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Atlantic City International Airport
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PEGASAS Project-20 Final Report General Aviation Runway Incursions: Root Causes and Recommended Mitigation Methods

December 2018

Final Report

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Donna F. Wilt, Margaret Browning, Karen Marais, Scott Winter, Dennis W. Wilt, Divya Bhargava, Indira Maharaj, Gajapriya Tamilselvan, Maria Chaparro	

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16. Abstract

This report presents the results of an 18-month study to determine the root causes and event patterns that result in runway incursions (RIs) caused by general aviation (GA) pilots and recommend new mitigation methods. The study was accomplished through a comprehensive analysis that included: (a) developing and administering an online national questionnaire targeting GA pilots; (b) interviews with GA pilots who have experienced an RI; (c) review of GA pilot training material; (d) review of changes in airports to prevent GA RIs; (e) review and analysis of the National Transportation Safety Board Aviation database, the FAA's Accident and Incident database, the Aviation Safety Reporting System, and the Runway Safety Office Runway Incursion database; (f) review of 14 CFR Part 121 RI prevention strategies; and (g) overall synthesis of findings to determine root causes.

The questionnaire collected a variety of information from GA pilots, including firsthand experiences with GA RIs at both towered and non-towered airports and suggestions for preventing RIs. Root causes and recommended mitigations are provided for both towered and non-towered airports, and recommendations for FAA publications and FAA guidance used in GA pilot training.

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LIST OF ABBREVIATIONS

AC	Advisory Circular
ACS	Airman Certification Standards
AFH	Airplane Flying Handbook
AIDS	Accident and Incident Data System
AIM	Aeronautical Information Manual
AMASS	Airport Movement Area Safety System
AOPA	Aircraft Owners and Pilots Association
ASDE-X	Airport Surface Detection Equipment, Model X
ASIAS	Aviation Safety Information Analysis and Sharing
ASRS	Aviation Safety Reporting System
ATC	Air traffic control
ATD	Aviation training device
ATP	Airline transport pilot
AWOS	Automated weather observing system
CFI	Certified flight instructor
CRM	Crew Resource Management
CS	Chart Supplement
CTAF	Common traffic advisory frequency
EAA	Experimental Aircraft Association
EFB	Electronic flight bag
ERGL	Elevated runway guard lights
FAROS	Final Approach Runway Occupancy Signal
FBO	Fixed base operator
FTD	Flight training device
GA	General aviation
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILT	Instructor-led training
LAHSO	Land and Hold Short Operations
LOE	Line operational evaluation
LUAW	Line Up and Wait
MFD	Multi-function display
NOTAM	Notice to Airmen
NTSB	National Transportation Safety Board
OE	Operational Error
OI	Operational Incident
PHAK	Pilot Handbook of Aeronautical Knowledge
PD	Pilot deviation
PIC	Pilot in command
PTS	Practical Testing Standards
RGL	Runway guard lights
RI	Runway incursion
RWS	Runway Incursion Database
RWSL	Runway Status Light system

SA	Situational Awareness
SAFE	Society of Aviation and Flight Educators
SAFO	Safety Alerts for Operators
SOP	Standard operating procedure
VFR	Visual Flight Rules
VPD	Vehicle or Pedestrian Deviation

EXECUTIVE SUMMARY

Runway incursions (RIs) have been a problem for many decades, and the trend appears to be increasing over the past few years. FAA data show that, overall, there has been a 45% increase in the number of RIs at towered airports from 2011 to 2015 (FAA, n.d.-a). In approximately 80% of those events, the responsibility for the incursion can be traced back to general aviation (GA) pilots, in which GA is defined as Title 14 Code of Federal Regulations (CFR) Part 91 operations. The FAA has invested substantial resources in reducing the number of incursions involving commercial operations. Whereas they have been successful in doing so, the results are not as successful in the case of GA. Despite the efforts of the FAA that reflect in improved markings and signage at airports, added handbook guidance, and identifying critical areas on airport diagrams, there has been no decrease in the number of GA RIs. Therefore, there is a need to conduct a comprehensive review and analysis to determine the underlying causes of RIs, and then develop a set of effective mitigation strategies targeting the key causes.

The goal of this study—to determine the root causes and event patterns that result in RIs caused by GA pilots and recommend new mitigation methods—was accomplished through a comprehensive analysis, which included: (a) developing and administering an online national questionnaire targeting GA pilots; (b) interviews with GA pilots who have experienced an RI; (c) review of GA pilot training material; (d) review of changes in airports to prevent GA RIs; (e) review and analysis of the National Transportation Safety Board Aviation database, the FAA's Accident and Incident database, the Aviation Safety Reporting System, and the Runway Safety Office Runway Incursion database; (f) review of 14 CFR Part 121 RI prevention strategies; and (g) overall synthesis of findings to determine root causes.

The purpose of the Institutional Review Board-approved, GA pilot questionnaire was to: (a) determine information needs of GA pilots related to RIs; (b) capture the current state of awareness of GA pilots toward both RIs and the current tools that exist as prevention strategies; (c) solicit pilot-generated strategies for preventing RIs; and (d) solicit information on personal experiences with GA RIs at either a towered or non-towered airport. A short article appeared in six popular online GA newsletters requesting that GA pilots complete the questionnaire via an Internet hyperlink. As a result, 1401 pilots completed the questionnaire, of whom 398 provided quantitative and qualitative information on past RIs. The responses on past incursions are almost evenly split between towered and non-towered airports.

Results and findings from the project are included in this final report. In synthesizing the findings from these tasks, the top root causes and recommended mitigation measures are grouped into general, towered airport specific, or non-towered airport specific.

The top root causes of GA pilot RIs, in general, include when the pilot:

- misses the runway hold-position marking or confuses it with another marking when the marking is in an atypical location, is poorly maintained, or does not have supplemental markings;
- misses, or is confused by, taxiway signage when it is difficult to read from a small, single-engine piston aircraft;

- is confused when taxiway signage is missing or nonstandard, or when not proficient on the meaning of black on yellow versus yellow on black on signage;
- lacks easily available, airport-specific information needed for training, for flight planning, and for enhanced situation awareness while taxiing;
- using electronic or paper airport diagrams, does not have details of hot spots and location of hold-position lines;
- does not have opportunities to practice realistic, specific-airport ground operations beforehand because GA pilots do not have access to simulators with this capability;
- does not take advantage of the flight review as an opportunity for continuing learning; and
- using an electronic flight bag (EFB), does not follow best practices for use of EFBs in the cockpit.

Top root causes of GA pilot RIs specific to towered airports include when the pilot:

- misunderstands air traffic controller instructions while holding in anticipation of takeoff clearance or clearance to cross runway;
- is confused or misunderstands instructions when controller uses improper phraseology or local idioms;
- is complacent with a familiar taxi clearance, whereas transients need a delay in taking time to process the same clearance;
- does not use best practices because of feeling pressured by a controller; and
- taxis completely across the field, crossing runways, to get to the departure runway.

Top root causes of GA pilot RIs specific to non-towered airports include when the pilot:

- erroneously assumes no one is around when nothing is heard on the radio;
- does not realize the radio is set up incorrectly (e.g., low volume or wrong frequency);
- does not communicate on the radio, even when aircraft are radio equipped or the pilot of an aircraft or ultralight without an electrical system does not use a hand-held radio to communicate;
- cannot estimate if there is enough time to take off before a landing aircraft;
- uses an airport sketch that lacks the information needed to safely taxi and communicate with the airport;
- acts based on knowledge about ground procedures and communication, passed down without current supporting guidance from FAA; and
- is not motivated to take safety seriously.

The GA pilot questionnaire generated 528 specific suggestions for mitigating RIs and hundreds of additional answers to the question, “What resources do GA pilots need, but not have?” Synthesizing these suggestions with the root causes resulted in more than 50 recommendations to mitigate RIs caused by GA pilots.

Top general recommendations for mitigating GA pilot deviation (PD) RIs include:

- Revise airport directory entry format in Chart Supplement to include information relevant to movement on the airfield and RI avoidance.
- Enhance applications and metasites with easy to find, airport-specific resources for flight planning by GA pilots.
- Add painted runway hold-position signs in conjunction with all runway hold markings.
- Create more intuitive signage more aligned with motor vehicle traffic signs.
- Augment taxiway signage with painted taxiway signage at intersections to clearly mark the taxiways.
- Facilitate widespread use of geo-referenced charts and taxi features of EFBs.
- Use GA simulation training devices with accurate visual representations of specific airports, the ability to create and simulate RIs, and realistic ground communications to allow pilots to practice realistic ground-operation skills, realistic RI scenarios, and communications at busy airports.
- Provide online video and interactive training that allows pilots to engage in scenario-based training and practice their risk-management and decision-making skills for avoiding RIs.
- Provide online courses and videos that can be accessed from anywhere at any time.
- Have resources with an engaging delivery of material.
- Take better advantage of flight reviews to deliver training material and continuing education on RI avoidance.

Top towered airport specific recommendations for mitigating GA PD RIs include:

- Establish standard GA taxi routes that would be available in the navigation database and can be displayed on an EFB.
- Create a new word in pilot/controller phraseology to break the expectation bias and indicate the information that follows is atypical.
- Assign GA aircraft to the runway that minimizes the risk of an RI.
- Address air traffic control (ATC) communication procedures when dealing with GA pilots who do not have the communications training and ability of airline pilots.
- Address the problems of RIs by aircraft waiting to takeoff as a separate issue from aircraft crossing the taxiway.
- Create training tools that do a good job simulating realistic ground communications, and allow pilots to practice realistic communications at busy airports.
- Update existing airport diagrams to include: hot spot descriptions, hold position lines, and surface-painted apron entrance point signs used for GA aircraft parking.
- Include a red stop light, controlled by ATC, at the runway hold position. Such a system could be a stripped-down, simplified version of the Runway Status Light System installed at large airports.

Top non-towered airport specific recommendation for mitigating GA PD RIs include

- Require all pilots to have and use two-way radios for all operations on the airport.
- Create taxi diagrams for non-towered airports, which include frequencies, taxiway designators, and location of markings.

- Revise AC 90-66, 90-42 and update Aeronautical Information Manual with expanded recommended ground procedures, communication procedures, and risk management for non-towered airports.
- Provide the ability to perform an automated radio check at all non-towered airports.
- Training pilots on estimating aircraft performance, separation and closure, and on risk management and decision-making regarding whether to take off ahead of landing traffic.

1. INTRODUCTION

The purpose of this study was to perform a comprehensive analysis of and determine the root causes and event patterns that result in general aviation (GA) RIs. RIs have been a problem for many decades, and the trend appears to be increasing over the past few years. FAA data show an overall 45% increase in the number of RIs from 2011 to 2015 (FAA, n.d.-a). The number of RIs has increased from 954 to 1383 during that same time period. In approximately 80% of those events, the responsibility for the incursion can be traced back to GA pilots, where GA is defined as Title 14 Code of Federal Regulations (CFR) Part 91 operations. When comparing GA events to non-GA events, figure 1 shows RIs by the calendar year for all but the least severe incursion. The rate of incursions by 14 CFR 91 GA aircraft is disproportionate compared to other type operations and is increasing annually.

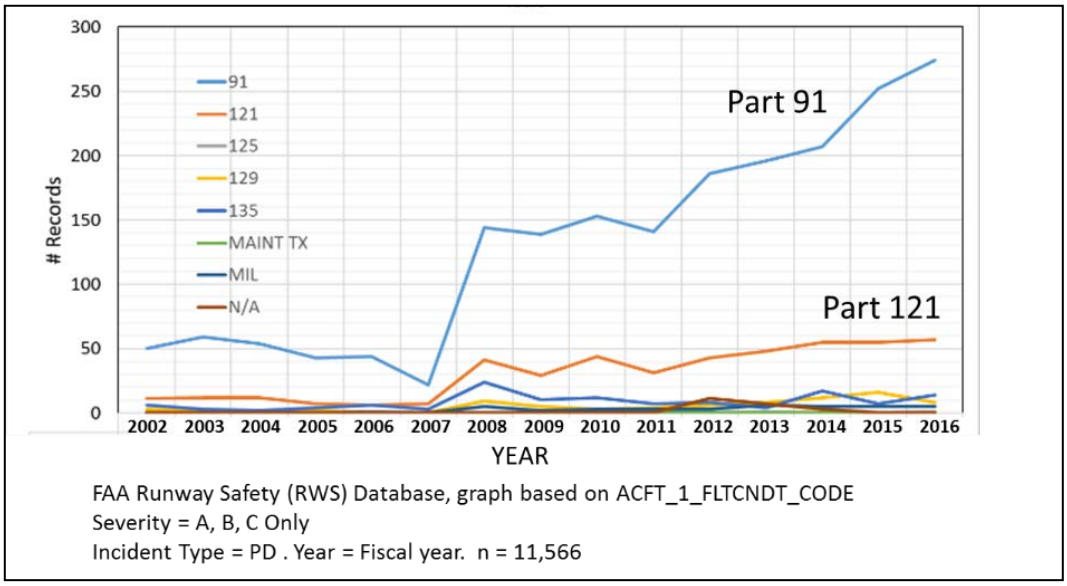


Figure 1. Increase in severity A, B, and C RIs at towered airports AIRCRAFT 1 FLIGHT CONDUCT CODE and CY year (note: FAA RWS database; severity code = A, B, C, only; n= 8,372)

Previously suggested causes for the disparity in number of RIs between GA and other operations are that (a) GA pilots fly much more varied types of missions, (b) there is a larger range of in-flight experience for GA pilots, (c) there are limited cockpit resources and flight support for single pilots, and (d) GA aircraft are less weather-tolerant (FAA, n.d.-a). The FAA has implemented various programs to help reduce GA incursions in the past; however, GA incursions are a growing problem. The National Transportation Safety Board (NTSB) has pointed out on its "Most Wanted" list for 2011, 2012, and 2013 that GA pilots, "…are the single most prevalent contributor to the total number of runway incursions" (FAA, 2011a, p4).

The FAA has invested substantial resources in reducing the number of incursions involving commercial operations. Although they have been successful in doing so, the results are not similar in the case of GA. Despite the efforts of the FAA reflected in improved markings and signage at airports, added handbook guidance, and identifying critical areas on airport diagrams, there has

been no decrease in the number of GA RIs. Therefore, a comprehensive review and analysis are needed to determine the underlying causes of RIs and then to develop a set of effective mitigation strategies targeting the key causes.

Section 2 reports on the evaluation of the current state of training materials, airport signage, and technological tools available to GA pilots to educate and prevent RIs.

Section 3 reports on the online GA pilot questionnaire developed and administered to assess the pilot community's knowledge of RIs and prevention techniques. The purpose of the GA pilot questionnaire was to: (a) determine the information needs of GA pilots for runway-related situation awareness and decision making; (b) capture the current state of awareness of GA pilots toward both RIs and the current tools that exist as prevention strategies; and (c) solicit pilot-generated strategies for preventing RIs. The questionnaire also solicited information on personal experiences with GA RIs at either a towered or non-towered airport.

Section 4 reports on the phenomenological study of pilots who have experienced an RI conducted at the Experimental Aircraft Association (EAA) AirVenture event. The interviews were designed to learn how the event occurred and the lessons learned from that experience. Through the sharing of lessons learned from sustainable safe and efficient operational practices, the flying community may continue to improve safety practices and minimize risks associated with air transportation.

Section 5 reports on the review of 14 CFR 121 RI prevention strategies that may be applicable to GA operations. Pilots and pilot-training leaders of 14 CFR 121 air-carrier operators were interviewed to discuss the best practices used in airline pilot training to avoid RIs.

Section 6 reports on the review of aviation databases for causal and contributing factors related to GA RIs. The databases included the NTSB database, the FAA's Accident and Incident Data System (AIDS), the Aviation Safety Reporting System (ASRS), and the Runway Safety Office Runway Incursion Database (RWS). This database review was primarily limited to events at towered airports.

Section 7 contains an overall synthesis of the root causes and event patterns that result in GA RIs at towered airports and recommends new mitigation methods.

2. EVALUATION OF THE CURRENT STATE OF RI TRAINING AND PREVENTION PROGRAMS

Identification of the current state of training materials, airport signage, and technological tools available to GA pilots to educate and prevent RIs was first assessed. The assessment of training materials was essential to complete early in the study to develop the questionnaire for pilot interviews. The following information provides a review on the current state of training and training materials available for GA pilots, including lighting, signage, and markings at airports; there is also a review of current technological tools available to GA pilots to prevent RIs.

2.1 STATE OF TRAINING, AND IDENTIFICATION OF TRAINING MATERIAL FOR GA TRAINING MATERIAL ON RIs

In an online search in April 2016, the following FAA source materials for RIs were found (see appendix A for examples of training materials):

Training Materials:

- FAA-H-8083-25A Pilot Handbook of Aeronautical Knowledge (PHAK) (FAA, 2008a, 2016b)
- FAA-H-8083-3A Airplane Flying Handbook (AFH) (FAA, 2004, 2016d)
- Aeronautical Information Manual (AIM) (FAA, 2016a)
- AC 91-73B Parts 91 and 135 Single Pilot, Flight School Procedures During Taxi Operations (FAA, 2012a)
- Runway Safety: A Best Practices Guide to Operations and Communications (FAA, n.d.-b)
- Safety Alerts for Operators (SAFO) 11004 Runway Incursion Prevention Actions (FAA, 2011c)
- AC 90-42, Traffic Advisory Practices at Airports Without Operating Control Towers (FAA, 1990)
- AC 90-66, Recommended Standard Traffic Patterns and Practices for Aeronautical Operations at Airports Without Operating Control Towers (FAA, 1993)
- AC 120-57, Surface Movement Guidance and Control System (FAA, 1996)

State of Training:

- Practical Test Standards:
    - FAA-S-8081-14B The Private Pilot Practical Test Standards for Airplane (FAA, 2011b)
    - FAA-S-ACS-6 Private Pilot Airman Certification Standards (ACS) (FAA, 2016c)
    - FAA-S-8081-12C Commercial Practical Test Standards for Airplane (FAA, 2012b)
    - FAA-S-8081-6D Flight Instructor Practical Test Standards for Airplane (FAA, 2012c)
    - FAA-S-8081-16B Commercial Practical Test Standards for Rotorcraft (FAA, 2013)
    - FAA-S-8081-29 Sport Pilot Practical Test Standards (FAA, 2014a)

Each resource listed above was reviewed to determine:

- Timeline: The timeline of publications and revisions to determine when the information was available to use in training.
- Content: What information is provided, and how it relates to GA operations.
- Availability: The availability and dissemination of the information so that instructors and pilots are likely to use the resource

The online search was updated in July 2016, and the following FAA changes were found:

- FAA-S-8081-14B The Private Practical Test Standards, superseded by FAA-S-ACS-6 Change 1 Private Pilot ACS (FAA, 2016c)
- FAA-H-8083-25B Pilot Handbook of Aeronautical Knowledge (PHAK) suspended FAA-H-8083-25B (FAA, 2016b)

2.1.1 Current Training Materials Available on RIs

2.1.1.1 FAA-H-8083-25 PHAK

PHAK is the primary guidance for GA pilot training.

Timeline: FAA Handbook FAA-H-8083-25A PHAK was released in 2008. The 2008 version does not contain explicit information about RIs. In 2012, Appendix 1 of the PHAK was released (FAA, 2012d). Entitled "Runway Incursion Avoidance," the appendix is devoted to avoiding RIs.

In June 2016, FAA-H-8083-25B was released. In this version, most of the information in Appendix 1 has been incorporated into Chapter 14 on Airport Operations and Appendix 1 has been deleted.

Content: The PHAK Appendix 1 (FAA, 2012d) included detailed information on:

- RI Overview
- Major Areas Contributing to RI Events
- Runway Confusion
- Taxi Route Planning
- Taxi Procedures (including situational awareness)
- Communications
- Aircraft Lights (to convey information on the ground)
- Signs, Markings, and Lighting

Appendix 1 of the PHAK included a detailed discussion of signage and markings at entrances and any taxiway that crosses a runway, including a definition of the name of marking, where it is at the airport, and how to interpret it. There were a large number (20) of color photos of actual markings and signage, in context. The handbook included runway hold position markings, surface painted signs, enhanced runway centerline, runway safety boundary signs, and runway hold position signs.

In the new revision (FAA, 2016b), Chapter 14 in FAA-H-8083-25B has parts of the same text and figures as the old PHAK Appendix 1 interspersed throughout the chapter. The section "Collision Avoidance" includes the portion of the old appendix on Runway Incursion Overview, Major Areas Contributing to RI Events, and Runway Confusion. The section adds a subsection on defining pilot deviation (PD). A subsection on air traffic control (ATC) instructions includes the communications material from the old PHAK Appendix 1 and emphasizes complying with ATC instructions and suggestions on how to comply.

The section "Airport Marking and Signs" incorporates the information and figures from the old Appendix 1. The following items were in the old PHAK Appendix 1 but are not in Revision B of the PHAK:

- Taxi Route Planning
- Taxi Procedures
- Situational Awareness (for ground movement)
- Aircraft Lights (to convey information on the ground)
- Hot Spots

Availability: PHAK Appendix 1 was not part of the main appendices in the FAA-H-8083-25A PHAK, which are ordered A–G. The table of contents of the PHAK was not updated to include Appendix 1. By looking at the table of contents, a reader would not notice the information was available. Prior to June 2016, the FAA-H-8083-25A was available for download from several FAA websites. The Training and Testing websites had links to download the PHAK, which did not include the PHAK Appendix 1 supplement. Another widely referenced website found was Handbooks & Manuals at http://www.faa.gov/regulations_policies/handbooks_manuals/.This website then links to Aviation Handbooks & Material at: http://www.faa.gov/regulations_policies/handbooks_manuals/aviation/.

The Aviation Handbooks & Material website lists handbooks and manuals for download, alphabetically, with the publication date and the change/add date. Prior to June 2016, Appendix 1 was listed as a separate download, so the PHAK Appendix 1 was available but downloading the PHAK did not include the supplement. The printed versions of the FAA-H-8083-25A sold by ASA after 2012 did include Appendix 1. However, it was not listed in the table of contents. Copies purchased prior to 2012 did not include it. After June 2016, the FAA website Aviation Handbooks & Material lists the one document FAA-H-8083-25B.

2.1.1.2 FAA-H-8083-3 AFH

The AFH and the PHAK are the primary guidance for GA pilot training.

Timeline: FAA-H-8083-3A AFH was released in 2004. Revision FAA-H-8083-3B was released October 2016 (FAA, 2016e).

Content: Chapter 2 of the AFH FAA-H-8083-3A includes two pages on the mechanics of taxiing. It does not include anything on avoiding RIs.

Availability: At the time of this task, FAA-H-8083-3A was available for download from several FAA websites. These have now been updated to the newest revision—FAA-H-8083-3B.

2.1.1.3 The AIM

Timeline: The AIM is updated twice a year (FAA, 2016a).

Content: AIM Chapter 2, "Aeronautical Lighting and Other Airport Visual Aids," and AIM Chapter 4, "Air Traffic Control," include information needed for RI avoidance.

AIM Chapter 2, “Aeronautical Lighting and Other Airport Visual Aids,” has several topics related to RI avoidance.

Chapter 2, Section 1 of the AIM defines airport lighting aids, including approach lighting, runway, and taxiway lights. The section contains drawings and three photos. The photos are of runway entrance lights, takeoff hold lights, and taxiway lead-on lights.

Runway Status Light System (RWSL) is described as a system “to clearly indicate when it is unsafe to enter, cross, takeoff from, or land on a runway” (FAA, 2016a. para. 2-7-1). Each component of the system is described with pilot actions. A standalone Final Approach Runway Occupancy Signal (FAROS) is also described. The AIM does not include a list of airports where RWSL or FAROS are available.

Chapter 2, Section 3 of the AIM defines airport marking aids and signage. The section contains mostly color drawings of runway and taxiway markings, and signage and different combinations of markings. There is information on how the pilot should interpret the sign or marking. There are no photos of actual markings or signage.

AIM Chapter 4, “Air Traffic Control” has several topics related to RI avoidance.

Chapter 4, Section 2 on Radio Communications Phraseology and Techniques covers pilot/ATC communications in detail. It provides phraseology and does not address RI avoidance. Instead, it supports what is in the other material regarding communication.

Chapter 4, Section 3 on Airport Operations includes general taxi procedures, taxiing during low visibility, intersection takeoffs, exiting the runway after landing, and pilot responsibilities for Land and Hold Short Operations (LAHSO). The AIM provides basic procedures for both and highlights the importance of situation awareness for LASO and best practices for taxiing. This section also includes Visual Flight Rules (VFR) helicopter operations at controlled airports.

Chapter 4, Section 5 includes a description of Airport Surface Detection Equipment, Model-X (ASDE-X) with a list of airports projected to receive the system.

The AIM does not have a specific section or paragraph on RI avoidance.

Availability: The current AIM is readily available for download on the FAA website. It is also available from commercial publishers as a paperback book combined with regulations in a “FAR/AIM” publication for pilots.

2.1.1.4 Advisory Circular AC 91-73 Parts 91 and 135 Single Pilot, Flight School Procedures During Taxi Operations

Timeline: Originally published in 2001, this document is intended to provide guidance for the development and implementation of standard pilot procedures for conducting safe aircraft operations on the airport surface. It is intended for use by 14 CFR 91 and 14 CFR 135 operators conducting single-pilot flight operations. This Advisory Circular (AC) was initiated by AFS 200.

Revision A was issued in 2003 (FAA, 2003), whereas the current revision, 91-73B, was issued in 2012 (FAA, 2012a). The AC is aimed at flight schools, not individual pilots, with a viewpoint of what to teach pilots. It only addresses towered airports.

Content: The purpose of this AC is to "develop practical guidance toward the goal of increasing safety and efficiency of aircraft movement on the airport surface while reducing the risk of runway incursions."

The AC is based on the concept that RIs can be reduced by developing and promoting standard operating procedures (SOPs) that "direct the attention of the pilot to essential tasks while the aircraft is in motion. The development and formalized training of safe operating procedures during taxi operations should be implemented by each operator." The AC emphasizes the use SOPs for "training all pilots" for "all phases of flight, including ground operations," and "evaluate on flight review of all pilots."

The AC focuses on seven major categories: Planning, Situational Awareness, Written Taxi Instructions, Pilot/Passenger Communications, ATC/ Pilot Communication, Taxiing, and Exterior Lighting.

The AC is supposed to be for single-pilot operations; however, the revisions are written from the viewpoint of an air carrier or corporate aircraft. The specifics in the original and Revision A are not applicable to light GA aircraft.

AC 91-73A Revision A emphasizes reducing workload but does not say how. It does not address the GA practice of doing a run-up near the runway after taxiing. It does not address where to do the workload items. Sitting on the ramp with the engine running while running up and performing checklists is not standard procedure for light GA aircraft. A GA ramp is not a safe place for run-ups. How many top RI airports have adequate area for run-ups? The AC is written with the attitude that this is an Instrument Flight Rules (IFR) operation and never considers VFR operations.

Appendix 1 in AC 91-73A Revision A, "Runway Incursion Prevention Introduction: The Philosophy of Using Standard Operating Procedures (SOP) for Runway Incursion Prevention" provides a rationale for using SOPs, an example of an SOP, and recommended practices and techniques for pilots.

Appendix 2 in AC 91-73A Revision A, "Standard Operating Procedures (SOP) Template for Ground Operations and the Prevention of Runway Incursions" is based on an air carrier flight crew. It assumes an IFR operation and air transport aircraft (e.g., jumpseat, flight-deck access, auto-brakes).

Appendix 3 in AC 91-73A Revision A is "Sample Procedures for Taxi—Departure and Arrival." This is a general procedure with emphasis on taxiing. It does not include items for setting up avionics or engine run-up (FAA, 2003, Appendix 3, p1).

AC 91-73B. Revision B of AC 91-73B is more suited for a light aircraft operation and has more flight-school-specific recommendations than Revision A. It emphasizes doing items "such as programming FMS/GPS … before beginning to taxi" (FAA, 2012a, p6).

The AC 91-73 Revision B appendices are completely different from Revision A appendices. Appendix 1 in Revision B, "Airport Surface Operations at Non-Towered Airport and Airports When the Tower is Closed" is "very similar to SOPs/Best Practices currently in the air carrier segment of the industry, modified for single-pilot operations" (FAA, 2012a, p10).

Appendix 2 in Revision B, "Pilot Briefing Card," is recommended for use in operator's briefing material, again based on air carrier industry.

Appendix 3 in Revision B, "Airport Surface Operations for Flight Schools and Instructors," lists 10 specific items that can be incorporated into flight-school operations to create a culture of best practices for ground operations.

Appendix 3 in Revision B states, "Instructors should be advised to limit cockpit instruction during critical phases of flight, particularly during taxiing, to mitigate the risks of a runway incursion or other surface incident. Placards should be developed and mounted on the panel of each aircraft to remind instructors of this action" (FAA, 2012a, Appendix 3, p1). This implies that instructors should not be teaching proper taxi procedures during taxi phase of flight.

AC 91-73B also lists other related reading material. Included are:

"RELATED READING MATERIAL. You can find this and other ACs on the FAA's website at http://www.faa.gov/regulations_policies/advisory_circulars.

a. FAA ACs (current editions).

AC 90-42, Traffic Advisory Practices at Airports Without Operating Control Towers
AC 90-66, Recommended Standard Traffic Patterns and Practices for Aeronautical Operations at Airports Without Operating Control Towers
AC 120-57, Surface Movement Guidance and Control System

b. Other Guidance

Safety Alerts for Operators (SAFO) 11004 Runway Incursion Prevention Actions
AIM
Pilot's Handbook of Aeronautical Knowledge

c. Websites

Aircraft Owners and Pilots Association (AOPA):
http://www.aopa.org/asf/runway_safety/
FAA Runway Safety Program: http://www.faa.gov/airports/runway_safety/
Final Approach Runway Occupancy Signal (FAROS):
http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/nextgen/research_tech_dev/td/projects/faros/
NASA Aviation Safety Reporting System (ASRS): http://asrs.arc.nasa.gov/
Runway Status Light (RWSL) Program:
http://www.faa.gov/air_traffic/technology/rwsl/
Notices to Airmen (NOTAMs): https://pilotweb.nas.faa.gov/PilotWeb/
http://livestream.com/FAASTeamTV/events/2185859

Availability: The current AC 91-73B is available for download from the FAA website https://www.faa.gov/regulations_policies/advisory_circulars/.

2.1.1.5 Runway Safety: A Best Practices Guide to Operations and Communications Brochure

Timeline: There is no date on the Runway Safety Best Practices Brochure (FAA, n.d.-b).

Content: The stated intent of the Runway Safety Best Practices Guide is "to provide airmen with basic information with respect to safely operating on the surface of both towered and non-towered airports."

The brochure is written for GA pilots and does not read like it is taken from air carrier material. The information is generally similar to that in AC 91-73B with more examples for GA pilots.

The brochure covers five areas:

- Planning surface operations using the airport diagram
- Taxi procedures for each phase of taxiing
- Use of aircraft lights to convey location and intent to other pilots
- Effective pilot/controller communications to enhance safe surface operations
- Airfield markings, signs, and lights

The section on taxi procedures covers each phase of taxi, including:

- Before taxiing
- While taxiing
- Line up and wait (LUAW)
- Takeoff
- After landing
- Taxi at non-towered airports

The section on taxi procedures also covers situational awareness of the aircraft's location and how it relates to the taxi route and what is happening around the aircraft, and suggests methods to help acquire and maintain situational awareness. The section on communications gives extensive examples of different situations and the appropriate communications, including land and hold short; exiting runway; initial contact with ground after landing; braking action reports; hold short, non-towered airport arrivals, and taxiing; takeoff/landing clearance; LUAW; intersection departure; LUAW on intersecting runways; and initial taxi instructions. As part of communications, there is a glossary of phraseology common to surface operations, which specifically gives terms used in taxi operations. The section on Marking, Signs, and Lights gives numerous photos in context with descriptions. The descriptions are not as technical as in the AIM.

Availability: The current brochure is available for download from the FAA website. Paper copies of the brochure are also available through the contact information on the FAA Runway Safety website at https://www.faa.gov/airports/runway_safety/publications/.

2.1.1.6 Safety Alerts for Operators 11004 RI Prevention Actions

Timeline: The Safety Alerts for Operators (SAFO) 11004 is dated June 11, 2011. There are no revisions. The SAFO is distributed by AFS-200 (FAA, 2011c).

Content: The SAFO is targeting pilots of air carrier and multi-pilot crew operations but suggests it is useful to other aviation professionals. The just over two-page SAFO contains recommendations and resources to reduce RIs involving pilot errors. The SAFO is recommending safety management support and support at all levels of management to increase situational awareness and procedures training on these areas:

- Situational Awareness
- Written Taxi Instructions
- Crew Resource Management (CRM)
- Communication
- Taxi
- Exterior Lighting

For each area, the AC includes high-level, succinct preventive actions that are elaborated on in the other guidance (i.e. PHAK, Best Practices Guide). The action list is included in appendix A.

Availability: The current AC is available for download on the FAA website.

2.1.1.7 AC 90-42, Traffic Advisory Practices at Airports Without Operating Control Towers

Timeline: AC 90-42F was issued on May 21, 1990, canceling 90-42E (FAA, 1990).

Content: AC 90-42F focuses on communication procedures and best practices at airports without operating control towers. There are no specific references or procedures for RI avoidance.

Availability: The current AC 90-42F is available for download from the FAA website.

2.1.1.8 AC 90-66, Recommended Standard Traffic Patterns and Practices for Aeronautical Operations at Airports Without Operating Control Towers

Timeline: AC 90-66A was issued on August 26, 1993, canceling 90-66. The responsible office is AFS-820 (FAA, 1993).

Content: General operating practices including straight-in approaches at airports without control towers. There are no specific references or procedures for RI avoidance.

Availability: The current AC 90-66A is available for download on the FAA website.

2.1.1.9 AC 120-57 Surface Movement Guidance and Control System

Timeline: AC 120-57 was originally issued September 4, 1992. It is superseded by AC 120-57A, issued on December 19, 1996. It was initiated by AFS-400 (FAA, 1996).

Content: AC 120-57 addresses 14 CFR Part 139 airports in which air carriers are authorized to conduct takeoffs and landings when the runway visual range is less than 1200 feet. The target audience for this AC is air carrier management and airport operators. The AC describes a plan for Surface Movement Guidance and Control System that includes enhanced visual aids and rigorous control procedures to enhance safe movement of aircraft and vehicles on the airport.

This AC is referenced in AC 91-73, 14 CFR 91 and 14 CFR 135 (Single Pilot, Flight School Procedures During Taxi Operations) but AC 120-57 has nothing specifically related to 14 CFR 91 and 14 CFR 135.

Availability: The current AC is available for download on the FAA website.

2.1.2 Current State of Training for RIs

Practical Testing Standards (PTS) exist for each pilot certificate issued by the FAA. The Private Pilot PTS for Airplane, Commercial Pilot PTS for Airplane, and Flight Instructor PTS for Airplane were examined in detail for their evaluation standards on RIs. Commercial Pilot Rotorcraft and Sport Pilot were also examined to determine the extent to which RIs were included in other standards.

2.1.2.1 The Private Pilot Practical Test Standard for Airplane

Timeline: FAA-S-8081-14A, released in 2002, included RI as a special emphasis item. Tasks did not explicitly include RI avoidance as elements. It did include elements that referred to "avoids runway incursions," "safe taxi procedures," and "complies with airport/taxiway markings, signals, ATC clearances, and instructions." In 2012, Task F, Runway Incursion Avoidance, was added to the Preflight Procedures Area of Operation (FAA, 2011b).

FAA-S-8081-14B was released in 2012. Revision B included references to RI avoidance in multiple locations, including adding RI as an element to every Task in Area of Operation IV, Takeoff, Landings, and Go-Arounds, and updated other areas.

FAA-S-8081-14B was discontinued June 15, 2016, when it was superseded by FAA-S-ACS-6 Private Pilot ACS.

Content: The PTS gives the standards by which applicants will be evaluated and provides references with guidance on the standards for each task. The PTS includes Airplane Single-Engine, Multi-Engine Land. Areas of Operations and Task for multi-engine are very similar to the single engine. The following discussion is for the single-engine task. The multi-engine tasks have similar material.

Item 7 of the Special Emphasis Areas is "Runway Incursion Avoidance." There is no explicit guidance referenced for the Special Emphasis Areas.

In Revision B, Area of Operation II Task D Taxiing, Element 5 is "Exhibits procedures for steering, maneuvering, maintaining taxiway, runway position, and situational awareness to avoid runway incursions." The only reference guidance on Task D is FAA-H-8083-3, the AFH.

Chapter 2 of FAA-H-8083-3A includes two pages on the mechanics of taxiing but does not include anything on avoiding RIs.

In Revision B, Area of Operation II, Task F is "Runway Incursion Avoidance." See appendix B for the content of the task. The references listed for Task include FAA-H-8083-3 (AFH), FAA-H-8083-25 (PHAK), AC 91-73, AC 150-5340-18; and AIM. AC 150-5340-18 is "Standards for Airport Sign Systems" and is intended for airport operators in citing and installing signage. This reference does not provide any guidance to pilots beyond what is already in the AIM and PHAK.

Availability: The Private Pilot PTS was widely available for download from the FAA website or from publishers such as ASA or Gleim.

2.1.2.2 Private Pilot ACS FAA-S-ACS-6

Timeline: The Private Pilot ACS FAA-S-ACS-6 superseded the Private Pilot PTS on June 15, 2016 (FAA, 2016c).

Content: For each task, the ACS incorporates the content of the PTS with knowledge and risk-management items primarily intended for the FAA written exam. The Special Emphasis Items from the PTS have been incorporated into the individual tasks.

The Runway Incursion Avoidance Task in the PTS has been incorporated into the Taxiing Task in the ACS (see appendix B).

Availability: The Private Pilot ACS is widely available for download from the FAA website. The commercial publishers released their reprints of the document in July 2016.

2.1.2.3 Commercial Pilot Practical Test Standard for Airplane FAA-S-8081-12

Timeline: FAA-S-8081-12C went into effect in 2012. The Commercial Pilot ACS for Airplane had not been released as of September 2016 (FAA, 2012b).

Content: The Area of Operations and Tasks are laid out in the Commercial Pilot PTS and for the Private Pilot PTS.

Major enhancements to Version FAA-S-8081-12C are the same as in the Private Pilot PTS.

Availability: The Commercial Pilot PTS is widely available for download from the FAA website or from publishers such as ASA or Gleim.

2.1.2.4 Commercial Pilot Practical Test Standard for Rotorcraft FAA-S-8081-16

Timeline: FAA-S-8081-16A went into effect on August 1, 2006. FAA-S-8081-16B went into effect on June 1, 2013. The Commercial Pilot ACS for Rotorcraft has not been released as of September 2016 (FAA, 2013).

Content: FAA-S-8081-16A included Runway Incursion Avoidance in:

- Special Emphasis Area
- Flight Instructor Responsibility
- Helicopter Element 7 of AOA II. Preflight Procedures. Task D. Before Takeoff Check "Avoids Runway Incursions."
- Helicopter Element 1 of AOA III. Airport Operations Task B. Traffic Pattern. "Exhibits knowledge of the elements related to traffic patterns. Including, procedures at airports and heliports with and without operating control towers, prevention of RIs, collision avoidance, wake turbulence avoidance, and wind shear."
- Helicopter Element 1 of AOA III. Airport and Heliport Operations. Tack C. "Exhibits knowledge of the elements related to airport/heliport runway, and taxiway operations with emphasis on RI avoidance."
- Gyroplane Element 1 of AOA III. Airport Operations Task B. Traffic Pattern. "Exhibits knowledge of the elements related to traffic patterns. Including, procedures at airports with and without operating control towers, prevention of RIs, collision avoidance, wake turbulence avoidance, and wind shear."
- Gyroplane Element 1 of AOA III. Airport Operations Task C. Airport Markings and Lighting. "Exhibits knowledge of the elements related to runway and taxiway operations with emphasis on RI avoidance."

Version B added Task II.D Runway Incursion Avoidance to both Helicopter and Gyroplane PTS. The elements of the task are the same as for the similar task in the airplane PTS.

Availability: The Commercial Pilot PTS for Rotorcraft is widely available for download from the FAA website or from publishers, such as ASA or Gleim.

2.1.2.5 Flight Instructor Practical Test Standards for Airplane FAA-S-8081-6D

Timeline: FAA-S-8081-6C went into effect on August 1, 2006. FAA-S-8081-6D went into effect on December 1, 2012. The Instructor ACS has not been released as of September 2016 (FAA, 2012c).

Content: Similar to other updates in 2012, Version D updates related to RI included:

Introduction

- "Special Emphasis Areas" section updated to include reference to RI avoidance
- "Flight Instructor Responsibility" section updated to include reference to RI avoidance
- "Examiner Responsibility" section updated to include reference to RI avoidance
- "Satisfactory Performance" section updated to include reference to RI mitigation techniques
- "Use of Distractions During Practical Tests" section updated to include reference to RI

For both Flight Instructor—Airplane Single-Engine and Airplane Multi-Engine,

- Version D added Area of Operation II updated to include Task B: "Runway Incursion Avoidance." The elements of the task are the same as for the similar task in the airplane PTS.

- Version D updated Area of Operation VII, Task F: "Normal and Crosswind Approach and Landing" to include RI language.

Availability: The Flight Instructor PTS for Airplane is widely available for download from the FAA website or from publishers, such as ASA or Gleim.

2.1.2.6 Sport Pilot Practical Test Standards for Airplane, Gyroplane, Glider, Flight Instructor FAA-S-8081-29

Timeline: The Sport Pilot PTS was effective December 1, 2004. There have been three changes since the initial release, none related to RI avoidance. The latest change occurred in 2014 and added the Risk Management Handbook to the reference list (FAA, 2014a).

Content: Similar to other PTS, the Sport Pilot PTS includes Special Emphasis Areas, one of which is RI avoidance. The Sport Pilot PTS does not include the Runway Incursion Avoidance Task that is in the Private and Commercial Pilot PTS. The Task D Taxiing does not include any reference to RI avoidance. "Prevention of runway incursions" is included in Element 1 of AOA III Task B Traffic Pattern. The Sport-Pilot Flight Instructor practical test does not include any RI beyond what is required for the Sport Pilot certificate.

Availability: The Sport Pilot PTS is widely available for download from the FAA website or from publishers, such as ASA, Sporty's, or Gleim.

2.2 STATE OF CHANGES IN THE NAS SYSTEM TO PREVENT RIs

In an effort to improve safety, the FAA developed the AC 150 series to standardize airport planning and design procedures. This collection of guidance material describes in detail for the airport manager the required and optional airport markings, signage, and lighting necessary to help pilots identify their location on the airfield. The information is consolidated for pilots and other users in AIM. The AIM provides a consolidated interpretation of airport marking information for users to identify colors, layouts, and design of these airport identifying features. This study will focus on those markings, signs, and the lighting used as surface navigational aids designed to protect the runway surface area from pilot and vehicle incursions.

It is important for pilots to identify and interpret airport signs, markings, and lights to navigate the airport surface areas and protected areas that present a hazard to aircraft operations. Airport markings provide pilots with location, directions, and procedural information. Markings are painted on movement and non-movement areas, including runways, taxiways, parking, and other airport surface areas as appropriate. Airport signs are above and adjacent to airport surface areas. Lighting may be flush with the pavement along painted markings or next to the pavement surfaces. Often, two types of identification features are used to improve the safety of operations and protect runways and other movement areas.

2.2.1 Taxiway Marking and Lighting

Pilots can identify their general location immediately by the color of lights and markings. All painted markings on taxiways are yellow, whereas runway surface area markings are painted with

white, reflective paint, except in the event of a closed runway, for which a yellow “X” will be painted on the runway surface.

To further assist pilots in identifying their locations in the event they cannot see the surface markings, blue taxiway edge lights (see figure 2) are installed every 50–100 feet on both sides of the taxiway pavement area, parallel to the taxiway centerline, and no more than 10 feet (3 m) from the edge of the taxiway. Airports may install blue reflectors in lieu of this, or to enhance the taxiway lighting system.

Figure 2. Blue taxiway edge lights installed on both sides of taxiway pavement area (source: http://www.airportsinternational.com, 2017)

If installed, optional taxiway lighting systems designed to facilitate aircraft movement along taxiways may be available, including taxiway centerline lights, runway guard lights (RGL), stop bars, and clearance bars. Taxiway centerline lights emphasize centerline markings to provide taxi guidance between runways and aprons. RGLs alert aircraft approaching the runway that they are about to enter an active runway. Stop bars provide a distinctive stop signal to aircraft approaching a runway during low-visibility periods and may be used as a means of preventing incursions. At runway-taxiway intersections, taxiway guidance signs are installed to define the entrance to the runway surface area. Elevated runway guard lights (ERGL), commonly known as “wig-wag” lights (see figure 3), are collocated with the runway hold position signs and surface painted hold position markings. They consist of a pair of elevated flashing yellow lights installed on either side of the taxiway near the holding position sign. Clearance bars alert pilots and vehicles that they are approaching an intersecting taxiway or hold point other than a runway hold position.

Figure 3. ERGL installed on either side of the taxiway near the holding position sign (source: http://www.lrc.rpi.edu)

AC 150/5340-30H (FAA, 2014b) describes how RGLs, stop bars, and color-coded lights help to prevent RIs and assist airport decision-makers in determining the appropriate lighting for the airport of which they have control. Specifically, the guidance advises airport managers as follows:

RIs.

1. RGLs provide RI protection regardless of visibility conditions and are recommended at runway holding positions to enhance the conspicuity of the hold position at problem intersections or where recommended by an FAA Runway Safety Action Team.
2. Stop bars used for RI prevention will primarily be the uncontrolled type.

    a. For example, an uncontrolled stop bar may be installed on a high-speed exit to a runway that is never used for entering or crossing the runway. This will prevent aircraft from inadvertently entering the runway from that exit.
    b. Controlled and uncontrolled stop bars may also be installed during certain runway use configurations or runway closures to prevent access to the runway.
    c. Stop bars may also be installed on runways used as part of a taxiing route at the intersection with another runway. In this case, the stop bar should be interlocked with any taxiway lighting installed on the runway so that the stop bar and taxiway lights will not be illuminated when the runway lights are illuminated. See paragraph 2.1.2.a(2)(c).

3. Color-coded (green/yellow) taxiway centerline lights are used to enhance pilot situational awareness of the runway area to reduce potential RIs (see figure 4).

Figure 4. Color-coded taxiway centerline lights installed to enhance pilot situational awareness (source: Airfield and runway lighting, 2017)

2.2.2 Runway Holding Areas

As aircraft approach the runway surface, runway holding signs and pavement markings are present to advise the pilot of its impeding location and nearby caution areas. Runway holding signs and markings are the equivalents to a roadway stop sign. Pilots are required to stop prior to all runway holding areas, ensuring they do not enter the runway area. At a towered airport, the pilot must receive an ATC clearance to enter the runway surface area. ATC will issue taxi instructions to the aircraft and holding instructions for all runways along the aircraft's route. When ATC issues a hold short of runway instruction, ATC is required to ensure the pilot reads back the hold instruction verbatim. Failure to comply with runway holding position markings or ATC runway holding instructions may result in the filing of a PD hazard report with the FAA against a pilot. All events are documented in the ATC log regardless of adverse filing actions, and conversations are maintained on voice recorders.

Runway holding areas are identified by signage and painted surface markings. Signage is identified by white numerals and alphanumeric characters outlined in black on a red background. On taxiways that intersect the threshold of the takeoff runway, only the designation of the runway may appear on the sign. If a taxiway intersects a runway somewhere other than the threshold, the sign has the designation of the intersecting runway. The runway numbers on the sign are arranged to correspond to the relative location of the respective runway thresholds. For example, figure 5 shows "5-23" to indicate the threshold for Runway 5 is to the left and the threshold for Runway 23 is to the right. Additionally, the signage will indicate the taxiway the aircraft is on in yellow with a black background. If the runway holding position sign is located on a taxiway at the intersection of two runways, the designations for both runways are shown on the sign with arrows showing the approximate alignment of each runway.

Figure 5. Runway signage indicating the thresholds (adapted from: FAA, 2017a)

Adjacent to the signage are surface markings where taxiways intersect with runways. As an aircraft approaches the runway, two solid yellow lines and two dashed lines will be visible. Prior to reaching the solid lines, it is imperative to stop and ensure that no portion of the aircraft intersects the first solid yellow line until a clearance from ATC has been received.

Surface painted runway holding position signs may be used by the pilot in determining the holding position. These markings consist of white characters with a black border on a red background and are painted on the left side of the taxiway centerline.

At most towered airports, enhanced taxiway centerline markings are used to warn aircraft of an upcoming runway. These markings consist of yellow dashed lines on either side of the normal solid taxiway centerline and the dashes extend up to 150 feet prior to a runway holding position marking.

2.3 STATE OF CHANGES IN COCKPIT TOOLS

These findings, current as of fall 2016, are the result of a web and document search for changes in cockpit tools (e.g., airport diagrams, electronic charts with own ship) used by GA pilots that may assist them in mitigating RI incidents.

The focus of this research was to provide the current capabilities available to GA pilots on electronic flight bag (EFB) instruments, usually a tablet computer, such as an Apple® iPad®. Some of these capabilities are also available on the multi-function flight display (MFD) of a particular manufacturer. Those capabilities available on the MFDs will be identified in the report.

2.3.1 ForeFlight Mobile®

ForeFlight Mobile has been in business since 2007. Their application is only capable of use on iOS or Apple devices. ForeFlight Web® is available for use on any web browser (ForeFlight, 2012).

As an advisory capability to assist in preventing RIs, ForeFlight Mobile added the Runway Proximity Advisor® capability to provide the pilot with an aural and visual warning when approaching and entering a runway on August 22, 2012, with the release of Version 4.2 (ForeFlight Blog, 2012). As the aircraft approaches the runway, the system will show a warning block across the airport diagram and will provide an aural warning with the same information (i.e., “Approaching Runway 03-21”). As the aircraft enters the runway, the system shows a similar warning block (see figure 6) and provides an aural warning (i.e., “Entered Runway 03-21”) (ForeFlight Blog, 2012).

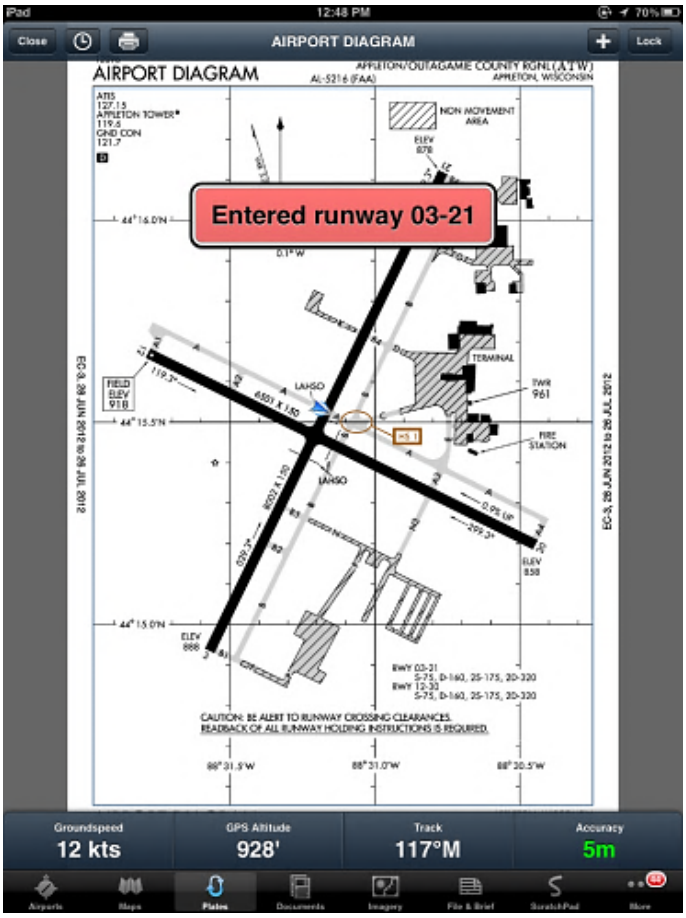


Figure 6. Visual warning when entering a runway 03-21 on ForeFlight (source: ForeFlight, 2012)

The capability for showing the geo-referenced position on the taxi diagram is available only for the ForeFlight Mobil Pro Plus® version of ForeFlight Mobile. ForeFlight Basic® and Basic Plus® do not offer this feature but do provide the Runway Proximity Advisor capability.

2.3.2 Garmin Pilot SafeTaxi®

Garmin has been a long-time manufacturer and supplier of aviation Global Positioning System (GPS) receivers and avionics. Their release of Garmin Pilot® in June 2012 allowed Garmin to compete with ForeFlight and the GA EFB capability suppliers. The system was initially provided for iOS devices but is now available for both iOS and Android™ operating systems.

In July 2013, SafeTaxi® was added to Garmin Pilot. SafeTaxi is also available on the MFD when showing the taxi diagram on Garmin cockpit display systems. This system provides a geo-referenced location on the taxi diagram. The capability also shows hot spots or areas of the airport where there have been RI issues, so the pilot can be more alert in those areas (see figure 7). The system does not provide a visual or aural warning when approaching or entering a runway (Garmin, 2016).

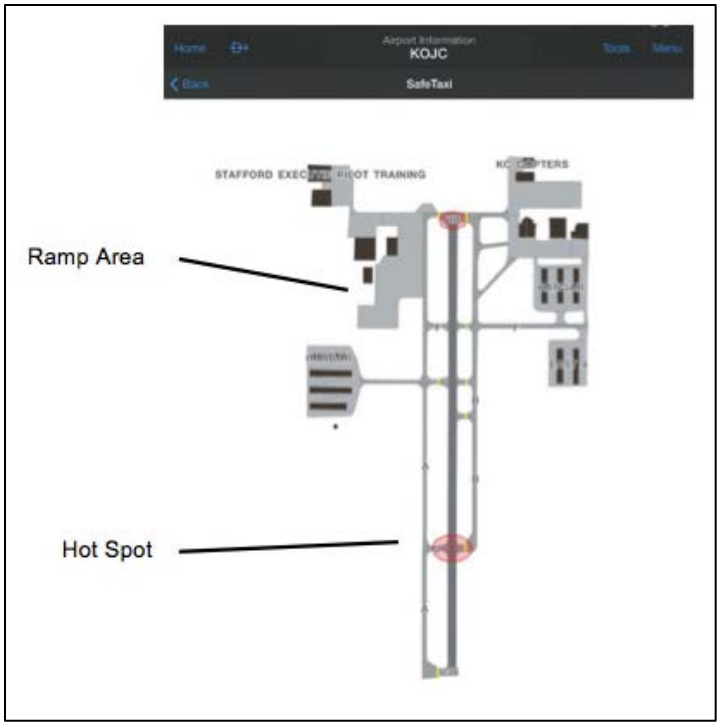


Figure 7. Capability of Garmin SafeTaxi showing hot spots (source: Garmin, 2016, p. 236)

2.3.3 Jeppesen Flight Deck

Jeppesen is a highly regarded and longtime supplier of aviation charts. Their Flight Deck Mobile application is usable only on iOS or Apple devices. The system allows for own-ship display on taxi charts while on the airport. Although the system is not specifically designed to reduce RIs, the fact that there is an own-ship display should assist the pilot in understanding where the aircraft is at the airport. There are no visual or aural warnings when approaching or entering a runway (Jeppesen, 2016). Taxi diagrams are similar to other charts shown; however, Jeppesen does not show hot spots on the taxi diagram.

2.3.4 WingX Pro7 SmartTaxi™

Hilton Software, WingX Pro7, introduced their SmartTaxi capability in 2012. The software is available only for iOS or Apple devices. This capability provides both visual and aural alerts to the pilot when approaching and entering a runway. In addition, the display will show the runway length remaining in both directions at the point of entry. This system is marketed by Hilton Software (owners of the WingX Pro7 brand) as a means to reduce RIs and to prevent using the wrong runway (Hilton Software, 2012). The availability of taxi diagrams showing the capabilities described is limited to videos on YouTube. The visual information of the runway that is being approached is on the top of the iPad display. The runway number is shown in the middle of the top of the screen when approaching the runway; the runway numbers are surrounded by a yellow block and the runway on the display becomes yellow. The runway length information is shown on the top right of the display. As the aircraft enters the runway, the runway on the display becomes red, and the runway numbers at the top of the display become surrounded by a red block. An aural alert

will tell you that you are approaching or entering the runway with the runway number and the lengths available in both directions.

3. REVIEW OF PILOT COMMUNITY KNOWLEDGE ON RIs AND PREVENTION TECHNIQUES

The purpose of this effort was to: (a) determine information needs of GA pilots for runway-related situation awareness and decision making; (b) capture the current state of awareness of GA pilots toward both RIs and the current tools that exist as prevention strategies; and (c) solicit pilot-generated strategies for preventing RIs. In addition to these items, the questionnaire also solicited information on personal experiences with GA RIs.

Based on the review of the current tools, technologies, and techniques available to GA pilots and described in section 2.0 of this report, a GA pilot questionnaire was created and administered to pilots concerning their awareness and participation with these tools, and requesting suggestions for mitigating RIs.

As a result of the phenomenological study conducted in summer 2016 with in-person interviews of pilots who had experienced RIs and recognizing that the questionnaire was an opportunity to gather firsthand information from pilots who indicated they had an RI, a section was included in the questionnaire to solicit questions from pilots about firsthand accounts of RIs without in-person interviews.

3.1 GA PILOT RI QUESTIONNAIRE METHODOLOGY

3.1.1 Population and Sample

The desired population for this questionnaire was all active GA pilots. The available population was pilots who are on the Internet and who subscribe to online aviation newsletters. The sample population was a convenient sample of pilots who actually opened and read the newsletters and chose to complete the questionnaire.

3.1.2 Instrument

Section 2.0 of this report details the current state of training materials, airport signage, and technological tools available to GA pilots to educate and prevent RIs as of 2016. On this basis, questions were then developed to determine the pilot community's knowledge and use of these items. A pilot version (as in preliminary) of the questionnaire was developed and available at the Society of Aviation and Flight Educators (SAFE) booth at EAA AirVenture 2016.

Questions were based on the findings of Task 1 of this project and on the interviews. The questionnaire consisted of five sections:

For all subjects

1. Aviation Experience and Demographics

- Demographics
    - Aviation Experience
        - Certificates
        - Hours
        - Characteristics of flying
            - How much at towered airports
            - Primary type of flying (single pilot, purpose)
    - Age, Gender, and Ethnicity

2. Training and Knowledge Related to RIs

    - Familiarity with educational material on RI avoidance
    - Prior training on RIs
    - Preferences in learning more about preventing RIs
    - Views toward GA RIs

3. Use of Taxiing Resources

    - Use of paper or electronic airport diagrams

4. Thoughts on Preventing RIs

    - Types of resources they would find beneficial to convey important information about preventing RIs
    - Specific suggestions for improvements on prevention of RIs
    - Resources they believe GA pilots need but do not have

5. Personal Experience of GA RIs

Subjects were then asked if they had ever been involved in an RI while a pilot on a GA flight. If so, would they answer more questions? For those who answered yes, additional questions included:

- Seriousness of the incursion?
- Were other objects involved?
- Towered or non-towered airport?
- What type operation (purpose) was your flight?
- Action/person that precipitated the incursion?
- Phase of flight, when the incursion occurred?
- Contributing factors: communications, human performance, radio equipment, spatial awareness, equipment, signs/markings?

See appendix C for the complete questionnaire and exact wording of questions.

Questions were either Likert scale, multiple choice, demand, or open-ended questions as appropriate. All multiple-choice questions had an option for "Other" and a place to write comments.

For contributing factors, pilots were presented a list of subfactor categories and were asked to check any that applied. A comment box allowed them to write their answers. The potential RI causal factor categories were taken from the 2016 Runway Incursion Technical Report published by Volpe National Transportation Center (Bisch, Calabrese, and Donohoe, 2016). Figure 8 shows RI causal factor categories.

Communication	Readback/hearback error
	Wrong aircraft accepted clearance
	Readback clearance correctly, executed different maneuver
	Controller misspoke or omitted information
	Lack or delay of communications
	Difficult to understand
	Communication—other
Human Performance	Procedural error
	Coordination error (e.g., not initiated, failure)
	Issued conflicting clearances
	Pilot/driver was distracted
	Controller was distracted
	Pilot delayed or stopped movement unexpectedly
	Unclear why pilot acted without clearance
	Unclear why vehicle driver acted without clearance
	Pedestrian acted without clearance
	Human performance—other
Spatial Awareness	Taxi route error
	Airport confusion
	Surface confusion
	Runway confusion
	Spatial awareness—other
Equipment	Frequency issue
	Frequency congestion
	Equipment problem
	Equipment—other
Signs/Markings	Hold-short line issue
	Runway/Taxiway sign issue
	Signs/Markings—other

Figure 8. Contributing factors and subfactors used in questionnaire (source: Bisch, et al., 2016, p. 22)

The questionnaire was implemented in Google Forms. An Internet hyperlink provided access to the questionnaire. The questionnaire was reviewed by university aviation faculty experienced in

instrument design, subject matter experts, and the RI advisory committee prior to use to ensure validity.

Figure 9 shows the process of creating the questionnaire, Institutional Review Board approval, advertising the questionnaire, the flow of questions, and analyzing the results.

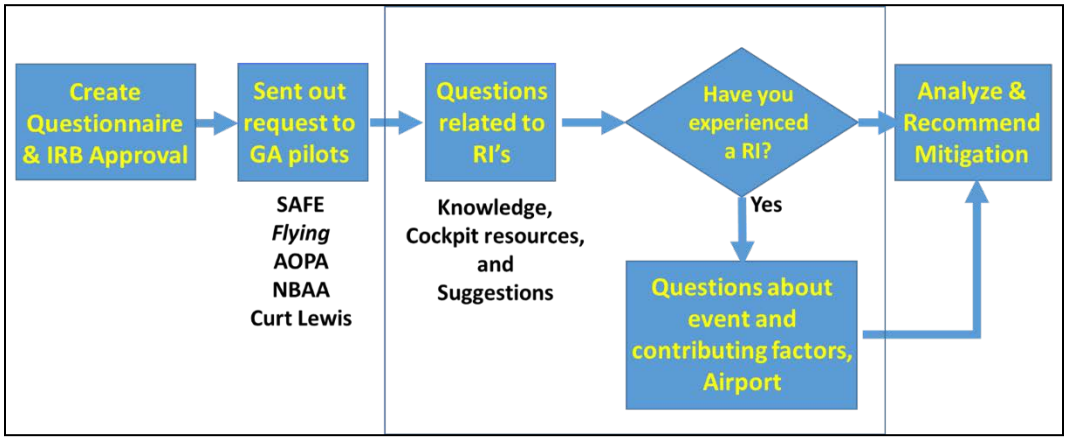


Figure 9. RI questionnaire process

3.1.3 Distribution of GA Pilot RI Questionnaire

A press release was prepared to request GA pilots complete the questionnaire via an Internet hyperlink provided in the press release. The press release was sent via email to GA organizations requesting it be published in their online newsletters. The questionnaire was open for responses from April 1, 2017 to May 8, 2017. Organizations that published the request to take the questionnaire were:

- Society of Aviation and Flight Educators' eNews (SAFE, 2017)
- Flying Magazine's eNewsletter (Flying, 2017)
- AOPA's Aviation eBrief (AOPA, 2017)
- Curt Lewis & Associates', Flight Safety Information (Curt Lewis, 2017)
- National Business Aviation Association (NBAA, 2017)

3.2 RESULTS OF GA PILOT RI QUESTIONNAIRE

The request to complete the questionnaire resulted in 1402 responses, of which 1401 were from respondents over the age of 18 and usable.

3.2.1 Demographics

All 1401 of the respondents provided information on their age and gender. The distribution for those who gave their exact ages is shown in figure 10. An additional 19 respondents did not give a specific age but rather a descriptor indicating they were old. The average age, not including the "old" responses, was 56.7 years. The median, including the "old" responses, was 66 years.

The respondents included 1326 men, 58 women, and 17 who preferred not to give their gender. Of the respondents, 1226 were Caucasian, 33 Hispanic, seven African American, 18 Asian, and 78 "other."

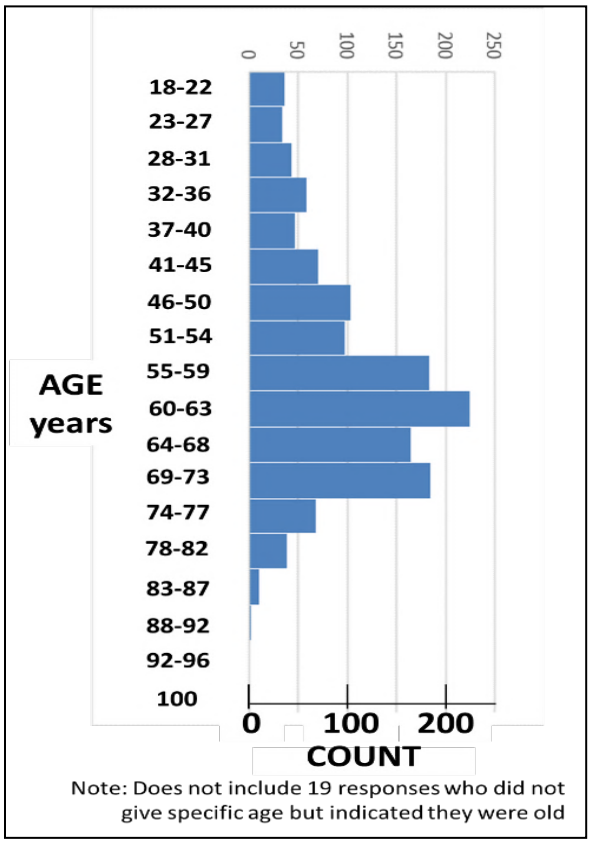


Figure 10. Age of questionnaire respondents

3.2.2 Flight Experience

Flight experience of the respondents was measured by their current pilot certificate and total flight hours. The type of experience was also measured by the percentage of flying at a towered airport, flying at unfamiliar airports, and whether they usually flew single-pilot or as a crew.

All respondents provided their highest current pilot certificate. The private pilot category was further broken down into whether they had an instrument rating on their certificate. Figure 11 shows a fairly even distribution between air transport, commercial, private without an instrument rating, and private with instrument rating.

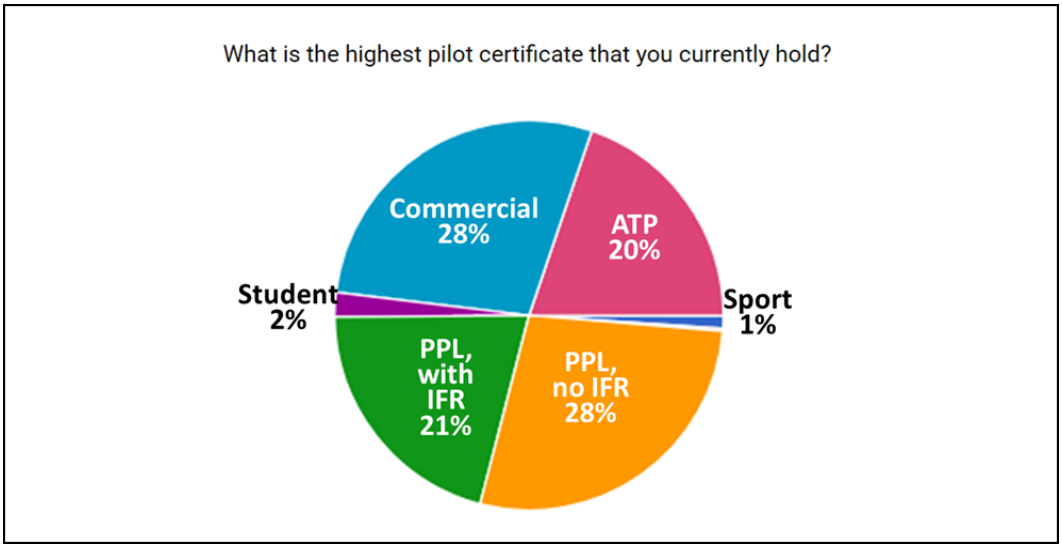


Figure 11. Pilot certificates of questionnaire respondents

All but one respondent answered the question on their current total flight hours. Some respondents provided descriptors such as "about" or "over" with a number of hours. If a respondent included a descriptor with a value, the value was used in the statistics. If a respondent included a value range, the average of the range was used. As shown in table 1, there was a very wide spread of experience as measured by total flight hours, with a skew to lower hours, as shown by the average of 3409 hours and lower median of 1200 hours.

Table 1. Flight hours reported by GA pilot questionnaire respondents

	Flight Time, hours
Minimum	0
Maximum	40,000
Average	3409
Median	1200
n=1400	

All 1401 respondents provided input to the question "What percentage of your flights depart or arrive at towered airports?" Some responses included a number for both past and current flights. In this case, the current number was used. Seventeen were ambiguous and not usable for the graph shown in figure 12. Of these, seven indicated they flew into towered airports "very little" or "rarely," whereas three indicated they "mostly" flew into towered airports.

All 1401 respondents provided input to the question "What percentage of your flights are at unfamiliar airports?" Again, some responses included a number for both past and current flying. In this case, the current number was used. Twelve responses were qualitative and not useable for the graph shown in figure 13. Of these, seven indicated they seldom or rarely flew into unfamiliar airports, two indicated they often flew into unfamiliar airports, and three were ambiguous.

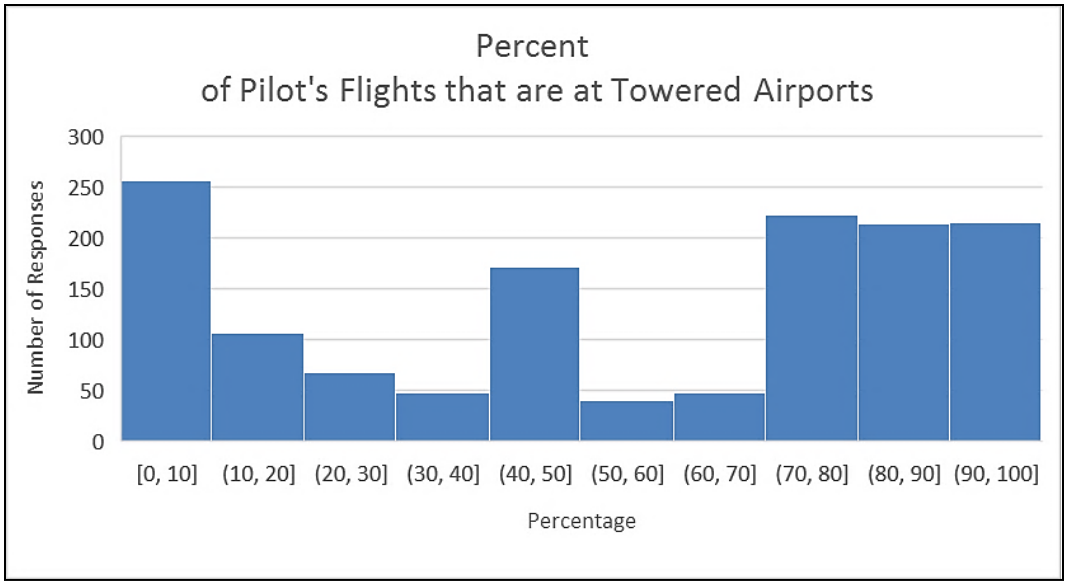


Figure 12. Respondents' input to "What percentage of your flights depart or arrive at towered airports?"

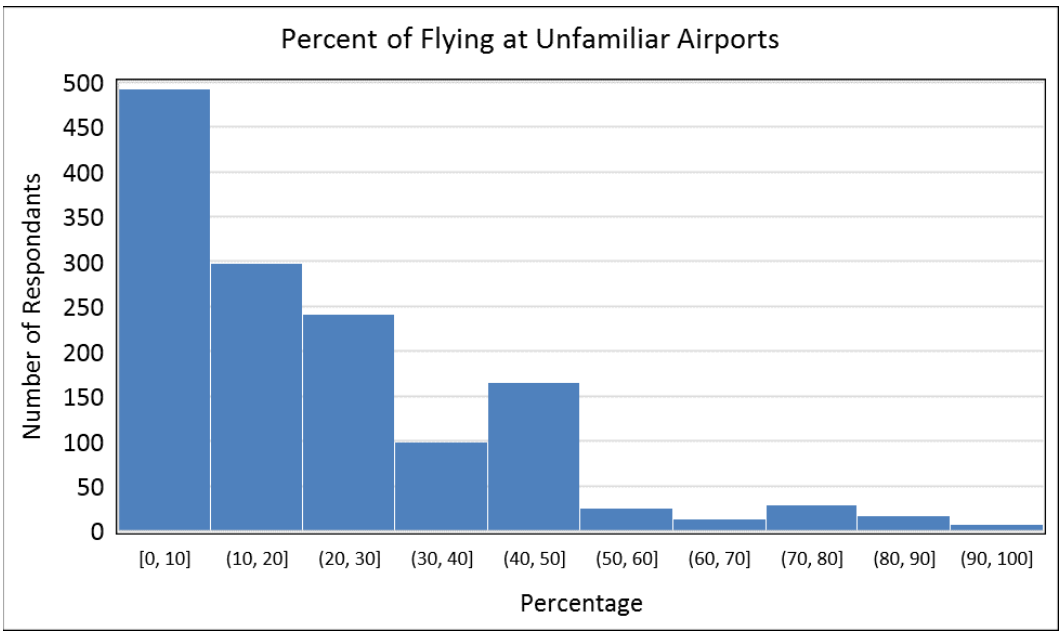


Figure 13. Respondents' input to "What percentage of your flights are at unfamiliar airports?"

All 1401 respondents provided input to the question "Do you primarily fly single-pilot or as part of a multi-crew operation?" As shown in figure 14, responses indicated 85% were single-pilot and 15% were crew operations.

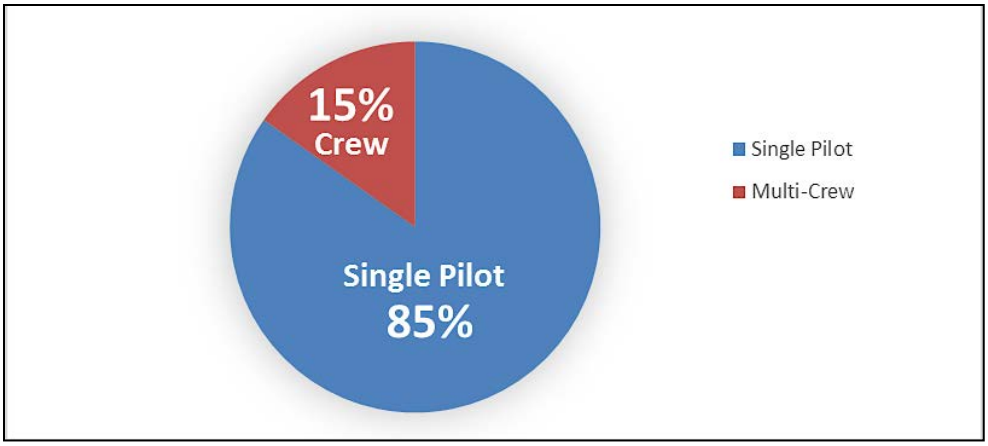


Figure 14. Respondents' input to "Do you primarily fly single-pilot or as part of a multi-crew operation?"

3.2.3 Attitudes Toward GA RIs

To determine GA pilots' attitude toward GA RIs and whether they feel RIs are a problem, the questionnaire included four statements to capture their views. For each statement, the possible responses ranged from 1 to 5, with 1 being Strongly Disagree, 3 being Neither Disagree or Agree, and 5 being Strongly Agree. The average Likert score for each statement is shown in figure 15.

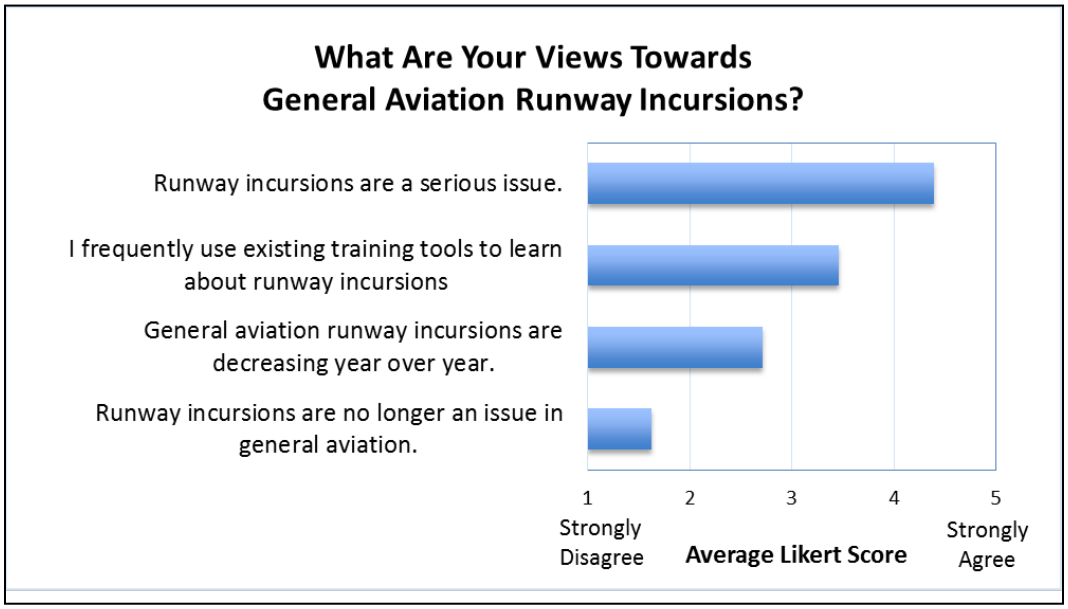


Figure 15. Average of Likert responses to "What are your views toward GA runway incursions?"

3.2.4 GA Pilot Responses for RI Training

3.2.4.1 Knowledge of Training Material About RIs

To capture GA pilots' current state of awareness with RI educational material, the questionnaire included a question on their familiarity with the following resources related to RI avoidance:

- The Best Practices Guide to Operations and Communication Brochure
- AC 91-73B "Parts 91 and 135 Single Pilot, Flight School Procedures during Taxi Operations"
- AC 90-42 "Traffic Advisory Practices at Airports Without Operating Control Towers"
- AC 90-66 "Recommended Standard Traffic Patterns and Practices for Aeronautical Operations at Airports Without Operating Control Towers"
- AOPA Online Course: Runway Safety
- FAA Runway Safety Program Website
- Flash Cards for Airport Signage
- Hot Spot Program
- PHAK Appendix 1.
- Runway Status Lights Program

Details for each specific resource are described in section 1.0 of this report.

For each resource, the possible answers ranged from 1 to 5, with 1 being Not at All Familiar, and 5 being Extremely Familiar. The average Likert score for each resource is shown in figure 16. On average, respondents were most familiar with the AOPA Online Course "Runway Safety" (n = 1401, avg. = 3.7, median = 4.0, std dev = 1.4). Respondents were least familiar with AC 91-73B, "Parts 91 and 135 Single Pilot, Flight School Procedures During Taxi Operations" (n = 1401, avg. = 2.3, median = 2.0, std dev = 1.4). Fifty-nine percent of respondents were either slightly familiar or not at all familiar with AC 91-73B.

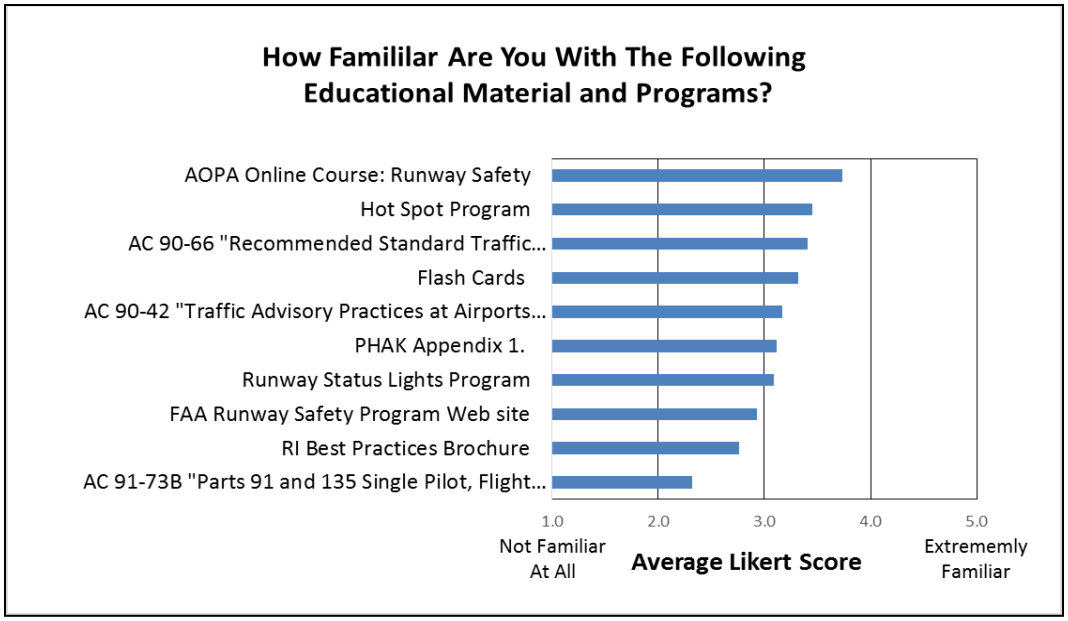


Figure 16. Average of Likert responses to "How familiar are you with the following educational materials and programs?"

3.2.4.2 Prior and Future Training on RIs

To determine if GA pilots feel they have had adequate training on RIs, the questionnaire included three statements on prior training. For each statement, the possible responses ranged from 1 to 5, with 1 being Strongly Disagree, 3 being Neither Disagree or Agree, and 5 being Strongly Agree. The average Likert score for each statement is shown in figure 17.

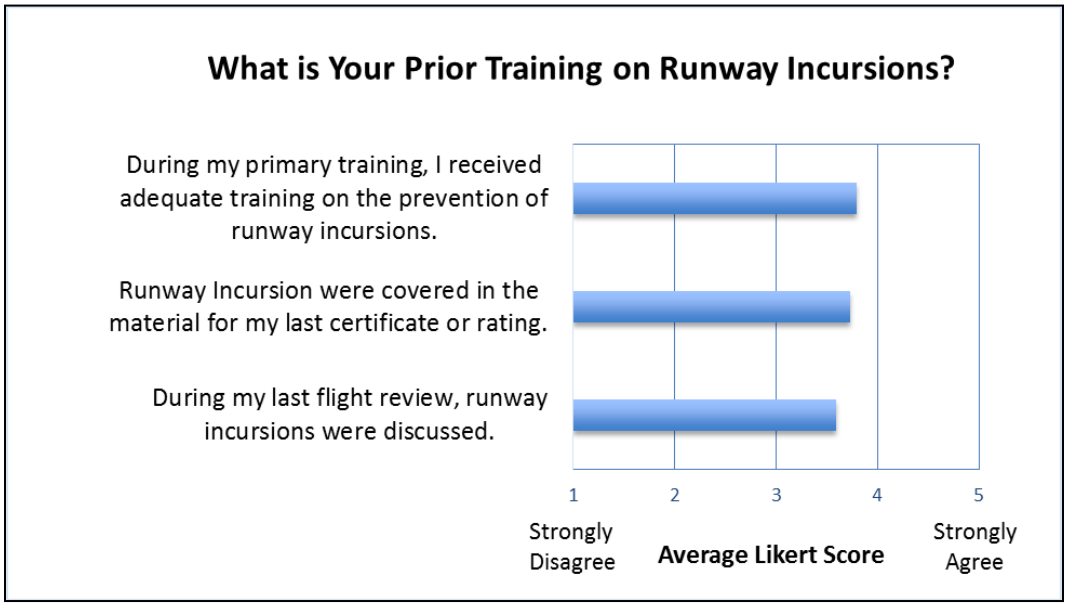


Figure 17. Average of Likert responses to "What is your prior training on runway incursions?"

On average, the lowest average Likert score was for the statement that RIs were discussed on their last flight review (*n* = 1401, avg. = 3.6, median = 4.0, std dev = 1.2). For this statement, 62% agreed or strongly agreed that they had discussed RIs on their last flight review.

To determine what GA pilots would do to learn more about preventing RIs, the questionnaire included eight different options, such as watch a video on RIs, complete an online interactive course, go to a website, attend an in-person safety seminar, attend a webinar, use an app, take a lesson with a flight instructor, and read a textual document rather than watching a video. For each option, participants were provided with possible responses ranging from 1 to 5, with 1 being Strongly Disagree and 3 being Strongly Agree. The average Likert score for each option is shown in figure 18.

On average, the lowest average Likert score was for reading a textual document (*n* = 1401, avg. = 3.3, median = 3.0, std dev = 1.2), whereas the highest average score was for watching a video on RIs (*n* = 1401, avg. = 3.9, median = 4.0, std dev = 0.92)

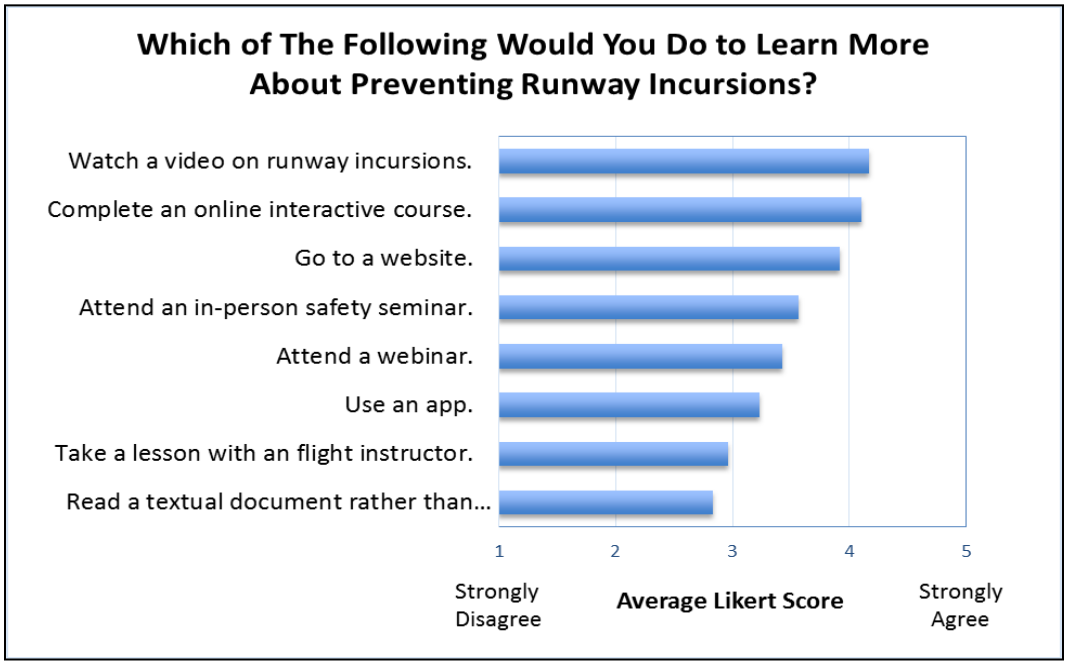


Figure 18. Average of Likert responses to "Which of the following would you do to learn more about preventing runway incursions?"

3.2.5 Use of Cockpit Tools

To capture GA pilots' current state of usage of cockpit tools that can reduce RIs, the questionnaire included a question on pilots' usage of products used while taxiing. The options included:

- Paper airport diagram
- Moving map in cockpit panel with airport diagram
- Electronic airport diagram without geo-reference aircraft
- Electronic airport diagram with geo-reference aircraft on chart

- Electronic chart with aural alerts when approaching or entering runway

Details for each specific option are described in section 2.0 of this report.

For each cockpit product option, the possible answers ranged from 1 to 5, with 1 being Never Use and 5 being Always Use. The average Likert score for each option is shown in figure 19. On average, respondents most often used the electronic airport diagram with geo-reference aircraft (*n* = 1401, avg. = 3.1, median = 3.0, std dev = 1.5). It is also of note that 83% of respondents indicated at least one product that they always or almost always use in the cockpit (see table 2). Conversely, only 1.5% of respondents indicated they never or almost never used any of the choices for cockpit products.

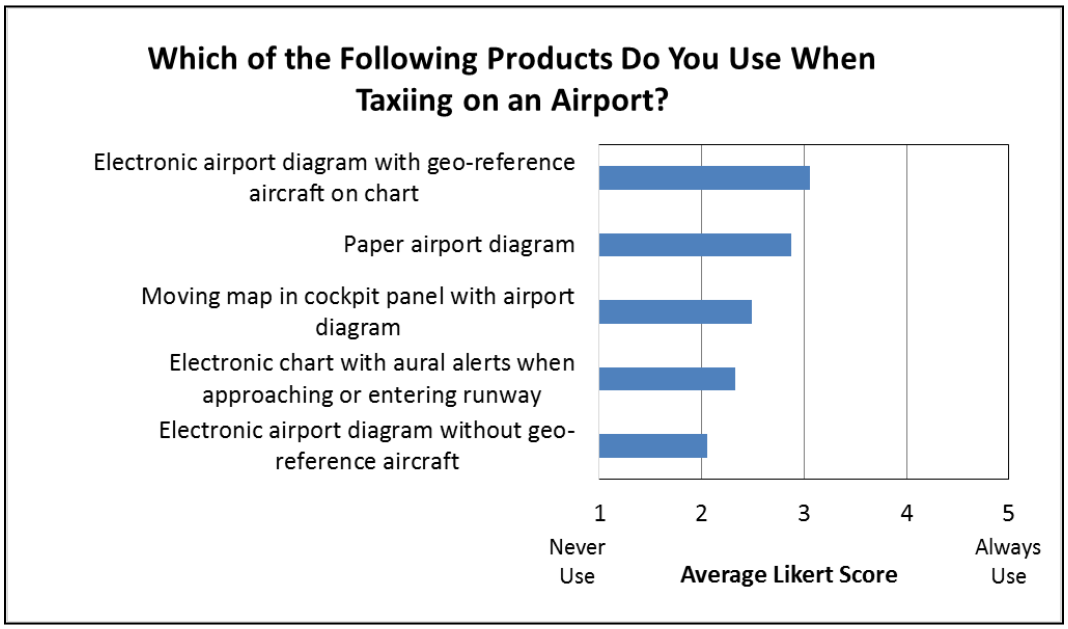


Figure 19. Average of Likert responses to "Which of the following products do you use when taxiing on an airport?"

Table 2. Respondents' highest usage score on at least one of the cockpit tools

Option	Percent Selected
Always	44%
Almost Always	39%
Occasionally	15%
Almost Never	0.9%
Never	0.5%

3.2.6 GA Pilot Response on How to Prevent RIs

Participants were asked three open-ended questions directed at how to mitigate and prevent RIs. The questions were:

- Describe what types of resources (textbooks, apps, brochures, online courses, videos) you would personally find beneficial to convey important information about preventing RIs.
- What resources do GA pilots need but do not have?
- Based on your experience, do you have specific suggestions for improvements on how to prevent RIs?

3.2.6.1 Beneficial Resources to Prevent RIs

The question "Describe what types of resources you would personally find beneficial to convey important information about preventing runway incursions" received 1124 responses. Responses related to training focused on either the content of resources or the delivery method. The top 10 recurrent themes in response to a question on beneficial resources are shown in table 3. Direct quotes from participants that are representative of the responses are given in appendix C.

Examples of good existing training specifically mentioned, Rob Machado, , FlightChops, Advanced Aircrew Academy, NBAA, King Schools, Sporty's, and AOPA Air Safety Videos, including their online courses, seminars, videos, and magazines.

Table 3. Top 10 recurrent themes in response to the question "Describe what types of resources you would personally find beneficial to convey important information about preventing runway incursions"

Beneficial Resource	Number of Responses
1. Videos	454
2. Online delivery	440
3. AOPA resources	187
4. FAA publications	80
5. Lighting and Signage	90
6. Text and Books	67
7. Seminars	65
8. Webinars	55
9. YouTube delivery	52
10. Interactive delivery	44

3.2.6.2 Resources GA Pilots Need but Do Not Have and Suggestions for Improvements on How to Reduce RIs

The question "What resources do GA pilots need but do not have?" received 889 responses. Some pilots answered this as to what is needed in general rather than specific resources. The top 10 recurrent themes in response to a question on resources they want but do not have are shown in table 4. See appendix C, table C-1 for the specific noteworthy comments for "Resources GA Pilots Need but Do Not Have."

Table 4. Top 10 recurrent themes in response to the question "What resources do GA pilots need but do not have?"

Needed Resource Themes	Number of Responses
1. The resources are already available, need better ways to use them	181
2. Don't know	141
3. Better training	63
4. Improved airport diagrams	51
5. Geo-referencing for airport diagrams	30
6. Low-cost cockpit and panel tools	43
7. Better signage	34
8. Electronics and EFBs	33
9. Common sense	17
10. Better instruction for Certified Flight Instructors	11

The question on specific suggestions to prevent RI received 1061 responses. Many responses overlapped both the previous two questions and said, "See above." The suggestions were grouped into the following 11 recurrent themes:

- Airport information for pilots
- Airport diagram and EFB
- Markings and signage
- Airport lighting
- Airport design
- Technology
- Communications
- Training
- Culture of safety
- Human behavior
- Best practices for GA pilots

Representative and noteworthy responses for each theme are summarized below and given in appendix C, tables C-2 through C-14.

3.2.6.2.1 Suggestions for Airport Information for Pilots

In the question regarding what resources are needed, numerous pilots indicated the material is out there; it just needs to be better disseminated and readily usable. This is consistent with the multiple suggestions for improvements related to the ability of pilots to access ground operations information for an airport. It is also consistent with numerous comments in other themes for specific needed resources or improvements discussed in this section.

Based on comments, ground information needs to be clearly and easily available so that fixed-base operators (FBOs) and others can present the information. How pilots can access the information needs to be publicized. Suggestions for where to publish the information are included in the Chart Supplement (CS), on the airport diagram, online, and are clearly posted in the FBO. Respondents also suggested including satellite imagery and including procedures for runway and taxiway use.

Refer to appendix C, table C-2 for the suggestions on airport information for pilots.

3.2.6.2.2 Suggestions for Airport Diagram and EFBs

Comments related to airport diagrams and EFBs appeared in questions both for needed resources and for improvements to reduce RIs. There were 130 responses that included the terms "chart," "diagram," or "map." In analyzing words related to airport diagrams, it was found that geo (e.g., geo-referenced or geo map), electronic charts, and location (e.g., show the location) were themes for airport diagrams.

Suggestions for improvements to current airport diagrams included showing the location of hold position lines and adding text explaining hot spots. Current airport sketches at non-towered airports need to be improved by replacing sketches with "real" airport diagrams so pilots have the same type of information that they expect on airport diagrams at towered airports.

Improvements to electronic diagrams were technology related, such as having standard taxi routes and the ability to show them on electronic diagrams when assigned by ATC. Comments related to electronic airport diagrams also included the importance of showing the aircraft location using geo-referenced airport diagrams, and that all pilots should have access to this information in the cockpit. There were 10 responses that said it was so important that vendors should be required to provide it for free.

Refer to appendix C, table C-3 for the supporting comments to improve airport diagrams and EFBs.

3.2.6.2.3 Suggestions for Markings, Lights, and Signage

Suggestions for improvements to reduce RIs related to current signage included the need for standardized, consistent signage (especially at non-towered airports), simplified signage, use of the back of the sign (especially for taxiways), and better maintenance. Suggestions related to changing signage and markings included more intuitive signs (i.e., similar to road signs), flashing signs at runway intersections or hot spots, and different colors for hold-position markings.

There were multiple suggestions to paint the taxiway designation at intersections to make it easier to identify specific taxiways, especially when the placement of signage makes it difficult to identify a taxiway's designation (e.g., from viewing angle, distance from taxiway centerline, multiple taxiways at intersection).

Suggestions related to current lighting included installing lights at taxiway/runway intersections in more airports (e.g., yellow in-pavement lights, RGL, clearance bar lights, or stop bar lights). Suggestions for lighting products that do not currently exist include the use of flashing hold-position lights, automated red and green traffic lights, and a new sign for hot spots.

Refer to appendix C, tables C-4, C-5, and C-6 for the suggestions to improve airport markings, lighting, and signage.

3.2.6.2.4 Suggestions Related to Airport Design

Several comments suggested that airport design should be improved, but did not specify how to improve it, whereas other comments highlighted the situations that help cause RIs and that need improvement, rather than offering a solution. Situations mentioned that cause problems were (a) strange configurations of runway boundaries, (b) hold-position markings in non-standard locations, (c) the location of signage on airfields designed for large air carriers but difficult to view from small aircraft, and (d) trying to accommodate aircraft that are too large for the airfield.

Refer to appendix C, table C-7 for the suggestions to improve airport design.

3.2.6.2.5 Suggestions Related to Communications

Communication-related suggestions to prevent RIs can be separated into either towered or non-towered airports.

3.2.6.2.5.1 Suggestions Related to Communications at Towered Airports

Analysis of comments related to ATC communications at towered airports revealed they could be grouped into themes of (a) progressive taxi, (b) speaking slower, (c) when to give a clearance, (d) customer service, and (e) clearance.

Regarding progressive taxi, comments suggested controllers should be more proactive in providing progressive taxi instructions. Variations were whether ATC should be required to (a) automatically ask if the pilot wants instructions, (b) give progressive taxi even if the pilot does not ask, or (c) always give instructions when asked.

There were 21 suggestions related to controllers speaking more slowly. Responses addressed when a controller should speak more slowly, such as clearances or when speaking to international pilots. Suggestions also differentiated between when controllers need to speak quickly and when they have time to speak more slowly.

Another theme of the comments related to when a controller gives a taxi clearance. Respondents wrote that controllers should not give taxi clearances when (a) the pilot is rolling out on the runway, (b) before the pilot has completed an after-landing checklist, or (c) when the pilot is obviously doing something else.

Some ATC-related comments could be described as customer service dealing with GA pilots. The suggestions were for controllers to be friendlier, more patient, less intimidating, helpful, and able to recognize a pilot that needs some extra help. Suggestions also included that pilots (a) learn to not be intimidated by controllers, (b) not be afraid to ask ATC to repeat a clearance or ask for a progressive taxi, and (c) know how to deny a clearance.

Finally, comments related to clearances included that ATC should assign runways based on minimizing runway crossings instead of direction of flight, and ATC should avoid taxi clearances

that include a runway crossing right away. The taxi clearances should also not assume the pilot is familiar with the airport (e.g., local idioms and local knowledge of the airfield).

Refer to appendix C, table C-8 for communication-related suggestions for towered airports.

3.2.6.2.5.2 Suggestions Related to Communications at Non-Towered Airports

Analysis of comments related to communications at non-towered airports revealed they could be grouped into themes of (a) radios usage, (b) common traffic advisory frequency (CTAF), and (c) ground procedures.

Various suggestions calling for the use of radios at non-towered airports included either (a) requiring the use of radios, (b) banning non-radio aircraft and vehicles, (c) requiring radios at all airports (d) requiring radios in all aircraft, and (e) encouraging radio reports.

Respondents recognized that pilots may not hear other aircraft at non-towered airports because one of the pilots may be transmitting or receiving on the wrong frequency. Suggestions were to post the CTAF in the runway area and be sure to use it. There was also a suggestion to use geographical or city names for airports, because naming airports after people causes confusion with radio calls.

Finally, suggested ground procedures at non-towered airports included (a) transmitting intentions, (b) turning 45 degrees to the runway to check for traffic prior to entering the runway, and (c) doing a 360-degree turn before takeoff.

Refer to appendix C, table C-9 for communication-related suggestions for non-towered airports.

3.2.6.2.6 Suggestions Related to Training

Topics related to education and training were the theme for resources need to reduce RIs and suggestions for improvements to reduce RIs. Analysis of comments found that the terms related to training revealed that comments can be grouped into (a) delivery methods, (b) when to train, (c) who to train, and (d) content of training.

Suggestions reflected current delivery methods that engage the student in an interactive environment that uses interactive web-based modules, scenarios in simulators, real-world situations, or one-on-one training to learn specific knowledge, procedures, and decision-making skills. Suggestions also highlighted methods that allow pilots to participate from anywhere via the Internet, and the use of free videos, webinars, and online courses taught through AOPA, EAA, and the FAA was recommended.

There were three themes for the responses regarding when pilots should have RI training: they should have RI training modeled on every training flight, they should get airport-specific training prior to flying to an airport, and they should get continuing education throughout their entire time as pilots.

Comments revealed that pilots think it is important that RI training be part of continuing education, from beginner to seasoned pilot. The term “flight review” or “BFR” (i.e., biennial flight review) appeared 71 times in response to the questions for needed resources and suggestions for

improvements. Comments were not only that RI training should be part of, or in concert with, the flight review but also that it should be documented and mandatory.

Other comments related to when to train suggested that (a) RI training be a larger part of sport and private curriculum, (b) that certified flight instructors (CFIs) should better model proper behavior on every flight, and (c) that pilots should be educated with airport-specific training (e.g., simulators or online training) prior to flying to an airport.

Pilots suggested a variety of topics that were important to include in training to reduce RIs. Themes for training content included:

- Recurrent training should include practicing at a type of airport they do not regularly use. Pilots that fly at quiet, simple airports should practice for busy, complex airports, and pilots who always fly at towered airports should practice for non-towered airports.
- Pilots need to learn the ability to judge whether there is time to cross a runway or take off ahead of another aircraft in the pattern at a non-towered airport.
- They should train and practice correct ground procedures at both towered and non-towered airports, including best practices and SOPs.
- Pilots need to learn the many aspects of human factors related to RIs, such as decision-making, planning ahead, paying attention to taxiing, managing errors, having a sterile cockpit, being vigilant, having situation awareness, being fatigued, and expectation bias.
- Communication procedures on the ground at both towered and non-towered airports.
- Airport-specific information.
- Real-life examples of airport environment and of incursions and consequences, rather than broad-brush, theoretical topics.
- Knowledge items including signage and markings, radio phraseology, and chart usage.
- The need for pilots to not be afraid to ask for help.
- Safe behavior and safe attitudes.

Suggestions for improvements to reduce RIs included RI-related training not just for pilots, but also training for controllers and airport operators. Suggestions included ensuring that RI training included all pilots, from those just beginning pilot training to those who are older, experienced, and "seasoned pilots." Comments also suggested that CFI's need more training on how to effectively teach their students.

Refer to appendix C, table C-10 for the common suggestions to improve training.

3.2.6.2.7 Suggestions Related to Culture of Safety

On analysis, 25 comments were found with the word "safety." Comments were not just about teaching safety, but also about cultivating a culture of safety and changing mindsets. Comments suggested that airport leadership needs to set the tone and instill safety at GA airports.

Refer to appendix C, table C-11 for the supporting comments on culture of safety.

3.2.6.2.8 Suggestions Related to Human Behavior

Analysis of comments found a theme of human behavior in the comments of how to reduce RIs. Comments did not provide specific suggestions but rather highlighted that any improvements need to consider human factors. Examples of topics related to human behavior that were cited included that: changing behavior is difficult, that humans make mistakes, that pilots can be afraid to ask for help, some pilots have a do-not-care attitude, that complacency is hard to stop, and that every pilot should take personal responsibility for their actions.

Refer to appendix C, table C-12 for the supporting comments on human behavior.

3.2.6.2.9 Suggestions Related to Best Practices in the Cockpit

Analysis of comments found that many provided specific suggestions that can be grouped as best practices in the cockpit. Within these best practices, themes were identified for sterile cockpit, taxi instructions, look out, awareness, taxiing, mandatory, and procedures.

Refer to appendix C, table C-13 for the supporting comments on best practices in the cockpit.

3.2.6.2.10 Other Suggestions Related to Reducing RIs

A few other suggestions were worth noting. One was about staging aircraft for takeoff at busy airports and whether the risk is worth the reward of increasing capacity. Another is about assigning takeoff runways that minimize runway crossing while taxiing.

There were several suggestions from pilots for increasing the penalty for incursions.

Refer to appendix C, table C-14 for the other supporting comments from pilots.

3.2.7 Prior Experiences With GA RI

Respondents were asked the following:

> Have you ever been involved in an RI while the pilot on a GA fight (14 CFR 91), either as the aircraft with the right-of-way, or the aircraft that inadvertently encroached on the runway?

Of the 1398 responses to this question, 455 (67.3%) indicated that, yes, they had been involved in an RI event. Of these, 398 agreed to answer more questions about the event. Questions topics included:

- Towered or non-towered airport
- Severity of event
- Who was responsible for event (RI category)?
- What type of operation was their flight?
- Where did event occur (i.e., specific phase of flight)?
- Contributing factors

To encourage responses, no time limit was given for when the event occurred, and the subjects were not asked the year or the location of the event.

3.2.7.1 GA RIs at Towered Airports

Of the 398 responses regarding experiences with a GA RI, 203 (51%) occurred at a towered airport.

3.2.7.1.1 Severity Category Rankings at Towered Airports

Respondents were asked the following question: How serious was the incursion? Possible responses corresponded to the FAA's definitions of RI Severity Category Rankings (FAA, 2017b), which were:

a. A serious incident in which a collision was narrowly avoided by extreme action or chance
b. An incident for which there was a significant potential for a collision
c. An incident characterized by ample time or distance to avoid a collision
d. An incident with only one aircraft but that met the definition of a RI

The responses were opinions, and there was no way to verify the accuracy of their assessments of severity.

Figure 20 shows the breakdown and relative size of self-reported severity of RI events. The results indicated 4% (5) of events that would fit Category A, 15% (30) that would fit Category B, 37% (75) that would fit Category C, and 46% (9) that would fit Category D. The distribution is similar to that of severity categories for GA operations in the FAA Runway Safety Database, as discussed in section 6.3. This lends validity to the information reported on this questionnaire.

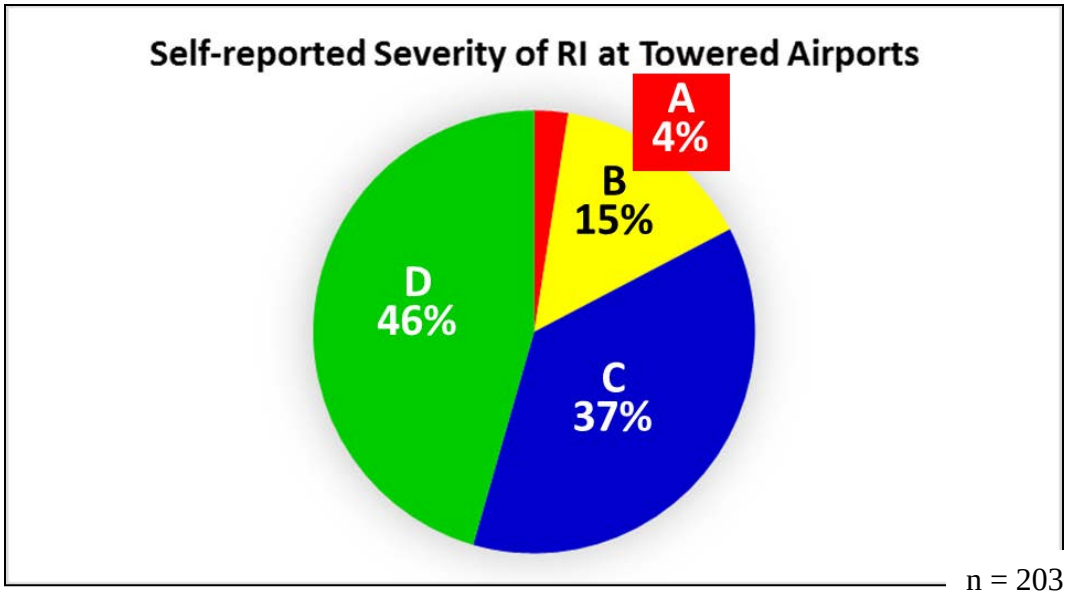


Figure 20. Severity category rankings for GA RIs at towered airports as reported on questionnaire

3.2.7.1.2 Incident Type Code at Towered Airports

Respondents were asked the following question: What action precipitated the incursion? Table 5 shows how the possible answers correspond to the FAA Incident Type Codes (FAA, 2017b).

Table 5. Possible answers to question "What action precipitated the incursion?" and corresponding FAA incident-type code for GA runway as reported by respondents

Possible Answer to Question	Corresponding FAA Incident Type Code
Action by you, the pilot, or your crew	Pilot Deviation (PD)
Action by a second aircraft	Pilot Deviation (PD)
Action by Air Traffic Controller	Operational Incident (OI)
Action by Vehicle/Pedestrian	Vehicle/Pedestrian (VPD)
Other	Other

Figure 21 shows the relative distribution of self-reported RI events, in terms of corresponding incident type codes. Different codes include self-reported pilot deviations (PDs Self), pilot deviation classified as other (PD Other), operational incident by ATC controller (ATC), and vehicle/pedestrian deviation (VPD). The number of responses to the question was 206, and half the respondents reported their action caused the RI event. The figure shows 72% (154) of the events were caused by pilots, 30% (63) were caused by ATC, and only 2% (4) were caused by vehicles or pedestrians. Percentages add to more than 100% because 23 respondents listed a pilot action plus an ATC action. Comparing this to information in the FAA Runway Safety Office RWS, the percent of PDs is slightly higher and the VPD much lower for RI involving GA operations at towered airports, as discussed in section 6.3 of this report.

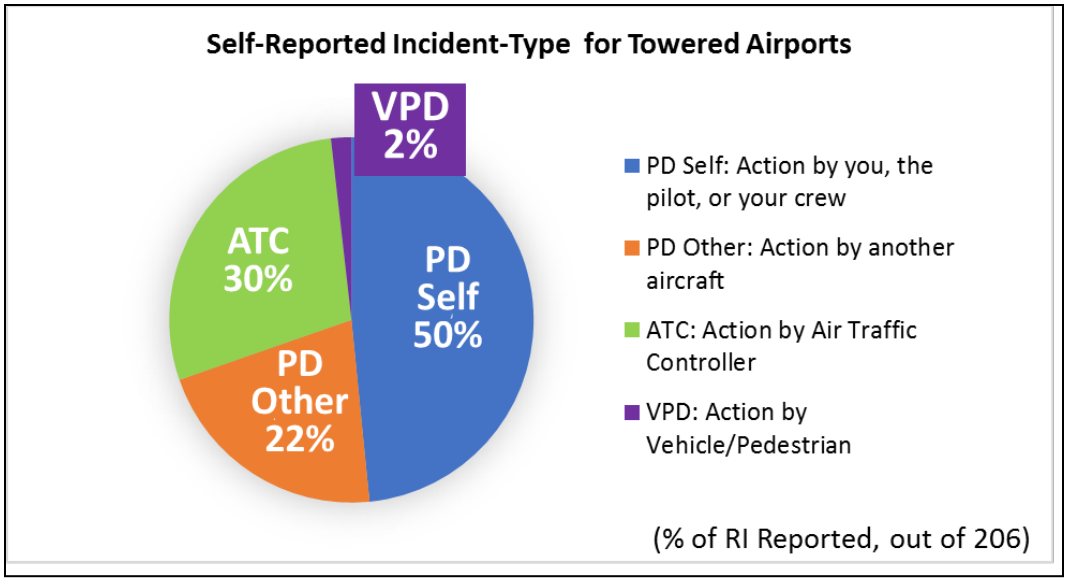


Figure 21. Incident type code for GA RIs at towered airports as reported in GA pilot questionnaire (note: percentages exceed 100% because of reporting multiple causal actions)

3.2.7.2 GA RIs at Non-Towered Airports

Of the 398 who answered questions about their experience with a GA RI, 195 (49%) reported that their RI occurred at a non-towered airport or an airport where the tower was closed at the time of the event. Subjects were asked the same questions for non-towered airports as for towered airports.

The questionnaire intentionally did not provide a definition of an RI at a non-towered airport. With the official definition, "Any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle, or person on the protected area of a surface designated for the landing and takeoff of aircraft", the words "incorrect presence" imply a clearance from ATC. A clearance is not applicable at non-towered airports. RIs due to operating contrary to an ATC clearance cannot exist at a non-towered airport. Therefore, the question regarding whether they had an RI used an operational description related to the aircraft with the right of way and an aircraft encroaching on the runway.

The responses indicated that 106 (53%) of the RIs at non-towered airports occurred on final approach; 32 (16%) occurred while landing on runway; 24 (12%) occurred when taxiing for takeoff 24 (12%); and 20 (10%) occurred during takeoff.

3.2.7.2.1 Severity Category Rankings at Non-Towered Airports

Figure 22 shows the relative distribution of self-reported RI events in terms of severity ranking code. The results indicated 6% (12) events that would fit Category A, 38% (74) that fit Category B, 52% (103) that fit Category C, and 4% (7) that fit Category D.

Although the definition of Severity Categories A, B, and C work with non-towered airport operations, it is not clear with Severity Category D, "An incident with only one aircraft but that

meets the definition of a Runway Incursion," because of the way non-towered airports operate. In checking the seven entries that identified as Category D, the situations were:

"Subject's aircraft was on final; a second aircraft was on the runway."

"Vehicle that should not have been on runway."

"[Subject pilot] announced opposite direction runway."

"[Subject pilot] exited runway incorrectly due to obscured windshield."

"[a second aircraft's] pilot turned around on runway to get to the ramp while I was on final."

"Subject's Aircraft was on final, a second aircraft entered the runway."

"Other aircraft was departing on intersecting runway while we were landing and rolling through intersection."

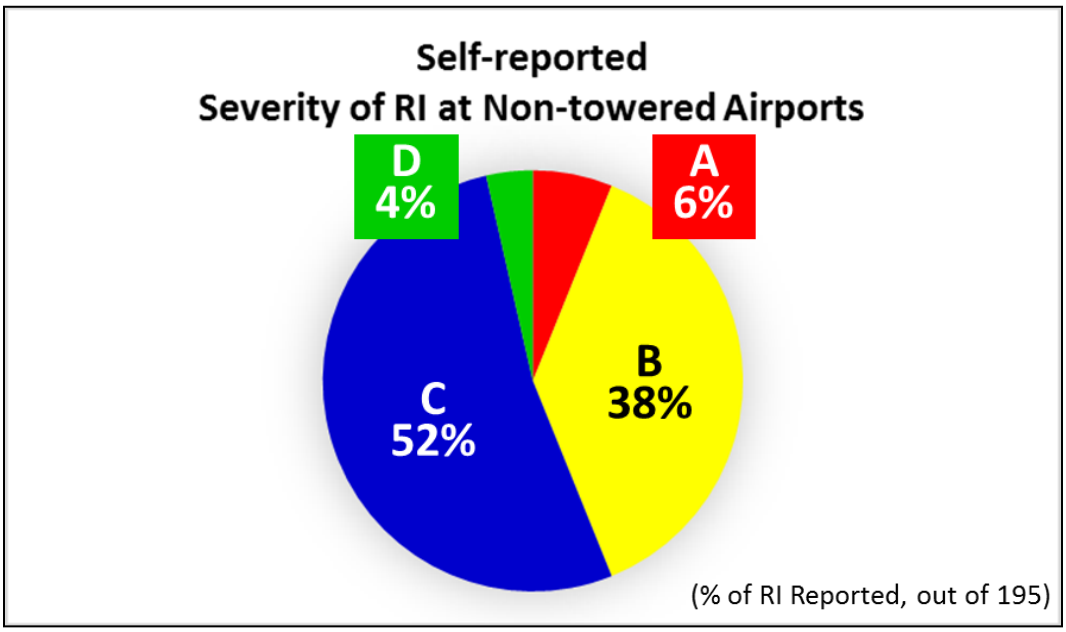


Figure 22. Severity category rankings for GA RIs at non-towered airports as reported on GA pilot questionnaire

3.2.7.2.2 Incident Type Code at Non-Towered Airports

Figure 23 shows the relative distribution of self-reported RI events at non-towered airports in terms of corresponding Incident Type Codes. Different codes include PD Self, PD Other, and VPD. The number of responses to the question was 195.

Because there are no ATC-attributed incursions at a non-towered airport, the distribution of VPD and pilot-caused accidents is very different from the towered airport data. For non-towered airports, just more than a quarter of the respondents reported their actions caused the RI event.

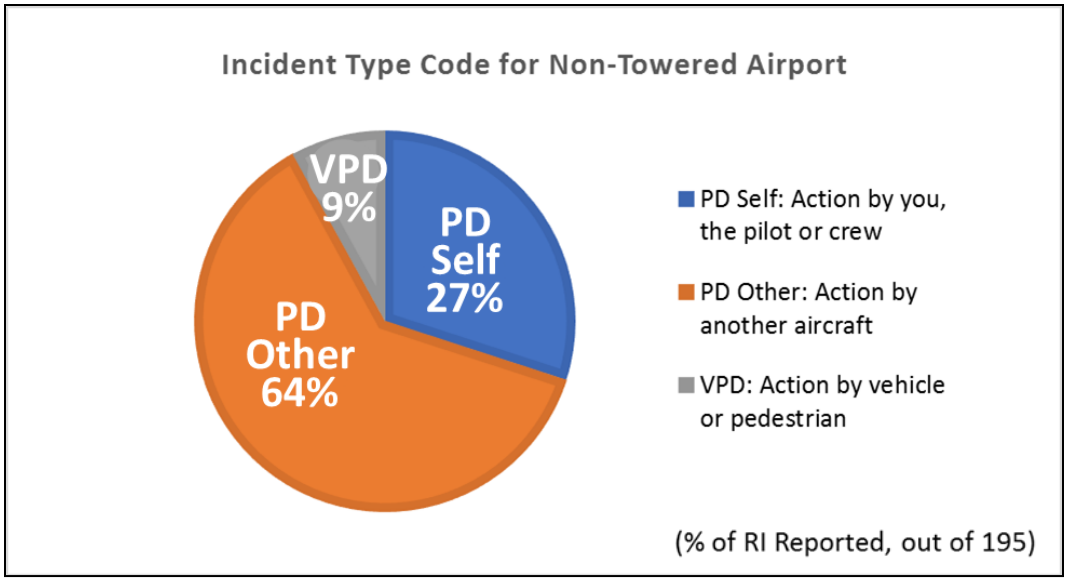


Figure 23. Incident type code for GA RIs at non-towered airports as reported on GA pilot questionnaire

It shows 27% (54) caused by the pilot completing the questionnaire, 64% (131) caused by another aircraft, and 9% (18) of events caused by vehicles or pedestrians.

The relative size between the PD self (42) to PD other (99) at the non-towered airport is almost flipped from the relative size at a towered airport, PD Self (107), and PD Other (47). This may be due to how pilots learn they have committed an RI. At a non-towered airport, the aircraft that taxis out and takes off in front of a landing aircraft may never realize the conflict happened; at a towered airport, the pilot will be asked to call the tower.

3.2.7.2.3 GA RI Causal Factors at Non-Towered Airports

As explained in section 3.1 on the development of the GA pilot questionnaire, the categories of a potential causal factor were taken from the categories used by Bisch et al. (2016) (see figure 8).

For each causal category, subjects were presented a list of subcategories and asked to select any that applied. They could also select “other” and provide a write-in answer.

3.2.7.2.3.1 Communication Factors as a Causal Factor for RIs at Non-Towered Airports

Figure 24 shows the percent of respondents that selected a communication subcategory as a causal factor for their RIs at non-towered airports. Subcategories are Never Heard Transmission, Other Related Issues, Difficult to Understand, and Delay in Transmission. Not Selected as a Factor indicates the respondent did not select any communication subcategory as a causal factor.

Figure 24 shows that of the respondents who reported on an RI at a non-towered airport, 35% reported that they Never Heard Transmission. This is the second highest value for a causal factor subcategory across all the possible categories and subcategories. Being at a non-towered airport, this would refer to the transmission of the pilot in the other aircraft. Even though radios are not

required at non-towered airports, there was a definite expectation that the pilot should be broadcasting if the aircraft is equipped with a radio.

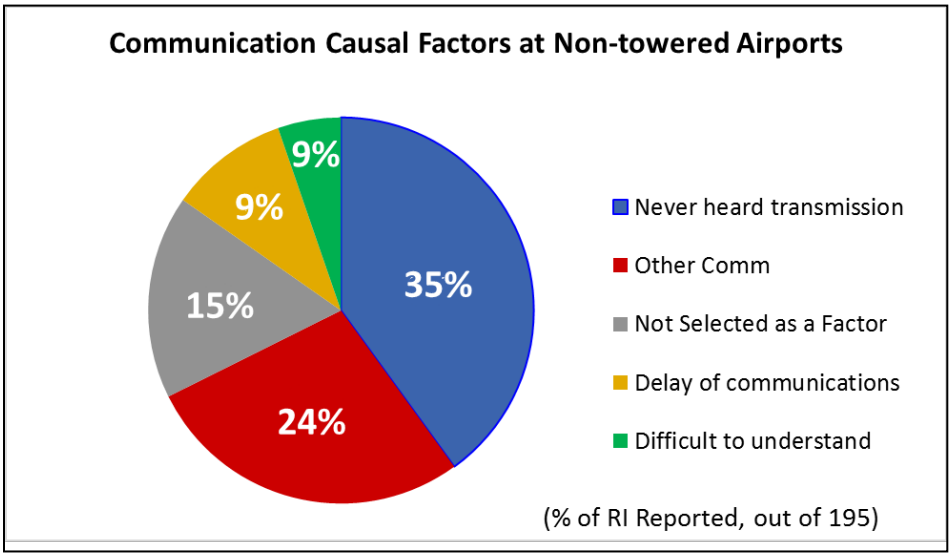


Figure 24. Communication causal factors in RIs at non-towered airports

The subcategory Other Communication was selected more than 100 times, all with comments. Investigation showed that the majority of entries for Other Communications were either not related to communications at all, or the comment was "not a factor" or similar. The inappropriate data entries for Other Communication were either moved to the appropriate data field or removed based on an assessment of the comment. After this review, there remained 24% legitimate communication causal factors.

Several respondents provided comments on communications as a causal factor for RIs at non-towered airports, a sampling of which are as follows:

"Ground vehicles not talking and apparently not listening."

"Aircraft not reporting their positions."

"Announced position/runway incorrectly."

"Wrong position reports."

"Monitoring wrong frequency."

"Pilot either did not hear or did not care about my radio transmissions."

"I remained on ATC frequency, forgetting to change to CTAF."

"Pilot failed to recognize that communication volume was zero."

"Ground vehicle was not radio equipped."

3.2.7.2.3.2 Spatial Awareness as a Causal Factor for RIs at Non-Towered Airports

Figure 25 shows the percent of respondents that selected a Spatial Awareness subcategory as a causal factor for their RIs at non-towered airports. Spatial awareness subcategories are Runway Confusion, Misjudged Spacing, Taxi Route Error, and Taxiway Confusion.

Figure 25 shows that, of the respondents who reported an RI at a non-towered airport, 82% (161) either left it blank, wrote "NA," or had a comment not related to spatial errors. Approximately 11% (21) noted runway confusion, meaning they landed on the wrong runway, landed in a direction the opposite of intended, or had another aircraft on the intersecting runway at the same time. Three comments specifically noted misjudging the spacing or time between the takeoff and landing. Most of the non-spatial comments were related to another aircraft or vehicle that pulled out in front of the respondent.

Several respondents made notable responses on spatial awareness, such as:

> "Airport was unaware I was landing opposite direction on the runway. We went around."
>
> "Driver was oblivious to his surroundings."
>
> "Attempted to land on intersecting runway."
>
> "Thought they had more time to depart."
>
> "Other pilot passed over me before landing."

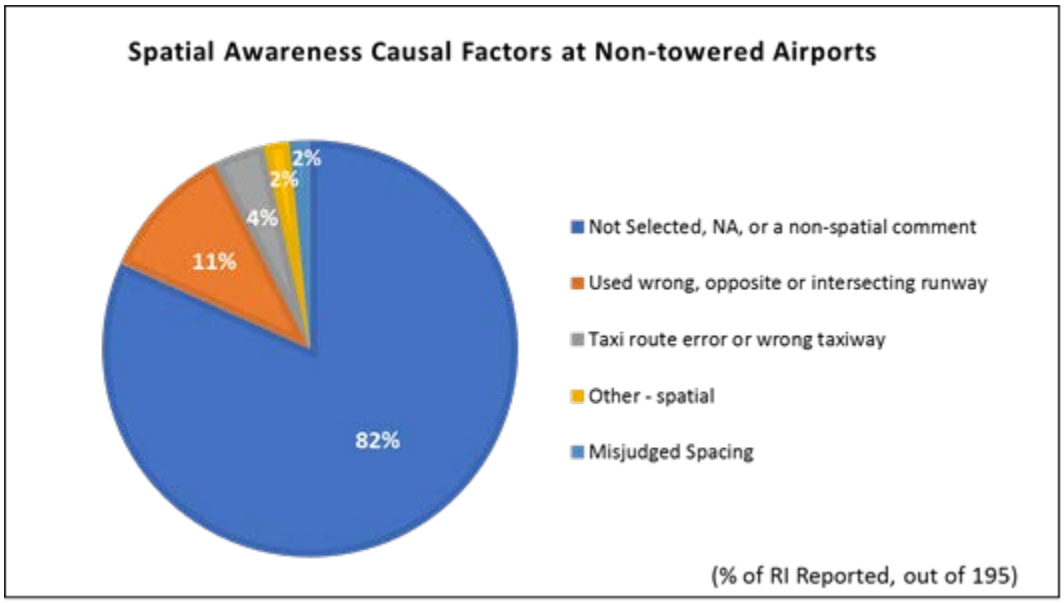


Figure 25. Spatial awareness causal factors in RIs at non-towered airports

3.2.7.2.3.3 Human Performance as a Causal Factor for RIs at Non-Towered Airports

Figure 26 shows the percent of respondents that selected a Human Performance subcategory as a causal factor for their RIs at non-towered airports. Human Performance subcategories are Acting Without Looking First, Complacency, and Distraction of Pilot/Driver.

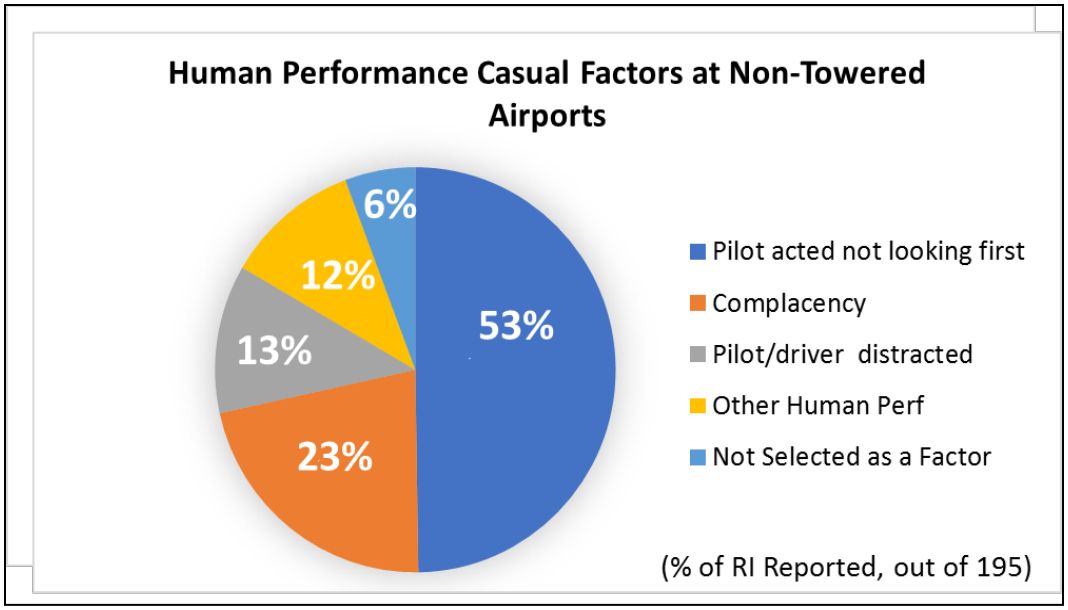


Figure 26. Human performance as a causal factor for RIs at non-towered airports

Figure 26 shows 53% of GA pilots acted without looking first. This is the highest value of any causal factor subcategory across all the possible categories and subcategories. Approximately 60% of GA pilots did not report human performance as a causal factor in their RI.

Human performance exists as a strong causal factor for RIs at non-towered airports. This is supported by several respondents' comments, which are as follows:

"Unfamiliar airport without a published diagram."

"Driver simply assumed runway was clear because it had been for the last few minutes."

"Listening to CFI on radio right seat."

"I didn't see the landing aircraft until I was back taxiing."

"Rusty pilot skills, forgotten knowledge of rules."

3.2.7.2.3.4 Signage and Markings as a Causal Factor for RIs at Non-Towered Airports

Figure 27 shows the percent of respondents that selected a Signage/Markings subcategory as a causal factor for their RIs at non-towered airports. Some contributing factors were Signage/Markings, Hold Short Line Issue, Runway/Taxiway Sign Issue, and Other Issues. Somewhat surprisingly, 91% of the respondents did not select any subcategory of Signage/Markings as a causal factor for their RI at non-towered airports.

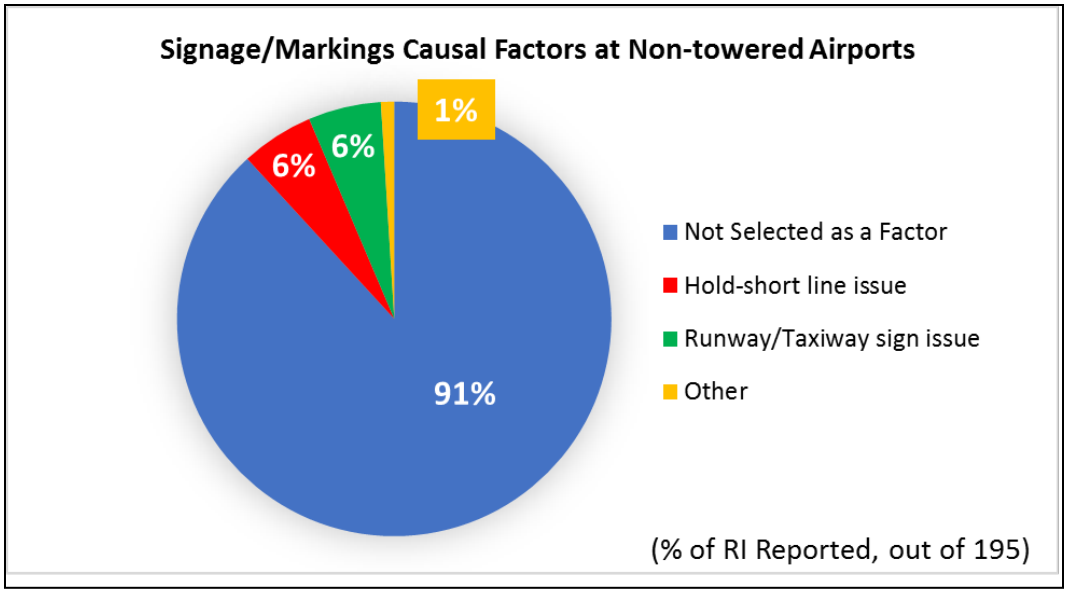


Figure 27. Signage/markings as a causal factor for RIs at non-towered airports

Some of the selective comments from respondents on signage/markings as a causal factor to RIs at non-towered airports include:

"Did not read signs."

"Hold-short line is in middle of adjacent run-up area, so easy to pass inadvertently."

"Stopped on hold short line."

"Grass runway with no real markings."

3.2.7.2.3.5 Equipment as a Causal Factor for RIs at Non-Towered Airports

Figure 28 shows the percent of respondents that selected equipment as a causal factor with the breakdown of their selections. It is interesting to note the preponderance of "no transmission by other aircraft" and "not selected as a factor." A pilot may not realize that the radios or audio panel are not set up properly in the aircraft. Either of the aircraft involved in an event may have equipment issues preventing them from either transmitting on the correct frequency or hearing other aircraft transmitting on frequency. In 10% of responses, the pilot realized monitoring the wrong frequency was a causal factor. It is possible that a portion of the "no transmission by other aircraft" actually stemmed from the same root cause.

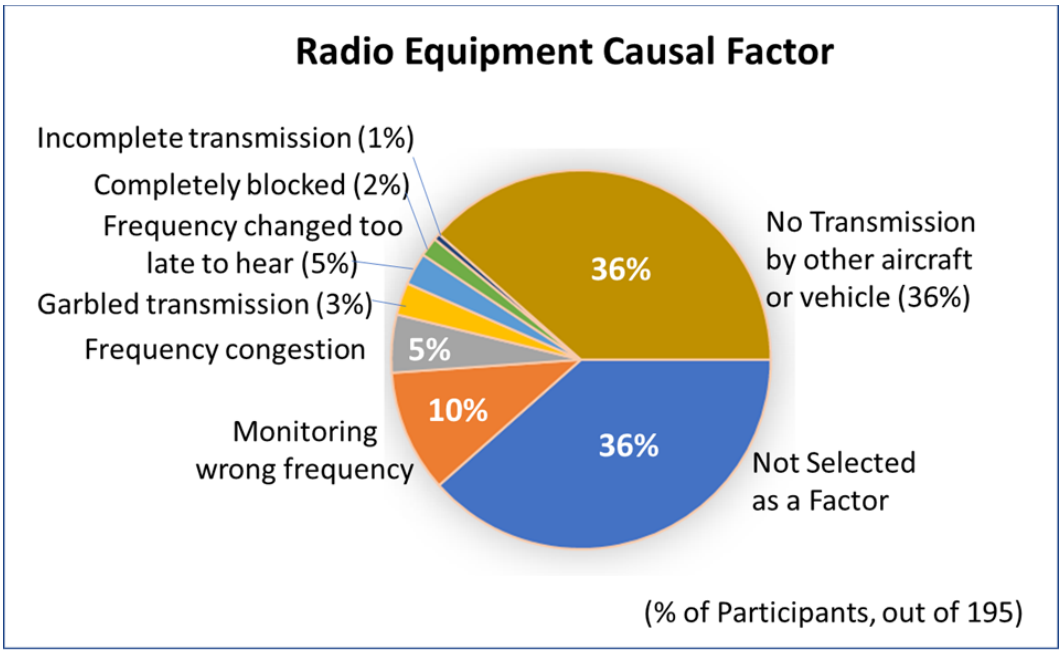


Figure 28. Radio equipment as a causal factor for RIs at non-towered airports

In summary, table 6 shows the top five causal factors subcategories. The most often cited was Human Performance: Acted without Looking First, which was cited by 53% of respondents.

Table 6. Top five causal factors subcategories for RIs at non-towered airports

Causal Factor and Subcategory	Percent Cited
1. Human Performance: Acted without Looking First	53%
2. Communication: Never Heard Transmission	35%
3. Communication: Other Communication Factors	24%
4. Human Performance: Complacency	23%
5. Human Performance: Pilot/Driver was Distracted	13%

4. PHENOMENOLOGICAL STUDY OF PILOTS THAT HAVE EXPERIENCED AN RI

The purpose of the phenomenological study was to complete interviews with pilots who had experienced an RI. The interviews were designed to learn how the event occurred and the lessons learned from that experience. The researchers used a qualitative design and a phenomenological study to gather and analyze data. A phenomenological study is well suited to this purpose because it can help in understanding the pilot's point of view and may contribute to the development of new ways to reduce RIs. The study provided information about the lived and shared experiences of participants (Creswell, 2007). Participants who met the qualifications were interviewed by

researchers to learn about their experiences. A foundational goal was to provide the research team with the lived experiences of these participants to help the researchers develop the questionnaire.

4.1 PILOT INTERVIEW METHODOLOGY

4.1.1 Participants

Participants from this study were recruited at the 2016 EAA AirVenture Oshkosh via a convenience sample and through researcher personal contacts. Three participants were interviewed at the conference. An additional two participants were interviewed via a video chat platform.

4.1.2 Interview Procedure

The researchers occupied booth space donated by SAFE at the 2016 EAA AirVenture in Oshkosh, WI. A posterboard was set up (see appendix D) to identify possible participants. Possible interview candidates were asked to complete a series of pre-screening questions to determine if they had been involved in an RI. If so, and if participants were willing to share their experiences, a member of the research team scheduled an appointment at a later time to complete the interview.

Interviews one, two, and three were conducted in private in recreational vehicles on the AirVenture grounds. When participants arrived, they were provided with a consent form and given instructions on the interview process. The researchers used a semi-structured interview process to 1) provide a standardized template from which to ask questions, and 2) to allow flexibility if the researchers wanted to follow up on any specific areas of the interview. The interviews were audio recorded for transcription afterward. Interviews ranged from 25 minutes up to almost an hour-and-a-half. After the interview, participants were debriefed as to the purpose of the study and dismissed. Researchers followed the Interview Protocol (See appendix E) to ensure standardization for each interviewee. Interviews four and five were conducted using video web conferencing. The paperwork was emailed prior to the interview.

4.2 DATA ANALYSIS

After the interview, the researchers transcribed the audio files using Dragon Naturally Speaking 13.0 dictation software. The transcribed files were checked for accuracy by a second researcher. These files were then imported into NVivo. a qualitative analysis software program. The researcher coded the data once the files were imported into NVivo.

The NVivo software used a format known as “nodes,” in which data were either classified as a “Parent Node” or a “Child Node.” The classification order was completed at the discretion of the researcher based on the information that the data provided. Each participant was coded as a “Parent Node.” There were five Parent Nodes, respective to each of the five participants.

Next, common themes were identified based on the interview questions and the purpose of the study, which was to determine the root cause of GA RIs. For example, participants were asked to recall an RI incident that they had experienced. Then they were asked to recall specific details about the incident, such as weather, time of day, cockpit sterility, ATC or radio communication, and so forth. These themes were extracted from the transcribed data, and assigned as “Child Nodes.” There were 13 Child Nodes, which NVivo automatically listed in alphabetical order. The

13 Child Nodes were “Aftermath,” “Approach Type,” “ATC Communication,” “Cockpit Sterility,” “Communication Breakdown,” “Decreased SA,” “Environmental Conditions,” “Fatigue,” “Incident Type,” “Location,” “Pilot Actions,” “Pilot Experience,” and “Time of Day.” Each Parent Node contained the same 13 Child Nodes. Once the transcribed data had been coded as either Parent or Child Node, the data were then analyzed utilizing NVivo’s Matrix Coding function and Word Frequency, which generated a Word Cloud, for each Parent Node.

4.3 PILOT INTERVIEW RESULTS

4.3.1 Word Frequency Analysis

To analyze the coded data in NVivo, the 13 themes that made up the Child Nodes were extracted from each Parent Node and were generated as numerical frequencies; it was implied that the higher the numerical value under each Child Node, the higher the frequency. It was also implied that the higher the frequency of each Child Node, there were more prominent factors that contributed to the RI events.

After the Child Node numerical frequencies were generated for each Parent Node, these data were then imported into NVivo’s Matrix Coding function. The Matrix Coding generated a table that showed the numerical frequency of each Child Node respective to each Parent Node. The results are shown in table 7. Using NVivo’s Word Frequency function, a Word Cloud was generated for each of the five Parent Nodes. This showed each participant’s transcript in the form of word frequencies. This means that recurrent words within each transcript were larger in size in the Word Cloud than words that were less recurrent, which appeared smaller in size in the Word Cloud. Therefore, the larger the size of the word, the more frequently it was said, and the smaller the size of the word, the less frequently it was said.

Table 7. Word frequency analysis results for interviews

	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
Aftermath	10	2	12	2	13
Approach Type	2	0	5	0	7
ATC Communication	26	9	9	0	22
Cockpit Sterility	3	4	1	9	2
Communication Breakdown	20	10	19	10	
Decreased SA	6	9	17	18	10
Environmental Conditions	19	6	2	5	8
Fatigue	5	6	0	2	0
Incident Type	17	5	10	6	5
Location	17	2	5	2	14
Pilot Actions	21	11	12	8	27
Pilot Experience	16	3	5	3	9
Time of Day	3	2	2	3	2

The matrix generated for each of the five Parent Nodes implied that the contributing factors to RI events were "ATC Communications," "Pilot Actions," "Communication Breakdown," and "Decreased SA." Two Parent Nodes Matrix showed "Pilot Actions" as the highest frequency. Within the context of the audio transcriptions:

> "ATC Communications" referred to events that took place at a towered airport and the communication between ATC and the participant.
>
> "Pilot Actions" referred to actions that the participant took that led to the RI event, how they responded during the event, or how they responded immediately after the event.
>
> "Communication Breakdown" referred to miscommunication between the participant, ATC, and other aircraft that were involved in the RI event.
>
> "Decreased SA" referred to whether the participant, ATC, or other aircraft involved in the RI event experienced decreased situation awareness immediately leading up to the event.

Overall, the majority of participants assumed personal responsibility for the events that led to the RI, citing a host of reasons, including impatience or overeagerness as the impetus that led to the chain of events. Below is a brief synopsis of each participant's interview, which highlight factors such as pilot rating and hours, details about the RI event, what participants cited as the root cause of the incursion, and the aftermath, among other details.

4.3.2 Synopsis of Interviews

4.3.2.1 Interview #1

Participant 1 described two RI events. Both were cases in which an aircraft entered the runway while the pilots were landing. At the time of the first event, Participant 1 held approximately 9000 hours as an airline transport pilot (ATP). On the day of the event, Participant 1 was the pilot in command (PIC) of a two-pilot crew in a corporate jet at a non-US airport in the western Pacific. It was mid-morning, with calm winds, and it was extremely hazy. They were on a visual approach, approximately a 3-mile final, when they heard ATC clear a Lion Air flight to taxi to Runway 10. ATC then told Lion Air, "After landing traffic, line up and wait." Lion Air proceeded to taxi onto the runway while the participant was starting a round-out for landing. This led to a "low energy go-around," and the participant just cleared the other aircraft.

Even though the root cause of this incursion appears to be ATC issuing a conditional clearance—the Lion Air pilot then did not comply with the conditional portion of the clearance—the participant thought the haze and glare could have played a factor. When asked during the interview what the participant thought was the root cause of the incursion, the response was lack of situation awareness on the part of the aircraft that taxied out onto the runway before they landed. He also noted that if he had not been extremely fatigued, he could have better anticipated the event based on monitoring radio transmissions.

For the second RI event, Participant 1 did not specify the timeline between the first and second event or the total flight hours. On the day of the event, the participant was again PIC of a corporate aircraft and had landed on the runway, where construction was blocking several of the usual taxiway entrance to the runway. As a result, arriving aircraft had a long roll out, and departing aircraft had to back-taxi prior to takeoff. During this event, a cargo aircraft was cleared to taxi and hold short of the runway. The participant was cleared to land. As the participant was rolling out on the runway, the cargo aircraft taxied out in front of them intending to back taxi.

> "So as we're rolling out, he decides he's going to back taxi on his own without a clearance and so we had to slam on the brakes. When the tower saw him, and told him to stop, stop, stop, and they told us to keep rolling because there's no way that we could have gotten off because of all the construction…Honestly we didn't really see him because, I mean, we're busy getting our airplane stopped and configured and we saw him [on the taxiway] and then he just sped up and came out in front of us…Just as he was entering the runway, we slammed on the brakes. I mean, we locked them up and stopped. I told the FO, I remember, 'I'm not going to the end. I don't know what he's doing.' And so I started slowing down normally, and then when he went out I just locked it up and got it stopped. There was no way I was going to follow the tower's instructions and keep going."

When asked what changes could be made to future training or cockpit/ATC procedures in the aftermath of the RI event, the participant suggested that "the FAA keep that message out about RIs and encourage all airlines to really drill it into their pilots because I mean this could have been a disaster with 300 people." And specific to GA, the participant said:

> "FAA really needs to get the message out to GA pilots that you're in the same air space as the commercial guys who go through this extensive training and you're still a pilot, still a professional, so raise the bar to what the airlines strive for and that will keep everybody safer…You know anywhere there is an ATC facility just have an awareness poster up…and I really think it should be part of the test standards to get a private pilot's license. Really drill on that and have the pilot do a go-around for a simulated runway incursion…Also stress really listening to what's going on on the radio. Because of that Providence incident—that's really what taught me to really pay attention to where all the aircraft are, especially in these environments that can be non-radar or really bad ATC."

4.3.2.2 Interview #2

Participant 2 held approximately 7,000–10,000 hours as an ATP at the time of the RI event. On the day of the event, Participant 2 was a pilot flying in the left seat of a two-pilot crew on a corporate jet taxiing at Teterboro Airport. "It was the end of a busy day of flying and we were on a repositioning leg from Teterboro to Farmingdale, Long Island." The aircraft had a routine taxi from the ramp to Runway 24 and was holding short of Runway 19 following a clearance they had received many times before. They were expecting to have to sit there for a few minutes waiting for a crossing clearance. As they were waiting, the participant said they heard "… blah blah blah cleared to cross Runway 19." Both pilots thought they heard their call sign. The participant read back their call sign and taxi clearance. ATC did not correct them.

The pilots looked left and saw an aircraft on final approach that "looked like it was out a ways out." They said to each other "we better get moving," so they hurried up, and then as they were approximately halfway across the runway, they heard "all kinds of noise from Ground Control indicating that obviously there was a misunderstanding." They continued to cross the runway and the airplane on final went around.

The participant said the weather was not a factor, there were no distractions in the cockpit, and the sun was not a factor. The participant believed fatigue was the root cause of the RI event.

> "I attribute fatigue, unacknowledged fatigue (as the root cause). Fatigue is insidious and it's one of those things you don't realize until you look back on something and say 'you know, I probably shouldn't have done that.' … I wouldn't say that I was totally drained or anything like that, but it's just as the day goes on, you know, your abilities drop, and at the end of the day your cognitive ability is not where it was at 7 in the morning."

4.3.2.3 Interview #3

Participant 3 described two RI events she had experienced in her career. The first event was an aircraft landing on the wrong runway. At the time of the first event, Participant 3 held in excess of 10,000 hours total time and held certificates as a flight instructor, an ATP, and a tower controller. On the day of the event, Participant 3 was operating in the capacity of a flight instructor with a student who was a licensed pilot flying in the left seat in a single-engine Cessna 177RG. It was midday and the weather was good.

> "We're landing on 13 Left. And I'm listening to the tower and there's a Navajo who is landing and the communication [is] "Navajo 1-2-3 you are number two for the airport, your traffic is a Cardinal short final for 13 Left, you're clear to land 13 Right. The Navajo says 'Roger, we got the traffic and in sight, we'll follow up.'…So we touched down and I hear the controller screaming Cardinal (inaudible) turn left turn right and I just, and I kind of knew what was going on and so I fire-walled it, and I exited on the high-speed taxiway…We had just exited the runway and the Navajo comes screaming by us. The Navajo…he saw me, why was he landing so close behind me?...When I heard the guy say 'we'll follow him,' you know, the antenna was up and I was seriously concerned, but again, I didn't know how far Navajo was behind me either."

The participant believed the cause of the incursion was a miscommunication on the parts of the ATC and the other aircraft and abstruse terminology on the part of the ATC. The "number two for the airport" versus "number two for landing" is confusing. In the aftermath of the RI event, the participant stated that communication needed to be improved, with terminology and renaming runways so as to eliminate any possibility for future misunderstanding: "Now, in hindsight, I might key in there and tell the controller, or tell that Navajo, he does know he's landing on the parallel [runway]? He's not landing behind me. Just for clarification."

The second RI event involved a vehicle on the runway at a non-towered airport. The participant was acting as a designated pilot examiner on an IFR checkride. They were on short final of a circling approach, below 200 feet AGL before the applicant realized the tractor was on the runway. In this event, the applicant performed a go-around. The participant cited the root cause of the incursion as decreased situation awareness on the part of the applicant because he was distracted by being on a checkride and by the tractor operator, who should not be on the runway while doing lawn maintenance.

The participant had several suggestions to reduce RIs. The first, regarding vehicles, was to have an iPad in the vehicles with an alert if the vehicle got near a runway (ForeFlight has this feature). Next, have airports do a better job of notifying pilots via NOTAMs that people and equipment will be near the runway. Furthermore, airport maintenance workers also need to be educated about being more aware when working near or around active runways. SA training is pertinent to all

parties who may come into contact with active runways. Last, the participant suggested that rumble strips, or any device that provides sensory feedback, be installed at the intersection of runways and taxiways as a means to increase situation awareness.

4.3.2.4 Interview #4

Participant 4's RI occurred at a non-towered airport in New York. He held 2000–3000 hours as a CFI at the time of the RI event. On the day of the event, Participant 4 had dropped off his aircraft for work at the avionics shop. The participant had made arrangements for a friend to retrieve him in another aircraft, a high-wing Super Cruiser, also owned by the participant. The Super Cruiser is a tandem, tail-wheel plane. The friend, a long-time private pilot, was piloting the flight in question. The participant stated they never discussed who was PIC.

Departing from the shop required a "somewhat long taxi" across the airport around "a lot of" glider operations, which were somewhat distracting to the participant. The participant was urging the pilot to hurry up. He was "eager to get going and a little irritated on how long it was taking."

> "We got to the threshold hold line of 23, hold for a run-up, and everything before takeoff checks and the person in front [seat] started asking a bunch of questions, and I was just eager to get going and I – yeah yeah yeah. Sitting where I was, in the back, got a high-wing airplane, couldn't see. [I] had not heard any announcements—although they might very well have been. There was so much chatter from the pilot in the front seat that I missed it and neglected to use my typical process, hold that right brake, get the airplane around to look inbound, we just went out onto the runway and initiated our takeoff. We didn't announce it, and just as we got out on the runway, an airplane came over the top of us and we go around and I felt like a complete idiot."

The participant believed he was PIC because he was the aircraft owner, but stated it was never verbalized. The chatter in the aircraft was "somewhat relevant" to the flight and occurred while the aircraft was stopped. He did not realize the other aircraft was on final until it flew over them and he saw the motion in the skylight and heard it.

The participant acknowledged that decreased situation awareness, lack of communication, chatter in the cockpit, and the overall impatience to return to their destination all contributed to the incursion. The participant said fatigue, airport markings, weather, and sun angle were not factors. He stated the root cause as "I was antsy to get going and I was irritated. You know—these are dumb questions and this is not the time or place for this—and it was because of my antsy-ness to get going…. To me that was the main contributor to the incident."

When asked what he would do different, he replied "Slow down. To be aware that things are busy, and whether it's an instructor or client or just as pilots, someone else who is flying and they're distracting you, be aware of that and take your time and be more diligent."

4.3.2.5 Interview #5

Participant 5 experienced an RI at Atlanta Hartfield-Jackson airport several years ago. At the time of the first event, Participant 5 had approximately 7550 hours total time, almost all in piston single-

engine aircraft. The participant was a seasoned flight instructor, Master CFI, FAA Safety Team lead representative, and current for IFR flight.

The participant had flown a Cirrus into Atlanta Hartfield several days earlier, and everything had gone well. He parked at the FBO on the north side of the field. On the day of the event, he arrived at the airport for departure with good weather. He was well rested and very relaxed. He had studied the airport diagram for what to expect. The pilot was alone in the aircraft. He got his IFR clearance and taxi clearance on the ramp. The airport diagram was on his clipboard as he taxied.

> "Since the FBO is on the north side of the whole complex, they typically would have us GA guys taxi across the airport to take off from one of the runways on the south side, so then we could turn left and not interfere with other traffic…[I] taxied on out to taxiway Dixie the Runway 26 Right and was holding short there. I was looking back up on final approach and I could see a jet way, way out there…watching for other traffic and being conscious of the pacing, how much time you got cross a runway…I was there and ground control said you know 'hold short of 2-6 right and monitor the tower.' Well, for some reason that instruction translated in my mind, because I could see the airliner way out there, that translated into monitor the tower [and] cross the runway…I started to cross the runway, of course I was monitoring tower. Tower told the airliner that something was on the runway and they had to go around. Immediately I knew that was me and I did a 180. I clearly crossed the Hold Short Line, but I don't think I got to the runway itself so I was back across the Hold Short Line."

The participant said the root cause of the incursion was:

> "I was just very, very much spring-loaded to move, move forward and be responsive to the instructions and I think that was my trap. I should have been a little bit more—what's a good word—ponderous, deliberative, and not, I was just trying to be a real good aviation citizen and not interfere with any amount of the vast airline activity out there and that turned out to be you know, my downfall, was actually trying to be so responsive."

The participant said he had studied the airport diagram prior to the flight, but had not "internalized" the significance of the five tower frequencies and local control frequencies, and that he could have been better prepared mentally. On previous trips to Atlanta, he needed to be reactive with respect to frequency changes and not proactive in anticipating the next frequency. He suggested that pilots be aware how complex ground operations were going to be prior to the flight. In that regard, he created a flight-planning tool to assess the complexity of an airport and the risk of an RI. Named the Castlen Matrix, it assesses the airport communications, runway crossings, hot spots, weather, daylight, familiarity, and business of the airport to determine a complexity score. This was published in FAA Safety Briefing magazine.

The participant also suggested that pilots plan their departure route to facilitate using the runway closest to the FBO. In his event, he had to cross multiple runways to get to the southern runway that accommodated a southerly turnout after departure. He suggested that in such situations, the pilot of a light aircraft request a route that would allow for an approximate 5-mile, straight out departure and then turn on course. By going straight out several miles, the light aircraft is well below any jet traffic and can then turn on the course.

4.4 PILOT INTERVIEW DISCUSSION, LIMITATIONS, AND CONCLUSIONS

There were educational implications as a result of the data analysis. Participants viewed their RI experiences as opportunities to retrospectively analyze the events that led up to the RI, analyze their decision-making skills, and improve their pilot skillset. Given the time sensitivity of this study and the nature of qualitative data collection, several limitations are noteworthy. First, it should be noted that the number of participants recruited were directly affected by the timeline with which the researchers were working. Second, the researchers had no control over when participants experienced the RI event, which could have impacted the way the events were recalled. Third, data collection was conducted via teleconference or face-to-face interviews, which could have influenced the information provided by the participants. Fourth, the majority of participants recollected RI events that happened several years before. No participants had recent RI experiences. Data from recent events could be informative and educational. Last, generalizability was a valid concern because the majority of participants experienced RI events primarily in the Midwest and East Coast of the U.S.

One salient outcome of the participants' experiences with an RI event was a much greater appreciation and respect for proper communication—whether it be between ATC and aircraft, or aircraft to aircraft—and respect for their cognitive functions. Conversely, they all cited a greater awareness of cognitive functions during flights, such as gaining better situation awareness or fatigue recognition. Additionally, it was interesting to note that participants claimed to do their due diligence with regard to reviewing airport diagrams and studying runways of the airports to which they were flying. However, it was their individual workload and performance in that immediate moment that surprised them because they found they were facing a possible RI event. Furthermore, participants agreed that, although they were disappointed that they were in such a precarious situation, the value of the lesson they learned assisted them with identifying their strengths and weaknesses as GA aviators. Moreover, this opportunity allowed them to cultivate their skillset and to walk away from this event to pass on their knowledge to other aviators in hopes of reducing RIs in the future. One takeaway was that even the most experienced or most prepared pilot can be lulled into a false sense of safety if they are not constantly aware of moment-to-moment events that unfold before them as they approach and depart from active taxiways and runways.

5. REVIEW OF PART 121 RI PREVENTION STRATEGIES

5.1 INTRODUCTION TO REVIEW OF PART 121 RI PREVENTION STRATEGIES

Safety is the foundation of the FAA business function. By sharing lessons learned regarding sustainable safe and efficient operational practices, the flying community may continue to improve safety practices and minimize risks associated with air transportation. The issue of runway safety has been a primary area of concern for decades.

Runway safety refers to the management of risk while operating in and around the designated landing and takeoff areas. The goal of runway risk management is to reduce or eliminate accidents and incidents on or near landing and takeoff surfaces. RIs are movement activities at an aerodrome involving the incorrect presence of an aircraft, vehicle, or person on the protected area of a surface designated for the landing and takeoff of aircraft (FAA, 2017c). It is the purpose of this research

to communicate the best practices of commercial airline businesses to reduce or eliminate RIs at towered airports.

Reducing RIs has received heightened attention since the 1977 Tenerife Airport disaster (see figure 29). Incursions continue to plague aviation safety management professionals. Movements to reduce RIs tend to spike immediately following major incidents.

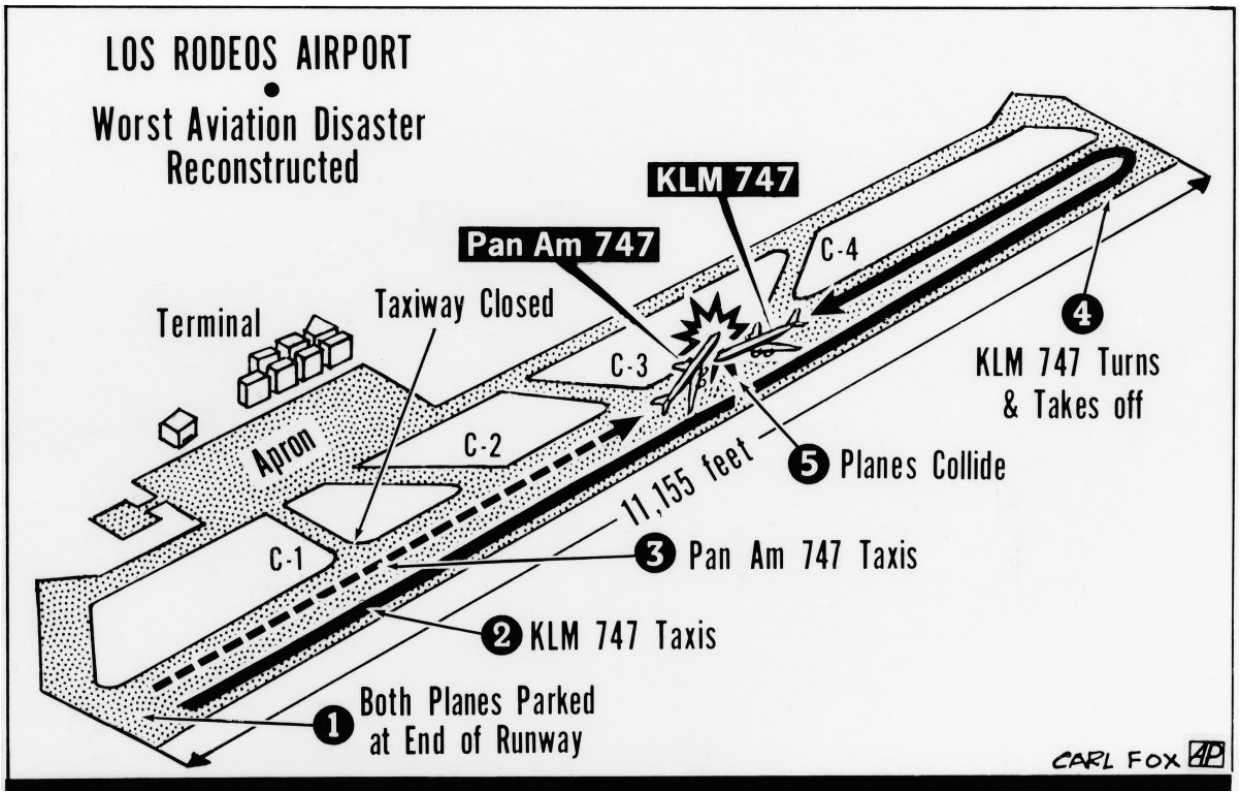


Figure 29. Tenerife aviation disaster reconstructed (source: Business Insider, 2017)

Forty years ago, two fully loaded Boeing 747s (KLM 4805 and Pan Am 1736) collided on the Los Rodeos Airport runway on the island of Tenerife. Reports indicated that the normally slow operations airport was overloaded with diverted aircraft from Los Palmas Airport. A blanket of fog had just covered the airport when the aircraft began to taxi to the runway. The aircraft were required to "back taxi" down the runway for an opposite-direction departure. This put both aircraft on the runway simultaneously. Reports also indicated that the aircraft could not see each other and could not be seen by the ATC tower. KLM Flight 4805 was instructed by the tower to back taxi down the runway, make a 180-degree turn, and hold for departure. Pan Am 1736 was instructed to back taxi down the runway and exit left onto a taxiway to clear the runway for the KLM 4805 departure (Subsecretaria de Aviacion Civil, Spain, 1978).

Pan Am 1736 missed its turn off and continued to the next taxiway. While this action occurred, the KLM had set up into departure position and held in position awaiting clearance. The first officer of the KLM received the routing clearance. Investigators cited that the pilots were tired, frustrated, annoyed, and busy with checklists. This led to KLM 4805 beginning the takeoff without a clearance, while Pan Am 1736 was still back-taxiing down the runway (Subsecretaria de

Aviacion Civil, Spain, 1978). The results were catastrophic. Five hundred and eighty-three people lost their lives in the disaster, the most deaths in a single accident in aviation history.

This accident began a global movement to improve runway safety. In the United States, the FAA created a Call to Action to address issues identified in the report and RIs specifically. For many years, intense focus and extensive resources were dedicated to improving runway safety. Initiatives included Crew (Cockpit) Resource Management (CRM); ATC and aircraft operation procedural changes; weather minimums; and pilot awareness outreach.

It is important to note the categories of regulatory requirements for pilot training certification. All pilots are certified under 14 CFR Part 61. 14 CFR 61 does not specifically list RI as a training or evaluation topic; rather the "spirit" of the training content is to train and check pilots by giving complex taxi instructions and evaluating their performance as an RI mitigation strategy (Personal Interview, Vice President of Pilot training, 2017). Instead, 14 CFR 61 points to the Practical Test Standard for a more detailed list of testing requirements for each level of pilot certification. These training tasks are mentioned in Commercial Pilot and Type Rating/ATP training. Continued training tasks are addressed under 14 CFR Part 121 Appendix E, Complex Taxi Training requirements and Appendix F, Testing Requirements (Personal Interview, Vice President of Pilot training, 2017).

Over the years, RI prevention has experienced peaks and valleys of attention. In 2007, the FAA reported a 23% improvement in RIs over fiscal year 2006. There were 24 serious RIs among 61 million aircraft operations. The FAA identified this as an "encouraging reduction" from the 31 serious RIs in 2006 and the 53 serious RIs in 2001. In the Runway Safety Report of June 2008, the FAA stated, "at this rate, a person could fly on one commercial flight every day for as many as 4280 years without encountering a serious runway incursion" (FAA, 2008b).

Though the number of serious RIs had shown significant improvement, the number of RIs had increased from 330 to 370 in fiscal year 2006 (NTSB, n.d.). The increase in RI, though less severe, prompted the FAA to issue a Call to Action. The plan identified a series of short-, mid-, and long-term initiatives to reduce RIs, focusing on changes in cockpit procedures, airport signage and markings, air traffic procedures, and technology improvement (FAA, 2008c).

The FAA also established a Runway Safety Council, a joint government/industry body to develop a systemic approach for improving runway safety. This audit was at the request of Senators John Rockefeller and Kay Bailey Hutchison of the Senate Commerce, Science, and Transportation Committee. The Senate request asked the council to conduct a comprehensive review of the current state of aviation safety, including a focus on runway safety issues. Later research concluded through Pearson correlation indicated a higher likelihood of incursions amid clear weather, during the daylight hours, and at airports with ATC towers (Cozza & Young, 2013).

5.2 PART 121 REVIEW METHODOLOGY

Pilots and pilot training leaders of 14 CFR 121 air carrier operators were interviewed to discuss the best practices used in the airline pilot training to avoid RIs. Interviewees overwhelmingly expressed agreement that RI has been a hot topic for decades. Millions of dollars have been spent

on research and development, training, equipment, and personnel to achieve significant improvement of runway safety operations, to include the reduction of RIs.

This study incorporates interviews of airline pilots, 14 CFR 121 airline training managers, and public information sources from FAA records to show some of the industry's current best practices to avoid RIs at towered airports. These data focus on pilot training in an effort to provide the GA public possible practices that may avert future incursions.

Participants in this project included three current airline pilots for major passenger or cargo air carriers, and two pilots currently in airline training management. The two pilots in management included one from a regional, passenger airline pilot training group, and one who was the executive vice president for pilot training of a major airline. Participants were asked open-ended questions about pilot-training initiatives that contribute to runway safety success, the safety culture of the organization, and personal opinions about RI-preventions techniques.

The research method was primarily a data-collection-based philosophy in a phenomenological study. Data were collected, categorized, and arranged with correlating data to show the raw feedback of system users. Because of the small number of participants, statistical measurement was not developed. Instead, participant response results are described as "all, several, or few" to illustrate the level of agreement among participants.

The best practices interviews in this study are based on the premise that weather and time of day are factors less likely to contribute to RIs. This study also concedes that the presence of an ATC tower does not necessarily reduce the number of RI incidents under fair-weather conditions. This study did not include air traffic controller participants, but focused on pilot prevention techniques so that the possibility exists to implement these best practices at uncontrolled airfields (FAA, 2008b).

5.3 PART 121 REVIEW RESULTS

When asked what is the most influential factor in preventing RIs, training personnel and pilot users agree that CRM is the most common and useful method to avoid and identify RIs. Interviewees specifically identified situation awareness and communication in the cockpit as the most useful and readily available tools. Cockpit communication is highly stressed during all phases of pilot training, recurring training, and in day-to-day operations. Practicing clear communications using standard phraseology, listening, and comprehension were identified as the best practice to prevent RIs.

A followup question regarding how situational awareness and communication were directly addressed during training was posed to participants. Pilot training managers strongly expressed that CRM and clear communications were emphasized throughout the training process regardless of the task, including RI lesson plans. The practice of "look left, look right, look up/down" is embedded in each and every landing and takeoff practice scenario, simulation, and inflight competency.

Embedded in the training process is the practice of "call-outs." This practice was described as verbal communication in which a pilot calls out an action and receives a verbal callout confirmation from the pilot completing the task. The callout and action response may be the same

pilot. As a pilot goes through a checklist, he will call out the checklist action, perform the task and call out the response. Example: landing checklist item "Check gear down." Pilot checks to see that gear is down and responds, "Gear down." This practice is used to ensure that all persons in the cockpit are aware of actions taken and results of action.

"Crew [cockpit] Resource Management can be traced to the early 1970s following a series of deadly accidents. Researchers discovered that it was not mechanical failure causing a vast majority of accidents but rather pilot/crew error" (FAA, n.d.-c). Whether in the tower or the cockpit, the concept of human resource management was noted by the majority of seasoned pilots to be one of the greatest safety implementations in aviation. The key component to CRM is communication. Creating an environment in which the exchange of information can be communicated and received among persons of various skill levels allows for comprehensive decision-making by leaders.

Simulation of runway events was identified as another best practice in ongoing pilot training. Simulated training conditions pilots to communicate and maintain situational awareness. "Like every new day in the cockpit, aircraft simulation exposes the pilot to unexpected events to help keep pilots aware," said one pilot. There is no way to train for every possible event that may occur during takeoff or landing; training managers said they focus on creating unusual scenarios and measure the speed of the reaction times pilots take to communicate and respond to a variety of incidents. When pilot responses are not satisfactory, additional training is provided, which may include basic flight skills, critical thinking, and confidence in decision making.

Basic flight-skills training incorporates FAA mandatory training items that pilots would have encountered in private pilot, instrument, and commercial flight training. These certificates and rating flight items may be related to physics of flight, use of the instruments, aircraft-performance characteristics, weather, situational awareness, communication, and other CRM topics.

Critical thinking involves training pilots to recall knowledge and analyze a situation to make the best possible decision. An example given was Captain Chesley Sullenberger landing on the Hudson River. Although pilots are trained to avoid emergency water landings at all costs, a pilot identified this as a perfect example of a pilot using his knowledge and experience to assess the situation, consider his options, and make the best decision possible for the situation. It was noted that a pilot must consider his experience level in the equation. As a result, the pilot must be confident in his decision and ability to complete a task. Trainers said that consistent, recurring training is necessary for all pilots, regardless of their experience levels. The vice president of pilot training of one of the three major airlines identified internally developed curricula and training methods as a best practice to prevent RIs.

Curricula and training methods developed include:

- New Hire Pilot Indoctrination—Nine-day Instructor-Led Training (ILT) course with four hours of e-learning.
    - Review Flight Operations Manual definitions of NTSB Incident, which includes RI.
    - Review Flight Operations Manual list of Mandatory Aviation Safety Reporting items.

- Pilot Qualification (checking out as an F/O or captain on a new aircraft type and receiving FAA type rating if not already held).

    - Procedures Training—Blended instruction using a 90-minute mission briefing and a four-hour ILT session in a non-motion flight training device (FTD), followed by a 30-minute debriefing. RI is trained in two ways:

        - Development of CRM skills
        - Training of procedures

    - Maneuvers Training—Four simulator periods followed by a maneuvers validation test.
    - Captains earn their Low Visibility certification in this phase, with includes CAT II approach/landing, CAT III approach/landing, and low vis taxi using Surface Movement Guidance Systems.

- Line Operations Simulations—Four simulator periods followed by line operational evaluation (LOE).

    - Gate-to-gate flight covering all phases of flight conducted in sequence.

        - Includes complex taxi instructions.
        - Change of taxi route.
        - May include low visibility taxi conditions.

    - Recurrent training—Simulator

        - Every other recurrent training visit includes an LOE as described above.
        - Captain low vis certifications are recertified.

Airlines require all pilots to attend regularly scheduled refresher training in a simulated environment. Pilots also receive scheduled and non-scheduled evaluations in the in-flight environment to help ensure competency and measure how pilots perform in real-time conditions outside of the training environment. One seasoned pilot said that some of the constant training, retraining, and evaluations are excessive.

Although pilots receive training on manual flying practices, the cockpit and flying environment has evolved with numerous technologies to assist pilots. Cockpit technology is designed to reduce pilot workload, provide current information, increase safety, and provide alerts to pilots.

New technological developments to help pilots and controllers become more aware of their surroundings were also identified as a best practice. Aerodrome detection equipment, collision-alert systems, and airport references such as signage, lighting, and markings were mentioned specifically. Some pilots expressed mixed feelings about the use of technology. Pilots and trainers expressed concern that people may become too reliant on technology or become complacent in areas where technology has replaced the manual performance of pilots.

Pilots and trainers were adamant about the benefits of new detection and prevention technologies to provide assistance in identifying hazards. Pilots also had some concern that technology has the potential to reduce pilot situation awareness because they may become too reliant on technology, and it may increase the number of distractions in the cockpit. However, overall, users felt equipment and alert systems improve the safety of flight.

Other mentionable resources for pilot training include FAA online training videos, publications, and regulatory sources. These resources are available online at the discretion of the flying community. When asked what best practices GA pilots could incorporate, the pilots and training managers said GA pilots should remain vigilant, continue to expand their knowledge, and engage in self-initiated recurring training.

In the corporate environment, the culture of the organization is especially important. In a comparison of various airlines' safety records and organizational cultures, history indicates that the corporate culture is a contributing factor to the increase or decrease of incidents. The vice president of pilot training was asked how the airline incorporates a culture of safety into pilot training and ongoing operations to contribute to lower RIs and other incidents.

He responded by saying safety culture begins with an unwavering commitment from the top. Every aspect of airline operations places the safety of passengers and employees first. Tangible examples of this include the company's "Rules of the Road" document and our corporate flight plan. "Safety culture is built on complete alignment of leadership expectations, corporate operating philosophy, policies, procedures, Safety Management Systems, and concomitant employee empowerment."

Fatigue is a factor consistently identified in accident reports and by pilots interviewed in this study as a potential contributing factor of RIs and other incidents. Airlines and pilots were asked how they or their company combat this issue. Pilots were in agreement that pilots have to take responsibility and be honest about their mental conditions before, during, and after their flights.

One pilot noted that outside stressors, such as family and finances, can lead to mental fatigue. He said he makes a practice of asking himself, before each flight, directed questions about his own mental condition by way of a laminated checklist he keeps in his pocket whenever he flies.

Airlines identified following the established 14 CFR Part 117 and 121 requirements as best practices that the GA pilots could use or be regulated to implement. These requirements include:

- The Fatigue Risk Management System under 14 CFR 121.473, 121.495, and 121.527.
- 14 CFR 117—Flight Duty rest requirements, including details of the pilot training program.
- ACs 117-2 and 120.103, which describe the FAA guidance on fatigue training.

Another best practice to implement is the reduction of distractions during taxiing, including carefully designed checklists that ensure pilots are not being set up for failure by performing unnecessary tasks during taxiing, and clear policies that support the PIC's authority to stop the operation at any time, including when encountering too many distractions during taxi. Training for ATC, flight attendants, and other persons on board an aircraft should emphasize the pilot's workload during taxi and that interruptions to critical communications requiring the pilot's

immediate attention need to be limited. Pilot training should include complex taxi clearances and checking scenarios.

Pilots should work with ATC to ensure taxi clearances are delivered using standard phraseology, especially complex taxi instructions. Airports should communicate better with pilots to address any marking inconsistencies. These are flagged in safety reporting programs. Pilots and airlines should avoid scheduling flights using similar flight numbers into the same airports at the same time. It causes clearance confusion with ATC on the ground and in the air.

5.4 CONCLUSION FOR REVIEW OF PART 121

In an effort to improve runway safety and reduce RIs in GA, it is important to identify specific phenomenon that may lead to movement activities in or around an aerodrome involving the incorrect presence of an aircraft, vehicle, or person on the protected area of a surface designated for landing and takeoff.

Best practices that should be implemented as part of the GA flying program include practicing good CRM, self-awareness, proper training, and reducing distractions. Whereas there is no way to eliminate all RIs, it is important to maintain a consistent effort of runway-safety management. Strong, sporadic reactions to major events creates an "up/down" safety culture destined to have repeat incidents when runway safety is in a valley.

Some literature produced in the aviation community suggests that pilots feel safety programs are reaction-based rather than prevention-based. This can lead to a sense of complacency when issues are highlighted. One pilot stated, "There is an inherit risk that must be accepted in aviation and, while vigilance is necessary at all times, they don't need to overdo it by spreading panic when statistically air travel is still the safest form of travel." The meaning of this statement is to know the risk, mitigate it to the extent possible, and accept the risk.

6. REVIEW OF AVIATION DATABASES FOR CAUSAL AND CONTRIBUTING FACTORS RELATED TO GA RIS

RIs have been increasing over the past few years. Data show a 45% increase in the number of RIs from 2011 to 2015 (FAA, n.d.-a). In approximately 80% of those events, the root cause of the incursion can be traced to GA pilots. Some of the reasons for the high involvement of GA pilots in RIs could be due to the variety of missions flown by GA pilots, limited cockpit resources and flight support, or less weather-tolerant GA aircraft.

The FAA has invested substantial resources in reducing the number of incursions involving commercial pilots. Although they have been successful in doing so, the results are not the same in the case of GA. Despite the efforts of the FAA to improve markings and signage at airports, add handbook guidance, and identify critical areas on airport diagrams, there has been no decrease in the number of GA RIs. Therefore, there is a need to conduct a comprehensive review and analysis to determine what the underlying causes of RIs are and to then develop a set of effective mitigation strategies targeting the key causes.

In sections 6.1–6.4, results from the analysis of the NTSB database, the FAA's AIDS, and the ASRS database are presented. The research team focused on RI accidents and incidents that

involved at least one GA aircraft and occurred at towered airports. Such information as the injuries and damage incurred in incursions, the geographical location, the weather conditions at the time of incursion, the traffic mix, and pilot details were determined. The research team then analyzed the narratives to understand the root causes of the RIs. Section 6.2 of this report focuses on the review of the NTSB database; section 6.3 focuses on the AIDS data; section 6.4 focuses on the RWS data; and section 6.5 focuses on the ASRS data.

6.1 REVIEW OF THE NTSB DATABASE

The purpose of this task was to review the NTSB database to find causes and contributing factors that lead to RIs in GA. To do so, the most recent NTSB Access Database was obtained and the data were pre-processed to isolate RI accidents and incidents. The data were then analyzed for patterns, causal factors, and influencing factors in RIs.

6.1.1 Overview of the NTSB Database

The NTSB Aviation Safety Database, managed by the NTSB, is the most comprehensive civil aircraft mishap database available. The NTSB designed this database to record causes or probable causes of accidents and make recommendations to avoid similar accidents in the future. The database contains records of aviation accidents and selected incidents that took place in the United States since 1962. These records do not include accidents or incidents that involve military or most public-use aircraft (e.g., police planes, search-and-rescue planes). The NTSB also investigates some accidents outside the United States; in such cases, an entry is made in the database, but no reports are released by the NTSB. Trained NTSB field investigators investigate accidents and selected incidents. Analysts at the NTSB headquarters review and verify the reports submitted by the investigators. The final determination of findings and causes is performed by senior NTSB management (Murphy and Levendoski, 1989).

6.1.2 Retrieving Data from the NTSB Databases

The NTSB database is publicly available from the NTSB's official website. The research team downloaded the NTSB database in March 2016 and again in February 2017 to add any data that may have been updated between the months. The NTSB database is a Microsoft® Access® file with various tables, each providing specific details about the accident or incident. For instance, the "Aircraft" table gives information about the involved aircraft's make and model, FAR part, airframe hours, or any damage that was caused to it. Each accident or incident can be identified by a unique 14-digit event ID. The event ID is the common field across the various tables and is used to search for details across the database. Figure 30 shows the different tables used in the analysis and a brief description of the information available in these tables.

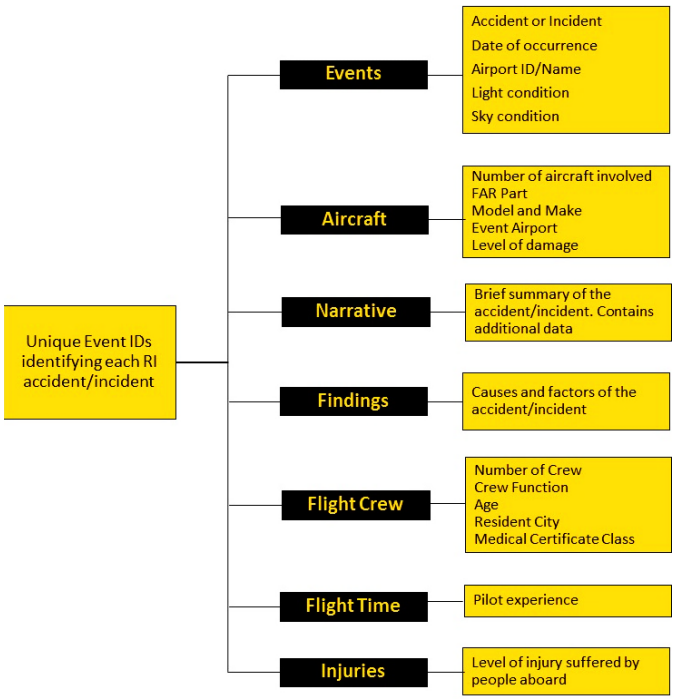


Figure 30. Various tables in the NTSB database

6.1.2.1 Change in NTSB Coding System

The NTSB database has information coded for each accident and incident. The NTSB maintains a coding manual that is a source document for codes used in the database. These codes describe the sequence of events in each accident or incident (NTSB, 1998). The NTSB changed its coding system in 2008. The available coding manual describes the pre-2008 coding system, and there is no coding manual available for the new coding system.

In 2008, the NTSB changed the occurrence codes, phases-of-flight codes, and the way it codes the key findings of the accident or incident. The NTSB defines an occurrence as a distinct major event of relative significance that leads to an accident or incident, and the phase of flight as the point in aircraft operations during which the occurrence takes place (NTSB, 1998).

In this report, accidents and incidents recorded in the NTSB database are referred to as "events." These events are identified by unique 14-digit event IDs. Each event consists of a series of occurrences. The occurrences describe what happened and the phase of flight in which it happened.

Before 2008, the NTSB assigned a three-digit occurrence code and a three-digit phase-of-flight code for each occurrence in the event. For example, consider an occurrence described by the occurrence code "320" and the phase-of-flight code "572." The occurrence code, 320, stands for "on ground/water collision with terrain/water," and the phase-of-flight code, 572, stands for "landing roll." Therefore, the event consists of an occurrence in which the aircraft collided with terrain, or it was a water collision that occurred while the aircraft was on a landing roll.

As part of the 2008 coding change, the NTSB changed the occurrence code to a six-digit number. The first three digits identify the phase of flight the aircraft was in, and the last three digits represent the "eventsoe_no" that identifies the type of occurrence. For example, consider an occurrence in an event described by the code 300320; 300 identifies the phase of flight as "takeoff" and 320identifies the type of occurrence as "Runway incursion veh/AC/person." Therefore, this code describes an RI that took place when the aircraft was taking off.

6.1.2.2 Filtering Data to Get a Set of RI Accidents and Incidents

In addition to the occurrence codes and phases-of-flight codes, the NTSB changed the way it coded the key accident findings.

Whereas the post-2008 coding system uses the code "XXX320: Runway Incursion veh/AC/person" to designate an RI, there is no specific code for RIs in the pre-2008 coding system. Therefore, the post-2008 data and the code XXX320 were a good starting point. Researchers first looked at reports under this code to understand what RIs are and what scenarios evolve into an RI. Cistone (2014) analyzed the NTSB database for data on airport surface deviations and formed a list of occurrence codes and phases of flight codes (in both the coding systems) that could be used to filter surface deviations. A subset of these codes was used to filter out RIs. For example, whereas Cistone considered codes that describe the collision of aircraft with an object or a collision between two aircraft at the ramp area, such codes were excluded because the FAA's definition of RI does not involve a collision with an object or a collision on a surface other than one designated for takeoff or landing. Refer to appendix F for the complete list of occurrence and phase-of-flight codes used for the pre-2008 and post-2008 coding systems, respectively.

Figure 31 shows the process of filtering events in the post-2008 coding system to find RIs that involved at least one GA (i.e., 14 CFR 91) aircraft and occurred at towered airports. The number in red indicates the number of events at each stage.

To begin, the "Events_Sequence" table in the database was considered. This table gives us the occurrence code. The occurrence code identifies what happened and the phase of flight. Next, all the events in the "Events_Sequence" table were filtered using the list of "eventsoe_no" that describes the type of occurrence (e.g., 320describes RI, 070describes airport occurrence). As a result of the filtering, there were 1606 events.

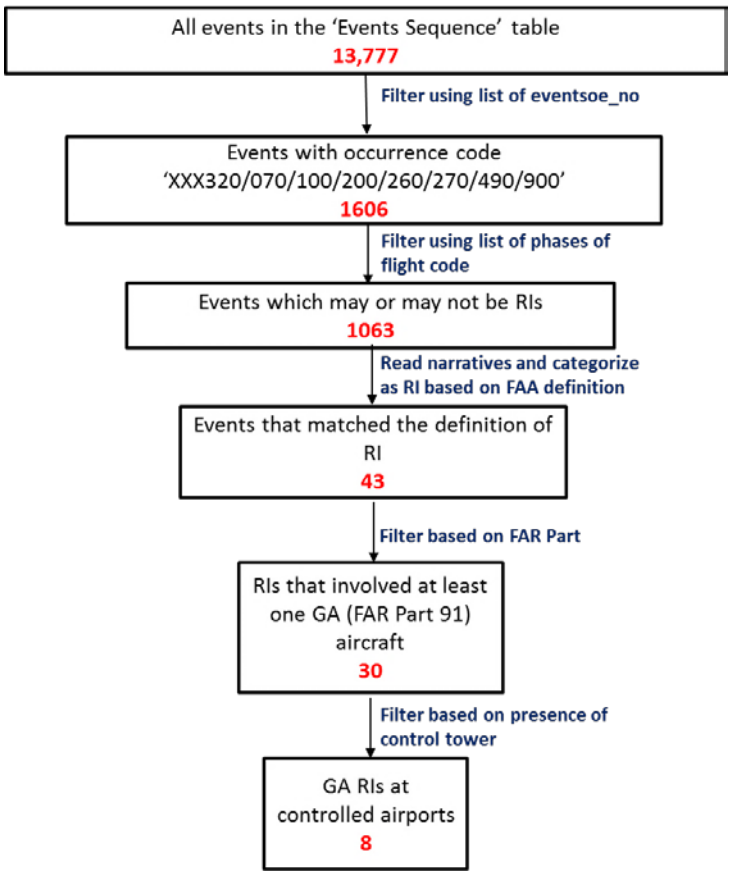


Figure 31. Filtering process for events in post-2008 coding system

Next, all events under the "eventsoe_no" were kept except for occurrence code "XXX270: Abrupt maneuver" and "XXX900: Miscellaneous/other." For events with these codes, the phase-of-flight codes were checked, and only those events that occurred in a phase of a flight relevant to RIs were kept. Appendix F shows the complete list of phases of flight codes used in this stage. Therefore, the number 1063 in the third stage represents all the events for the codes XXX320/070/100/200/260/490 and filtered events for the codes XXX270/900. However, this filtering does not guarantee that all events are RIs. For example, the code XXX200, which stands for "ground collision," includes events in which a collision occurred between two aircraft on a taxiway. To identify which events are actually RIs, researchers read the narratives of each of these reports and used the FAA definition of RIs to identify them. Therefore, at least 43 events were found that matched the FAA definition of RI.

Next, the "Aircraft" table was used to find the 14 CFR part of the aircraft involved. Sometimes, the 14 CFR part is mentioned in the narratives but not in the "Aircraft" table, and sometimes it is not mentioned anywhere in the database. In six of these 43 events, researchers could not find the 14 CFR part in the database. In the remaining 37 events, 30 RI events were found that involved at least one GA aircraft.

For each event, it was determined whether it occurred at a towered airport. In four of these 30 events, the database mentioned the city in which the event occurred instead of the airport name, or

the airport was found to be just an airfield. From the remaining 26 events, eight events were found that occurred at towered airports.

Figure 32 shows the process of filtering events in the pre-2008 coding system to find RIs that involved at least one GA aircraft and occurred at towered airports.

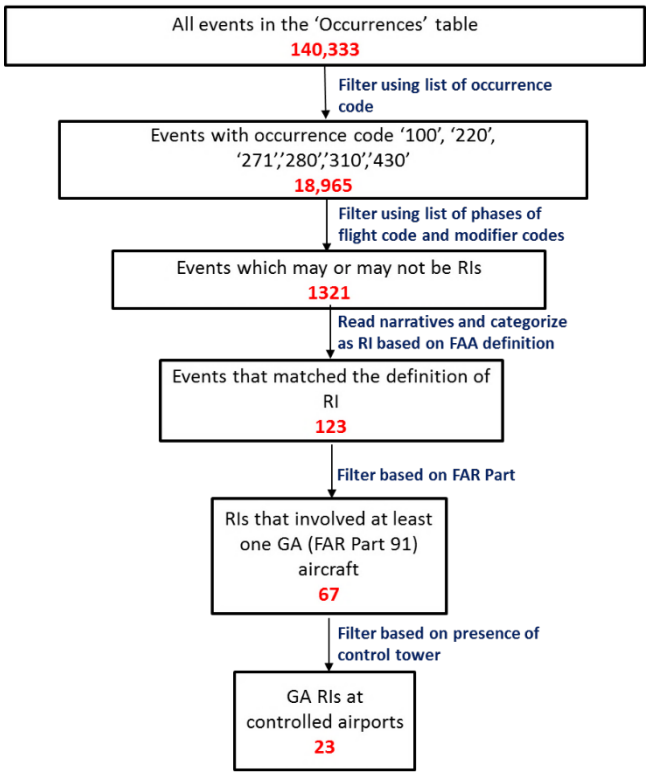


Figure 32. Filtering process for events in pre-2008 coding system

In the pre-2008 coding system, the "Occurrences" table provides information on the type of event and the phase of flight. First, the 140,333 events in the pre-2008 coding system were filtered to 18,965, based on the list of occurrence codes. These events were then filtered based on the phase of flight code. For events under the code "220: in-flight collision with object" and "310: on ground/water collision with object," the events were filtered using the modifier codes for vehicle, aircraft, and person. These modifier codes specify that the collision occurred either with a vehicle, aircraft, or another person, which is in line with the FAA definition of an RI. Therefore, there was a set of 1321 events that could be RIs.

Using the "Narratives" table, researchers read the narratives of each of these 1321 events and used the FAA's definition to determine whether they were RIs. Of these 1321 events, at least 123 events were found that matched the definition of an RI. Next, similar to how events in the post-2008 coding system were filtered, the tables and information available in the database were used to determine the 14 CFR part of the aircraft involved. In 18 of the 123 events, the 14 CFR part was not available. Of the remaining 105 events, 67 involved at least one GA (14 CFR 91) aircraft.

To determine whether the airport was towered, the same steps were used as for events in the post-2008 coding system. In four of the 67 events, the database specified the city where the event occurred. Of the remaining 63 events, 23 occurred at towered airports.

6.1.3 Summary of NTSB RI Data

At least three RIs were found in the NTSB database (23 in pre-2008 and 8 in post-2008) that involved at least one GA aircraft and also occurred at towered airports. This number can change based on when the database is downloaded because the NTSB updates its records on a regular basis. Many recent accidents and incidents are also still under investigation. Table 8 shows the percentage of accidents and incidents still being investigated.

Table 8. Percentage of accidents and incidents still under investigation

Year	Accidents still under investigation (% of total accidents and incidents that year)
2013	0.9%
2014	5.3%
2015	22.6%
2016	47.5%

Considering both coding systems, 58% of the RIs were found to involve at least one GA aircraft; 42% did not involve any GA aircraft. Sixty-eight percent of the GA RIs also occurred at non-towered airports. One reason could be that the non-towered airports outnumber the towered airports. There are 20,000 non-towered airports in the United States compared to only 500 towered airports, meaning that the higher number of RIs at non-towered airports may simply be a reflection of the higher number of operations.

During the research, it was found that some stakeholders define RIs as incidents exclusively; in this view, if a runway event involving incorrect presence involves damage or injury, it is an accident, not an RI. In contrast, the NTSB calls incorrect presence runway events that result in accidents RIs. For this NTSB task, NTSB-RIs was defined as the set of accidents and incidents in the NTSB database that match the FAA definition of RI, involve at least one GA aircraft, and occurred at a towered airport in the U.S.

Of the 31 NTSB-RIs, there were 16 accidents and 15 incidents. Although the events from 1962 to February 9,2017 (most recent date of download) were analyzed, the time range of the identified NTSB-RIs is from September 17, 1983 to April 3, 2012 (i.e., no NTSB-RIs from 2012 onwards were found).

6.1.4 Results and Discussion for NTSB Database Analysis

In this section, the results for both coding systems together are presented, except when discussing the causes of NTSB-RIs. Because the coding of key findings for the two systems is different, and there is no mapping of codes available, the causes of NTSB-RIs are presented separately for the two coding systems.

To analyze the NTSB-RIs, an Excel® sheet was created using the information available in the database. From the information contained in the database, such details as geographical location, traffic mix, causes, and consequences of RIs were analyzed. Information is missing from many NTSB-RIs entries in the database. For instance, some entries do not include the pilot age. For each analysis, the number of data points is indicated for which the information being analyzed is available.

6.1.4.1 Injuries and Damage

Figure 33 shows the four levels of injury coded in the NTSB database in increasing order of severity.

Figure 33. Levels of injuries caused by NTSB-RIs

Most of the NTSB-RIs did not result in any injuries. In total, six events of 31 involved at least one injury. In two of the six events, there was at least one fatal injury. Both these events involved a collision between two aircraft on the runway. In both events, one aircraft was on takeoff roll, while the other entered on to the occupied runway from an intersection.

In one of the accidents, the pilot did not follow the instructions given by the ATC (Event ID: 20001206X02586). The ATC instructed the pilot of a Cessna to hold short of Runway 31; however, the pilot taxied to an intersection at Runway 30R, assuming he would depart from Runway 30R. Runway 30R was the departing runway for a MD-82 aircraft. Another factor that investigators found was that the air traffic controller was not able to maintain visual contact with the Cessna as it moved to the intersection in the northeast portion of the airport. The report recommended the use of ASDE-3 with an Airport Movement Area Safety System (AMASS) to improve the visual scanning.

In the other accident (Event ID: 20001212X20686), which involved fatal injuries, the investigators found that one of the reasons for the incursion was that the flight progress strip of the aircraft departing from the intersection was not clearly marked as an intersection departure.

In three of six events that involved at least one injury, there was at least one serious injury. All three events involved two aircraft. In two of the six events, there was at least one minor injury.

Next, the damage caused to the aircraft by an RI is discussed. Figure 34 shows the four levels of injury coded in the database in increasing order of severity.

Figure 34. Possible levels of aircraft damage caused by NTSB-RIs

Of the 31 NTSB-RIs, 14 did not involve any damage to the aircraft. The remaining 17 events involved at least one aircraft being damaged. In three of these 17 events, the aircraft were damaged from fire after a collision.

The 31 RIs that involved at least one GA aircraft and occurred at towered airports involved at least 48 aircraft. Of these 48 aircraft, at least 42 were GA aircraft. Eight of these GA aircraft were involved in single-aircraft RI (i.e., either the incursion involved a pedestrian or a vehicle, or the aircraft was in an incorrect place). The remaining 34 of the GA aircraft were involved in two-aircraft incursions. Figure 35 shows the total number of GA aircraft involved in incursions.

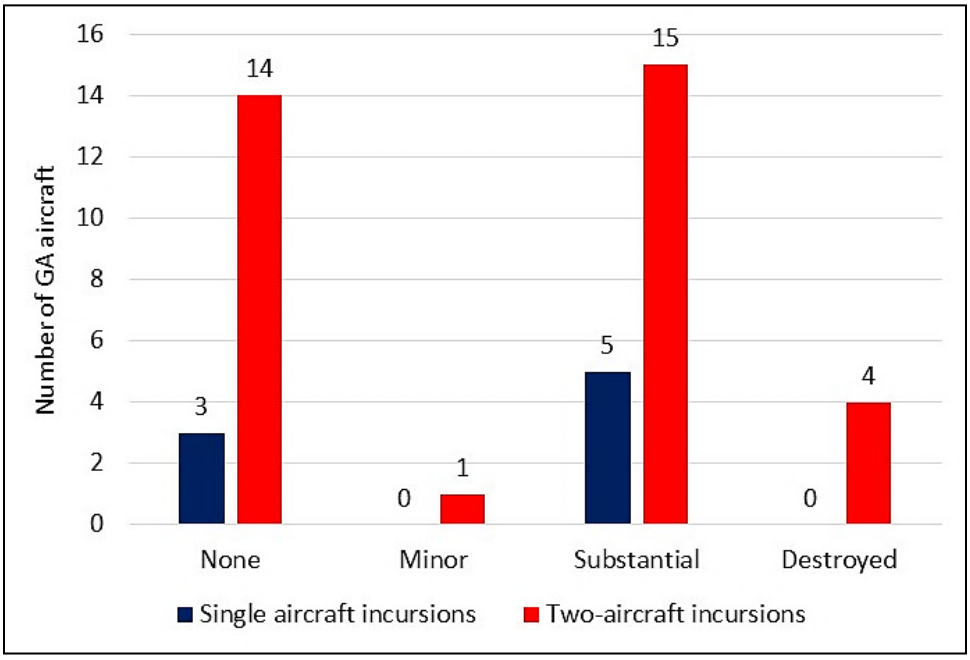


Figure 35. Number of GA aircraft and the level of damage for NTSB-RIs

Figure 35 shows that, not surprisingly, GA aircraft involved in two-aircraft incursions are more likely to be damaged than those in single aircraft incursions. There are also more incursions involving two aircraft rather than a single aircraft. Researchers found that eight events involved a single aircraft, whereas 23 events involved two aircraft. Figure 36 shows the number of NTSB-RIs that resulted in accidents and incidents.

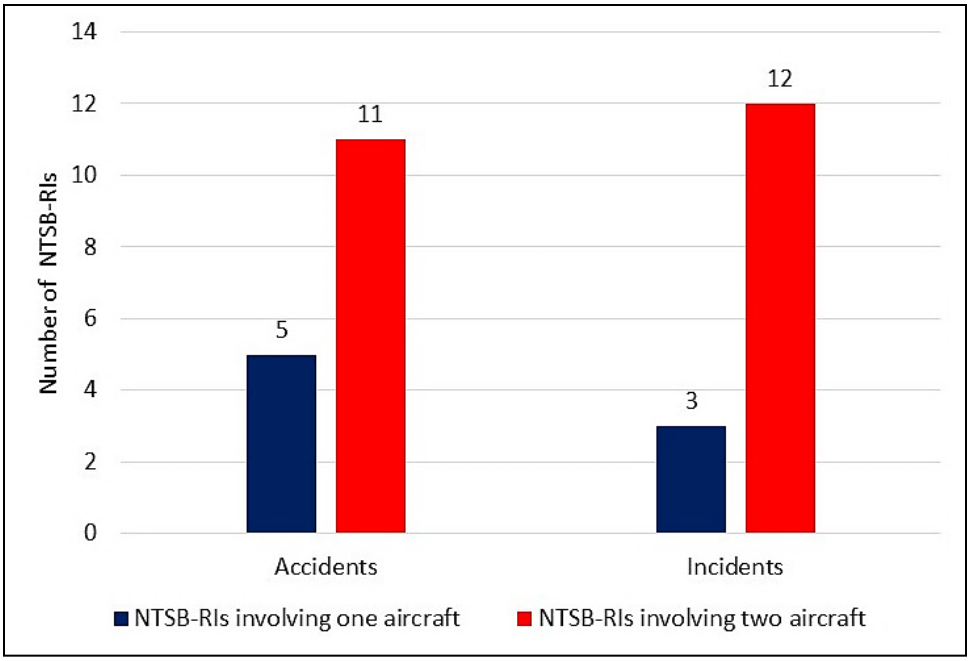


Figure 36. Number of NTSB-RIs that resulted in accidents and incidents

NTSB-RIs classified as accidents most often involved the entities colliding on the runway and causing injuries to people on board or damage to the aircraft. Incidents were most often the result of near misses between the entities involved or cases such as an aircraft landing on a taxiway rather than a runway but resulting in no injuries or damage to aircraft.

6.1.4.2 Geographic Locations of the NTSB-RIs

Figure 37 shows the geographical locations of RIs reported in the NTSB database. One of the geographical locations of NTSB RIs was Teterboro Airport. Teterboro Airport (Airport ID: KTEB), with two NTSB-RI in 2007 and one in 2008, has the highest number of NTSB-RIs.

All three events at Teterboro included “Improper Control Tower” as a cause. Investigators found that the control tower was not equipped with an airport surface-area movement monitoring system, such as AMASS. AMASS visually and aurally prompts the controllers when a situation arises that has the potential to compromise surface safety. The airport is not currently equipped with AMASS.

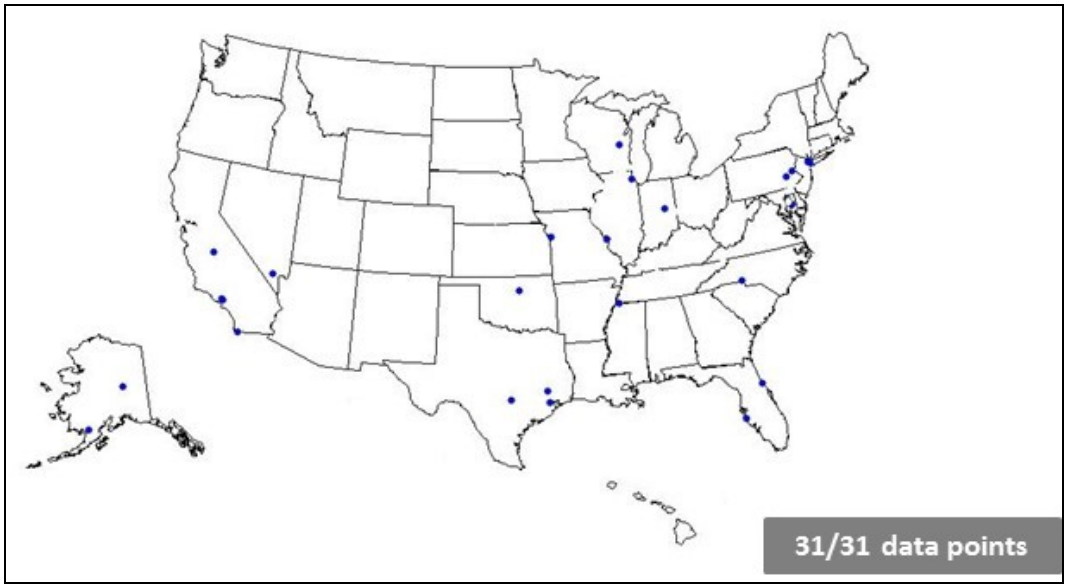


Figure 37. Light conditions at the time of incursion for GA NTSB RIs

6.1.4.3 Light and sky condition

Most of the NTSB-RIs occurred during the day, probably in part because more flights occur during the day. Figure 38 shows the different light conditions in which these NTSB-RIs occurred. Of the 17 events that occurred in the daylight, in three events, at least one aircraft involved was operating under an IFR flight plan. In the remaining cases, the pilot did not file a flight plan. Of the six events that occurred during night, night dark, or night bright, in four events, at least one aircraft involved was operating under an IFR flight plan. For the event that occurred at dawn, both aircraft involved were under an IFR flight plan, and for the event that occurred at dusk, both aircraft had no flight plan filed.

Most of the NTSB-RIs occurred when the sky conditions were clear. Figure 39 shows the different sky conditions in which these NTSB-RIs occurred. Ten NTSB-RIs (one-third of the total) occurred during the day and when the sky condition was clear. Cozza and Young (2013) analyzed incursions in the NTSB database between October 2008 and September 2011. They too found that more incursions occur in daylight and clear weather. One of the reasons could be that there are more operations during daytime hours and in clear weather. Additionally, regulatory and equipment limitations often preclude GA operations in night hours or in reduced visibility conditions (Cozza and Young, 2013).

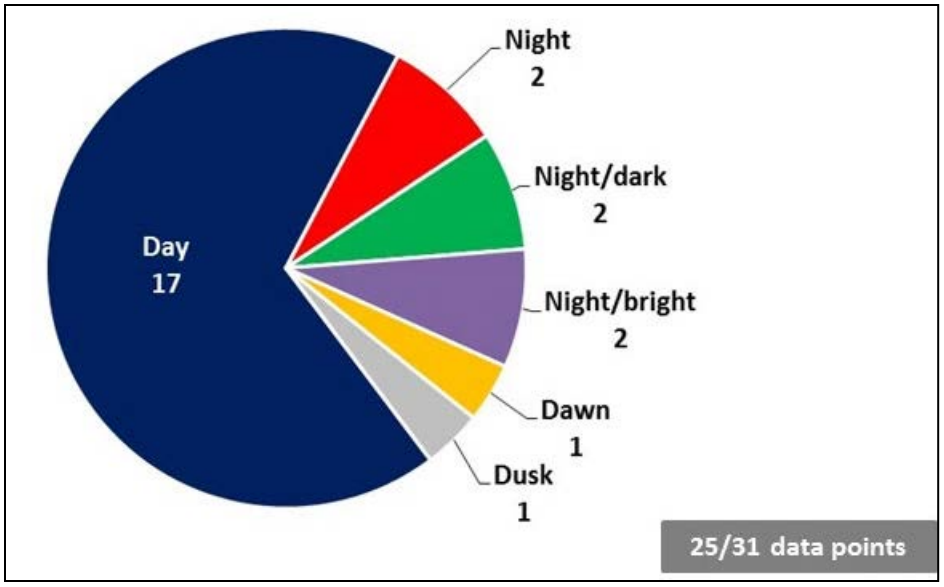


Figure 38. Light conditions at the time of incursion for GA NTSB RIs

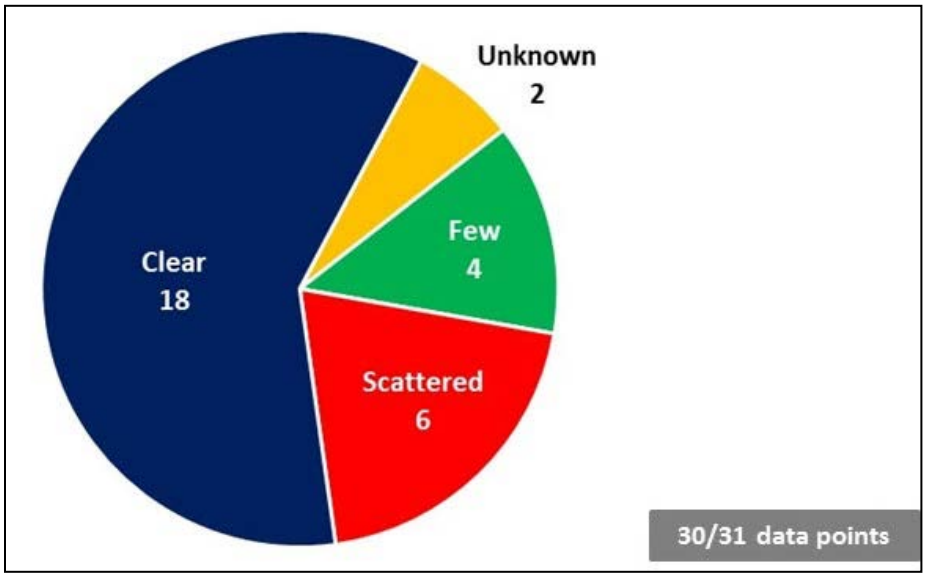


Figure 39. Sky conditions at the time of incursion

6.1.4.4 Traffic Mix

The NTSB-RIs identified either one or two aircraft, and possibly ground vehicles or pedestrians. Of the 31 NTSB-RIs, eight events involved a single aircraft, and the remaining 23 involved two aircraft. The incursions that involved a single aircraft may have been due to the incorrect presence of a ground vehicle or a pedestrian on the runway, or because the aircraft was in a place it was not supposed to be (e.g., the aircraft landed on a closed runway). Figure 40 shows the traffic mix in the NTSB-RIs.

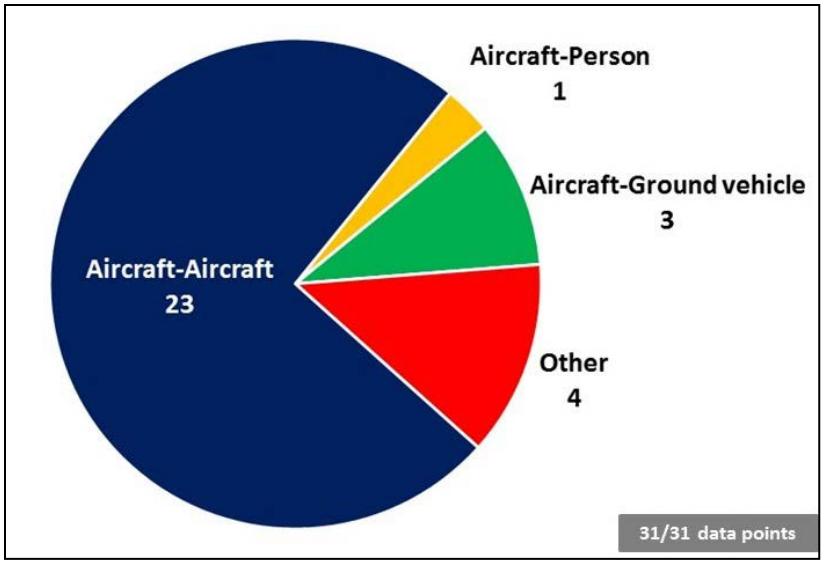


Figure 40. Traffic mix in GA NTSB-RIs

In figure 40, the "Other" category is used to describe NTSB-RIs in which the single aircraft involved was in an incorrect place (e.g., it landed on the wrong runway).

6.1.4.5 Type of GA Operations

There were at least 42 GA aircraft involved in the 31 NTSB-RIs. Most of these flights were personal flights. Figure 41 shows the types of operations carried out by these GA aircraft involved in the incursion.

For one NTSB-RI, the type of operation was not available, and for one NTSB-RI, the coded type of operation was unknown. The "Other" category is used to describe operations such as ferry or executive. One of the reasons for the high number of personal flights and instructional flights being involved in RIs could be that these two types account for almost half of all GA operations (Elias, 2009).

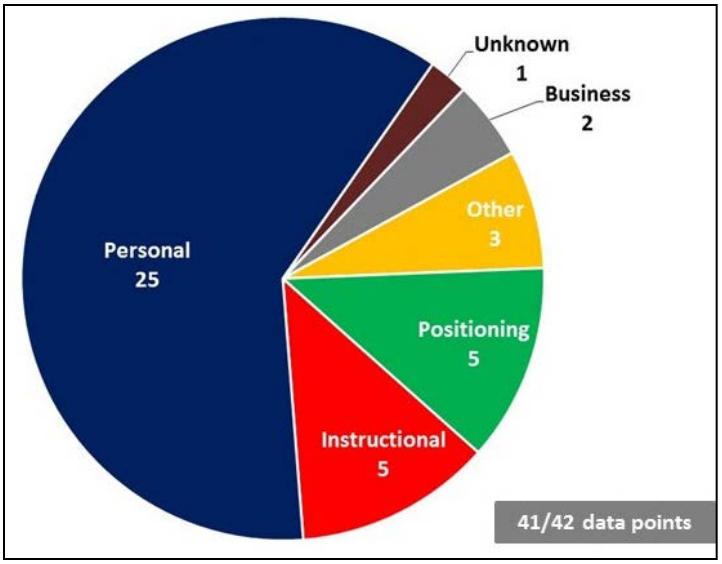


Figure 41. Types of GA operations in NTSB-RIs

6.1.4.6 Causes of NTSB-RIs

As mentioned earlier, the NTSB changed the way it coded key findings in 2008. For events in the pre-2008 coding system, each finding is described by a subject code, a modifier code, and a person code. Subject codes are used to identify equipment, processes, phenomena, or errors made by individuals that led to the accident or incident. Modifier codes are used in conjunction with subject codes to provide additional detail, clarification, or specificity. Person codes are used to indicate the personnel associated with the finding. For example, consider a finding for which the pilot failed to maintain visual lookout. The finding is coded as "visual lookout" (subject code: 24021), "not maintained" (modifier code: 3127), "pilot-in-command" (person code: 4000).

For events in the post-2008 coding system, the findings are represented by a 10-digit code. Consider the 10-digit finding code 0202154044. The first 02 represents the category "Personnel Issues;" the second 02 represents the subcategory "Psychological;" 15 represents the section "Attention/Monitoring;" 40 represents the subsection "Monitoring other aircraft;" and 44 represents the modifier "Pilot."

In this section, the causes of NTSB-RIs are discussed, first in the pre-2008 coding system and then in the post-2008 coding system.

6.1.4.6.1 Pre-2008 coding system

In the pre-2008 coding system, each finding that is coded is assigned a group code. Table 9 shows the group codes that are assigned, the types of finding, and their descriptions.

Table 9. Group codes for findings in the pre-2008 NTSB coding system

Group Code	Type of finding	Description
1	Primary non-people finding	Aircraft/Environment
2	Primary people finding	Human Performance
3	Non-primary finding	Direct Underlying Factors
4	Non-primary finding	Indirect Underlying Factors

The non-primary findings may be people-related and are used to further explain a primary finding. Note that there are no guidelines in the manual that indicate how findings are classified as primary or non-primary. However, the goal was to present and analyze each cause or error that led to the incursion and not differentiate them as primary and non-primary findings. To use a more comprehensive taxonomy, and to be consistent with the post-2008 classification of findings, the data divide the key findings into four categories—personnel-related issues, environment-related issues, organizational issues, and aircraft-related issues.

The findings with group code 2 are classified as personnel-related issues, and sorted findings with group code 1 into aircraft-related issues environment-related issues. The findings with group codes 3and 4 were then analyzed and sorted into one of the four categories. There might be subjectivity involved in classifying the findings into these categories, and the classification may not be perfect. However, whereas the finding may not be in the most accurate category, it is still present in one of the four, and is analyzed.

Table 10 shows the four categories in which the events were classified and the number of findings in each category.

Table 10. Number of findings for NTSB-RIs in various categories

Category	Number of findings
Personnel-related issues	54
Environment-related issues	13
Organizational issues	7
Aircraft-related issues	6

The findings classified as aircraft-related issues were most often a result of the incursion rather than a cause. For example, one of the aircraft-related issues was “landing gear overload.” On reading the narrative (Event ID: 20001214X36282), it was found that the overload occurred when the pilot evasively turned right on the runway during landing rollout when he noticed another aircraft landing behind him.

In the remainder of this section, the findings under each of these three categories are discussed.

Personnel-related issues are errors made by the people involved, such as the pilot, the air traffic and ground controllers, vehicle drivers, airport personnel, or pedestrians. Of the 54 personnel-

related issues, 31 findings were related to the pilot or flight crew. Figure 42 shows the errors made by pilots that contributed to the incursion.

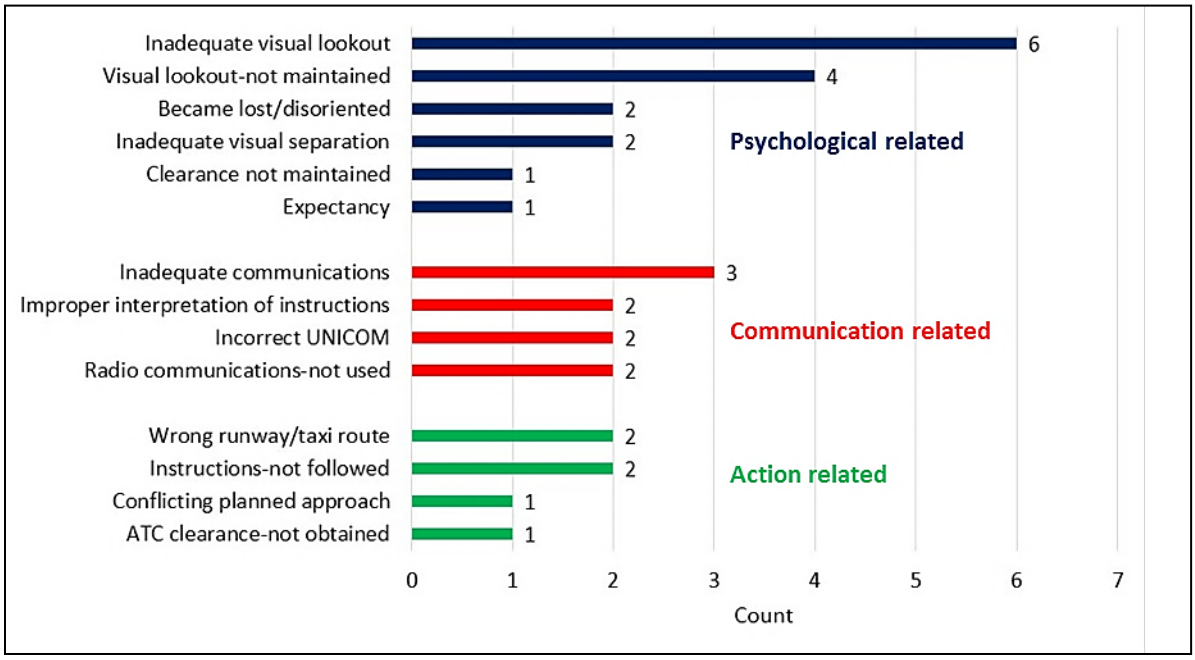


Figure 42. Pilot-related errors in events in the pre-2008 NTSB coding system

The most frequent pilot error was inadequate visual lookout or not maintaining visual lookout. All the events in which the pilot was cited for inadequate visual lookout or not maintaining visual lookout occurred in the daytime. The reports do not mention what may have led to reduced visibility. However, the researchers often found that in these accidents or incidents, the pilots were not aware of any traffic due to inadequate or lack of radio communications. The red bars in figure 42 show the errors pilots made in communications. The pilot's assumption that there was no other aircraft in the vicinity may be one of the reasons they did not look out. The AIM advises pilots to "See and Avoid" (i.e. "[w]hen meteorological conditions permit, regardless of type of flight plan or whether under control of a radar facility, the pilot is responsible to see and avoid other traffic, terrain, or obstacles").

Out of the 54 personnel-related issues, 19 were determined to be controller-related issues. Figure 43 shows the errors made by controllers that contributed to the incursion. Controller-related issues most often include prematurely clearing an aircraft onto the runway.

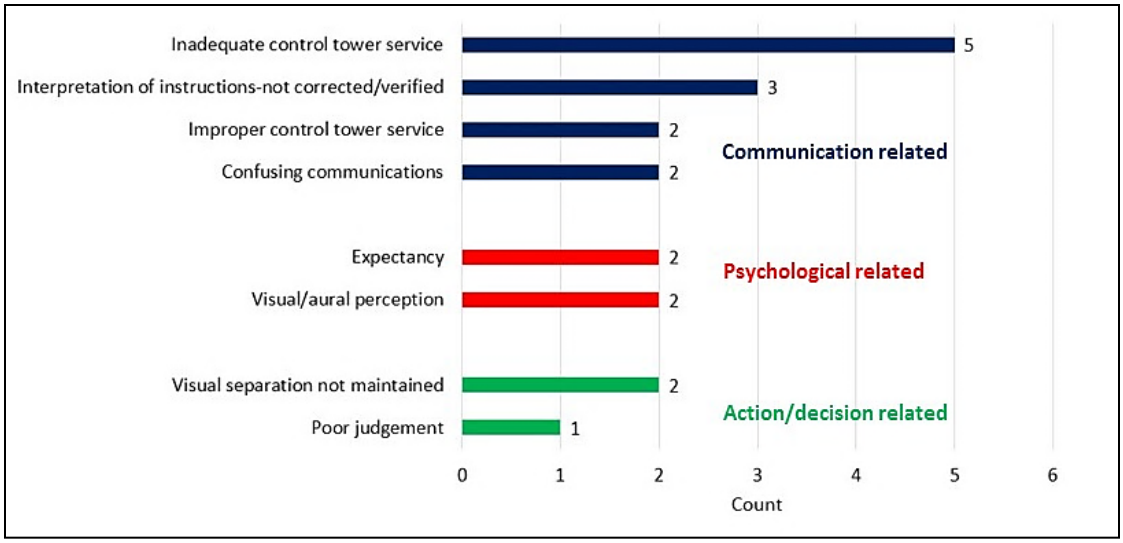


Figure 43. Controller-related errors in events in the pre-2008 NTSB coding system

An example of an event for which there was inadequate control tower service is an accident that involved an intersection departure (Event ID: 20001212X20686). One of the aircraft was to depart Runway 14 from an intersection. For intersection departures, the ground controllers must clearly mark the flight progress strip as intersection departure (e.g., F/14, 14/F,14XF). However, the local controller stated that there was no written standard strip-marking procedure for intersection departures. He also stated that the ground controllers at the airport do not place the progress strips in a sequence before giving it to the local controller. Therefore, the controller prematurely cleared the aircraft to taxi and hold position from an intersecting taxiway on the occupied runway.

In another event (Event ID: 20030925X01600), the controller was engaged in a discussion with someone about a helicopter in the proximity of the airport when two planes collided at the airport. Witnesses said that the controller was one of the best. The controller, in an interview, stated that he was exhausted from working overtime.

Four of the 54 personnel-related issues involved personnel other than the pilot or controller. Table 11 lists the error, the count of error in NTSB-RIs in the pre-2008 coding system, and the coded description of who made the error.

Table 11. Errors made by personnel other than pilots or controllers in events in the pre-2008 NTSB coding system

Error	Count	Personnel
Inadequate communications	2	Unspecified person
Poor judgement	1	Other person
Improper planning by vehicle driver	1	Vehicle driver

Results show 13 environmental-related issues. Figure 44 shows the count of various issues that contributed to an incursion.

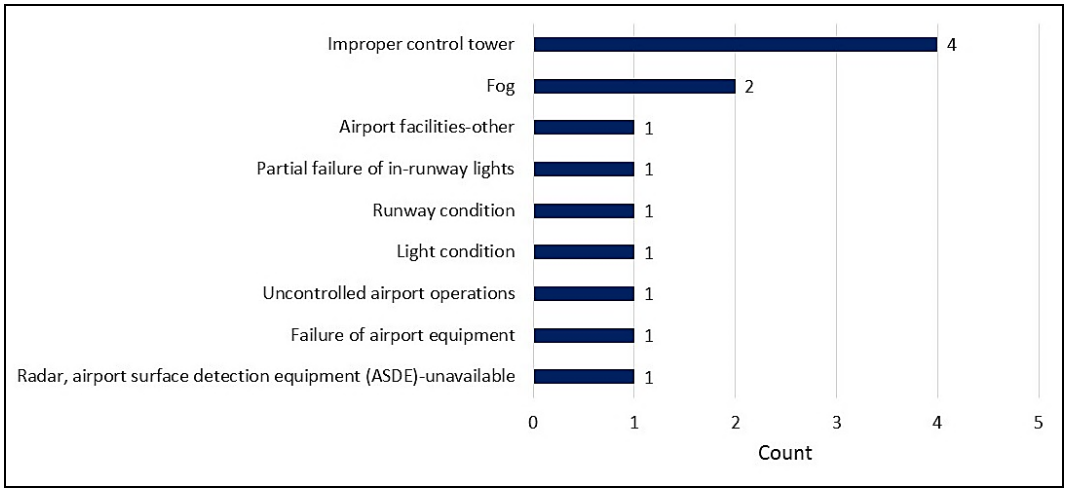


Figure 44. Environmental-related issues in events in the pre-2008 NTSB coding system

As mentioned earlier, "Improper control tower" was a common cause in events that occurred at the Teterboro airport, which does not have an AMASS installed. In addition to these events, there was an event that occurred at O'Hare International Airport in Chicago. At the time of the event, the airport managers reported that the ASDE-X did not have crossing runway logic installed, and the ASDE-X did not alarm during the incident.

There was one event (Event ID: 20030925X01600), in 2001, where "Improper control tower" was not cited as a cause per se, but it is worth mentioning. It pertains to the control tower at the Van Nuys Airport (KVNY) in California. The report cites from the airport website that KVNY was ranked as the world's busiest GA airport. The controllers at the LC1 position do not always have an unobstructed view of the runways and taxiways. The controllers reported that they often have to walk across the cab to fully scan the runways.

Results show seven organizational-related issues. Table 12 shows the various organizational issues, its count in NTSB-RIs, and the personnel responsible for it.

Table 12. Organizational issues in events in the pre-2008 NTSB coding system

Error	Count	Personnel
Insufficient standards/requirements	2	FAA
Inadequate procedures	2	FAA
Inadequate supervision by ATC personnel	1	Supervisor
Inadequate equipment	1	Unspecified person
Inadequate design of facility	1	Unspecified person

In one event (Event ID: 20001208X05680), a near mid-air collision occurred at the Fairbanks International Airport in Alaska. The incursion occurred when a pilot took off from Runway 19L without clearance. The incursion led to a near mid-air collision with another aircraft landing on a Ski Strip 19-01. At this airport, the Runway 19L-01R and the Ski Strip 19-01 are oriented in the same magnetic heading, but there is no lateral displacement between the two, as shown in

figure 45. The arrival end of the ski strip is directly south of the departure end of Runway 19L. Investigators found that the air traffic controller's handbook did not contain procedures to be used when two runways are oriented in the same magnetic heading but not laterally parallel to each other.

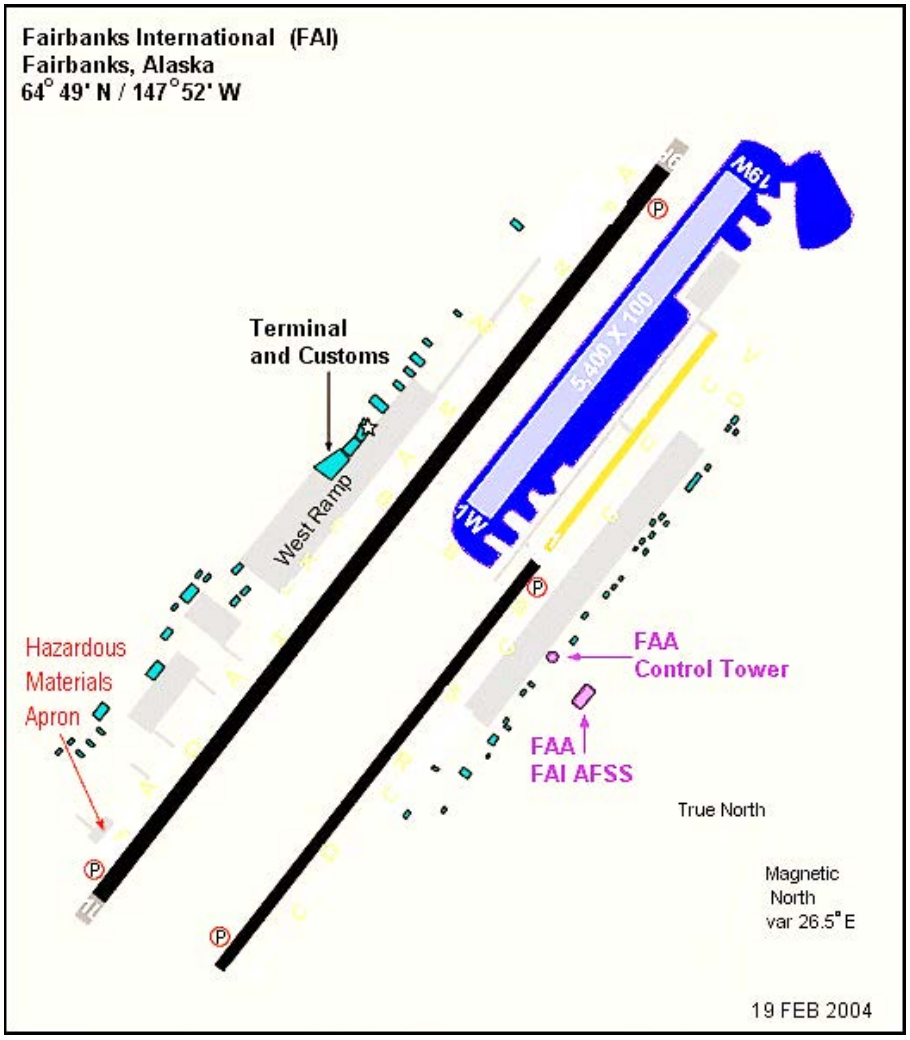


Figure 45. Runway layout at KFAI (source: Airports-Worldwide.com, 2017)

In the event in which the ATC supervisor was cited for inadequate supervision (Event ID: 20001213X29069), the controller did not correct the pilot's misinterpretation of instructions, and the supervisor did not monitor this situation.

6.1.4.6.2 Post-2008 NTSB coding system

The research team found only "Personnel related issues" and "Organizational issues" as causes of NTSB-RIs in the post-2008 coding system. Table 13 shows the count of these two issues in NTSB-RIs.

Table 13. The Number of findings in various categories

Category	Number of findings
Personnel-related issues	25
Organizational issues	3

Of the 25 personnel-related issues, results show that 19 were controller-related issues, five were pilot-related issues, and one was an airport personnel-related issue, as shown in figure 46.

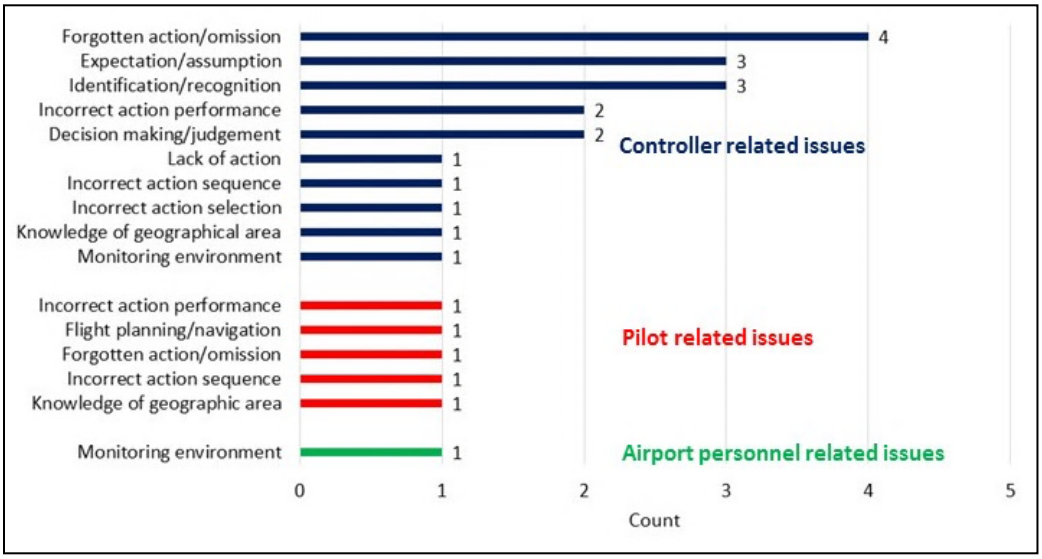


Figure 46. Personnel-related issues in events in the post-2008 NTSB coding system

Common controller errors include unintentionally clearing an aircraft to take off from or land on an occupied runway. The reports go beyond just blaming the controller for giving an incorrect clearance to investigating why the controller might have made the error.

For example, one event (Event ID: 20080922X01509) involved a Canadair CRJ-700 aborting takeoff on noticing a Cessna on the runway. The event occurred at night. The Cessna had landed on the runway but had missed its exit taxiway. The controller thought he saw the Cessna light turn toward the exit, and the runway appeared to be clear. However, the Cessna was still on the runway. The controller then cleared the CRJ-700 for takeoff. The report mentions that the controller had turned his attention to a third aircraft in the pattern, which could be one of the reasons the controller did not see the conflict develop on the runway. Further, the controller stated that there was little to no training for night operations at the airport because of insufficient traffic. The controller thought the runway was clear, but from controller and pilots' interviews, investigators found that it was difficult to spot the Cessna on the runway for two reasons: (1) the Cessna did not have any strobe lights on to help the controller or the other pilot identify the aircraft, and (2) the runway lights might have been set to an intensity that made it difficult to spot the small GA aircraft on the runway.

In another example, there was a near collision between two aircraft at intersecting runways because the controller did not maintain the required separation (Event ID: 20100420X55951). The report states that the local controller and controller in charge were distracted by a third aircraft, and their attention was focused on the radar display and not out the tower window.

Results show only five pilot-related issues in NTSB-RIs coded in the post-2008 system. In one event (Event ID: 20080923X01518), the pilot was cited for "lack of knowledge of geographic area" and "incorrect action performance." In this event, the pilot had landed on the runway and was instructed by the controller to exit on taxiway B3; however, the pilot was unable to because the aircraft was heavy with six occupants and took longer to decelerate. After noticing that the pilot had missed the turn on taxiway B3, the controller instructed the pilot to exit on taxiway B5. The pilot had difficulty finding taxiway B5; meanwhile, a second aircraft had landed on the same runway. The investigators found that the runway does not intersect with taxiway B5 at all. To reach taxiway B5, the aircraft must make a hard-left turn on B4 and then right on B5. The investigators also found that controllers were unaware that the taxiway B5 did not intersect the runway. In addition, there were no signs for taxiway B4, and the taxiway was lined with reflectors instead of taxiway edge lights. These reflectors were orange instead of the standard blue used for taxiways.

Three organizational related issues were found. Table 14 shows the count of the organizational issues and the personnel involved in it.

Table 14. Organizational issues in events in the post-2008 NTSB coding system

Error	Count	Personnel
ATC Training	1	ATC
Oversight/Monitoring of ATC	1	ATC
Adequacy of Safety Program	1	FAA/Regulator

The first issue, ATC training, was related to the previously discussed example (Event ID: 20080922X01509) in which the controller was not sufficiently trained or experienced in night operations at the Lehigh Valley International Airport (ABE), in part because of insufficient traffic. Of the 81 hours he was trained on local control, only 49 minutes were at night. He stated that although he received a daytime tour of the airfield during his training, he had never been out at the airfield at night.

The event in which the ATC was cited for oversight and monitoring involved an aircraft colliding with construction barriers when landing on a closed runway (Event ID: 20120405X40552). The pilot reported that he had called the Flight Service Station before the flight, the briefer did not mention the NOTAM on the closed runway, and the pilot did not ask about the NOTAMs. Additionally, there was no mention of the closed runway on the Automatic Terminal Information Service.

The third case involved a collision between a ground vehicle and an aircraft on the runway (Event ID: 20080820X01264). The controller had cleared the vehicle to cross the active runway, but the ground vehicle driver did not scan the runway before entering it. Investigators found that although the FAA-approved Airport Certification Manual included "Procedures for Ground Vehicle

Operations," it did not specifically mention ground vehicle operators must visually confirm that an active runway was clear before crossing with ATC clearance. As a result of the accident, this addition was made to the procedures at the airport.

6.2 REVIEW OF AIDS DATABASE

The purpose of this task was to review the FAA AIDS to find causes and contributing factors that lead to RIs in GA. To do so, researchers obtained the most recent set of FAA incident reports. Then, the incident data were preprocessed to isolate RIs that involved at least one GA aircraft and occurred at towered airports. Then, the RI data were analyzed to find causal and influencing factors in RIs.

6.2.1 Overview of AIDS Database

The FAA AIDS database contains records of incidents in all categories of civil aviation. The incidents in the database are those events that do not meet the aircraft damage or personal injury criteria described by NTSB's definition of an accident. A separate report is issued for each aircraft involved in the incident. The database contains reports of incidents from 1978 onward (Nazeri, 2007).

6.2.2 Retrieving Data From AIDS Database

The database is publicly available from the FAA's Aviation Safety Information Analysis and Sharing (ASIAS) website. The website provides an AIDS search form that can be used to search for events based on narratives, report number, event date, event location, operations of aircraft, or aircraft details, such as aircraft make and model. The database can be downloaded as a CSV file; however, the narratives cannot be downloaded directly from the website. The CSV file that can be downloaded contains details such as event date and location, aircraft details, injury and damage details, and pilot details. To read the narratives of the events, one must select the events of interest and then select the "Brief Report(s)" option to get the narratives.

The database contains more than 100,000 records of incidents from 1978 onward. Figure 47 shows the process of filtering the data to obtain the set of RIs that occurred at towered airports and involved at least one GA aircraft.

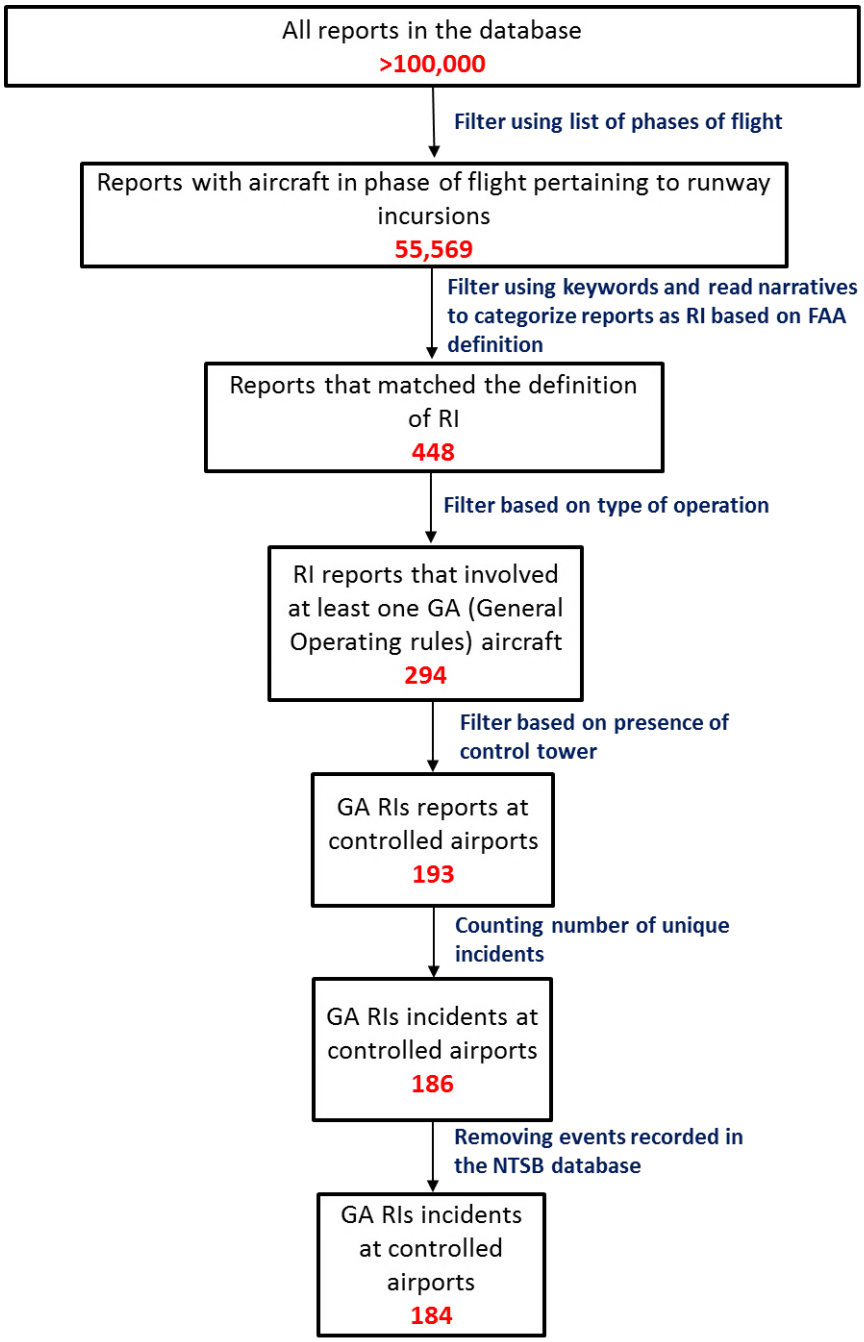


Figure 47. Filtering of AIDS reports to isolate RIs

First, the database was filtered by focusing only on those phases of flight that pertain to RIs. The database does not provide a formal definition of the terms it uses to describe the various flight phases. The phases of flight related to taxi, takeoff, and landing were then used to narrow the search. In cases in which it was not clear what the flight phase meant, the definition given by International Civil Aviation Organization (ICAO) was followed (ICAO, 2013). Table 15 shows the list of phases of flight used to narrow the search and the number of incidents in each.

Table 15. The phases of flight related to RIs and number of incidents in each phase

Phase of flight	Number of incidents
Final approach	3946
Go round	451
Ground taxi (other airplane)	7665
Landing	642
Landing-approach	741
Landing-rollout	1481
Landing-touchdown	2599
Operations on ground from landing	334
Operations on ground to takeoff	27
Other ground operations	1726
Other (specify)	260
Roll out (fixed wing)	16224
Takeoff	113
Takeoff-ground roll	2970
Takeoff-aborted	14
Takeoff-climb out	677
Takeoff-departure	391
Takeoff-rotation	197
Taxi	8637
TO-aborted (fixed wing)	1773
TO-initial climb	2826
Touch and go landing	1545
Unknown	330
Total	55569

For some phases of flight, such as taxi, operations on ground, or other ground operations, keywords were used to filter events that could potentially be an RI. These keywords that the researchers used were “runway incursion,” “incursion,” “crossed runway,” “failed to hold short,” “without clearance,” and “closed runway.” In addition to filtering reports based on keywords that could be present in incursions, reports based on keywords that could not be an RI were also filtered. Some of these keywords include “overran,” “ran off runway,” “ran off,” “veered,” which more likely describe a runway excursion; “gear up,” “gear retracted,” and “instead of flaps,” which describe situations in which the pilot landed without the gear down or retracted landing gear instead of flaps.

Although these keywords helped in narrowing the search, the researchers still had a substantial amount of reports to read before they could be classified as RIs or not. There were 448 RIs reports

in total. It is possible that there were some missed RIs, but the structured approach to identifying RIs makes the likely number of missed RIs very low.

Although the database does not mention the 14 CFR Part of the aircraft involved, it does give the information on the type of flight conducted. These 448 reports were filtered using the general operating rules type of flight conducted because 14 CFR 91 is titled "General Operating and Flight Rules." Therefore, 294 reports were found that related to RIs involving at least one GA aircraft.

The airport IDs where the incursion occurred were found using www.airnav.com. Using the airport name, city, and state that was available in the database, the airport ID and subsequently whether there was a control tower could be determined. For 20 of the 294 reports, the location of the incident is missing from the database. For these reports, the narratives were read and inferred whether it was towered. For example, for report number 19860627058349I, the airport name was not specified in the database, but the narrative mentioned that the ATC instructed the pilot to taxi into position and hold. Therefore, it was inferred that the airport was towered at that time. Of these 20 reports, it was found that four reports had sufficient information to conclude that the airport was towered.

For six of the 294 reports, the airport IDs could not be found. One reason could be that these airports are not operative anymore. The narratives were read, and it was inferred that two reports were for towered airports. For the remaining reports, the information was not sufficient to deduce whether the airport was towered or not.

There were 82 reports for non-towered airports. The narratives for these reports found that three reports mentioned an ATC. Because www.airnav.com shows the recent information, it is possible that at the time the incident occurred, those airports were towered but no longer are.

As a result, 193 reports were identified that were for incursions at towered airports. The database publishes a report for each aircraft involved in the incident. The researchers looked for reports with the same date and location and, from the narratives, cross-checked whether the reports were for the same incident. In such cases, the database specifies the general information regarding whether the aircraft was the first or second aircraft involved in the incident. The researchers treated reports pertaining to the same incident as one. Therefore, 186 incidents were found that occurred at towered airports and involved at least one GA aircraft.

Using the event date and location, two of the 188 incidents were also recorded in the NTSB database and had already been analyzed with the NTSB data. Table 16 shows the two events present in the NTSB database.

Table 16. Same events in AIDS and NTSB database

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

6.2.3 Summary of RI Data From AIDS Database

Approximately 66% of the total RI reports involved at least one GA aircraft. After filtering the database, the researchers found 184 RI incidents that occurred at towered airports and involved at least one GA aircraft. In comparison, only 78 incidents occurred at non-towered airports. One reason could be that towered airports inherently have a higher number of operations than non-towered airports (Cozza and Young, 2013). The dates of occurrence of these RIs range from February 23, 1978 to February 4, 2014.

6.2.4 Results and Discussion for AIDS Database

From the information contained in the database, such details as geographical location, pilot details, causes, and consequences of RIs were analyzed. Information is missing from some entries in the database. For instance, some entries do not include the pilot's total flight hours. For each analysis, the number of data points is indicated for which the information being analyzed is available.

6.2.4.1 Details of Events From AIDS Database

Because these reports are for incidents, it is not surprising that that none of the incidents involved any injury to the people involved in the incursion. At least 190 aircraft were involved in the 184 RI incidents. Figure 48 shows the level of damage incurred and the number of aircraft in each category.

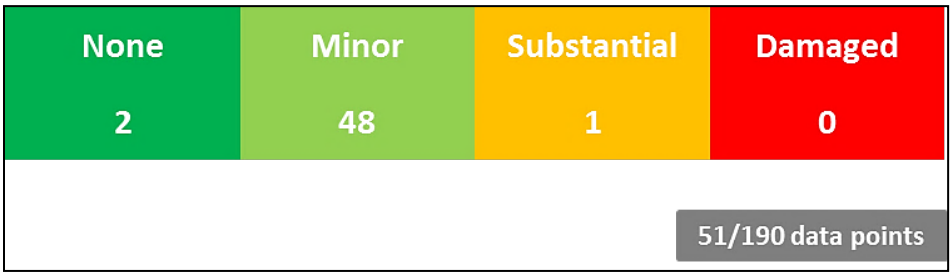


Figure 48. Number of aircraft and their level of damage in AIDS-RI

In 16 cases of the 48 in which the aircraft incurred minor damage, the pilot was operating at a closed runway. The damage was due to collision with some object on the closed runway while the pilot was landing or taking off. For example, in one incident (AIDS Report Number: 19780827039449I), the pilot took off from a closed runway. In doing so, the aircraft struck and destroyed a barricade and, therefore, incurred damage. In another case (AIDS Report Number: 19840128015369I), the pilot did not check NOTAMs or did not see the white crosses on the

runway indicating that it was closed. The pilot landed on the closed runway and struck steel posts on the closed runway.

In six of the 48 cases, the pilot entered onto an active runway. For example, in one incident (AIDS Report Number: 20080103000269I), the pilot was instructed to hold short of the runway. The pilot got distracted by his friends nearby and crossed the hold short line. The ATC noticed the error and asked the pilot to stop. The pilot braked so hard that the aircraft nosed over, resulting in a propeller strike. A similar incident occurred in Minnesota (AIDS Report Number: 20091212052849I), in which the pilot was taxiing at high speeds. When the ATC reminded the pilot that he had to hold short of the runway, the pilot braked hard enough to cause the aircraft to tip on its nose and cause a propeller strike.

Other cases include incidents in which the pilot proceeded without instruction onto an active runway, collided with an object when operating on a taxiway when they were not supposed to be there, or operated on a runway other than the one assigned to them.

In the incident in which the aircraft incurred substantial damage, the pilot was operating on a runway other than the one assigned to him (AIDS Report Number: 20080206013599I). The tower had cleared the pilot to take off from Runway 31. The pilot thought that he was on Runway 31 but was on Runway 6. It was too late when the pilot realized his error. He went off the runway into the grass area, then into water while attempting to stop.

Figure 49 shows the geographical locations of the incidents. In five of the 184 incidents, the database did not specify the airport name where the incursion occurred. In those cases, the researchers plotted the city where the incursion occurred as mentioned in the database.

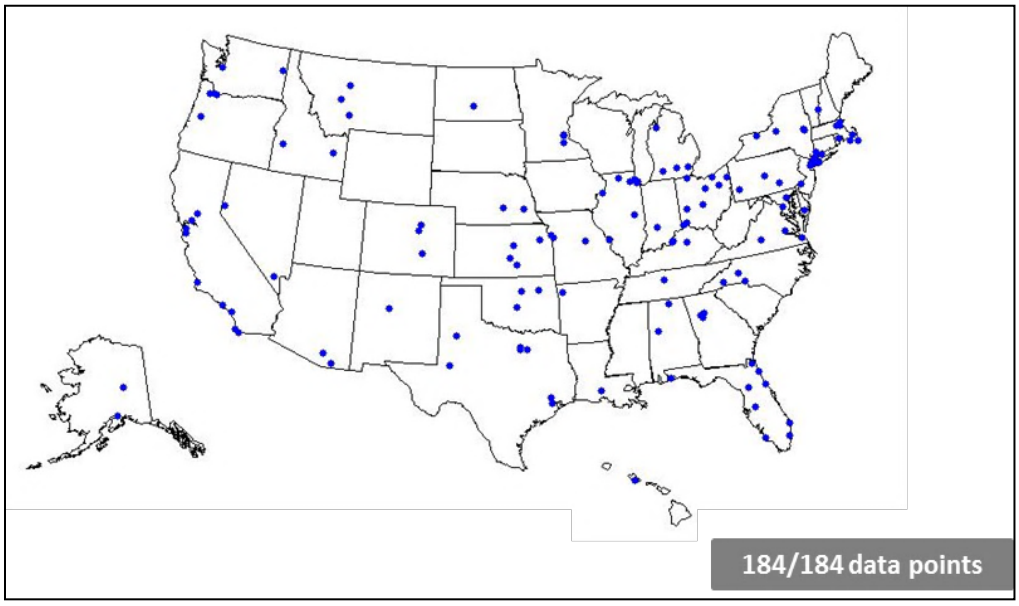


Figure 49. Geographic locations of RI incidents in AIDS database

Cleveland-Hopkins International airport (Airport ID: KCLE), with eight RIs (two in 1996, four in 1997, and two in 1999), has the highest number of incursion incidents. In the four incidents that

occurred in 1997, the incursions occurred because the pilot crossed the hold-short line for Runway 23. One report (AIDS Report Number: 19970511036359I) stated that the intersection was confusing and poorly marked. Another report (AIDS Report Number: 19971012043899I) stated that the pilot did not see the hold-short line because it was faded at the time of the incident. After the fourth incursion on October 13, 1997, the runway signage was changed.

Figure 50 shows the primary, secondary, and light conditions at the time of the incident. Most of the incursions occurred in VFR conditions. Most RIs occurred during the day, and weather was not a contributing factor. From the analysis of RIs in the NTSB database, it was found that most incursions occurred during the day and in clear weather. This could be because there are more operations in good weather conditions and when the visibility is good, rather than in unfavorable weather conditions. Regulatory and equipment limitations also often prevent GA operations in conditions of reduced visibility (Cozza and Young, 2013).

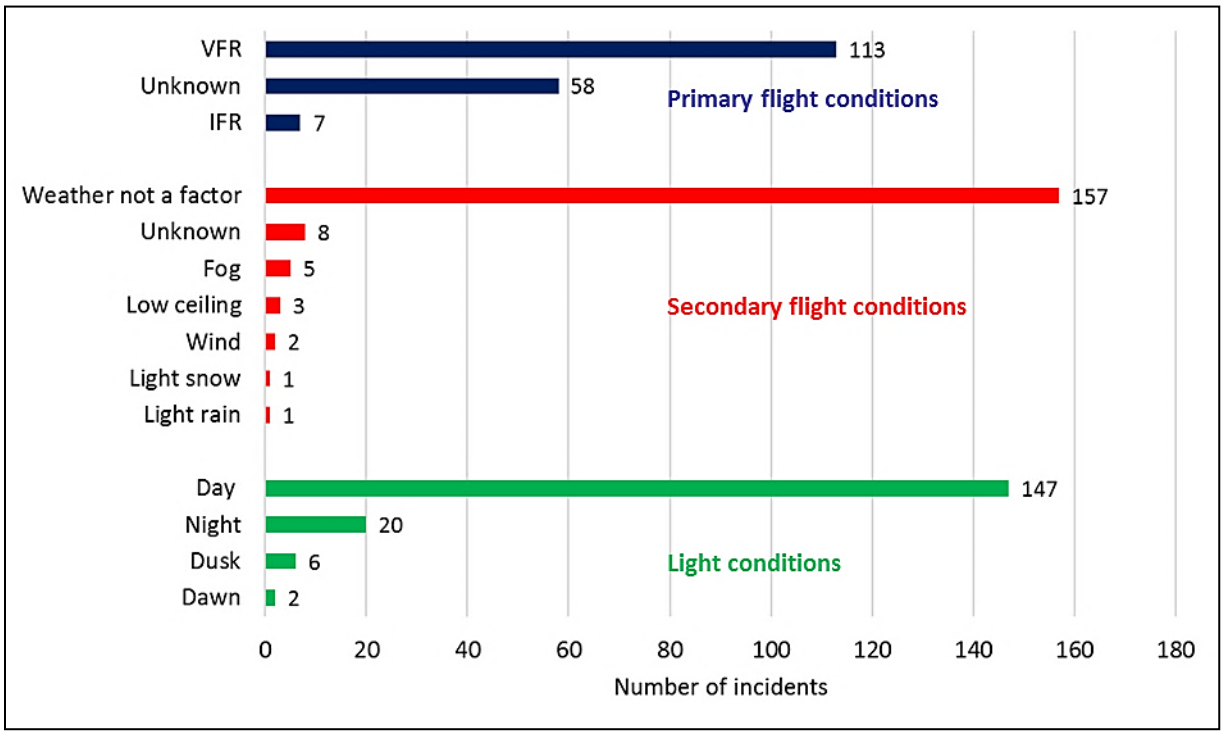


Figure 50. Weather conditions at the time of RI incidents

Figure 51 shows the traffic mix for the 184 incidents. Most of the incursions involved a single aircraft. These single-aircraft RIs are represented by the "other" category. The "other" category describes incursions that may have occurred from the pilot crossing a runway without authorization, landing or taking off from a taxiway, landing or taking off without clearance, or operating on a runway other than the one assigned.

There was one incident (AIDS Report Number: 19980623029399I) involving a single vehicle. The vehicle was crossing the runway without ATC's authorization. The report stated that the vehicle was not in radio communication with the control tower. There was no conflict with another aircraft.

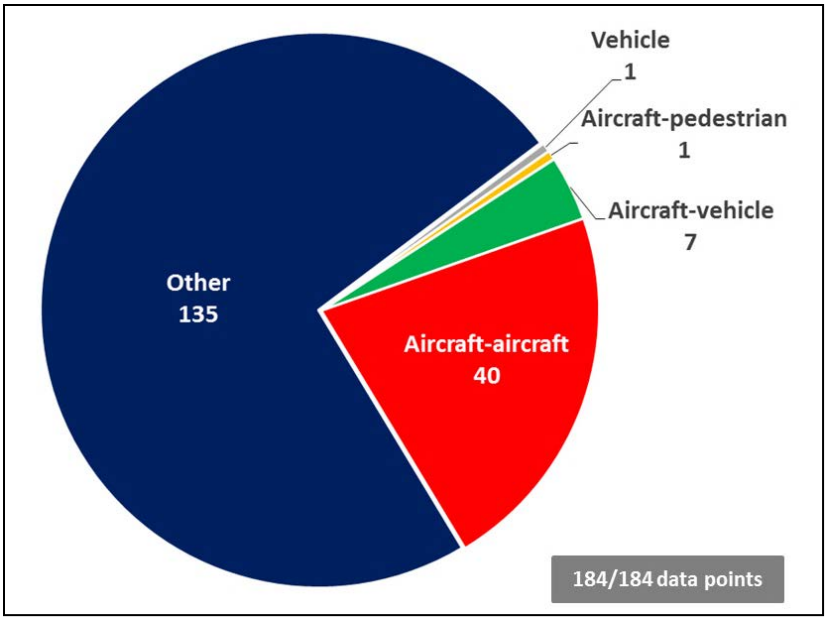


Figure 51. Traffic mix of RI incidents

There were at least 187 GA aircraft involved in the 184 incidents since 1978. Most of these flights were personal flights. Figure 52 shows the types of operations carried out by these GA aircraft involved in the incursion.

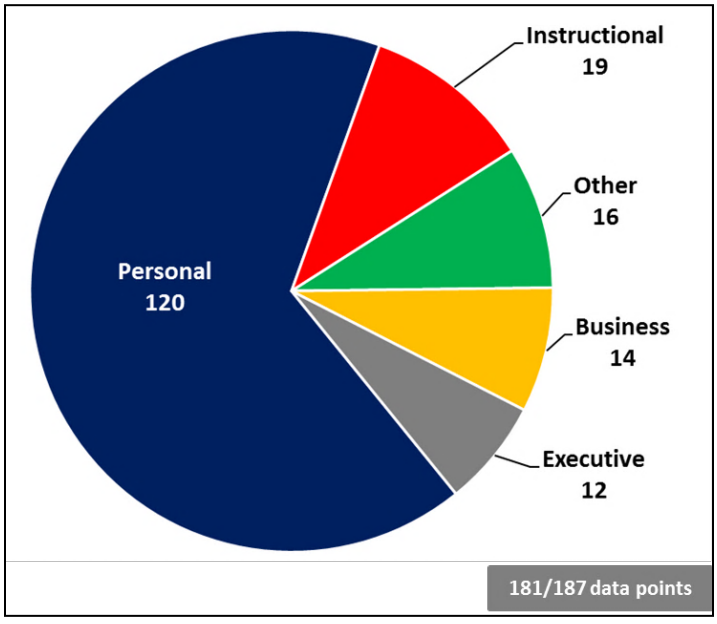


Figure 52. Types of GA operations involved in RI incidents

The database did not mention the type of operation for six GA flights. The "other" category describes operations such as "air taxi," "industrial/special," or "for hire." The finding that most of these flights were personal flights is similar to what was found from the analysis of the NTSB database. Here, the researchers came to the same conclusion that one of the reasons that GA flights

involved in RIs are more often personal flights and instructional flights is because these two types of flights account for almost half of all GA operations (Elias, 2009).

At least 190 pilots were involved in the 184 incidents. Figure 53 shows the number of pilots and their type of certification. The researchers could find the type of certification from the database for only 180 pilots. Almost 50% of these pilots were private pilots, and 18% were commercial pilots.

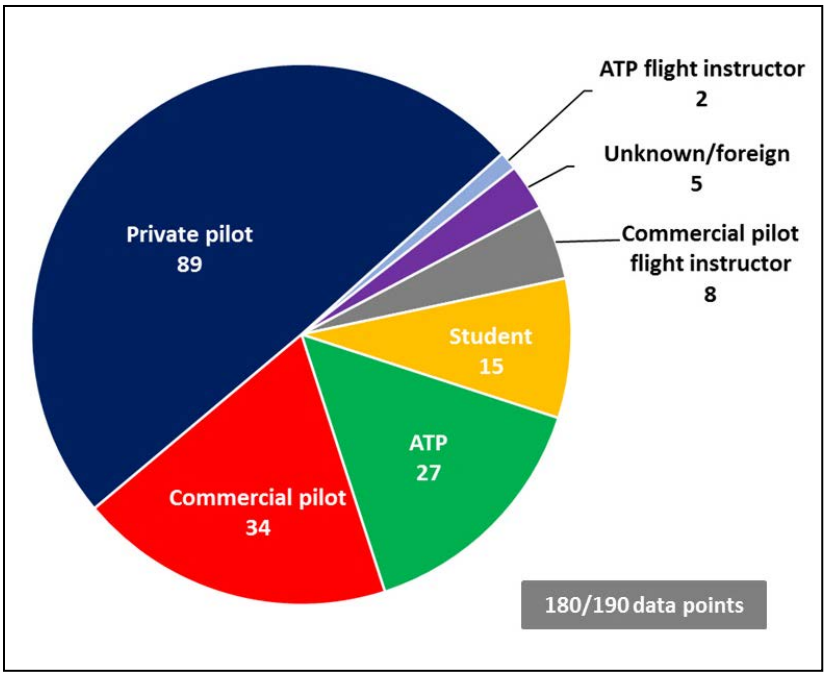


Figure 53. Pilots' type of certification

Figure 54 shows the total number of flight hours of the pilots involved in the RIs. These data are available for 151 pilots. Most of the pilots had less than 250 hours of experience. Because the graph is not skewed toward pilots with more or less experience, it was concluded that pilots of all experience levels need to be aware of the risk of an RI.

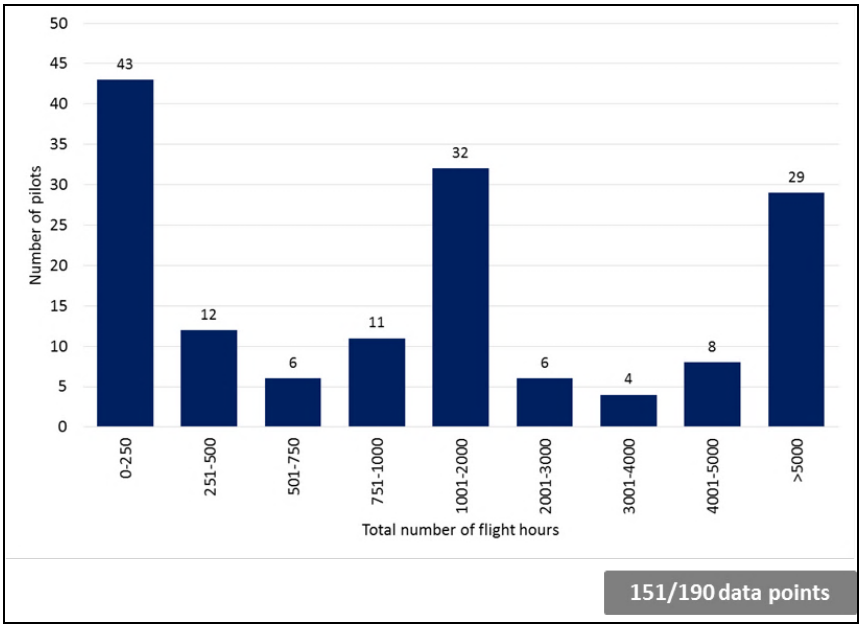


Figure 54. Pilot experience measured by total flight hours

6.2.4.2 Causes of RIs Based on AIDS Database

To analyze the causes of RIs in the database, the incidents are categorized into eight categories, depending on how the incursion occurred. Figure 55 shows the categories and the number of incidents in each category. In this section, each category and the present causes leading up to the incursion are discussed.

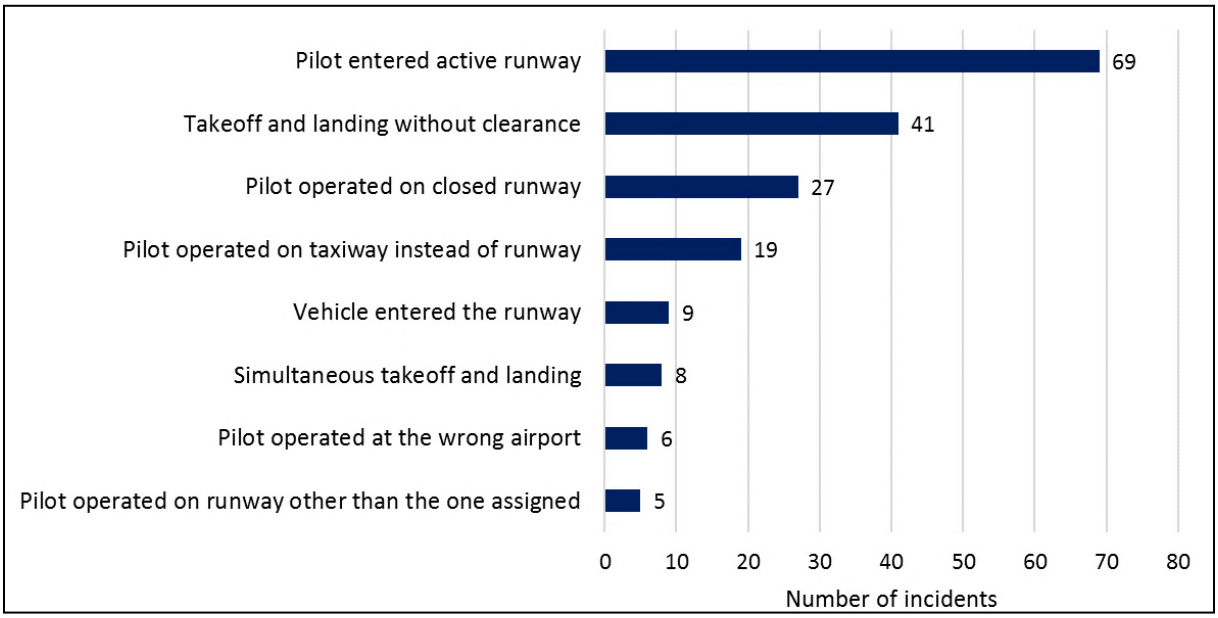


Figure 55. Causal categories for RI events in AIDS database

The researchers classified incursions that occurred because of the pilot crossing the hold-short line, entering a runway without clearance, or crossing the runway when the runway is occupied, in this category. The major reasons a for pilot entering the active runway are that the pilot failed to hold short of the runway as instructed by the air traffic controller or proceeded on to the runway without a clearance from the ATC. Figure 56 shows what error was and made and the number of incursions that resulted from those errors.

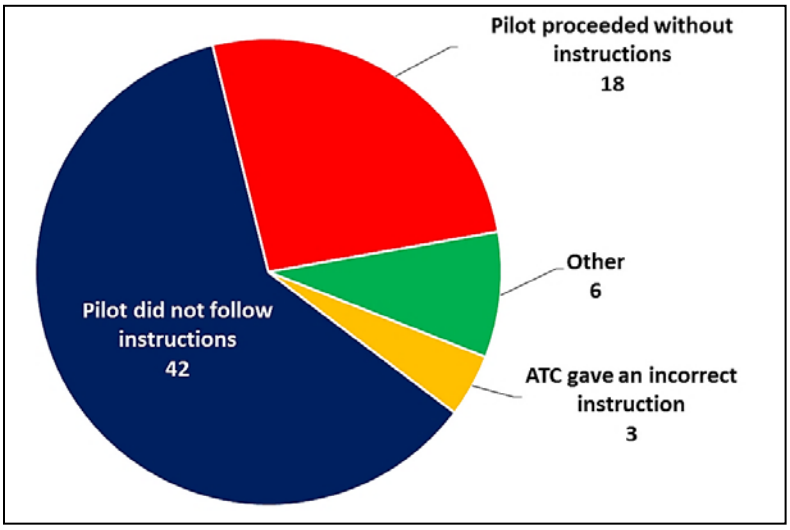


Figure 56. Types of errors leading to the pilot entering an active runway for RI events in AIDS database

The "other" categories include incidents in which it was unclear what error was made and who made the error. For example, one report (AIDS Report Number: 19800722062169I) states that the pilot crossed the active runway. It was not known if the pilot was instructed not to do so or was not given any instruction at all.

In some cases, the narratives provide additional information that helps explain why the pilot made the error. Figure 57 shows the reasons found in the reports, which may explain why the pilot made the errors that caused the incursion.

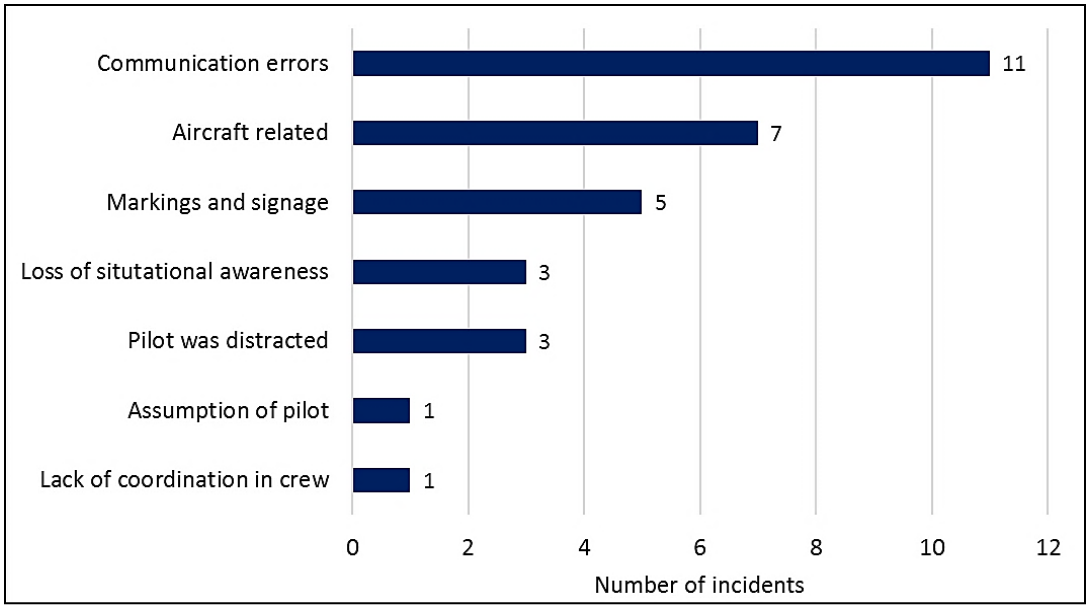


Figure 57. Reasons for pilot entering an active runway for RI events in AIDS database

Most often, the pilot entered onto an active runway because of communication factors. For example, in one incident (AIDS Report Number: 20000503020339I), the ATC asked the pilot to hold short of Runway 31L. The pilot read back "cross Runway 31L." The ATC failed to correct the wrong read back, and, subsequently, the pilot crossed the runway. Other incidents in which communication was a factor included pilot misunderstanding ATC instructions, not understanding ATC's phraseology, not listening to ATC instructions, pilot on the wrong frequency, or the ATC's instructions being confusing.

Aircraft-related issues often contributed to the incursion. Aircraft-related issues mostly include radio problems. For example, because of the radio malfunctioning, a pilot entered an active runway without clearance (AIDS Report Number: 19891121064209I, 19920403016519I). In one incident (AIDS Report Number: 19881014058319I), the pilot crossed the hold-short line because the brakes on the aircraft failed. In two cases (AIDS Report Number: 20091212052849I, 19900910056059I), the pilot was taxiing at high speeds and could not stop before entering the active runway.

Errors in marking and signage, such as hold-short lines being faded at the time of incursion or poorly marked intersections, also contributed to the pilot crossing the hold-short line when they were not supposed to.

Forty-one incidents were found in which the pilot took off from or landed on a runway without an air traffic controller's clearance. In five incidents, the pilot could not contact the tower because of problems with the radio and, therefore, landed without clearance. In one incident (AIDS Report Number: 19860327017459I), the pilot departed without ATC clearance because the pilot thought the tower was closed. In another incident (AIDS Report Number: 19960226029319I), the pilot of a Cherokee was instructed to hold in position on Runway 16. The pilot read back the instructions and was holding on Runway 16. The tower then stated, "Cherokee N29282 cleared to the Neil Armstrong airport via radar vectors, Findley, direct, maintain 4000": however, the tower did not

state the pilot was cleared for takeoff. The pilot thought he was cleared and took off from the airport.

In one incident (AIDS Report Number: 19990328021389I), the pilot was under the influence of alcohol and did not hold a current medical certificate. The pilot took off and landed at an airport without clearance, resulting in the revocation of that pilot's pilot certificate.

One of the incidents involved a collision between two aircraft (AIDS Report Number: 19810128003332I and 19810128003331I). One of the aircraft landed without clearance, and the ATC was cited for not handling the conflict between the two aircraft.

The third major reason for incursions was that the pilot operated on a closed runway. Incursions could be a result of a pilot taxiing, taking off from, or landing on a closed runway. Figure 58 shows the reasons why the pilot may have been on a closed runway.

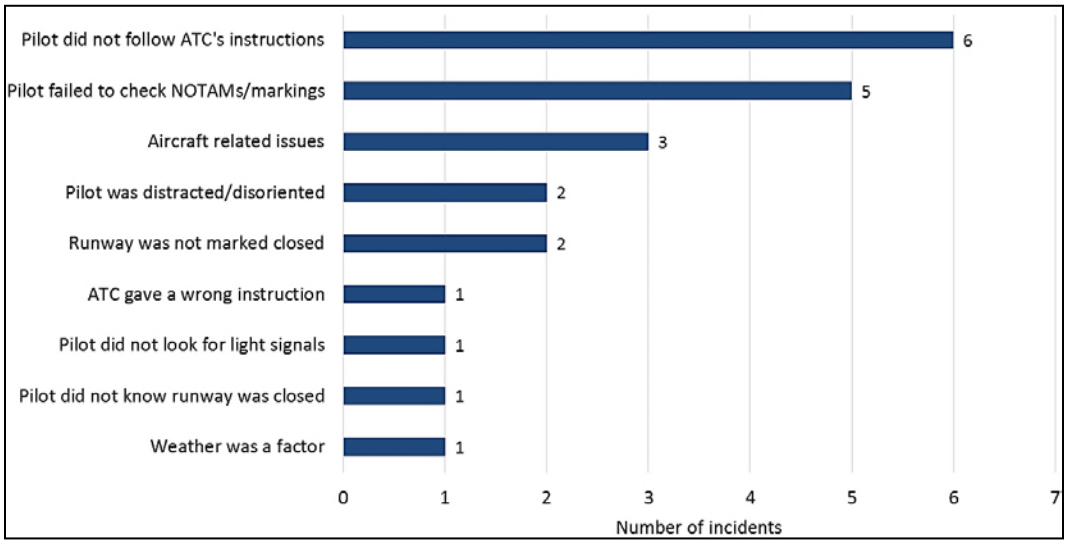


Figure 58. Reasons for pilot operating on a closed runway

The top reason for the pilot operating on a closed runway is that the pilot failed to follow the ATC's instructions. For example, in one incident (AIDS Report Number: 19960516022429I), the pilot was cleared to depart on Runway 23L, but the pilot took off from closed Runway 28 instead. Similarly, in another incident (AIDS Report Number: 19960811038319I), the pilot was cleared to take off from Runway 6R but departed on the closed portion of Runway 24L instead. The report further states that the instructions from the ATC were confusing and that the local controller should have been more situationally aware of what was happening. In another incident (AIDS Report Number: 20090327005609I), the ATC had cleared the aircraft to land on a closed runway.

Some other reasons for the pilot operating on a closed runway include the pilot failing to check NOTAMs, or failing to see the markings on the runway indicating that it was closed (AIDS Report Number: 19950719043409I, 19840128015369I).

Aircraft-related issues include failure of radios, which caused pilots to be unable to receive information about the closed runway (e.g., AIDS Report Number: 19810623051959I).

Figure 59 shows why a pilot operated on a taxiway instead of a runway. The top reason is the pilot not following ATC's instructions. For example, in one incident (AIDS Report Number: 19960905044189I), the pilot was cleared to take off on Runway 7, but took off from a taxiway. In another incident (AIDS Report Number: 19780223000869I), the pilot landed on a taxiway after being cleared to land on Runway 17.

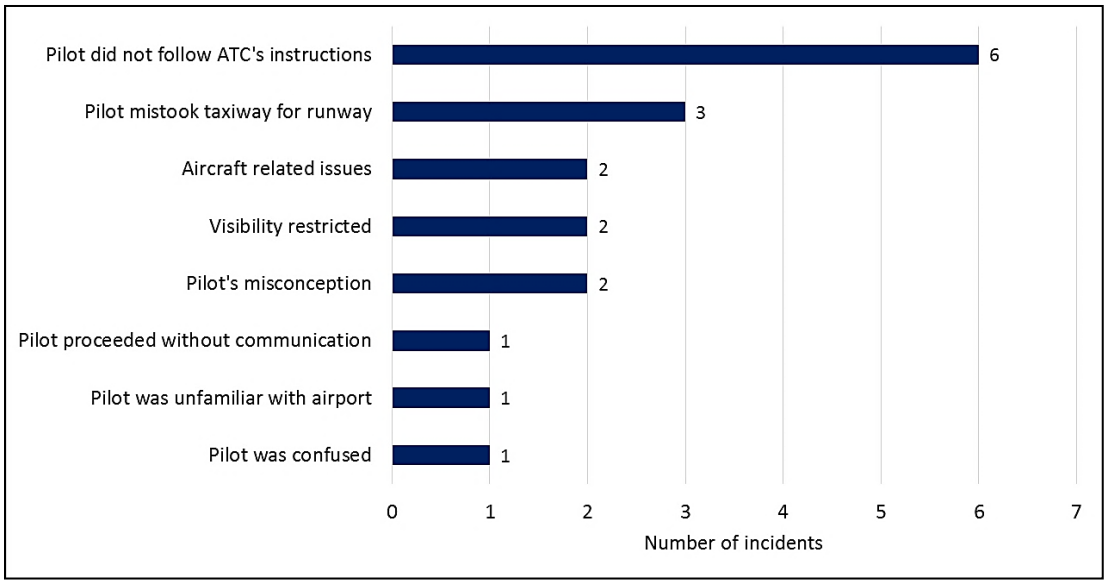


Figure 59. Reasons for pilot operating on a taxiway instead of a runway for AIDS database

In one incident (AIDS Report Number: 19800619055599I), the pilot mistook a taxiway for the assigned runway. The glare from the sun interfered with the pilot's vision.

Eight incidents involved a vehicle entering onto the runway, out of which six involved a conflict with an aircraft intending to land or take off from the runway. In the other two cases, the vehicle was on the runway without communication with the ATC. In one incursion (AIDS Report Number: 19950105002969I), the driver was detained, and in another (AIDS Report Number: 19931025050189I) the driver was arrested for entering the active runway. In one incident (AIDS Report Number: 19940109004599I), the incursion occurred because of the incorrect presence of a pedestrian on the runway, who was arrested by the airport security for being there.

In only two incident reports, there was a cause mentioned for a conflict between two aircraft taking off from or landing on the same or opposite runways. In one case (AIDS Report Number: 19920611026909I), the pilot had contacted the wrong airport (contacted Downtown Airport instead of International). The ATC at the downtown airport had cleared the pilot for takeoff. In another incident (AIDS Report Number: 20000920029839I), two aircraft were taking off from opposite runways. The flight service stations tried to advise the pilot of opposite traffic, but the pilot did not respond. The transmissions were also not very clear.

In three of the five incidents, the pilot landed at the wrong airport without communicating with the ATC. The reason for lack of communication was a loss of electrical power in the aircraft (AIDS Report Number: 19800929071729I) and loss of radios (AIDS Report Number: 19890819048319I).

In the other two cases, the reasons for the pilot landing at the wrong airport were that the pilot was distracted (AIDS Report Number: 19800912070349I), and the pilot received conflicting information from the ATC (AIDS Report Number: 19920807038009I).

Of the 6 incidents in which the pilot operated on a runway other than the one assigned, only two incident reports provide information to explain why the pilot did so. In one of the incidents, the report (AIDS Report Number: 19820120005259I) states that the pilot misunderstood the ATC instruction and taxied onto the wrong runway. In the other incident (AIDS Report Number: 19960106041059I), the pilot was cleared to take off from Runway 5L. The pilot had flown out of the airport several times, but this time he did not verify 5L as the departure runway. He taxied onto Runway 23R and began the takeoff roll. He assumed that the ATC would correct him if he was on the wrong path. However, the pilot had taken off by the time ATC realized the pilot's error.

6.2.5 Conclusion of AIDS and NTSB Database Analysis

From analyzing the RI accidents and incidents recorded in the two databases, it was found that RIs more often involve GA aircraft. The reason behind more involvement of GA aircraft could be the high number of GA operations in general.

From the analysis of the NTSB database, it was found that the most common error that pilots make is not monitoring other aircraft or the environment. From the data on light and sky conditions, most of these incursions occurred in daylight and clear weather. Therefore, reduced visibility or adverse environmental conditions are seldom the cause of the pilot not maintaining a visual lookout. The AIDS database also points out that RIs mostly occur in clear weather and during the day. One of the reasons could be the higher number of operations given the favorable conditions. The data on pilot experience from the AIDS database suggest that pilots with various certification and different levels of experience are involved in RIs; therefore, every pilot must be careful during ground operations.

Analysis of the AIDS database shows that the most common reason for an RI is pilots crossing the hold-short line when they are not supposed to. Whereas the top reason for a pilot doing so is human error, other factors, such as radio problems and marking and signage problems, should not be neglected when developing mitigation strategies.

The most common controller error was clearing an aircraft to land on or take off from an occupied runway. However, reports suggest that the controller alone cannot be blamed for these errors because there are other factors, such as insufficient training or inadequate procedures, that often led to the controller error.

Although an RI is often classified as OE (operational error), PD (pilot deviation), or VPD (vehicle driver/pedestrian deviation), it is important to note that there are factors, such as environmental and organizational issues, which affect human performance. Therefore, it is important not to ignore these contributing factors when developing prevention strategies.

In this section on NTSB and AIDS data, the researchers focused only on incursions that occurred at towered airports. It is worth noting that 68% of the incursions recorded in the NTSB database that involved at least one GA aircraft occurred at non-towered airports. However, from the AIDS database, it was found that 66% of the RIs that involved at least one GA aircraft occurred at

towered airports. One of the reasons for the higher number of incursions at towered airports could be the higher frequency of reporting than at non-towered airport. However, there are many more incursions that occur at both towered and non-towered airports but that may not be reported. One reason could be that neither the controllers nor the pilots realize that an RI has occurred.

6.3 REVIEW OF FAA RUNWAY SAFETY (RSW) DATABASE FOR GA RIs

6.3.1 Methodology

The Runway Safety Office RWS database was developed as a part of the ASIAS system to facilitate the exchange of safety information between users. The RWS database is available to analyze data for patterns, causal factors, and influencing factors in RIs (FAA, 2017b).

To accomplish this, a current, complete export of the RWS data with all available fields included was obtained directly from the Office of Accident Investigation and Prevention (AVP-210) Runway Safety Office , not through the online search web site. This file was converted to Excel for creating the data set to analyze. The database included 20,199 reports from October 1, 2001 to April 29, 2017.

The metadata of Runway Safety System Database consists of 178 parameters, with 22 considered as the variables of interest for the quantitative analysis. The variables of interest include:

EVENT DATE

FAA INCIDENT TYPE CODE

RI CATEGORY RANKING

EVENT AIRPORT ID

AIRCRAFT 1 CATEGORY

AIRCRAFT 2 CATEGORY

AIRCRAFT 1 FLIGHT CONDUCT CODE

AIRCRAFT 2 FLIGHT CONDUCT CODE

STDNT PLT INVLD FLAG

HLD SHRT INTRCTN FLAG

HLD SHRT RDBCK FLAG

HLD SHRT CRSD DESC

RWY ENTERED DESC

RWY TWY CRSD DESC

TIPH DESC

TIPH TWOC FLG

FLIGHT PHASE DESC

EVENT TKOF LNDG DESC

LAHSO FLAG

ARPT AMASS FLAG

WO CLRNC FLAG

CLSD RWY TWY FLAG

EVENT ID

A specific dataset was created to analyze PDs committed by GA pilots. For purposes of this RWS analysis, GA pilot is defined as the pilot of an aircraft coded as 14 CFR 91 for either AIRCRAFT 1 FLIGHT CONDUCT CODE or AIRCRAFT 2 FLIGHT CONDUCT CODE in Runway Safety Database. Military operations are not coded as 14 CFR 91 in the RWS database. Figure 60 shows the methodology for creating the dataset used for analysis, ultimately resulting in the GA-Pilot Deviation Runway Incursion Data Set.

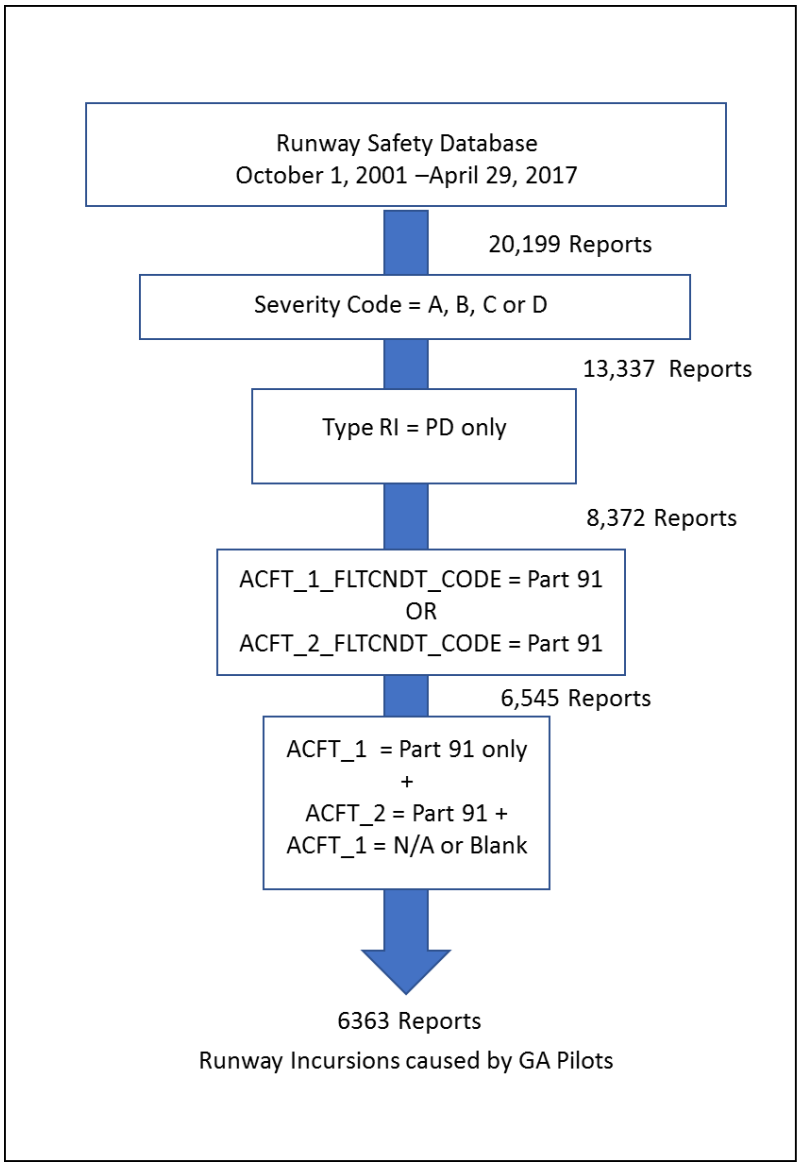


Figure 60. Methodology for creating RWS GA PD dataset, including the number of reports in dataset

The first step in creating the RWS GA Pilot Deviation Data Set was to delete events that were not RIs. The RWS data include events that occur on the airport that are not RIs. There is a code RUNWAY INCURSION FLAG that is set to YES for most of the events that meet the definition of an RI; however, this field was blank in 1509 of the reports that included an RI Severity Code and met the definition of an RI. Therefore, the database was sorted using the RI CATEGORY RANKINGS A, B, C, or D associated with RIs to create the dataset limited to RIs. This resulted in 13,337 records, including all types of RIs conducted under all flight operations.

At this level, the dataset included events that were committed by pilots and controllers, vehicles, or pedestrians. Step two removed deviations committed by controllers, vehicles, or pedestrians

using the code FAA INCIDENT TYPE CODE of PD for pilot deviation. This resulted in 8372 records, all of which were RIs committed by pilots.

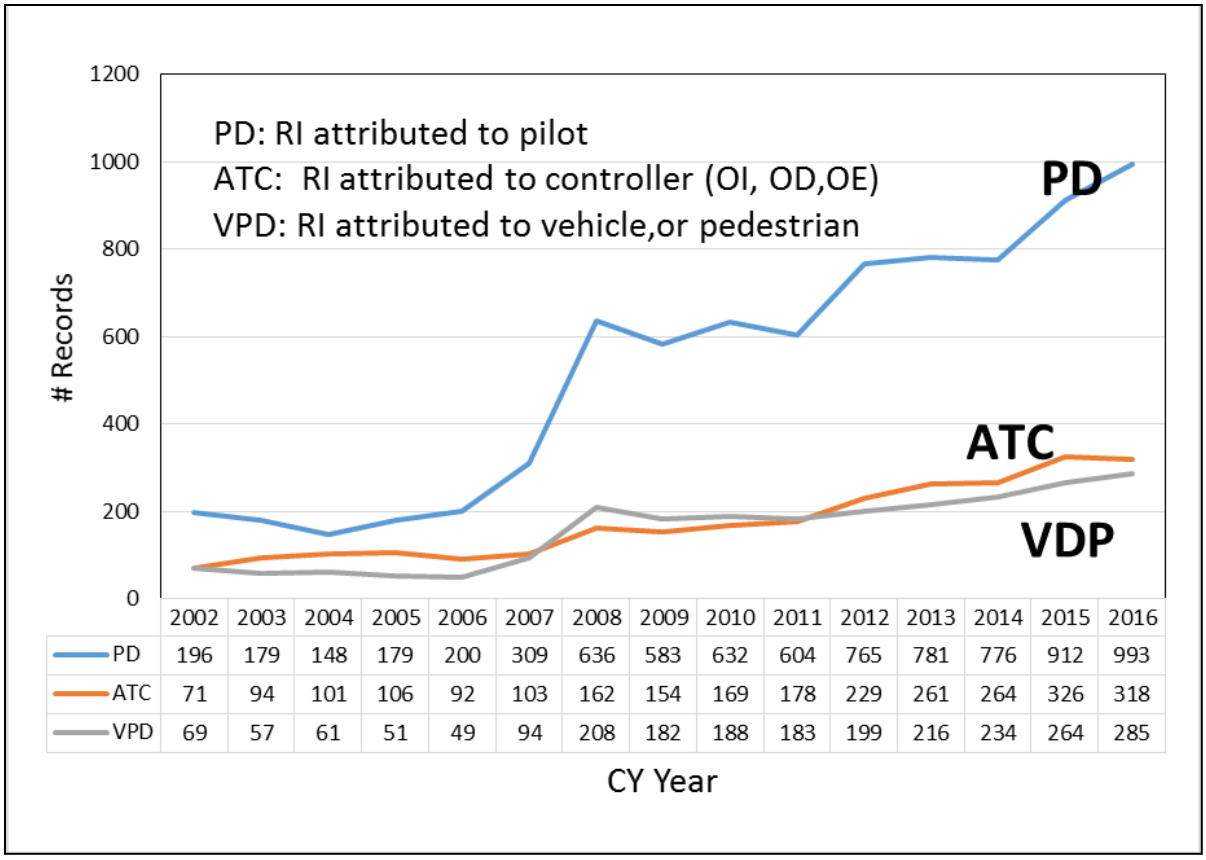
Step three selected only records for which the Aircraft 1 Flight Conduct Code or Aircraft 2 Flight Conduct was set at 91. This is so 14 CFR 91 aircraft, or as defined here, GA pilots, are included in every event in the dataset. This resulted in 6545 records, all of which were RIs caused by a PF with at least one GA pilot involved.

Whereas the 6545 RI records all included a PD and a GA pilot, it is possible the GA pilot was the innocent victim of an RI by a 14 CFR 121 pilot or other non-GA pilot. When a record includes two aircraft, the aircraft committing the deviation is listed as Aircraft 1. When only one aircraft is involved, the information on the aircraft may be coded as either Aircraft 1 or Aircraft 2. To capture all the PDs caused by GA pilots and eliminate those caused by 14 CFR 121 or other non-GA pilots, the final sort was limited to records with AIRCRAFT 1 FLIGHT CONDUCT CODE of 91 and the combination of AIRCRAFT 2 FLIGHT CONDUCT CODE of 91 whereas AIRCRAFT 1 FLIGHT CONDUCT CODE was N/A or blank. The result was the RWS GA-Pilot Deviation Runway Incursion Data Set with 6363 records.

The RWS database entry is a report. One event can generate multiple reports when there are multiple causes or multiple aircraft involved in a situation. For example, in one event, a small aircraft was disabled, and ATC incorrectly believed the aircraft was clear of the Runway Safety Area. Six aircraft landed before ATC became aware that the aircraft was not completely clear, resulting in six separate RI reports in the RWS database. The multiple reports are an overstatement in the number of events by less than 1%. Therefore, the dependent variable in this analysis is the number of records.

6.3.2 Results of RWS Database Review

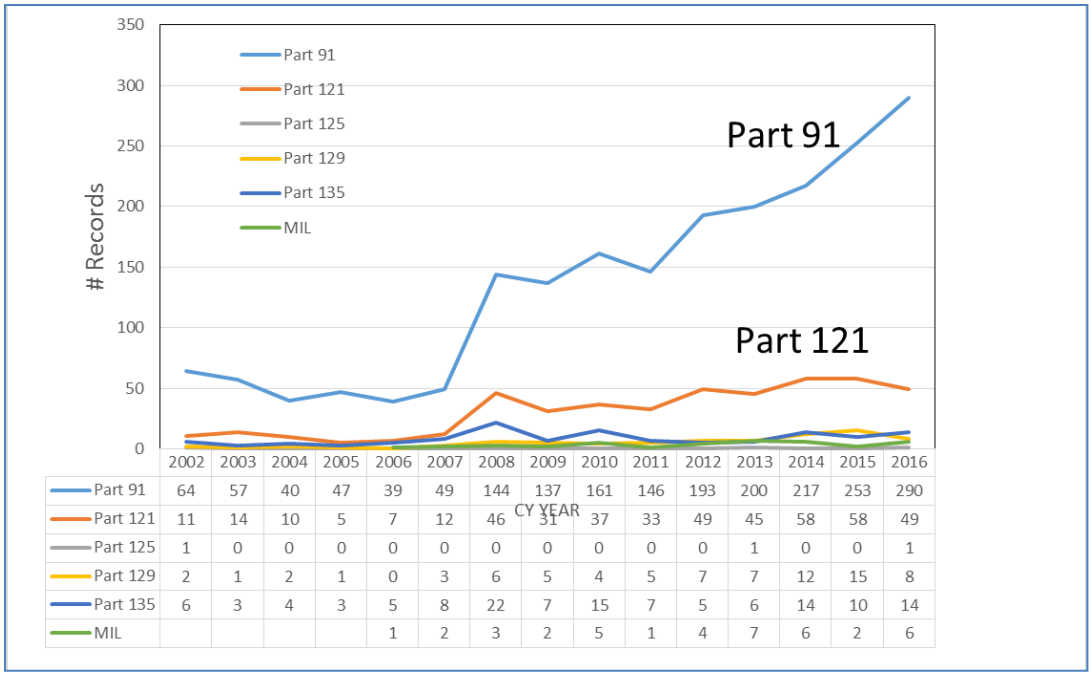
Figure 61 shows the annual change in the number of RIs at towered airports caused by any type pilot, controller, vehicle, or pedestrian. Note that the number of RIs has been increasing each year, and those attributed to PDs are increasing at a faster rate than others attributed to ATC or VPD.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
PD	196	179	148	179	200	309	636	583	632	604	765	781	776	912	993
ATC	71	94	101	106	92	103	162	154	169	178	229	261	264	326	318
VPD	69	57	61	51	49	94	208	182	188	183	199	216	234	264	285

Figure 61. RIs at towered airports by FAA incident type code and CY year (note: FAA RWS database; severity code = A, B, C, or D; *n* = 13,336; ATC = OI+OD+OE; *n* = 13,337)

Figure 62 focuses on the PDs and what regulation the pilot causing the error was operating under at the time of the incursion. The figure shows RI for severity codes A, B, and C only. Severity Code D is not included in this graph because it overshadows the more dangerous incursions. Note that the 14 CFR 121 incursions have increased slightly since 2009, whereas the 14 CFR 91 incursions have almost doubled.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Part 91	64	57	40	47	39	49	144	137	161	146	193	200	217	253	290
Part 121	11	14	10	5	7	12	46	31	37	33	49	45	58	58	49
Part 125	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Part 129	2	1	2	1	0	3	6	5	4	5	7	7	12	15	8
Part 135	6	3	4	3	5	8	22	7	15	7	5	6	14	10	14
MIL					1	2	3	2	5	1	4	7	6	2	6

Figure 62. RIs at towered airports by AIRCRAFT 1 FLIGHT CONDUCT CODE and CY year (note: FAA RWS database; severity code = A, B, C only; *n* = 8372)

Focusing on the 14 CFR 91, GA pilots, and RIs attributed to the GA pilots, figure 63 shows GA-PDs for the most severe category A and category B ranking whereas figure 64 shows the same GA-PDs for category C and D. Since 2009, the number of A and B events has remained very small. However, category C and D events have increased substantially.

14 CFR 91 operations is a very large and diverse mix of aircraft. Table 17 shows the most common aircraft categories involved in GA-PD RIs, as defined by AIRCRAFT 1 CATEGORY. Although small single-engine piston aircraft represent 73% of the total GA-PD RIs, they accounted for 79% of the Category B incursions. Similarly, small twin-engine jets represent just 2% of the total GA-PD RIs; they accounted for 5% of the Category A incursions.

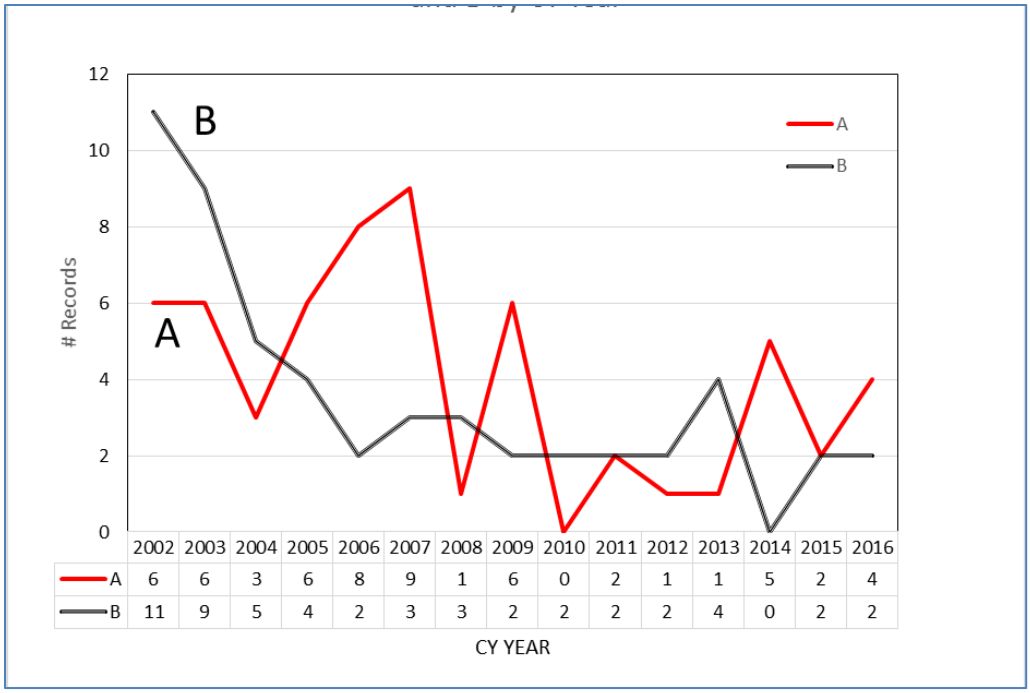


Figure 63. GA-PD RIs at towered airports by CY year for severity code A, B (note: RWS GA PD data set; *n* = 6363)

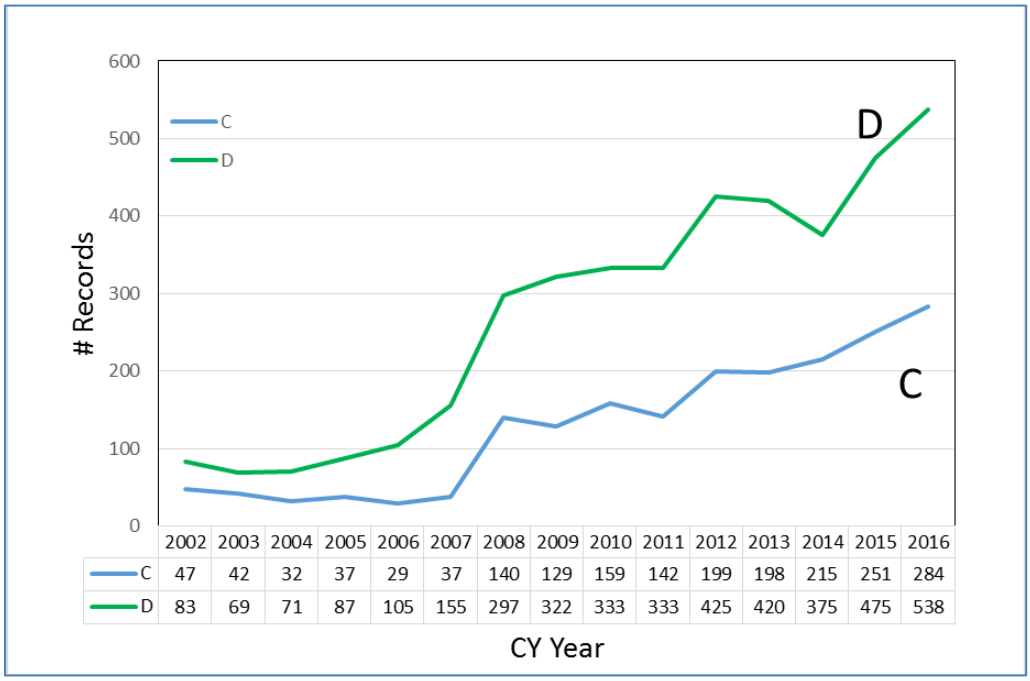


Figure 64. GA-PDRIs at towered airports by severity code C, D, and CY year (note: RWS GA PD data set; *n* = 6363)

Table 17. GA-PD RIs at towered airports by aircraft 1 runway safety category (note: RWS GA PD data set; *n* = 6363)

	Severity Code				Total	
	A	B	C	D	Count	%
Single-Engine Piston, Small	43	44	1455	3122	4664	73%
Twin-Engine Piston, Small	5	7	162	389	563	9%
Twin-Engine Jet, Small +	3	3	146	242	394	6%
Single-Engine Turbine, Small	2	1	55	131	189	3%
Twin-Engine Turbine, Small	1	1	40	115	157	2%
Twin-Engine Turbine, Small +	2	0	49	88	139	2%
Twin-Engine Jet, Small	3	0	31	66	100	2%
Twin-Engine Jet, Large	0	0	39	33	72	1%
Other	1	0	12	35	47	1%
Total	60	56	2002	4245	6363	100%

Figure 65 shows the top 10 airports for GA-PD RIs for the entire time period. The airports are:

1. VGT North Las Vegas
2. DVT Phoenix Deer Valley
3. FFZ Falcon Field Airport
4. FXE Fort Lauderdale Executive
5. CNO Chino
6. TUS Tucson International
7. PRC Ernest A Love Field (Prescott)
8. APA Centennial
9. PDK Peachtree DeKalb
10. DAB Daytona Beach International

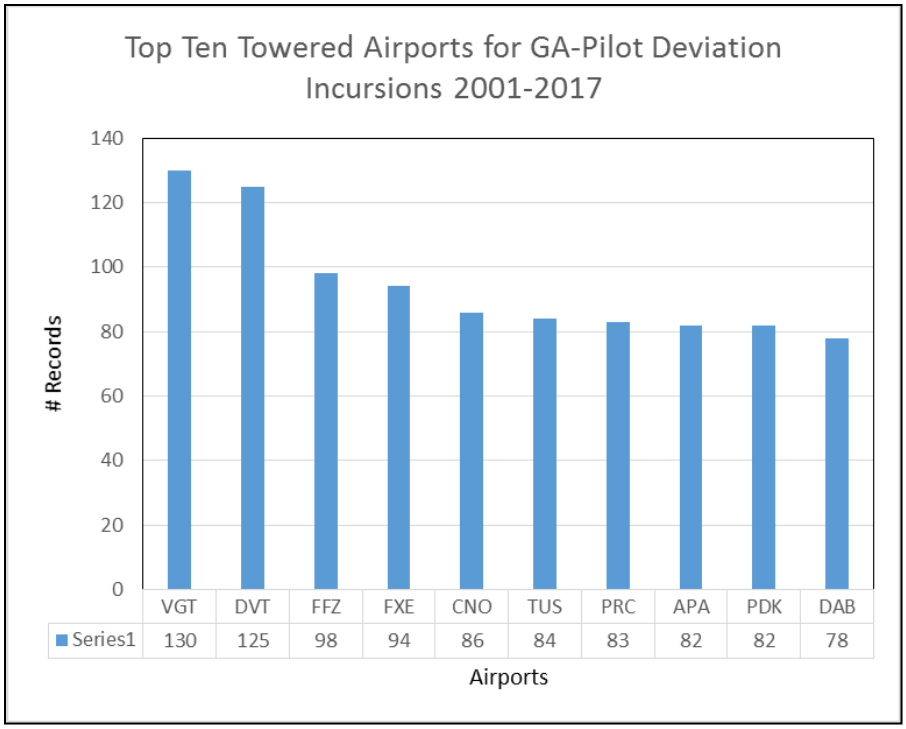


Figure 65. Top 10 towered airports for GA-PD RIs (note: RWS GA PD dataset; *n* = 6363)

Falcon Field, Mesa, AZ and Deer Valley Airport, Phoenix, AZ are reliever airports for Phoenix Sky Harbor International Airport. In addition, CAE Oxford Aviation Academy is located on Falcon Field, as are helicopter training and a mix of other operations. There are also two large flight schools at Deer Valley Airport. Daytona Beach and Love Field in Prescott, AZ are home to Embry Riddle Aeronautical University flight training programs. Fort Lauderdale Executive, Centennial, and Peachtree DeKalb are reliever airports in large metropolitan areas with a mix of operations (SkyVector, 2017).

All airports in the top 10 are busy GA airports except for Tucson and Daytona Beach. Tucson is fairly evenly divided between commercial, military, and GA operations, whereas Daytona is primarily GA operations. All airports in the top 10 have a three-runway configuration, except Deer Valley and Falcon Field, which have two parallel runways (SkyVector, 2017).

Analysis of the data for the top 10 airports by year shows small discernable differences between the airports. Table 18 shows the data for each year. For example, it can be seen that the events at North Las Vegas airport peaked in 2012 and have been decreasing, whereas events at Chino Airport started rising in 2012 and reached their highest in 2016.

The ASRS includes reports from individuals (pilots, air traffic controllers, and airport employees) who have either participated or witnessed an aviation event. These events may occur at any phase of flight, including taxi. Event information available for analysis from ASRS is de-identified so that the date is not available, and in most cases, neither is the name of the airport. This makes it impossible to cross reference the events in the RWS database.

Table 18. Annual RIs at top 10 towered airports for GA-PD RIs (note: RWS GA PD data set; *n* = 6363)

Year	Airports									
	VGT	DVT	FFZ	FXE	CNO	TUS	PRC	APA	PDK	DAB
2002	5	1	0	4	0	1	1	3	1	0
2003	2	3	0	7	4	0	2	1	1	0
2004	1	0	0	0	2	1	1	0	2	1
2005	5	4	1	2	0	0	3	0	5	0
2006	9	2	1	4	0	2	2	2	5	3
2007	13	0	8	1	0	1	2	1	5	5
2008	9	7	11	9	0	8	4	4	4	7
2009	6	13	1	5	3	15	12	5	11	7
2010	4	14	4	10	2	7	4	5	6	3
2011	18	11	6	7	4	5	5	16	5	10
2012	19	16	10	3	11	11	8	2	1	7
2013	13	11	14	9	10	6	5	5	6	10
2014	8	9	12	7	6	8	8	9	10	8
2015	3	19	7	10	14	2	12	17	11	7
2016	8	12	21	10	23	13	9	11	7	8
Total	130	125	98	94	86	84	83	82	82	78

6.4 REVIEW OF ASRS FOR GA RIs

To review RI events in the ASRS database, a separate dataset was created of ASRS reports of RIs involving an aircraft operating under 14 CFR 91 at towered airports (ASRS, 2017).

6.4.1 Methodology for ASRS Database Review

The ASRS search includes different searchable database fields, one of which is Events Type. Figure 66 shows the methodology for searching and sorting ASRS reports for GA RIs at towered airports. The top-level search of categories and criteria is shown in figure 67. It was found that for events that match the FAA definition of an RI, the Event Type field can be coded differently between events. Only a fraction of the reports that meet the definition of RI are actually coded as Ground Incursion: Runway. Therefore, it was necessary to review many events that were not identified as RIs to pick out those events that are actual RIs.

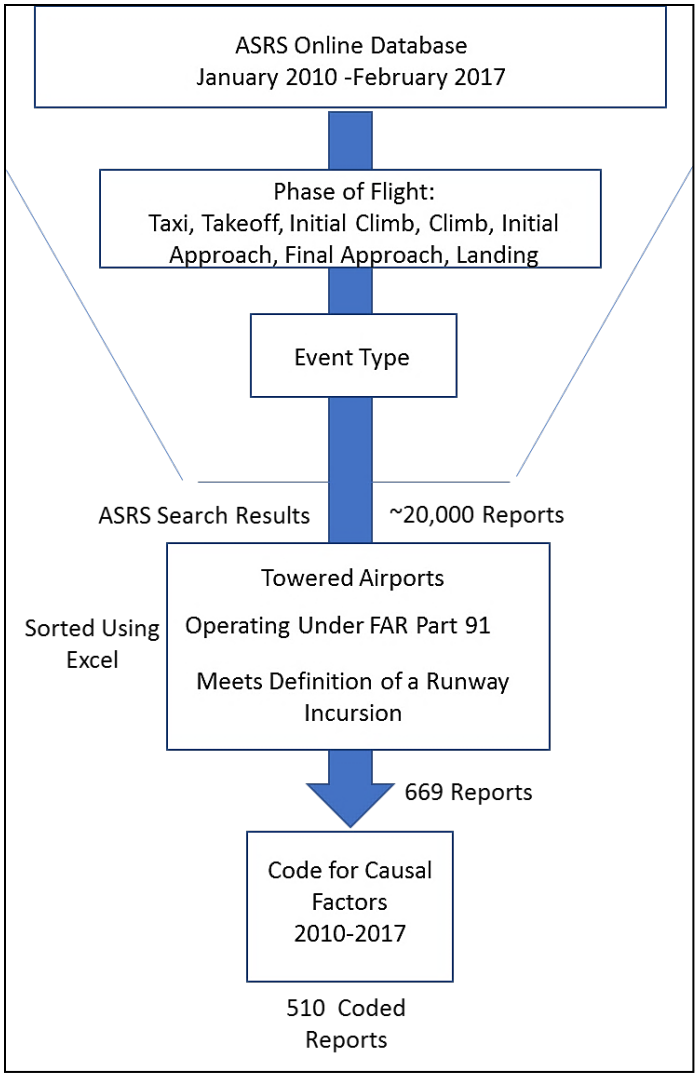


Figure 66. Methodology for searching and sorting ASRS reports for GA RIs at towered airports

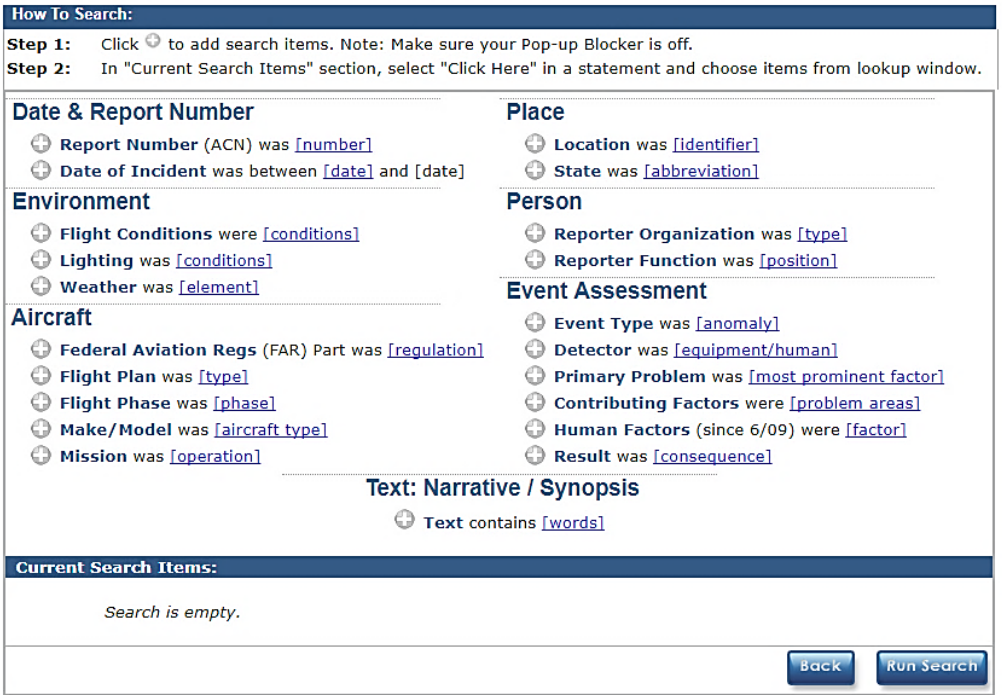


Figure 67. Top-level ASRS search engine (ASRS, 2017)

After discovering that RIs could be coded under many different event types, it was necessary to review many ASRS reports to try to obtain all pertinent data. Using the Event Anomalies and Values shown in table 19, the ASRS database was searched for reports of events occurring from January 2008 through February 2017. The results were approximately 20,000 reports, which were downloaded for further sorting and analysis.

Table 19. Event type and anomalies used to search ASRS database

Anomalies	Values Used
Ground Incursion Runway Taxiway Airspace Violation ATC Issue Conflict Ground Conflict— Critical and Less Severe Deviation—Procedural Clearance FAR Landing Without Clearance Maintenance Other/Unknown	Flight Deck/Cabin/Aircraft Event Other/Unknown Ground Event/Encounter Aircraft Ground Strike—Aircraft Object Other/Unknown Person/Animal/Bird Vehicle Aircraft Equipment Problem Critical Less Severe

The downloaded reports were then searched to remove all events taking place at non-towered airports and most airborne events to leave only the events that occurred at towered airports. Similarly, the remaining reports were again searched, using the keywords "Part 121," and "Part 135," to remove events that did not involve at least one GA aircraft RI. Finally, the synopsis section of each report was reviewed specifically for an event that resembled an RI. If the synopsis was not consistent with an RI, the event was removed from the data set.

The result of this search was a dataset of 510 reports of RIs at towered airports involving at least one aircraft operating under 14 CFR 91. The reports from January 2010 through February 2017 were then coded for causal factors using the same Google Docs form created to collect information on RIs for the GA pilot questionnaire discussed in section 3 of this report. There are 510 reports coded using the Google Docs analysis form.

6.4.2 Results of ASRS Database Review

As shown in figure 68, in 2013 and 2014, the reports of GA RIs at towered airports were noticeably lower than in the years immediately before or after. More analysis may be needed to determine why this is the case. The data in 2017 are through February 2017, not for the entire year.

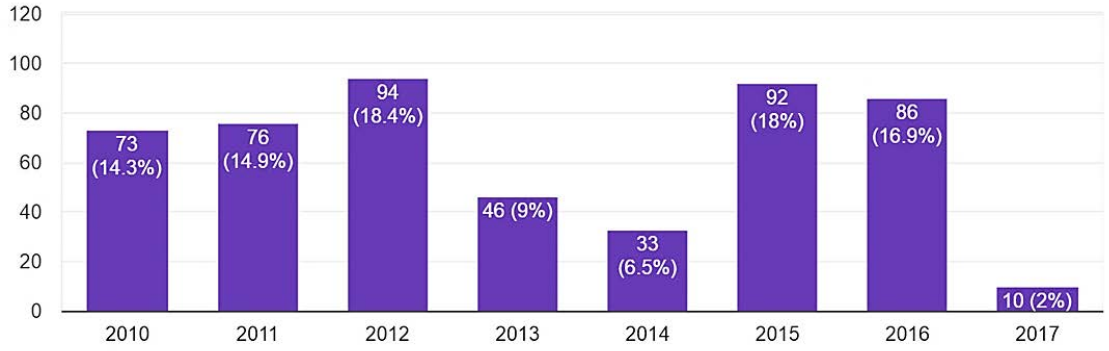


Figure 68. Number of ASRS reports for GA RIs at towered airports by year

6.4.2.1 Certificates of Pilots for ASRS Reports for GA RIs

The ASRS database allows for the reporter to provide the pilot's certificate for each pilot involved. The field "Person 1" may be the pilot of the aircraft that committed the RI, a pilot in another aircraft that witnessed an RI, or, if the category is unknown, it is likely that ATC reported the incident. In figure 69, there is an almost even distribution between, private, commercial, and air transport pilots.

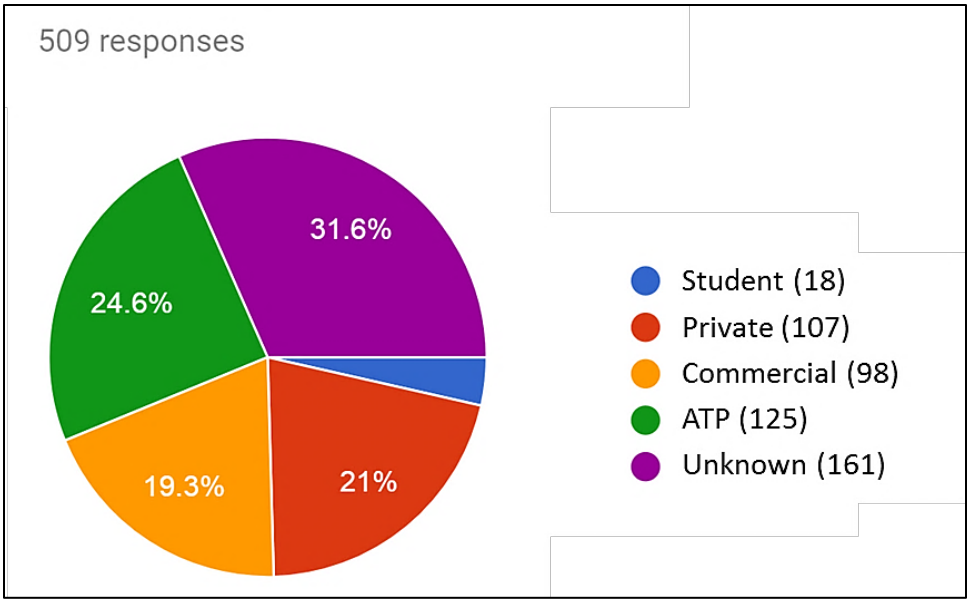


Figure 69. Pilot certificates for ASRS reports for GA RIs at towered airports 2010–February 2017

6.4.2.2 Severity Category Ranking for ASRS Reports for GA RIs

The severity-category-based information was taken from actual coded data in the report or from the narratives included in the report; the reviewer assigned and coded a Runway Incursion Severity Rating of A, B, C, or D for each report. The information coded into the ASRS report included the severity rating according to the reviewer.

The data from the ASRS reports show there were 20 A, 120 B, 100 C, and 269 level D RIs reported from January 2010 through February 2017 (see figure 37). It is interesting to note that this distribution of severity has a higher percentage of B events and a lower percentage of C events compared to the distribution in the RWS database, as shown in figure 70.

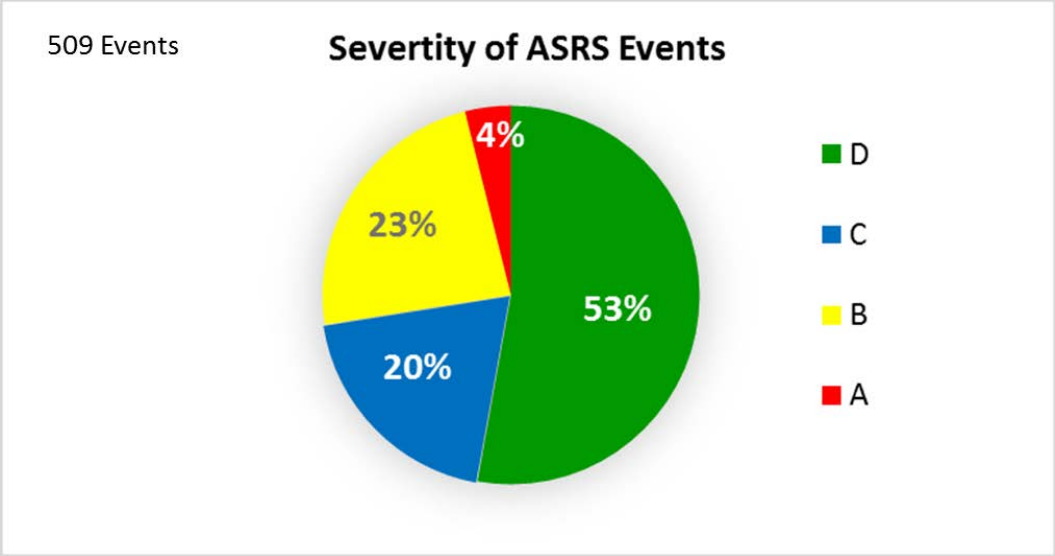


Figure 70. Severity category rankings for ASRS reports for GA RIs at towered airports as coded on researcher, 2010–February 2017

6.4.2.3 Incident Type Code

The action that precipitated the RIs reported are shown in figure 71. Those actions that could be chosen are Action by the Pilot or Crew, Action by Air Traffic Controller, Action by Vehicle or Pedestrian, Unknown, and Other.

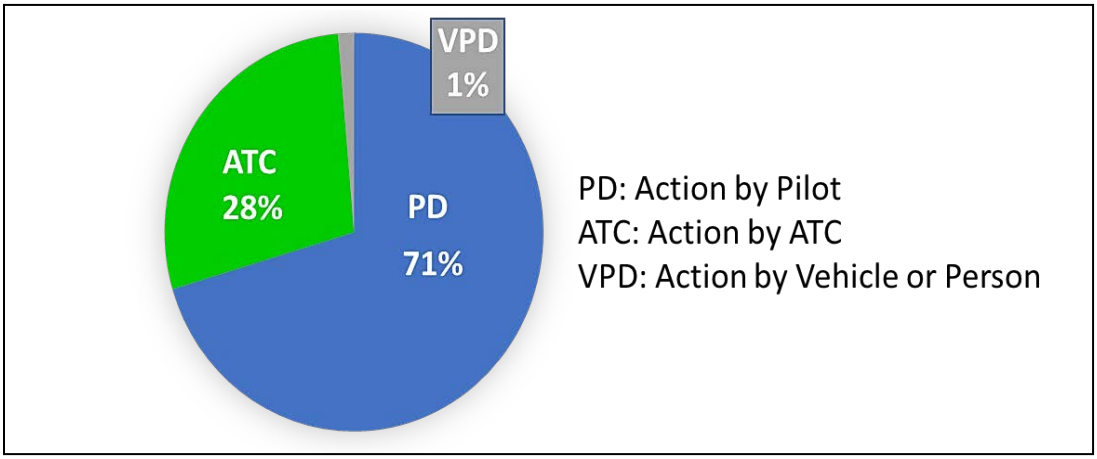


Figure 71. Action that precipitated the RI operation for ASRS reports for GA RIs at towered airports 2010–February 2017

6.4.2.4 Aircraft Involved in RI

The aircraft coded in the ASRS reports as Aircraft 1 or the aircraft listed first in the ASRS report may or may not be the aircraft that committed the RI. If the person submitting the ASRS reporter was the pilot, then Aircraft 1 was the aircraft she/he was piloting. If the reporter was ATC, then the aircraft was likely the aircraft that committed the incursion. Of the aircraft types shown in

figure 72, there were 288 light single-engine, 36 high-performance single-engine, 29 light twin-engine, 17 large piston or turboprop (e.g., King Air), 107 corporate jet, eight helicopters, three military, and two military transport aircraft.

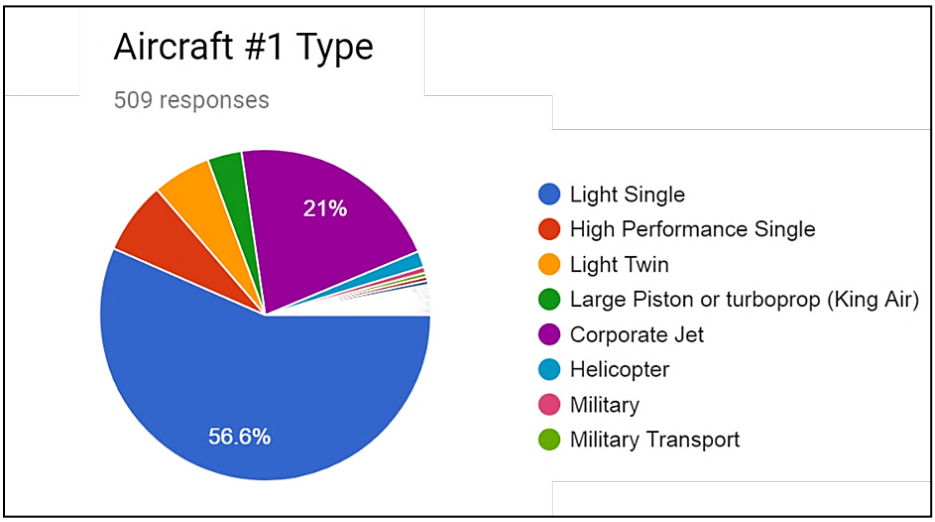


Figure 72. Type of aircraft coded as Aircraft 1 for ASRS reports for GA RIs at towered airports 2010–February 2017

Note: Military aircraft appear because data field Aircraft 1 may be different than the aircraft involved in the incursion.

6.4.2.5 Aircraft Operator and Mission

Each aircraft in the ASRS report is coded for the Aircraft Operator and the Mission. To put the ASRS data in the same format as the GA pilot questionnaire data, this information was taken together to determine a Type of Operation (see figure 73). Most of the "Unknown" category events are because the reporter was either an air traffic controller or was not aware of the operation type.

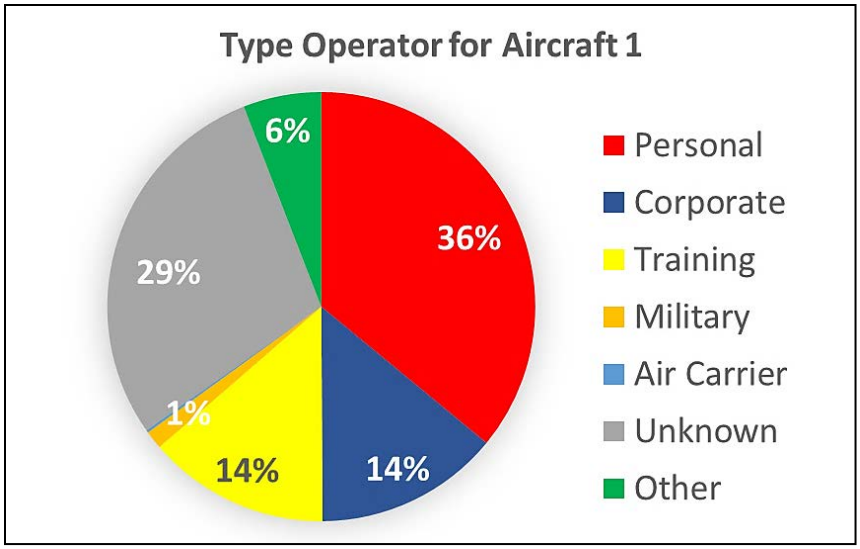


Figure 73. Type of operation for ASRS reports for GA RIs at towered airports 2010–February 2017

6.4.2.6 Phase of Flight

Figure 74 shows the flight phase where the RI occurred. The RIs that were reported had 117 while taking off, 30 during final approach, 121 after landing while on the runway, 166 while taxiing for takeoff, and 65 while taxiing after landing.

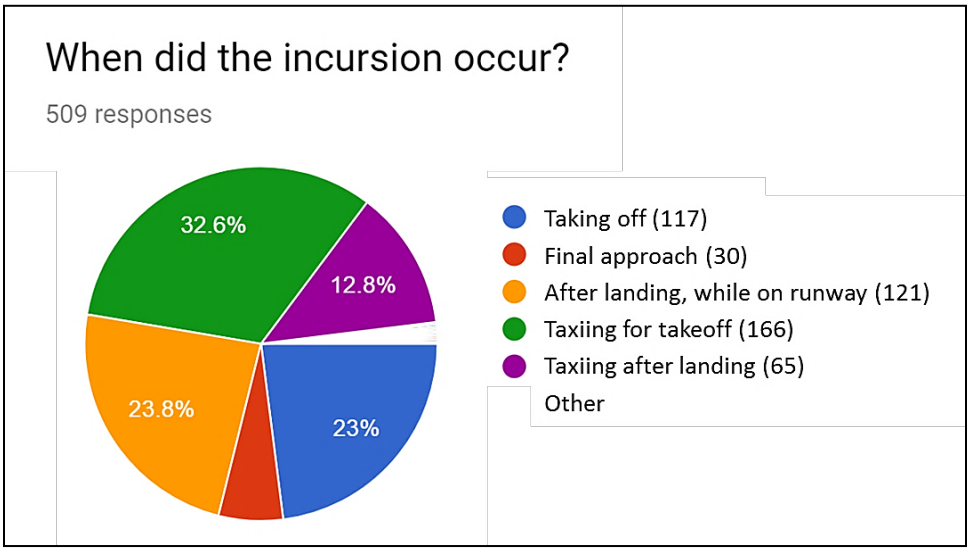


Figure 74. Flight phase of RI operation for ASRS reports for GA RIs at towered airports 2010–February 2017

For those events that occurred in the taxi phase, more specific data were coded. Figure 75 shows 58% of taxi-phase incidents were at the hold-position line waiting for takeoff.

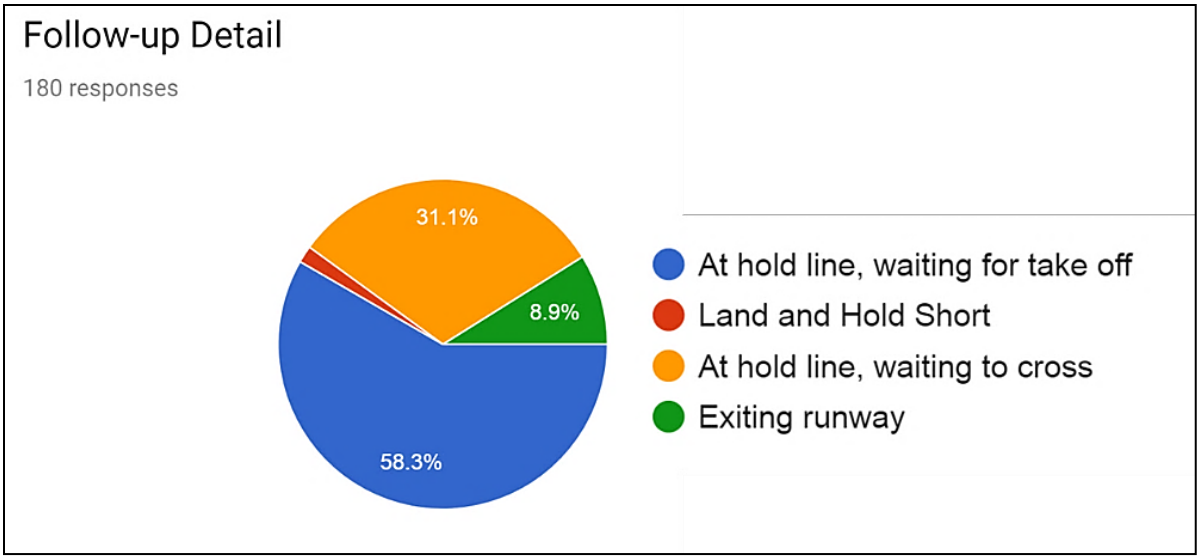


Figure 75. Additional detail on phase of flight information for ASRS reports for GA RIs at towered airports, 2010–February 2017

6.4.2.7 Causal Factors

To determine the causal factors in the RI event, each analysis of each ASRS report was analyzed by a subject matter expert with more than 30 years' experience as a GA pilot and a career in the aviation industry. Based on the narratives in the incident reports, the data were coded for causal factors using the same Google Docs form as the GA pilot questionnaire. Because the coding form allowed any causal subfactors that applied to be checked, it is very likely that when a pilot acted without clearance, she/he was also distracted.

Figure 76 shows the top communications factors that contributed to the RI events found in the ASRS. The top communication cause was Readback correct/Execute differently. This occurred in 108 of the events, which represents 21% of the total reports analyzed for this review. Those communications errors or issues coded as "Other" refer to many different problems that did not warrant their own category.

Figure 77 shows the top human performance factors that contributed to the RI events found in the ASRS. Human performance certainly is a factor in most RIs. Based on the narratives in the incident reports, the majority of human-performance issues was due to ATC error, the pilot was distracted, or the pilot acted without clearance. Because the Google Docs form allowed any subfactors that applied, it is very likely that when a pilot acted without clearance, she/he was also distracted. There was no listing for ATC being distracted, but many of the ATC errors were due to workload issues and distractions based on the narrative comments in the report.

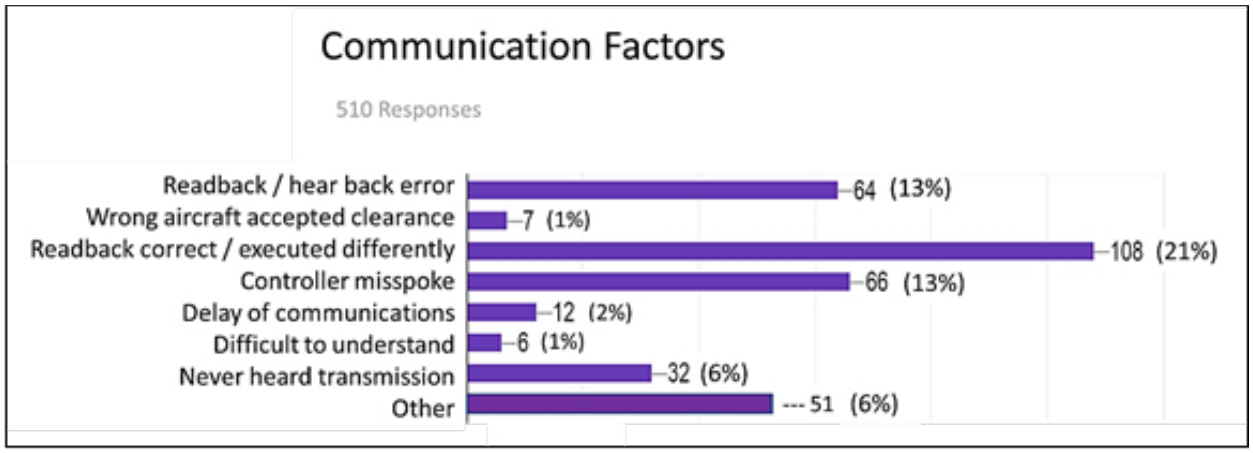


Figure 76. Communications as causal factors for ASRS reports for GA RIs at towered airports 2010–February 2017

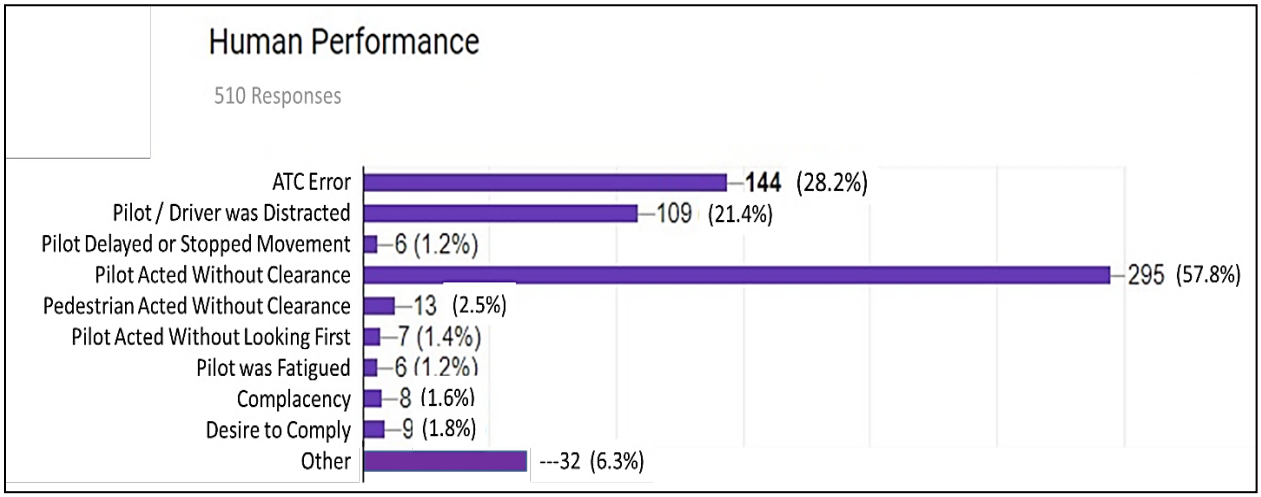


Figure 77. Human performance as causal factor for ASRS reports for GA RIs at towered airports 2010–February 2017

Figure 78 shows the top radio factors that contributed to the RI events found in the ASRS. Radio issues can cause problems for the pilot and ATC. Radio equipment is listed as a contributing factor to 72 of the RIs. Monitoring the wrong frequency is by far the most frequent radio causal subfactor. Monitoring the wrong frequency may be caused by a pilot's mental error for by the pilot's use of incorrect or outdated information.

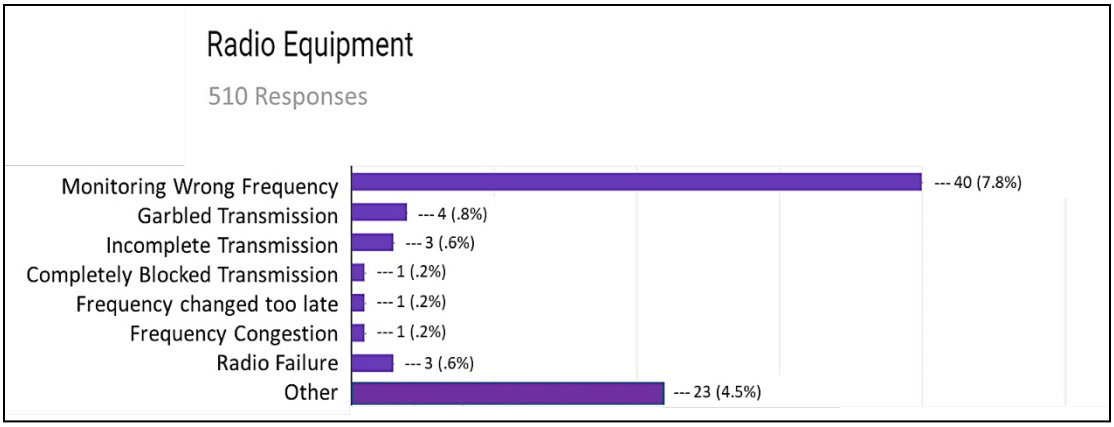


Figure 78. Radio equipment as causal factor for ASRS reports for GA RIs at towered airports 2010–February 2017

Figure 79 shows the spatial awareness factors that contributed to the RI events found in the ASRS. There were many RIs that were coded as issues with spatial awareness. Many of these were taxi route errors in which the pilot either missed a turn or turned onto the runway thinking she/he was on a taxiway. Another major issue with spatial awareness was taking off in the wrong direction or taking off on the wrong runway when the runways intersected at the runway end. Pilots sometimes landed on the wrong runway, especially if there were parallel runways.

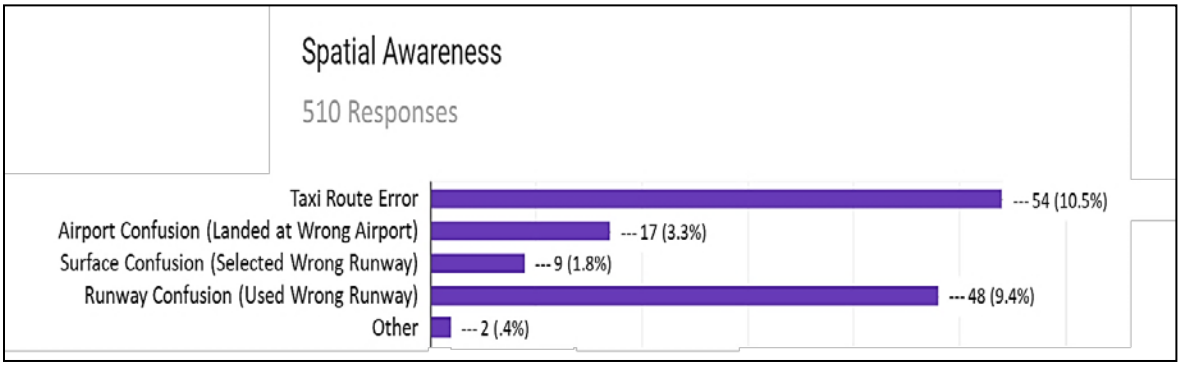


Figure 79. Spatial awareness as causal factor for ASRS reports for GA RIs at towered airports 2010-February 2017

There were 42 RIs that were coded as equipment problems being a contributing factor. Total electrical failures, engine failures or partial engine failures caused pilots to land without a clearance or land on the closest runway. Emergencies may not have been declared during many of these problems. There were two brake failures that were contributing factors to RIs.

Figure 80 shows the signage and marking factors that contributed to the RI events found in the ASRS. There were 79 RIs in which the hold-short line was hard to see or in a strange location. Additionally, there were 45 RIs coded as having a runway or taxiway sign issue.

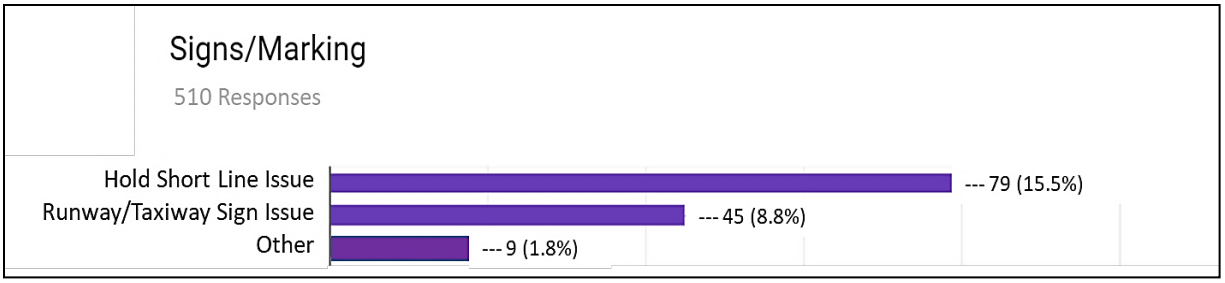


Figure 80. Signs and markings as causal factor for ASRS reports for GA RIs at towered airports, 2010–February 2017

7. SYNTHESIS OF FINDINGS, ROOT CAUSES, MITIGATIONS, AND MEASURES OF SUCCESS

The information obtained in this study through database searches, interviews, and questionnaires, was analyzed using various methods to determine the root causes and event patterns that result in GA RIs at both towered and non-towered airports, and recommend new mitigation measures to reduce the risk of RIs.

What is a typical GA pilot or flight that has an RI? The study looked at descriptive statistics across multiple databases and the GA pilot questionnaire, although it did not calculate any inferential statistics. Based on the findings, there is no typical GA pilot or flight that has an RI.

It can be said that the overwhelming number of GA RIs occur during the day in VFR weather conditions. The data are not adjusted for the percent of GA operations that occur during the day in VFR weather conditions.

The findings dispel the idea that inexperienced pilots, instructional flights, and single-pilot operations make up the bulk of PD RIs. Data from the GA pilot questionnaire and the NTSB, ASRS, and RWS databases find all are consistent in suggesting that pilots of all experience levels need to be aware of the risk of an RI. The GA pilot questionnaire found that for pilots who reported RIs at non-towered airports, only 26% indicated the flight was single-pilot. From this it could be inferred that up to 74% of these flights had multiple pilots onboard, either as a crew member, instructor, or pilot-passenger.

From the GA pilot questionnaire, respondents who reported RIs at non-towered airports found a diverse purpose of flights. Approximately half were personal flights, and the other half were a mix of dual or solo instructional flights, business, or corporate flights.

From this study, the causes of GA RIs and recommended mitigation measures are grouped into the following areas:

- Airport Information for Pilots
- Cockpit Tools
- Signage and Markings
- Communications
- Recommended Practices for Operations at Airports

- Training
- Culture of Safety at GA Airports

Within each of these areas, towered and non-towered airports, general causes, and recommended mitigation measures are addressed.

7.1 AIRPORT INFORMATION FOR PILOTS

GA training materials on RIs emphasize the importance of studying the airport information in the CS, studying the airport diagram, and checking the NOTAMs as part of preflight planning. Suggestions submitted from the GA pilot questionnaire and validated as part of this study indicate that specific local information that would help reduce RI is either not available or is too time consuming to find during the planning process. The mitigation measure is to make it easier and quicker for pilots to get airport-specific information before the flight.

7.1.1 Information on Location of Hold-Position Markings

The information available at specific airports depends somewhat on whether it is a towered airport. Airport specific information on the location of hold position markings is not available on the airport diagram for towered airports, on airport sketches for non-towered airports, or in the CS. It is no longer reasonable to assume the hold position line is parallel to and approximately 250 feet away from the runway, but pilots do not see where markings and signage are actually located until they are taxiing on the runway. If the markings are in poor condition, there are environmental conditions that make the markings hard to see or, if the pilot has a high workload, the possibility of not recognizing the hold marking or runway sign increases.

If the pilot takes the time to search the Internet, sites such as Google Earth, SkyVector.com, 1800wxbrief, or AOPA's Airport Guide include satellite images of the airport. The location of hold position markings can be seen in satellite images of the airport and provide this important information if the image is recent. Except for Google Earth, the images looked at for this study did not include a date, and it was apparent that some images were not recent. Easy access to current satellite imagery of the airport would allow GA to see the actual markings prior to flight.

7.1.2 Information in CS

The airport directory entries for specific airports in the CS lack information important for avoiding RIs at either towered or non-towered airports, including information on hot spots and availability of signage.

Based on the questionnaire, it is reasonable to conclude the majority of GA pilots today are using Internet websites and EFB applications instead of paper charts and products. The website and applications used by GA pilots generally aggregate data and present it in a usable format. Using the flight-planning websites or the EFB applications, a pilot can pull up the airport entry from the most recent CS. The apps reformat the standardized information from the airport entry and include a copy of the remarks. The remarks are usually left as written, with numerous cryptic abbreviations. This is important because this is where any remarks related to avoiding RIs will be located.

The information on decoding abbreviations and hot spots is published in the front or back matter of the CS. However, pilots cannot easily pull up the front or back matter of the CS on the pilot software tools. For that, the pilot has to separately search FAA's Digital d-CS website, have a saved copy on their EFB or computer, or have a paper copy of the CS.

Based on the findings from this study, recommended RI mitigation methods related to the CS include:

- Put airport information relevant to mitigating RIs in the airport directory portion of the CS
- Redesign the format of the airport-directory entry using human factors techniques to be user friendly
    - Include the information relevant to mitigating RIs in ways that make it easy to search and find the information.
    - Reduce the use of abbreviations. Use plain language to improve understanding and to facilitate search. Remarks, in particular, should be in plain language.
    - Take the safety information that typically is found in the remarks and create their own entries so it is more obvious and more easily searchable.
- Improve the Airport Directory entry in the CS by including:
    - Links to relevant information including:
        - Current information page on airport's website
        - Local procedures, including noise-abatement procedures and preferred runway (rather than a phone number to the airport manager's office)
        - Recent satellite image (with date of image) with a link to information on changes to the airport since image was taken
        - Airport's NOTAMs
    - Information hot spots
    - Information on surface-painted apron entrance-point signs used for GA aircraft parking
    - Availability of SuperAWOS™, or similar if applicable, and how to activate it.
    - Nonstandard signage or no signage

The purpose of providing links and other information is not to compete with industry products. Rather, it is to provide an official source to pilots and make it easier for meta-sites, such as SkyVector, AOPA, or ForeFlight, to provide current, accurate, airport-specific resources to their users at an affordable price.

7.1.3 Information on Airport Diagrams and Sketches

Pilots rely heavily on airport diagrams (at towered airports) and airport sketches (at non-towered airports), both for planning and for use while taxiing on the airfield.

Currently, government-published airport diagrams do not actually show taxiways; they show the outline of pavement. In particular, taxilane limits are not shown on the diagrams.

With current technology, a recommendation is to create an electronic airport diagram that combines real imagery with graphics. Such a product could zoom in to show the actual airport markings, including hold position line and taxilane markings, and zoom out to show a more traditional airport diagram.

With respect to airport diagrams at towered airports, suggestions from the GA pilot questionnaire included improving existing airport diagrams by adding the text for hot spots and by adding the location of hold position lines and other critical markings.

At towered airports, other information would also be beneficial to include on the airport diagram is Surface-Painted Apron Entrance-Point Signs used for GA aircraft parking. This would reduce confusion about taxi clearances after exiting the runway causing an aircraft to stop without fully clearing the runway.

Airport diagrams are not currently available for non-towered airports. Pilots rely on the airport sketch found in the CS. Some small GA airports do not even have a sketch in the CS. For those that do, airport sketches show the outline of pavement and do not include most of the important information available on the airport diagram. Information important to mitigating RIs on airport diagrams but not on airport sketches include:

- Communication frequencies
- AWOS frequencies
- Taxiway designators
- Identification of buildings including FBOs
- Hot spots or other notes to alert pilots to potential hazards

One of the top suggestions in the GA pilot questionnaire for how to reduce RIs was to have real airport diagrams at non-towered airports. Based on the findings from this study, recommended RI mitigation methods related to airport diagrams include:

- Provide airport diagrams for all airports comparable to those at towered airports.
- Show taxiway designators, frequencies, hold position lines, location of key locations, and traffic pattern.
- Provide alerts specific to the airport, such as line-of-sight issues or lack of signage.

7.2 USE OF COCKPIT TOOLS

Responses on the GA pilot questionnaire confirmed that GA pilots have wholeheartedly adopted the EFB and praised the ability for geo-referenced location on the air field when used on a device with a GPS position capability. As described in section 2.0, ForeFlight is the popular EFB application among GA pilots. ForeFlight and other EFB applications can be used for planning and in the cockpit.

The Apple iPad is the preferred device for GA pilots, although some EFB products can run on other devices. The features described in this report are consistent with comments on the GA pilot questionnaire. Although enhancements to subscriptions, such as geo-referenced location taxiing or Jeppesen airport diagrams, can improve safety, the comments on the GA pilot questionnaire noted the extra cost to upgrade is an obstacle to getting all of GA using these products.

ForeFlight, with the geo-referencing Runway Proximity Advisor option, provides a visual and aural alert when the aircraft approaches and when it enters a runway. However, the alert is not provided through the headset.

Although some EFB vendors create their own content, the bulk of the content is a repackaging of information retrieved from government publications or other sources. ForeFlight provides an airport sketch for airports that do not have sketches in the CS.

One issue with EFBs in GA is that the pilot spends too much time looking at the EFB and not looking outside. Approximately 10% of suggestions in the GA pilot questionnaire were related to looking outside while taxiing. This is exacerbated when the EFB is mounted in the pilot's lap. If the image on the EFB could be projected closer to the pilot's line of sight, it would mitigate the head-down issue. Practical training on safe use of the EFB in the cockpit is also important.

Based on the findings from this study, recommended RI mitigation methods related to cockpit tools include:

- Provide geo-referenced capability at no additional charge.
- Provide aural alerts from EFB in the headset.
- Include best practices for proper use of an EFB in the cockpit as part of training.
- Make it easier for pilots to see the information on their EFB without looking down at their laps.

7.3 SIGNAGE AND MARKINGS

Comments from the GA pilot questionnaire pointed out that signage is often difficult to read because of the angle at which it is viewed from small GA aircraft. The angle to signs makes them hard to read, as does low visibility.

Respondents to the GA pilot questionnaire suggested markings that are clearly painted and well maintained, and a new look to signage that is more intuitive and more consistent with motor vehicle traffic signs. Other suggestions were to use more colors and have different signage at hot spots that would alert pilots to the danger.

Airports are inconsistent with the use of painted runway hold-position signs. Some intersections have them, and others do not. Adding painted runway signs in conjunction with all hold position signs will further differentiate hold-position markings and provide a red lead up to the hold line to emphasize stopping.

It often seems that taxiway signs are designed to be viewed from one direction and also from a distance prior to reaching the intersection. The back of the sign is completely black. In small GA aircraft, it is possible to be in a position on a taxiway to look for a sign only to see the black back.

Analysis of ASRS reports from towered airports show that 57% of reports were from light single-engine aircraft. Similarly, in the RWS database, 71% of the RIs attributed to 14 CFR 91 operations were single-engine piston aircraft. Several comments in the GA pilot questionnaire related to the confusion in trying to read taxiway signage when viewed from small single-engine piston aircraft on a wide taxiway. The respondents suggested painted taxiway signs as a solution.

Although some non-towered airports have standard taxiway and runway signage, others have either no signage or homemade non-standard signs. Non-standard signs are better than no signs. Although the homemade stop signs may be useful, they make it all the more difficult to notice standard signage and remember its meaning when at a towered airport. Further, there is nothing in the airport entry in the CS to indicate that an airport lacks signage or has non-standard signs.

Small non-towered airports may lack any way for operators of aircraft or vehicles to identify the names of taxiways. This makes it difficult for pilots without a geo-location app to identify their locations or for any pilot to give an unambiguous location on the field. This is particularly an issue when the taxiway crosses a runway.

Non-standard signage that works well could be the starting point for creating new standards.

Based on the findings from this study, recommended RI mitigation methods related to signage and markings at both towered and non-towered airports include:

At all airports:

- Use painted runway signs in conjunction with all runway hold markings.
- Insure hold markings are clearly painted and well maintained.
- Create more intuitive signage.

At larger airports:

- Put information on both front and back of taxiway signage.
- Use painted taxiway signs at intersections to clearly mark the designators of the taxiways.
- Design markings and signage at wide intersections that is less confusing to small single-engine aircraft.

At non-towered airports:

- Get all airports into compliance with standard runway and taxiway markings and signage.
- Better maintain existing markings.
- Identify all taxiways with signage or markings, especially those that intersect the runway.
- Use painted runway hold position signs at all runway ends and runway intersections.
- Add note in airport entry of CS if there is no signage or non-standard signage.

7.4 COMMUNICATIONS

Communications issues at towered airports are very different from the issues at non-towered airports. A pilot who flies primarily at a non-towered airport does not maintain the communication skills required for a towered airport.

7.4.1 Communication for Taxiing at Towered Airports

Most of the suggestions regarding ATC communication were in some way related to ATC realizing that GA pilots are not the same as airline pilots, and controllers need to respect this and have communications and communication procedures that respect this.

Using technology of EFB to reduce frequency congestion would improve communications and reduce confusion. Suggestions included taxi procedures that would appear or could be drawn on an electronic airport diagram. This would reduce radio frequency congestion and reduce confusion about the route.

General suggestions for mitigation methods at towered airports focused on understanding and comprehending ATC instructions. Suggestions and research from this study include:

- Create and use a new keyword in pilot/controller phraseology to break the expectation bias and indicate that the information that follows is atypical, so pay extra attention
- Do not give instructions to pilots when ATC knows the pilot is busy.
- Speak slowly unless there is a good reason to speak quickly.
- Use standard phraseology, no local idioms.
- Provide taxi clearances in chunks.
- Offer progressive taxi; do not wait.

7.4.2 Communication at Runway Entrance for Takeoff at Towered Airport

At a towered airport, PD incursions at the runway entrance and when an aircraft is ready and waiting to take off are a communication issue and a human performance issue. The comments from databases, interviews, and the questionnaire indicate a different mindset and causes between prematurely taxiing out after waiting at the runway entrance holding-position line and accidently taxiing across a runway at an intersection while traversing the field.

Training material for GA to reduce RIs does not specifically address the situation of waiting to take off. Rather, the training material addresses expectation biased in taxi clearances, but not the expectation biased at the hold-position line.

Instructors teach pilots to be ready to enter the go as soon as ATC gives the word. Experienced pilots anticipate ATC instructions to help keep aircraft flowing and minimize delays. This creates expectation bias and a desire to comply at the hold-position line.

Factors that contributes to risk for RI as evidenced by this study are:

- Expectation bias by pilots (e.g., to think they were cleared for takeoff)
- Expectation bias by controllers (e.g., to not catch readback errors)

- Phraseology used by ATC at hold-position line for takeoff creating confusion
- Frequency congestion (e.g., pilot misses part of ATC transmission and assumes the aircraft is cleared for takeoff)
- GA pilot training does not highlight this specific situation

Based on the findings from this study, suggested mitigation methods at the runway entrance include:

- Address the problems of RIs by aircraft waiting to take off as a separate issue from those by aircraft crossing the runway.
- Include a red stop light, controlled by ATC, at the runway hold position. Such a system could be a stripped-down, simplified version of the RWSL installed at large airports.
- Ensure controllers use only proper phraseology, including always using the runway number in all takeoff and landing clearances

7.4.3 Ground Communication Procedures at Non-Towered Airports

There is no requirement in 14 CFR 91 for aircraft to have or to use radio communications at non-towered airports. To reduce RIs, several respondents recommended that all aircraft be required to have two-way radios and for pilots to announce on the radio. Given today's technology, with the availability of small, low-cost, handheld radios, it is reasonable that all aircraft and vehicles on the airfield, including aircraft without electrical systems, powered parachutes, and ultralights, be required to have and use a two-way VHF Comm radio.

With respect to communication procedures at non-towered airports without recommended procedures or examples of best practices, instructors pass on whatever they were taught and often do not make radio calls simply because it is not required.

It is recommended that communication procedures for ground operations at non-towered airports be updated, expanded, and published in AIM. In addition to the communications in the air, the expanded procedures should include:

- Perform a radio check prior to taxi or prior to initial inbound radio call.
- Pilots announce their taxi route prior to taxi in a format similar to an ATC clearance.
- Pilots announce crossing runways in the same format that ATC would issue a clearance to cross a runway, using the runway number and taxiway identifier.
- Pilots to announce entering the runway for takeoff, using the runway number, and intentions after takeoff (e.g., stay in pattern).
- Announce intentions prior to landing (e.g., touch and go, full stop)
- Pilots announce clearance of runway using the runway number and taxiway identifier.
- After landing and exiting the runway, pilots to announce their taxi route in a format similar to an ATC clearance.
- Announce if pilot is doing something out of the ordinary (e.g., landing on Runway 10 because of proximity to jump operations).
- Provide examples of best practices.

- Create recommended radio procedures for ground operations at non-towered airports. The procedures should be published in the AIM so all pilots will have ready access to the information.

"Never Heard Transmission" was selected by 35% of the respondents reported for RIs at non-towered airports. This response was selected in situations in which the subject's aircraft was on final, and an aircraft pulled out on the runway. The implication from the comments is that the subject was making radio calls, but never heard the aircraft on the ground say anything before pulling out.

Possible reasons why the pilot never heard the transmission:

- The pilot of the other aircraft was not using a radio.
- The pilot of the other aircraft used a radio but was on the wrong frequency.
- The pilot completing the questionnaire was on the wrong frequency or had the volume turned down.

The first bullet could be mitigated by requiring pilots of all aircraft to use a two-way radio. The next two bullets could be mitigated by having a reliable, automated way to perform a radio check.

In the past, non-towered airports with an FBO usually had a person who operated the UNICOM radio. Pilots inbound would make an initial call to the UNICOM operator and "request airport advisories." The operator would reply with basic weather, runway being used, and traffic in the pattern. In addition to conveying information, this exchange verified the pilot was tuned to the correct frequency and that the radio volume was set appropriately. Pilots on the ground can also ask for a radio check, and there was enough activity on the field that the UNICOM operator or someone else would reply.

Today, the call for airport advisories has become a thing of the past. This is likely due, in part, to the proliferation of automated weather advisory service (AWOS). Aircraft activity at airports has also dropped over the years, and there may be no one to respond to a call for a radio check. Without the radio check, a pilot can be on the wrong frequency and not know it, greatly increasing the chance for entering the runway while an aircraft is landing or using a runway other than other aircraft in the pattern.

Having a reliable, automated way for pilots to perform a radio check at non-towered airports could mitigate communication problems with "never heard transmission." One way currently available to do this is SuperAWOS™, used at some non-towered airports that do not have AWOS. A feature of this product allows the system to automatically reply on the CTAF frequency when a pilot keys the microphone three or four times.

The name of an airport and what to call it in radio transmissions can be a factor in RIs. The airport is listed by city, and has an official name. The official name can change periodically, such as to honor a government worker or to better market the airport and area. Compound names are common, such as Terre Haute Intl-Hulman Field, or long, such as Central IL Regional Airport at Bloomington-Normal. It is not uncommon for a control tower call sign to not match the name of the airport where it is located.

The result of name changes to airports is that locals use one call sign for the airport whereas transients use another. If the name of the airport is long, pilots might shorten it up in different ways. The problem arises at a non-towered airport when one pilot thinks the aircraft transmissions are for a different airport on the same UNICOM frequency when, in fact, both aircraft are at the same airport.

A suggested mitigation to the confusion caused by calling the airport by different names is to have a designated airport call sign associated with the CTAF and published with the CTAF frequency.

A summary of suggested mitigation at non-towered airports based on suggestions and research from this study include:

For non-towered airports:

- Requiring two-way radios for all flights and vehicles on airside of the airport.
- Requiring that pilots communicate if they have an operational two-way radio.
- Having expanded communication procedures for ground operations published AC 90-66 and in AIM.
- Having a method for performing automated radio check.
- Recommending airport call sign associated with CTAF.

7.5 RECOMMENDED PRACTICES FOR AERONAUTICAL OPERATIONS AT AIRPORTS

The study found, on average, that GA pilots were slightly familiar with the published material on recommended practices.

Best practices for pilots at towered airports are widely available. The FAA brochure *Runway Safety A Best Practices Guide to Operations and Communications* is one of the best resources for GA pilots. Although this brochure is primarily for towered airports, it does offer a few best practices for non-towered airports. Best practices covered in this brochure include:

- Taxi Procedures and practices.
- Communications techniques.
- Use of the airport diagram.
- Knowing airfield markings, signs, and lights
- Looking out.
- Maintaining situation awareness.

7.5.1 Towered Airport Specific Practices

This study had several suggestions regarding airport procedures at towered and non-towered airports. First, at towered airports, creating standard taxi procedures for GA and using technology to draw the taxi route on an electronic airport diagram. This would be similar to the concept of standard taxi routes used by agreement between ATC and airlines with the same benefits of reduced frequency congestion and less opportunity for error or confusion. Standard taxi routes to the ramp would reduce the need for progressive taxi instructions. The standard GA taxi routes would be in the navigational database and in the CS for retrieval and display on the EFB.

Second, again at towered airports with multiple runways, assigning a GA aircraft to the runway that has a low risk for an RI while taxiing as opposed to the one most convenient for the direction of flight. The GA aircraft can depart straight out for several miles, and then turn on course below the flight paths of higher performance aircraft.

The risk of recommended procedures is that they become routine and expected, therefore creating the opportunity for expectation bias and complacency. A new keyword in pilot/controller phraseology that breaks the expectation bias would be useful in such situations.

Two comments in the GA pilot questionnaire were from pilots who had been charged with an RI for operating without a clearance because they thought the tower was closed. It would be helpful if the tower had a procedure, published in the AIM, to announce when they are open and to be proactive if pilots are in the pattern or taxiing with the belief that the tower is closed.

Based on the findings from this study, recommended RI mitigation methods related to recommended practices for aeronautical operations at towered airports include:

- Assign GA aircraft to the runway that minimizes the risk of an RI.
- Establish standard GA taxi routes that would be available in the navigation database and can be displayed on EFB.
- Publish, in the AIM, what a pilot should expect if they are operating on an airport or in the traffic pattern when the tower is opening or closing.

7.5.2 Non-Towered Airport-Specific Practices

At non-towered airports, there are various situations in which pilots make decisions to land on different runways that intersect or are in opposite directions, setting the stage for a possible collision. One situation that can happen is a wind shift while multiple aircraft are in the pattern. Because there is no method to swap runways in an orderly, safe manner, the aircraft often continue to land with a tailwind until it becomes unsafe, or until an incoming aircraft enters the pattern opposite to everyone else. Addressing this situation with a suggested procedure would be helpful. Other situations include using the long runway versus using the runway most into the wind or using the most convenient runway versus using the runway most into the wind.

AC 90-66A and AC 90-42A address recommended practices at non-towered airports. The review of training material as part of this study and the comments on the GA pilot questionnaire both indicate that AC 90-66A should be revised as a way to improve safety at non-towered airports and mitigate RIs. AC 90-66A and AC 90-42A were last revised in 1993 and 1990, respectively.

Recommended revisions to AC 90-66A and 90-42A include:

- Update with an emphasis on current safety practices, risk management, and aeronautical decision making.
    - Address risk management for various scenarios.
- Add a section on recommended procedures for preventing RIs including:

  - How to visually clear the runway prior to taxi onto runway.
  - How to judge separation and closure for landing traffic for a mix of aircraft and performance.

- Provide more recommended procedures and examples of best practices for operating at non-towered airports.
- Emphasize always checking CS and NOTAMs for local exceptions to the general practices.
- Create a recommended procedure for non-towered airports on how to switch runway operations when the wind shifts and multiple aircraft are in the pattern.

7.6 TRAINING

Training is both part of the problem and part of the solution to mitigating RIs involving GA operations. The analysis of current training material in this study, with responses on the GA pilot questionnaire, identified gaps in training that could be the root cause of an incursion. The findings also provide for changes and improvements to GA training that could help mitigate RIs.

7.6.1 Synthesis of Findings Regarding Training

Approximately 30% of GA pilot questionnaire suggestions for reducing RIs are related to training. The suggestions are consistent with responses to other questions on familiarity with RI-specific training material and on preferred ways to learn, and with findings from the task on reviewing training material.

The findings show most pilots are at least somewhat familiar with best practices to avoid RIs at towered airports and with the hot spot program. If the pilots or instructors were certified after 2012, they would be more familiar with and have learned RI avoidance in the PHAK and PTS, which were revised starting in 2012 to include significant information and tasks on RI avoidance. GA pilots who have not earned a certificate since before 2012 would be less likely to be familiar with and have learned the material required by the PTS.

In section 3 of this report, the GA pilot questionnaire suggestions related to training are grouped into four areas:

- Content of training
- Delivery methods
- When to have training
- Who should receive training

From the GA pilot questionnaire, of those who reported an RI at a non-towered airport, 54% reported it occurred while they were on final approach. In most cases, another aircraft pulled out on the runway in front of the landing aircraft. Although it is possible the intruding aircraft did not see or hear the landing aircraft, it is also very possible the aircraft on the ground misjudged the separation and time available before the landing aircraft reached the runway. This topic was specifically mentioned by one participant who completed the GA pilot questionnaire, and it came up in a pilot interview for an RI described in section 4 of this report.

The review of training material did not reveal any published guidance or training material on this topic. Pilots need enough knowledge to manage the risk and decide whether there is enough separation and time available before they taxi out for takeoff at non-towered airports. Starting at the private pilot level, training should include how to judge separation and time available for takeoff based on knowing basic aircraft recognition and landing speed performance and on having basic rules to help make decisions.

Aviation training devices (ATDs) used in most GA flight schools do not have accurate visual representation of the airfield ground environment that would allow the type of practice needed to master ground operations. The devices currently in use are optimized as instrument procedure trainers, and the fidelity for taxiing is low. As a result, training in ATDs often start the lesson by positioning the aircraft on the runway ready for takeoff.

Pilot questionnaire respondents pointed out a need for better simulators for the GA market that can be used to practice ground operations at specific airports, to set up RI scenarios in the simulators, and to practice realistic communications on a busy frequency.

Pilot questionnaire respondents also pointed out a need for better educating tenants at non-towered airports. They suggested non-towered airports have online training for tenants regarding rules and operating at the airport.

For other questions in the questionnaire regarding "what would you do to learn more about preventing runway incursion?" the top two responses were "watch a video" and "complete an online interactive course."

The comments in the questionnaire highlight that pilots need to continue practicing and need to continue covering material as a continuing process. Using the flight review as a mechanism for formal continuing education was a recurrent theme in the comments. A suggestion was to have designated "hot topics" to be covered on flight review and provide CFIs with short "canned" resources for each topic. This would also help standardize the flight review.

Although there was only one comment on it in the GA pilot questionnaire, in GA, dual instruction can be a source of distraction in the cockpit. The comment blamed the instructor for the RI because the pilot did not hear ATC because of the instructor's continued talking. Instructors and examiners need to be reminded that learning is opportunistic, and people learn from observing others. On every flight, instructors set the example. Therefore, they should always demonstrate best practices for RI avoidance.

All the RI causes and recommended mitigations already discussed in the section have a training component. Pilots need to have the requisite knowledge, need to be able to manage the risk, and need to have the skills to execute a safe, successful flight—all of which come through training. Factors related to training that are given elsewhere in section 7 of this report include:

- Improve training on best practices for proper use of an EFB in the cockpit.
- Make airport-specific information easily available so it can be studied and included in training.

- Include training material that addresses the expectation bias and communications at the hold-position line at towered airports.
- Revise AC 90-66A and AC 90-42A to update and include enhanced ground operation procedures at non-towered airports

7.6.2 Root Cause and Recommended Mitigation Related to Training

Based on the findings from this study, the root cause of RIs related to training can be summarized as:

- Lack of content in several areas related to factors in RIs.
- Lack of opportunities to practice skills related to RI avoidance.
- Lack of participation in continuing education.

Based on the findings from this study, recommended mitigation methods related to training content include:

- Improve airport-specific information in the CS that can be resource material for aircraft-specific training.
- Create airport-specific videos so pilots can learn about airports beforehand.
- Expanded material in guidance documents on recommended ground procedures for non-towered airports.
- Expanded material in guidance documents regarding risk management at non-towered airports.
- Create training resources on estimating aircraft performance, separation, closure, and decision making on whether to take off ahead of landing traffic.
- Start teaching decision making on whether to take off ahead of landing traffic.
- Enhance training on ground communications for both towered and non-towered airports.
- Better training for tenants at non-towered airports regarding rules and operating procedures on the airport.

Based on the findings from this study, recommended mitigation methods related to opportunities to practice skills related to RI avoidance include:

- ATD, FTD, or other training devices with accurate visual representations that allow practicing ground-operation skills for the specific airport.
- ATD, FTD, or other training devices with the ability to create and simulate realistic RI scenarios.
- Training tools that do a good job simulating realistic ground communications and allow pilots to practice realistic communications at busy airports.
- Online video and interactive training that allow pilots to engage in scenario-based training and practice their risk-management and decision-making skills.
- Providing these opportunities either free or at an affordable price for GA pilots.

Based on the findings from this study, recommended mitigation methods related to lack of participation in continuing education related to RI avoidance include:

- Treating RI avoidance training as one piece of lifelong learning.
- Incentives that actually get pilots to participate.
- Improving the opportunity to practice for pilots who are not full-time pilots.
- Motivating long-time pilots to take the benefits of continuing education seriously.
- Having resources with an engaging delivery of material.
- Online courses and videos that can be completed from anywhere at any time.
- Taking better advantage of flight reviews to deliver training material.
- FAA designating “hot topics” to be covered on flight review, and rotating topics every 2 years.
- Taking advantage of learning opportunities..
- Effectively promoting a culture in GA that supports lifelong learning.

7.7 CULTURE OF SAFETY IN GA

Finally, RIs can be mitigated by promoting a culture of safety in GA and, in particular, at GA airports. A culture of safety helps instill the importance of implementing the recommendations discussed in this report. For example, when airport operators appreciate how information in the CS affects safety, it can provide motivation to assign the resources needed to keep the information complete and up to date.

Airports that do not have airline traffic and do not have to meet the requirements of 14 CFR Part 139 likely do not have the resources to implement safety programs. However, that should not preclude taking safety seriously and in a professional manner.

There are several possible ways to promote a culture of safety that include events, education, improvements, and enforcement. One way to increase safety is through positive reinforcement. Towered airports can provide opportunities for controllers, pilots, and airport personnel who operate on the field to get together for both educational and social activities that promote and motivate all to follow the best practices.

Another way to increase safety is enforcement. Through the different suggestions and comments in the questionnaire, there were a few suggestions to implement mandatory procedures, training, and required use of two-way radios at non-towered airports.

Of the reported incursions, the purpose of GA is diverse, including pleasure, business, training, and corporate. The motivation for these pilots to adopt a higher culture of safety will be different than for professional pilots.

Numerous questionnaire suggestions for mitigation spoke to general safety procedures and the attitude of pilots, controllers, and airport management. Based on these suggestions and research from this study, recommendations include:

- Actively promote a culture of safety, including all stakeholders at GA airports.
- Airport management takes safety seriously and sets the tone to change attitudes and mindsets of local pilots regarding safety.
- Bring the tenets of Safety Management Systems to GA airports.
- Motivate pilots to want to be safe and exhibit best practices.

- Enable airports to get funding for airport safety enhancements in addition to capital funds, such as training material development, maintaining current information on websites, creating educational campaigns, and planning safety seminars.

7.8 MEASURES OF SUCCESS

Measuring the success of mitigation measures is an important part of reducing RIs. Recommended methods include:

- To measure success at towered airports, use the current RWS database.
  - Enhance the information collected to quantify more of the human factors details that are now in the narrative.
  - Create a field, and specify the Flight Conduct Code of the aircraft that caused the PD incursion.
- To measure overall GA success at towered and non-towered airports, use the ASRS database.
  - The coding of events in ASRS should be standardized to accurately flag RIs under a single field that can be used to develop trends tracked over time.
- To measure success at specific airports, create a metric for annual RIs at airports normalized by the number of GA and 14 CFR 121 operations.
- To measure the success of training, use the ACS coding system for airman testing, and track the number of failures on pilot knowledge and practical tests, referencing relevant ACS codes.
- To measure the success of implementing mitigation at an airport, have a third party create and administer a pilot survey to rate the airport facility and ATC at the airport. This should be conducted annually to measure trends.
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APPENDIX A—PREVENTIVE ACTIONS FROM SAFO 11004 RUNWAY INCURSION PREVENTION ACTIONS

- **Planning:**

  - Review the meaning of airport signage, markings, and lighting.
  - Review airfield Notice to Airmen and current Automatic Terminal Information Service for any taxiway closures, runway closures, construction activity, or other airfield specific risks.
  - Review the current airport diagrams and planned taxi route, including hot spots.
  - Be aware that hold-short lines may be located as far as 400 feet from the runway edge.
  - Before initial taxi out or before landing, brief a plan to include location of hold-short lines.
  - Plan to complete as many checklist items as possible at the gate before initial taxi.

- **Situational Awareness:**

  - All pilots display the current airport diagram for immediate reference during taxi.
  - Cross reference the heading indicator to assure turns are being made in the correct direction and you are following the assigned taxi route.
  - Exercise increased awareness when taxiing between parallel runways.
  - Wait until you have exited the runway and you are sure of your taxi clearance prior to beginning an after-landing checklist, or non-essential communications.

- **Written Taxi Instructions:**

  - Write down the taxi clearance or enter it into the FMC “scratch pad.”
  - Clarify complex or lengthy taxi instructions, or request a “progressive taxi.”

- **Crew Resource Management (CRM):**

  - Use CRM to control crew workload, and reduce distractions.
  - Keep other crewmembers in the loop by announcing when going “heads down” and also reporting “back up, are there any changes?”
  - Approaching a clearance limit, verbalize the hold-short clearance limit.
  - Prior to crossing any hold-short line, visually check to ensure there is no conflicting traffic on the runway. Verbalize “clear right, clear left.”

- **Communication:**

  - Adhere to proper radio terminology guidelines set forth in the Aeronautical Information Manual.
  - Be alert to similar aircraft call signs operating on the field.
  - Stop aircraft on the taxiway, and request ATC clarification if there is confusion regarding aircraft position or ATC taxi clearance.

- If you have been holding in position on the runway for more than 90 seconds, or on seeing a potential conflict, contact the Tower.
- When assigned a departure at an intersection, state "intersection departure" during the clearance readback.

- **Taxi:**

  - Maintain appropriate taxi speed.
  - Avoid transferring aircraft control at unsafe speeds or in turns.
  - Have a heightened situational awareness of hold-short line location when using high-speed taxiways or during shorter taxi distances.

- **Exterior Lighting:**

  - Taxi with taxi light on when moving, off when stopped.
  - Turn on all exterior lights when crossing any runway.
  - If cleared to "Line Up and Wait," turn on all exterior lights except landing lights.
  - When "Cleared for Takeoff," turn on all exterior lights, including landing lights.
  - If you see an aircraft in takeoff position on a runway with landing lights on, that aircraft has most likely received its takeoff clearance and will be departing immediately.

APPENDIX B—EXAMPLE TASKS FROM PRACTICAL TEST STANDARDS AND AIRMAN CERTIFICATE STANDARDS

Private Pilot Practical Tests Standards for Airplane. Tasks with Elements Evaluating Runway Incursion Avoidance.

Area of Operation II, Task G: Before Takeoff Check.

> Element 7 "Avoids runway incursions and ensures no conflict with traffic prior to taxiing into takeoff position."

> Area of Operation III, Task B Traffic Pattern

> Element 1: "Exhibits satisfactory knowledge of the elements related to traffic patterns. This shall include procedures at airports with and without operating control towers, prevention of runway incursions, collision avoidance, wake turbulence avoidance, and wind shear."

> References include FAA-H-8083-3, FAA-H-8083-25; AC 90-66; AIM.

Area of Operation III, Task C: Airport/Seaplane Base, Runway, and Taxiway Signs, Markings, and Lighting

> Element 1. "Exhibits satisfactory knowledge of the elements related to airport/seaplane base, runway, and taxiway operations with emphasis on runway incursion avoidance."

> Element 2: "Properly identifies and interprets airport/seaplane base, runway, and taxiway signs, markings, and lighting, with emphasis on runway incursion avoidance."

> References: FAA-H-8083-23 (Seaplane and Helicopter Operations), FAA-H-8083-25; AIM; AFD; AC 91-73, AC 150-5340-18.

Area of Operation IV, Task A: Normal and Crosswind Takeoff and Climb (ASEL and ASES)

> Element 1. Uses procedures before taxiing onto the runway or takeoff area to ensure runway incursion avoidance. Verify ATC clearance/no aircraft on final at non-towered airports before entering the runway, and ensure that the aircraft is on the correct takeoff runway.

> References: FAA-H-8083-3, FAA-H-8083-23; POH/AFM.

Area of Operation IV, Task B Normal and Crosswind Approach and Landing

> Element 12. Uses after-landing runway-incursion-avoidance procedures.

> References: FAA-H-8083-3, FAA-H-8083-23; POH/AFM.

Area of Operation IV, Task C: Soft-Field Takeoff and Climb (ASEL)

Element 1. Uses procedures before taxiing onto the runway or takeoff area to ensure runway-incursion avoidance. Verify ATC clearance/no aircraft on final at non-towered airports before entering the runway, and ensure that the aircraft is on the correct takeoff runway.

References: FAA-H-8083-3, FAA-H-8083-23; POH/AFM.

Area of Operation IV, Task D: Soft-Field Approach and Landing (ASEL)

Element 9. Uses after-landing runway-incursion-avoidance procedures.

Area of Operation IV, Task E: Short-Field Takeoff (Confined Area—ASES) and Maximum Performance Climb (ASEL and ASES)

Element 1. Uses procedures before taxiing onto the runway or takeoff area to ensure runway incursion avoidance. Verify ATC clearance/no aircraft on final at non-towered airports before entering the runway, and ensure that the aircraft is on the correct takeoff runway.

References: FAA-H-8083-3, FAA-H-8083-23; POH/AFM.

Area of Operation IV, Task F Short-Field Approach and Landing

Element 12. Uses after-landing runway-incursion-avoidance procedures.

References: FAA-H-8083-3, FAA-H-8083-23; POH/AFM.

8. Complies with seaplane base signs, signals, and clearances.

Task F: Runway Incursion Avoidance (ASEL and ASES)

References: FAA-H-8083-3, FAA-H-8083-25; AC 91-73, AC 150-5340-18; AIM.

Objective: To determine that the applicant exhibits knowledge of the elements of runway incursion avoidance by:

1. Exhibiting distinct challenges and requirements during taxi operations not found in other phases of flight operations.
2. Exhibiting procedures for appropriate cockpit activities during taxiing including taxi route planning, briefing the location of HOT SPOTS, communicating and coordinating with ATC.
3. Exhibiting procedures for steering, maneuvering, maintaining taxiway, runway position, and situational awareness.
4. Knowing the relevance/importance of hold lines.
5. Exhibiting procedures to ensure the pilot maintains strict focus to the movement of the aircraft and ATC communications, including the elimination of all distractive activities (i.e. cell phone, texting, conversations with passengers) during aircraft taxi, takeoff and climb out to cruise altitude.
6. Utilizing procedures for holding the pilot's workload to a minimum during taxi operations.
7. Utilizing taxi operation planning procedures, such as recording taxi instructions, reading back taxi clearances, and reviewing taxi routes on the airport diagram.
8. Utilizing procedures to insure that clearance or instructions that are actually received are adhered to rather than the ones expected to be received.
9. Utilizing procedures to maintain/enhance situational awareness when conducting taxi operations in relation to other aircraft operations in the vicinity as well as to other vehicles moving on the airport.
10. Exhibiting procedures for briefing if a landing rollout to a taxiway exit will place the pilot in close proximity to another runway which can result in a runway incursion.
11. Conducting appropriate after landing/taxi procedures in the event the aircraft is on a taxiway that is between parallel runways.
12. Knowing specific procedures for operations at an airport with an operating air traffic control tower, with emphasis on ATC communications and runway entry/crossing authorizations.
13. Utilizing ATC communications and pilot actions before takeoff, before landing, and after landing at towered and non-towered airports.
14. Knowing procedures unique to night operations.
15. Knowing operations at non-towered airports.
16. Knowing the use of aircraft exterior lighting.
17. Knowing the hazards of Low visibility operations.

Figure B-1. Private Pilot Practical Test Standards for Airplane FAA-S-8081-14B Task F, Runway Incursion Avoidance

II. Preflight Procedures

Task	*Task D. Taxiing (ASEL, AMEL)*
References	FAA-H-8083-2, FAA-H-8083-3, FAA-H-8083-25; POH/AFM; AC 91-73; Chart Supplements U.S.; AIM
Objective	To determine that the applicant exhibits satisfactory knowledge, risk management, and skills associated with safe taxi operations, including runway incursion avoidance.
Knowledge	The applicant demonstrates understanding of:
PA.II.D.K1	1. Positioning aircraft controls for wind.
PA.II.D.K2	2. Airport markings, signs, and lights.
PA.II.D.K3	3. Aircraft lighting.
PA.II.D.K4	4. Safe taxi procedures at towered and non-towered airports:
PA.II.D.K4a	a. Maneuvering
PA.II.D.K4b	b. Maintain taxiway/runway alignment
PA.II.D.K4c	c. Situational awareness to avoid runway incursions
PA.II.D.K4d	d. Taxiing to avoid other aircraft/vehicles and hazards
PA.II.D.K5	5. Visual indicators for wind.
PA.II.D.K6	6. Airport information resources including Chart Supplements U.S., airport diagrams, and appropriate publications.
PA.II.D.K7	7. Good cockpit discipline during taxi, including maintaining a sterile cockpit, proper speed, separation between other aircraft and vehicles, and communication procedures.
PA.II.D.K8	8. Procedures for appropriate cockpit activities while taxiing including taxi route planning, briefing the location of Hot Spots, communicating and coordinating with ATC.
PA.II.D.K9	9. Rules for entering or crossing runways.
PA.II.D.K10	10. Procedures unique to night operations.
PA.II.D.K11	11. Hazards of low visibility operations.
PA.II.D.K12	12. Proper engine management including leaning, per manufacturer's recommendations.
Risk Management	The applicant demonstrates the ability to identify, assess and mitigate risks, encompassing:
PA.II.D.R1	1. Distractions during aircraft taxi.
PA.II.D.R2	2. Improper task management during taxi.
PA.II.D.R3	3. Confirmation or expectation bias as related to taxi instructions.
PA.II.D.R4	4. Taxi instructions/clearances.
PA.II.D.R5	5. Improper resource management.
Skills	The applicant demonstrates the ability to:
PA.II.D.S1	1. Perform a brake check immediately after the airplane begins moving.
PA.II.D.S2	2. Position the flight controls properly for the existing wind conditions.
PA.II.D.S3	3. Control direction and speed without excessive use of brakes.
PA.II.D.S4	4. Control the airplane during ground operations.
PA.II.D.S4a	a. Maneuvering
PA.II.D.S4b	b. Maintaining taxiway/runway alignment
PA.II.D.S4c	c. Maintaining situational awareness to avoid runway incursions
PA.II.D.S4d	d. Taxiing to avoid other aircraft/vehicles and hazards
PA.II.D.S5	5. Exhibit proper positioning of the aircraft relative to hold lines.
PA.II.D.S6	6. Exhibit procedures to ensure clearances/instructions are received, recorded, and read back correctly.
PA.II.D.S7	7. Exhibit situational awareness and taxi procedures in the event the aircraft is on a taxiway that is between parallel runways.
PA.II.D.S8	8. Use an airport diagram or taxi chart during taxi.
PA.II.D.S9	9. Comply with airport/taxiway markings, signals, ATC clearances and instructions.
PA.II.D.S10	10. Use procedures to minimize pilot workload during taxi operations.
PA.II.D.S11	11. Demonstrate briefing procedures to avoid runway incursions.

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Figure B-2. Private Pilot Airman Certification Standards for Airplane FAA-S-ACS-6 Task D, Taxiing

APPENDIX C—GA PILOT QUESTIONNAIRE AND NOTEABLE RESPONSES AND SUGGESTIONS

General Aviation Runway Incursion Questionnaire

Thank you for your participation. There will be a few questions regarding your knowledge of runway safety tools related to general aviation runway incursions. You will also be asked some demographic questions. It is expected that the survey will take you 15 minutes to complete. Your participation is voluntary, and you may opt out at any time.

* Required

1. **Are you at least 18 years old?** *
   Mark only one oval.

   ◯ Yes

   ◯ No *Skip to "Thank you for your willingness to participate, but you must be 18 years of age or older.."*

Taxiing Resources

2. **Which of the following products do you use when taxiing on an airport?** *
   Mark only one oval per row.

	Never use	Almost never	Occasionally or Sometimes	Almost every time	Every time
Electronic airport diagram with geo-reference aircraft on chart	◯	◯	◯	◯	◯
Electronic chart with aural alerts when approaching or entering runway	◯	◯	◯	◯	◯
Electronic airport diagram without geo-reference aircraft	◯	◯	◯	◯	◯
Paper airport diagram	◯	◯	◯	◯	◯
Moving map in cockpit panel with airport diagram	◯	◯	◯	◯	◯

3. **For the products that you selected "Every time" or "Almost every time" (if any), is there any particular reason why you use them?**

4. **For the products you selected as "Never use" or "Almost never" (if any), is there any particular reason why you do not use them?**

5. **If you do not use any of the above products, please indicate what other resources you use when taxiing.**

Runway Incursions Safety Programs and Resources

6. **How familiar are you with the following educational materials and programs?** *

Mark only one oval per row.

	Not at all familiar	Slightly familiar	Somewhat familiar	Moderately familiar	Extremely familiar
AC 91-73B "Parts 91 and 135 Single Pilot, Flight School Procedures during Taxi Operations"					
Flash Cards with Airport Signage					
Best_Practices_Brochure, FAA Runway_Safety_					
Appendix 1. Runway Incursion Avoidance in Pilot Handbook of Aeronautical Knowledge					
Hot Spot Program					
AC 90-42 "Traffic Advisory Practices at Airports Without Operating Control Towers"					
AC 90-66 "Recommended Standard Traffic Patterns and Practices for Aeronautical Operations at Airports Without Operating Control Towers"					
Runway Status Lights Program					
FAA Runway Safety Program Web site					
AOPA Online Course: Runway Safety					

Training and Views Regarding Runway Incursions

7. **What is your prior training on runway incursions?** *

Mark only one oval per row.

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
During my last flight review, runway incursions were discussed.					
During my primary training, I received adequate training on the prevention of runway incursions.					
Runway Incursion were covered in the material for my last certificate or rating.					

8. **Which of the following would you do to learn more about preventing runway incursions?** *
Mark only one oval per row.

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
I would to read a textual document rather than watch a video.					
I would complete an online interactive course.					
I would attend a webinar.					
I would use an app.					
I would watch a video on runway incursions.					
I would take a lesson with an flight instructor.					
I would go to a website.					
I would attend an in-person safety seminar.					

9. **What are your views towards general aviation runway incursions?** *
Mark only one oval per row.

	Strongly Disagree	Disagree	Neither Disagree nor Agree	Agree	Strongly Agree
I frequently use existing training tools to learn about runway incursions					
Runway incursions are no longer an issue in general aviation.					
Runway incursions are a serious issue.					
General aviation runway incursions are decreasing year over year.					

Thoughts on Preventing Runway Incursions

Please answer the following open-ended questions on your ideas to prevent runway incursions.

10. **Describe what types of resources (textbooks, apps, brochures, online courses, videos, etc.) you would personally find beneficial to convey important information about preventing runway incursions.**

11. **Based on your experience, do you have specific suggestions for improvements on how to prevent runway incursions?**

12. **What resources do GA pilots need but they don't have?**

Personal Experience with Runway Incursions

13. **Have you ever been involved in a runway incursion while the pilot on a general aviation flight (Part 91), either as the aircraft with the right-of-way, or the aircraft that inadvertently encroached on the runway?** *
Mark only one oval.

- Yes
- No *Skip to question 29.*

Personal Experience with Runway Incursions

14. **Would you be willing to answer more questions about this event?** *
Mark only one oval.

- No *Skip to question 29.*
- Yes

Thank you for providing additional information regarding your runway incursion experience.

15. **Severity Rating: How serious was the incursion?** *
Mark only one oval.

- A serious incident in which a collision was narrowly avoided by extreme action or chance..
- An incident where there was a significant potential for a collision.
- An incident characterized by ample time and/or distance to avoid a collision.
- An incident with only one aircraft but that meets the definition of a Runway Incursion

16. **In addition to your aircraft, what other objects were involved in this incursion?** *
Check all that apply.

- [ ] Another Aircraft
- [ ] Ground Vehicle or Equipment
- [ ] Pedestrian or Personnel
- [ ] None
- [ ] Other: _____

17. **Was this incident at a towered or non-towered airport?**
Mark only one oval.

- ◯ Towered airport
- ◯ Non-Towered airport or tower closed at airport

18. **Why type operation was your flight? (check any that apply)**
Check all that apply.

- [ ] Pleasure
- [ ] Corporate
- [ ] Personal business
- [ ] Training
- [ ] Single pilot
- [ ] Other: _____

19. **What action precipitated the incursion?** *
Check all that apply.

- [ ] Action by you, the pilot, or your crew
- [ ] Action by a second aircraft
- [ ] Action by Air Traffic Controller
- [ ] Action by Vehicle/Pedestrian
- [ ] Other: _____

20. **When did the incursion occur?**
Mark only one oval.

- ◯ When I was taking off
- ◯ When I on final approach
- ◯ After I landed, while on runway
- ◯ While I was taxiing for takeoff
- ◯ While I was taxiing after landing
- ◯ Other: _____

Runway Incursion Contributing Factors

Please review the 5 following contributing factors categories. Identify any sub-factors that were present as part of the incursion. Check as many as apply.

21. **Communication (please check any that apply)**

Check all that apply.

- [ ] Readback/hearback error
- [ ] Delay of communications
- [ ] Difficult to understand
- [ ] Never heard transmission
- [ ] Controller misspoke or omitted information
- [ ] Read back clearance correctly, executed differently
- [ ] Wrong aircraft accepted clearance
- [ ] Other: _____

22. **Human Performance (please check any that apply)**

Check all that apply.

- [ ] ATC Error
- [ ] Complacency
- [ ] Pilot acted without clearance
- [ ] Pilot delayed or stopped movement unexpectedly
- [ ] Pilot/driver was distracted
- [ ] Pilot acted without looking first
- [ ] Angry or irritated
- [ ] Pedestrian acted without clearance
- [ ] Pilot was fatigued
- [ ] Desire to comply
- [ ] Other: _____

23. **Radio Equipment**

Check all that apply.

- [ ] Completely blocked transmission
- [ ] Incomplete transmission (stepped on)
- [ ] Frequency congestion
- [ ] Monitoring wrong frequency
- [ ] Frequency changed too late to hear
- [ ] Garbled transmission during or after readback
- [ ] Other: _____

24. **Spatial Awareness (please check any that apply)**
Check all that apply.

- [ ] Airport confusion (landed wrong airport)
- [ ] Taxi route error
- [ ] Runway confusion (used wrong runway)
- [ ] Surface confusion (selected wrong taxiway)
- [ ] Other: _____

25. **Equipment (please check any that apply)**
Check all that apply.

- [ ] Aircraft Equipment problem
- [ ] Other: _____

26. **Signs/Marking (please check any that apply)**
Check all that apply.

- [ ] Runway/Taxiway sign issue
- [ ] Hold-short line issue
- [ ] Other: _____

Runway Incursion Follow-Up

27. **Would you be willing to provide your contact information to be possibly interviewed by a member of the research team?** *
Mark only one oval.

- ◯ Yes
- ◯ No *Skip to question 29.*

Contact Information

28. **What is your name and email address?**

_____

_____

_____

_____

_____

Aviation Experience and Demographics

The following questions will ask you about flight credentials and demographics.

Aviation Experience

29. **What is the highest pilot certificate that you currently hold?** *
Mark only one oval.

- ◯ Sport
- ◯ Recreational
- ◯ Private Pilot, no Instrument Flight Rules (IFR)
- ◯ Private/Instrument Flight Rules (IFR)
- ◯ Student Pilot
- ◯ Commercial Pilot
- ◯ Air Transport Pilot (ATP)

30. **What is your total flight time (in hours)?** *

_____

31. **What is your primary type of flying?** *
Mark only one oval.

- ◯ Personal
- ◯ Business
- ◯ Corporate
- ◯ Student training
- ◯ Instructor training
- ◯ Military
- ◯ Other

32. **Do you primarily fly single-pilot or as part of a multi-crew operation?** *
Mark only one oval.

- ◯ Single-pilot
- ◯ Multi-Crew

33. **What percentage of your flights depart or arrive at towered airports?** *

_____

34. **What percentage of your time is spent flying is at unfamiliar airports?** *

_____

Demographics

35. **What is your gender?** *
Mark only one oval.

- ◯ Male
- ◯ Female
- ◯ Prefer not to say

36. **What is your age?** *

_____

37. **What is your ethnicity?** *
Mark only one oval.

- ◯ Caucasian
- ◯ Hispanic, Latin American, etc.
- ◯ African descent (e.g. African American)
- ◯ Asian
- ◯ Other: please type here

You have come to the end of the questionnaire. Thank you for your participation! If you would like more information, please contact: Dr. Scott R. Winter: swinter@fit.edu

Stop filling out this form.

Thank you for your willingness to participate, but you must be 18 years of age or older.

Powered by Google Forms

NOTABLE RESPONSES

Table C-1. Resources GA Pilots Need but Do Not Have

What resources do GA pilots need but they don't have?	"Radios should be mandatory equipment"
	"Highlighted taxi routes on electronic devices would be great."
	"One-stop shopping for the information we need without having to spend too much time searching poorly designed websites."
	"Progressive taxi instructions by the Foreflight EFB."
	"Interactive runway incursion simulator games."
	"Detailed airport diagrams for untowered fields."
	"Free or low-cost geo-referenced airport diagrams for all airports."
	"Current photos of the airport and taxiways. Google Earth type REAL imagery would I think be helpful to a lot of pilots. "
	"Local area tips about each airport. A set of 'checkout tips' that ATC or the airport operator wished pilots knew. Pilot friendly info different than the airfield directory."
	"An understandable NOTAM system."
	"A better hot spot system with better explanation as to why the spots are 'hot.'"
	"More detailed airport diagrams for non-towered airports. Current diagrams in 'Chart Supplements' are marginal at best."
	"Availability of detailed airport diagrams at all airports."
	"Can ADSB help with runway incursions? Perhaps just like when airborne, ADSB in/out may be able to provide incursion alerts."

Table C-1. Resources GA Pilots Need but Do Not Have (continued)

What resources do GA pilots need but they don't have?	"Behavior based safety training."
	"Better access to airport diagrams for smaller fields."
	"Better, more consistent airport signage."
	"The 100% solution for crossing incursions would be to install railroad style gates that prevent aircraft from crossing until the way is cleared by a tower operator."
	"Ground radar services."
	"Rwy incursion is NOT a stand alone topic. I find it most effective to discuss it in context with other topics, such as 'pre-flight,' 'ground ops,' 'human factors,' 'fatigue,' etc."
	"In-cockpit digital instruction from ATC controller to panel readout for the pilot to refer to without the need to copy."
	"A better place to chat with other pilots and share experiences and lessons learned."
	"Controllers that speak no faster than automated telephone prompters with vocal characteristics not modified by regional or ethnic influences."
	"The biggest cause of these problems…is this culture of talking fast on the radios and not using a full repeat-back. At airports there seems to be a race by controllers and pilots to spit out words in a slurry as fast as possible. Transmissions are often stepped on. The culture of speed-speak has to change. Slow down and speak clearly, be sure the instructions have been understood with a clear thorough read back, before proceeding."
	"Get into pilots heads and see what they see instead of creating 'statute' training plans, re-establish scope and understanding and design in-line with the results. You're dealing with humans, not machines, therefore, the program must be established on cognitive hierarchy."
	"As low as GA airplanes sit, the taxiway lights and intersections can be difficult to see. The signs, while mostly effective, may be so far off to the side that their directions may not be clear. Perhaps in those situations, the taxiway directions could be painted on the taxiway surface such that it looks like a 3-D object 'in the middle of the road.'"

Table C-2. Suggestions to provide Airport Information to Pilots

Suggestions on how to provide Airport Information to Pilots before flight	"Make sure ground operations information - are available and emphasized in flight planning areas of all airports. Encourage FBO's to post and maintain such materials - and provide materials for them."
	"Poster with signage in use at each airport posted in FBO and available online as pdf."
	"Remind us of a website where we can get the information quickly."
	"More publicity on how to access runway diagrams."
	"There exist some confusing non-standard airport markings, they should have an easy way to find out about them, like on the airport diagram."
	"Satellite imagery."
	"Make notes in the AFD for each airport that guides unfamiliar pilots to the best procedures for runway and taxi use."

Table C-3. Suggestions for airport diagram and Electronic Flight Bags

Suggested Improvements on Airport Diagrams and EFBs	“Put a brief textual description in addition to the hot spot markings on airport diagrams. Something that’s available to the pilot on the page with the diagram.”
	“Update airport diagrams for accuracy.”
	“More diagrams for uncontrolled airfields.”
	“Promote geo-referenced EFBs.”
	“All pilots should have access to, and be required to use electronic geo-referenced charts all times.”
	"Require georeferenced airport diagrams and plates to be free in EFB and panel mount units that want to use/resell govt data.”
	“More/better in-cockpit geo-referenced electronic displays.”
	“Encourage, even subsidize, the use by all pilots of electronic taxi diagrams displaying ownership location.”
	“Highlight runway hold line location on electronic airport diagrams in a similar manner to highlight hot spots.”
	“I can google driving instructions to anyone's phone. Waiting for magenta line taxi instructions from the tower to my geo referenced taxi diagram over ADS-B. Why isn't it here yet?”
	“Encourage pilots to use geo-referenced airport diagrams. Maybe the FAA could make this a free resource for pilots. Encourage pilots to only land at larger airports (especially if they haven't landed there before) when a second pilot is on-board. Improve airport layouts. I know this is an expensive proposition but airports are very cumbersome to navigate.”
	“Requiring geo-reference taxi diagrams.”
	“The FAA should allow GA pilots to equip aircraft with non TSO'd safety gear.”
	“Work with ForeFlight.”
	“I personally would like to see electronic airport diagrams that not only feature own-ship position, but also the option to see traffic on the airfield.”
	“Support active tools like Foreflight and voice recognition for ATC commands.”

Table C-3. Suggestions for airport diagram and Electronic Flight Bags (continued)

Suggested Improvements on Airport Diagrams and Electronic Flight Bags	"Using a geo-reference moving map on the ground."
	"Have a hot spot feature in Foreflight which would allow pilots the ability to review pertinent runway incursion information as needed."
	"Continue to help manufacturers develop apps to provide real time SA on airports. Continue to develop signs and taxiway markings to help identify when approaching a hold short line."
	"Integrated visual alerts on the panel, and aural alerts via the audio panel, when not cleared to enter runway."
	"Make "Safe taxi" type applications standard issue."
	"SAFETAXI should be free."

Table C-4. Suggestions for airport markings

Suggested Improvements for Airport Markings	"Paint the designator of each taxiway on the centerline at each diverging intersection so that you can easily determine "Charlie" etc. in low vis conditions. Sometimes the signs are nearly impossible to see especially after a CATIII approach."
	"FAA tried a paint color differentiation on hold short lines (yellow on dashed taxi side, white on solid runway side). It wasn't adopted, but I still think it's a good idea."
	"Have non-typical hold short line marked in a different way. Look at KAFJ."
	"Maintain better maintenance on hold short line paint with emphasis on visibility in dark/wet conditions."
	"Paint the runway numbers and taxiway letters on the runways and taxiways. What's so hard about that?"
	"Clear taxiway markings at all intersections."
	"More frequent repainting of hold short lines, better system of airport signage."

Table C-5. Suggestions for airport lighting

Suggested Improvements for Airport Lighting	"In pavement warning lights at hotspots."
	"Some airports have flashing hold short lights that warn pilots that they are coming up to a hold short line".
	"Better lighting at airports. i.e., stop signs, not yellow flashing lights at runways."
	"Wig wag lights at every intersection."
	"Status lights at uncontrolled airports."
	"Increased installation of status lights and traffic surveillance systems as developments make them less expensive."
	"More warning lights."
	"Runway status lights."
	"Bigger, brighter lights."
	"The new lights are a good attention getter."
	"At my home airport, centerline light is not used. It is extremely difficult to find my way around the airport at night, runway painting is faded, improved centerline lighting would go a long way."
	"I would suggest that the greatest danger is at night. At night, an airport is nothing but a vast sea of blue lights. Suggest that at a towered field, at night, ground control pay extra attention to a transient pilot."
	"Daytime flashing lights."
	"Flashing lights are more noticeable than taxiway markings."
	"Flashing red lights especially where parallel taxiways are close to runway."
	"More flashing lights at runway hold markings."
	"Flashing lights, they use at bigger airports."
	"Status indicators at GA airports with complicated or incursion prone intersections and hot spots."
	"Indicator that shows that runway is 'busy'."
	"Stop and go lights."

Table C-6. Suggestions for airport signage

Suggested Improvements for Airport Signage	"Improve the signage!!!"
	"Better signage in better positions."
	"Change the signage to correspond with common rules of the road. Possibly automated ground traffic broadcast on a dedicated low strength frequency, activated by embedded traffic loops in taxiway, activating broadcast."
	"Change airport signage to a more intuitive format."
	"Better and consistent signage at airports."
	"I think the signage at airports and on the runways, can be improved. How about 'stop lights' at intersections that are controlled by the control tower or electronically that would stop planes before making an incursion?"
	"Better signage might help–even 'Do not cross without clearance 'signs at towered airports with high GA activity."
	"Improve signage at airports. Signs are often faded, absent or non-standard (especially non-towered airport."
	"Utilize the backside of taxiway markings to show the same info as on front. that way you wouldn't taxi into an intersection and then not know where you are."
	"For "hotspots" special signage or markings."
	"Maintain existing signage better."

Table C-7. Suggestions for airport design

Suggested Improvements for Airport Design	"Improve airport layouts. I know this is an expensive proposition but airports are very cumbersome to navigate."
	"Better airport design! Seems to be designed to create runway incursions intentionally as they tried to accommodate jets too large for the airport design."
	"Improve bad airport design. My close calls with incursions have been related to airport layouts that cannot be understood quickly while reading signs while taxiing."
	"Standardize hold position distances (DXR for example with offset hold line)."
	"Airport design, simplify signage."
	"Big open spaces or areas that may make sense to pilots in big airplanes can be confusing to pilots in small closer to the ground little airplanes."
	"Class Bs–large taxiways and runways–are a challenger for closer to the ground GA pilots, because there are fewer visual cues to overall location to inform current location."
	"Multiple turnoffs from a runway at appropriate points for multiple types of aircraft that might potentially use a runway."
	"Have runup areas at the end of the runway to force aircraft to taxi in the direction of the traffic pattern for visual clearance."
	"Redesign airports that have a confusing taxi/runway area. They may have already been identified as hot spots. Rather than pointing them out, fix them."
	"Ensure runway boundaries are clear and taxiways do not have strange configurations around runway intersections."
	"ADSB Out technology could be used to create a traffic light system for Runways, detecting when someone in on approach final."
	"Reduce the amount of information conveyed by signage. Keep signage simple and offer progressive taxi to GA pilots."

Table C-8. Communication-related suggestions for towered airports

Progressive Taxi	"FORCE ATC TO GIVE PROGRESSIVE TAXI WHEN ASKED"
	"It would be very effective if the ground controllers (towered airports) automatically asked if you want progressive taxi instructions and the pilot could decline or accept. Many pilots will not ask for them when arriving at a new airport."
	"Enhanced progressive taxi procedures, especially during low visibility operations."
	"Controller issued progressive taxi instructions should be mandatory at towered airports."
	"Reduce the amount of information conveyed by signage. Keep signage simple and offer progressive taxi to GA pilots rather than expecting them to know and ask for it."
ATC Speaking	"I think at most airports where GA aircraft operate, there is an opportunity for controllers to slow down a little (some speak incredibly fast regardless of circumstance)."
	"Controller to read clearances slowly and listen carefully to readbacks."
	"Have ATC verbiage warning of hot spots."
	"Extra vigilance at training towers. Often poor or unclear instructions cause confusion at my home base."
	"Controllers should give shorter taxi instructions (no more than 2 or 3 taxiway clearances at a time). Adapt taxiway lighting to show green (facing the pilot) in the approved direction of taxi and red on all areas where taxi isn't approved."
	"Need controllers to talk slower; have pilots stop, request "say again" if not sure about clearance."
	"Better communication from ATC. Many of the controllers would benefit from training to improve diction, projection, and pronunciation."
	"Encourage ground controllers to ask if inbound pilots are familiar and to offer progressive taxiing if not."
	"Controllers could also read taxi clearances more slowly and clearly."
	"ATC should do a much better job, especially in very busy airports, to establish taxi routes avoiding hotspots (if possible), and most of all, slow down when delivering taxi clearances, especially in international airports, when language is prominently an added component to the equation."

Table C-8. Communication-related suggestions for towered airports (continued)

ATC Procedures	"ATC shouldn't distract the pilot with questions when the pilot is near a runway and has a chance of a runway incursion."
	"Don't be intimidated or hurried by air traffic controllers. If in doubt, stop and ask."
	"Controller should never assume working familiarity of an airport."
	"Don't give taxi instructions during rollout on the runway."
	"Better tower communications for training aircraft existing the runway. Students have been or are being taught to run an after-landing checklist before calling for a taxi clearance, but then are rushed to get moving after clearing the runway."
ATC Attitude	"Tower controllers could be more helpful when a pilot is unfamiliar."
	"Better ATC training in recognizing someone who's confused, or a requirement for a pilot landing or departing to mention 'first time at this airport.'"
	"At controlled airports, more patience from tower/ground ATC."
	"At towered fields controllers should be trained to act as friends of pilots who are unfamiliar instead of acting as though they are being put out by pilots who need assistance in taxi procedures."
	"When taxiing on/through a runway to get to another runway, the clearance should specifically state the geography of the clearance i.e., to get to departure runway acknowledge you understand that you will need clearance through/on runway before continuing on."
	"Ask for repeat of clearance if you don't completely understand or ask for progressive taxi instructions at towered airports."
	"Always communicate intentions, learn how to deny land and hold short operations clearance if uncomfortable and there is a tower on the field. Make runway incursions a required topic for a BFR, or for the wings equivalent."
	"For ATC: be extremely hesitant to provide a taxi clearance to provide a taxi clearance which includes a runway crossing right away, sometimes better to provide crossing clearance at the moment when runway has to be crossed."

Table C-9. Communication-related suggestions for non-towered airports

Radio	"Improved radio telephony compliance."
	"Better radio procedures at non-towered airports."
	"It would help if radios were required for all airports."
	"At non-towered airports, employ a methodology to ensure aircraft are using the correct CTAF [frequency] when issuing position reports and stating intentions."
	"Require radios in ALL aircraft. Given our busy airspace is absolutely incomprehensible, why the FAA hasn't made a radio with monitoring required in all airspace? I fly and teach daily out of an airport that has a downslope. You can't see the end of the other runway. Moreover, there is quite often a 90-degree crosswind. At least once every other week somebody takes off on a runway without making proper calls and near misses have occurred."
	"Encourage more radio use in Class E airports."
	"Ban non-radio equipped aircraft and vehicles from uncontrolled airports."
	"Schools where foreign students are learning to fly need to be clamped down on. They commonly allow pilots in the cockpit with very poor English language skills which becomes critical when student is focusing on mechanics of operating controls and does not understand tower announcements or pilot announcements on untowered airports."
	"Stop naming airports after people - use geographical/ city names. It confuses radio calls."
Correct CTAF	"At non-towered airports always use CTAF."
	"Most incursions I have experienced are the result of the offending pilot being on the wrong frequency and not looking down final before entering the runway. Posting the CTAF in the run-up area w/ a reminder to look before crossing the hold bar may help."
	"Posting the CTAF in the run-up area w/ a reminder to look before crossing the hold bar may help."
Procedures at Non-Towered Airports	"Non-towered fields, keep encouraging radio reports, do clearing turns ON THE GROUND to assure a clear runway for takeoff. Do the same prior to crossing any runways during taxi. Give yourself a room for a couple of left and right 45 degree looks prior to crossing a runway."
	"Hold open discussions with non-towered pilots."
	"Do a 360 after run-up and always announce intentions."

Table C-10. Common suggestions for training^

Education	"Without the benefit of data, I can only guess about what might cause an incursion, but my guess is that most GA runway incursions happen at controlled airports. I believe this is caused by a lack of practice or experience operating within this environment. I believe there are many GA pilots that learned to fly at an uncontrolled field and therefore they never developed a comfort level or practiced the skills enough to operate safely at a controlled field. Another contributing factor is the lack of frequency that GA pilots operate within this environment. They avoid this busy airspace for a host of reasons and then one day they have to go there. Now they are trying to navigate a much larger and more complex ground environment, keep up with the traffic, talk on the radios, and maintain situational awareness. Maybe one might consider a requirement that pilots would have to operate at a field with at least control tower at every BFR. Lastly, incursions happening at uncontrolled fields, I would guess, would be largely contributed to complacency."
Delivery Methods	"An interactive web base module where you are in the seat and have to make decisions is ideal recurring training."
	"Set up a scenario in a simulator."
	"Design the program from the cognitive stand point, understand the environment and don't just throw teaching at the environment--it is a waste of time, 'design the environment,' get rid of the non-pilot designers--they don't know what's going on."
	"Make the training more scenario based than theoretical. Many pilots encounter runway incursions in the real world, after their training. The 'oh crap' moments if you will. Finding a way to make it personal and very applicable seems like the best way to prevent future runway incursions."
	"Courses at local pilot meetings"
	"More FREE and readily available videos, webinars, and online courses through FAA, AOPA, and EAA."
	"Somehow make it mandatory to have pilot continuing education."
When to Have Training	"Emphasis during training and BFRs"
	"Get the CFI community on board to teach and model it on every lesson."
	"Completion certificate from online FAA course required for each flight review and practical test."
	"Not enough training at the correct time in the Private course and no or little emphasis in currency and advanced training lead to this lax runway situation."
	"Require a written with flight review that covers 'hot topics.'"
	"Annual computer-based training associated with certificate number."
	"With regard to non-towered airports refreshers are necessary at least at every FR."

Table C-10. Common suggestions for training (continued)

Content of Training	"Needs to be more questions on a knowledge test"
	"Pilots needs to be taught that different aircraft have very different performance envelopes. For example, I fly a very high performance aircraft and fly a very tight pattern...Other pilots will pull out in front of me (happens every single week) because they are expecting performance similar to 'normal' aircraft. Often, I resort to calling them on the radio and asking them to hold."
	"Emphasize SOP as aircraft ops during training. Runway excursion practices should then be baked in SOP."
	"More and better self-education resources—YouTube works really well for this."
	"Use Google Earth or other actual video from the cockpit perspective, rather than flash cards, and other clean graphics—use the real-world view."
	"Make the subject a larger part of the sport and private pilot required curriculum. Push continuing education."
	"Videos or trainings that show real examples of incursions that have happened —real life situations are better teachers than hypothetical examples. Encouragement to ask for progressive taxi when unfamiliar is no shame."
	"Nowhere in any of FAA or other sources of training do you review or recommend asking for a PROGRESIVE taxi instruction, why is that?"
	"We need to stop creating broad-brush education that repeats the same old message. Instead, we should try to create education that is specific to each airport."
	"Publish online interactive courses specific to individual large, complex airports."
	"Provide real-world examples from ASRS reports."
	"CFIs need to do a better job training students to pay attention to other traffic."
	"Pilot education, CONTROLLER education. Both pilots and controllers need to be familiar with each other's operational perspective. When I lived in the KARB area, I would offer tower crew familiarization flights to help demonstrate the pilot's perspective. More pilots, especially students should be offered time in a tower cab and in a radar room."
	"Annual briefing by the Airport management and the Tower operators. We all make mistakes and the FAA employees are included in the family. Another chance for the pilots and ground crew to work hand in hand to resolve issues and come up with good suggestions for change."
	"Prior to endorsements to fly to an airport with a control tower, make mandatory a completion of an approved safety course in runway/taxiway knowledge in coordinating movement on the ground with the tower."
	"Make it mandatory in training. Require a logbook endorsement, or amend current endorsements to include a specific RI reference."

Table C-10. Common suggestions for training (continued)

Who should have Training	"Education specifically targeting what I have seen to be two hazards groups; new/student pilots and "weekend warriors" or those that fly infrequently"
	"Make the subject a larger part of the sport and private pilot required curriculum. Push continuing education."
	"More education for 'seasoned pilots', complacency is a problem."
	"Insure adequate training at busy/complex airports for students training at quiet/simple airports."
	"Also better ATC training in recognizing someone who's confused, or a requirement for a pilot landing or departing to mention 'first time at this airport.'"
	"Better education at the instructor level on asking for 'progressive instructions.'"
	"Education to small airport operators on runway incursions."
	"Better English language training for ESL operators."
Flight Reviews	"Better training during flight reviews. Many at non-towered airports don't seem concerned about rules."
	"More GA pilots should participate in the WINGS program, especially for flight reviews, because it is very through and updates pilot better than just a CFI sign-off."
	"Make runway incursion training (with other things) a mandatory topic during flight reviews."
	"During flight training and flight reviews education or re-education needs to occur. There are too many out there doing the way they have always done it. An increased awareness of their surroundings would help!"
	"Practical standards and flight reviews need to contain more actual interaction with runway signage and indications."
Target Audience	"More education for 'seasoned pilots', complacency is a problem."
	"Pilot education and controller education. Both pilots and controllers need to be familiar with each other's operational perspective."
CFI	"Better education at the instructor level on asking for 'progressive instructions.'"
	"The best training is early intervention. Flight instructors need to do a more thorough job at teaching runway incursion avoidance. Maybe they need to be supplied with more tools to help them convey the importance of it to students. Also, I find poor standardization from ATC when giving taxi instructions. I prefer the full taxi route clearances so that I can become familiar with it prior to moving the aircraft on the airport surface. Partial clearances and directional instructions (turn left on alpha, right on bravo, etc.) are very confusing and more difficult to follow in my opinion."

Table C-10. Common suggestions for training (continued)

CFI	"Ensure adequate training at busy/complex airports for students training at quiet/simple airports."
	"Encourage people to talk to their flight instructor at least once every 90 days; encourage flight instructors to remind students and former students about runway incursions every time they see them."
Curriculum & Content	"Videos or trainings that show real examples of incursions that have happened – real life situations are better teachers than hypothetical examples. Encouragement to ask for progressive taxi when unfamiliar is no shame."
	"Make the training more scenario based than theoretical. Many pilots encounter runway incursions in the real world, after their training. Finding a way to make it personal and very applicable seems like the best way to prevent future runway incursions."
	"Teach students, very early, to obtain progressive taxi instructions at unfamiliar airports. Brief potential taxi instructions (plans at non-towered airports) during the pre-flight planning."
	"Education to small airport operators on runway incursions."
	"Emphasis on heads up taxiing, no working the GPS, or other avionics automation that is now common place in technically advanced aircraft."
	"We need to stop creating broad-brush education that repeats the same old message. Instead, we should try to create education that is specific to each airport. That will require Government and industry to collaborate to determine where are incursions are taking place at each airport (hotspots)."
	"Increased emphasis in primary training on chart usage, airport familiarization and assigned/intended runway heading verification. Increased emphasis on use of CTAF frequencies and controlled airport procedures for those who may be less familiar with such. Awareness of spots on uncontrolled airports where a runway crossing does not share direct line of sight to departing aircraft on the runway."
Online Training	"Older GA aircraft rely heavily on pilots where more modern equipped aircraft have better situational awareness capes for pilots. iPads bring more safety into the cockpit, but an interactive web base module where you are in the seat and have to make decisions is ideal recurrent training."
	"Flash questionnaires/training clips on various websites like flying magazine or AOPA online."
	"Completion certificate from online FAA course required for each flight review and practical test."
	"Public online interactive courses specific to individual large, complex airports."
	"I think online training opportunities and Wings credit would be the biggest motivators."
	"Videos or trainings that show real examples of incursions that have happened – real life situations are better teachers than hypothetical examples. Encouragement to ask for progressive taxi when unfamiliar is no shame."

Table C-11. Supporting comments for safety culture

Supporting Comments for Safety Culture	"There is plenty of information out there, however not every person has a safety oriented mentality. Change the mindset of those individuals and most issues will disappear."
	"Airport leadership needs to be a lot more aggressive in instilling safety practices at GA airports."
	"I see many flight review applicants who have the attitude of not needing taxiway diagrams at familiar airports. I feel it is up to instructors to give students good behaviors for every flight. If you have the same habits for every flight, then you will be less likely to skip good practices at any point."
	"Old school; taxi was not important… need 'attitude adjustment.'"
	"Drive non-towered airport managers/authorities to set a tone for appropriate behaviors (flying proper patterns, use of proper communications, flowing rules) at their airports."
	"Create a culture of utmost vigilance among GA."
	"Encourage pilots to take taxiing as seriously as flying."
	"Pilot awareness and cultivating a culture of safety."
	"There is plenty of information out there, however, not every person has a safety oriented mentality. Change the mindset of those individuals and most issues will disappear."
	"Drive untowered airport managers/authorities to set a tone for appropriate behavior at their airports by calling out offenders."
	"Airport leadership needs to be a lot more aggressive in instilling safety practices at GA airports. Too many GA pilots are not as good as they think they are. High time pilots like crop dusters can be careless and fly as if they own the airport. Time is money to them so they cut corners on safety."
Supporting Comments for Safety Culture	"Old school; taxi was not important...need 'attitude adjustment.'"
	"Just need to be constantly reinforced by controllers and others in non-controlled airports."
	"Practice correct procedures. Actually care about doing the right thing."
	"I see many flight review applicants who have the attitude of not needing taxiway diagrams at familiar airports. I feel it is up to instructors to give students good behaviors for every flight. If you have the same habits for every flight, then you will be less likely to skip good practices at any point."
	"Always be aware. Maneuvering an aircraft is more hazardous on the ground than in the air. That concept needs emphasis."
	"Make 'unfamiliar with the airport' not be so much of a stigma. It has gotten me sent to the holding area."
	"Teach people to not be afraid to ask for help from ground control. Some pilots are either ashamed to ask for help, or are afraid to say that they don't know exactly what to do."

Table C-12. Supporting comments for human behavior

Supporting Comments for Human Behavior	"Most pilots seem to spend too much time messing with gadgets and don't plan ahead now that everything can be looked when it occurs to them."
	"Pilots need to be more conscientious about where they are on the ground and how to get from point A to point B. If they aren't 100% sure, they need to ask for progressive taxi instructions."
	"When you have a human factor involved, you cannot totally prevent or eliminate. A human pilot will always make mistakes. Bottom line is that it is in the hands of the individual pilot in the cockpit at that particular moment with his/her particular state of mind plus any available distractions. Sometimes it could be even a miscommunication with a controller. Given all of the above factors, the only way to influence that is to raise the importance of the subject and emphasizing with recurring communications, using all available means, so the next time the pilot is taxiing the aircraft, it is at the top if his priorities with regard to his decision making. Another way is to promote reduction of workload during taxi."
	"We need to find a way to reach those pilots who simply stop learning after they get their license."
	"I have only had one instance when 2 people remained on the runway well after landing. One tried to back taxi as I was landing instead of using the available taxiway and the other person stayed the runway even though I announced landing 15 miles, 10 miles, and down wind and final. Perhaps it had something to do with his age and willingness to listen and cooperate with normal procedures."
	"The latest runway incursion story I heard was caused by a pilot who just didn't seem to care about safety. I think pilots really need to take more initiative to take what we do seriously. If we can incentivize pilots to spend time learning continuously, that would help. I think we really need pilots to care, but I'm not sure how to make that happen."
	"Teach people to not be afraid to ask for help from ground control. Some pilots are either ashamed to ask for help, or are afraid to say that they don't know exactly what to do."
	"Never be too proud or afraid to ask, pay attention to what you are doing, no multitasking."
	"It's tough because you are trying to change pilot behavior more than just providing information. Changing behavior is always a difficult task."
	"We, as pilots, need to make it our personal responsibility to remain situationally aware."
	"How do we fight complacency? I think that is a pilot's worst enemy."

Table C-12. Supporting comments for human behavior (continued)

Supporting Comments for Human Behavior	"As long as humans are in the process and we continue to fly we will never prevent all incursions. Remove human from process."
	"Get older pilots to take this seriously!"
	"Given all of the [different] factors, the only way to influence that is to raise the importance of the subject and emphasizing with recurring communications, using all available means, so the next time the pilot is taxiing the aircraft, it is at the top if his priorities with regard to his decision making. Another way is to promote reduction of workload during taxi."
	"We need to find a way to reach those pilots who simply stop learning after they get their license. How? I don't know, that's above my pay grade."
	"Instructors and industry can only do so much. At some point personal accountability needs to take over. As long as there are pilots (and ground personnel) who think 'it will never happen to me,' there will continue to be runway incursions. "I do think that the increase in technology plays a part in two ways. Those who know how to maximize what it offers will benefit from what it was intended to do. Those who do not know how to use the technology will find themselves in places they are not supposed to be and not where they thought they were. I won't blame this all on the pilots though. "Airport design has some part in runway incursions. The lack of standardization often confuses the situation when a pilot thinks he should be seeing one thing and then sees another. We have come a long way on standardization though."
	"Mistakes happen, if you are not sure, ask."

Table C-13. Supporting comments for the best practices in the cockpit

Cockpit	"Sterile cockpit, pre-brief airport layout, emphasize 'no-dial twiddle zone' during taxi."
	"In my experience, maintaining a sterile cockpit is essential in preventing runway incursions."
	"Review airport diagrams before moving the aircraft, determine most probable taxi route, and keep your attention on taxiing the aircraft and not doing other tasks."
	"Recommend sterile cockpit procedures not only for Air Carrier operation below 10,000 feet but for all aircraft when operating on movement areas. 25 years in air traffic control and investigating and briefing runway incursions has shown that distractions during taxi, and expectation bias affecting hear back – read back issues for crossing and take off instructions are leading causes in runway incursions."
	"Pilots need to complete any and all pre-taxi items and keep their head out of the cockpit while taxiing. SWA implemented over a decade ago the procedure where before they leave the non-movement area (gate area) they complete all pre-taxi items and do not perform any checklist while taxiing. This resulted in them implementing this procedure basically eliminating runway incursions for SWA."
Instructions	"Use a taxiway diagram, and use the Directional Gyro to verify runways. Although signage and markings are standardized, they are cryptic and numerous. GA pilots generally encounter them only occasionally and so find their interpretation difficult. On the other end of the experience scale, ground controllers issue instructions in a machine-gun style."
	"Pilots simply need to listen and follow instructions and know at all times where they are on the airport."
	"Simplify taxi process, mitigate complicated taxi instructions, signs, and routes."
	"Plan your ground route using airport diagrams, maintain situational awareness at all times, maintain a listening watch, radio position and read back instructions."
	"Make it simple, slow down ground instructions, better maps, more GPS devices in cockpit."
Look	"Regardless if cleared, look before you move onto the runway!"
	"Go slow, take you time, look up, don't get consumed with finishing up checklists while taxiing, clear the area around you before proceeding and turning."
	"Always look out the windows, stay alert, stop at any intersection you doubt."
	"Get pilots to look outside and quit staring at Foreflight or other heads-down gizmos-in flight or on the ground."
	"Pay attention during all phases of flight before and after. Look out the window!"
	"Listen carefully, look where it takes you, proceed cautiously and ask questions."

Table C-13. Supporting comments for the best practices in the cockpit (continued)

Awareness	"Staying vigilant and situational awareness."
	"Less cockpit chatter and situational awareness."
	"Reinforcing pilot situational awareness and avoiding complacency."
	"Increase awareness by including in annual/biennial flights."
Taxiing	"Go slow, take your time, look up, don't get consumed with finishing up checklists while taxiing, clear the area around you before proceeding and turning."
	"Pilot taxiing should announce he has hold short/taxiway/runway in sight when he/she does."
	"Be aware of what's going on outside the cockpit when taxiing."
	"Pay attention to where you are and where you are going. Don't do checklists while you are taxiing. Don't be distracted."
	"Focus on one thing at a time and do not multitask during taxiing."
	"Do not multi task! When taxiing pay 100% attention to outside environment."
Mandatory	"Mandatory procedures for departing high wing planes to turn towards traffic on final to make sure no short final, final planes prior to taking active runway. Had near miss causing 'Go around!' There are two flight training operations at based airports."
	"Make it mandatory to turn high planes at least 45 degrees towards planes on final, short final, airport pilot meetings to get all pilots in order to see landing planes."
	"Mandatory periodic logbook endorsements."

Table C-13. Supporting comments for the best practices in the cockpit (continued)

Procedures	"Good Charts, Good Signage, more attention by pilots. Pilots need to follow standard operating procedures not to enter a runway environment until it is clear of incursion exposures."
	"Practice correct procedures. Actually care about doing the right thing."
	"Standardization of procedures, mindset of being prepared and focused."
	"Be familiar with the airport and country procedures before your flight. Review the taxi chart and with two men crew. One should track taxi progress. Stop and ask controller questions."
	"Use a taxiway diagram, and use the Directional Gyro to verify runways. Although signage and markings are standardized, they are cryptic and numerous. GA pilots generally encounter them only occasionally and so find their interpretation difficult. On the other end of the experience scale, ground controllers issue instructions in a machine-gun style. Not a good combination!"
	"Emphasize clearing the runway without undue delay."
	"Be sure the tower can see where you are. ADS-B may help."
	"Mandatory procedures for departing high wing planes to turn towards traffic on final to make sure no short final, final planes prior to taking active runway."
	"Make it mandatory to turn high wing planes at least 45 degrees towards planes on final, short final, airport pilot meetings to get all pilots in order to see landing planes."
	"Sterile cockpit, prebrief airport layout, emphasize 'no dial twiddle zone' during taxi."
	"Maintaining a sterile cockpit is essential in preventing runway incursions. In training, too many of my flight instructors blabbed on and on as I would taxi. Bad! I tell my passengers after their briefing they need to be quiet until we are in the air."
	"Make runway-incursion thinking part of the before takeoff checklist. Talk thought your takeoff briefing saying out loud, 'I am taking off on Runway XX, I will rotate at xx KIAS, climb and departing the pattern to the...'"
	"Stop 10 feet short of the hold line."
	"Regardless if cleared, look before you move onto any runway!"
	"Stop and scan at every runway all the time, ATC or not."
	"Emphasize 'looking' twice, use of anti-collision lighting even during VFR conditions and the verifying of clearances."
	"Preparation, verify ATC instructions, if uncertain-ask, determine the three most likely routes, write downs routes/instructions."
	"Recommend sterile cockpit procedures not only for air carrier operation below 10,000 feet but for all aircraft when operating on movement areas. 25 years in air traffic control and investigating and briefing runway incursions has shown that distractions during taxi, and expectation bias affecting hear back—read back issues for crossing and take off instructions are leading causes in runway incursions."

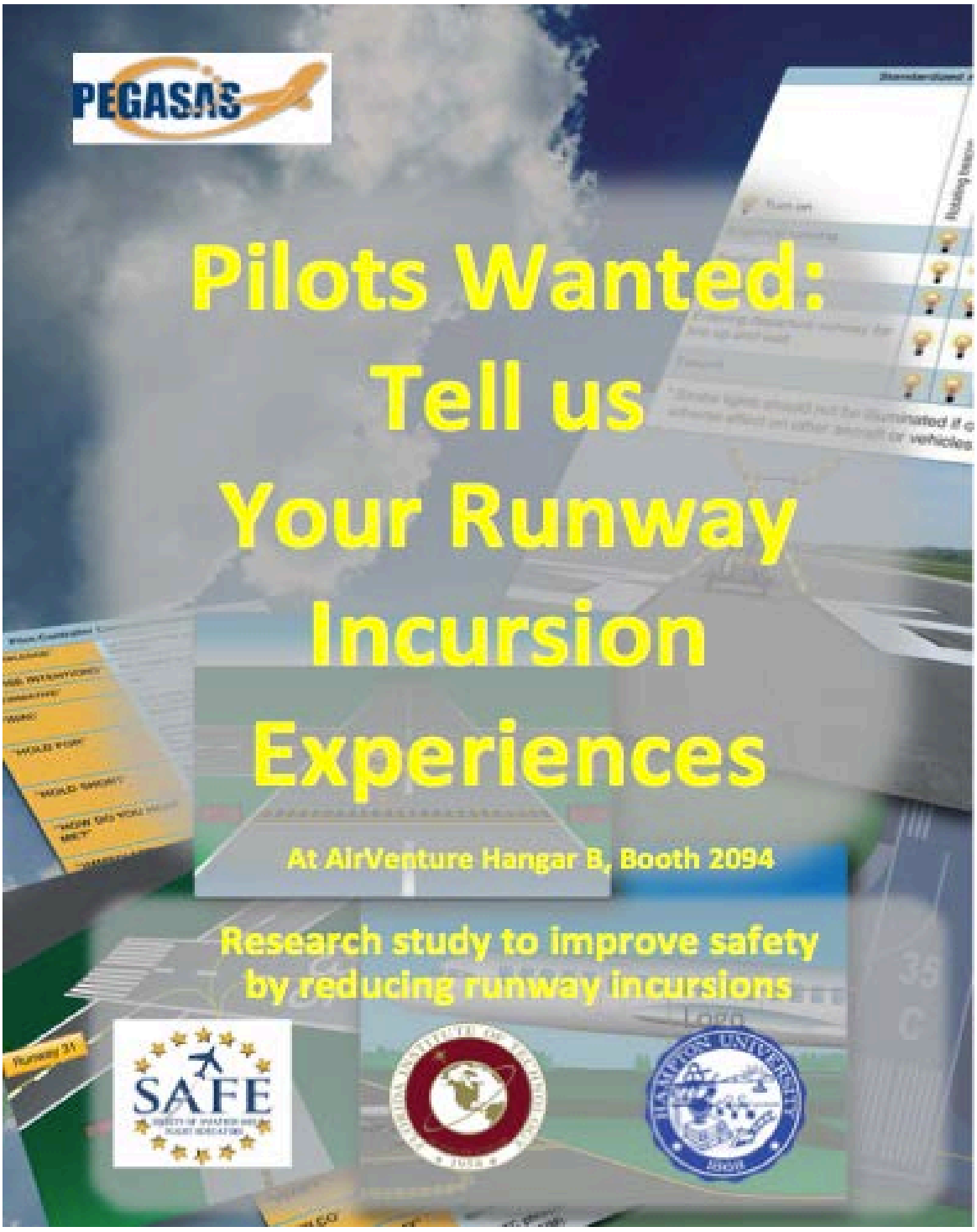
Table C-13. Supporting comments for the best practices in the cockpit (continued)

Procedures	"At small airports, having pilots make announcements to where they are going."
	"Pilots need to complete any and all pre-taxi items and keep their head out of the cockpit while taxiing. SWA implemented over a decade ago the procedure where before they leave the non-movement area (gate area) they complete all pre-taxi items and do not perform any checklist while taxiing. This resulted in them implementing this procedure basically eliminating runway incursions for SWA. Also, if the truth were known, you would be amazed or astonished at what pilots really DO NOT know about airport markings."
	"Pilot taxiing should announce he has hold short/taxiway/ runway in sight when s/he does."
	"Get your head up, know your route, write it down, use the diagrams. Looking down while trying to figure out where you are going is asking for trouble."
	"Students should be taught to give the radio a sustained listen when operating at untowered fields - too often it's tune and go, resulting in minimal awareness of other operations at the field."
	"Biggest concern are not night operations, which are clearly different from daytime. should emphasize night operations issues more."
	"Do a 360 after runup and always announce intentions [ctaf]."
	"My home base is non-towered. Often enough, pilots from towered fields 'straight in' even if they are landing in the opposite direction of current traffic. Emphasis should be made by ATC to switch to CTAF and follow the direction being used at the time on the airfield. Also, CFI's should emphasize the proper method of landing at non-towered fields if they are used to doing their training at other fields."
	"Encourage pilots to write down taxi clearances, even routine ones."
	"Insist on strong SOPs, and on strict adherence."

Table C-14. Other supporting comments

ATC Practices	"In addition ATC should change the practice of having aircraft land or depart a runway because it's the one on the side flight is going to or coming from. ATC should assign runways based on minimum taxi time as taxi is the time when most of the safety systems such as TCAS are inactive. If they were active there is not much a pilot can do other than stop. At my home airport I frequently taxi 3-4 miles and cross 2 runways to get to the "ATC preferred" runway."
	"At busy airports, it's tempting for controllers to pack planes in closely. It's common to get a line-up-and-wait while someone is just turning off the runway, others are getting cleared to taxi up to the runway, and people are on final. When planes have similar N-numbers or rusty pilots, it's easy for someone to "cross the line". I understand why these situations develop, and frequently contribute by accepting a tight clearance when I feel comfortable accepting it. However, I think it's probably a good idea for tower facilities to periodically assess how much risk they take on by packing planes closely and how much it actually helps capacity. I always feel proud and happy when my speedy action helps a controller get a departure out or squeeze another plane into the pattern, but sometimes I wonder whether the controller and I have optimized for the right thing."
Enforcement	"Make infractions more strict. Though I like Harrison Ford immensely, he got off way too easy."
	"5 hrs additional traffic pattern training with an instructor for each offense."
	"Mandatory 90 day suspension of the pilot certificate for those who violate."

APPENDIX D —GA RUNWAY INCURSION POSTER



APPENDIX E—GA PILOT INTERVIEW PROTOCOL

Pre-Interview Checklist

Interviewer Preparation for Actual Cognitive Interview

Welcome and Guidelines for Participant Arriving On Time

Warm-up Session

Interview Session

Closing and Debrief

Appendices

A. Interviewer's Recording Form
B. Interview Consent Form
C. Guidance for Interviewer Responses
D. Guidelines for Participants Who Do Not Show up on Time

Pre-Interview Checklist

1. Assemble the following materials:

Pre-interview materials

_____Pens
_____Blank paper
_____Device with access to airport diagrams and aviation data
_____Consent form (See samples in Appendix B)

Interview Record form (See samples in Appendix B)

_____Primary Recording device
_____Backup Recording device
_____Fully Charged battery for Primary and Backup Recording Devices
_____Charger for recording devices
_____Any Materials for the participant to review: e.g., Map of Air Venture

2. Make sure the recorder is working properly. Practice recording in advance to verify that the recorder can adequately pick up sound.
3. Contact the participant to remind him/her of the cognitive interview and location. Tell him/her to allow 60 minutes to complete the pre-interview and cognitive interview.

Interviewer Preparation for Actual Cognitive Interview

1. Arrive at least 15 minutes early to set up materials and familiarize yourself with the interview location.
2. Test the functioning of the primary and backup recorders to make sure they are working properly.
3. Set up the table and chairs so the two chairs are perpendicular to one another. This perpendicular arrangement facilitates conversation.
4. Verify that you have the materials to be reviewed during the pre-interview and cognitive interview (e.g., consent forms, airport diagrams).
5. Set up equipment and materials so they are easily accessible to you.
6. Complete the appropriate information on the Cognitive Interview Recording Form.
7. Review the interview script.

Review the following interview tips:

- Allow enough time so that the pre-interview and cognitive interview are not rushed. More complete and in-depth responses to fewer questions will be more useful than minimal or less in-depth responses to more questions.
- Provide non-verbal reinforcement to let the participant know that you are listening, such as nodding your head, saying "hmm mmm," "okay," or "I see."
- Encourage the participant to provide specifics about what she/he is thinking.
- Use the following prompts if the participant appears to be having difficulty thinking aloud:

    - "Tell me what you're thinking."
    - "What are you thinking about right now?"

- Listen to what the participant thinks about or mentions so you can probe further on these items later on, if needed. For example, if a participant says she/he liked a graphic or thought a section she/he read was interesting, but does not explain why, probe with additional questions. Use the probes in Table 1 as a guide.

Welcome Guidelines for Participants Arriving On Time

Follow the steps below if the participant arrives on time. If the participant arrives late or does not show, proceed to the guidelines in Appendix D

Script: *Blue Italic – spoken by interviewer* Red – instructions to interviewer

1. Introduce yourself, thank the participant for coming, and show him/her where to sit.
Hi, I'm __ from FIT/HU. Thank you for taking time here at AirVenture to participate in our study.

2. Establish rapport with the participant to ease anxiety that s/he may have about participating in the pre-interview and cognitive interview. Ask about their day in order to establish rapport and to be able to ask the Warm Up Question.
Find common ground: similar aviation experiences, interests,
Such as: *when did you get in today?/ have you been there all day/ have you had lunch yet?/ are you here with someone?*

3. Remind the participant about the purpose of the project, and tell him/her you are interested in hearing what he/she has to say about the materials.
The purpose of this interview is to learn more about why runway incursions really happen with general aviation pilots. Up to now, the FAA has focused on airlines. With this knowledge, changes can be made that will actually improve the situation. This is a unique opportunity, and I'm very interested in hearing about your experiences in this area.

4. Record(write) the start time, date, and participant code on the interview recording form.

5. Hand the participant the interview consent form, and read the form aloud to the participant.
This is the interview consent form. I'm going to read it to you and answer any questions before you sign it.

6. Pull up the Airport Diagram and information for the airport where the RI occurred.
To help with the interview, I'd like to have the airport diagram available for you to refer to. Can you please give me the name of the airport?
7. Answer any questions.
What questions do you have before we get started?"

Warm-up Session

Script: *Blue Italic – spoken by interviewer* Red – instructions to interviewer

Before we begin the actual interview, I would like to introduce you to the think-aloud process for conducting an interview. Thinking aloud may be new and unfamiliar to you, but please know there are no wrong answers. I am only interested in knowing what is going through your mind.

I'd like to start with a warm-up question. Any information you provide during this warm-up will not be used in the project; this session is merely to help you become familiar and comfortable with the 'think aloud' process."

If I ask you a question, and you don't remember, simply say so, and do not make up information.

Warm-up Question 1

First Warm up Question: "Try to visualize the place where you live, and think about how many windows there are in that place. As you count the windows, tell me what you are seeing and thinking about.." (Willis, 1994)

Assist the pilot to take more active roles by: (1) explicitly instructing them to do so; (2) asking open-ended questions; and (3) not interrupting witnesses during their narrative responses.

Warm-up Question 2

Second Warm up Question: Here is a map of Air Venture. Please tell me about what you have done (this morning/ afternoon) at Air Venture, starting with when you (walked in the gate/ate lunch).

Follow-up by probing for more information on one item mentioned.

Possible Items mentioned while reviewing the material:
Food/Eating
Restrooms
Walking/trams
Other people/crowds
Exhibits/aircraft
Weather

You mentioned _____. Can you remember some details about that specific experience?

Interview Session

"I will be recording the interview. Do I have your permission to record the interview?"
☐ If yes, start the primary and back-up recorder, and read the consent form (Appendix B) to the participant.
☐ If no, re-read the consent form (Appendix B) to the participant.
You created an ID for the Runway Incursion Questionnaire you completed earlier at the SAFE Booth. This ID will be used to connect your questionnaire to this interview while maintaining your confidentiality. Can you please say the ID you created earlier?
Would you please say the airport where the event occurred and the year it occurred?
Wait for response.
"The interview format will be the same 'think-aloud' process that we used in the warm-up interview you participated in earlier. What questions do you have before we begin?"
☐ Answer any questions.
"Please remember that there are no wrong answers. I'm not with the FAA, so you will not hurt my feelings. Feel free to say anything you're thinking."

Interview Question 1

First, I am going to have you tell me the story of what happened the day you were involved in a runway incursion. Please think back to that day, and mentally recreate the event. Think about what happened and also about how you were feeling, what you were thinking about, and your emotional state on that day.
Take as long as you want. Tell me everything you think about, even if you think it's trivial, and don't worry if you jump around in time, or if it contradicts something you said earlier.

Here is a copy of the airport diagram that you can look over if that helps.
As the participant speaks, discretely note the probe words that are mentioned on the next page. Add others as warranted.

When the participant is finished telling the story, proceed to question 2.

Probes (check any key words that are used:

Possible Items mentioned while telling the story:	
Possible Areas Mentioned	

ATC Instructions	**Activities in the cockpit**	**Feelings/ Attitudes**	**Communications**	**Taxiway**	**Runway**	**Signage, Markings**	**Weather**
__ *IFR*	__ *talking*	__ *upset*	__ *congestion*	__ *traffic*	__ *traffic*	__ *lacking*	__ *day*
__ *taxi*	__ *avionics*	__ *confused*	__ *confusion*	__ *confusion*	__ *confusion*	__ *confusion*	__ *night*
__ *takeoff*	__ *charts*	__ *apprehensive*	__ *apprehensive*	__ *diagram*	__ *intersection*	__ *faded*	__ *sun*
__ *landing*	__ *checklists*	__ *distracted*	__ *problems*	__ *construction*		__ *good*	__ *rain/snow*
__ *progressive*	__ *passenger*	__ *tired*	__ *sound quality*				__ *fog*
	__ *student/CFI*	__ *hurry*	__ *understand*				
		__ *stressed*	__ *fast*				
		__ *angry*					

Question 2 Follow up for more detail

Possible follow-up questions, as appropriate:

Now I'd like to see if you can remember some more detail about a few things you mentioned.

a. *You mentioned _____. Tell me that part again and, if you can, provide some more detail.*

Repeat this question as often as appropriate to get more relevant information.

b. *When did you realize …*
c. *How/Why did you decide to ….*
d. *Where was your attention leading up to ….*
e. *Other questions as may be appropriate*

Question 3

Even if you already told the story, I would like to go back and focus on the particular aspects of the actual occurrence.

What do you remember about …

a. *what you saw (followup, What do you remember about markings and signage?)*
b. *what you heard*
    - *(followup, Do you remember anything about xxx?)*
c. *what you were doing in the cockpit*
    - *(followup, What do you remember about the charts you were using?)*
d. *the weather.*
    - *(followup, Do you remember anything about where was the sun?)*
e. *how you were feeling?*
    - *(followup, Do you remember anything about being XXX?)*

Question 4

Ask the following questions. The question can be omitted if it has already been covered.

a. *How familiar were you with this specific airport?*
b. *What do you remember about how you prepared for this specific flight?*
c. *How do you think your training prepared you for this specific flight?*

Question 5.

In the end, what do you think was the root cause of this incursion?

Question 6.

What would you do different, or like to see changed, if you had it to do over again?

Question 7.

Is there anything else that we haven't already covered that you would like to say?

When participant is finished, stop both recorders.

Closing and De-brief

Read post-interview thank you and debrief.

Thank you for participating in this research, which is to determine the root cause of runway incursions in general aviation and to recommend changes to prevent runway incursions by general aviation pilots.
I want to reiterate that the information you have provided is confidential. Your name is not attached to it in any way. The audio file will be transcribed so it can be analyzed with other runway incursion events. Once the data analysis has been completed, the audio files will be deleted.
If you have any questions later, please contact Dr. Scott Winter at FIT. Here is his card.
Thank you again for helping, and enjoy you're the rest of your day.

Interviewer's Recording Form

Participant Name:
Contact Phone Number at Air Venture:
Scheduled Interview time:
Scheduled location:

Detach and destroy above information after completion of interview.

The following information will be completed when participant arrives for interview.
Participant Code:
Interviewer's Name: _____
Actual Date: _____
Actual Time: _____
Actual Location: _____
Check each that was conducted:
Welcome Guidelines for on time arrivals
Complete Interview Consent Form

Warm-up Session
Interview Session
Closing and De-Brief

Finish Time: _____

Interview Consent Form

For IRB Office Use Only

Participant Initials _____

RESEARCH PARTICIPANT CONSENT FORM
General Aviation Runway Incursion Interview
Donna F. Wilt Co-Principle Investigator
Scott Winter, Principle Investigator
Florida Institute of Technology
College of Aeronautics

Purpose of Research
The purpose of this research is to determine the root cause of runway incursions in general aviation and recommend changes to prevent Runway Inclusion for General Aviation pilots.

Specific Procedures
After a pre-interview briefing, you will be asked to describe your experiences related to runway incursions. The researchers request that you complete the interview to the best of your recollection without conjecture or embellishment. The interview will be audio taped for post-experiment transcription and analysis by the research team. After the completion of the interview, you will be debriefed and dismissed.

Duration of Participation
The duration of this is anticipated to take approximately 60 minutes.

Risks
It is not anticipated that you will experience any risk greater than normal daily activities as a result of your participation in this study. You may opt out of the study at any time. If at any time you feel uncomfortable discussing this possibly traumatic experience, the researchers ask you to notify them so the interview can be stopped and possible professional assistance be provided. You may opt out at any time.

Benefits
The benefits of this research study are anticipated to be providing the researchers with the root cause of runway incursions in general aviation and the information needed to recommend changes to prevent runway inclusion for general aviation pilots.

Compensation
There will be no direct compensation for your participation in the study. However, the information you provide may greatly assist in identifying ways to reduce and mitigate future runway incursions.

Confidentiality. The project's research records may be reviewed by contacting the principle investigator. Participant confidentiality is of the highest concern to researchers and all project materials will be stored and protected in accordance with FIT Institutional Review Board protocols and requirements. Your will be asked to provide the discrete code you created and used on the Runway Incursion questionnaire so that the two instruments can be correlated while keeping your identity completely anonymous. Audio files will be stored on a password-protected computer. Once the data analysis has been completed, the audio files will be deleted. At the completing of the interview, the identifying information on the form will be detached and provided to you for your records or disposal.

Page 1

Participant Initials _____

Voluntary Nature of Participation
Your participation in this study is voluntary. If you agree to participate you can withdraw your participation at any time without penalty.

Contact Information:
If you have any questions about this research project, you can contact Scott R. Winter, principal investigator, at (321) 674 – 7639. If you have concerns about the treatment of research participants, you can contact the Institutional Review Board at FIT, School of Psychology, Dr. Lisa Steelman. The phone number for the Board is (321) 674-8960.

Documentation of Informed Consent
I have had the opportunity to read this consent form and have the research study explained. I have had the opportunity to ask questions about the research project and my questions have been answered. I am prepared to participate in the research project described above. I will receive a copy of this consent form after I sign it.

_____ _____
Participant's Signature Date

_____
Participant's Name

_____ _____
Researcher's Signature Date

Guidance for Interviewer Responses

If the participant:	You may respond:
Asks what she/he is supposed to do.	*"I am interested in what you are thinking as you look over the map. Do whatever you need to help you think aloud about the pamphlet."*
Appears to be having difficulty thinking aloud.	*"Tell me what you are thinking."* *"What thoughts are going through your mind right now?"*
Is thinking aloud with no difficulty.	*"That's great. Thinking out loud like this is just what I need."* *"Good. Your comments help me understand what you're thinking about."*
Asks you questions about the map.	*"I'm very interested in knowing what questions you have; however, due to the nature of the project, I cannot answer your questions at this time.* *I will write down your questions and take them back to the researcher and she will follow-up with you on your questions.* *Please continue to express any questions you have while you are looking over the map.* *It will be helpful to know what questions you have about the map."*

Guidelines for Participants Who Do Not Show up on Time

If the participant shows up less than 10 minutes late:

- Continue the interview as planned. Skip the first warm-up question.

If the participant shows up more than 10 minutes late:

- Explain that there is not enough time to conduct the interview and reschedule.

If the participant does not show up:

- Call and attempt to reschedule.

APPENDIX F—NTSB OCCURRENCE AND PHASE OF FLIGHT CODES

Occurrence codes used to filter events in the pre-2008 coding system

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

Phases of flight codes used to filter events in the pre-2008 coding system

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

Modifier codes used to filter events in the pre-2008 coding system

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

Eventsoe_no codes used to filter events in the post-2008 coding system

Code Number	Description
XXX320	Runway incursion veh/AC/person
XXX070	Airport occurrence
XXX100	Air traffic event
XXX200	Ground collision
XXX260	Near mid-air collision
XXX270	Abrupt maneuver
XXX490	Collision during takeoff/landing
XXX900	Miscellaneous/other

Phases of flight codes used to filter events in the post-2008 coding system

Code Number	Description
250XXX	Taxi
251XXX	Taxi to runway
252XXX	Taxi into position
253XXX	Taxi—from runway
300XXX	Takeoff
301XXX	Takeoff—aborted
550XXX	Landing
551XXX	Landing flare/touchdown
552XXX	Landing—roll