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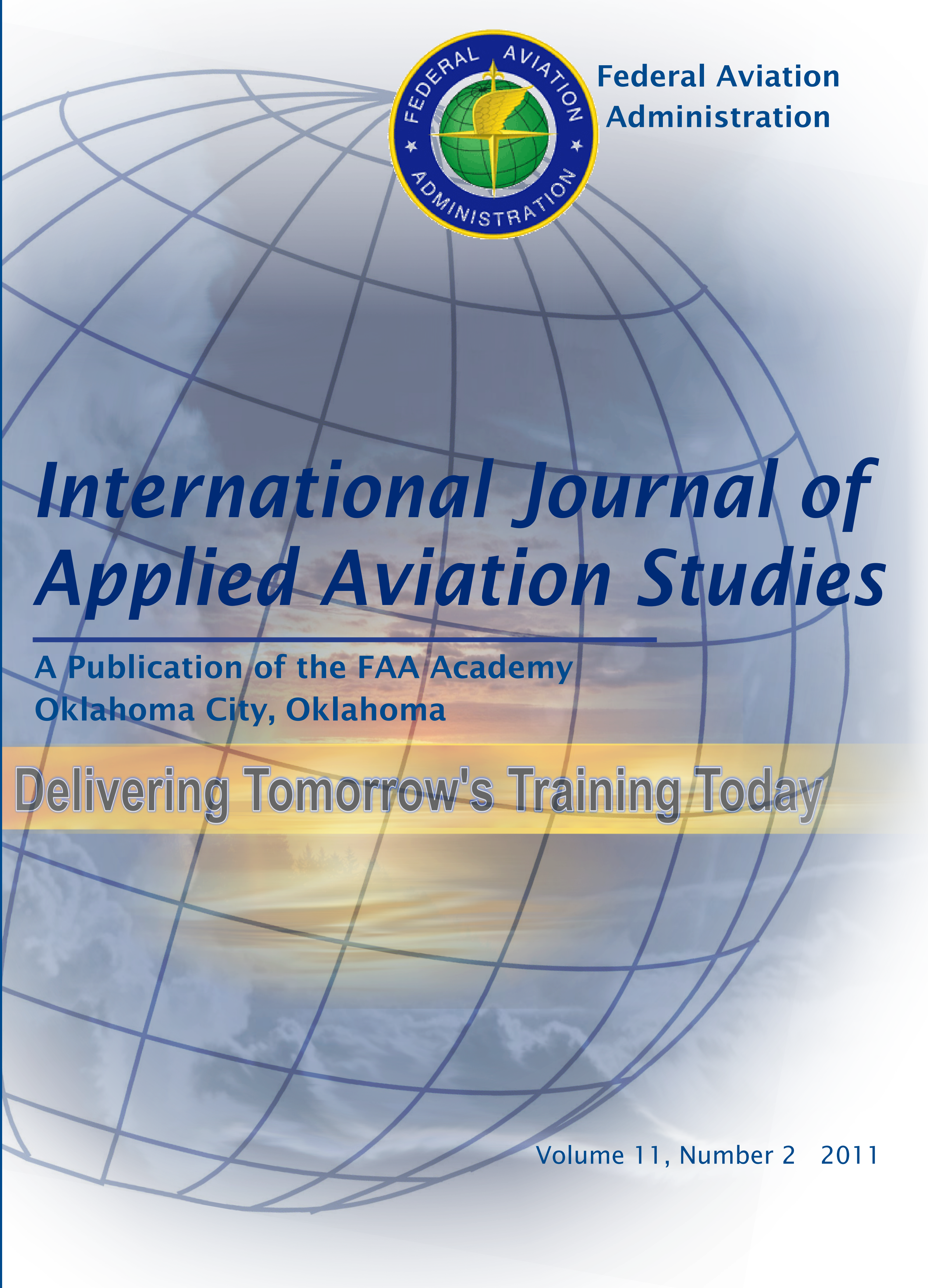

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[1] Cornelius Lanczos, a mathematician working in the field of applied analysis, expressed the history of mathematics in three phases:

1) A given physical situation is translated into the realm of numbers,
2) By purely formal operations with these numbers certain mathematical results are obtained, [and]
3) These results are translated back into the world of physical reality (1988, p. 1).[1]

Formal papers, in subjects related to aviation, roughly follow the same course. However, there appears to be a weakness in aviation research, that being the omission of the third phase.

It is not good enough that conclusions are drawn, if those conclusions fail to improve the system observed. Clearly, the observed have a say in implementing the conclusions of research, but their failure to implement the conclusions drawn by the researcher may be more indicative of a lack of understanding than a lack of desire. Researchers tend to peer into complex systems as through a soda straw, forming formal opinions on the finite without understanding the complete system. Industry, ever mindful of the complete system, may find research irrelevant, because it makes much to do about nothing.

The editorial staff, to include those listed as consulting editors, is committed to the improvement of all individuals within the aviation community. We seek to enhance existing systems bearing in mind that small improvements must not upset the delicate balance between too little and too much help. We also seek to promote safety, not by lip service, but by demonstration in how we execute our studies and how we report our findings.

We feel that the best way to translate results back to the physical world is to incorporate the viewpoints of people around the globe. Without the influence of a worldwide community, we deny the significance of diversity, and ignore the perspectives of gifted scientists from different countries. It is our hope that each reader will feel the same.

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[1] Lanczos, C. (1988). Applied Analysis. Mineola, NY: Dover Publications, Inc.

EDITOR'S NOTES

To support the FAA's efforts to reduce costs, the IJAAS will only be available from our web site at http://www.faa.gov/about/office_org/headquarters_offices/arc/programs/academy/journal/.

Papers

In our lead article, *The Line Operations Safety Audit Program: Transitioning from Flight Operations to Maintenance and Ramp Operations,* Ma, Pedigo, Gildea, Hackworth, and Holcomb review the application of the Line Operations Safety Audit (LOSA) program to maintenance and ramp operations. Tools were developed for airlines and maintenance organization to use to initiate M-LOSA and R-LOSA programs.

The purpose of the study presented in *A Mixed Method Approach to Runway Incursion Rating* was to illuminate the underlying factors contributing to runway incursions using a mixed methods analysis of quantitative Runway Safety Office data and qualitative Aviation Safety Reporting System data. Joslin, Goodheart, and Tuccio found a number of emergent themes among ASRS reports that contribute to a more complete understanding of runway incursions.

In *A Case for Federal Aviation Regulations to Develop Civil Supersonic Transport Aircraft,* Joslin's study proposes that codification of Federal Aviation Regulations allowing overland supersonic flight would incentivize industry stakeholder development and fielding of civil supersonic transport aircraft. Regulations allowing overland civil supersonic flight will establish a viable market potential, clarify aircraft design requirements, and unlock the manufacturing and operational implementation of supersonic civil transport aircraft.

A boomerang effect was observed, whereby exposure to information about aviation's contribution to global climate change led to a significant increase in perceived desire to fly. In *The Effect of Information about the Environmental Impact of Flying and People's Desire to Fly*, Gilbey, Perezgonzalez, and Tani used a between-subjects experimental design to test whether participants exposed to information about the environmental impact would alter their choices in transportation.

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Papers

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Delivering Tomorrow's Training Today

The Line Operations Safety Audit Program: Transitioning from Flight Operations to Maintenance and Ramp Operations?

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Abstract

Managing risk has become increasingly important in modern organizations, including medicine, aviation, and finance. Accident investigation concentrates on failures, which are important for discovering major breakdowns, but failures are rare events. Proactive approaches offer the flexibility of observing normal operations A Line Operations Safety Audit (LOSA) is a voluntary safety program that collects safety data during normal airline operations and was originally designed for flight deck operations. The goal of this FAA-sponsored project is to capitalize on the 10-plus years of successful audits on the flight deck. The hazards that threaten the safety of flight deck operations are not unique to that environment. Similar problems are present during maintenance and ramp operations. This report provides a review of the use of LOSA, discusses LOSA's essential operating characteristics, lessons learned on the flight deck, and describes the extension of LOSA to maintenance and ramp operations. The research team developed tools for airlines and maintenance organizations to use as they initiate their maintenance (M-LOSA) and ramp (R-LOSA) programs.

The Line Operations Safety Audit Program: Transitioning from Flight Operations to Maintenance and Ramp Operations

Managing risks has become increasingly important in modern organizations, including medicine, aviation, and finance. The initial identification and interpretation of hazards are some of the most challenging aspects of risk management, since many hazards remain hidden, unnoticed, or misunderstood for long periods of time before an accident (Macrae, 2009; Turner, 1994). The risks associated with these hazards seem obvious after an accident; however, the early signs pointing to an emerging hazard and its consequent risk are often extremely weak and ambiguous (Reason, 1997; Vaughan, 1996).

Systems such as the National Aeronautics and Space Administration (NASA)'s Aviation Safety Reporting System (ASRS) and the Maintenance Aviation Safety Action Program (M-ASAP) encourage air carrier and repair station employees to voluntarily report certain safety information. These programs provide an important, previously unavailable, source of data that is captured rapidly and directly from those responsible for the day-to-day safe operation of the aviation system. However, systems like these are used proactively and are based on previous adverse events.

Note: A condensed version of this paper is previously published as a DOT/FAA report (DOT/FAA/AM-11/15, September 2011).

A Line Operations Safety Audit (LOSA) is a tool for collecting safety data during normal airline operations. As a voluntary safety program, a LOSA does not require Federal Aviation Administration (FAA) approval, acceptance, or monitoring, as stated in the FAA LOSA Advisory Circular 120-90 (2006). The agreement allows the air carrier or air agency to maintain control of the audit results.[1]

Monitoring routine operations, the cornerstone of the LOSA process, addresses an important aspect of safety auditing, namely, that risks and human error can never be completely eliminated. Recognizing correct and incorrect actions to manage these risks and errors before they manifest into larger incidents/accidents makes LOSA a truly proactive, rather than a reactive strategy, as well as a workable predictive way of risk mitigation (ICAO, 2009; Maurino, 2001). Several companies have instituted LOSA programs and have garnered many valuable lessons, safety improvements, and significant returns on their investment.

LOSA has evolved into a strategy comprised of systematic line observations of routine operations to provide safety data, both in the technical and human performance areas. During a LOSA observation, observers record and code potential threats to safety, how the threats were addressed, the errors generated, how the errors were managed, and how the observed behaviors could be associated with incidents and accidents. The data from LOSA observations provide indicators of organizational strengths and weaknesses, which facilitate the development of countermeasures to operational threats and errors (ICAO, 2002). Prior to the implementation of LOSA, safety analysis of the effect of human performance in aviation had been retrospective, thus overlooking processes immediately preceding the human error that resulted in incidents/accidents (Maurino, 2001). Investigators targeted those actions and inactions that did not produce desired outcomes, often without fully considering the mismanagement of processes leading to these safety breakdowns.

Accident investigation concentrates on failures, which are important for discovering major breakdowns in the system, but failures are rare events. Self-reporting of incidents and potential hazards preceding major accidents can be limited because personal biases about behavioral norms may result in overlooking significant actions, and there are always concerns about professional consequences.

In addition to flight deck operations, there is a need to study aviation maintenance and ramp operations from a neutral perspective during normal operations. Maintenance organizations and ground operators have the opportunity to benefit from the 10-year success of normal operations audits on the flight deck. LOSA provides a minimally invasive safety audit of maintenance and ramp operations to evaluate an organization (including its systems, processes, and personnel), ascertain the validity and reliability of its information, and consequently assess its internal controls. Maintenance safety audits are intended to complement other safety-data sources such as ASRS and M-ASAP by tapping different feedback mechanisms and by identifying hazards before they become events or accidents.

The purpose of this report is to document the development of LOSA in flight operations, its successes and lessons learned, and describe the extension of the flight deck version of LOSA to aviation maintenance and ramp operations.

Background

LOSA development was initially started in 1991 at the University of Texas at Austin (UT-Austin) with funding from the FAA. The development of LOSA stemmed from a request by Delta Air Lines to validate the operational impact of its three-day Crew Resource Management (CRM) training course. Analysts soon realized that existing data collection methods did not assemble adequate information regarding flight crew adherence to standard operating procedures (SOPs) and environmental influences on flight crew performance. To explore the effectiveness of CRM training transfer,

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[1] The FAA ATA Human Factors Taskforce has discussed referring to LOSA within maintenance and ramp operations as an assessment rather than audit to reflect the nonpunitive intent of the program.

a partnership was established between the UT-Austin Human Factors Research Project and Delta Air Lines in 1994. The goal was to develop a line audit methodology utilizing jump-seat observations on regularly scheduled flights (i.e., LOSA). In its early form, LOSA mostly focused on CRM performance (Klinect, Murray, Merritt, & Helmreich, 2003). The audits provided actionable data about strengths and weaknesses allowing prioritization and improvement of CRM training. They also supported the validity of findings from the CRM training data. Other major airlines then conducted their own CRM audits in collaboration with UT-Austin.

The next major development of LOSA evolved from the advancement of systems thinking and human error research in the field of aviation human factors. In 1997, the UT-Austin team collaborated with Continental Airlines to expand the method to focus on the management of common threats and errors. This ultimately evolved into the Threat and Error Management (TEM) model and the creation of the current LOSA's underlying theoretical framework. Continental Airlines was the first to use a TEM-based LOSA to target areas for improvement (e.g., pilots' error management training). In 1997 and 1998, the UT-Austin research team conducted LOSAs at three airlines (Klinect, Wilhelm, & Helmreich, 1999). The observers documented threats (external events such as adverse weather or errors originated by non-cockpit personnel), recorded flight crew errors, and rated the crew using CRM behavioral markers in accordance with TEM performance. Along with the documented threats and errors, observers also recorded how each event was managed by the flight crew. Initial data showed that threats and errors are common. Their types and occurrences varied across airlines. Notably, LOSA data illuminated the behaviors that led to effective and ineffective threat and error management. The nuances included in this proactive data collection strategy populate a richer and more extensive library of threats and errors than reactive accident/incident reporting. LOSA examines responses to errors that have not yet resulted in an accident or incident. Capturing effective responses allows LOSA data to provide insight into normal flight operations and aid training. Follow-up studies showed a sizable improvement at Continental Airlines in safety and overall crew performance (Klinect, et al., 2003).

LOSA data collection is conducted using the LOSA observation form under strict non-jeopardy conditions, meaning that crews are not at risk of receiving reprimands due to observed actions. Establishing that there is a non-punitive policy toward errors during data collection improves the validity of the data by encouraging those being observed to carry on their natural work behaviors.

LOSA was first operationally deployed as an International Civil Aviation Organization (ICAO)-endorsed safety program following the First LOSA Week[2], which was hosted by Cathay Pacific Airways in March 2001. After several years of development and refinement, LOSA has evolved into a strategy to provide safety data comprised of normal operations in technical and human performance areas. The LOSA observations provide data to develop countermeasures to operational threats and errors (ICAO, 2002). It has since been used and validated by many international airlines and is now recognized as a key element in an airline's Safety Management System (SMS). It also provides a data-driven mechanism for measuring change (Veilette, 2008). Based on the success at many carriers that use LOSA, ICAO made LOSA a central focus of its Flight Safety and Human Factors Program and endorsed it as an industry best-practice for normal operations monitoring. The FAA also approves LOSA as one of its voluntary safety programs (Merritt & Klinect, 2006).

UT-Austin provided "how-to" guides as an open source through numerous conference presentations and papers to the airline industry about flight deck LOSA, as well as details about why and how to set up a LOSA. UT-Austin helped de-

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[2] The First LOSA Week, a pioneering event organized by the International Civil Aviation Organization indicates the completion of a transformation from research concepts to operational tools. Since then, LOSA evolved and extended into the Normal Operations Safety Survey (NOSS), designed for air traffic control operations, and has become a successful and acknowledged contribution to the management of safety (ICAO, 2008).

Table 1

LOSA Characteristics with flight deck examples

Characteristic	Examples in Flight Deck LOSA
1. Peer-to-peer observations during normal operations	• Routine flights only - no line checks or training flights • No debriefings or post-flight interviews asking crews to comment on their errors and/or undesired aircraft states
2. Anonymous, confidential, and non-punitive data collection	• No crew names, flight numbers, or other identifying information • Observer identity kept anonymous • Data used for safety purposes only, not disciplinary action
3. Voluntary participation	• Flight crews have the right to decline a LOSA observation
4. Trusted and trained observers	• Observer selection – management/union list of candidates • Diverse observer team – pilots, check airmen, instructors, safety experts, members of human factors groups, external observers • Training length (5 days): ground school (2), test observations (2), & recalibration (1) • Majority should be regular pilots from within the airline
5. Joint management/union sponsorship	• Steering committee – flight operations, training, safety, and union • Symbolized with a signed agreement and sent to all pilots
6. Systematic observation instrument based on TEM	• Safety-targeted data collection form • Observers record TEM events that they see and/or hear and write narratives for contextual support
7. Secure data collection repository	• Third party or pilot association gate keeper • Pilots must believe that observations will not be “misplaced” or improperly disseminated
8. Data verification roundtables	• Three to five representatives from various parts of the airline scan the raw data for inaccuracies • TEM data checked for coding accuracy and consistency with SOP • On completion, data analysis begins
9. Data-derived targets for enhancement	• Serve as benchmarks for organizational change • LOSA adopts a “measure, change, measure again” approach
10. Feedback of results to the workforce	• LOSA findings and information on how airline management intends to respond to the findings with organizational change

velop two primary guidelines: 1) Line Operations Safety Audit (ICAO, 2002)[3], and 2) Advisory Circular 120-90 Line Operations Safety Audits (FAA, 2006).

Consequently, The LOSA Collaborative (a private organization) was formed in the interest of protecting the collected LOSA data.

LOSA Operating Characteristics

The ICAO LOSA (2002) manual described 10 must-have LOSA operating characteristics (Table 1). These characteristics ensure the integrity of the LOSA methodology and its data. (ICAO, 2002).

Benefits of LOSA

LOSA does not rely on outcomes, such as an incident or accident, to generate data. It provides a unique opportunity to sample all activities in normal operations, both successful and unsuccessful, by noting the problems crews encounter and how they manage them (FAA, 2006).

Proactive approaches are aligned with the principles of risk management and SMS. Instead of focusing on problems, LOSA offers the flexibility of observing normal operations (where threats will always exist) and targeting problematic areas. LOSA is a project-based process, which includes advance planning, observer selection and training, data collection, analyses, and a final report. Repeating a LOSA can help maintain a broad focus of an earlier LOSA and track any targeted enhancements. ICAO recommends "to sustain safety in a constantly changing environment, data must be collected and analyzed on a routine basis to identify the targets for enhancement and then a formal Safety Change Process (SCP) to bring out improvement" (ICAO, 2002). Prior to programs like LOSA, SCPs were based on findings from incident/accident investigations, experience, and intuition. Today, SCPs must deal with the precursors of incidents/accidents and be based on the accumulated data repository and interactive detailed analysis methods generated by programs like LOSA.

Flight deck LOSA has resulted in numerous improvements including the modification of dispatch paperwork, reallocation of resources, and revision of procedures based on the problems uncovered through standardized observations and scientific data analyses. LOSA data have greater accuracy than anecdotal observations and can help answer questions about problem frequency, surrounding conditions, and events leading up to an issue. The data also provide better detail than voluntary reports, and identify problematic procedures and policies by highlighting poor adherence rates (Veilette, 2008). At Continental Airlines, an airline-wide LOSA in 1996 uncovered that pilots were having trouble flying uniform approaches to company-defined standards. As it turned out, the problem was not that the pilots were managing approaches ineffectively but that the company's standards were ambiguous. LOSA results made it possible to convince management to modify SOPs for approaches, and the results, verified through a LOSA in 2000, showed a 59% reduction in nonconforming approaches (Croft, 2001). In addition, a 55% decline in unstabilized approaches was achieved by the company as a result of training developed from the LOSA findings (Tullo, 2002).

Problems with LOSA Implementation

Lack of adherence to the 10 LOSA characteristics, which sometimes occurs in internal LOSA programs, can reduce the effectiveness of the LOSA audit (ICAO, 2002). First, LOSA results are not always shared with the pilots. This may be the result of management considering a particular LOSA observation result "not great news" and deciding not to take action. A potential countermeasure to this problem is to instill the concept that providing feedback will advance future LOSA efforts in the sense of (a) illustrating that pilots' opinions and

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[3] The ICAO LOSA manual is outdated. For example, the hierarchical "sticks and boxes" diagram in the manual implies that every error has a threat, which was found to not be true through actual LOSA observations. Most errors are "spontaneous errors" without any previous threat (J. Klinect, personal communication, April 1, 2009).

inputs are taken seriously by the company and (b) motivating observers and those being observed to participate more collaboratively in future studies. Second, airlines' internal LOSA programs sometimes specify the identities of the observers and those being observed. This is a problem because potential disclosure of identity may prevent observers from providing honest feedback. Information such as name, employee identification number, flight number, and date should not be recorded on a LOSA audit form. Departure/arrival cities, aircraft type, and pilot role are the only demographic information that should be recorded. Everything possible should be done to encourage anonymity. Pilots' trust in the LOSA program is paramount, and any violation of anonymity, whether a penalty follows or not, violates that trust. Third, some internal LOSA programs logged threats and errors but did not describe how they were managed. A threat or error may not occur frequently but may still be poorly managed and have unwanted outcomes. This highlights the importance of LOSA not being just a threats-and-errors counting exercise; the management of these threats and errors is critical.

McDonald and Fuller (1994) found that some organizations focus only on auditing documentation, physical resources, and infrastructure, while neglecting observations of operational activities. Audits conducted by external agencies and internal safety departments may prompt altered and rehearsed work behaviors, which potentially lead to inaccurate data. LOSA is different but complementary to other proactive safety programs such as Flight Operational Quality Assurance (FOQA) and ASAP by providing a "neutral, third-party perspective" (FAA, 2006). Each offers unique insight; and used together they can aid understanding and mitigate operational risk.

Extension to Aviation Maintenance and Ramp Operations

There remains substantial opportunity for safety improvement on the ramp and in the hangar. The Flight Safety Foundation (Lacagnina, 2007) estimated that the airline industry worldwide was losing $5 billion a year in direct and indirect costs associated with aircraft damage on the ramp. It was further estimated that 243,000 people were injured on the ramp every year. Thus, we believe that additional methods of reducing damage and injuries are imperative. The LOSA process holds promise as a means of reducing the incidents and accidents in ramp and maintenance operations because LOSA enables ramp and maintenance workers to identify and develop methods to address threats and errors before they lead to an incident or accident.

Several companies have instituted LOSA themed programs aimed at reducing maintenance errors and ground operation damage. These LOSA programs predate the current LOSA effort and provided many valuable lessons. The development of numerous subject matter experts (SMEs) were one of the beneficial outcomes of these efforts: they provided guidance during the development of the current LOSA program.

These companies have also experienced marked success as a result of their efforts. Continental Airlines, Delta Airlines, and Qantas Airlines reported benefits from their LOSA programs and are listed below.

Continental Airlines[4]

Ramp-LOSA (R-LOSA). In 2008, among 447 problems identified by the flight operations LOSA at COAir, 147 (29%) were ground safety issues. An examination of flight operations LOSA archival data revealed that the industry average is only 16%

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[4] The information in this section is based on a site visit to George Bush Intercontinental Airport on March 18, 2008 and personal communications with Doc Garrett (Senior Manager, Maintenance Human Factors, Logistics & GSE Systems, Tech Ops); Rodney Luetzen (Managing Director, Reliability); Gerry McGill (Regional Manager, Safety & Regulatory Compliance, Flight Ops); and Guy Schroeder (Director Ground Safety, Safety & Regulatory Compliance) between March 2008

for flight operations ground safety issues.

To improve ground safety performance, COAir established several safety programs under the umbrella of its SMS; for example, the Safety Recognition Program and R-LOSA. Station #1 had the same ground safety programs as Station #2 but, Station #1 added the R-LOSA program in 2007. Both stations improved their group safety performance dramatically over a three-year span (2006-2009). Data for 2009 are only available from January through October. Monthly averages for the first 10 months were used to estimate November and December 2009 ground damage mishaps, and consequently, the averages for the entire year. However, the improvement observed by Station #1 is more than Station #2, which can potentially be attributed to the effectiveness of R-LOSA program (Note that Station #1's initial safety performance was better than Station #2). Ground safety performance was assessed using three measures: (1) ground damage mishaps (total number of occurrences), (2) ground damage mishaps (mishap rate per 10,000 departures), and (3) cost of ground damage mishaps.

Ground operation mishaps can further be categorized as attributable mishaps and non-attributable mishaps. Attributable mishaps are a result of human error and are charged back to the responsible department or vendor. Non-Attributable Mishaps include Foreign Object Damage (FOD). The costs are not recovered for these mishaps. Both stations showed a dramatic decrease in the total number of ground damage mishaps from 2006 to 2009. The number of attributable and non-attributable mishaps for Station #1 dropped 73% and 85%, respectively, whereas the drops for Station #2 were 58% and 67%, respectively. The cost of ground damage also decreased overall between the years of 2006 and 2009 in both stations. However, the cost of attributable mishaps for Station #1 increased very slightly in 2008.

For Station #1, the ground damage mishap rate also decreased significantly from 2006 to 2009: per 10,000 departures, attributable mishaps dropped 61% and non-attributable mishaps dropped to zero. For Station #2, both attributable and non-attributable mishap rates decreased from 2006 to 2009 (43% and 45%, respectively). The cost of ground damage also decreased overall between the years of 2006 and 2009 in both stations. The most significant improvements were observed in the following four areas: ground handling operations, struck by vehicle in motion, taxi-tow-push, and maintenance operations.

Maintenance LOSA (M-LOSA). M-LOSA findings help make deactivation procedures more workable, efficient, and safer. As an example, B767 leading edge device deactivation and reactivation procedures used to take three hours to properly lockout and tagout[5] without individual sign-offs. An M-LOSA auditor identified this inefficiency, which was then addressed by Tech Publications by rewriting their deactivation/reactivation procedures. Previously, the lockout and tagout process involved unnecessary deactivation of some systems following a 37-page procedure. Some steps required personnel to repeatedly reference different sections of the manual and there were no individual sign-offs when following the manual (e.g., deactivate the slats per AMM 27). The new workcard is 2-pages long with clearly defined steps. Now, with individual sign-offs, this modified process takes between 30 and 45 minutes to complete. The new standardized procedures also help to avoid problems caused by shift changes (deactivation and reactivation are often carried out on different shifts) and interruptions. This deactivation/reactivation procedure has been implemented in the entire Continental Airlines fleet. Because of the changes implemented by M-LOSA, the threats have been reduced tremendously and no damage to the aircraft has occurred at the time of this publication.

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[5] "Lock out and tag out" refers to specific practices and procedures to safeguard employees from the unexpected energization or startup of machinery and equipment, or the release of hazardous energy during service or maintenance activities.

Delta Air Lines[6]

Due to ground operations safety concerns, the Delta leadership team made several requests to the Atlanta Airport Authority asking that they repaint the clearance lines in the international concourse. However, the requests were ignored until Delta presented the results of a Ramp Operations Safety Audit (ROSA) at an airport operator meeting. ROSA is considered an effective communication tool and a critical component of Delta's SMS. ROSA data are reactive in addressing existing problems and proactive in helping the leadership team form goals and objectives with a reasonable timeline.

The ROSA data illustrated serious problems caused by the missing clearance lines. The Atlanta Airport Authority was convinced of the urgency in repainting the clearance lines by the ROSA data. Following repainting, ground equipment operators have consistently obeyed the rule of parking outside the clearance lines when airplanes are not at the gate. This practice has been consistently implemented across six different concourses. Consequently, parking violation-induced ground equipment damage and occurrence of FOD on the ramp have decreased. The ready availability of the equipment has also improved significantly.

Qantas Airways[7]

In January 2008, Qantas Airways successfully conducted its first Ground Operational Safety Audit (GOSA), an adaptation of the airlines' long-established LOSA methodology to the ramp environment. GOSA was used to observe the behavior of ramp teams during aircraft turnarounds and provided quantitative data on the threats, errors, and undesirable operational states that threatened the operational safety of ground operations. GOSA provided Qantas ramp management a means of gathering data on strengths and weaknesses of the operation, interface problems, effectiveness of training, quality and usability of procedures, and a rationale for resource allocation. It has also provided quantitative and qualitative data on the processes undertaken by staff that result in work shortcuts, injury, or risk to other staff. The implementation of GOSA has resulted in positive tangible outcomes for Qantas. Many simple day-to-day procedures have been adapted to reflect the results of the audits. This has had the beneficial effects of streamlining ramp practices and contributing to staff engagement.

GOSA has allowed Qantas to gather data on the work practices of external ramp service providers, and subsequently work with those providers to eradicate ineffective procedures. Qantas was then able to further satisfy its customers by ensuring compliant, efficient, and cohesive ramp service.

Air Transport Association (ATA) Human Factors Task Force

In December 2008, a group FAA and Saint Louis University researchers researchers began collaborating with the Air Transport Association (ATA) Maintenance and Ramp Human Factors Task Force (ATA HF Task Force). The Task Force developed M-LOSA and R-LOSA forms, training documentation, and the base structure for data warehousing and reporting. Development progressed through numerous consultations, combined with iterative development, testing, and refinement. The development of the maintenance and ramp LOSA forms, procedures, and software involved a core team of approximately 30 experts from the maintenance, ramp, and human factors communities. The team produced more than 20-line, base maintenance, and ramp operations forms designed for use in various LOSA audits (see sample, Appendix).

Form Development

The ATA HF Task Force found that forms comprising a combination of checklists and comments would be more effective for this domain, rather than the narrative method used with the flight deck LOSA.

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[6] The information in this section is based on personal communication with Mr. Alex Vargas, Manager of Aviation Safety, Delta Airlines ROSA (A. Vargas, personal communication, February 19, 2009).

[7] The information in this section is based on personal communication with Shaun Trimby, Coordinator Human Factors and Safety Programs, Qantas Airways (S. Trimby, personal communication, March 5, 2009).

The forms and checklists were constructed to reflect the procedures followed by maintenance and ramp workers. Maintenance forms are based on procedures such as *Troubleshooting* and *Prepare to Install* with ramp forms based on procedures such as *Downloading* and *Uploading*. The line items on the forms follow the general flow of activities found during each procedure. This makes it easier for a LOSA observer to locate where a particular item should be recorded. If the observer encounters activities, threats, and errors that are not encompassed by the forms, he or she is instructed to address these items in detail in the general comments for that form.

The most common categories of threats and errors (e.g., fatigue, incorrect maintenance manual) are assigned codes. The codes provide the ability to query and analyze the data more quickly and in ways not possible (e.g., inferential statistics) with a largely narrative approach. The comments provide additional detail that can be accessed as needed but come with the drawback of requiring more time to read, comprehend, and interpret the information.

Beta Testing

After initial development of the forms, beta testing allowed input from more than 100 maintenance technicians and ramp personnel. We conducted beta tests for ramp, line maintenance, and base maintenance at numerous locations across the United States. The task force selected Part 135 and Part 121 carriers representing both passenger and cargo operations for beta testing. For each beta test, a team of 10-15 experts were deployed. LOSA trainers preceded the team to prepare the maintenance and ramp workers for being observed and to train a carefully chosen team to conduct the initial observations. The instructors provided information on the basics of LOSA, including the confidential, non-jeopardy characteristics of the observations, as well as detailed training on how to conduct a LOSA including the recording and coding of data.

The task force beta testing team remained on site and answered questions and recorded feedback throughout the initial weeks of testing. Following each shift, we debriefed and addressed questions and captured lessons learned on LOSA procedures and checklist content. The task force discussed the lessons learned at ensuing meetings and made changes as necessary.

Database Development

Databases were created to streamline audit information. Currently, users enter data collected from audits into an Access® database for future analyses and reporting. Efforts are underway to develop a more robust and powerful software tool based on Structured Query Language. The tool under development will allow LOSA teams to enter the data from a virtually unlimited number of LOSA observations. The new system will also allow connections from a greater number of observers, stations, and organizations. These factors are critical as the numbers of observations are anticipated to rapidly extend into the thousands.

Training

Training was developed to ensure effective implementation of the LOSA program that described the purpose of LOSA, theoretical foundation (TEM model), how to conduct a LOSA via the checklist forms, and data management. Computer-based training via scenario-based, guided presentation allows companies the flexibility to introduce the basics of LOSA while considering practical examples. The training materials provide the necessary background to prepare LOSA observers who have no background in TEM or LOSA. The initial training module provides an introduction to threat and error management, how it relates to the maintenance or ramp environment, and the initial foundation for LOSA. The second module in the training provides detailed information on LOSA, how and why it was developed, previous successes, and what it means for ramp and maintenance workers. The third and final module provides the observers with scenario-based practice. The scenarios allow the observer to experience a distilled version of several real-world observations, practice recording the data, and the chance to review what LOSA experts have recorded for each scenario.

The task force's goal was to develop a practical, customizable, and scalable methodology and deliver it to the industry as a part of a freely available toolset. The culmination of that goal was realized when the ATA HF Task Force released the M-LOSA and R-LOSA forms, procedures, software, and training materials for the public on the Internet (https://hfskyway.faa.gov/HFSkyway/LOSAHome.aspx).

Conclusions

This report provides a review of the development and implementation of flight deck LOSA, as well as description of attempts to transit LOSA to aviation maintenance and ramp operations. The R-LOSA and M-LOSA methodologies aim to use pre-identified *visible precursors* to ramp or maintenance events, thus ensuring an efficient, reliable, and valid audit of normal activity.

Precursors may lay hidden for years waiting for the chance to team up with other factors to cause an incident. The R-LOSA and M-LOSA audits are expected to encourage behavior change in ramp and maintenance operations and allow sub-units of an organization to build in some flexibility to address their key problems and conquer them one at a time. The periodic audits can help ensure that specific problems identified have been resolved, as well as assess the effectiveness of safety recommendations.

The development of R-LOSA and M-LOSA will build upon existing knowledge regarding safety across high-consequence industries. In particular, the impact of observation of normal behaviors in the aircraft maintenance and ramp operations will help qualify and quantify the efforts made by aircraft mechanics and ramp agents to prevent or reduce incidents and accidents.

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A Mixed Method Approach to Runway Incursion Rating

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Abstract

Reduction of runway incursions has been a top strategic objective for the Federal Aviation Administration (FAA) for the last decade. The purpose of this study was to illuminate the underlying factors contributing to runway incursions using a mixed methods analysis of quantitative Runway Safety Office (RSO) data and qualitative ASRS data. A literature review describes how the FAA RSO categorizes incursions by severity from an air traffic control perspective, primarily based on closest horizontal and vertical proximity of conflicting aircraft; and how the Aviation Safety Reporting System (ASRS) makes no provision for categorization by severity, instead primarily collecting narratives of self-reported pilot experiences. The study compares the existing RSO runway incursion categorization structure with a researcher-developed scheme for ASRS reports using mixed methods to establish if the two categorization schemes could be harmonized to achieve a greater understanding of the contributory elements of runway incursion incidents. The study rated ASRS severities higher than RSO severities, and found a number of emergent themes among ASRS reports that contribute to a more complete understanding of runway incursions.

A Mixed Method Approach to Runway Incursion Rating

For over three decades, reduction of runway incursions has been a topic of scrutiny by the Federal Aviation Administration (FAA) and the National Transportation Safety Board (NTSB). Each agency has targeted runway incursions (RI) in its strategic planning, and though various directives and initiatives have been implemented, the rate at which RIs occur continues to rise. This continuing hazard informed this study, the purpose of which was to illuminate the underlying factors contributing to RIs using a mixed methods analysis of quantitative and qualitative data.

This study addressed the research problem by exploring if the analysis of quantitative FAA Runway Safety Office (RSO) reports accurately captures the severity category and contributory causal factors involved in RI incidents. In the search for answers to the research question, this study adopted a constructivist worldview, focusing on an integrated combination of both quantitative and qualitative methodologies to discover ways to improve interpretation of runway safety data as a means to decrease RI occurrences. An etic perspective (i.e., the cultural outsider) provided by RSO reports was combined with an emic perspective (i.e., the cultural insider) provided by expert-rater participation in pilot reported incursions. The etic/emic contrast allowed for varied ontological representations of the realities of RIs and an epistemological closeness between researchers and pilot subjects. The inductive nature of this study was further in line with a constructivist view (Creswell & Plano Clark, 2011). Previous research on the application of qualitative or mixed method research design to Aviation Safety Reporting System (ASRS) reports has not to date defined quantitative or qualitative methods in the assignment of narrative reports to categories of interest, exploration of thematic trends or implementation of any qualitative study beyond reporting narrative excerpts. As such, this mixed methods study represents a novel method in this area allowing a greater depth of understanding of RI phenomena.

Adopting a scope similar to a pilot study, this research was intended to develop a credible and trustworthy ASRS categorization of RIs in support of future efforts to examine RI causality and categorization across a more comprehensive sample of airports and reports. In addition, this research provided a practical foundation for the expansion or modification of the existing ASRS data collection instrument to enable more robust categorization of data in support of the ongoing global aviation goal of runway incursion mitigation. An explanatory sequential mixed methods design was used, which first collected quantitative data from RSO reports generated by FAA air traffic controllers. In the next strand, expert raters simultaneously assigned quantitative severity ratings to ASRS narratives and qualitatively coded ICAO causal factors against each narrative. The FAA RSO and ASRS severity ratings were quantitatively compared. The qualitative ICAO causal codes were used to explain the quantitative results (FAA, 2010b; NASA, 2011). The quantitative and qualitative strands were both drawn upon to deduce meta-inferences from collected data.

An explanatory mixed methods design was selected because although substantial quantitative data exist on runway incursions, emic perspective qualitative data from pilot self-reports explain the mechanisms behind the persistent occurrence of RIs in greater resolution than was available through current methods of investigation. The quantitative research question was: is there a difference between pilot self-reported RI severity and RSO reported severity. The qualitative research question was: to what extent does the pilot reported qualitative narrative data from ASRS reports help to explain the quantitative results about runway incursion severity reported by the FAA RSO.

Literature Review

Runway incursions have occupied the public psyche since the catastrophic collision of two Boeing 747 aircraft on the runway at Tenerife, Spain in 1977, which killed 583 and remains the most deadly civil air disaster in history (Tarrel, 1985). As defined by the International Civil Aviation Organization (ICAO), an RI is "any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle or person on the protected area of a surface designated for the landing and takeoff of aircraft" (EUROCONTROL, 2011, p. v). The 2009 European Aviation Safety Agency (EASA) Annual Safety Review listed runway incursions in the top 10 accident categories and implemented a European Action Plan for the Prevention of Runway Incursions (EUROCONTROL, 2011). Although runway incursion rate information was not provided, EUROCONTROL states in its web-available data that total runway incursions have increased every year since data collection began in 1999 and presently there is an average of two runway incursion incidents each day in Europe with 51% attributable to pilot deviations (PD) (EUROCONTROL, n.d.).

Despite a strong European interest in stemming the ongoing incidence of RIs, the problem is far from isolated to Europe. Current figures from the FAA Runway Safety website (http://www/faa.gov/airports/runway_safety) indicate the United States rate of runway incursions per million aircraft operations has increased from 12.3 to 18.9 over the last six years, 2005 to 2010, culminating in a total of 966 reported RIs in 2010 with over 60% from PDs (FAA, 2010a). Whereas rises may in part be because of changes in RI definitions (Joslin, 2011), these figures have prompted regulators around the world to develop communications and training strategies in an attempt to mitigate the hazard. The NTSB in 1991 identified the roots of the FAA's plan for RI mitigation as originating from a 1987 FAA directive to identify the causes of RIs and to articulate a plan for mitigating the problem (Rankin II, 2008). As a result, the FAA, ICAO, EASA, and other aviation authorities increasingly have focused on runway safety over the past two decades.

In the United States, classification of runway incursions within the FAA RSO database is accomplished using a severity scale harmonized with ICAO illustrated in Appendix A as well as by type: PD, operator error/deviation, and vehicle/pedestrian deviation (FAA, 2009). Scores are generated through the use of a Runway Incursion Severity Classification Calculator, the data entry screen on which is shown in Appendix B (ICAO, 2007). The most prevalent type of runway incursions were of the PD type, defined by Flight Standards Information Management Systems (FSMIS) (2009) as actions of a pilot resulting in a failure to comply with Air Traffic Control (ATC) clearances or instructions.

To date, the primary strategies aimed at reducing RI threats have been those seeking to implement training and engineering protection by way of proposals to modify airport lighting, surface markings, signage, ground-based tracking displays, and cockpit devices (FAA, 2007). Rankin II (2008) identifies the top five most effective RI initiatives as (a) training of ground vehicle operators, (b) airport surface detection equipment, (c) stop bar lighting, (d) airport surface traffic automation, and (e) airport movement area safety system. In contrast, relatively little research exists focused on understanding the *covert* errors informing an effective mitigation strategy (Hendrickson, 2009, p. 3). While technology based initiatives undoubtedly have a place in a plan to reduce RIs, without a full understanding of the causal factors at issue, it is possible such initiatives are misguided.

A survey of relevant literature suggested addressing the issue of RIs from a phenomenological perspective may be appropriate. Interpretive phenomenological analysis has been used in a variety of contexts as a means to gain an *insider perspective* rather than simply gather objective statements (van Bekkum, Williams, & Morris, 2011, p. 200). This emic perspective is often absent from strategies for reducing error and may well provide insight into how more effective initiatives may be developed. The emphasis in this study on discovery and meaning rather than on prediction per se also made a phenomenological approach applicable, not least of all because of the ability of this approach to balance out the traditional need for overtly observable data (Osborne, 1994). Though their study is outside the direct scope of the present study, van Bekkum, Williams, and Morris (2011) provided interesting insight regarding how purposive sampling coupled with transparent phenomenological analysis can lead to the identification of what the authors generally refer to as tentative and emerging themes. Haverila, R. B. Earl, and R. N. Earl (2011) addressed content analysis of narratives in a thematic way consistent with interpretive phenomenological analysis. The researchers in this instance performed an analysis of interview responses to create a *broadly interpretive approach* where quantitative counts could be used as well as specific quotations to "…summarize important facets of the raw textual material analyzed" (Haverila, Earl, & Earl, 2011, pp. 1359-60). As a means of discovery of both manifest and latent content, both thematic and content analysis have been established as robust methodological approaches; however, neither thematic nor content analysis have been previously demonstrated in assessment and interpretation of narrative RI reports.

Available literature also indicated a focused application of qualitative or mixed method research design to ASRS analysis has been only superficial. Tarrel (1985) approached the categorization of ASRS from what he refers to as an *epidemiological* perspective, mirroring the methodology often used in the study of influential factors of disease. Though this study is not without merit, it does not outline any defined quantitative or qualitative method in its assignment of narrative reports to categories of interest. However, Tarrel (1985) does acknowledge ASRS reports are typically used to identify unwanted behavior, despite substantial variability in the self-reported data on which to base such conclusions. Instead, it is suggested patterns of circumstance combinations, rather than behaviors may be perceived through content analysis and then used for further study. There is no evidence the conclusions from Tarrel's (1985) work were ever quantitatively evaluated or used in any further research. In 2003, National Aeronautics and Space Administration (NASA) ASRS undertook a study with similar goals in mind; however, its execution indicates that although free-form questioning was used to interview pilots who had submitted ASRS reports for an RI, there is no indication of intent to explore thematic trends or implement any qualitative study beyond reporting narrative excerpts. The report simply ends by offering an appendix of factors and recommendations gleaned from telephone interviews with pilots, reinforcing the need for further investigation in this area. NASA encourages the use of ASRS reports specifically for the *qualitative information* in report narratives (ASRS, 2011). Hendrickson's (2009) dissertation provides perhaps the most useful insight into the concept of using content analysis to investigate causal elements as reported in ASRS narratives. Hendrickson (2009) used latent semantic analysis, an information retrieval and language processing technique, to develop a classification of ASRS narratives based on human performance drivers. Hendrickson (2009) identifies several shortcomings of the ASRS structure; chief among which are the system's limited capacity for efficient analysis and the lack of any sort of reason codes or taxonomy by which reports can be classified. While Hendrickson (2009) seems to have made strides in this area, there is no specific focus on any particular kind of report. Based upon the literature available, there exists a clear need for application of methodology capable of identifying underlying causal themes in narrative reports of RI incidents.

Research Hypotheses

The two research hypotheses presented in this study were as follows: a) a significant difference exists between the runway incursion severity classification from FAA RSO reports and ASRS pilot reports, and b) thematic constructs extracted from the ASRS narratives inform a greater understanding of FAA RSO reports.

Research Methodology

Research Design

This study broadly adopted an explanatory sequential mixed methods approach, using a quantitative methodology in the data gathering and descriptive phase of the research and progressing into the qualitative realm as FAA RI data were compared with those derived qualitatively from ASRS reports (quan → QUAL = validate through additional quantitative analysis). While both quantitative and qualitative techniques were critical to the success of this research, qualitative information was prioritized because of the nature of the ASRS narrative analysis. Notably, although the authors characterize this study design as explanatory, it does share some elemental similarity with an embedded design, wherein the qualitative strand lies within a traditionally quantitative study as a means of enhancing the design. The emphasis on one type of data, in this case qualitative, is also typical of the embedded design and was embraced in the design of this research. In short, the complex nature of the problem demanded a modicum of design flexibility; and while the heart of this research lies in an explanatory methodology, readers will notice an embedded design noticeably influenced this study (Creswell & Plano Clark, 2011). Figure 1 summarizes the sequence and objectives of the subject research design.

Sampling

The data collection sites for this study were from two sources of publically available U.S. historical data: (a) Air Traffic Controller (ATC) reported RI PD type incidents from the FAA RSO database, and (b) voluntarily submitted pilot reports of RI

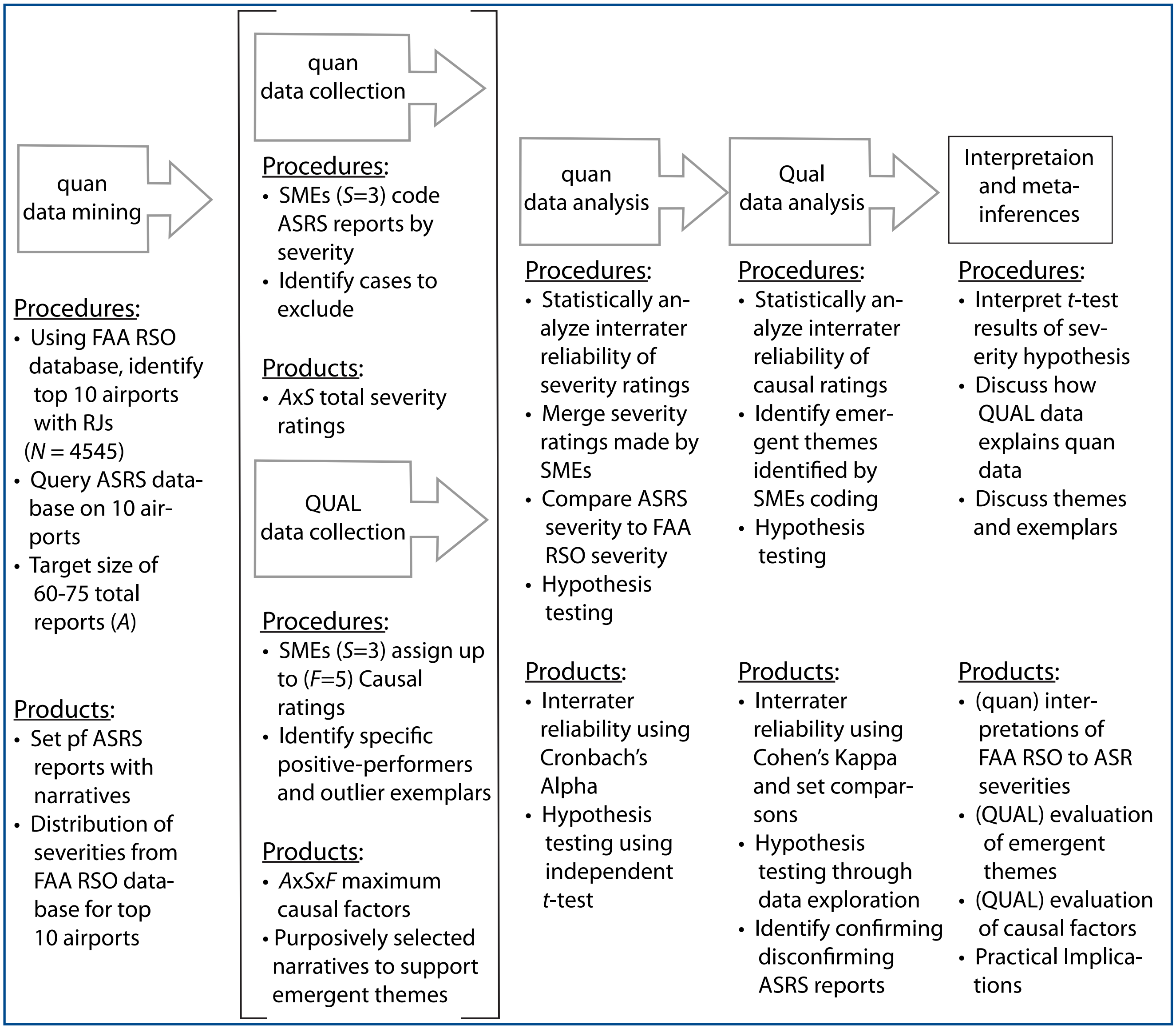

Figure 1. Sequential explanatory mixed methods analysis of runway incursions.

incidents from the ASRS database administered by the NASA. As one means of maintaining limited scope, the sample data were considered only if they stemmed from an occurrence in the last decade. This restriction allowed the researchers to focus on data for which a homogenous rating system has been adopted (ICAO, n.d.). This is to say earlier data may be subject to different coding schemes by virtue of improvements to the FAA's own data collection advancements. Rather than collecting data from every U.S. public-use airport, this research focused on purposive sampling of only the 10 airports with the highest frequency of PD-type RI incidents over the 10-year sampling frame through purposive sampling. This strategy limited the number of individual reports to be reviewed while still providing fidelity appropriate to the scope of this study. A specific, targeted search string was applied to further limit ASRS reports to PD-type RI reports. A small sample size of approximately 70 cases was determined to be appropriate for an evaluation of the ASRS textual data from open-ended narratives, as suggested by the mixed methods literature (Creswell & Plano Clark, 2011; Teddlie & Tashakkori, 2009).

Permissions

The study had no direct interaction with subjects and relied instead upon previously collected historical information. The ASRS program and federal regulations informed participants of their rights in the ASRS program, as illustrated in Appendix C, and the FAA RI reports were a reporting function of the federal government to administer air transportation safety (FAA, 2010; NASA, 2011).

Instrument

The data were recorded and collected on a researcher-developed expert rater worksheet with pull down menus to ensure standardized responses, as shown in Appendix D. Rater categories used ICAO Runway Incursion Causal Factors (ICAO, 2007) taxonomy and the FAA/ICAO Runway Incursion Severity (FAA, 2009) taxonomy as illustrated in Appendix A and Appendix E. Profiles of the three expert raters are provided in Appendix I.

Data Collection

Purposive sampling of the ASRS database provided a pool of narrative reports used for pretesting the expert raters. Initially, ratings were assigned independently without guidance or communication between the raters in an organic effort to determine the most intuitive rating scheme. The raters refined the rating methodology by combining best practices of each individual effort to apply a set of coding guidelines to the narrative review process. Allowing that each rater could have identified a boundless number of causal factors among the selected ASRS reports, they were limited to assignment of a maximum of five ICAO causal factors per ASRS report. In total, three pretest training exercises were executed with 10 random ASRS cases from airports not in the research study reports to familiarize the raters with the process and to identify opportunities for improvement in the data collection plan. Based on the training exercises the following procedures were adopted for this study:

a. Unique text for identification was recorded for each ASRS case. This acted as a data entry quality measure, as means to check if a rater may have been recording data on the wrong line.

b. Causal Factor Taxonomy of ICAO 9870, Appendix D, *Manual on the Prevention of Runway Incursions* was augmented with two additional choices developed by the expert raters.

c. ASRS cases were sorted using a random number generator.

d. Only one set of 10 ASRS cases were evaluated per day to mitigate expert rater fatigue.

e. Raters conducted their evaluation on "one pass" for each case without going back and changing ratings.

f. Cases were marked as “exception” if they did not meet the criteria for a runway incursion or if there were insufficient data.

Data collection for both hypotheses were conducted simultaneously.

Hypothesis A: RSO and ASRS Severity

In the first phase, FAA RI reports for 2000-2010 were mined quantitatively. The source of the reports was the FAA Runway Safety website (http://www.faa.gov/airports/runway_safety/statistics) and data were collected in spreadsheet format. The reports were filtered by PD-type runway incursions, and the top 10 airports by runway incursion counts were identified.

The second step was primarily a quantitative step to develop a purposive sampling of ASRS reports from the top 10 airports identified in Step 1. ASRS reports were filtered through a targeted search string, to provide in-depth information about runway incursions. The existing search engine on the ASRS website (http://akama.arc.nasa.gov/ASRSDBOnline/QueryWizard_Filter.aspx) was used (Appendix F) with the following criteria:

a. The word *incursion* in the narrative,

b. Airport identifier location of top 10 airports identified from the FAA RSO database,

c. ASRS *event type* categories specific to RI events,

d. Events occurring in between January 2000 and October 2011, and

e. Reports submitted by pilots.

The criteria were chosen to provide general alignment with the FAA quantitative sample, and to reduce the qualitative data to a size conducive to in-depth analysis. No effort was made to match the exact set of reports from the FAA RSO database and ASRS, because such an approach would be difficult at best given the anonymous nature of ASRS reports and further may have artificially limited the study because there is no requirement for ASRS reports to be submitted for every FAA RSO report. As such, some FAA RSO reports may not have corresponding ASRS reports, and the same is true for ASRS reports, which may not have a corresponding RSO report.

The ASRS reports were coded for severity by the three expert-raters. When the expert-raters believed insufficient information existed to make a rating, the raters had the option of recording the ASRS report as an exception. This is discussed further in the results section.

Hypothesis B: Causal Explanations of Severity

Using the same set of reports identified for severities in hypothesis A, causal explanations of severity differences were sought. The three expert raters identified up to five causal factors, each selected from the previously discussed ICAO taxonomy, and assigned these codes based on an analysis of each ASRS narrative. This method is consistent with the qualitative coding guideline, "…dividing the text into small units, [and] assigning a label to each unit" (Creswell & Plano Clark, 2011, p. 208). The data were recorded and collected on a researcher-developed expert rater worksheet shown in Appendix D.

The five, qualitative causal factors were collected during the same coding process used to create the severity ratings of each ASRS report. This collection method allowed the study to focus simultaneously on the quantitative and qualitative perspectives of the narrative and also apply an emic and etic perspective.

Data Analysis Method

Each hypothesis was addressed during data analysis. Hypothesis A (severity) was a quantitative analysis, while hypothesis B (causal explanations) was qualitative with quantitative assessments of transformed codes to assist in thematic discovery.

Hypothesis A: RSO and ASRS Severity

Hypothesis A was supported in three areas. These areas were FAA RSO database mining, severity interrater reliability, and severity comparisons to FAA RSO severity reports. Severity and ICAO causal codes were transformed from ASRS narratives and coded into quantitative data. Each analysis is discussed in turn.

FAA RSO database mining. The FAA RSO RI reports from 2000 through 2010 were analyzed using a Microsoft Excel pivot table, filtered to include just PD-type reports. The pivot table provided frequency counts of RSO reports by airport. The resulting sort of most frequent airport identified the top 10 airports by PD RI occurrence frequency.

FAA severity interrater reliability. Each rater determined an RI severity for each ASRS report. The rating, a letter from A to E, was recoded into a number of one to five. The normality of each rater's rating distribution was evaluated and transformations applied to achieve normality. The transformed ratings for each rater were analyzed using Cronbach's Alpha to determine a measure of interrater reliability on severity codes (Leech, Barrett & Morgan, 2008).

ASRS Severity ratings compared to FAA RSO ratings. As described in the prior section, severity codes A through E determined by each rater were re-coded to numbers one through five. When all three raters produced a severity rating for the same ASRS case, the mean rating was used to provide one numerical rating. The average ASRS ratings were compared to the FAA RSO ratings from pilot deviation type runway incursions recorded by the FAA at the same 10 airports, using an independent *t*-test.

Hypothesis B: Causal Explanations of Severity

While this data analysis was primarily qualitative, quantitative analysis of interrater reliability was first performed. Following the interrater reliability, themes were extracted and qualitatively analyzed. Each step is discussed in turn.

ICAO causal coding quantitative analysis. Each rater examined the ASRS narrative reports and assigned up to five ICAO causal codes per report, effectively re-coding the narratives into nominal, quantitative data. The nominal causal codes were quantitatively analyzed as follows:

Frequency counts. A simple frequency count was made of each ICAO causal category used by each rater. A sort of these frequency counts created thematic insight into the most common among ASRS reports examined. Further, the frequency counts allowed for identification of which ICAO causal codes were not used by any rater.

Interrater reliability. Each rater was allowed to assign between one and five nominal ICAO causal ratings per ASRS report. This coding style presented a challenge to assessment of the interrater reliability, as most statistics available expect a fixed number of codes per item, interval level coding, or only two raters. Three methods were used to assess interrater reliability.

Union of ICAO ratings. Given each rater could assign up to five ICAO causal ratings per ASRS report, this meant per ASRS report there could be 0 to 15 unique possible codes assigned, if the codes were unioned together. The union technique resulted in a distinct list of ICAO causal codes per ASRS report as well as a count of how many unioned codes were used per ASRS report.

Intersection of ICAO ratings. In contrast to the union operation per ASRS report, an intersection of ratings was also applied to each ASRS report. The intersection operation only retained those codes used by all raters per ASRS report. The intersection technique resulted in a distinct list of ICAO causal codes per ASRS report used by all raters as well as a count of these codings.

Cohen's Kappa interrater reliability. Cohen's Kappa provides a measure of interrater reliability of two raters assigning one nominal code to a list of items (Leech, Barrett & Morgan, 2008). Cohen's Kappa was run for each rater pair, resulting in three comparisons. For reach rater pair, Cohen's Kappa was run five times. Each of the five runs per rater used a structured query language (SQL) procedure to create a unique nominal string of characters representing a code for each rating. For example, the first run of Cohen's Kappa used SQL to find any one matching code per ASRS between the two raters. The second run used SQL to find two matching codes per ASRS between the two raters; the two matching codes were concatenated together to create a unique but matching nominal string between the two raters. This process continued for three, four, and five matches. When matches were not found, a unique character string per rater was inserted as a placeholder. At the end of the SQL procedure, dummy ASRS records were inserted to comply with a Cohen procedural requirement of both raters using all possible codes. The procedure resulted in a three by five set of Cohen's Kappas.

ICAO causal coding qualitative analysis. The qualitative analysis resulted from reading of the ASRS narratives and the assignment of up to five nominal ICAO causal codes. In addition to assignment of causal codes, during the rating process, narrative examples illuminating the emic meaning of the codes were identified to connect the quantitative themes to the qualitative discoveries.

The saturation coding process led to a better understanding of the ICAO causal codes as representing three themes. As such, the analysis presents ASRS themes through the lens of the three ICAO causal code themes. The qualitative codes provided a basis for identification of themes existing in the ASRS reports evaluated through frequency of occurrence. The ASRS narratives were connected to these themes to present mixed methods support of explanatory reasons for the occurrence of RIs.

Results

The data collection process was executed as described. FAA and ASRS reports were examined in detail, and the data analysis methodology was applied supportive of hypotheses A (severity) and B (causal factors). The results of this effort follow.

Results Common to Hypotheses A and B

The initial strand of results was common to both hypotheses. These common results are presented first.

FAA RSO top 10 airports. The FAA RSO database from fiscal year 2000 through 2010 reported 4,545 RI reports. Of these, 3,451 were PD-type reports. Table 1 shows the RIs sorted by frequency for the top 15 airports as reported on the FAA RSO website (http://www.faa.gov/airports/runway_safety/statistics). The study selected the top 10 airports: VGT, LAX, SNA, FXE, BOS, LGB, PDK, SAT, PRC, ATL, which yielded 484 PD-type RI reports. While LAS had more occurrences than ATL in Table 1, the data available at the start of the study placed ATL ahead of LAS, thus ATL was the tenth airport rather than LAS.

ASRS reports selected. The results of the quantitative analysis of FAA RSO reports guided the ASRS query as described in the methodology section and produced a total of 68 ASRS reports.

Table 1

Top 15 Occurrences of RIs by Airports

Airport Ident	Airport	Count
LAX	Los Angeles Intl, CA	74
VGT	North Las Vegas Airport, NV	74
SNA	John Wayne Airport-Orange Co, Santa Ana, CA	66
FXE	Fort Lauderdale Executive Airport, FL	58
BOS	General Edward Lawerence Logan Intl, Boston MA	55
LGB	Long Beach/Daugherty Field, CA	54
PDK	Dekalb-Peachtree Airport, Atlanta, GA	44
SAT	San Antonio Intl, TX	41
PRC	Ernest A Love Field, Prescott, AZ	39
LAS	McCarran Intl, Las Vegas, NV	38
ATL	Hartsfield-Jackson Atlanta Intl, GA	37
TUS	Phoenix Deer Valley Airport, AZ	37
DVT	Tucson Intl, AZ	37
CCR	Buchanan Field, Concord, CA	35
ADS	Addison Airport, Dallas, TX	34

Rater coding results. Each rater worked independently creating three sets of codes. The rater results are presented in Appendix G. Each rater had the option of marking an ASRS report as an exception; for example when the report was not a PD type report or a report was not made by the crew involved in the RI. It was decided an exception existed if at least two raters identified a report as such. Application of this rule resulted in 14 records being eliminated from analysis, yielding the ASRS identification numbers shown in Table 2. Thus out of 68 total ASRS reports, only 54 were used in subsequent quantitative and qualitative analysis.

Table 2

ASRS Report Identifiers Excluded from Further Analysis

ASRS ID	ASRS ID	ASRS ID	ASRS ID
523642	585771	506520	561190
630406	522030	775974	560876
504850	543639	562179	913109
905932	637297	492148	

Two reports were excluded because they were submitted by air traffic controllers and thus lacked an emic, PD perspective. A report of an airborne intercept by military aircraft for a restricted airspace incursion was also excluded.

In cases for which only two out of three of the three raters opted for exclusion, the reasons varied. In six cases, reports were excluded because they dealt with taxiway errors away from the runway. The disagreeing rater believed these should be included as they were precursors to runway incursions; however they did not meet the FAA (2009) definition of a runway incursion. In another two cases, the pilot submitted ASRS described an ATC operational error. In one report, an aircraft could not clear the runway due to insufficient space on a taxiway, causing a go-around. One report was excluded because the narrative information was internally inconsistent as expressed by the pilot. Another report was exclude because the pilot missed an advisory hold short line but still held short of the mandatory hold short line. Last, a report was excluded where the pilot crossed a hold short line and taxied into position and hold. In this last excluded case, ASRS #637297, the pilot said in part,

AT BOSTON, I WAS ISSUED THE CLRNC TO TAXI TO RWY 4R… I WAS THEN ISSUED THE CLRNC TO PROCEED 'TO THE VISUAL HOLD POINT.' AFTER CLRING THE SHORT FINAL APCH COURSE, I PROCEEDED ONTO THE RWY TO THE VISUAL HOLD POINT WHERE THERE USED TO BE A SIGN TO THE L OF THE RWY INDICATING THE POINT TO WHICH ACFT SHOULD TAXI UP TO IN ORDER TO BEGIN THE TKOF RUN. I COULD NOT SPOT THAT SIGN AS IT WAS UNLIT. I SET THE PARKING BRAKE WHILE IN THE TKOF POS AND A FEW SECONDS LATER I RECEIVED A TKOF CLRNC.

For two of the raters, the aforementioned report presented an ambiguity in information suggesting controller error. However, one rater interpreted this as a clear case of taking an active runway when being told to hold short.

Hypothesis A: RSO and ASRS Severity

The severity codes assigned were analyzed. Of the 54 ASRS reports available for analysis, only 41 had a severity code assigned by all of raters. In large part this was a result of the two out of three condition for an ASRS report to be excluded. This meant if one rater thought an ASRS report should be excepted, individually a severity was not assigned. In a few cases, one or more raters rated the ASRS but failed to assign a severity code.

Interrater reliability of RI severity coding. The interrater reliability of severity codes was assessed using Cronbach's Alpha. To achieve a more normal distribution of ratings for each rater, each rating was logarithmically transformed for evaluation by Cronbach's Alpha. Even after the logarithmic transformation, one rater's distributions of severity remained slightly skewed. Cronbach's Alpha for the log of the severity was .637, which indicates the three raters achieved only minimal internal consistency (Leech, Barrett & Morgan, 2008).

Hypothesis testing of RI severity. To address the first hypothesis that a significant difference existed between runway incursion severity classification from FAA RSO reports and ASRS pilot reports coded in the study through qualitative content analysis, the mean ASRS severity score was compared to the FAA RSO reported severity. An independent-means t-test was conducted, with Table 3 displaying basic descriptive statistics, Table 4 offering a summary of the test statistics, and Figure 2 showing a graphical representation. As indicated by the Levene's statistic in Table 4, the assumption that the groups had roughly homogeneous variance was satisfied. The *t*-test revealed the code assigned by expert raters on average indicated a greater severity level (M = 2.07, SD = .73) than did FAA RI ratings (M = 3.54, SD = .66), with M=1 corresponding to the most severe level. This difference was significant $t(523) = 13.53$, $p < .01$, and represented a calculated medium-size effect of $r = .51$.

Hypothesis B: Causal Explanations of Severity

Each rater was instructed to assign between one and five ICAO causal codes to each ASRS report. The process was a qual → quan transformation.

Table 3

Severity Rating t-test Descriptive Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
Rating	FAA	484	3.54	.66	.03
	ASRS	41	2.07	.73	.11

Table 4

t-test of Severity Rating Between ASRS and FAA Reports

	Levene's		t-test						
								95% CI	
	F	Sig.	t	df	Sig	Mean Δ	SE Δ	Lower	Upper
Equal variances assumed	.001	.976	13.53	523	.000	1.47	.109	1.26	1.68

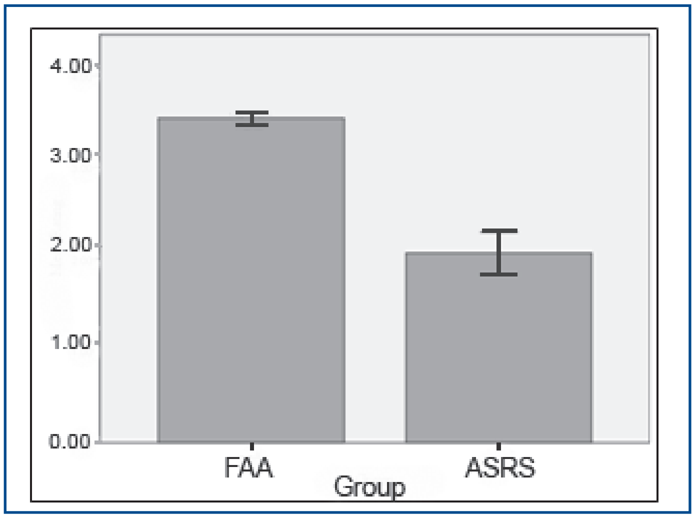

Figure 2. Error bar graph of mean severity rating by group (95% confidence interval shown).

This section discusses the various quantitative and qualitative aspects of the qualitative coding, including measures of interrater reliability.

Groupings of ICAO causal codes. During training and pre-testing rating exercises, it was decided to supplement the ICAO causals codes with two additional codes, 2.5.1, *Crew Coordination*, and 2.5.2, *Did Not Read Back Clearance*, to avoid overuse of the broad *other* categorizations. Through the coding process it was discovered the codes used represented three broad themes of classifications: descriptive, causal, and contributory, which are presented in Table 5. The clas-

Table 5

ICAO Causal Codes Classification

Code	Description
Descriptive	
2.4.5	Entered the runway after being instructed to "hold short"
2.4.6	Lined up on the runway after instruction to taxi to the runway-holding position (point)
2.4.7	Took off without a clearance after being instructed to "line up and wait"
2.4.8	Took off without a clearance after being instructed to taxi to the runway-holding position (point)
2.4.9	Landed or departed on the wrong runway
2.4.10	Landed or departed on the taxiway
Causal	
2.1.3	Accepted a similar aircraft's clearance: • with similar call signs • without similar call signs
2.2.6	Crew mistook their position on the aerodrome (thought they were in a different location)
2.2.8	Reported incorrect location to ATC
2.2.9	Taxied fast
2.4.1	Misunderstood clearance: • conditional • follow • other
2.4.4	Forgot part of the clearance or instruction
Contributory	
2.1.1	Transmission was completely blocked
2.1.2	Transmission was partially blocked ("stepped-on")
2.1.4	Deviation from established ICAO standard phraseologies
2.1.5	Used other than ICAO language requirements for air-ground radiotelephony communications (language normally used by the station on the ground or the English language) in a situation not covered by ICAO standard phraseology
2.1.6	Used language not in accordance with ICAO language requirements for air-ground radiotelephony communications (language normally used by the station on the ground or the English language)

Code	Description
2.1.7	Speech quality: • not proficient in ICAO language requirements for air-ground radiotelephony communications (language normally used by the station on the ground or the English language) • poorly enunciated or heavily accented • spoken rapidly • spoken with an inconsistent volume
2.1.8	Did not use headsets
2.1.9	Received clearance or instructions during periods of high cockpit workload
2.1.10	Did not advise ATC of a delay on the runway prior to take-off
2.2.1	Crew conducting checklists while taxiing
2.2.2	Crew member programming flight management system or other flight deck system while taxiing
2.2.3	Crew member was on another radio frequency
2.2.4	Competing radio communications
2.2.5	Unfamiliar with the aerodrome layout
2.2.7	Fatigue
2.2.10	Did not refer to the aerodrome diagram
2.2.11	Did not listen to the automatic terminal information service (ATIS)
2.2.12	Works on the maneuvering area were not previously advised by NOTAM
2.2.13	Used out-of-date or inaccurate publications or charts
2.2.14	Failed to apply or correctly observe sterile cockpit procedures
2.3.1	Not ICAO-compliant
2.3.2	Not provided
2.3.3	Irregularly spaced
2.3.4	Ambiguous and difficult to follow
2.3.5	Poorly sized
2.3.6	Poorly situated
2.3.7	Poorly maintained
2.4.2	Flight crew did not ask for clarification when they did not understand a clearance or instruction
2.4.3	Did not inform ATC when could not comply with a clearance
2.5.1	Crew Coordination (Non-ICAO, rater-developed code)
2.5.2	Did not readback clearance (Non-ICAO, rater-developed code)

sifications improve the discussions informing the results.

Frequency of ICAO code use. Of the 45 total codes available, 16 were not used by any rater and the remaining 29 were used at least once by one rater. The frequency of ICAO code use is shown in Table 6 ordered from most used to least used. Codes not used by any rater are shown in Appendix H.

Across the 54 ASRS reports retained in the study, in total 439 codes were assigned. Six codes were used under a 60% cumulative threshold. All the unused codes and the top six used codes are shown in Table 7 grouped by the ICAO classification themes.

Table 6

Frequency of ICAO Code Use by All Raters

Count	Cum Count	Cum Pct	Code	Description
77	77	18%	2.4.5	Entered the runway after being instructed to “hold short”
52	129	29%	2.5.1	Crew Coordination
48	177	40%	2.4.1	Misunderstood clearance: • conditional • follow • other
30	207	47%	2.4.2	Flight crew did not ask for clarification when they did not understand a clearance or instruction
23	230	52%	2.2.5	Unfamiliar with the aerodrome layout
22	252	57%	2.2.1	Crew conducting checklists while taxiing
18	270	62%	2.2.7	Fatigue
15	285	65%	2.2.2	Crew member programming flight management system or other flight deck system while taxiing
15	300	68%	2.2.6	Crew mistook their position on the aerodrome (thought they were in a different location)
13	313	71%	2.3.6	Poorly situated
12	325	74%	2.5.2	Did not readback clearance
11	336	77%	2.2.4	Competing radio communications
11	347	79%	2.4.6	Lined up on the runway after instruction to taxi to the runway-holding position (point)
10	357	81%	2.1.9	Received clearance or instructions during periods of high cockpit workload
10	367	84%	2.3.4	Ambiguous and difficult to follow
8	375	85%	2.1.3	Accepted a similar aircraft’s clearance: • with similar call signs • without similar call signs
8	383	87%	2.2.15	Other (please specify).
8	391	89%	2.2.3	Crew member was on another radio frequency
7	398	91%	2.4.4	Forgot part of the clearance or instruction
6	404	92%	2.2.10	Did not refer to the aerodrome diagram
6	410	93%	2.2.9	Taxied fast
6	416	95%	2.3.7	Poorly maintained
5	421	96%	2.1.2	Transmission was partially blocked (“stepped-on”)
5	426	97%	2.4.11	Other (please specify).
4	430	98%	2.4.7	Took off without a clearance after being instructed to “line up and wait”
3	433	99%	2.1.4	Deviation from established ICAO standard phraseologies
3	436	99%	2.2.13	Used out-of-date or inaccurate publications or charts
2	438	100%	2.4.3	Did not inform ATC when could not comply with a clearance
1	439	100%	2.3.2	Not provided

Table 7

Top Six ICAO Codes and Unused Codes Grouped by Study Identified Themes

Code	Count	Description
Descriptive		
2.4.5	77	Entered the runway after being instructed to "hold short"
Causal		
2.4.1	48	Misunderstood clearance: • conditional • follow • other
Contributory		
2.2.1	22	Crew conducting checklists while taxiing
2.2.5	23	Unfamiliar with the aerodrome layout
2.4.2	30	Flight crew did not ask for clarification when they did not understand a clearance or instruction
2.5.1	52	Crew Coordination
UNUSED CODES		
Descriptive		
2.4.10	0	Landed or departed on the taxiway
2.4.8	0	Took off without a clearance after being instructed to taxi to the runway-holding position (point)
2.4.9	0	Landed or departed on the wrong runway
Causal		
2.2.8	0	Reported incorrect location to ATC
Contributory		
2.1.1	0	Transmission was completely blocked
2.1.10	0	Did not advise ATC of a delay on the runway prior to take-off
2.1.5	0	Used other than ICAO language requirements for air-ground radiotelephony communications (language normally used by the station on the ground or the English language) in a situation not covered by ICAO standard phraseology
2.1.6	0	Used language not in accordance with ICAO language requirements for air-ground radiotelephony communications (language normally used by the station on the ground or the English language)
2.1.7	0	Speech quality: • not proficient in ICAO language requirements for air-ground radiotelephony communications (language normally used by the station on the ground or the English language) • poorly enunciated or heavily accented • spoken rapidly • spoken with
2.1.8	0	Did not use headsets
2.2.11	0	Did not listen to the automatic terminal information service (ATIS)
2.2.12	0	Works on the maneuvering area were not previously advised by NOTAM
2.2.14	0	Failed to apply or correctly observe sterile cockpit procedures
2.3.1	0	Not ICAO-compliant
2.3.3	0	Irregularly spaced
2.3.5	0	Poorly sized

Interrater reliability measures. Three quantitative analyses were performed to assess ICAO code interrater reliability: union, intersection, and Cohen's Kappa.

The union and intersection of rater coding is shown in Figure 3. The union of ratings shows a mode between five and six ratings. Given the maximum possible ratings for three raters permitted to assign up to five codes is 15, a mode between five and six provides some indication of interrater reliability. The intersection of ratings shows a rapid drop off from one to two common ratings amongst all raters.

Finally, the Cohen's Kappa procedure outlined in the method section was performed. The Kappa statistic is plotted in Figure 4. Similar to the intersection of Figure 3, there is a rapid drop off in convergence for all rater pairs after two causal factors.

Discussion

The quantitative and qualitative results presented provide measures of severity code comparison and relations to runway incursion causation themes.

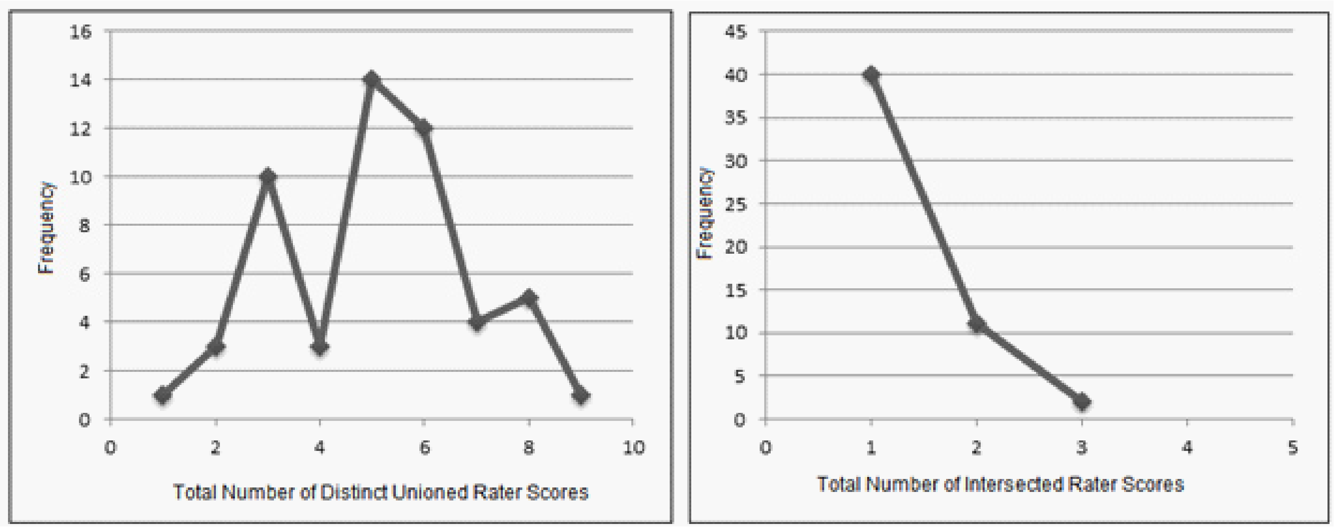

Figure 3. Rating union among ASRS reports and three raters.

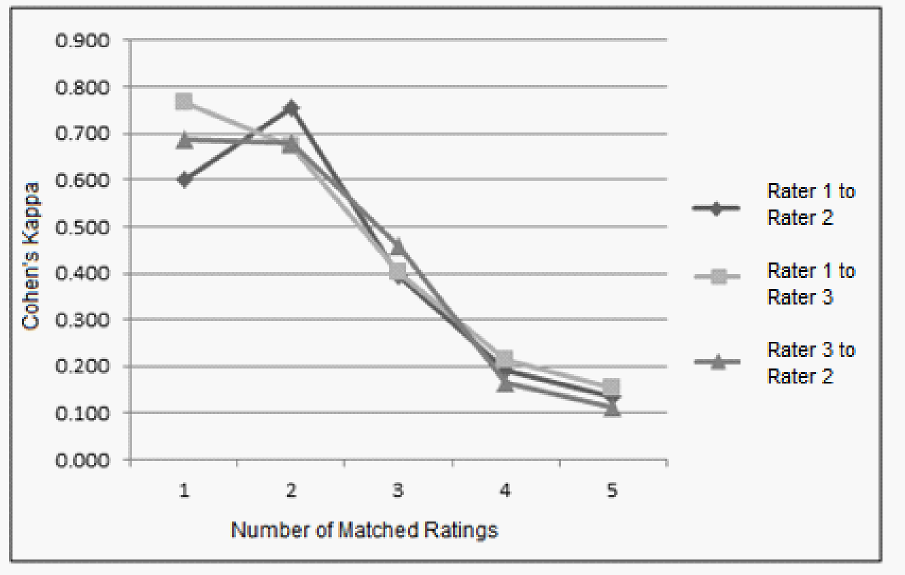

Figure 4. Cohen's Kappa by rater pair at rating code agreement levels.

These results are discussed and interpreted in this section.

Hypothesis A: Severity Comparisons

There was a statistically significant difference ($p < .01$) between the severity of the FAA RSO reports and the ASRS reports investigated. One possible inference based on this difference is only RI events perceived as being relatively severe trigger a pilot report via the ASRS system. The obverse being for cases in which a pilot is either unaware of an incursion or where the event appears to a pilot involved to have little potential for a catastrophic outcome, no report will be filed. However, because the query methodology was focused on reducing the sample ASRS data down to only 70 cases for the purpose of qualitative analysis, the study could not find confidence in the severity *t*-test significance and effect alone.

However, as each ASRS report was read, the raters agreed many reports rated as A or B severity were likely not so by the FAA RSO rating standard. This is because the FAA RSO rating standard is based upon temporal and aircraft proximity conditions. To wit, if an aircraft taxied onto an active runway after being told to hold short, the FAA RSO database would rate the event as a C if no other aircraft were in the vicinity; but all raters agreed this type of occurrence turned out to be an A or B on our scale, depending on *why* the crew erred. This explanatory emphasis is further explained as emergent themes are investigated.

Hypothesis B: Causal Explanations

The causal themes presented in Table 5 and the frequencies of use were used to guide the review of qualitative examples of explanatory ASRS reports. The review of these reports reinforced the strong explanatory nature of this study, allowing the raters, in effect, to become a part of each scenario through the rich narrative data. The natural inference is the emic awareness of the peculiarities of each event explains the statistically significant difference between the raters' own severity ratings and those assigned in the mined FAA RSO reports.

Descriptive theme: Code 2.4.5. The most frequent causal code used was 2.4.5, *Entered the runway after being instructed to "hold short."* This code is descriptive and relates what happened but not necessarily why it happened. ASRS report #577552 was an example of where all three raters agreed on the use of 2.4.5,

> TWR CLRED US TO 'TURN L ON TXWY L' AND HOLD SHORT OF RWY 19L, ACR'S USE RWY 19R. NORMALLY, WHEN TWR CLRS YOU TO 'TURN L ON TXWY L' YOU ARE CLRED TO CROSS RWY 19L AND HOLD SHORT OF RWY 19R. NOT THIS TIME. WE WERE CLRLY TOLD TO HOLD SHORT OF RWY 19L. I EVEN REPEATED THE CLRNC TO THE FO. AFTER TURNING L ON TXWY L I THEN, OUT OF HABIT, CROSSED THE RWY 19L HOLD LINE AND WOULD HAVE CROSSED ONTO THE RWY EXCEPT I SAW A SMALL PLANE ON SHORT FINAL FOR RWY 19L.

In this example, the pilot stopped, but it is a fairly typical example of the hold short code. It was found many ASRS reports had emic suggestions. The reporter in #577552 went on to say,

> THE POINT IS, I DISTINCTLY HEARD THE CLRNC TO HOLD SHORT OF RWY 19L, EVEN REPEATED IT, BUT STILL, OUT OF HABIT, INTENDED TO CROSS RWY 19L AND HOLD SHORT OF RWY 19R AS USUAL. UNTIL NOW I THOUGHT RWY INCURSIONS WERE THE RESULTS OF NOT PAYING ATTN (I'VE NEVER DONE THIS IN 30+ YRS OF FLYING). NOW, EVEN I CAN'T EXPLAIN WHY I DID THIS.

The authors were impressed with the frankness of the pilot, which speaks highly of the trust in the ASRS system. The pilot's observation of habit patterns are an important theme, found absent from the ICAO coding system.

Contributory theme: Code 2.5.1. The second most frequent causal code used was a code of 2.5.1 for *Crew Coordination*, which was developed by the expert raters during the training/pre-test exercise. This code is causal and relates why the event happened. ASRS report #638598 was an example of failure to follow basic crew coordination procedures as perceived by the first officer.

> AS WE APCHED RWY 33R/15L, I TOLD THE CAPT WE NEEDED TO HOLD SHORT OF RWY 33R. HE CONTINUED TO TAXI. I SAID AGAIN TO STOP THE ACFT UNTIL WE HAD A CHANCE TO TALK WITH GND CTL. THE CAPT SAID THAT THE RWY WAS NOT ACTIVE, THEREFORE, IT WAS OK TO CROSS WITHOUT CLRNC. I STRONGLY DISAGREED AND SAID FOR THE THIRD TIME TO HOLD SHORT. THE CAPT DID NOT, AND WE CROSSED RWY 33R/15L. FURTHERMORE, HIS LACK OF CRM IN THIS SIT WAS UNACCEPTABLE. HE DID WHAT HE WANTED TO DO.

Causal theme: Code 2.4.1. Cases of *misunderstood clearance*, causal code 2.4.1, were also the subject of frequent rater agreement. ASRS report #578955 provides insight as a case fairly typical of those observed with misunderstood clearances. This report also captures the common contributing factors observed in such scenarios. The pilot describes possible causative factors to the incursion as crew inexperience, being rushed, and expectancy:

> IT WAS THE LAST LEG OF THE DAY, THE LAST DAY OF A 4-DAY. MY FO WAS VERY NEW… TOO MANY THINGS HAD BEEN TOO UNUSUAL IN THE LAST FEW MINS…. I HAD A ROCK SOLID EXPECTATION THAT WE WERE GOING TO TAKE OFF ON THE L. THAT'S THE WAY IT ALWAYS IS AND DURING PUSH, GND CTL EVEN SAID 'PUSH FOR RWY 24L.' I WILL NOT MAKE THESE ASSUMPTIONS IN THE FUTURE AT LAX, OR ANYWHERE ELSE.

As with many of the reports reviewed, emic messages from the reporter are clear. The pilot noted many times his own disappointment that a miscommunication had led to an incursion, stating:

> I DID A RWY INCURSION. I AM VERY DISAPPOINTED WITH MYSELF. I KNOW HOW DANGEROUS THIS MISTAKE IS AND THE EMPHASIS THE COMPANY PUTS ON IT… AGAIN I SAID, 'SORRY FOR THE MIX-UP.' TWR SAID, 'NO PROB'… IT WAS MY FAULT, PERIOD. I ALWAYS THOUGHT IF I EVER DID SOMETHING LIKE THIS, IT WOULD BE AT AN UNFAMILIAR FIELD AND IN BAD VISIBILITY.

The pilot's commentary from an ASRS report adds a level of depth to an event not captured in FAA RSO reports, and the authors were convinced by such communication the hypothesis that thematic constructs extracted from ASRS narrative data are valuable in informing a greater understanding of runway incursion events may be supported.

Contributory theme: Code 2.4.2. The analysis also identified failure to ask for *clearance clarification,* 2.4.2, as a theme in many cases. All raters agreed ASRS report #528006 provided an example of an avoidable incursion had the pilot simply asked for clarification:

> …THE CTLR ALSO TOLD THE LNDG AIRPLANE THAT THERE WOULD BE 2 DEPS PRIOR TO HIS ARR, WHICH THE PLT ACKNOWLEDGED. THEN THE EVENTS LEADING UP TO AN ALMOST CERTAIN INCURSION BTWN MYSELF AND THE LNDG ACFT BEGAN. SINCE THERE WAS JUST MY AIRPLANE AND THE AIRPLANE STILL HOLDING SHORT AT RWY 2L, I KNEW WE WERE THE 2 ACFT TO DEPART PRIOR TO THE ARRIVING ACFT. I THOUGHT IT STRANGE WHEN THE CTLR THEN CLRED THE ACFT HOLDING SHORT OF RWY 2L TO CROSS OVER RWY 2L FOR RWY 2R. WHAT I THOUGHT HE SHOULD HAVE DONE FIRST WAS TO CLR ME FOR TKOF. HE THEN TOLD ME TO TAXI INTO POS AND HOLD ON RWY 2L. I THOUGHT SOMETHING WAS AMISS AND SHOULD HAVE QUESTIONED HIM, BUT I THOUGHT

> HE KNEW WHERE I WAS AND SURELY MEANT RWY 2R OF MAYBE HE SAID 2R AND I JUST THOUGHT HE SAID 2L. I BEGAN TO TAXI ONTO RWY 2R AND THEN I HEARD THE CTLR SCREAM MY TAIL NUMBER TO STOP.

When the pilot says, "…I thought something was amiss and should have questioned…," is not uncommon. Many cases were seen where the pilot had an inner feeling something was not right. In ASRS report #579253, the pilot notes,

> …THE FO AND I BOTH HAD OUR ARPT DIAGRAMS OUT AND WERE DISCUSSING 'WHAT DID THE CTLR SAY?' I HAD BEEN TAXIING VERY SLOWLY, AND WAS ALMOST STOPPED SO THAT WE COULD GET A CLARIFIED CLRNC WHEN THE CTLR CALLED US AND TOLD US TO 'HOLD SHORT OF RWY 4L.'

Similar to #528006, the raters noted a pilot sensing an impending problem. In this case the pilot slowed and avoided an incursion; however, the controller still issued a go-around to another aircraft because the aircraft's intentions were not clear to the controller.

Contributory theme: Code 2.2.5. While 2.2.5, *unfamiliar with aerodrome layout*, was within the top six, the authors were surprised it was not more highly rated. ASRS report #545129 succinctly epitomized the code 2.2.5,

> …BOS HAS A BRAVO HOLD POINT AND BOTH CAPT AND FO DISTR BY DISCUSSING PROPER TAXI RTE TO HOLD POINT BRAVO -- BOTH FO AND CAPT SPENDING A LOT OF TIME LOOKING DOWN AT ARPT DIAGRAM. CONTRIBUTING FACTORS: 1) DISTR IN COCKPIT AS BOTH FO AND CAPT REFERRING TO ARPT DIAGRAM -- UNFAMILIAR WITH ARPT…

Similar to nearly all the reports rated, there were multiple factors at play; unfamiliarity was often accompanied by other distractions as noted in this report.

Contributory theme: Code 2.2.1. The last high ranking theme was 2.2.1, *crew conducting checklists while taxiing*. ASRS report #541888 presented this example,

> …AS THE PLT WAS TAXIING I [co-pilot] WAS RUNNING THE CHKLIST THEN PROGRAMMING THE FMS FOR OUR RTE FROM KBOS AND VERIFYING THE RTE ON THE LOW ALT ENRTE CHARTS. AFTER PROGRAMMING THE FMS WHILE THE FLYING PLT WAS STILL TAXIING. I WAS THEN STUDYING THE LOGAN 2 DEP PROCEDURE FOR RWY 27 AND FINDING THE DEP FREQUENCY WE WOULD EVENTUALLY NEED. AT THIS POINT BOSTON - LOGAN GND ISSUED US THE FOLLOWING TAXI CLRNC, 'ACFT X CROSS RWY 33L ON D AND TAXI TO RWY 27 CONTACT 128.8.' WHILE I READ BACK THIS CLRNC LOOKING-UP FROM THE DP AND CHANGING FROM 121.9 TO 128.8 THE PLT HAD MADE A L TURN ON G INSTEAD OF D AND TAXIED ONTO RWY 33L…

While in this case the co-pilot discussed fatigue issues, the distraction element was quite clear. This report had a unique aspect in that the ASRS data set had put the captain's and copilot's opinions together into the same report. The captain's perspective was,

> … BEFORE LEAVING FBO PARKING RAMP PLT ASKED CO-PLT FOR ARPT DIAGRAM. PLT REVIEW ARPT TAXI RTS AND UNDERSTOOD CLRNC. PLT HANDED THE ARPT DIAGRAM BACK TO CO-PLT FOR HIM TO FOLLOW ALONG DURING TAXI…A CLRNC WAS ISSUED BY THE GND/TWR CTLR (SAME PERSON AT BOTH POSITIONS) TO CROSS RWY 33L. THE CREW BELIEVED THEY WERE ON TXWY G PROCEEDED ONTO RWY 33L. THE PLT REALIZING HE WAS ON THE WRONG TXWY MADE A 180 DEG TURN TO EXIT RWY 33L AT TXWY G. THE CO-PLT WAS HAVING DIFFICULTY COM WITH GND/TWR CTLR AT WHICH

> TIME THE PLT MADE CONTACT AND ANNOUNCED CLR OF RWY 33L AT INTERSECTION G.

The raters were struck by the different perspectives of the captain and co-pilot describing the same event. While avoidance of self-incrimination may explain part of the difference, the raters believed there were genuine issues of disagreement and also thought the co-pilot summarized the crew distraction issue effectively by saying,

> THE POSSIBLE CORRECTIVE ACTION WOULD FOR ME AS A CO-PLT NOT TO TOTALLY RELY ON THE PLT TO TAXI WHILE I AM BUSY WITH OTHER CO-PLT DUTIES AND TO BOTH JUST CONCENTRATE AT THE TASK AT HAND TAXIING AT A MAJOR ARPT AT NIGHT TO PREVENT ANY RWY INCURSIONS.

The raters wholly agreed with the self-evident assessment made by the co-pilot. As the raters immersed themselves in the emic perspective, assessment of this closing comment was consistent with the overarching theme of inadequate crew coordination.

Airport Layout Issues

In the emic examination of ASRS reports, each rater noted certain airports have limited maneuvering areas after landing, such as the parallel runways at LAX, inherently causing problems difficult to address through hot spots alone.

There appear to be remaining airport layout issues for accommodating larger aircraft at some older airports. These airports may have been designed before the introduction of larger aircraft, coupled with busier operations in which aircraft can get *stacked up*. It also appears the predominance of runway/taxiway signage and lighting issues may have been fixed, because there were very few ASRS comments in this area.

Conclusions

The qualitative analysis of ASRS narratives provided greater understanding of the FAA RSO reports and indicated the most commonly observed scenario for runway incursions were aircraft entering the runway, after being told by ATC to hold short, when the crew misunderstood the clearance and failed to request clarification. Overarching themes characterized by these events included reliance by crews on assumptions and expectations as well as poor crew coordination skills, especially during conditions of unusually high workload or unfamiliar airport surroundings.

The literature review demonstrated a need for further analysis of RI incidents by illuminating the very rigid structure in which FAA RI data is currently examined and understood. Research in dissimilar fields has much to offer in terms of textual analysis as a means of identifying emerging trends, arguably a first step toward validating and targeting mitigation techniques. Through the application of explanatory sequential mixed methods research to elucidate the significant difference between RSO severity classification and those assigned by expert raters tasked with achieving a deeper awareness of the situational circumstances unique to each event, this study contributed to the understanding of the complex causality of RI cases. This study informs further research in the domain to build toward a more comprehensive understanding of how future runway incidents can be prevented.

Future Research Directions

Controls, or aviation system defenses, for managing and reducing the risk and controlling runway incursion hazards have been grouped by ICAO under the three general categories of technology, training, and regulations (ICAO, 2008, p. 5-ix). This study indicated the best mitigation strategy may be to focus future research on training, specifically in the areas of pilot-controller communication and crew coordination. As research in this area continues toward maturity, the results of this study suggest substantial gains in understanding the nature of the problem may be achieved through careful thematic analysis. While emerging themes were identified in this study in a relatively rudimentary fashion and with a constrained data set, future research efforts may be best focused on analytical techniques, such as those discussed previously and implemented by Haverila, R.B. Earl, and R.N. Earl (2011) and van Bekkum, Williams, and Morris (2011) toward in-depth semantic content analysis. Such research may lead to evidence that RI events are rated artificially low in severity as a result of incomplete understanding of the dynamic components of each incident.

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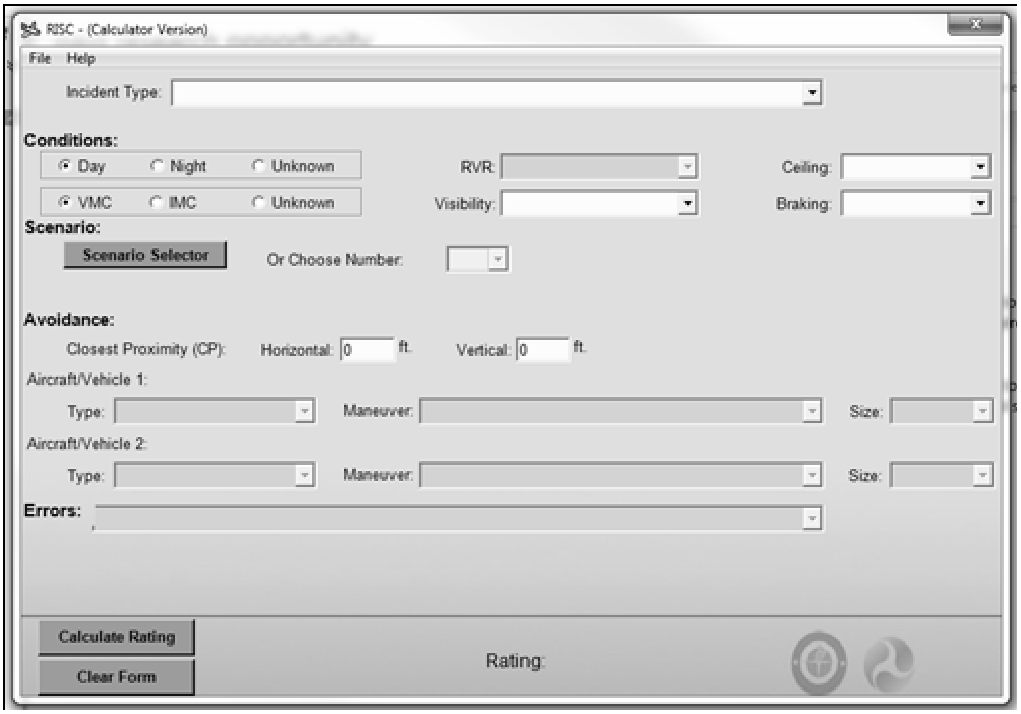
Appendix A

FAA/ICAO Runway Incursion Taxonomy for Severity

A	A serious incident in which a collision was narrowly avoided
B	An incident in which separation decreases and there is a significant potential for collision, which may result in a time critical corrective/evasive response to avoid a collision.
C	An incident characterized by ample time and/or distance to avoid a collision.
D	Incident that meets the definition of runway incursion such as incorrect presence of a single vehicle/person/aircraft on the protected area of a surface designated for the landing and take-off of aircraft but with no immediate safety consequences.
Not Defined	(FAA non-conflict surface incidents include more than just ICAO class "D" events)
E	Insufficient information inconclusive or conflicting evidence precludes severity assessment.

Appendix B

Runway Incursion Severity Classification (RISC) 4.2



● Day ○ Night ○ Unknown

● VMC ○ IMC ○ Unknown

Horizontal: 0 ft.

Vertical: 0 ft.

Personality and Motivational Needs in Indian Military Pilots

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Abstract

Research on cultural differences provides a different aspect of the attributes in pilots that might affect job performance. Basic attributes of personality and motivation are of importance for military aviators to maintain optimal personal effectiveness, flying proficiency and safety in aviation. Ninety military pilots were assessed on the Edwards Personal Preference Schedule (EPPS), and the Revised Neuroticism Extraversion and Openness Personality Inventory (NEO-PI-R). The results of this study showed that Indian aircrew were lower on achievement, dominance, change and heterosexuality when compared to American aircrew. They were significantly higher on other needs such as affiliation, deference, order, succorance, abasement and nurturance. The results on the NEO-PI-R showed that the group was significantly higher on neuroticism and significantly lower on extraversion and conscientiousness. These cross cultural differences can be attributed to the collectivistic nature of Indian culture as opposed to the individualistic nature of American culture. The findings imply that cultural factors are likely to influence personality and motivation and that this issue needs to be taken into account during aircrew selection, training and clinical evaluation.

Personality And Motivational Needs In Indian Military Pilots

The aviation scenario encompasses many demanding and challenging situations in the air and/or on the ground. The personality and motivation of the aviator are two characteristics which are likely to have their impact during demanding situations. Hence knowledge about pilot's personality and motivation and their influence on flying performance has an important bearing on flight safety.

Previous studies of personality in pilots can be divided into two spheres of research: those that deal with occupational issues and the others which deal with clinical issues. Occupational issues initially concentrated on areas related to selection and training. More recently Boyd, Patterson & Thompson (2005) studied if personality testing prior to flight training could identify measurable differences between pilots who eventually fly fighter and non-fighter military aircraft. Significant differences between the scores of pilots assigned to fly airlift/tankers and fighter pilots were found for the NEO domains of *Agreeableness* and *Conscientiousness*. Fighter pilots had lower levels of *Agreeableness* and higher levels of *Conscientiousness*. However, the authors found that homogeneity of scores prevented any practical application.

A number of meta-analyses have been conducted to estimate the relationship between personality and flying training criteria (Hunter & Burke, 1994;

Martinussen, 1996). More recently, Campbell, Castaneda, and Pulos (2010) performed a meta-analysis on 26 studies examining the effects of personality as a predictor of pilots' performance in aviation training. They found two personality domains (*Neuroticism* and *Extraversion*) and one facet of *Neuroticism (Anxiety)* to have an impact on training success; indicating that emotionally stable, extroverted individuals would be better suited to undergo the stress of aviation training.

Occupational issues also involve studies that suggest that personality interacts with flying performance. A study conducted in USAF on 100 pilots using the "Big Five" model of personality and a multi-component model of pilots combat performance rated 60 traits for effective performance on dimensions such as flying skills and crew management. The personality trait of conscientiousness was agreed to by all, as the most important determinant of performance on all dimensions (Siem & Murray, 1994).

Personality could also be one of the many factors, which contributes to hazardous thought patterns and unsafe behaviour. Interpersonal relationships and individual contribution to teamwork are important aspects of personality manifested in the crew resource management model. Threat and error safety models also emphasize the identification and subsequent intervention of unsafe pilot behavior, which in part may stem from the intrinsic personality and motivation characteristics of aircrew. King, Orme, and Retzlaff (2001) found that pilots with higher levels of NEO PI-R *Conscientiousness* facets of *Competence* and *Dutifulness* were at an increased risk of pilot-error mishaps or incidents.

In the clinical realm there have been some important studies that have assessed personality, using the five factor model (FFM). Two studies have compared results with general population norms and recommend that separate norms on aviator populations need to be used when clinically assessing aircrew. This is because of differences in descriptive statistics. Callister, King, Retzlaff, and Marsh (1997) conducted an empirical investigation of personality types in military aviation when they compared U.S. Air Force (USAF) 1,301 student pilots against the general population using the normative scores of the NEO-PI-R. When compared to the norms of the NEO-PI-R, the sample of USAF student pilots were most elevated on extraversion and openness (to new experiences and ideas) and lower on agreeableness (ability to get along with others). Another study by Barto, Chapelle, King, Ree & Teachout (2011) on 12,702 USAF pilot trainees found that compared to the general population, pilots scored lower on *Neuroticism* and *Agreeableness* and higher on *Extraversion*, *Openness to Experience,* and *Conscientiousness.*

The FFM was also found to be clinically relevant in assessing aeronautical adaptability and some studies have outlined the aeronautically non-adaptable traits that are incompatible with aviation (Christen & Moore, 1998; Ellis, Moore & Dolgin, 2001). Campbell, Moore, Poythress & Kennedy (2009) used the FFM to determine whether or not a sample of clinically- referred military aviators exhibited commonly occurring personality clusters. The NEO-PI-R was used to evaluate 956 clinically- referred U.S. Naval aviators and flight officers on five domains. A two-cluster model provided the best fit to the data. MANOVA indicated significant differences between the two cluster groups with respect to four of the five factors (N, E, A, and C). The greatest differences were for N and E, with the smaller group (Group 1, N= 291) being significantly more neurotic and less extroverted than Group 2 (N= 665). Elevated neuroticism and depressed extraversion were the defining traits of the personality cluster less suited for aviation duty (Group 1). Results support assessment of neuroticism and extraversion during clinical mental health evaluations related to military aviation duty.

Previous research on motivation has used Murray's psychogenic need theory and McClelland's trichotomy of needs as a theoretical base. The social motives according to them were of three types; that is, need for achievement, need for affiliation and need for power (Gordon, 1998). There are a number of studies on aviators, that use the

EPPS to measure need for achievement and affiliation. The EPPS has shown to be a relatively robust instrument for differentiating among groups of different occupations and between successful and unsuccessful workers in a given occupation.

Using EPPS, studies suggest that both fighter pilots and pilot trainees have several personality characteristics that differ from male members of the general community (Ashman & Telfer, 1983; Fine & Hartman,1968; Fry & Reinhardt, 1969; Novello & Yousseff, 1974). It was seen that pilot groups were significantly higher on five factors of achievement, exhibition, dominance, change and heterosexuality. They were significantly lower on seven factors of deference, order, affiliation, succorance, abasement, nurturance and endurance. The jet pilots were significantly higher on aggression and consistency and lower on autonomy than the U.S. adult male norms. The difference was attributed to the selection and training in military aviation that has heightened aggression and consistency and depressed autonomy (Novello & Yousseff, 1974).

The need for achievement has been measured in two different studies on pilots who were outstanding. Successful or "high achiever" jet pilots differed significantly from the normative group in that they expressed a greater need for flying achievement (Fry & Reinhardt, 1969). One study on 105 fighter pilots who were selected from the upper 10% of their peer group found that the outstanding jet aviators were desirous of success and scored high on achievement. They kept an emotional distance and isolated themselves from deep interpersonal relationships. They were highly preferential of being independent, autonomous and focused on external events (Reinhardt, 1970).

Almost all research done on aircrew using the NEO-PI-R and the EPPS has been carried out in Western countries and comparatively much less research has been done in Eastern countries such as India. The question arises whether aircrew personality and motivation concepts that have been developed in the West can be merely duplicated and applied cross-culturally. There are three main reasons why one should look into the effects of differing cultures on personality and motivation. Firstly, cross-cultural differences can exist, even when cultural equivalence is found within the Big Five factor structure. Triandis and Suh (2002) postulated that personality may reflect both universally and culturally specific aspects. In support of this, studies suggest that personality dimensions express themselves differently in different contexts, and differences between Americans and Asians have been observed on the five personality domains (Yang, 1986; McCrae, Yik, Trapnell, Bond, and Paulhus, 1998; Mastor, Jin, & Cooper, 2000; Eap, DeGarmo, Kawakami, Hara, Hall, & Teten, 2008). This suggests that cultural context may also be associated with personality differences in Indian as compared to American aircrew.

Secondly, aviation environment and personnel can be specifically influenced by cultural context. For instance, there has been much discussion on the role of culture on CRM and aviation mishaps (Merritt & Maurino, 2004) and one of the reasons could be because of the influence of organizational style of management in Eastern countries (Li, Harris & Chen, 2007). Thirdly, previous preliminary research from our laboratory indicates the possibility of cultural variations in Indian military pilots on characteristics such as achievement, affiliation and locus of control (Joseph, Thomas & Roopa, 2005; Joseph & Ganesh, 2006).

The Indian and American cultures have been found to differ in three out of five cultural characteristics; Individualism, Power Distance and Long Term Orientation (Hofstede, 2001). The dimension of Individualism is the extent that individuals assume an identity beyond a group. The Power Distance Index identifies the extent that different members of a group see inequality versus equality in a power struggle. Long-Term Orientation measures values in terms of values of the future as opposed to values of the present. These cultural characteristics have been known to influence personality and motivation (Triandis & Suh, 2002). Cultural differences in personality and motivation could have an enormous bearing and implication for Indian aircrew, especially in areas of pilot selection and training, occupational issues like flying performance and flight safety and clinical issues such as in aircrew evaluation.

Therefore, this study was carried out to observe whether this group of Indian military pilots shares similar basic personality and motivational characteristics with Western pilots. It was hypothesized that Indian pilots would differ in some ways from their Western counterparts. In line with previous research Indian pilots were expected to be lower in achievement, dominance, extraversion and conscientiousness and higher on affiliation and neuroticism than American pilots.

Method

Subjects

Ninety male aircrew from the three Services (Indian Army, Navy & predominantly from Air Force) were selected for the study. The age group was restricted to between 20-42 years for this study. Of the three groups, 30 were pilots flying fighters, 30 flying helicopters and 30 pilots grounded due to medical reasons. The grounded pilots were from different streams and included both temporary and permanently medically unfit pilots (12-fighters, 13-Helicopters & 5-Transports). The demographic

Table 1

Demographic characteristics of the pilots in the three groups.

Demographic Characteristics	Groups	Mean	SD
Age in years	Fighter	28.3	4.15
	Helicopter	33.37	4. 17
	Medically unfit	30.20	3.04
Service in years	Fighter	6.13	4.37
	Helicopter	11.53	4.58
	Medically unfit	8.30	2.98
Total flying hours	Fighter	884.67	765.95
	Helicopter	1150.83	720.26
	Medically unfit	1011.67	752.51
Flying hours on type	Fighter	211.13	220.60
	Helicopter	405.23	329.60
	Medically unfit	292.62	235.65

characteristics of the pilots in this study are given in the Table 1. The mean age of all the pilots was 30.62 years with a SD of 4.33. The minimum age of the pilots was 24 and the maximum was 42 years. The number of years of education of all 90 pilots was 15 years.

Materials and Procedure

The subjects volunteered to participate in the study. After establishing a good rapport, the need for the study was explained to the individual and a demographic inventory was filled in using a structured interview. The subjects were given necessary instructions before starting the tests. Following this the NEO-PI-R and EPPS were administered and scored manually according to the directions given in the manuals (Costa & McCrae, 1992; Edwards, 1959).

The NEO PI-R is a concise measure of five main domains of personality: neuroticism, extraversion, openness, agreeableness and conscientiousness. Each domain has six facets and therefore there are a total of 30 facet scores. The questionnaire has 240 statements, to be answered with responses from “strongly agree”, “agree”, “neutral”, “disagree” and “strongly disagree”. The reliability of the internal consistencies for the individual facet scales range from 0.56 to 0.81 in self reports. The 48 item domain scale has correspondingly larger coefficient alphas which range from 0.86 to 0.95. With congruence coefficients between contrasting groups ranging from 0.91 to 0.99, the test shows factorial validity across gender, race and age groups (Costa & McCrae, 1992).

EPPS provides measures of Murray’s manifest needs including motivational needs of achievement, affiliation and dominance. It also provides a measure of test consistency and profile stability. There are 225 statements which are to be answered in such a way that a “yes” response indicates that the subject believes the statement is characteristic of himself and a “no” response indicates that it is not characteristic. Social desirability is minimized. The 15 needs measured are achievement, deference, order, exhibition, autonomy, affiliation, intraception, succorance, dominance, abasement, nurturance, change, endurance, heterosexuality and aggression. Operational definitions of each need are provided in the test manual. The test has high reliability and validity; the split half reliability correlations for all needs vary from 0.60 to 0.87 and the test retest reliability from 0.74 to 0.88. Inter correlations between variables are low (Edwards, 1959). Data of variables for 90 subjects were entered into the Statistical Package for Social Sciences (SPSS) worksheet on computer and were statistically analyzed.

Results

The descriptive data showed that in general the pilots were in the average range of the adult population norms on the variables of EPPS, and NEO-PI-R, except that the pilots were higher on dominance on the EPPS scale. They were not found to be high on their need for achievement and affiliation.

The descriptive EPPS data was also compared to the previous published data of aircrew as shown in Table 2 (next page). The results of the present study showed that the group was lower on achievement and higher on affiliation. They were significantly higher on other needs such as deference, order, succorance, abasement and nurturance when compared to previous studies. They were found to be significantly lower on dominance, change and heterosexuality.

The descriptive NEO-PI-R domain data was also compared to the previous published data of aircrew as shown in Table 3 (next page). Results of the study showed that the current group was significantly higher on neuroticism and lower on extraversion and conscientousness. On the agreeableness factor the current group was significantly lower than the Campbell et al. data and higher than the Callister et al. data.

The descriptive NEO-PI-R facets data were also compared to the previous published data of aircrew as shown in Table 4 (page 59). Results of the present study showed that the current group was signif-

Table 2

Comparison of EPPS Raw Score Means and SDs of aircrew in the present study with previous studies

Type of Need	Present study (N=90)	Fry & Reinhart (N= 288)	Ashman & Telfer (N=18)	Novello & Youssef (N=158)
Achievement	15.54 (4.00)	17.96 (3.85)**	18.50	16.30 (4.12)
Deference	13.47 (2.92)	11.55 (3.35)**	11.14	12.10 (3.16)**
Order	15.12 (4.25)	11.67 (4.47)**	12.64	12.14 (4.58)**
Exhibitionism	13.97 (4.16)	14.46 (3.49)	13.93	14.24 (3.87)
Autonomy	13.57 (3.90)	13.31 (4.00)	15.29	14.48 (4.24)
Affiliation	13.60 (4.31)	13.21 (3.98)	09.50	12.21 (3.74)*
Intraception	14.14 (4.34)	13.77 (4.73)	13.07	13.94 (4.69)
Succorance	10.76 (4.64)	08.65 (4.15)**	08.50	09.19 (4.47)*
Dominance	17.42 (4.14)	19.47 (4.38)**	19.14	17.04 (4.47)
Abasement	12.28 (4.50)	10.27 (4.41)**	09.79	11.78 (5.29)
Nurturance	14.93 (4.73)	10.95 (4.30)**	09.07	11.97 (4.36)**
Change	13.49 (5.33)	17.09(4.04)**	17.21	16.59 (4.35)**
Endurance	15.12 (4.67)	15.27 (5.07)	16.07	14.98 (4.69)
Heterosexuality	13.06 (5.88)	18.54 (5.04)**	20.86	16.13 (6.63)**
Aggression	12.91 (4.07)	13.75 (4.24)	15.29	13.14 (4.80)
Consistency	11.72 (1.65)	11.84 (1.85)	-	11.01 (2.24)

*p<0.05, **p<0.01 for independent samples t test comparison with present study.

Cohen's d values for effect size ranged from 0.35 to 1.00 for significant findings

Table 3

Comparison of NEO-PI-R Domain Raw Score Means and SDs of aircrew in the present study with previous western studies

Personality Factor	Present study (N=90)	Campbell et al. (N=956)	Callister et al. (N=1198)	Barto et al. (N= 11,725)
Neuroticism	81.87(23.34)	70.33 (26.47)**	71.00 (19.60)**	67.88(18.39)**
Extraversion	116.31 (19.11)	121.17 (19.62)*	126.13(18.01)**	127.68(17.15)**
Openness	112.39 (16.35)	115.37 (17.88)	114.39 (18.96)	112.94(18.10)
Agreeableness	117.80 (16.03)	123.47(16.54)**	112.89 (18.51)**	114.78 (16.61)
Conscientiousness	123.33 (20.84)	130.21(21.46)**	128.24 (19.15)*	131.40(17.55)**

*p<0.05, **p<0.01 for independent samples t test comparison with present study.

Cohen's d values for effect size ranged from 0.25 to 0.67 for significant findings

Table 4

Comparison of NEO-PI-R Facet Raw Score Means and SDs of aircrew in the present study with previous western studies

Personality Facet	Present study (N=90)	Callister et al. (N=1198)	Barto et al. (N= 11,725)
N1 Anxiety	14.42(5.14)	12.75 (4.69)**	12.19 (4.51)**
N2 Angry Hostility	13.48(5.35)	12.39 (4.84)	11.78 (4.44)**
N3 Depression	13.63(5.17)	10.82 (4.70)**	9.97 (4.30)**
N4 Self consciousness	15.67 (4.10)	12.99 (4.54)**	12.58 (4.25)**
N5 Impulsiveness	15.53 (4.07)	15.11 (4.65)	14.69 (4.44)*
N6 Vulnerability	09.38(5.12)	06.91 (3.53)**	06.66 (3.25)**
E1 Warmth	22.16 (4.13)	22.77 (4.13)	23.11 (3.88)*
E2 Gregariousness	18.26 (4.97)	18.32 (5.25)	19.01 (5.01)
E3 Assertiveness	17.52 (4.39)	19.80 (4.47)**	20.21 (4.37)**
E4 Activity	17.96 (3.94)	20.81 (3.85)**	20.69 (3.67)**
E5 Excitement seeking	19.36 (4.43)	22.92 (3.82)**	23.19 (3.66)**
E6 Positive emotions	22.41 (4.25)	21.48 (4.54)	21.46 (4.36)*
O1 Fantasy	18.42 (11.22)	19.15 (5.17)	18.23 (4.97)
O2 Aesthetics	19.14 (4.79)	17.00 (6.04)**	16.14 (5.68)**
O3 Feelings	20.02 (4.74)	20.93 (4.51)	20.66 (4.23)
O4 Actions	16.29 (3.80)	16.52 (4.02)	16.77 (3.97)
O5 Ideas	19.70 (4.55)	21.88 (5.33)**	21.94 (5.22)**
O6 Values	19.94 (3.84)	18.89 (4.79)*	19.20 (4.49)
A1 Trust	21.42 (4.48)	20.05 (4.83)*	20.39 (4.42)*
A2 Straightforwardness	19.90 (4.94)	18.71 (4.71)*	19.10 (4.41)
A3 Altruism	23.00 (3.83)	23.26 (3.87)	23.72 (3.54)
A4 Compliance	15.64 (4.62)	16.19 (4.42)	16.18 (4.17)
A5 Modesty	16.74 (3.62)	16.78 (4.88)	16.84 (4.69)
A6 Tender mindedness	21.09 (3.26)	17.88 (4.15)**	18.55 (3.72)**
C1 Competence	21.83 (4.05)	24.06 (3.48)**	24.48 (3.28)**
C2 Order	19.93 (4.72)	18.76 (4.67)*	19.08 (4.30)
C3 Dutifulness	22.53 (4.39)	23.72 (3.74)*	24.19 (3.56)**
C4 Achievement striving	20.02 (4.69)	22.52 (4.37)**	23.07 (3.85)**
C5 Self discipline	20.79 (5.27)	21.71(4.56)	22.69 (4.13)**
C6 Deliberation	18.16 (4.79)	17.44 (4.30)	17.89 (4.17)

*p<0.05, **p<0.01 for independent samples t test comparison with present study

Cohen’s d values for effect size ranged from 0.23 to 0.94 for significant findings icantly higher compared to both the previous studies on neuroticism facets of anxiety, depression and vulnerability. They were also significantly higher than one of the studies on the other facets of angry hostility and impulsiveness.

The current group was significantly lower compared to both the previous studies on extraversion facets of assertiveness, activity, excitement seeking and higher on positive emotions. They were also significantly lower than one of the studies on the other facet of warmth. Though the domain comparison of openness did not indicate an overall significant difference, facets of this domain showed this pilot group to be higher on aesthetics and values and lower on ideas. On the agreeableness domain Indian pilots were higher on facets of trust, straightforwardness and tender mindedness. As can be seen from Table 4 the facets of conscientiousness such as competence, dutifulness, achievement striving and self discipline were all significantly lower in Indian pilots.

Discussion

On the variables of the NEO-PI-R the Indian military pilots were seen to be in the average range of the adult U.S. population norms. Previous research indicated personality differences between general population Americans and Asians (Yang, 1986; McCrae et al., 1998; Mastor et al., 2000; Eap et al., 2008). In line with these findings, the results of the present study also showed that Indian pilots, when compared to Western pilots were significantly higher on neuroticism and lower on extraversion and conscientiousness. Consistent with the findings of McCrae, et al. (1998) and Eap et al. (2008), Indian aircrew were higher on neuroticism and all its facets; that is, anxiety, angry hostility, depression, self consciousness, impulsiveness and vulnerability when compared to Western pilots. However, when compared to the Indian male population, they had *lower mean scores* on neuroticism and four of its facets (Lodhi, Deo & Belhekar, 2002). This therefore further substantiates the role of culture influencing neuroticism domain scores in Indians on the whole. The work on cross cultural differences showed the Indian society to be less individualistic and more collectivistic. It is known that people from collectivistic cultures express their emotions more and also tend to report more negative emotions (Triandis & Suh, 2002). More than emotions, social norms (approval from others) predict life satisfaction for collectivists.

Indian pilots were found to be lower on extraversion which is consistent with previous studies (Yang, 1986; Mastor et al., 2000; McCrae et al., 1998; McCrae & Terracciano, 2005; Eap et al., 2008) that found that European Americans score higher on extraversion than people of Asian descent. This finding has been attributed to the individualistic culture of Americans as opposed to the collectivistic culture of Asians. However, when Indian pilots are compared to the Indian male population, they had *higher mean scores* on extraversion and all six of its facets (Lodhi, Deo & Belhekar, 2002).

There are a number of studies that have shown that pilots who are high achievers to be high on the conscientiousness factor (Fitzgibbons, Davis & Schutte, 2004). This study does not show this similarity probably because achievement is an aspect of conscientiousness, which is seen to be lower in Indian pilots. This finding is consistent with the results of the Eap et al. (2008), who found conscientiousness to be lower in those of Asian origin. However, once again, when Indian pilots are compared to the Indian male population they had higher mean scores on conscientiousness and five of its facets (Lodhi, Deo & Belhekar, 2002). These cultural differences highlight the importance of context in understanding personality differences in pilots.

The extensive research on U.S. military pilots has found the aviators to be consistently higher on the need for achievement compared to the average U.S. adult population norms (Ashman & Telfer, 1983; Novello & Yousseff, 1974; Fine & Hartman,1968; Fry & Reinhardt, 1969, Reinhardt, 1970; Retzlaff & Gibertini, 1987).

The results of this study indicate certain differences in the motivational needs of Indian military pilot. The results of this study are not in consonance with U.S. studies as Indian military pilots were found to be in the average range using a similar comparison. Indian military pilots were also seen to be in the average range for the need for affiliation. This result does not corroborate with other studies, which show the aviators to be low on affiliation (Ashman & Telfer, 1983; Fine & Hartman,1968; Fry & Reinhardt, 1969; Novello & Yousseff, 1974). In another Indian study it was seen that almost the same number of pilots ranked achievement *and* affiliation in the first position (Joseph, Thomas & Roopa, 2005).

Indian military aviator is high on the variable of dominance when compared to average U.S. population norms. This is in line with the number of studies that show military pilots to be high on dominance (Ashman & Telfer, 1983; Fine & Hartman,1968; Fry & Reinhardt, 1969; Novello & Yousseff, 1974; Reinhardt, 1970; Retzlaff & Gibertini, 1987). Such characteristics as dominance are part of military value system and are adaptive traits given the nature of their missions. The need for power is a need to have control over one's own work or the work of others. Persons who insist on autonomy in their work or seek supervisor responsibilities have a need for power (Gordon, 1998). Indian military pilot maybe high on dominance because it is a requirement in the defense services with its hierarchy. There is need to lead soldiers, be an officer, and to set an example for the rest. Even though Indians are high on dominance compared to U.S. general population, when absolute mean values are compared, Indian pilots scored lower on dominance than Western counterparts.

Indian pilots were also significantly higher on other needs such as deference, succorance, abasement and nurturance when compared to previous studies on aircrew. They were found to be significantly lower on change and heterosexuality. These needs are also partly determined by the collectivistic culture. Within collectivistic cultures, Indian culture is vertical as opposed to horizontal (Hofstede, 1980, 2001; Markus & Kitayama, 1991; Triandis & Suh 2002; Triandis, 1995). Vertical collectivistic cultures are traditionalist and emphasize in-group cohesion, respect for in-group norms, and the directives of authorities. It is correlated with the tendency to be submissive to authority and to endorse conventionalism (Triandis & Suh, 2002). When compared to Indian society, the importance of achievement and individualism is much higher in Western culture. Indian society, on the other hand, places more emphasis on affiliation, deference, succorance and nurturance. Indians see helping an in-group member as duty-based, whereas Americans see it more as a matter of personal choice. Americans are less likely to feel responsible compared to Indians for helping siblings or colleagues whom they personally do not like (Triandis & Suh, 2002). This may explain why Indian pilots are lower on their need for achievement, dominance, change and heterosexuality and higher than the Western pilots on their need for affiliation, deference, succorance and nurturance. With the present state of knowledge it is not possible to assess Indian pilots' standing with respect to Indian general population because norms on the EPPS have not been developed.

In conclusion, the Indian military pilots' descriptive EPPS and NEO-PI-R data was compared to the previous published data of Western aircrew. The results of present study showed that the group was lower on achievement and higher on affiliation. They were significantly higher on other needs such as deference, order, succorance, abasement and nurturance. They were also found to be significantly lower on dominance, change and heterosexuality when compared to previous Western studies. The results on the NEO-PI-R showed that the group was significantly higher on neuroticism and lower on extraversion and conscientiousness. These cross cultural differences were attributed to the collectivistic nature of Indian culture which has influenced both the personality and need structure.

This study could be a basis for further research, leading to a better understanding of the motivational needs and basic personality components of Indian military pilots in selection, training and medical evaluation. These results call for the development of indigenous standards for aircrew selection so that optimal personality and motivational characteristics (with respect to the general Indian population) may be selected out and selected in. Military aviation training in India has to take into consideration these aspects of personality that can influence thought patterns and safety attitudes. This could call for more intense continuity training during different phases of military pilots' career. Lastly, the outcome of this study implies that pilot normative data needs to also be culture specific. Such norms should be used when clinically assessing a pilot in conjunction with general population norms so that reliable and valid judgments are made. There is an ultimate requirement of having highly motivated aviators with best flying abilities and mission safety attitudes in the Indian military.

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A Case for Federal Aviation Regulations to Develop Civil Supersonic Transport Aircraft

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Abstract

This report drew upon a variety of government, industry, and academic studies to make conclusions and provide recommendations for the codification of Federal Aviation Regulations allowing overland supersonic flight would incentivize industry stakeholder development and fielding of civil supersonic transport aircraft. The absence of less restrictive regulations that would permit overland supersonic operations has hindered industry to go beyond technological research and market surveys, into actual production and air carrier operations. The novel phenomenon of a sonic boom that is associated with supersonic flight has elevated regulations as the requisite dominant and leading factor. A civil supersonic transport aircraft that has to fly at subsonic speeds overland has proven not economically feasible. However, overland supersonic flight with unconstrained sonic boom levels is not environmentally acceptable and unfeasible as well. Regulations allowing overland civil supersonic flight will establish a viable market potential, clarify aircraft design requirements, and unlock the manufacturing and operational implementation of supersonic civil transport aircraft.

A Case for Federal Aviation Regulations to Develop Civil Supersonic Transport Aircraft

This report drew upon a variety of government, industry, and academic studies to make conclusions and provide recommendations for the codification of Federal Aviation Regulations (FAR) allowing overland supersonic flight would incentivize industry stakeholder development and fielding of civil supersonic transport aircraft into the National Airspace System (NAS). Since the retirement in 2003 of the Concorde[1], the first and only operational supersonic civil transport aircraft, industry have been reluctant to fully invest in a production design of a supersonic aircraft that would be restricted from supersonic flight over land. Concorde's prohibition for supersonic flight over land limited its commercial success and was a major contributor to its demise (Maxwell & Dickinson, 1980; Zha, Im, & Espinal, 2010). The absence of less restrictive regulations that would permit over land supersonic operations has hindered industry stakeholders to go beyond technological research

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[1] The Concorde aircraft was jointly developed and funded by the French and British as the first and only supersonic civil transport aircraft to provide scheduled air service. The first scheduled transatlantic flight occurred in 1976 and the last flight was in 2003. Air France and British Airways were the only airlines to fly the aircraft (Cathers,1990; Van Teuren, 2005)

and market surveys into actual production and air carrier operations.

Factors normally considered by industry in business cases for investing in any new airplane can be grouped into three categories (a) market potential, (b) technology, and (c) regulations (Henne, 2003). The novel phenomenon of a sonic boom associated with supersonic flight has elevated regulations as the requisite dominant and leading factor (Welge, Nelson, & Bonet, 2010). Regulations allowing overland civil supersonic flight are essential to establish a viable market potential, clarify aircraft design requirements, and unlock the manufacturing and operational implementation of supersonic civil transport aircraft (Aronstein & Schueler, 2005). The two assumptions for this report were that the regulatory limitation that prohibits overland supersonic flight under U.S.C. Title 14 Code of Federal Regulations (CFR) §91.817[2] has been rescinded, and that regulations for a prescribed acceptable overland sonic boom level have been established.

Sonic Boom

There are several unique issues associated with supersonic flight, such as high altitude ozone depleting emissions of nitric oxides and jet engine noise in the airport environment (Hamel, Folk, Jimenez, & Mavris, 2009). However, the most challenging technological and marketing issue associated with supersonic flight has been the overland sonic boom (Candel, 2004). A sonic boom is the ground trace of the pressure disturbance created by the passage of an aircraft moving faster than the speed of sound, typically measured in pounds/square foot (psf) (Supersonic Aerodynamics, 2008; Welge, Nelson, & Bonet, 2010). The characteristics of a sonic boom must be understood to determine operationally realistic and environmentally acceptable regulatory sonic boom levels that can then be used to set the technological design requirements and work out any business case for market potential (Chudoba et al., 2007).

The presence of a sonic boom during supersonic flight is fundamentally tied to the laws of thermodynamics and consists of the initial *transition boom* as the aircraft passes through Mach 1, followed by the continuous *nominal boom* in cruise flight. A sonic boom can be controlled through aircraft geometry, aircraft weight, Mach number, altitude, and flight profile. The primary sonic boom characteristics controlled by the aforementioned variables are strength (amplitude), lay-down or carpet area, directionality, and persistence of the boom (Aronstein & Schueler, 2005). An aircraft traveling at supersonic speed produces shock waves that merge in the near-field and eventually propagate to the ground in the far-field, creating an impulsive change in pressure. The external geometric aircraft design, aircraft weight, and instantaneous flight profile (dive angle, turns, maneuvering, and acceleration) primarily drive the near-field sonic boom characteristics, which coalesce and propagate towards the far-field. Atmospherics, topography, and turbulence drive the far-field characteristics, which determine the geometry and dimensions of the sonic boom carpet area on the ground.

A sonic boom radiates in all directions, not just downward, and under some atmospheric conditions can bounce off the upper atmosphere and propagate a secondary *over the top* boom a considerable distance downrange of the aircraft to one or more secondary ground impact areas. The sonic boom can also extend well outside the direction of the actual flight path due to winds, temperature gradients, or when a supersonic aircraft performs even a gentle turn. Sonic boom paths curve towards regions where the temperature, and thus the speed of sound, is lower and where the wind component is greater (Poling, Robinson, & Sutherland, 1997). The regulatory restriction for overland supersonic flight includes impingement of the aircraft's sonic boom over land, hence the aircraft may be miles away from actual landfall when it must slow to subsonic speeds. The presence of an *over-the-top*

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[2] No person may operate a civil aircraft for which the maximum operating limit speed exceeds a Mach number of 1, to or from an airport in the United States, unless information available to the flight crew includes flight limitations that ensure that flights entering or leaving the United States will not cause a sonic boom to reach the surface within the United States (Civil Aircraft Sonic Boom, 1963)

sonic boom can back up the requirement for subsonic speeds even farther away from landfall.

The exterior design of the aircraft (i.e. nose shape, wing thickness, wing sweep, fuselage length) affects the trade-off between sonic boom rise time associated with the rumble sensed by the public, and the absolute overpressure associated with the sharp startling crack sound that is heard. A favorable combination of atmospheric state, flight altitude, and Mach number can exist where a *sonic cut-off* condition is achieved and the boom bounces (refracts) off a flight level below the aircraft, never hitting the ground. This so-called *Mach cut-off* speed is the highest speed at which an aircraft can operate in cruise flight without producing booms on the ground. In the standard atmosphere this value hovers around Mach 1.15, which is of little marketable value when competing with current subsonic aircraft that operate in excess of Mach 0.9 (Plotkin, 1989; Maglieri & Sothcott, 1990; Henne, 2003). Climb and descent angles increase or decrease *Mach cut-off*, with boom intensities decreasing rapidly with altitude. Consequently, flying a climb angle that progressively increases with increasing Mach-altitude can further delay the initial transition boom until the aircraft reaches even higher altitudes.

Propagation path and ground zone impact area of the sonic boom vary with atmospheric pressure, temperature, density, humidity, turbulence, and wind (Loubeau & Coulouvrat, 2009). Turbulence and topography may reduce the *boom* amplitude by randomly redirecting the sonic boom energy. Humidity in clouds may also attenuate or disperse the *boom*. The variability of global and regional climate changes as well as local weather and turbulence are random, hence the ground sonic boom is uncertain and must be predicated on some meteorological model and certification standards determined by sonic boom level regulations.

Technological Design

A successful supersonic transport must be designed with the intent of maintaining efficiency in supersonic cruise as well as in subsonic segments during the take-off and landing phases. Aircraft designers start with the regulatory acceptable sonic boom signature, and factor in the variables of aircraft weight, cruising altitude, and Mach number. The required aircraft geometric shape that will produce the desired sonic boom signature can then be determined. The nose design is a trade-off between aerodynamic drag and sonic boom generation. A blunt nose with a long fuselage minimizes the sonic boom but maximizes the aerodynamic drag, which increases the required engine thrust and fuel consumption. A sharp nose with a shorter fuselage has the opposite effect (Aronstein & Schueler, 2005; Candel, 2004). The fuselage volume for fuel, structure, systems, and payload have to be considered as well (See Figure 1).

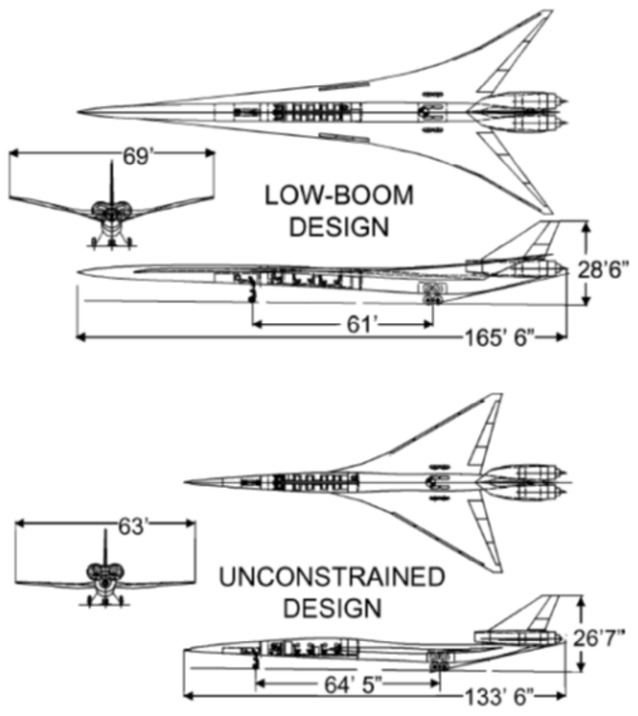

Figure 1. Conceptual aircraft design with and without sonic boom constraint. Adapted from "Two Supersonic Business Aircraft Conceptual Designs with and without sonic boom constraint" by Aronstein and Schueler, 2005, *Journal of Aircraft, 42*(3), 775-786.

Regulatory acceptable overland sonic boom levels will determine aircraft exterior design by dictating the required nose and fuselage/wing geometry and dimensions. The aircraft exterior design sets the optimum cruise speed, fuel load, and interior dimensions of the cabin that establish the trip time, range, and passenger load used in the analysis of the market potential. The sonic boom signature is also affected by the weight of the aircraft, that influences the fuel and passenger load (See Figure 2).

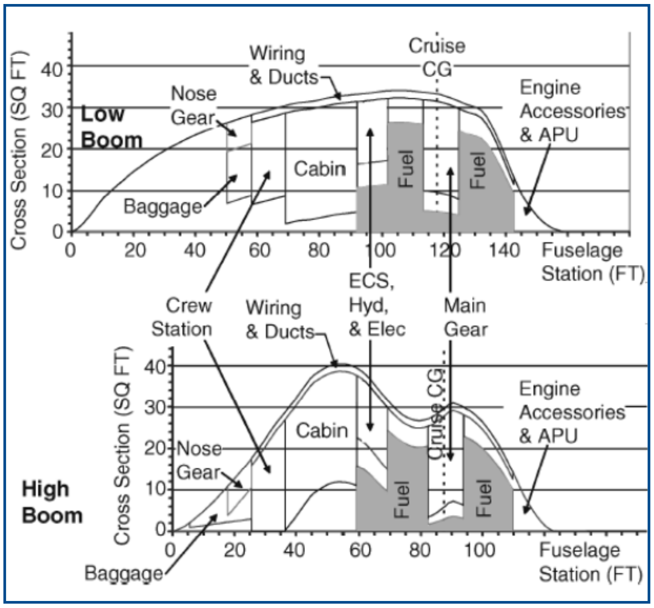

Figure 2. Internal volume configuration variance with magnitude of allowable sonic boom. Adapted from “Two Supersonic Business Aircraft Conceptual Designs With and Without Sonic Boom Constraint” by Aronstein and Schueler , 2005, *Journal of Aircraft, 42*(3), 775-786.

Manufacturers of overland civil supersonic aircraft will be required to design flight deck displays that provide sonic boom situational awareness as well as the information necessary to adjust flight path, airspeed, and aircraft configuration so that civil supersonic transport pilots can comply with the sonic boom regulations. The aircraft design will require sensors and systems that provide actual and predicted atmospheric data (temperature, winds, humidity, and cloud cover) which influence the strength, direction, and laydown area of the sonic boom as depicted on a cockpit display. Researchers at the Dryden Flight Research Center have developed a cockpit sonic boom display that has been of interest to several aircraft developers, such as Aerion, Gulfstream, and Boeing (Haering, 2010). Research has shown that the geographical laydown area can be placed within 1 mile of a desired location once the vehicle geometry, performance, and atmospheric conditions are known (Maglieri & Sothcott, 1990).

The shaping and configuration of the exterior structure affect the cockpit forward field-of-view. A sleek elongated nose shape compromises the pilot’s forward field-of-view which then must be augmented with video cameras, synthetic vision (SV), or other electronic means to provide the pilot an adequate real-time conformal image of the outside world to safely operate the aircraft during visual maneuvering in an approach/departure, landing/take-off, and taxi. NASA researchers have already partnered with industry stakeholders on the research and development of these so-called external vision systems (XVS) (Rogers, 1997). The alternative is to design an aircraft with a mechanically drooping nose, as was done on the Concorde, and incur considerable cost and weight penalties. However, the technical design requirements and costs, for the aircraft fuselage/wing structure, propulsion systems, and flight deck systems cannot be determined until Federal Aviation Regulations set the maximum acceptable overland sonic boom levels (See Appendix).

Airport Planning

Before reaching cruise speed, a supersonic aircraft must accelerate and initially break the sound barrier at which time a large-scale *transition boom* is generated, exceeding the *nominal boom* signature that is characteristic of cruise flight above Mach 1. Allowing boom- generating supersonic accelerations to occur over land will relieve the time and fuel consuming requirement for supersonic aircraft operating out of inland airports to fly a subsonic detour and reach water prior to going supersonic. The over land accelerations would be conducted in sonic boom corridors over sparsely populated areas (Welge, Nelson, & Bonet, 2010). These corridors would determine the candidate origin/destination airports that could accommodate supersonic aircraft, which directly affects the market potential determined by industry stakeholders' business cases. The aircraft weight and wing geometry would determine the required runway length for take-off and landing and required runway/taxiway load bearing capacity, and determine the potential airports that can be utilized as origins/destinations, and enroute fuel stops.

However, airports with acceptable runways and approach/departure corridors for sonic boom transition areas cannot be identified until the regulations for sonic boom levels establish the allowable pressure disturbance levels for the specific geographical area based on its use, population, inhabitants, and structures (See Appendix).

Market Potential

Economic viability of supersonic transports is significantly enhanced when some level of sonic boom is allowed that permits overland supersonic operations (Wesoky, Facey, & Shepherd, 1991). The benefits to the operator are time-related savings manifested by increased asset utilization from increased number of trips per day and reduced costs for staffing flights. The shorter flight times also translate into a reduced need for in-flight catering, large galleys, lavatory capacity, and extra cabin volume that is expected on longer flights. The benefits of significantly shorter flight times for passengers carry a high potential value for those who must travel frequently or those for who health issues currently discourage long-haul travel. Research and analysis has indicated that the market potential for overland supersonic flight would initially focus on the business traveller who places a high value on time-savings (Smith, 2003). However, the regulatory restriction from overland supersonic flight cuts deeply into time-savings and has consequently hurt the business case for supersonic civil transport aircraft. Regulations for allowable sonic boom levels would determine the allowable operating areas and airports which also folds into the market potential .

Studies by Henne (2003) and Chudoba et al. (2007) indicated that civil business aircraft operations flew over water on average only 25% of the trip, which would mean that under current regulations supersonic speeds would only be maintained for 25% of the trip distance. In another study, Lee and Nicholls (1997) showed how the operating costs per trip varies with the percent of the trip that is flown at subsonic speeds. As the subsonic leg increases, the trip time increases, which increases crew costs and reduces the utilization of the aircraft. Maximum economic benefit can only be realized by maximizing supersonic flight throughout the entire trip (See Figure 3).

Market assessments have indicated a significant market potential for civil supersonic aircraft, ranging from 180 to 450 aircraft, if overland superson-

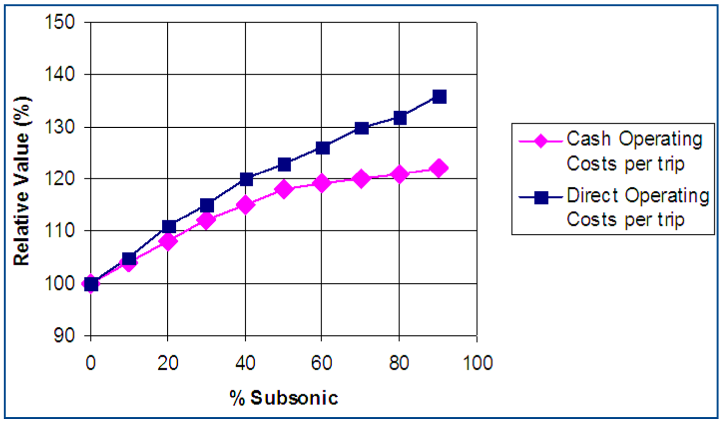

Figure 3. Percentage of cost (relative value) increase with percent of trip flown at subsonic speeds. Adapted from "The Investigation of Supersonic Commercial Transport Performance Issues Using Multivariate Optimization" by Lee and Nicholls,1997, *AIAA 97-5569.*

ic flight were allowed (Hamel, Folk, Jimenez, & Mavris, 2009; Smith, 2003). The margins for a profitable operation are narrow, and a prohibition from overland supersonic flight make it unfeasible (Welge, Nelson, & Bonet, 2010; Henne, 2003). A comparison of flight times for a Supersonic Business Jet (SSBJ) flying from New York to Moscow, with and without an overland sonic boom restriction, show the time savings at various supersonic cruise speeds when speed does not have to be reduced to less than Mach 1 overland. An aircraft departing overwater from New York and cruising enroute to Moscow at Mach 1.8 would have a trip time of 4.6 hours, if not constrained to reduce to subsonic speeds cruise speeds when reaching landfall over Europe (Figure 4). However, the trip time would be increased to 5.5 hours if the aircraft had a restriction from overland supersonic cruise flight (Figure 4).

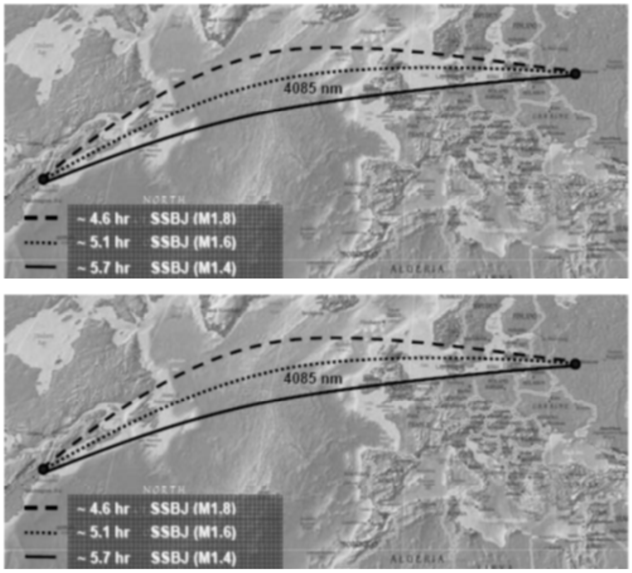

Figure 4. Comparison of Trip Time from New York to Moscow with and without an overland sonic boom restriction. Adapted from “What price supersonic speed? An applied market research case study-part 2” by Chudoba et al., 2007, *45th AIAA Aerospace Sciences Meeting and Exhibit*, Reno NV.

Regulations

The Federal Aviation Administration is aware of the implications of the prohibition for overland supersonic flight, and has sponsored research to quantify sonic boom levels and perceived level of decibels (PLdB) that are acceptable to the residential community, not harmful to the environment or wildlife, and that do not adversely affect buildings or other man-made structures (Croft, 2010; Coen, 2003). Sonic boom overpressure, the objective effect, can be readily measured. The subjective effect perceived by humans, typically measured in perceived level of decibels (PLdB), is a combination of overpressure, duration, rise time, and shape. Studies have analyzed the effects of sonic booms on observers inside structures constructed from different materials, and outdoors with varying amounts of ambient background noise levels to determine the sonic boom level that would be acceptable to the public and not harmful or a nuisance to wildlife, structures, or other man-made object, such as seismic sensors and car alarms (Coulouvrat, 2009).

The regulation that addresses supersonic flight in the United States was enacted in 1973 under U.S. C. Title 14 CFR 91.817. The regulation considers any sonic boom that impacts the ground as unacceptable and consequently prohibits civil aircraft from exceeding Mach 1 over U.S. territory, as well as supersonic operations to or from any U.S. airport in which any sonic boom would reach the ground. The International Civil Aviation Organization (ICAO) Committee on Aviation and Environmental Protection (CAEP) has recognized that current guidance for supersonic flight is outdated and established a timeline for the implementation of a new rule for supersonic flight (Table 1).

Less stringent criteria, proposed in 1974 by the U.S. Environmental Protection Agency (EPA), recommended a sonic boom peak pressure level not to exceed 0.75 psf. Viable supersonic aircraft designs have been presented by Gulfstream, Boeing, and Raytheon with overpressures in the 0.4 to 0.7 psf range and a perceived level of ≤70 PLdB (Radloff, 2003; Raytheon, 2003; Wolz, 2003) . Studies indicate that these designs, with sonic boom sig-

Table 1.

ICAO supersonic regulatory goals and timelines. Adapted from International Civil Aviation Organization (2006). Review of Supersonic Standards-CAEP/7-WP-10. Montreal, Canada: Author

Certification Condition	**Environmental Protection Area**	**CAEP 7 Mtg (2007)**	**CAEP 8 Mtg (2010)**	**CAEP 8 Mtg (20130)**
Noise certification	Surrounding Airport community noise impact	Agree Terms of Reference & Possible timeline for rule development	Consider Adoption of Current Subsonic Noise Rule for Supersonic airplanes	If required, Propose Modification to Current Supersonic Noise rule for Supersonic Airplanes
Sonic Boom	En-route Sonic Boom control	Agree Terms of Reference & Possible timeline for rule development	Report status on Acceptable metric and on Animal and Human response Assesments Reassess terms of Reference	Propose Supersonic Rule with: 1) Acceptable metric 2) Acceptable limits 3) Demonstration method
LTO Emissions	Local Air Quality control	Agree Terms of Reference & Possible timeline for rule development	Consider Adoption of revised Emissions Rules for Supersonic Airplanes	If required, (if no action taken at CAEP/8) consider adoption of revised Emissions rules for Supersonic Airplanes
Cruise Emissions	Global Atmospheric Impacts (e.g. climate change, ozone)	Consider existing global emissions assessments and promote new assessments	Report Status on new cruise emission assessments	Propose guidance on importance of cruise emissions with link to type of fleet (SSBJ and HSCT may be different)

natures significantly less than Concorde's 2.0+ psf and estimated 100+ PLdB, might be acceptable to the community and environment, (Cathers, 1990; Wedge, Chester, & Bonet, 2010) .

The FAA has a website (http://www.faa.gov/about/office_org/headquarters_ offices/apl/noise_emissions/supersonic_aircraft_noise/) soliciting technical information from other federal agencies, industries, universities, and other interested parties on the mitigation of over land sonic booms from supersonic aircraft to determine whether there is sufficient new data to support future rulemaking actions. The FAA (2008) has also issued a policy that states the following:

> Since March 1973, supersonic flight over land by civil aircraft has been prohibited by regulation in the United States. The Concorde was the only civil supersonic airplanethat offered service to the United States, and it is no longer in service. Interest in supersonic aircraft technology has not disappeared. Current research is dedicated toward reducing the

> impact of sonic booms before they reach the ground, in an effort to make overland flight acceptable. Recent research has produced promising results for low boom intensity, and has renewed interest in developing supersonic civil aircraft that could be considered environmentally acceptable for supersonic flight overland. Supersonic aircraft technologists, designers, and prospective manufacturers have approached the FAA and International Civil Aviation Organization (ICAO) for guidance on the feasibility of changing the current operational limitations. The U.S. regulation prohibits civil supersonic aircraft flight overland. Before the FAA can address a change in operational restrictions, it needs thorough research to serve as a basis for any regulatory decisions. Public involvement will be essential in defining an acceptable sonic boom requirement, and public participation would be part of any potential rulemaking process. (FAA, 2008, p.2)

Conclusion

The historical precedent from the demise of the Concorde and subsequent business analyses have established that the viability of a profitable civil supersonic aircraft operation rests with allowing supersonic flight over land. Incentivizing the airline industry to procure and operate civil supersonic transport aircraft requires a clear definition of the market potential for a profitable operation. The airline industry relies on the aircraft manufacturers to provide an aircraft design that can meet or exceed airline operator requirements for passenger load, trip time, and range, with the underlying specification that overland supersonic flight will be possible. In turn, the aircraft manufacturers are subject to the normal aircraft certification regulatory compliances, with the additional constraints of sonic boom control. Although the airlines may identify a demand for supersonic flight, and the manufacturers may have mature technologies for designing a supersonic aircraft, neither can proceed any further until the regulatory requirements for an acceptable over land sonic boom level are determined. The maximum allowable over land regulatory sonic boom level will determine the possible combinations of aircraft cruise speed, weight, and exterior design geometry/dimensions, which in turn determine the interior dimensions for passenger/fuel load, range, and trip times for establishing a business case that is attractive enough to incentivize an investment by the airline industry in supersonic transport aircraft. The candidate origin/destinations for supersonic air carrier service are set by the specific overland flight corridors determined by the allowable overland regulatory sonic boom levels.

Establishing Federal Aviation Regulations for acceptable over land sonic boom levels is the prerequisite for determining aircraft design requirements and market potential, both of which are essential to incentivize industry stakeholders to develop and introduce a supersonic civil transport aircraft into the National Airspace System.

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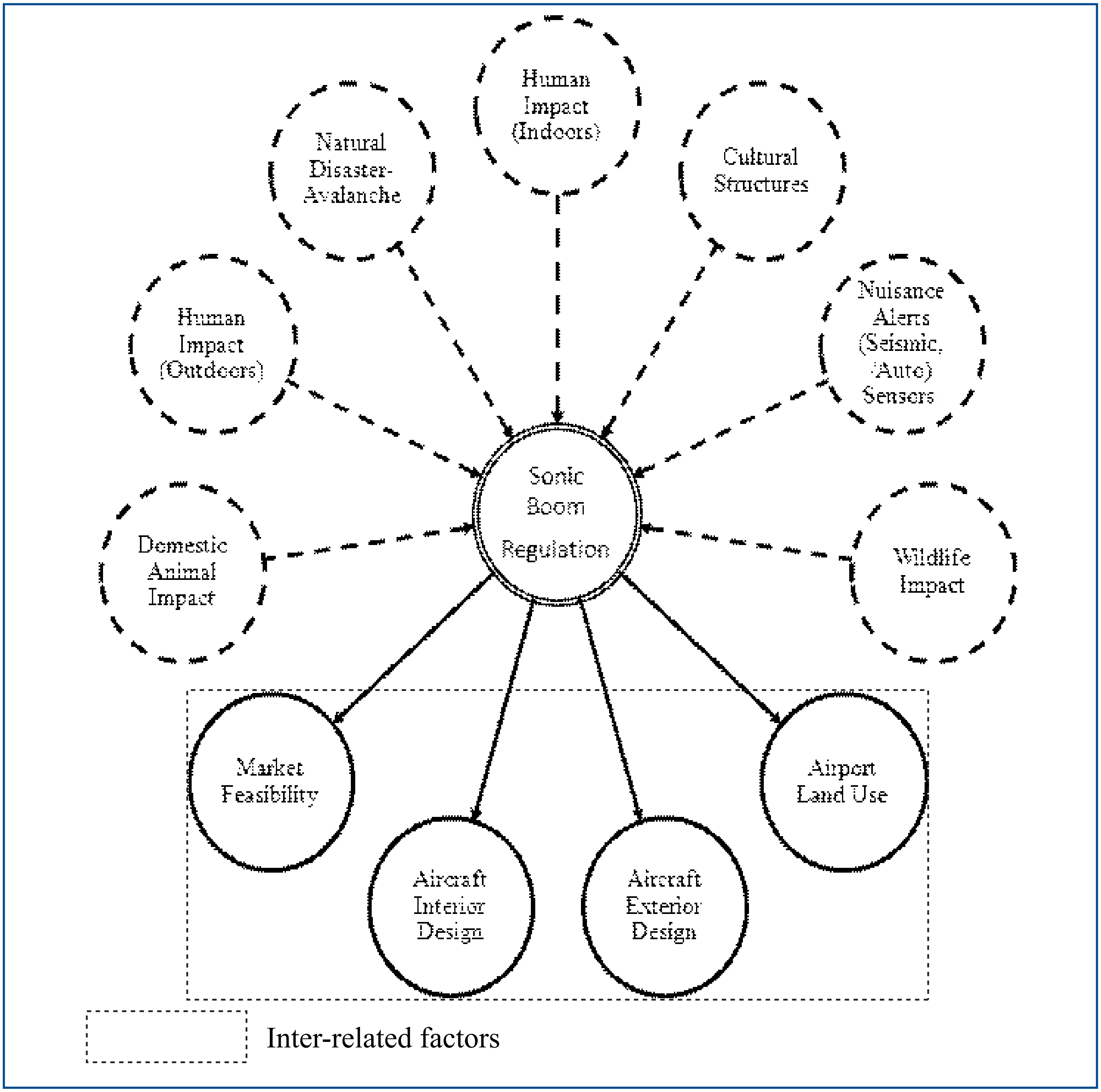
Appendix

Factors and Relationships for Sonic Boom Regulations (Joslin, 2011)



The Effect of Information About the Environmental Impact of Flying and People's Desire to Fly

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Abstract

It is widely believed that the aviation industry contributes to global climate change. Both the industry and its detrimental effect upon the environment are predicted to grow over the next 10–15 years. Although numerous lobby groups have tried to deter people from unnecessary air travel by explaining how aviation is a factor in causing global climate change, few people report they will try to limit the amount of flights that they take. A between-subjects experimental design was used to test whether participants exposed to information about the adverse effect of aviation on the environment desire to fly more than those not exposed to such information. Evidence of a boomerang effect was observed, whereby exposure to information about aviation's contribution to global climate change led to a significant increase in perceived desire to fly.

The Effect of Information about the Environmental Impact of Flying and People's Desire to Fly

It is widely believed that anthropogenic greenhouse gas (GHG) emissions contribute to global climate change (GCC) and that the effects of GCC may include extreme weather patterns, waterborne diseases, and an overall effect upon food chains (Kovats, Menne, McMicheal, Bertollini, & Soskolne, 2000), although it should be noted that the link between GHG and GCC has not gone unchallenged (e.g., Spencer, 2010). It is also widely acknowledged that the aviation industry contributes to anthropogenic GHG emissions, although estimates vary regarding the extent of the contribution. For example, it has been reported that international aviation is responsible for between 2.5% and 3% of total anthropogenic GHG emissions (Scheelhaase & Grimme, 2007), whilst domestic and international aviation combined account for between 3.5% (Penner, Lister, Griggs, Dokken, & McFarland, 1999) and 4.6% (Gössling & Peeters, 2007). In addition to GHG emissions, it is argued that airports adversely affect the environment through increased noise, air pollution, and damage to wildlife, heritage, and landscapes (Benfield, Bell, Troup, & Soderstrom, 2010; Blickley & Patricelli, 2010; Jarup et al., 2008; Oosterlynck & Swyngedouw, 2010).

The aviation industry has grown approximately 5% per year for the last 30 years and is predicted

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to grow at a similar rate for at least the next 10–15 years (Beloba, Odoni, & Barnhart, 2009). In contrast, there may be a reduction of 20% in aviation GHG emissions by the year 2050 through the implementation of new aircraft technologies (Penner et al., 1999), and yet further gains from improved flight management (Becken, 2007). Nevertheless, at best, it has been predicted that growth of the aviation industry will cancel out any gains as a result of technical and management improvements (Gössling & Peeters, 2007), whilst a more pessimistic outlook is that, as the aviation industry grows, its overall effect on the environment is likely to increase proportionally, regardless of any increases in energy efficiency (Cairns & Newson, 2006). Consistent with the latter prediction, in the European Union, net GHG emissions from aviation increased by 87% between 1990 and 2006 (EU, 2006), even although aircraft became more efficient during that period (Thomas, Norris, Forbes Smith, Creedy, & Pepper, 2008).

Given the adverse effect that aviation is argued to have on the environment, several calls have been made to limit any further expansion of the aviation industry (e.g., Friends of the Earth, nd; Greenpeace, 2010; Griggs & Howarth, 2008, May & Hill, 2006; Plane Stupid, 2011). One way to reduce the demand for air travel, and its subsequent effect on the environment, would be to make flying more expensive by introducing new taxes or charges, although such an approach would likely be highly unpopular, thereby making this strategy potentially hard to defend for governments (Cairns & Newson, 2006; Griggs & Howarth, 2008). It is also believed that acquiring knowledge about environmental effects may increase people's awareness and ultimately encourage pro-environmental behaviour (Bamberg & Möser, 2007; O'Connor, Bord, & Fisher, 1999). Accordingly, different methods have been used to communicate the effect that air travel has on the environment in the hope that it will affect consumer behaviour. For example, Friends of the Earth (nd.) make available a short booklet about the effect of aviation on the environment, which includes suggestions for how people could reduce the number of times they need to fly (e.g., by taking holidays locally, rather than flying overseas), whilst the lobby group, PlaneStupid.com, have adopted a more proactive stance and participated in non-violent direct action at Stansted Airport by breaching the perimeter fence and disrupting flights to protest against a planned expansion (Gavin, 2010). In practice it has been reported that fewer than one in five people try to reduce the amount of flights that they take each year as a result of environmental concerns (Vaughan, 2009), and that air travel is increasing year on year (Beloba et al., 2009), all of which suggests that information about aviation's effect on the environment is not getting to consumers or, if it is, that it is having little or no effect.

In the wider context of behaviour modification and attitude change, education programmes and mass media campaigns frequently prove ineffective in dealing with public health issues, even when the suggested changes may improve or maintain people's health (Ringold, 2002) and probably save them money. For example, although unrelated to aviation, it has been found that health campaigns aimed at reducing the incidence of behaviours such as cigarette smoking, drug abuse, and excessive alcohol consumption often fail to succeed, whilst some campaigns even produce an effect in the opposite direction to that which was intended (Ringold, 2002). Attitudinal and behavioural changes that occur in a direction opposite to that which was intended are sometimes referred to as boomerang effects (Ringold, 2002).

Ringold (2002) argued that Brehm's (1966) reactance theory explains why some attempts at attitude change either fail or result in a boomerang effect. Although a review of reactance theory is beyond the scope of the current study, Brehm (1966) essentially argued that, as a reaction to impositions or regulations that encroach upon real or perceived freedoms and autonomy, people perceive the restricted behaviour or product as more desirable. Thus, people may perceive their ability to travel by air as a freedom to be enjoyed, at least when time and funds permit, and information aimed at reducing people's use of air travel as a potential imposition upon this perceived freedom.

The present study therefore sought to test the hypothesis that exposure to information about the effect of aviation upon the environment will lead to a boomerang effect, whereby air travel is subsequently perceived as more desirable.

METHOD

Participants

Participants were eighty undergraduate students (40 male, 36 female, 4 did not report gender). The mean age (9 did not report age) was 21.38 yr. (*SD* = 6.45, range = 17– 53). Thirty-nine students were recruited from a class in aviation management and forty-one were recruited from a class in cognitive psychology.

Materials and Procedure

The dependent variable was the degree to which flying is perceived as desirable. Thirteen statements (see table 1) were developed to tap various different aspects of people's desire to fly. For each of the 13 statements, participants were instructed to indicate the extent to which they agreed or disagreed using an 11-point scale, where 0 = *completely disagree*, 5 = *neither agree nor disagree*, and 10 = *completely agree*. To reduce the likelihood of a response set, some statements were negatively worded. Once the negatively worded statements were reverse scored, the overall scale mean would be interpreted as providing a general indication of how a person perceives the desirability of air travel, with higher scores indicating higher degrees of desirability. Participants were also asked to report their age and gender.

The independent variable was exposure to information that explains how aviation damages the environment and had two levels: i) exposure to information; or ii) no exposure to information. Participants assigned to the experimental condition were exposed to information which included

Table 1

Statements Measuring Desire To Fly

Number	Statements
1	I really like travelling by air.
2	If I can, I will travel by air as much as possible in the future.
3	I personally should take my holiday in the country where I currently live, as it can be just as good as visiting far-off destinations by air travel and will help save the environment.*
4	Airlines should pay extra taxes to offset pollution they cause. *
5	I think the average person in the country where I live wants to travel by air as much as they can in the future.
6	If holiday makers want to fly, they must pay extra taxes for the environmental damage that they cause.*
7	I should have freedom of choice to travel by air when I want.
8	It is selfish to want to fly to distant and/or exotic locations because it creates pollution and global warming.*
9	I intend to holiday at home to avoid contributing to air pollution.*
10	Air travellers unfairly affect non-air travellers by contributing to greenhouse emissions.*
11	I think that business people should try to cut back on flying if they possibly can (e.g., use teleconference rather than a business meeting), so not to contribute to global warming.*
12	Aircraft passengers should pay extra taxes to offset the global warming they contribute to.*
13	I think people should holiday in the country where they are currently living, rather than overseas, so as not to contribute to global warming.*

two video clips, both of which conveyed information about the negative effects of aviation on the environment, and a copy of a booklet published by Friends of the Earth. The video clips lasted approximately 5 min in total. The booklet provided by Friends of the Earth (nd) outlined factual information about aviation's effect on the environment including some tips on how to reduce the number of times that people fly (e.g., by taking holidays at home or using teleconference for business meetings), from which the experimenter read out loud five points about how to reduce one's reliance upon air travel, prior to instructing participants to complete the questionnaire. As the manipulation was short in duration (approx 7 min), participants in the control group were not exposed to unrelated audiovisual or text material.

Participants were approached at the end of a scheduled lecture and were asked to participate in a brief study to explore people's attitudes to air travel. Participants were blind to the experimental manipulation, but it was not possible to blind the survey administrator. Aviation students were randomly assigned to the experimental or control condition by drawing (without replacement) odd or even numbers for each participant, thus assigning them to either the control condition or experimental condition. As psychology students had already been randomly allocated to one of two groups at the time of testing, and because of classroom size constraints, one psychology class was randomly assigned to the experimental condition (by the flip of a coin) and the other to the control condition.

RESULTS

No participants declined to participate in the study and no questionnaires were spoiled, although 10 failed to report their age and/or gender. These participants were omitted from the following analyses.

One-way analysis of variance found that psychology students were significantly older than aviation students, $F(1, 69) = 9.38$, $p = 0.003$, partial $\eta^2 = 0.12$, ($M_{\text{Av}} = 19.03$ yr, $SD = 2.04$; $M_{\text{Pscyh}} = 23.54$ yr, $SD = 8.18$). Chi-sq test found that gender was significantly related to course, χ^2 $(1, n = 76) = 21.39$, $p < 0.001$; more males (29) than females (7) were enrolled in the aviation class, and fewer males (11) than females (29) were enrolled in the psychology class.

Internal consistency (Cronbach's Alpha) of the 13-statement questionnaire was 0.77 and could not be improved further by removal of any item(s). A 2x2 analysis of covariance, using age and gender as covariates, revealed highly significant main effects for: *exposure to information*, $F(1, 64) = 14.74$, $p < 0.001$, partial $\eta^2 = 0.19$, air travel was perceived as more desirable by those exposed to information ($M = 6.19$, $SD = 1.23$) than by those in the control condition ($M = 5.26$, $SD = 1.42$); and also for *course*, $F(1, 64) = 24.34$, $p < 0.001$, partial $\eta^2 = 0.28$; aviation students ($M = 6.40$, $SD = 1.31$) perceived air travel to be more desirable than did psychology students ($M = 5.04$, $SD = 1.15$). The interaction between *exposure to information* and *course* was not significant.

The above findings did not alter significantly when all participants were included in a 2x2 analysis of variance.

DISCUSSION

Similar to the boomerang effect found for many types of public health interventions (Ringold, 2002), the current findings support the hypothesis that providing¬¬¬ information about aviation's effect on the environment will have the opposite effect to that which was intended. In specific terms, following exposure to information about how aviation harms the environment and that potential solutions involve restrictions to the freedom of flying, people perceive flying as more desirable. As a result, the current strategy of the green lobby, i.e., to convince people that flying causes environmental damage, appears destined to fail.

If information-based interventions are indeed ineffective, or worse still lead to a boomerang effect, then other types of intervention, no matter how unfavourably they are received, may need to be considered. For example, evidence suggests that increased taxation increases the number of people who attempt to give up cigarette smoking (Hu, Sung, & Keeler, 1995), or reduce their level of alcohol consumption (Waagenar, Salois, & Komro, 2009), although air travel is very different from these two behaviours. It is considered likely that governments will be unwilling to implement changes such as these for a perceived right or freedom such as air travel for fear of not being elected to a further term. Alternatively, technological advancements in aviation may reduce the effect of aviation on the environment so that it no longer poses a significant threat to GCC, although there is no evidence this will occur anytime soon (Cairns & Newson, 2006).

Ultimately, expansion of aviation may not be halted by the environmental lobby, but by the lack of availability of low-cost aviation fuel, mainly as a result of the widely-anticipated advent of peak oil (May & Hill, 2006). However, as flying is currently much more dependent on oil-based fuels (Kivits, Charles & Ryan, 2010) than is driving (Zapata, 2010)—because, at least in the foreseeable future, electric aircraft are unlikely to be viable for passenger travel (Gohardani, Doulgeris, & Singh, In Press), whilst electric cars are already widely available and their production is rapidly increasing (Bradsher, 2009)—it is possible that reduced reliance on oil for cars will free-up and save remaining oil based fuel for aviation. We acknowledge this may require a significant change in current consumer attitudes and preferences and perhaps even some government legislation.

It was also found that participants enrolled in aviation courses perceived air travel to be more desirable than participants enrolled in psychology courses. This was interpreted as evidence that the 13-statement questionnaire tapped the construct of desire to fly, as it would be reasonable to expect students enrolled in an aviation degree to perceive air travel as more desirable than groups not explicitly studying aviation (i.e., their future livelihoods depend on the continuation of air transport). Furthermore, the lack of evidence of an interaction between *exposure to information* and *course* suggests that the difference in baseline desirability of air travel did not affect internal validity.

There are two potential limitations to the findings reported here. First, concerns the use of intact groups regarding the participants who were psychology students. However, as it was ascertained that the prior allocation to groups was not based upon any pre-existing characteristics, and as differences between aviation and psychology students was not the primary point of this study, this limitation is not believed to have seriously compromised the validity of the findings. Second, the participants in this study were students studying at a New Zealand University. It is possible that their views and the way in which they are influenced by information about the environment is limited to a New Zealand geographical context. For example, New Zealand's relative geographical isolation from other countries and few countrywide train services (TranzScenic, 2011) make alternatives to both domestic and international air travel financially unviable, whereas, in Europe, viable alternatives such as high-speed rail networks have led, for example, to the near-complete discontinuation of air services between Paris and Brussels (Dobruszkes, 2011). Although travellers to and from New Zealand are highly dependent on international air services (Becken, 2002), tourists in New Zealand are reportedly open to discussions on the environmental impacts of their travel (Fairweather, Maslin, & Simmons, 2005). That said, the findings of the current study suggest such discussions could lead to air travel being perceived as more desirable.

As the study reported herein investigated the desirability to travel by air, rather than actual behaviour (e.g., how much participants travelled by air before and after exposure to information), it is possible that the effect of exposure to information about aviation's effect on the environment is relatively short-lived. That said, given that it is possible to buy flights and/or holiday packages virtually instantaneously at any time of the day using the World Wide Web, even a temporary increase in the perceived desirability of flying would result in increased level of air travel within a population. This possibility could be investigated in future research using a larger representative sample where the outcomes of interest include both desire to fly and number of flights actually taken.

The current findings suggest that if the green lobby is to influence people's attitudes about flying by providing knowledge about the effect it has on the environment, and thus reduce people's desire to fly, they should be aware that so doing may result in a boomerang effect, whereby prospective passengers exhibit an *increased* desire to travel by air.

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