board, 2017). Any one of the three controllers (the Ellsworth approach controller, the Ellsworth tower controller, or the Rapid City Tower Controller) could have potentially aided in the detection of Delta 2845's approach to the wrong airport.

Disposition.

The NTSB lists the defining event as "Runway incursion veh/AC/Person" (p. 1) which demonstrates that even as recently as 2016, entities involved in US aviation safety still lack a consistent structure for defining and classifying wrong surface events. The flight crew was using an instrument approach procedure programmed into the aircraft's flight management system, however, neither flight crewmember detected the error through this method. The report leaves questions about the crew's use of an instrument approach procedure programmed into the Flight Management System and at what point that was no longer utilized or depicted as visual aid on the primary flight display or multifunction display. The NTSB recommended changes to the ATC radar data processing system responsible for generating Minimum Safe Altitude Warnings (MSAW) to apply to the destination airport in the flight plan. The radar did not indicate an

MSAW because the system automatically reprocessed the target to apply parameters for RCA rather than the correct airport of RAP.

Taxiway Overflight Air Canada 759

On July 7th, 2017, an Airbus A320 operating Air Canada flight 759 was making an approach to San Francisco International Airport's runway 28R at night. The pilots of Air Canada 759 mistakenly lined up with the parallel taxiway Charlie (C), where 4 aircraft were waiting for departure (National Transportation Safety Board, 2018). At the time, the parallel runway 28L was closed and unlit (with the exception of a lighted "X" at the approach end, which denotes a closed runway), as required under FAR Part 139 regulations (National Transportation Safety Board, 2018). The NTSB heavily scrutinized the incident due to the flight operating under FAR Part 121 (commercial service air carrier regulations) and the potential catastrophic nature of the near miss. Analysis of radar data, CCTV footage, and aircraft performance data from the aircraft's flight data recorder found that Air Canada 759 missed striking an aircraft on taxiway C by approximately 10-20 feet (National Transportation Safety Board, 2018). The airport layout can be referenced in Figure 11. A detailed depiction of the incident aircraft's flightpath as it approached the taxiway can be referenced in Figure 12.

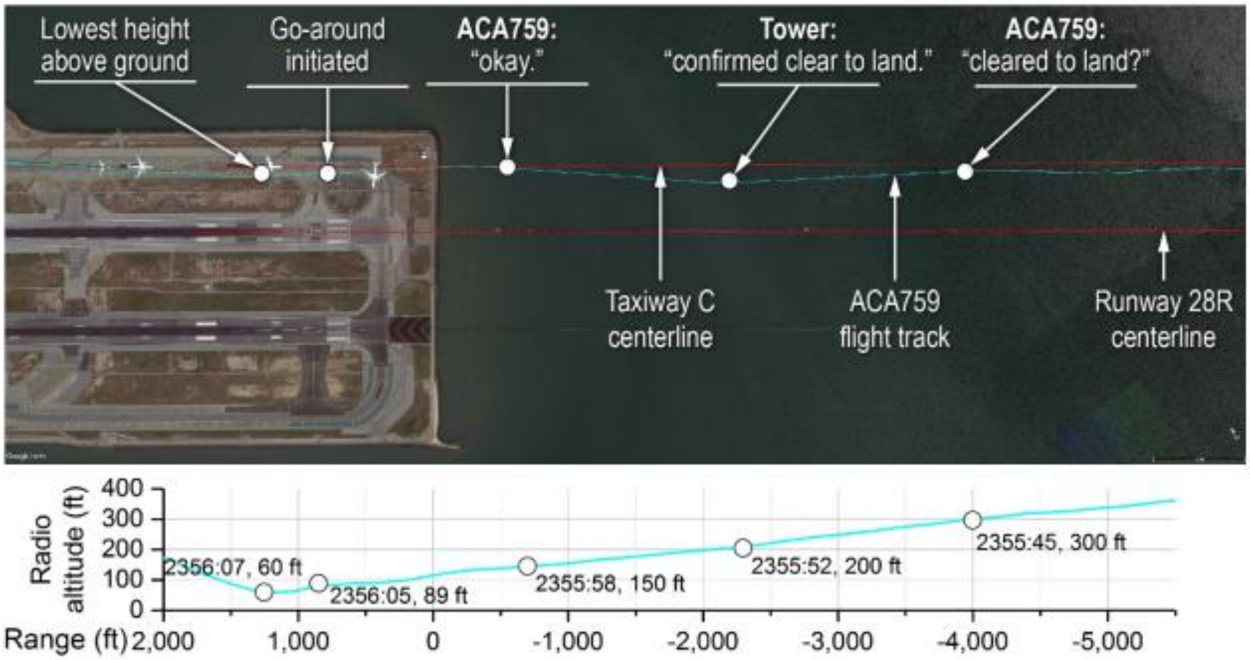
Figure 11

SFO Airport Layout Map

Note. Simplified airport layout map of SFO Airport. From "Taxiway Overflight Air Canada 759," by the National Transportation Safety Board, 2017 (https://www.ntsb.gov/investigations/AccidentReports/Reports/AIR1801.pdf). In the public domain.

Figure 12

Air Canada 759's Approach Track over SFO



Note. This plot of data was created by the NTSB with information gathered after the incident and is not reflective of information available to the pilot or controllers. Range depicted at the bottom is the distance to and beyond the airport seawall. From "Taxiway Overflight Air Canada 759," by the National Transportation Safety Board, 2017 (https://www.ntsb.gov/investigations/AccidentReports/Reports/AIR1801.pdf). In the public domain.

Prior to descent, Air Canada's operating procedures state that the crew should set up the approach in the aircraft's flight computer and tune to the Instrument Landing System (ILS) frequency listed on the approach plate. According to the report, a visual approach to runway 28R was advertised in SFO's ATIS. The crew loaded the approach procedure in their flight computer, which was based on the visual approach being advertised (National Transportation Safety Board, 2018). This was the only approach in the airlines procedure database for the incident aircraft model in which the instrument approach frequency must be manually entered by the crew to aid in identifying and aligning with the correct landing runway. The First Officer inadvertently skipped this step, and the captain did not catch the error when verifying the correct setup for the approach (National Transportation Safety Board, 2018).

The crew of a preceding aircraft landing (Delta 512) on runway 28R used instrument guidance and visually identified the correct runway during landing but indicated that the runway 28R and taxiway C surfaces could have been confused if the approach was not backed up with lateral guidance (National Transportation Safety Board, 2018). Without instrument guidance, the crew was relying entirely on visual cues to identify and align the aircraft with the runway. The NTSB (2018) found that the crew were distracted during critical phases of flight and prevented them from visually identifying alignment with the correct surface. Despite reviewing the NOTAMs for SFO during both the preflight dispatch release and in the ATIS, the Captain stated that he recalled seeing the runway closure in the NOTAMs but was unable to recall the information when it was necessary on final approach. This, coupled with the fact that the crew had recently flown into SFO, but never when runway 28R or runway 28L was closed led the NTSB to conclude that the crew had an expectation bias that contributed to their inability to correctly identify the landing surface (National Transportation Safety Board, 2018).

Air Traffic Control.

The controller responsible for runway 28R recalled the aircraft's position in reference to the runway appeared "extremely strange" (p. 8) on short final (National Transportation Safety Board, 2018). The report states that:

the distance and angle (parallax) of the tower cab relative to the approach end of runway 28R and taxiway C would have made it difficult for the controller to visually recognize that ACA759 was aligned with the taxiway instead of the runway, especially at night and with the lights from the construction on runway 28L and airport vehicle movements. (National Transportation Safety Board, 2018, p. 44)

The Taxiway Arrival Predication enhancement had not yet been developed at the time of the incident, meaning that the ASSC was not capable of detecting and alerting the controller that Air Canada 759 was aligned with taxiway C (National Transportation Safety Board, 2018). The NTSB had previously recommended that ASDE-X be improved following the Delta 767 taxiway landing at ATL (National Transportation Safety Board, 2010).

Airport Geometric Factors.

SFO has two sets of two parallel runways: 1L/19R, 1R/19L, 28L/10R and 28R/10L (see Figure 11). In addition to this, three partial length parallel taxiways and two full length parallel taxiways. The closure of runway 28L was marked by a lighted, flashing white “X” at the approach end of runway 28L (National Transportation Safety Board, 2018). The NTSB noted that the “X” was oriented to face the 28L final approach course and likely was not in the direct field of view of the flight crew. Neither the lack of precision approach path indicator, touchdown zone lights, full length runway edge lights, or approach light nor the presence of blue taxiway edge lights or green taxiway centerline lights on taxiway C could overcome the crew’s expectation bias (National Transportation Safety Board, 2018). Lights from aircraft waiting on taxiway C, including wingtip navigation lights were of similar width to the intending landing runway (National Transportation Safety Board, 2018).

Disposition.

After the crew executed a go-around, they were able to land safely on the next approach without incident. None of the passengers or crew members were injured. The NTSB (2018) determined the probable cause of the incident to be:

> the flight crew's misidentification of taxiway C as the intended landing runway, which resulted from the crewmembers' lack of awareness of the parallel runway closure due to their ineffective review of notice to airmen (NOTAM) information before the flight and during the approach briefing. (p. 68)

The NTSB's (2018) recommendations focused on improving aircraft and ATCT-based technology for detecting and alerting to an aircraft being aligned with a taxiway, improving the display of NOTAM information to reduce the likelihood a pilot will miss a key NOTAM, ensuring visual approach procedures are backed up with instrument guidance, making the appearance of a closed parallel runways appear more conspicuous to pilots, and addressing inadequate fatigue policies.

Chapter III: Methodology

To answer the three research questions and explore why wrong surface events continue to occur, historical events were analyzed to understand how the context of an event influences pilots' actions and contributes to the occurrences of wrong surface events. Existing literature on flight deck and ATCT-based technology was examined to understand the functionality and assess an ability to address human error in wrong surface events. Human subjects were interviewed to understand different aviation professional's awareness of wrong surface events.

Context that Influences Pilots Actions in Wrong Surface Events

To discover what context can be identified to help explain the actions of pilots which contribute to wrong surface events, four wrong surface events were reviewed in detail, and human error framework was applied to determine the contextual themes which influence the actions of pilots, as well as the overall outcome of the event. Events were selected as a representative sample of all types of wrong surface events and were described in the literature review.

The crash of Comair 5191 was selected as representative sample of both a wrong surface departure and attempted wrong surface departure. This event was a major aviation accident and was highly publicized. The report of Comair 5191 details similar events, effectively covering both wrong surface departures in which pilots departed the wrong surface and attempted wrong surface departures in which the pilots were able to detect and avoid the error, or in the case of Comair 5191, crashed on takeoff.

While there have been many examples of wrong airport landings that have been highly publicized, only Delta 2845 was selected as a representative sample of a wrong airport landing.

Delta 60 was selected as a representative sample of a wrong surface landing. The event occurred at a major US airport that ranks consistently among the busiest airport by both air traffic operations (takeoffs and landings) as well as passenger traffic, thus posing a higher risk to the safety of the public. Though Delta 60's taxiway landing was not highly publicized, it was selected in part due to the outcome, which was a safe landing, and because the NTSB replicated the event in similar conditions to examine the flight crew's visual perspective.

Air Canada 759 was selected as a representative sample of a wrong surface approach due to the prolific nature of the event. It has been highly publicized and scrutinized on account of the potentially catastrophic outcome of the event.

Within each event report, contextual themes were identified and described under the framework of human error established in the literature review. A comprehensive review of each event was conducted to identify: (a) human error contribution context, (b) actions taken by the flight crew that influenced human error, and (c) the outcome of the event for discussion.

Impacts of Flight Deck and ATCT-Based Technology on Wrong Surface Events

To examine the impact of flight deck and air traffic control tower-based technological solutions on wrong surface events and how effective they are at preventing them, a review of literature was conducted on to human-machine interfaces capable of detecting and alerting flight crew or air traffic controllers to wrong surface alignment in order to allow the flight crew to correct the misalignment. These documents were then applied to the human error contextual details from each event reviewed in research question one to assess whether or not a flight deck or ATCT-based system would have effectively alerted to the given conditions in each event.

Any flight deck-based tool discovered in the literature review will represent the flight deck based technology. Flight deck based technologies include SURF-IA, GPWS, and other situational awareness tools with active visual and/or aural alerting. The ASDE-X or ASSC will represent the ATCT-Based technology.

Awareness of Wrong Surface Events Among Aviation Professionals

To explore the impacts current training, education, and procedural requirements among pilots and air traffic controllers in aiding the detection and interruption of wrong surface events, a number of aviation professionals and students at various stages in their careers were interviewed to understand their awareness of wrong surface events, including the risks, prevention strategies, terms used, types of wrong surface events, and a number of historical wrong surface events that have occurred in the NAS.

Population

The population for this research question study were from five categories: (a) students at various stages of training, (b) certified flight instructors, (c) Part 121 airline transport pilots (d) training department staff responsible for pilot training curriculum, and (e) air traffic control specialists who are certified professional controllers at FAA airport traffic control towers. The population is reflective of those who are in a position to detect or interrupt a wrong surface event as it is occurring or educate others on wrong surface event risks, prevention strategies, or historical events with the intention of creating awareness across various levels of experience. Solicitations for all subject types were made on various forms of social media, so it is unknown how many potential subjects may have seen the solicitation and elected to not reach out to participate.

Sample

Convenience sampling was used recruit a variety of pilots, air traffic control specialists, and training personnel through networks and channels personally known to the researcher. Subjects were carefully selected to ensure they had no personal or advanced knowledge of the research topic. A total of ten pilots and two training department staff were contacted and provided with the study information sheet. Air traffic controllers were recruited via a social media group consisting of 785 members, although not all members are certified air traffic control specialists at ATCTs. Ultimately, only six air traffic control subjects were interested, met the criteria, and were provided with the study information sheet. Participation was voluntarily and subjects were not compensated. The only benefit was the potential to become more aware of wrong surface event risks, events, and prevention strategies. The final sample group that agreed to be interviewed is shown in Table 3.

Table 3

Count of Subjects by Category

Subject Category	Number
Pilots	
Student Pilots in Training	2
Certified Flight Instructors	1
Part 121 Airline Transport Pilots	4
Training Department Staff	1
Air Traffic Control Specialists	3
Total	11

Instrument and Data Collection

The instrument contained in the appendix was developed for gauging awareness and familiarity of wrong surface events by assessing risks associated with wrong surface events, prevention strategies and familiarity with historical wrong surface event through a series of guided interview topics and questions. Subjects were interviewed regarding their awareness of wrong surface events by assessing five factors defined in in Table 4 and evaluating the subject's response by each measure.

The questions asked of each subject were coded by the subject category or the question's topic. Subject question IDs are Air Traffic Controllers (A), Pilots (P), Training Department Staff (TD), preceded by a "B" if the question was meant to establish a subject's background or qualifications. General questions or topics targeting wrong surface events (G), Event (E), Event

Narrative (EN). General question 4 was asked after subject-specific questions (P, A, TD) and prior to any questions that used the term "wrong surface event" to assess whether the subject was able to draw any connection to their subject-specific topics and wrong surface events through means of sharing stories of any experiences.

Table 4

Factors to Assess Awareness of Wrong Surface Events Among Aviation Professionals

Factor	Definition	Measure
Technique (T)	The subject uses technique that may serve as prevention strategies.	T1: Does not use or have experience in the given technique T2: Uses a modification of or has some experience in the given technique T3: Uses or has a high level of experience in the given technique
Importance (I)	The subject's ability to recognize the importance of a prevention strategy as it applies to general risk prevention.	I1: Does not recognize or recognizes little use the importance of a prevention strategy I2: Recognizes the importance of a given prevention strategy
Connection (C)	The ability of the subject to connect a given topic or prevention strategy to wrong surface event risks specifically.	C1: Does not connect the topic or strategy to the risk of a wrong surface event specifically C2: Connects the topic or strategy specifically to the risk of a wrong surface event

Factor	Definition	Measure
Familiarity (F)	The subject's awareness of prompt (i.e., historical wrong surface events and their details)	F1: Not familiar with the prompt F2: Vaguely familiar with the prompt but cannot recall specific details and/or recalls some details incorrectly F3: Very familiar with the prompt and/or recalls details clearly and correctly
Deduction (D)	Whether the subject was able to guess a detail or event correctly. Demonstrates critical thinking ability relative training and experience.	D1: Not able to guess correctly or did not guess D2: Able to guess partially or completely correctly D3: Able to guess entirely correctly or highly accurately

Note. Deduction was included since multiple subjects either guessed or deduced a topic, strategy, or detail correctly.

The interviews lasted approximately 30 minutes in length. They assessed awareness by discussing and prompting subjects to engage in discussion on references to the factors or prevention strategies identified in the analysis of wrong surface events and in the literature review to gain an understanding of how pilot training programs are creating pilot awareness and how air traffic controllers are trained to be aware of wrong surface events. The survey tool, found in the appendix, was developed for the purpose of this thesis and specifically for answering Research Question 3. Accordingly, the survey tool was strictly intended for answering Research Question 3 in a qualitative, exploratory research method. The survey tool contains the questions or topics discussed, the purpose for their inclusion, the means in which subjects were measured on each topic or question, and sheet of four airport diagrams shown to each subject to see if they could identify parallel offset runway thresholds, a common airport layout that the FAA believes contributes to wrong surface events.

Subjects were asked questions and encouraged to share stories, experiences, or topics they believe could relate to any question asked or topic discussed to extract as much information that could pertain to the research question as possible. The interview subjects that were (a) students at various stages of training, (b) certified flight instructors, (c) Part 121 airline transport pilots, were asked questions from the “Pilot” section. Certified flight instructors who were actively exercising the privileges of their CFI certificate were additionally asked questions from the “CFI Supplemental” section. Interview subjects that were (d) training/safety department staff were asked questions from the “Pilot Training/Safety Department Staff” section. Interview subjects that were (e) air traffic control specialists were asked questions from the “Air Traffic Controller” section.

Notes were taken from each interview related to the interview questions and topics to assess the subject through the means of measure contained in Table 4.

Chapter IV: Findings

The human error context and impacts on pilot action from Research Question 1 were used to establish methodology for Research Question 2. Then the findings from Research Question 1 and 2 were used to establish the methodology for Research Question 3 to explore a human subject's awareness of context, risks, terminology, wrong surface event narratives, and possible prevention strategies. The findings from all three questions were used to study the impacts training and technology may have had on the context and actions that contribute to human error in wrong surface events and ultimately determine better mechanisms for preventing these events.

Research Question 1: What context can be identified to help explain the actions of pilots that contribute to wrong surface events?

Upon examination of the wrong surface departure of Comair 5191, the wrong airport landing of Delta 2845, the wrong surface landing of Delta 60, and the wrong surface approach of Air Canada 759, it was found that wrong surface events are a type of error known as a slip, which occurs when the actions were not as planned.

Comair 5191

The events and the contextual factors identified in the NTSB report of Comair 5191 are contained in Table 5.

Table 5

Contextual Factors Findings in Comair 5191 Accident

Contextual Factor	Impact on pilot action
The runway thresholds were in close proximity to each other and taxiways linking the runways contributed to complex geometry.	The complex airport geometry made it easier for the crew to believe they were at the intended takeoff runway when they lined up with the wrong surface.
Inaccurate airport charts. Airport charts did not display the airport layout as it was on the day of the accident.	Lack of accurate airport charts made it more likely for the crew to become lost or disoriented on the airfield.
Pertinent NOTAMs related to ongoing construction and airport layout changes were not provided to the crew.	Crew was not provided with information that may have aided them in risk awareness.
Darkness	Lack of visual references made it more difficult for the crew to have a visual perspective of the correct runway and airport layout, including painted runway markings
There were multiple lighting outages on the airfield. Runway 26 lighting was turned off due to construction.	The lighting outages may have contributed to the crew being primed to expect other lighting outages.
Enhanced taxiway centerlines and surface painted hold signs were not present at LEX.	The lack of additional visual aids to assist the crew in properly identifying the correct runway for departure.
Airport construction	Airport construction resulted in abnormal conditions and closures that differed from the crews expected visual perspective.
Lack of reference to other air traffic	No other aircraft were operating out for the crew to observe taking off. The crew was unable to reference the position of other traffic to create an accurate expectation of correct visual perspective.

Contextual Factor	Impact on pilot action
The aircraft was not equipped with visual or aural warning systems to notify the crew of their misalignment nor a system that provided enhanced positional awareness. The heading bug was not conspicuous enough for the crew to detect a discrepancy.	The crew did not have sufficient technology to aid in the detection and interruption plan continuation contributing to their error.
Procedures and communication did not require clear instructions that emphasized a runway crossing prior to beginning takeoff roll.	The crew was not provided with aural cues that could aid in position determination.
Tasks competing for air traffic controller’s attention	The controller was not observing the runway at the time the aircraft was taking off and alert the crew to the misalignment.
ATCT parallax and darkness combination	The viewing angle of the runways from the control tower and darkness at the time of the event made it challenging to accurately detect and interrupt the event by informing the flight crew.

The outcome of the Comair 5191 was a crash resulting in the destruction of the aircraft and the fatalities of 49 passengers and crew members, with one crewmember surviving.

Delta 60 Taxiway Landing

The events and the contextual factors identified in the NTSB report of Delta 60’s Taxiway Landing Incident are contained in Table 6.

Table 6

Contextual Factors Findings in Delta 60 Incident

Contextual Factor	Impact on pilot action
Approach assignment (26R) differed from the runway planned for in approach briefing (27L)	Crew workload increases during runway changes and runway changes with similar runway numbers could cause confusion.
ATL Tower offered a late runway change runway 27R at the outer marker to 26R Approach. The crew accepted the clearance.	Crew conducted the sidestep maneuver by visually aligned with what they believed to be runway 27R
Taxiway M edge lights were set to a brightness step 3 of 3, taxiway M centerline lights set to a brightness step 2 of 5, while the runway lights (centerline and edge lights) were set to step 1 of 5. Taxiway M lights were upgraded to brighter LED lights. Multiple pilots reported the brighter taxiway lights were confusing.	Delta 60 crew reported they aligned with the brightest set of lights they saw after conducting the sidestep maneuver to runway 27R, which ended up being taxiway M.
Runway 27R approach lighting was turned off due to construction.	The crew did not have the expected visual perspective or visual cues that would aid in detecting a misalignment.
Nighttime (early morning) lighting	Darkness prevented the crew from being able to see details on the airfield
Airport geometry: Parallel runways and taxiway layout at ATL	Numerous parallel runways and taxiways contributed to challenges in identifying the correct surface when conducting the sidestep maneuver within the final approach fix.
The ATCT's ASDE-X was not capable of detecting and alerting to taxiway misalignments and the safety logic system had determined Delta 60 was aligned with runway 27R.	The lack of detection prevented an alert from being issued to the controller and the flight crew from becoming aware of the misalignment.
Company approach procedures lacked specificity. Delta's procedures required a briefing every time an approach or runway change was issued.	The crew may have become task saturated and was prone to memory storage and attention failures.

Contextual Factor	Impact on pilot action
One of the three required crewmembers became ill shortly after takeoff and was unable to perform any additional duties. This crewmember would have been on the flight deck during the approach and landing.	An additional (third) crewmember would have been one additional person on the flight deck that may have detected the misalignment.
The crew was unable to take scheduled rest breaks in flight, became fatigues and identified this as a hazard in the approach briefing.	Crew experienced an adverse psychological state known for lower cognitive function.

The outcome of Delta's 60s taxiway landing was that the aircraft landed on taxiway M, a surface not intended for the landing or takeoff of aircraft safely without damage. The NTSB report did not detail any risk to aircraft on the ground, therefore it is assumed there were no aircraft on taxiway M at risk of a ground collision between the Delta 767 aircraft and an aircraft on the ground.

Delta 2845 Wrong Airport Landing

The events and the contextual factors identified in the NTSB report of Delta 2845's wrong airport landing incident are contained in Table 7.

Table 7

Contextual Factors Findings in Delta 2845 Incident

Contextual Factor	Impact on pilot action
Close proximity between Rapid City Airport to Ellsworth AFB. The airfields had similar runway configurations due to the similar prevailing wind conditions.	Close proximity of airports with similar runway configurations can contribute to misidentification.
The aircraft was at a higher altitude than intended on the approach and the crew discussed a need to descend more rapidly.	Crew was preoccupied with the need to descend to set up for the approach and may have felt rushed to be able to set up properly for the approach.
ATC issued a cautionary advisory related to the position of Rapid City Airport and Ellsworth AFB that was similar to the advisory as a standard position advisory given on an instrument approach.	The crew mistaking the cautionary advisory as a position advisory resulted in plan continuation, where they believed they were lining up for the correct airport.
The aircraft was located along the RNAV final approach course to runway 14 at Rapid City Airport when the controller cleared it for the visual approach at a reasonable altitude for landing on runway 14. The approach controller did not have any indication it was aligned with the wrong airport at the time he cleared the aircraft for approach and instructed the crew to contact RAP tower.	The position and altitude offered no indication as to a misalignment to ATC, so the crew would not have been alerted to the misalignment by the approach controller before responsibility was transferred to RAP tower.
The crew expressed uncertainty in their position relative to Rapid City Airport but did not verify their position with ATC or through automation tools on the flight deck.	The crew missed an opportunity to detect their alignment with the correct airport, resulting in plan continuation.
The crew had no previous experience flying into RAP.	The crew had no awareness of the visual perception.
The crew deactivated the autopilot and flight directors to conduct the visual approach.	Removed visual cues that may have aided in misalignment

Contextual Factor	Impact on pilot action
After being cleared for the visual approach to runway 14 at RAP, the approach became unstable due to a high descent rate.	Unstable approach may have resulted in the crew becoming preoccupied with trying to stabilize the approach. The unstable approach may have resulted from the incorrect airport alignment.
ATC radar system Minimum Safe Altitude Warning (MSAW) applied parameters for landing at RCA instead of RAP. The system did not issue an MSAW alert the Ellsworth Approach Controller when the aircraft descended on final for RCA.	The approach controller did not have a technological system to detect and alert to this type of error and was unable to notify the flight crew.

The outcome of Delta 2845's wrong airport landing was the aircraft landing safely at Ellsworth Air Force Base, the incorrect destination airport, without any damage.

Air Canada 759 Wrong Surface Approach

The events and the contextual factors identified in the NTSB report of Air Canada 759's wrong surface approach incident are contained in Table 8.

Table 8

Contextual Factors Findings in Air Canada 759 Incident

Contextual Factor	Impact on pilot action
Air Canada 759's departure from Toronto was delayed. The flight scheduled to arrive prior to runway 28L closing.	The crew paid less attention to that NOTAM in the dispatch release.
Crew had recent experience flying in to SFO	The flight crew may have been primed to expect a certain landing runway and/or no runway closures.
NOTAM for runway closure was in the ATIS, which the crew obtained. Obtaining the ATIS is a routine habitual task.	Routine habitual tasks prone to attention failures.
Lack of clarity between the flight crew in the autopilot descent mode was being used.	Increased workload as the first officer was programming the approach into the flight management computer.
The crew did not tune or verify the ILS frequency as required in the approach procedure.	Attention failure resulted in the lack of automation to aid in the proper runway alignment or detection of a misalignment
Runway 28L was closed at the time the crew was landing.	The crew was primed to expect both runways to be open and aligned with the lit surface on the right side believe it was runway 28R when it was actually taxiway C.
The captain asked the first officer to set the autopilot heading bug during a critical time in the approach.	The first officer spent time "heads down" setting the heading rather than looking outside the aircraft.
Taxiway C was parallel to runway 28R	A parallel taxiway running the full length of the runway could appear to the flight crew to be a runway, resulting in plan continuation bias.
The captain prompts the first officer to verify the runway is clear after observing flashing lights (aircraft beacon on runway guard lights). ATC verifies runway 28R is clear.	Impacted the crew's plan continuation belief that they were aligned with the correct surface and no aircraft were on the runway.

Contextual Factor	Impact on pilot action
The incident aircraft's track dropped from the ATCT's ASSC display on short final. The controller was unable to use the ASSC to determine the aircraft's position. ASSC was not equipped to detect and alert to aircraft aligned with a taxiway.	ATC technology could not aid in the detection and notification to the crew of the misalignment.
ATCT parallax and darkness combination	The viewing angle of the runways from the control tower and darkness at the time of the event made it challenging to accurately detect and interrupt the event by informing the flight crew.
Air Canada and Transport Canada's fatigue policies didn't effectively address fatigue prevention. The captain of the flight had been awake for 19 hours at the time of the incident, which was fully permissible under policies and regulations.	Ineffective fatigue regulations resulted in a higher risk for fatigue and human error.
Crew fatigue	Fatigue had an adverse impact on the captain's psychological state and cognitive functioning abilities.

The outcome of Air Canada 759's wrong surface event was an overflight of a taxiway occupied by four passenger aircraft awaiting departure. The NTSB estimated then main landing gear of Air Canada 759 missed striking the tail of an Airbus A340 on the taxiway by 10-20 feet.

Research Question 2: What impact have flight deck and air traffic control tower-based technological solutions made on wrong surface events? How effective are these solutions at aiding in detection and prevention?

Based on review of literature related to flight deck and ATCT-Based detection and alerting technology applied to the wrong surface events review in research question one, the findings of the technology's efficacy were determined and summarized in Table 8 followed by more detailed findings.

Table 9

Efficacy of Technological Alerting Tools in Wrong Surface Events

Event	Likely to Alert	
	Flight Deck System	ASDE-X/ASSC
Comair 5191	Yes	No
Delta 60	Yes	Yes
Delta 2845	Unknown	No[a]
Air Canada 759	Yes	Yes

[a] An appropriately configured STARS system would have issued a Minimum Safe Altitude Warning (MSAW) alert

Comair 5191

A flight deck-based system would have detected and alerted to the misalignment . Most systems would inform the pilot in an audible warning similar to "on runway 26." This is a common function on runway incursion prevention systems (Joslin, 2014; Lancaster et al., 2010; Ludwig, 2007; Vernaleken et al., 2006, 2007). Some systems may not have alerted to the misalignment due to engineering or design limitations.

An ASDE-X or ASSC system would not have detected and alerted to the wrong surface departure of Comair 5191 as the scenario does not meet any of the collision situations contained in Table 9. Runway 26 was open at the time of the incident. If runway 26 was closed at the time of the incident, it would require the controller to configure an ASDE-X or ASSC system manually and separately from other procedural requirements. As shown in Table 1, the tower at Blue Grass Airport is not equipped with an ASDE-X or ASSC system.

Delta 60

A flight deck based system known as an enhanced ground proximity warning system would have alerted to the misalignment of Delta 60. Current systems exist that are capable of detecting a taxiway misalignment and notifying the flight crew with an aural warning (National Transportation Safety Board, 2018).

Based on information available from the incident report, the ASSC specification document, and the Taxiway Arrival Prediction implementation report from ATL tower, an ASDE-X or ASSC system would have detected and alerted to crew of Delta 60's taxiway misalignment, notifying the air traffic controller with a visual alert on the ASDE-X display system and with an aural warning in the tower cab (Federal Aviation Administration, 2018c, 2021d; National Transportation Safety Board, 2017). ATL tower was equipped with an ASDE-X at the time of the incident. According to the NTSB (2010), "The ASDE-X was not programmed to activate alerts for an aircraft landing or departing from a taxiway and, therefore, when the local controller scanned the ASDE-X display, system safety logic bars indicated that DAL 60 was properly aligned with runway 27R" (pp. 7-8). Since the incident, Taxiway Arrival Prediction has been installed and validated at ATL tower (Federal Aviation Administration, 2018c).

Delta 2845

There are multiple methods of automation that can be used to aid in ensuring an aircraft is aligned with the correct airport however, it is unknown whether an automated flight deck based system would have detected and alerted the flight crew by visual or aural means to the wrong airport landing.

An ASDE-X or ASSC system would not have detected the wrong airport landing made by the crew of Delta 2845. The system is airport specific and only provides alerts based on fused surveillance data relative to the alert areas created in the software at the airport of installation. RAP tower is not one among the list of ATCT facilities in Table 1 that is equipped with an ASSC or ASDE-X system. The NTSB (2017) states in their report that MSAW alerts on FAA or Department of Defense STARS should detect wrong airport landings if the system parameters are applied to the destination airport and not another airport based on incorrect trajectory.

Air Canada 759

A flight deck based system would have alerted to the wrong surface approach made by the crew of Air Canada 759. According to the NTSB (2018), Air Canada's fleet of A320 aircraft were being upgraded with Honeywell Mark V enhanced ground proximity warning systems, which Honeywell demonstrated to the NTSB in simulations that under the same conditions, the system would have produced an aural warning to the crew stating "caution taxiway, caution taxiway" (p. 26) when the aircraft was 2,600 feet, or 0.43 nautical miles from the airport seawall.

An ASDE-X or ASSC system would have detected the wrong surface approach made by the crew of Air Canada 759. Citing the need for modifications to the ASDE-X and ASSC systems throughout the NAS, the NTSB (2018) report states:

> The SFO air traffic control tower was equipped with an ASSC system, which was not designed to predict an imminent collision involving an arriving airplane lined up with a taxiway; thus, the ASSC system did not produce an alarm as the incident airplane approached taxiway C. If an airplane were to align with a taxiway, an automated ASDE alert could assist controllers in identifying and preventing a potential taxiway landing as

> well as a potential collision with aircraft, vehicles, or objects that are positioned along taxiways. An FAA demonstration in February 2018 showed the potential effectiveness of such a system (p. xi)

The FAA's (2021d, 2022a) ASSC System Specifications Document and the Taxiway Arrival Prediction Implementation report from SFO support the finding that the requested modifications from the NTSB have been met and fulfilled.

Research Question 3: What impact does current training, education, and procedural requirements and recommendations have among pilots and air traffic controllers in aiding detection and interruption wrong surface events? How effective is this at creating awareness and preventing human error contributing to wrong surface events?

The results from research question three were broken down and presented by subject category in the following order: (a) Pilots (P), (b) Training Department Staff (TD), (c) Air Traffic Control Specialists (A). Each subject category contains a brief narrative of the subject's background. General questions (G), and Events (E) and Event Narrative (EN) questions asked to all subjects were coded and presented with alongside all subjects for comparison. Results from CFI Supplemental Questions were not found to be significantly valuable by the researcher and were not included in the findings.

Pilot Results

Subject 1 is a pilot and current certified flight instructor with approximately 620 hours actively teaching seven students. Subject 1 holds valid and current Commercial Multi Engine Land Certificate, CFI and CFII Single Engine Land Certificates, and is instrument rated.

Subject 2 is a pilot currently in training for a Commercial Single Engine Land certificate with approximately 230 hours. Subject 2 holds a valid and current Private Pilot Single Engine Land Certificate and is instrument rated.

Subject 3 is a pilot currently employed as a captain at a major airline in the United States with approximately 20,000 hours (3,000 in current type aircraft). Subject 3 holds a valid and current Airline Transport Pilot and Commercial Multi Engine Land Certificate, is instrument rated, and holds multiple type ratings for medium sized and large air carrier aircraft.

Subject 4 is a pilot currently in training for an instrument rating with approximately 150 hours. Subject 4 holds a valid and current Private Pilot Single Engine Land Certificate.

Subject 5 is a pilot currently employed as a first officer at a large airline in the United States with approximately 1,050 hours (24 in current type aircraft). Subject 5 holds a valid and current Airline Transport Pilot and Commercial Multi Engine Land Certificate, is instrument rated and holds a type rating for a medium sized air carrier aircraft.

Subject 6 is a pilot currently employed as a first officer at a large airline in the United States with approximately 2,300 hours (900 in current type aircraft). Subject 6 holds a valid and current Airline Transport Pilot and Commercial Multi Engine Land Certificate, is instrument rated and holds a type rating for a medium sized air carrier aircraft.

Subject 7 is a pilot currently employed as a first officer at a major airline in the United States with approximately 10,000 hours (5,000 in current type aircraft). Subject 7 holds a valid and current Airline Transport Pilot, Commercial Multi Engine Land, is instrument rated, and holds multiple type ratings for small regional aircraft and a large air carrier aircraft. Subject 7 also holds valid and current Certified Flight Instructor, Certified Flight Instructor Instrument, and Multi Engine Instructor certificates but does not actively instruct student pilots.

Results from Pilot (P) Questions are found in Table 10 followed by associated supplemental narrative information.

Table 10

Pilot Results

Subject	Question ID																										
	P1			P2			P3			P4			P5			P6			P7			P8			P9		
	T	I	C	T	I	C	T	I	C	T	I	C	T	I	C	T	I	C	T	I	C	T	I	C	T	I	C
1	3	2	1	2	2	1	3	2	1		2	1	2	2	1	3	2	2	1	1	1		1	1	3	2	1
2	3	2	2	2	2	1	3	2	1		2	1	3	2	1	3	2	2	2	1	1		2	1	3	2	1
3	3	2	2[a]	3	2	1	3	2	2	3	2	1	3	2	1	3	2	1	3	2	2	3	2	1	3	2	1
4	3	2	1	3	2	2	3	2	2		2	1	3	2	1	2	2	2		2	1			1	3	2	1
5	3	2	1	3	2	2	3	2	1	3	2	2	3	2	1	3	2	1	2	2	2	3	2	1	3	2	1
6	3	2	2	3	2	2	3	2	2	3	2	1	3	2	1	3	2	1	3	2	1	3	2	1	3	2	1
7	2	2	2[a]	1	2	1	3	2	1	3	2	1	3	2	1	3	2	1	3	2	1	3	2	1	3	2	1

Note. Blank spaces indicate that the question did not apply to the subject's flight experience and/or training. Subjects who received C2 ratings made specific mentions of verifying the correct runway or airport alignment.

[a] Subject specifically referenced the Comair 5191 Wrong Surface Departure prior to being prompted or asked about Comair 5191 or wrong surface events.

Pilot (P) Question Results Narrative.

Question P1: Has your training involved visually confirming, speaking, or otherwise verifying the runway number on the sign or pavement? Explain why you believe that is and/or why it may be helpful.

Subjects responding to P1 generally stated they verified the runway number in some way prior to takeoff in the form of a takeoff clearance.

Question P2: Has your training involved confirming or speaking the compass heading displayed on the PFD or magnetic compass? Explain why you believe that is and/or why it may be helpful.

Subjects responding to P2 typically reported they verified the compass was functioning and displaying the proper heading relative to the direction they were facing before or during taxiing but not relative to the runway heading during takeoff as a means of verifying the correct runway, except Subjects 4 and 5 who made specific mentions of using it to ensure they're departing the correct runway.

Question P3: Has your training involved setting the heading bug or course needle to runway heading before takeoff? Explain why you believe that is and/or why it may be helpful. All subjects reported that set a heading bug to runway heading prior to takeoff.

Subjects that were airline pilots reported that it was a required procedure, but referenced it was usually done in reference to their departure instructions, for example, if they were instructed by ATC to fly a certain heading on departure.

Question P4: Has your training involved programming an instrument approach to argument a visual approach or other similar technique? Explain why you believe that is and/or why it may be helpful.

Experience with this was typical only in airline pilot subjects, since student pilot and CFI subjects reported that their use of instrument approaches were to train on or learn certain instrument approach procedures and visual approaches are uncommon in IFR training.

Question P5: Has your training involved becoming familiar with your destination airport, including layout, proximity to other airports, runway configurations, geographical features like rivers and highways in the context of what you visually expect to see when you fly into the area? Explain why you believe that is and/or why it may be helpful.

When responding to P5, subjects said they examined airports for the runways they had, referring to runway numbers, but didn't necessarily examine other elements of airport geometry like taxiway layout or the features of the surrounding area. Subjects responding to P5 also stated they were generally concerned with the location of their parking spot once they landed. When asked about the importance of the technique in P5, most subjects said it was important to gain an understanding of the expected visual perspectives when arriving in the airspace around an airport.

Question P6: Has your training involved becoming familiar with runway lighting (i.e., visual approach lighting, visual glideslope lighting, instrument approach lighting

systems) at your destination airport? Explain why you believe that is and/or why it may be helpful.

Subjects responding to P6 generally reported that they familiarized themselves with instrument approach lighting to ensure they were able to meet approach minimums, make a legal approach. As indicated in Table 10, Subjects 1, 2, and 4 made specific comments that it aided them in ensuring they were landing on the correct runway or at the correct airport.

Question P7: Has your training or any of your flying involved late runway changes? Explain why you believe that is and/or why it may be helpful. Question P8: Has your training or any of your flying involved late approach changes? Explain why you believe that is and/or why it may be helpful.

The themes of late runway and late approach changes from P7 and P8 were not commonly experienced by pilots in training or giving training. Airline pilot subjects had varying degrees of experience with late approach and runway changes. Subject 4 indicated they tend to want to avoid them on account of the increased workload and task saturation they incur on the crew. Subject 5 stated that late runway and approach changes involving sidestep maneuvers were a topic of recent emphasis and simulator training at their airline to ensure they were proficient at the maneuver when asked to perform it by ATC. Subject 6 stated they are primarily focused on reprogramming the flight management computer in cases of late runway or approach changes.

Question P9: Has your training or any of your flying involved reviewing the ATIS? By listening, reading printed? What are you specifically listening for? Explain why you believe that is and/or why it may be helpful.

Subjects responding to P9 gave similar responses stating they were primarily listening for wind and altimeter in the ATIS. Subjects also stated they were listening for runways and approaches in use, but this was a response that was secondary in most subjects and had to be specifically asked to the remining subjects.

Training Department Staff Results

Subject 11 is a Chief Flight Instructor at a flight training organization that trains a variety of flight students. The organization conducts flight training for students pursing private pilot certificates, commercial pilot certificates (single and multi-engine land) as well as certified flight instructor, certified flight instructor instrument, and multi-engine instructor certificates. The organization does not provide airline transport pilot training. The results from the interview of Subject 11 are contained in Table 11.

Table 11

Training Organization Results

Question ID	Technique (T)	Importance (I)	Connection (C)
TD1	3	2	2
TD2	3	2	2
TD3		2	1
TD4	3	2	2
TD5	2	1	1
TD6		2	1
TD7	2	2	1
TD8	3	2	1
TD9	3	2	1
TD10	2	2	1

Note. TD3 Technique was not applicable since this organization conducts student training. It is not typical for student training to conduct visual approaches when operating under IFR since the purpose of the flight is to train to student on procedures such as instrument approaches. TD6 Technique is uncommon in this organization's flight training environment.

Training Department Staff Narrative.

Subject 11's representation of a large flight training organization produces a representation of the students trained at the program and the beliefs the subject has of how students are trained and what training topics the organization prioritizes. When Subject 11 received Technique ratings of 3, they reported that students should be conducting those techniques and they are required by policy. In all cases, Subject 11 stated it's often challenging to ensure all student pilots are complying, but procedures are a taught in an effort to make use of good practice. Subject 11 stated each of the techniques was important, but often emphasized other reasons for this. For example, in reference to TD4 (Does your training curriculum include becoming familiar with your destination airport, including layout, proximity to other airports, runway configurations, geographical features like rivers and highways in the context of what you visually expect to see when you fly into the area? Explain why that is or why it may be helpful), the subject stated that familiarity of the airport layout is important to enable the pilot to know where they are taxiing on the ground and where there parking spot is, and not so much about familiarizing the visual perspective of the airport from the air. In their response to TD9 (Does your training curriculum include airport signs markings and lights? Explain why that is or why it may be helpful), the subject focused on the importance of the students being able identify what lighting means, rather than where they expect to see lighting in reference to the airfield's geometry. When responding to TD10 (Does your training curriculum include risks associated with taxiways parallel to runways running the full length of the runway? Explain why that is or why it may be helpful), the subject discussed mainly the importance of knowing airport hotspots and ground-based runway incursion risks.

Air Traffic Control Results

Subject 8 an air traffic control specialist at a primary ATCT within a Class B airspace and became a Certified Professional Controller (CPC) at that facility in October 2021. Subject 8 indicated it takes anywhere from 7 months to approximately 3 years to become fully certified at the facility, depending on prior experience. Due to the complexity of traffic at this airport, new trainees at this facility must already be CPCs at a less complex ATCT prior to transferring to this facility. Training at the facility involves computer based instruction followed by a tower classroom course for a period of about one week then tower simulators on the ground and local positions and several hours of on-the-job familiarization, which involves monitoring and observing each position in the tower. Trainees then begin on-the-job training where they control real air traffic under close observation of another controller who is specially trained as an on-the-job training instructor (OJTI). Each position has a guideline for the number of training hours necessary for certification. Subject 8 has prior ATCT experience at one smaller facility prior to transferring to their current facility. Subject 8's facility is equipped with an ASSC system.

Subject 9 is an air traffic control specialist and supervisor at a small ATCT within Class D airspace and in close proximity to a larger Class C ATCT where they started in mid-2018. Subject 9 first became a Certified Professional Controller in July 2013 and reports that while training time varies greatly depending on prior experience at other facilities, it typically takes about 11 months to become a CPC at this facility. Training typically involves standard computer based instructor and classroom style instruction followed by on-the-job training where it takes about three to four months to complete flight data and ground control positions and four to six months to complete local control positions. Each position has training benchmarks where there a number of hours necessary for certification. This facility known as a VFR Tower and is not equipped with a certified tower radar display.

Subject 10 is an air traffic control specialist at a medium sized, primary ATCT within Class C airspace and was first certified in December 2020. Training at this facility involves standard computer based instruction followed by ground and local classroom training, simulators, or tabletop training. Trainees then complete on-the-job training on ground control for approximately four to five months on ground control and about six months on local control to become certified in the tower.

Question A1: What kind of training and experience do you personally have with wrong surface events at your facility or other facilities you've worked at?

Subjects 8 and 10 stated they did not receive any training on wrong surface events. Subject 9 did not detail any specific training they receive but that the training mostly has to do with "vigilance."

All three subjects demonstrated a high familiarity (F3) with the prompt and had either direct personal experiences with or direct personal knowledge of wrong surface events at or near their facility. Subject 8 and Subject 10 stated they had experience in observing or dealing with wrong airport landings specifically. Subject 8 stated that a nearby airport had a similar runway configuration and the controller at the airport of intended landing was unaware the aircraft had landed at the wrong airport until controllers from the other tower called to inquire about an unknown aircraft that had landed on the runway.

Subject 9 had experience with a wrong surface landing in which a pilot read back the correct runway when issued a landing clearance but landed on the wrong runway. Subject 9 also stated that they believed the FAA doesn't want to share or publish data related to wrong surface events.

Question A2: What kind of training do you receive specific to the ASDE-X/ASSC?

Subject 8 demonstrated a high familiarity (F3) with the prompt and said they were familiar with the Taxiway Arrival Prediction enhancement that was installed at their facility without being prompted on it specifically.

Subject 8 stated they completed a computer based training module on the ASDE-X/ASSC that was approximately 6 hours long and contained very outdated content they believe looked like it was from the mid-1990s. Subject 8 stated that while the training was "in-depth" it was not always detailed on the information they believed they needed and most experience with the ASDE-X or ASSC comes from actually interacting with the system on the ground or local control position at their facility.

Question A2 was not applicable to Subjects 9 or 10 since their facility is not equipped with an ASDE-X or ASSC.

Question A3: Have you ever experienced an automated alert on the ASDE-X/ASSC for a wrong surface event? If so, please describe.

Subject 8 explained that automated alerts for wrong surface were most common and their facility for helicopters flying through the taxiway arrival region an generating an alert. The ASDE-X and ASSC are capable of filtering certain type aircraft from alerting if the aircraft's type code is entered into the target's data block scratchpad on the Tower Display Workstation. Subject 8 stated that most of these results were false alerts due to a controller forgetting to put the helicopter type code in the scratchpad into the data block. Subject 8 stated that while false alerts are a nuisance, the controllers at their facility are trained to always react to alerts in accordance with the FAA Order JO 7110.65 even when they know the alerts are false or nuisance alerts. Subject described a known issue of "ghost targets" appearing on the ASDE-X/ASSC display at their facility for a period of approximately one year and it resulted in aircraft being issued go-around instruction despite no aircraft or vehicle actually existing. A "ghost target" is where the system display is depicting a false radar target or track and can occur for many reasons.

Subject 8 shared a story in which the ASDE-X was displaying a "ghost target" on one of the runways in advance of an arriving aircraft. The controller in this case scanned the runway for an aircraft or vehicle and did not observe one. Knowing this track would cause a safety logic alert to be triggered, the controller contacted the tower supervisor to request to disregard the alert. The supervisor required that an airport operations vehicle inspect the runway first before the controller could clear the aircraft to land and disregard the safety logic alert. Airport operations verified the runway was clear and the arriving aircraft landed without incident, triggering a safety logic alert that the controller disregarded.

Question A3 was not applicable to Subjects 9 or 10 since their facility is not equipped with an ASDE-X or ASSC.

General Question Results

Results for General Questions 1, 2, and 3 for all subjects are contained in Table 12 with associated narratives below. No substantial data was gathered from General Question 4.

Table 12

Wrong Surface Event Awareness General Question Familiarity and Deduction Findings

Subject	Question ID					
	G1		G2[a]		G3	
	F	D	F	D	F	D
Pilots (P)						
1	1	1	2	3	1	2
2	1	1	1	2	1	2
3	1	1	1	2	1	2
4	1	1	2	3	1	
5	2	1	2	3	2	1
6	1	1	3	3[b]	2[c]	2[c]
7	1	1	3	3	2	1
Air Traffic Controllers (A)						
8	2		3	3	3	
9	3	3	3	3	2	2
10	3	2	2	3	2	3
Training Department Staff (TD)						
11	-	-	2	2	1	

Note. G2 Deduction findings are reflective of whether the subject identified parallel offset thresholds in Interview Appendix A correctly. G3 Deduction findings were not applicable in cases where the subject had a high familiarity score (F3). Subject 4 did not guess on G3. Subject 8 did not guess on G1. Subject 11 was not asked G1 and did not guess on G3.

[a] Parallel Offset Runways are found at Dallas Love Field (31L & R) and at John F Kennedy International (4L & R, 22L & R, 13L & R).

[b] Subject 6 identified all Parallel offset runways correctly but runways 13L and 13R at JFK.

[c] Subject 6 had heard the term “wrong surface landing” only and correctly and accurately described this term.

Question G1: Are you familiar with the following phraseology a tower controller might use: "Not in sight runway (##), cleared to land"?

Most Pilot subjects had low familiarity results (F1) and stated that they had never heard the phraseology used. Pilot subjects either guessed this was used when a controller is unable to see an aircraft due to low visibility or instrument meteorological conditions, or the lack of a tower radar display, all of which were incorrect.

Question G1a (ATC Variation): Are you familiar with the phraseology contained in the FAA Order JO 7110.65 Chapter 3, Section 10, subparagraph 7: "Not in sight, runway (##) cleared to land"; Do you know when to use it? Have you used it or heard it used?
While Air Traffic Control subjects were generally more aware of the phraseology, none of the subjects had used it in a landing clearance. Subjects 8 and 10 were incorrect as to when the phraseology should be used. Subject 9 was correct but stated that they withhold the landing clearance in cases where they are unable to see the landing aircraft.

Question G2: Are you familiar with the term "parallel offset runway"? If so, describe what you think it is. ***Show the subject Interview Appendix A and ask the subject if they're able to identify a parallel offset runway.***

Pilot subjects generally expressed partial or little familiarity with the term parallel offset runways, which refers to parallel runways with offset thresholds. Pilot subjects that stated they were familiar with the term often struggled to describe or define it. Most often, Pilot subjects could not determine what "offset" referred to. When asked to identify parallel offset runways in the Interview Appendix A, many pilot subjects expressed doubts about their initial inclination as to what parallel offset runways were. Subject 5 correctly and accurately described parallel offset runways but admitted they were guessing. Subject 4 and 7 immediately and accurately identified parallel offset runways in Interview Appendix A quicker than any other subject, including ATC subjects.

All Air Traffic Control subjects demonstrated high familiarity and confidence in the definition and identification of parallel offset runways.

Subject 11 was similar to pilot subjects, stating they believed they knew what the term meant, but could not define what offset meant. When shown Interview Appendix A, Subject 11 exhibited doubts whether offset referred to the thresholds being offset, or the centerlines being offset with a terminal building or other infrastructure in the middle, as seen in Interview Appendix A, Sacramento International Airport.

Question G3: Have you ever heard of a wrong surface event (including wrong surface approach, wrong surface landing, or wrong surface departure)? If so, explain how and what you believe it is.

Pilot subjects were generally unfamiliar with the term “wrong surface event” or associated wrong surface departure, approach, or landing. Pilot subjects often partially described a wrong surface event accurately but would only accurately describe one type of event. For example, Subject 4 stated they were uncertain but believed it to be when aircraft takes off or lands on a surface they weren’t cleared for, like a runway or taxiway. Subject 7 initially appeared to demonstrate the most confidence in their familiarity of the term but stated that it was when an aircraft or vehicle is on the wrong surface and described something similar to ground or runway incursion.

Air Traffic Control subject's familiarity was similar to that of pilots. They were familiar with the term and could generally describe it more accurately as the surface that was not the intended landing or takeoff surface but gave incomplete descriptions. For example, Subject 9 only referred to wrong surface landings as wrong surface events.

Subject 11, the Training Department staff, was unfamiliar with the term "wrong surface event" but stated that it "made sense" that was the term used to describe the events they were asked about in the Event and Event Narrative questions.

Event and Event Narrative Results

Event and Event Narrative Results from all subjects are found in Table 13.

Table 13

Wrong Surface Event Title and Narrative Familiarity and Deduction Results – All Subjects

Subject	Question ID																	
	E1		E2		E3		E4		EN1		EN2		EN3		EN4		EN5	
	F	D	F	D	F	D	F	D	F	D	F	D	F	D	F	D	F	D
Pilots (P)																		
1	1	1	1	1	1	1	1	1	2	1	2	2	1	1	2	1	2	1
2	1	1	2	2	1	1	1	1	3		3		1	1	2[a]	1	3	
3	1	1	3		2	3	1	1	1	1	1	1	3		2	3	3	
4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	3		1	1
5	1	1	1	1	1	1	1	1	3		1	1	1	1	3		1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2
7	3		3		1	1	1	1	1		2		3		3		3	
Air Traffic Controllers (A)																		
8	3		1	1	1	1	1	1	2	1	2	1	1	1	3		1	1
9	3		3[b]		1	1	1	1	2[c]	1	3		1	1	2[a]	1	3	
10	3		3		1	1	1	1	2[c]	1	1	1	1	1	3		3	
Training Department Staff (TD)																		
11	1	1	3		1	1	1	1	2[c]	1	2	2	1	1	1	1	3	

Note. In cases where subjects were rated an F3 (highly familiar with the event and its details), deduction ratings were not applicable. In cases where subjects were rated an F1 or F2 a blank deduction rating indicates they did not guess. F represents Familiarity, D represents deduction (see Table 4).

[a] The subject recalled a similar taxiway landing event that occurred at another airport.

[b] The subject was initially unfamiliar but recalled the details once they asked about and were prompted with the location of the event (Kentucky).

[c] The subject recalled the wrong location but mentioned several other wrong airport landings

Chapter V: Discussion

Wrong surface events continue to be a threat to aviation safety and a topic of focus for the FAA. Broadly speaking, this research found several challenges and shortcomings in the classification of these events, the technology that has been adapted to detect and prevent them, and the level of awareness and understanding of wrong surface events among users of the NAS. Despite these issues, appropriately targeted human error prevention strategies can help to mitigate the likelihood of future events where pilots land, depart, or attempts to land or depart on a surface other than the intended landing surface or land at the wrong airport.

Context that Influences Pilot Actions in Wrong Surface Events

Targeting human error mitigation strategies required an examination for the context which influences pilot actions and contributes to the occurrence of wrong surface events. The events reviewed demonstrated similar themes of priming, plan continuation, expectation bias, failures in attention, and failures in memory storage. All four reports lacked consistency in their structure and information available, making the collation of reports about specific types of events for consistent analysis challenging. These findings are consistent with other findings in human factors and human error literature and research (Dekker, 2002, 2006; Reason, 2008; Wiegmann & Shappell, 2003). Despite this, the findings of all four events support existing human error literature in that appropriately designed and targeted technology, procedures, and training can aid in detecting and interruption of human error contributing to wrong surface events.

Many wrong surface events have been classified as runway incursions and examined in subsequent research on technological solutions to runway incursions as such. For example, the defining event in the taxiway landing of Delta 60 was listed in the NTSB report as "Miscellaneous/Other" (p. 1), while the wrong airport lading of Delta 2845 was listed as “runway incursion veh/AC/person” (National Transportation Safety Board, 2010, 2017, p. 1). This highlights a need for consistent classification of these events as wrong surface events by the FAA, NTSB, and other aviation industry stakeholders. Doing so will aid in training and education to increase awareness and to make research on these events and prevention strategies more beneficial.

The outcomes of these events can make it easy to blame the pilots or air traffic controllers for loss of situational awareness. All four accident or incident reports reviewed as a part of Research Question 1 had probable cause findings beginning with “the flight crew’s misidentification” (National Transportation Safety Board, 2017, p. 2, 2018, p. 68); “the flight crew’s failure to identify” (National Transportation Safety Board, 2010, p. 2); or “the flight crew’s failure to use available cues and aids to identify” (National Transportation Safety Board, 2007, p. 105). While the reports include additional contributing factors, it was only after multiple complete readthroughs of these reports that context was able to be extracted to answer Research Question 1. Important context contributing to human error can be lost without a thorough analysis of these incident and accident reports, making human error research challenging at best.

The Comair 5191 accident report’s probable cause and contributing factors list two assignments of blame to the pilots for failing to identify the aircraft’s location on the airport surface and one to the FAA for failing to require all runway crossings be authorized by specific and individual ATC clearances. The Comair 5191 accident report is the oldest of those examined and is more reflective of a dated view of human error in which the humans are the source and cause of all failure. New views on human error reflect more on the system or environment being poorly suited for humans, which this framework acknowledges are imperfect by nature, to detect and correct errors. Under that view, numerous themes in wrong surface departures were identified through both the accident of Comair 5191 and through similar events included in the report by the NTSB. Complex airport geometry, darkness, lighting outages, lack of other air traffic to reference, construction, and lack of surface painted markings were representative of environmental pitfalls that exhibited themes of plan continuation and priming. Some of these issues have been addressed since the Comair 5191 accident, supporting the finding that targeted human error mitigation strategies can aid in the prevention of error contributing to wrong surface events. These include: the requirement surface painted hold position signs and enhanced taxiway centerline markings and the reconstruction of LEX's runways to disconnect the thresholds that were in close proximity. Even after the crash of Comair 5191, wrong surface departures continue to occur from runway with thresholds in close proximity and from in the form of wrong direction intersection departures. While results in Table 13 indicate a higher level of awareness of the Comair crash by Event Narrative (EN) among subjects, the fatal outcome of the event is likely a leading reason for that.

The wrong surface approach of Air Canada 759 and wrong surface landing of Delta 60 identified similar human error themes involving changes in the runway assigned or runway closures, multiple parallel surfaces including runways and taxiways that could give the appearance of the intended landing surface, and visual lighting cues that supported the crew's belief that they were aligned with the correct surface.

Wrong airport landings are a continuing challenge to address. As found in Table 7, the close proximity of the airports contributed to both the flight crew and radar approach controller to believe they were in a position to land at the correct airport. The findings demonstrate the risk visual approaches have to contributing to wrong airport landings when no automation is used to augment the approach. Airports in close proximity experience similar prevailing winds, resulting in the construction of similarly configured runways at different airports, another contextual factor identified in Table 7.

Limitations of the Findings in Research Question One

The main limitation of the findings related to contextual factors the influence pilots' actions in wrong surface events is that they came from a small sample size of only 4 events. Reports were not reviewed with any specific model or classification system. However, as previously mentioned, examination of human factors and human error classification is challenging as most reports lack consistency in their structure, limiting the examination to one single classification structure may result in certain context not being applicable to that structure. Since this research question involved the complete reading of multiple lengthy incident an accident reports, it's possible some context could have been missed, however since the goal of the research question was to examine what context could be identified and the broader goal of this research was to aid in the targeted prevention of human error that contributes to wrong surface events, there is great value in identifying the recurring themes in these events.

Impacts of Flight Deck and ATCT-Based Technology on Wrong Surface Events

Technological solutions to mitigate the occurrence of wrong surface event function by alerting a human in a position to interrupt a wrong surface event. The system must be designed to alert to a given event when conditions indicating the likely occurrence of a wrong surface are met with little to no false or nuisance alerts.

The two main categories for technological solutions to wrong surface events are flight deck-based systems and air traffic control tower-based surface safety systems. Neither category of technology was originally developed or built for the purpose of preventing wrong surface events. Instead, both have been adapted from their original purpose to detect and alert to runway incursions to aid in the prevention of incidents and accidents. The incident and accident reports review in Research Question identified weaknesses in surface safety systems. Therefore, it can be concluded that the theory behind the adaptation of surface safety systems for detecting and alerting to wrong surface events is sound. It is assumed that a properly designed flight deck or ATCT-based technology that alerts to a wrong surface event would prevent the occurrence of that event by alerting pilots or alerting air traffic controllers who would inform pilots, allowing the pilots to correct the error. However, in practice, it can be challenging to anticipate what those parameters might be, required a retroactive review of events to ensure they address the error context appropriately. ATCT-based technology, for example, was originally designed as a runway incursion prevention tool, and not for detecting and alerting controllers to possible wrong surface events. Adapting technology after its original conceptual design may result in unintended shortcomings.

Both ATCT and flight deck-based system require the appropriate parameters to be configured or to exist in order to effectively generate alerts. In the case of the Air Canada 759 Taxiway Overflight incident, the San Francisco ATCT was equipped with an ASSC that had the additional feature of an extended runway centerline extended out to 2.5 nautical miles, which provided a zoomed in perspective that most ATCTs didn’t have, enabling the controller to detect the misalignment potentially visually on the ASSC display. However, the incident aircraft’s track dropped due to a limitation in the system’s depiction area known as the coverage cone (National Transportation Safety Board, 2018). This eliminated the only way the air traffic controller would have of accurately determining the aircraft’s incorrect lateral alignment with the taxiway instead of the runway. After the development of Taxiway Arrival Prediction, the efficacy of ASDE-X and ASSC at preventing wrong surface approaches and landings to taxiways should serve as a model for other technological tools to aid in human error prevention of all types of wrong surface events.

Despite a logical application of surface safety systems to some types of wrong surface events, both categories of system each have several shortcomings in their use and design that prevents them from being a consistently reliable tool for prevention of wrong surface events. Flight deck-based systems are likely the most effective at correctly detecting and alerting to wrong surface events in a timely manner and to the flight crew, who are the only people capable of controlling the aircraft to avert and prevent the occurrence of wrong surface events. However, flight-deck based alerting systems would have to be installed on all aircraft operating in the national airspace system in order to effectively prevent wrong surface events.

While many airlines have installed such systems on their aircraft, thereby reducing the likelihood of the most severe occurrences involving high capacity passenger-carrying aircraft, general aviation aircraft such as small and medium sized business jets and most propeller driven aircraft face a high cost barrier to installing and using such a system. Unless the FAA were to create a policy requiring surface safety systems capable of detecting and alerting to wrong surface events to be installed on aircraft, wrong surface events will continue to occur among aircraft without the technology. Similar to the requirement for aircraft to be equipped with ADS-B, the proposed rulemaking would likely face significant opposition due to the high cost and take years to implement.

Air traffic control tower-based surface safety systems are particularly robust due to the redundancy of radar and aircraft position and movement data from multiple sources, fusing this into a single picture displayed in air traffic control towers capable of safety logic processing. The primary limitation is the cost and limited installation locations of systems at a limited number of ATCT's. It's unclear how much an ASSC system and all the components cost to install, but the limited number of ATCT's equipped with them suggest that the FAA has to prioritize the installation of these systems in a cost-benefit strategy by concentrating on the airports with the most air traffic operations takeoffs and landings (see Table 1). Since only a small number of facilities are equipped with these systems, their impact on reducing occurrence of wrong surface events is severely limited.

Limitations of the Findings in Research Question Two

Research on surface both flight deck-based and air traffic control tower-based surface safety system has yet to expand beyond runway incursions. As systems have evolved to detect and alert to various types of wrong surface events, more research should be done on their efficacy for preventing such events. This research question's methodology examined a limited number of ATCT and flight-deck based technologies that were found to have capabilities that enabled them to detect and alert to wrong surface events. This was partially due to the availability of data and information from the FAA. A FOIA request was made in April 2022 was largely unable to be fulfilled due to the cost to obtain the information. Additionally, portions of the request related to the ASDE-X were exempt from a FOIA request since the documents were from the manufacturer of the ASDE-X. The exemption protects trade secrets and commercial or financial information obtained from a person that is privileged or confidential.

Awareness of Wrong Surface Events Among Aviation Professionals

Subject interviews provided valuable context and perspective of different aviation professionals awareness of wrong surface events, risks, and potential prevention strategies.

Currently, FAA strategies of training and education fall well short of meaningful progress toward the reduction of wrong surface events. While the FAA research, data, information, and analysis on these events is comprehensive, it’s unlikely pilots are seeking out additional information on these types of incidents.

In general, there was a low level of awareness of wrong surface events and their risks among all subjects. This was driven by a low level of familiarity with the term “wrong surface event,” with air traffic control subjects tending to have more exposure to the term understanding of it. While some subjects were able to correctly or accurately describe or deduce what the term meant towards the end of their interview, no subject could accurately describe all elements of the definition. Typically, subjects were able to only describe a wrong surface landing, for example. It can therefore be concluded that the term “wrong surface event” is not commonly used or understood by many aviation professionals. Without an understanding or awareness of the term, it’s likely challenging for prevention strategies to be targeted. It can be concluded that the FAA’s usage of the term is widely ineffective.

Generally, subjects that were air traffic controllers demonstrated a more extensive knowledge of specific wrong surface events. This was likely due to the fact that they are employed by the FAA and receive more exposure to FAA guidance and training related to wrong surface events. Remarkably, all air traffic control subjects had personal experience or direct knowledge of a wrong surface event at their facility. Most often and unexpectedly, it was a wrong airport landing which suggests wrong airport landings occur more frequently than existing information may lead some to believe. Findings from air traffic control subject interviews also support the findings from Research Question 1 suggesting air traffic controllers are often not in a position to be able to detect a wrong surface approach or landing due to the viewing angle and depth perception limitations of the runways and taxiways, highlighting the importance for technological prevention mechanisms like the Taxiway Arrival Prediction on the ASDE-X and ASSC. Both the findings from the review of historical wrong surface event reports in Tables 5, 6, 7, and 8, results from subject interviews also found that pilots of aircraft are in better positions to interrupt wrong surface events than air traffic controllers based on their available techniques for detection and the fact that only the pilot or pilots flying must react to correct an event.

This research found that subjects demonstrated a higher level of familiarity with wrong airport landings compared to other types of wrong surface events, which may be more highly scrutinized due to their outcome (see Table 13, EN 1 and EN2). Incidents of aircraft landing at the wrong airport tend to be covered more heavily in the media. This conclusion is supported by existing human error literature (Dekker, 2006; Reason, 2008). In addition, subjects demonstrated higher levels of familiarity of the Comair crash, which was the oldest incident they were asked about and the only incident involving fatalities. Two subjects made specific mentions of it when asked about confirming the runway number on the sign or pavement prior to departure (See Table 10, P1). This also suggests that pilots are more aware of human-error related events and prevention strategies when the outcome is more severe.

Most subjects were largely unfamiliar with the phraseology contained in Question G1 (Not in sight, runway (##), cleared to land). Air traffic control subjects stated the phraseology was not commonly used. Only one subject actually knew the proper time to use the phraseology, which according to the FAA Order JO 7110.65Z says it should be used “when an arriving aircraft reports at a position where he/she should be seen but has not been visually observed” (p. 3-10-8) and that observing the aircraft on a certified tower radar display satisfies the requirement (Federal Aviation Administration, 2022d). Subject 7 stated that they were entirely unfamiliar with this “nonstandard phraseology” due to it not being contained in the FAR/AIM (Federal Aviation Regulations/Aeronautical Information Manual), despite it being phraseology available for controllers to use. Since the FAA (2021b) suggests this phraseology may indicate a wrong airport landing could be occurring results from this research found that subjects are largely unaware of what the phraseology means or could indicate, it can be concluded that this strategy is ineffective at indicating the occurrence of a wrong airport landing since pilots would not understand what it means. The lack of understanding as to what this phraseology means is synonymous with the theme of an overall lack of education and awareness among aviation professionals on the topic of wrong surface events and is an ineffective prevention strategy.

While all the pilot subjects interviewed performed techniques that could aid in the prevention of a wrong surface event, they were generally unable to connect the usage and importance of those techniques to the risk of wrong surface events (see Table 10). Some of the subjects modified techniques identified as potential contributing factors to wrong surface events. For example, Subject 6 reported that during late runway and approach changes, they are typically focused on reprogramming the flight management computer, a contextual factor identified as contributing to the Air Canada 759 wrong surface approach incident. Subject 3, the most experienced pilot subject interviewed, stated they tend not to accept late runway and approach changes due to the risks associated with increased workload during a critical phase of flight, a method of practice which may contribute to a decreased risk of wrong surface approaches and landings. Subject 7 also suggested training and education related to late runway changes should focus on encouraging pilots to be assertive and not accept a clearance which may involve increased risk due to higher workload. While these late sidestep maneuvers may aid in the flow of air traffic into a busy airport or result in a shorter taxi, it introduces a higher risk of an occurrence of a wrong surface event.

The only subject interviewed from a training department or organization was able to provide critical information on the awareness and training that exists for pilot training programs and therefore for pilots training in those programs and going on to fly in the NAS. The results in Table 11 suggest that little to no training is conducted at this specific organization to address the risks of wrong surface events. While some risks of wrong surface events may not be prevalent in a flight training environment, such as the risk of numerous fatalities as would occur in an airline accident, the training environment where pilots are earning their certificates to fly privately and commercially present an opportunity to address awareness and risks of wrong surface events earlier in the pilot's flying career to potentially reduce the likelihood of an occurrence later.

Limitations of the Findings in Research Question Three

The conclusions that can be drawn from subject interviews are limited by the instrument design and small population sample. None of the results gathered were assessed for statistical significance. However, subject interviews were meant to be exploratory in nature and achieved the result which offered findings to support a conclusion from the other two research questions.

Recommendations

The FAA, NTSB, airlines, flight training programs, and other aviation industry stakeholders should adopt the term wrong surface event universally and separate this term from runway incursions to separate the context unique to when an aircraft lands or departs from an unintended surface.

Research indicates wrong surface events, especially in Research Question 2 is heavily limited by the unwillingness of the FAA to share data on wrong surface events, research that is independent from the FAA will likely continue to be a challenge. As such, it is recommended to the FAA to make the data on wrong surface events more publicly available for the purposes of advancing aviation safety through academic exploration research.

With improvements in technology, several types of wrong surface events continue to be an unaddressed risk in the NAS. Companies that develop technology aiding in preventing wrong surface events should ensure their systems are capable of detecting and alerting to all types of wrong surface events, such as wrong runway intersection departures. This technology should be installed on more aircraft to provide additional means of human error prevention. Since many technological systems for error prevention are developed or implemented in direct response to a fatal accident, it is critical systems which currently exist be installed and utilized before a deadly wrong surface event occurs. Many existing systems installed on aircraft currently have the capability to detect and alert to a wide variety of wrong surface events. Aircraft owners and operators should take action to upgrade aircraft safety systems to aid in the prevention of human error contributing to wrong surface events.

A key finding from the results of all three research questions was that air traffic controllers are generally not in good positions to detect and interrupt wrong surface events due to the angles and depth perceptions the view from the control tower has of runways, taxiways, and final approach courses, referred to as the parallax. The ASDE-X and ASSC is installed at a small number of airports and while it was found to be a highly effective tool for detecting and alerting to certain wrong surface events. However, it is limited by the fact that it's only installed at 41 facilities in the NAS and no evidence was found that the system's safety logic alerting functions don’t detect and alert to wrong surface departures and can’t alert to wrong airport landings by the nature of the system’s functionality. Accordingly, it is recommended that human error prevention training strategies be targeted toward pilots, who are in the best position to prevent catastrophic outcomes resulting from human error contribution.

Most importantly, the FAA should make greater efforts to ensure pilots are better trained and aware of the risks and hazards associated with landing, departing, or attempted to land or depart on a surface not intended for landing or takeoff. Findings indicate pilots have a relatively low level of awareness of these events, it stands to reason that is the greatest opportunity for improvement in terms of utilizing training as a prevention strategy. Wider usage of the term wrong surface event may help, it is possible it would require a regulatory requirement to train pilots on this risk before measurable decreases in wrong surface events are realized.

Further Research

Researching wrong surface events will likely continue to be a challenge under the current structure of aviation safety and human error analysis tools and framework. The structure of aviation safety incident and accident reports struggle to clearly identify and describe the root cause of a wrong surface event, often labeling as pilot error.

The relatively low level of awareness among pilots and flight training organization presents an opportunity for more research. Many airlines participate in Flight Operations Quality Assurance (FOQA) data programs. It is possible for data event parameters to be created using the same fundamental concepts of an ASDE-X or ASSC alert region to detect and capture events of possible wrong surface approaches to taxiways or other surfaces, wrong surface departures, and wrong airport landings to gather a larger data pool of specific locations such as airports or certain surfaces with the highest prevalence of wrong surface events.

Opportunities for a more in-depth mixed methods study on awareness of wrong surface events among aviation professionals could be adapted from the initial constructs in Research Question 3. Since conclusions were limited by the small sample size and exploratory nature of the methodology, a larger, more detailed survey tool could be developed and a study with more subjects could be conducted to provide statistically significant conclusions.

Further quantitative research could be done if the FAA were to share more numerical data with researchers wishing to examine it. Until then, gathering quantitative data for analysis will be cumbersome and expensive to accomplish.

Conclusion

The purpose of this research was to understand how human error contributes to wrong surface approach and assess the efficacy and opportunity for targeted prevention strategies. The research questions and qualitative findings successfully applied the human error framework to identify context contributing to pilot actions in historical wrong surface events reports, assessed known human error prevention strategies by examining current functionality, and efficacy of technologies, and examined current awareness and training of aviation professionals relating to wrong surface events. The findings also identified opportunities for improving pilot education and training to increase awareness of the risks and hazards associated with wrong surface events and opportunities for future research on wrong surface events to add to the relatively small body of research and provide critical insight into a serious and ongoing aviation safety issue in the NAS.

References

Antuano, M. J., & Mohler, S. R. (1988). Geographic disorientation: Landing at the wrong airport. *Accident Prevention*.

Bazargan, M., Fleming, K., & Subramanian, P. (2002). A simulation study to investigate runway capacity using TAAM. *Proceedings of the Winter Simulation Conference*, *2*, 1235–1243.

Berge, M. E., Haraldsdottir, A., & Scharl, J. (2006). The Multiple Runway Planner (MRP): Modeling and Analysis for Arrival Planning. *2006 Ieee/Aiaa 25TH Digital Avionics Systems Conference*, 1–11. https://doi.org/10.1109/DASC.2006.313684

Cardosi, K. (2001). Controller and pilot error in surface operations. *4th USA/Europe Air Traffic Management R&D Seminar*, 5–9.

Dekker, S. (2002). *The field guide to human error investigations*. Ashgate.

Dekker, S. (2006). *The field guide to understanding human error*. Ashgate.

Ebermann, H.-J., & Scheiderer, J. (2013). *Human factors on the flight deck: Safe piloting behaviour in practice*. Springer.

Federal Aviation Administration. (2007). *Aviation Safety Information and Sharing: Wrong Runway Departures*. https://www.asias.faa.gov/apex/f?p=100:8:::NO::P8_STDY_VAR:3

Federal Aviation Administration (Director). (2018a, July 25). *Wrong Surface Landing*. https://www.youtube.com/watch?v=5II-s_j35cI

Federal Aviation Administration. (2018b, August 30). *FAASTeam Notices*. FAASafety.Gov. https://www.faasafety.gov/SPANS/noticeView.aspx?nid=7994

Federal Aviation Administration. (2018c). *ASDE-X Taxiway Arrival Prediction Implementation at Atlanta Hartsfield International Airport*.

Federal Aviation Administration. (2018d, September 25). *Surface Safety: Wrong-Surface Events | Federal Aviation Administration*. Surface Safety Events. https://www.faa.gov/newsroom/surface-safety-wrong-surface-events

Federal Aviation Administration. (2018e). *ASDE-X Taxiway Arrival Predictions: Implementation at Dallas/Fort Worth International Airport*.

Federal Aviation Administration. (2019). *ASDE-X Taxiway Arrival Predictions: Implementation at George Bush International Airport*.

Federal Aviation Administration (Director). (2020a, August 5). *From The Flight Deck—Wrong Direction Intersection Takeoffs*. https://www.youtube.com/watch?v=FET0oUgClOI

Federal Aviation Administration. (2020b, August 18). *Runway Incursions | Federal Aviation Administration*. https://www.faa.gov/airports/runway_safety/resources/runway_incursions

Federal Aviation Administration (Director). (2021a, January 8). *From the Flight Deck—Wrong Surface Landings*. https://www.youtube.com/watch?v=n5fyP8FkZ5E

Federal Aviation Administration (Director). (2021b, February 19). *From the Flight Deck—Wrong Airport Landings*. https://www.youtube.com/watch?v=nrbzhBn_HnU

Federal Aviation Administration. (2021c). *ASSC Taxiway Arrival Predictions: Implementation at Louis Armstrong International Airport*.

Federal Aviation Administration. (2021d). *National Airspace System (NAS) Subsystem Level Specification for Surveillance and Broadcast Services Program: Airport Surface Surveillance Capability (ASSC)*.

Federal Aviation Administration. (2022a). *ASSC Taxiway Arrival Predictions: Implementation at San Fransisco International Airport*.

Federal Aviation Administration. (2022b, October 31). *Airport Surface Detection Equipment, Model X (ASDE-X) | Federal Aviation Administration*. https://www.faa.gov/air_traffic/technology/asde-x

Federal Aviation Administration. (2022c). *Aeronautical Information Manual—AIM*. U.S. Dept. of Transportation, Federal Aviation Administration. https://www.faa.gov/air_traffic/publications/atpubs/aim_html/

Federal Aviation Administration. (2022d). *Order JO 7110.65Z - Air Traffic Control with Change 1, 2, & 3*. U.S. Dept. of Transportation, Federal Aviation Administration. https://www.faa.gov/documentLibrary/media/Order/7110.65Z_ATC_Bsc_w_Chg_1_2_and_3_dtd_11-3-22.pdf

Federal Aviation Administration. (2023a, February 7). *ADS-B Airport Surface Surveillance Capability (ASSC) | Federal Aviation Administration*. https://www.faa.gov/air_traffic/technology/adsb/atc/assc

Federal Aviation Administration (Director). (2023b, February 27). *Runway Safety Pilot Simulator: Wrong Surface Event Part 1: Pilot*. https://www.youtube.com/watch?v=ZlLLEr-AVuQ

Georgilidakis, S. (2022, March 30). INCIDENT: Delta A220 Takeoff Goes Wrong (almost)! *Mentour Pilot*. https://mentourpilot.com/incident-delta-a220-takeoff-goes-wrong-almost/

Glesne, C. (2016). *Becoming qualitative researchers: An introduction* (Fifth edition). Pearson.

Hartwig, M. (2020, November 10). U.S. Air Force Plane Lands at Commuter Airport by Mistake. *Alt_driver*. https://altdriver.com/news/c17-landing-at-wrong-airport/

Isaac, A. R. (1999). *Air traffic control: Human performance factors*. Ashgate.

Jin, L., & Lo, E. (2017). A Study of Accidents and Incidents of Landing on Wrong Runways and Wrong Airports. *19th International Symposium on Aviation Psychology*, 107–112.

Johnson, M. E., Zhao, X., Faulkner, B., & Young, J. P. (2016). Statistical models of runway incursions based on runway intersections and taxiways. *Journal of Aviation Technology and Engineering*, *5*(2), 3.

Joslin, R. (2014). Validation of New Technology Using Legacy Metrics: Examination of SURF-IA Alerting for Runway Incursion Incidents. *Journal of Aviation Technology and Engineering*, *4*(1). https://doi.org/10.7771/2159-6670.1096

Kirwan, B., Rodgers, M. D., & Schäfer, D. (2005). *Human factors impacts in air traffic management*. Ashgate.

Lancaster, J. A., Khatwa, R., Conner, K. J., & Glover, J. H. (2010). Flight simulator evaluation of an Airport Surface Display with Indications and Alerts (SURF IA). *29th Digital Avionics Systems Conference*, 4-D.

Landry, S. J., Chen, X. W., & Nof, S. Y. (2013). A decision support methodology for dynamic taxiway and runway conflict prevention. *Decision Support Systems*, *55*(1), 165–174.

Li, G., Baker, S., Lamb, M., Grabowski, J., & Rebok, G. (2002). Human factors in aviation crashes involving older pilots. *Aviation, Space, and Environmental Medicine*, *73*, 134–138.

Liang, M., Delahaye, D., & Marechal, P. (2018). Conflict-free arrival and departure trajectory planning for parallel runway with advanced point-merge system. *Transportation Research Part C: Emerging Technologies*, *95*, 207–227.

Ludwig, D. (2007). Direct alerting to the cockpit for runway incursions. *2007 IEEE/AIAA 26th Digital Avionics Systems Conference*, 5.A.6-1-5.A.6-10. https://doi.org/10.1109/DASC.2007.4391930

Maxwell, J. A. (2013). *Qualitative research design: An interactive approach* (3rd ed.). Sage Publications.

National Transportation Safety Board. (2007). *Attempted Takeoff From Wrong Runway Comair Flight 5191* (NTSB/AAR-07/05; p. 161). https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR0705.pdf#search=ComAir%205191

National Transportation Safety Board. (2010). *Delta 60 Aviation Incident Final Report* (OPS10IA001). https://skybrary.aero/sites/default/files/bookshelf/1692.pdf

National Transportation Safety Board. (2017). *Delta 2845 Aviation Incident Final Report* (DCA16IA200). https://reports.aviation-safety.net/2016/20160707_A320_N333NW.pdf

National Transportation Safety Board. (2018). *Taxiway Overflight Air Canada Flight 759* (NTSB/AIR-18/01; p. 93). https://www.ntsb.gov/investigations/AccidentReports/Reports/AIR1801.pdf

Ngai, E. (2021, October 26). *Wrong Surface Events* [Personal communication].

Office of Inspector General. (2014). *FAA Faces Significant Obstacles in Advancing the Implementation and Use of Performance-Based Navigation Procedures* (Audit Report AV-2014-057). US Department of Transportation. https://www.oig.dot.gov/sites/default/files/FAA%20PBN%20Flight%20Procedures%20Audit%20Report%5E06-17-14.pdf

Reason, J. T. (1997). *Managing the risks of organizational accidents*. Ashgate.

Reason, J. T. (2008). *The Human Contribution: Unsafe Acts, Accidents and Heroic Recoveries*. Ashgate.

Riley, C., Welch, W. M., & Jansen, B. (2014, January 12). *Southwest suspends pilots after landing at wrong airport*. USA TODAY. https://www.usatoday.com/story/travel/flights/2014/01/12/plane-lands-wrong-branson-airport/4447699/

Schonefeld, J., & Moller, D. P. F. (2012). Runway incursion prevention systems: A review of runway incursion avoidance and alerting system approaches. *Progress in Aerospace Sciences*, *51*, 31–49. https://doi.org/10.1016/j.paerosci.2012.02.002

Stanton, N. A., Harris, D., Salmon, P. M., Demagalski, J. M., Marshall, A., Young, M. S., Dekker, S., & Waldman, T. (2006). Predicting design induced pilot error using HET (human error template)—A new formal human error identification method for flight decks. *Aeronautical Journal*, *110*(1104), Article 1104.

Vaddi, V., Sweriduk, G., Cheng, V., Kwan, J., Lin, V., & Nguyen, J. (2011). Concept and requirements for airport surface conflict detection and resolution. *11th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference, Including the AIAA Balloon Systems Conference and 19th AIAA Lighter-Than*, 7050.

Vernaleken, C., Mihalic, L., Güttler, M., & Klingauf, U. (2006). A fresh look at runway incursions: Onboard surface movement awareness and alerting system based on SVS. *Enhanced and Synthetic Vision 2006*, *6226*, 202–217. https://doi.org/10.1117/12.664897

Vernaleken, C., Urvoy, C., & Klingauf, U. (2007). Prevention of runway incursions due to closed runways or unsuitable runway choices by enhanced crew situational awareness and alerting. *Enhanced and Synthetic Vision 2007*, *6559*, 189–200. https://doi.org/10.1117/12.719573

Walters, S. (2022a, July 8). *FOIA 2022-06437 Response Part 1 of 3* [Personal communication].

Walters, S. (2022b, July 8). *FOIA 2022-06437 Response Part 2 of 3* [Personal communication].

Walters, S. (2022c, July 8). *FOIA 2022-06437 Response Part 3 of 3* [Personal communication].

Wiegmann, D. A., & Shappell, S. A. (2003). *A human error approach to aviation accident analysis: The human factors analysis and classification system*. Ashgate.

You can see ATC (Director). (2022, March 30). *WRONG DIRECTION for takeoff | Delta Airbus A220-100 | Chicago, ATC*. https://www.youtube.com/watch?v=FDFRYlWF21U

Young, S. D., & Jones, D. R. (2001). Runway incursion prevention: A technology solution. *ANNUAL INTERNATIONAL AIR SAFETY SEMINAR*, *54*, 221–238.

Appendix

Awareness of Wrong Surface Events Among Aviation Professionals

Consolidated Interview Instrument

Air Traffic Control Specialists

Question ID	Topic/Question	Purpose	Means of Measure
BA1	Date in which the subject earned their Certified Professional Controller (CPC) rating	Establishes when the subject became a fully certified air traffic controller and was no longer a trainee	Year or month and year
BA2	Date in which the subject earned their On-the-Job Training Instructor rating (if applicable)	Establishes when the subject became a training instructor for other air traffic control specialist trainees	Year or month and year
BA3	Start date at their current facility	Establishes how long the subject has been working and training at their current air traffic control tower and studying, becoming familiar with, or otherwise observing conditions at that airport	Year or month and year
BA4	Describe the phases of training, what they involve, and how long they take	Provides background on what training the controller receives at their facility to enable them to perform the duties of their job relative to the nuances of their specific airfield and ATC facility	Narrative of training phases
G1a	Are you familiar with the phraseology contained in the FAA Order JO 7110.65 Chapter 3, Section 10, subparagraph 7: "Not in sight, runway (##) cleared to land"; Do you know when to use it? Have you used it or heard it used?	Establishes familiarity and usage of phraseology the FAA suggests to pilots that may suggest a wrong airport landing is occurring.	T1, T2, T3 C1, C2 F1, F2, F3 D1, D2

Question ID	Topic/Question	Purpose	Means of Measure
G2	Are you familiar with the term “parallel offset runway”? If so, describe what you think it is. *Show the subject Interview Appendix A and ask the subject if they’re able to identify a parallel offset runway.*	Assesses familiarity with a term used to describe airport geometry that the FAA has identified as contributing to wrong surface events. Examines the subject’s ability to identify that airport geometry.	F1, F2, F3 D1, D2
A1	What kind of training and experience do you personally have with wrong surface events at your facility or other facilities you’ve worked at?	Establishes the subject’s familiarity with wrong surface events and what education the FAA may provides	F1, F2, F3
A2	What kind of training do you receive specific to the ASDE-X/ASSC?	Provides understanding of the interaction (Liveware-Software-Hardware) an air traffic controller may have with technology that is being utilized to detect and alert to wrong surface events	F1, F2, F3 Narrative explaining the details of training or experience
A3	Have you ever experienced an automated alert on the ASDE-X/ASSC for a wrong surface event? If so, please describe.	Provides context and details surrounding a detection of a wrong surface event by technology examined in this research and assesses the impacts of that technology on the event and the air traffic controller interfacing with the technology.	Narrative explaining the details of the experience

Pilots

Question ID	Topic/Question	Purpose	Means of Measure
BP1	Total flight hours	Establishes level of flight experience	Number of logged flight hours
BP2	Ratings and Endorsements held	Establishes level of flight training including topics trained on and level of experience	Types of ratings or endorsements

Question ID	Topic/Question	Purpose	Means of Measure
BP1	Total time in type (Part 121 Airline Transport Pilot Only)	Establishes experience level in specific aircraft & familiarity with any aircraft-specific situational awareness tools, including flight deck-based alerting systems.	Number of logged flight hours
BP2	Captain or First Officer (Part 121 Airline Transport Pilot Only)	Establishes experience level at airline and in aircraft.	Captain or First Officer
P1	Has your training involved visually confirming, speaking, or otherwise verifying the runway number on the sign or pavement? Explain why you believe that is and/or why it may be helpful.	Wrong surface departure prevention strategy. Establishes awareness of risks of wrong surface departures and a strategy to prevent them.	T1, T2, T3 I1, I2 C1, C2
P2	Has your training involved confirming or speaking the compass heading displayed on the PFD or magnetic compass? Explain why you believe that is and/or why it may be helpful.	Wrong surface departure prevention strategy. establishes awareness of risks of wrong surface departures and a strategy or technique that may help prevent them.	T1, T2, T3 I1, I2 C1, C2
P3	Has your training involved setting the heading bug or course needle to runway heading before takeoff? Explain why you believe that is and/or why it may be helpful.	Wrong surface departure prevention strategy. establishes awareness of risks of wrong surface departures and a strategy or technique that may help prevent them.	T1, T2, T3 I1, I2 C1, C2
P4	Has your training involved programming an instrument approach to argument a visual approach or other similar technique? Explain why you believe that is and/or why it may be helpful.	Wrong surface approach and landing prevention strategy. Establishes awareness of risks of wrong surface approaches and landings and a strategy technique that may help prevent them.	T1, T2, T3 I1, I2 C1, C2
P5	Has your training involved becoming familiar with your destination airport, including layout, proximity to other airports, runway configurations, geographical features like rivers and highways in the context of what you visually expect to see when you fly into the area? Explain why you believe that is and/or why it may be helpful.	Wrong airport landing prevention strategy. Establishes awareness of techniques that may aid in creating an expected visual context and perception of the area around an airport such as associated airport geometry and other similar configured nearby airports.	T1, T2, T3 I1, I2 C1, C2

Question ID	**Topic/Question**	**Purpose**	**Means of Measure**
P6	Has your training involved becoming familiar with runway lighting (i.e., visual approach lighting, visual glideslope lighting, instrument approach lighting systems) at your destination airport? Explain why you believe that is and/or why it may be helpful.	Wrong surface approach and landing prevention strategy. Establishes awareness of techniques that may aid in creating an expected visual context and perception of the area around an airport.	T1, T2, T3 I1, I2 C1, C2
P7	Has your training or any of your flying involved late runway changes? Explain why you believe that is and/or why it may be helpful.	Establishes recognition of risks due to increased workloads. Assesses whether the subject can recognize the risk of wrong surface approach and landings.	T1, T2, T3 I1, I2 C1, C2
P8	Has your training or any of your flying involved late approach changes? Explain why you believe that is and/or why it may be helpful.	Establishes recognition of risks due to increased workloads. Assesses whether the subject can recognize the risk of wrong surface approach and landings.	T1, T2, T3 I1, I2 C1, C2
P9	Has your training or any of your flying involved reviewing the ATIS? By listening, reading printed? What are you specifically listening for? Explain why you believe that is and/or why it may be helpful.	Assesses what information the subject listens for in the ATIS and how they use it to plan for and expect assignment of a departure runway, approach, and landing runway. Examining for themes of expectation bias or plan continuation risks and wrong surface event prevention strategies.	T1, T2, T3 I1, I2 C1, C2
G1b	Are you familiar with the following phraseology a tower controller might use: “Not in sight runway (##), cleared to land”?	Establishes awareness of FAA suggested scenario in which a wrong airport landing may be occurring.	F1, F2, F3 D1, D2, D3

Question ID	Topic/Question	Purpose	Means of Measure
G2	Are you familiar with the term “parallel offset runway”? *Show the subject Interview Appendix A and ask the subject if they’re able to identify a parallel offset runway.*	Assesses familiarity with air traffic instruction that the FAA says could indicate a wrong surface landing. Assesses familiar with air traffic instruction that may be uncommon and whether the subject can ascertain what it means.	F1, F2, F3 D1, D2, D3

CFI Supplemental

Question ID	Topic/Question	Purpose	Means of Measure
CF1	How many students are you actively teaching?	Establishes baseline level of CFI experience with educating multiple students in airplanes.	Number of students
CF2	Do you teach your students to visually confirm the runway number on the sign or pavement or similar techniques? If so, what are they and explain why.	Establishes how the CFI may educate students to be aware of risk and prevention strategies with themes related to wrong surface events.	T1, T2, T3 I1, I2 C1, C2
CF3	Do you teach your students to visually confirm the runway number on the sign or pavement or similar techniques? If so, what are they and explain why.	Establishes how the CFI may educate students to be aware of risk and prevention strategies with themes related to wrong surface events.	T1, T2, T3 I1, I2 C1, C2

Pilot Training/Safety Department Staff

Question ID	Topic/Question	Purpose	Means of Measure
BT1	Discuss the subject’s organization’s training cycle/structure (if applicable)	Establish a background of what the pilot training environment is like	Narrative explaining training

Question ID	**Topic/Question**	**Purpose**	**Means of Measure**
TD1	Does your training curriculum include visually confirming, speaking, or otherwise verifying the runway number on the sign or pavement? Explain why that is or why it may be helpful.	Wrong surface departure prevention strategy. Establishes awareness of risks of wrong surface departures and a strategy to prevent them. Examines whether or not the organization is aware of wrong surface events and educates pilots on wrong surface event risks and prevention strategies.	T1, T2, T3 I1, I2 C1, C2
TD2	Does your training curriculum include confirming or speaking the compass heading displayed on the PFD or magnetic compass? Explain why that is or why it may be helpful.	Wrong surface departure prevention strategy. Establishes awareness of risks of wrong surface departures and a strategy to prevent them. Examines whether or not the organization is aware of wrong surface events and educates pilots on wrong surface event risks and prevention strategies.	T1, T2, T3 I1, I2 C1, C2
TD3	Does your training curriculum include programming an instrument approach to argument a visual approach or other similar technique? Explain why that is or why it may be helpful.	Wrong surface approach and landing prevention strategy. Establishes awareness of risks of wrong surface approaches and landings. Examines whether or not the organization is aware of wrong surface events and educates pilots on wrong surface event risks and prevention strategies.	T1, T2, T3 I1, I2 C1, C2

Question ID	Topic/Question	Purpose	Means of Measure
TD4	Does your training curriculum include becoming familiar with your destination airport, including layout, proximity to other airports, runway configurations, geographical features like rivers and highways in the context of what you visually expect to see when you fly into the area? Explain why that is or why it may be helpful.	Wrong airport landing prevention strategy. Establishes awareness of techniques that may aid in creating an expected visual context and perception of the area around an airport such as associated airport geometry and other similar configured nearby airports. Examines whether or not the organization is aware of wrong surface events and educates pilots on wrong surface event risks and prevention strategies.	T1, T2, T3 I1, I2 C1, C2
TD5	Does your training curriculum include becoming familiar with runway lighting (i.e., visual approach lighting, visual glideslope lighting, instrument approach lighting systems) at your destination airport? Explain why that is or why it may be helpful.	Wrong surface approach and landing prevention strategy. Establishes awareness of techniques that may aid in creating an expected visual context and perception of the area around an airport. Examines whether or not the organization is aware of wrong surface events and educates pilots on wrong surface event risks and prevention strategies.	T1, T2, T3 I1, I2 C1, C2
TD6	Does your training curriculum include late runway changes? Explain why that is or why it may be helpful.	Establishes recognition of risks due to increased workloads. Assesses whether the subject can recognize the risk of wrong surface approach and landings. Examines whether or not the organization is aware of wrong surface events and educates pilots on wrong surface event risks and prevention strategies.	T1, T2, T3 I1, I2 C1, C2

Question ID	Topic/Question	Purpose	Means of Measure
TD7	Does your training curriculum include late approach changes? Explain why that is or why it may be helpful.	Establishes recognition of risks due to increased workloads. Assesses whether the subject can recognize the risk of wrong surface approach and landings. Examines whether or not the organization is aware of wrong surface events and educates pilots on wrong surface event risks and prevention strategies.	T1, T2, T3 I1, I2 C1, C2
TD8	Does your training curriculum include reviewing the ATIS? By listening, reading printed? What are you specifically ensuring pilots are listening for? Explain why that is or why it may be helpful.	Assesses what information the subject believes their organization teaches pilots to listen for in the ATIS and how they use it to plan for and expect assignment of a departure runway, approach, and landing runway. Examining for themes of expectation bias or plan continuation risks and wrong surface event prevention strategies. Examines whether or not the organization is aware of wrong surface events and educates pilots on wrong surface event risks and prevention strategies.	T1, T2, T3 I1, I2 C1, C2
TD9	Does your training curriculum include airport signs markings and lights? Explain why that is or why it may be helpful.	Wrong surface event prevention strategy. Establishes awareness of risks of wrong surface events and a strategy that may help prevent them. Examines whether or not the organization is aware of wrong surface events and educates pilots on wrong surface event risks and prevention strategies.	T1, T2, T3 I1, I2 C1, C2

Question ID	Topic/Question	Purpose	Means of Measure
TD10	Does your training curriculum include risks associated with taxiways parallel to runways running the full length of the runway? Explain why that is or why it may be helpful.	Assesses familiarity with risks associated with wrong surface events. Examines whether or not the organization is aware of wrong surface events and educates pilots on wrong surface event risks and prevention strategies.	T1, T2, T3 I1, I2 C1, C2
G2	Are you familiar with the term "parallel offset runway"? *Show the subject Interview Appendix A and ask the subject if they're able to identify a parallel offset runway.*	Assesses familiarity with air traffic instruction that the FAA says could indicate a wrong surface landing. Assesses familiar with air traffic instruction that may be uncommon and whether the subject can ascertain what it means.	F1, F2, F3 D1, D2, D3

All subjects

Question ID	Topic/Question	Purpose	Means of Measure
G4	Do you have any stories related to the subjects discussed that you wish to share?	Meant to prompt conversation about anything related to human error prevention or human factors that could have thematic elements involving wrong surface events.	C1, C2
E1	Are you familiar with the following incident or accident: Air Canada 759? If so, describe what you know.	Assesses familiarity with a wrong surface event, recognizing the risks associated.	F1, F2, F3 D1, D2, D3
E2	Are you familiar with the following incident or accident: Comair 5191? If so, describe what you know.	Assesses familiarity with a wrong surface event, recognizing the risks associated.	F1, F2, F3 D1, D2, D3
E3	Are you familiar with the following incident or accident: Delta 60? If so, describe what you know.	Assesses familiarity with a wrong surface event, recognizing the risks associated.	F1, F2, F3 D1, D2, D3
E4	Are you familiar with the following incident or accident: Southwest 4013? If so, describe what you know.	Assesses familiarity with a wrong surface event, recognizing the risks associated.	F1, F2, F3 D1, D2, D3

Question ID	Topic/Question	Purpose	Means of Measure
EN1	Are you familiar with the following incident or accident: An incident where a C17 landed at a small airport instead of the nearby Air Force Base? If so, describe what you know.	Assesses familiarity with a wrong surface event, recognizing the risks associated. Event occurred at MacDill AFB in Florida	F1, F2, F3 D1, D2, D3
EN2	Are you familiar with the following incident or accident: An incident where a Southwest plane landed at a small GA airport instead of the nearby Branson, Missouri? If so, describe what you know.	Assesses familiarity with a wrong surface event, recognizing the risks associated. Event was Southwest 4013.	F1, F2, F3 D1, D2, D3
EN3	Are you familiar with the following incident or accident: An incident where a Delta 767 from Brazil landed on a taxiway in Atlanta? If so, describe what you know.	Assesses familiarity with a wrong surface event, recognizing the risks associated. Event was Delta 60.	F1, F2, F3 D1, D2, D3
EN4	Are you familiar with the following incident or accident: A near miss at SFO airport in which an aircraft almost landed on a taxiway and nearly hit several other aircraft waiting for departure? If so, describe what you know.	Assesses familiarity with a wrong surface event, recognizing the risks associated. Event was Air Canada 759.	F1, F2, F3 D1, D2, D3
EN5	Are you familiar with the following incident or accident: An incident where an aircraft attempted to depart a runway that ended up being the incorrect runway, was too short, and resulted in a fatal crash? If so, describe what you know.	Assesses familiarity with a wrong surface event, recognizing the risks associated. Event was Comair 5191.	F1, F2, F3 D1, D2, D3
G3	Have you ever heard of a wrong surface event (including wrong surface approach, wrong surface landing, or wrong surface departure)? If so, explain how and what you believe it is.	Assesses familiarity with a wrong surface event, recognizing the risks associated.	F1, F2, F3 D1, D2, D3

Interview Appendix A