Developing a Single-Pilot Line Operations Safety Audit

An Aviation Pilot Study

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Original Article

Abstract. A single-pilot form of the line operations safety audit was trialed with a mid-sized emergency medical service air operator using two observers with a sample of pilots flying 14 sectors. The conceptual basis for observing pilot performance and analyzing data was the threat and error management model, focusing on threats, errors, undesired aircraft states, and their management. Forty-six threats and 42 crew errors were observed. Pilots generally used sound strategies to prevent errors and to manage successfully those that occurred. Threats resulting from operational pressures were well managed. The study achieved its objective of determining whether a single-pilot line operations safety audit could be successfully developed and used as a basis for systematic data collection.

Keywords: aviation safety, in-flight observations, threat and error management model, countermeasures, undesired aircraft states

Introduction

Among proactive approaches increasingly supplementing traditional routes to improved aviation safety is the line operations safety audit (LOSA; Klinect, Murray, & Helmreich, 2003; Thomas, 2004). The LOSA is a safety management tool developed for, and used in, aviation to collect data on and manage threats and errors occurring during everyday operations. Endorsed by the International Civil Aviation Organization (ICAO, 2002), LOSA methodology involves observing normal multicrew operations with minimal observer effect to capture flight crew performance. Aircraft operators are assisted in discovering how close they are to safety limits without breaching them.

Bringing single-pilot commercial aircraft operations up to the safety and operating efficiency levels of multicrewed operations presents significant challenges. For example, Horne (2008) estimated that 62% of the US turboprop fleet are single-pilot operated, yet 74% of all turboprop crashes involved single-pilot aircraft. In 2008 in Australia, single-pilot operations accounted for 2,059 incidents and 204 crashes, involving 49 fatalities and 45 serious injuries (Australian Transport Safety Bureau, 2009). Finding ways to reduce crash incident rates in single-pilot operations is urgent. LOSA is well-established in multicrew operations, where it draws on the communication among personnel for its rich data, but whether it is transferrable to single-pilot operations has hitherto not been researched.

This paper reports a study to determine the validity and practicality of a single-pilot LOSA concept. The key question was whether, without cross talk between pilots, there would be sufficient rich and valid data to draw conclusions that could usefully inform training, change processes, and protocols. This is a new departure for LOSA.

LOSA Origins

LOSA was developed to assist crew resource management (CRM) practices in reducing human error in complex flight operations (Helmreich et al., 2002). When it emerged that identification of threats and threat management were critical in this process, these were added to the concept. Recognizing the ubiquitous nature of threats and errors in normal operations and, importantly, their management by flight crew, this framework culminated in the threat and error management (TEM) model within LOSA (Helmreich, Wilhelm, Klinect, & Merritt, 2001). The inaugural TEM LOSA Collaboration between the University of Texas and Continental Airlines in 1996 provided proof of concept for LOSA, transforming it from a research methodology to an industry safety tool (Klinect, 2005).

A LOSA aims to provide airlines with an operational baseline of their strengths and weaknesses, giving them insights into flight deck performance during normal flights. LOSA data have demonstrated that 98% of flights experience one or more threats (average four per flight), with errors observed on 82% of flights (Klinect, 2005), most of which are well managed. By understanding what crews do successfully, as well as where things go wrong, training

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and safety initiatives can be made more effective. Flight crew and flight operations managers can readily follow TEM concepts, particularly error reduction and mitigation, rather than aiming for the impossibility of error elimination.

Not everyone agrees that counting threats and errors is a reliable way of measuring safety. Dekker (2003) stated that error categorization is not equivalent to understanding error. Dougherty (1990) commented that error classification schemes are often unable to distinguish cause from consequence and identified safety as being more than the measurement and management of negatives (errors), aspects of which can only be captured by a less numerical approach. These authors variously identified the critical importance of safety culture to safe practices. A strong possibility is that companies that conduct a LOSA already have a positive safety culture. The influence of these authors ensured that CRM (and LOSA) was accompanied by proactive organizational support, while Cooper et al. (1980) saw secondary benefits of improved morale and enhanced efficiency. Rochlin (1986) argued that collective commitment to safety was an institutionalized social construct, ensuring that organizations not only performed well but also transmitted an operational culture of mutual responsibility. By engaging in repeat LOSAs, an organization reaffirms its commitment to safety through a dynamic, interactive, and interdependent process.

International Acceptance

The LOSA gained international recognition in 2001 when it became a central focus of the Flight Safety and Human Factors Program (Klinect et al., 2003). The LOSA has since become a Q1 central focus for (2002), which has recognized it as best practice for airlines, dramatically increasing its use. Since the inception of LOSAs in 1994 at the request of Delta Airlines Q2 (Klinect et al., 2003), observations to complete them have been conducted on well over 10,000 flights with nearly 50 airlines worldwide. Airlines with repeat LOSAs report a significant decrease in errors when improved training or procedures have been adopted in response to LOSA findings. Regional airlines have seen the potential benefits of a safety audit with plans by the LOSA Collaborative to bring regional airlines within the LOSA domain (Rosenkrans, 2007). Several regional airline LOSAs have been completed, and differences in patterns of threat and error management between small regional and large international airlines are apparent (Murray & Bates, 2010).

Theoretical and Methodological Framework

Threat and Error Management Model

TEM seeks to improve safety margins in aviation operations through practical integration of human factors knowledge (Maurino, 2005). The model (see Figure 1) conceptualizes operational activity in terms of threats and errors that flight crews must manage to maintain adequate safety margins. The model captures performance in its "natural" or normal operating context by quantifying aspects of performance effectiveness. The TEM model is descriptive and diagnostic of both human and system performance in normal operations. When combined with an observational methodology such as LOSA, TEM is used to understand systemic patterns within a large set of events, as with operational audits. It helps to clarify human performance, needs, strengths, and vulnerabilities.

From a flight crew perspective, the three basic components of the TEM model are threats, errors, and undesired aircraft states (UASs). Threats and errors are part of everyday aviation operations that must be managed by flight crew, as otherwise they have the potential to generate UASs, which can lead to unsafe outcomes. UAS management is the last opportunity to avoid an unsafe outcome. Threats are events or errors external to flight crew influence that can increase the operational complexity of a flight, and which require immediate crew attention to maintain safety margins. Environmental threats, which are outside the direct control of the flight crew and the airline include adverse weather, hazardous airport conditions, air traffic control shortcomings, bird strikes, and high terrain. Airline threats, which are outside the direct control of the flight crew, but within management's purview, include aircraft malfunctions, cabin interruptions, operational pressure, ground/ramp errors/events, cabin events and interruptions (e.g., human factors), ground maintenance errors, and inadequacies of manuals and charts. Increasing complexity in the operating environment, including challenging and distracting events, increases the workload as flight crews must divert their attention from normal flight duties to manage those threats. A mismanaged threat is one that is linked to, or that induces, flight crew error.

Approximately 15% of aviation errors are directly linked to a threat, with the remaining 85% related to human performance (Klinect, 2005). Crew errors can vary from minor deviations, such as entering the wrong assigned altitude into the autopilot and immediately rectifying the mistake, to more severe errors, such as failing to set flaps before takeoff. Regardless of cause or severity, error outcome depends on whether the crew detects and manages the error before it leads to an unsafe outcome. The foundation of TEM lies in understanding error management rather than solely focusing on error commission.

The TEM model recognizes three basic categories of flight crew error, defined as flight crew action or inaction that leads to a deviation from organizational expectations or crew intentions: aircraft handling errors, procedural errors, and communication errors. The four types of aircraft handling errors are manual handling / flight control, automation, system/instrument/radio, and ground navigation. The seven types of procedural errors are briefing, callout, checklist, standard operating procedure (SOP) cross-verification, documentation, pilot flying / pilot not flying duty, and "other". The two types of communication errors are crew-external and pilot-to-pilot. A mismanaged error is one that is linked to, or that induces, additional error or a UAS. A further classification is associated with whether the deviation was unintentional or deliberate (e.g., SOP noncompliance).

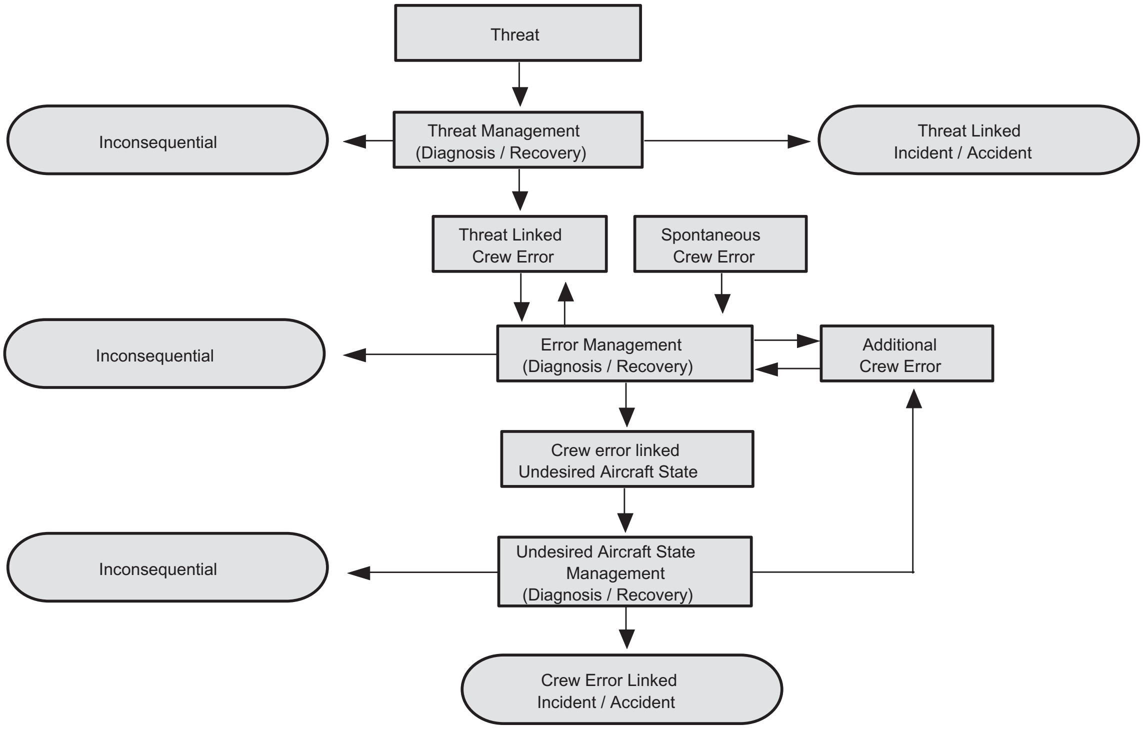

Figure 1. The threat and error management model (TEM). Adapted from "Line operations safety audit (LOSA): Definition and operating characteristics," by J. R. Klinect, P. S. Murray, & R. Helmreich, 2003, In *Proceedings of the 12th International Symposium on Aviation Psychology* (pp. 663–668). Dayton, OH: Ohio State University. Reproduced
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A UAS is an aircraft configuration that generates a safety-compromised situation resulting from ineffective threat and error management due to flight crew error. The pilot usually detects the UAS without recognizing the original error, which may not need to be corrected. For example, the solution to a "floated landing" on a short runway may be a go-around. The potential for a serious outcome means that UAS management is vital.

Threat and Error Countermeasures

The TEM model provided a broader base for understanding CRM performance skills, also described as threat and error countermeasures, which are used to anticipate threats, avoid errors, and detect and mitigate events/errors that occur. Research led to the development of 12 crew countermeasures in four higher level activities: team climate, planning, execution, and review/modification (Helmreich, 2001). Table 1 (after Klinect, 2005) outlines the threat and error countermeasures.

Aims of the Current Study

The first aim was to determine whether a single-pilot line operations safety audit (LOSA-SP) could be successfully developed and used as a basis for systematic data collection in a single-pilot operational environment. A single-pilot version of the LOSA was devised and trialed with two observers monitoring a sample of pilots flying various sectors. The second aim was to determine whether the TEM model could be used as the conceptual basis for data collection and analysis. The specific aim here was to determine whether pilot performance could be rated using four standard threat and error countermeasure categories.

Method

LOSA-SP Methodology

To facilitate the differences applicable to single-pilot operations, adaptations were made to the LOSA methodology, including revising some error categories. LOSA indicators based on the TEM framework were retained but adjusted to suit single-pilot operations. The University of Texas proposed 10 operating characteristics (Helmreich, 2001) critical to successful implementation of a LOSA, which have been adopted and endorsed by the International Civil Aviation Organization (ICAO) (2002). These were replicated for single-pilot operations. The LOSA-SP collected data on pilot demographics, threat occurrence and threat management, error occurrence and error management, and CRM effectiveness, through TEM-based behavioral markers.

Table 1. Threat and Error Countermeasures

Observed performance ratings			
1. Poor: Had safety implications	**2. Marginal**: Adequate but needs improvement	**3. Good**: Effective	**4. Outstanding**: Truly noteworthy
	Planning performance markers		
SOP briefing	Required briefings interactive and operationally thorough		*Concise, not rushed, clear boundaries established*
Plans stated	Operational plans and decisions communicated and acknowledged		*Shared understanding about plans*
Contingency management	Pilot anticipated, developed, and communicated strategies to manage safety risks		*Used all available resources to manage threats, errors, and undesired aircraft states*
	Execution performance markers		
Monitor/ cross-check	Pilot actively monitored and cross-checked: position, systems, and other crew members		*Aircraft position, settings, and crew actions verified; pilot maintained situation awareness*
Workload management	Operational tasks prioritized and properly managed to handle primary flight duties		*Avoided task fixation and did not allow work overload*
Automation management	Automation properly managed to balance situational/ workload requirements		*Automation setup briefed to other members*
Taxiway/runway management	Pilot used caution and kept watch outside when navigating taxiways and runways		*Clearances verbalized and charts used*
	Review/modify performance markers		
Evaluation of plans	Existing plans reviewed and modified when necessary		*Crew decisions and actions openly analyzed*
Inquiry	Crew members not afraid to ask questions to investigate/clarify current plans of action when necessary		*Crew members spoke up without hesitation*
	Team climate performance markers (overall performance only)		
Communication environment	Environment for open communication established and maintained		*Good cross talk – flow of information fluid, clear, direct*
Leadership	Captain showed leadership and verbally coordinated flight deck activities		*In command, decisive, encouraged crew participation*
Overall crew performance	Overall crew performance as risk managers		

Q12 *Note.* SOP = standard operating procedure. Reprinted with permission from *Line operations safety audit (LOSA): A cockpit methodology for monitoring commercial airline safety performance* (Dissertation), by J. R. Klinect. Austin, TX: University of Texas. Copyright 2005 by The LOSA Collaborative.

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Integrity of Methodology

Salient issues when conducting LOSA observations include data reliability (Reid, 1982), establishing trust with those being observed (Johnson, 1975), coding system accuracy (Bakeman, 2000), and observational reactivity, which occurs when individuals alter their normal behaviors because of an observer's presence (Klinect et al., 2003). In single-pilot operations, the LOSA observer uses the copilot's seat. Management commitment to the audit, together with promulgating a "just culture," is paramount to success. It is important to recruit pilots who are both willing to act as observers and representative of the group. To counter any possible bias of individuals affecting observations within a small company, the training included a full explanation of the LOSA methodology.

Operating Characteristics

The LOSA-SP was developed by closely matching the 10 characteristics with those specified by the International Civil Aviation Organization (ICAO) (2002). Q4

1. *Observations during normal flight operations:* Occupying the copilot seat, observers did not converse with the pilot, nor help in high-load situations. Observations were made discretely using note taking. Narra-

tives were recorded as soon after the flight as possible. Laptop computers or personal digital assistants were not allowed, as these could distract the pilot.

2. *Joint management/pilot sponsorship:* The steering committee, involved at all stages of the project, included management and pilots.
3. *Voluntary crew participation:* Observations were conducted only when pilots agreed to the observer being on board. Information was given to the pilots prior to flights commencing, and their consent was obtained. None refused to participate.
4. *De-identified, confidential, and safety-minded data collection:* Observations were based on International Civil Aviation Organization (ICAO) (2002) guidelines, ensuring that no identifying information was recorded.
5. *Targeted observation instrument:* Observers used specially designed schedules based on TEM and adapted from LOSAs for multicrew operations. The schedules targeted threats, errors, and UASs, and how each was identified and managed. Codes were developed by the company, pilots, and the research team.
6. *Trusted, trained, and calibrated observers:* Observers were volunteer pilots trained by the researchers. Following initial training, the observers carried out a trial run on two flight sectors, returning for data calibration to ensure coding consistency and reliability.
7. *Trusted data collection site:* All observation worksheets were retained by the researchers for data entry, storage, cleaning, and analysis. No one in the company could access the observation data, and no pilot could be identified from the worksheets.
8. *Data verification roundtables:* Sessions were conducted primarily by the researchers for coding reliability and checked with subject matter experts (managers) from the company.
9. *Data-derived targets for enhancement:* In multicrew LOSAs, trends are analyzed and prioritized for attention after data analysis. In this study, where data were sufficiently robust, recommendations were provided to the company.
10. *Feedback of results to line pilots:* Management reported back to the pilots on the major issues.

Procedure

After initial meetings with crew and management at a mid-sized emergency medical system (EMS) company operating single-pilot, twin turboprop, fixed-wing aircraft, a draft research proposal was developed. Following agreement by the company and pilot representatives to participate, an introductory newsletter was circulated, observer expressions of interest were invited, and a LOSA presentation was made to pilots and managers. A 5-day observer training course for two volunteer pilots was conducted by the third author (P.S.M.).

Observer Training

LOSA observer training occurred in two parts: (1) education in procedural protocol and (2) teaching TEM concepts and classifications (Klinect et al., 2003). Training emphasized the confidentiality and anonymity of observations, how to brief crews, and introduced "LOSA etiquette," including when to speak up regarding a safety-critical event not detected by a pilot. It teaches observers how to recognize, record, and code TEM performance. Observers were trained to focus on capturing data first, and classifying and coding them later (Appendix A shows the error management worksheet and Appendix B the threat management worksheet). Training included demonstrations and examples, as well as test exercises and a trial run with subsequent recalibration.

Pilots were trained to observe passively, not forming part of the constituted crew and making no operational input. The observers then flew 14 sectors of the company's route network and crew, including day and night flights. Observations were conducted on a strict "no jeopardy" basis, so that no names, flight numbers, or dates were recorded. Management agreed that, regardless of event, crew members would not be tracked through LOSA observations. After a flight, the pilot was asked standard questions about aspects of the operational environment, including their perceptions of the operation, such as what they considered to be the greatest safety issue.

Observers were instructed to rate a countermeasure if they observed it or if its absence was significant (e.g., a pilot failed to evaluate their plan in light of new information). A once-only rating was given for overall crew effectiveness, leadership, and communication. Planning countermeasures, which are integral to threat management, and execution countermeasures, considered crucial for error detection and error management, were rated during predeparture/taxi-out, cruise, and descent/approach/landing. Observers rated pilots' performance using a 4-point scale: 1 = poor – had safety implications; 2 = marginal – adequate but needs improvement; 3 = good – effective; and 4 = outstanding – truly noteworthy (see Table 1).

Results

Sample Description

Crew experience ranged from 5 to 47 years (3,500–22,500 hr), with experience on the specific aircraft type ranging from 100 to 15,000 hr (mean 2,773 hr). All observed pilots were male, and their work experience with the company ranged from 1 to 25 years (mean 8.25 years). Of the 14 observed flights (10 day, 4 night), 13 were on familiar routes, with 12 being normal flights and two involving short-notice changes of route or destination prior to departure.

Table 2. Number of Threats Observed by Category and Whether These Were Managed

Threat	Managed	Mismanaged	*N*
Air traffic control	16	1	17
Airport conditions	8	0	8
Weather	3	3	6
Airline operational pressures	5	0	5
Environmental operational pressures	4	0	4
Aircraft automation features	0	2	2
Cabin	0	1	1
Others	3	0	3
Total	**39**	**7**	**46**

Observed Threats

Forty-six threats were observed during the 14 flights (mean 3.3 threats/flight). Table 2 shows the numbers of threats observed by major category, with further descriptions of the categories below.

Air Traffic Control

Air traffic control (ATC) threats were most frequent, with challenging or late clearances being the major concern. Other threats were making frequent heading or altitude changes, incorrect notices to airmen (NOTAMs), and poor quality ATC transmissions. While a small number of threats was recorded due to ATC errors, the major difficulties were caused by clearances that challenged the crew to perform ATC requirements. Most of these threats occurred during the descent and approach phases when ATC managed traffic under congested conditions.

Airport Conditions

Airport threats were the second most frequent category. Some were due to runway maintenance or contamination, one being exacerbated by an unresponsive airport safety officer. Other threats reflected the company's operating environment, which involved pilots encountering unfamiliar airstrips, short airstrips with low apron maneuvering capacity, and airports operating in nontowered Class G airspace.

Weather Conditions

The third most frequent threat was posed by weather conditions. Marginal visual flight rules, mainly due to low cloud, added to threat frequency. Other threats included smaller airstrips with no terminal aerodrome forecast (TAF).

Operational Pressures

The fourth most frequent threat category, operational pressures, was almost exclusively associated with company operational requirements, such as changes in task or route, which is normal for this company's operations.

Environmental Operational Pressure

Fifth was environmental operational pressure, partly due to the complications of the airspace in which the company operated. Threats included high ground, high lowest safe altitude (LSALT), and high traffic volumes in uncontrolled airspace.

Other Threat Types

A small number of "other" threats were recorded that could potentially cause problems. Aircraft automation posed a threat on two occasions.

Phase of Flight

The five flight phases in which a threat could occur were predeparture/taxi-out, take-off/climb, cruise, descent/approach/landing, and taxi-in (see Figure 2). The highest frequency of threats originated in the predeparture/taxi-out phase. These included tasks and associated workload or with changes to it, and threats associated with ATC at the departure airfield. The descent/approach/landing phase had the next highest number of threats, with none in the taxi-in phase, despite pilots commenting that some airports had "tight" maneuvering areas, perhaps indicating some level of "normalization" of these threats.

Errors

Forty-two crew errors were observed during the 14 flights (mean 3.0/flight). Crew errors were classified under four categories: intentional noncompliance, aircraft handling, procedural, and communication errors (see Table 3). Intentional noncompliance and procedures errors were significant.

While LOSA methodology captures errors committed, it is equally important to assess management and mismanagement rates. Most errors occurred in the predeparture/taxi-out phase (Figure 2), which could be associated with a large number of threats and high workload, particularly with a change in task or destination. This phase also required the use of checklists, which were sometimes either omitted or performed from memory. Several errors were associated with the pilot being "head-down" (e.g., updating systems) while taxiing.

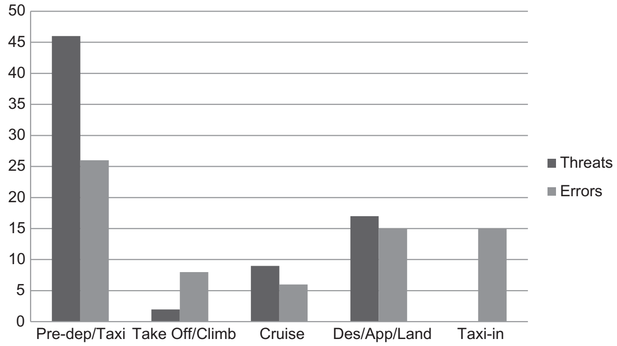

Figure 2. Threats and errors by phase of flight. App = approach; Des = descent; Pre-dep = predeparture.

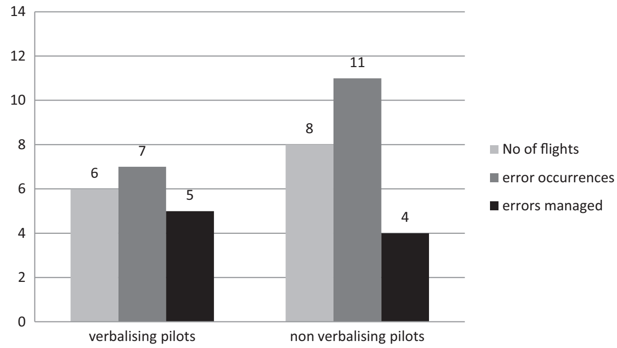

Figure 3. Procedural errors of verbalizing and nonverbalizing pilots.

Table 3. Error Types: Numbers Managed and Mismanaged

Error type	Managed	Mismanaged	*N*
Intentional noncompliance	3	19	22
Aircraft handling	0	1	1
Procedural	9	9	18
Communication	0	1	1
Total	**12**	**30**	**42**

Error Management

In multicrew operations, there is invariably a requirement for pilots to verbalize their actions, briefings, and intentions. Checklists are conducted as "challenge and response." Generally there is no such requirement in single-pilot operations, with views being divided on the value of this process. While this company did not stipulate that pilots should verbalize, it was informally reported to the research team that there was a fairly even split between pilots who did and did not verbalize. On six of the 14 observed flights, pilots verbalized their actions and intentions and used checklists out loud in a "challenge and response" fashion. On these flights, seven procedural errors were observed (1.1 errors/flight), of which five were managed well. Of eight flights where the pilot did not verbalize, 11 procedural errors were observed (1.4 errors/flight), of which four were well managed (see Figure 3).

Threat Management

While all threats can potentially affect safety adversely, some categories were better managed than others. "Mismanaged" threats (those not detected, or which led to errors) are of particular concern, especially those with high rates of occurrence and high rates of mismanagement (i.e., having increased risk potential). For example, a pilot is required to conduct many essential procedures from memory, and a checklist is then used to ensure that the actions required have been correctly completed. While a missed checklist might not be a major event in itself unless coupled with an earlier procedural error by the pilot, risk increases significantly when checklists are missed on several occasions. Table 2 shows that although ATC created the greatest number of threats, those threats were well managed on all but one occasion. Conversely, while weather accounted for six threats (12.5%), these were mismanaged on 50% of occasions.

Undesired Aircraft States

Six UASs were observed (mean 0.43/flight), all with inconsequential outcomes. Table 4 shows the most common UASs and their management.

Countermeasures

If performance on any item was rated as anything other than "good," then observers were required to explain their rating in their accompanying narratives. To illustrate the observers' range of marks for each countermeasure, Table 5 shows the four highest and the four lowest ratings. Of the lowest scoring markers, monitor/cross-check showed the greatest variation in scores, with as many pilots scoring "4 – outstanding" as scored "1 – poor" or "2 – marginal."

Standardization

Standardization addresses the issue of whether pilots complied with the company's SOPs, and whether these effectively reduced risk. The observations identified useful variations in performance in these areas.

Checklists

Checklists were the biggest category of observed errors, which included pilots omitting prestart, after start, after landing, and shutdown checklists. Some incorrect checklists were used, and items were sometimes missed from checklists. Checklists were sometimes completed late or from

Table 4. Number of Managed and Mismanaged Undesired Aircraft States (UASs)

UAS description	Managed	Mismanaged	*N*
Configuration states	2	1	3
Ground states	1	0	1
Aircraft handling states	1	0	1
Approach/landing states	0	1	1
Total	**4**	**2**	**6**

Table 5. Countermeasures: Lowest and Highest Scoring Markers

	Average rating	Average rating excluding two "perfect" flights*
Highest scoring markers		
Workload	4.0	4.0
Evaluation of plans	3.6	3.5
SOPs	3.6	3.5
Communication	3.5	3.5
Lowest scoring markers		
Taxi	3.8	1.6
Monitor/cross-check	3.3	2.7
Contingency planning	3.3	2.9
Automation	3.5	3.0

Note. SOPs = standard operating procedures.
*The observer gave ratings of "4 – outstanding" for much of the pilot's performance during two flights, which were judged as almost "perfect." The small number of flights observed (14) meant that these ratings affected the data for some markings, so the final column shows the figures excluding the ratings for these two flights.

memory. While most checklist errors were undetected by the pilots, and the outcomes were mostly inconsequential, on at least one occasion a missed checklist item led to a UAS.

Cross-Verification

Required cross-verification was not carried out on several occasions. These included no verification of flight management system (FMS) flight plans to paper copies, LSALT not checked on chart, and cabin security not confirmed. These errors went undetected, on two occasions leading to further errors.

External Communication

On some occasions, no broadcast calls were made to local traffic, or incorrect departure calls were made.

Crew Communication

Sterile cockpit procedures are specified so that the pilot is not involved in potentially distracting nonoperational conversations during critical phases of flight. On two occasions, these were not maintained at low altitudes, as a result of not isolating the cockpit from the cabin interphone system, as required by the SOP.

Briefings

Briefings not carried out sometimes led to further errors. In one instance, a pilot did not advise of an instrument approach as he expected to become visual early in the descent. The weather was worse than anticipated, leading to a hasty and unbriefed instrument approach, and subsequently a missed approach and a diversion. On another occasion, there was no check of a TAF at an alternative airfield, leading to a hurried briefing when it was found that this was required, also resulting in a missed approach.

Safety Interviews: Key Findings

The following paragraphs introduce a more subjective element of the strengths and weaknesses of pilots' technical performance, coupled with opinions from crew interviews.

Taxiing

Taxiing was rated lowest in terms of performance marks, being either poor or marginal. A number of head-down high pilot workload incidents were observed. On most occasions, the pilot averted an adverse event by intermittently looking up to maintain correct position. However, an aircraft once veered significantly on the taxiway, resulting in a UAS.

Automation Management

Pilots' automation skills varied from outstanding to poor. Pilots with previous experience of the aircraft type were best equipped to manage the FMS. Pilots with little experience on the aircraft type made more errors, indicating that more targeted training could benefit pilots new to type.

Safety Concerns

Of pilots who commented, short notice changes and night operations were of greatest concern, particularly night operations flying into "black-hole" airports without appropriate navigation aids or with unfamiliar airstrips. Comments included aircraft parking and taxiing areas being too small, requiring tight maneuvering with little margin for error. Also mentioned were workload and the amount of information to be consulted prior to a flight, particularly for a late task change.

Suggested Safety Improvements

A general comment was that SOPs should be more specific. Concerns were also expressed about the centralized tasking center and its "complacency" toward night operations.

Automation

Pilots commented on the poorly located database unit (DBU), which resulted in too much head-down time in the event of changes to approach or departure. Some saw failures of the attitude heading reference system (AHRS). One comment concerned a well-documented failure – the FMS memory battery failing, resulting in the autopilot disengaging.

Company Operational Efficiency

Pilots were confident that the company was sound. Their concern was with external agencies that needed to be made more aware of the company's needs so as to enhance its efficiency.

Discussion

Threat and Error Management

While based on a relatively small sample of operations, the LOSA-SP methodology produced useful and strongly indicative safety data. Larger samples are required for more definitive conclusions and recommendations. In light of well-publicized crash rates in single-pilot fixed-wing and rotary-wing operations, this type of research is vital in identifying safety improvements in all single-pilot operations.

The mismanagement rate of intentional noncompliance errors is high because if pilots decide to ignore a rule or procedure, this is in the expectation of no negative consequences. This may be because the procedure is unrealistic and is widely ignored, or because a pilot has "normalized" the deviance of procedures as consistent with the organization's safety culture (Vaughan, 1999, 2005). While errors in this category generally lead to inconsequential outcomes, repeated intentional noncompliance errors can substantially increase overall risk. Given that several shortcomings were observed in checklists use, and that checklists may be the last line of procedural defense against human error, these should be the most important operational area for review.

Communication with an external party (e.g., ATC) could be critical to safe operations, and although these did not constitute a large number of errors, consequences of this error type are potentially severe. In larger single-pilot operations studies, it will be necessary to observe a greater number and variety of errors during interactions between pilots and other parties, including cabin crew, ATC, and ground operations.

While aircraft handling errors are more easily detected than other errors, their consequences are often more serious, leading immediately to a UAS. Where monitoring and cross-checking procedures are well executed, aircraft handling errors should be identified and corrected before a more serious error or UAS occurs. Although these data were insufficient to draw definitive conclusions, a high level of mismanagement of aircraft-handling errors in multicrew LOSAs could indicate weaknesses in monitoring and cross-checking.

Monitoring and cross-checking also affect procedural error mismanagement rates. These are best explained as simple mistakes, such as the wrong altitude being set on the flight control unit (FCU) panel. The observed 50% mismanagement rate emphasizes the need to review and reinforce monitoring and cross-checking procedures. However, communication errors in single-pilot operations may be hard to detect as it is difficult for an observer to confirm monitoring and cross-checking occurrences. Where a pilot does not verbalize his/her intentions (which is optional), even an experienced observer could miss a procedure. However, evidence from this study suggested that, compared with those who did not do so, pilots who verbalized their intentions were more assiduous in cross-checking and made fewer mismanaged procedural errors.

Threats from operational pressures were all observed to be well managed. Nevertheless, they add to overall flight complexity, and their reduction should be a management target. Aircraft threats also fall within the operator's domain, and training could reduce the frequency of threats from this source. Threats due to the cabin environment might indicate advantages of a multicrew CRM training environment (O'Connor et al., 2008) to include nonpilot EMS crew members. Facing a variety of standard threats, as well as those unique to the company's operation, the observed pilots generally used sound strategies to prevent errors and to manage successfully those that occurred.

Undesired Aircraft States

While the data revealed that all observed UAS outcomes were inconsequential, they are insufficient to draw firm conclusions. Thus, broadly based strategies to detect and manage UASs are important in improving safety. A subjective view of the UAS distribution suggested that incorrect aircraft configuration states and approach/landing states, vital to safety management, were of particular concern. This UAS category is highly important, and it was recommended to the company that individual reports be analyzed to see what lessons might be learned, and to determine strategies for reducing them. For example, in simulator training, approach and landing UASs can be introduced with good effect (e.g., poor ATC vectors onto final approach, leaving an aircraft in a high/fast situation requiring significant pilot management to avoid an unstable approach).

Other Issues and Further Recommendations

The observers and research team were impressed with the dedication of the pilots and EMS crew. This was obvious from the high morale among company crews and the in-flight energy displayed while performing routine procedures that form the foundation for safe flying. Evidence from audit and interview data indicated that the company had established a strong framework to support its flight operations. Well-motivated and hard working, the pilots enjoyed their work and each other's company. They were very adept at managing changing workloads and adapting quickly to new instructions. They were seldom observed to be flustered and scored highly on evaluation of plans. All seemed comfortable with questioning changes and ensuring flight safety.

There were examples of links between organizational culture, crew performance, and flight safety. The positive organizational culture reported at Southwest Airlines has been hailed as the driving force behind its excellent safety record and financial success (Freiberg & Freiberg, 1996). Conversely, negative organizational cultural factors have been cited as contributing to the Challenger disaster, and the 1996 ValueJet 592 crash (Vaughan, 1996). In the current study, questioning revealed belief in a robust safety culture, which could have contributed to the trust in the audit and reactions to the findings. Merely setting up a LOSA study has been found to increase safety awareness, also evident in the current study.

Most observed flights were on familiar routes, albeit with a few short notice changes. Of interest would be comparing observation data from flights originating from short notice callouts. The sample size in this study was selected to determine whether the LOSA methodology could be adapted to single-pilot operations. This objective was achieved, as the LOSA methodology was largely transferrable so that all TEM model categories were observable. However, while the methodology was transferrable with some adaptations for single-pilot operations (e.g., crew–crew communication), much of the adaptation was operator specific. This suggests that while the methodology could be used in a single-pilot concept, further refinement is required, in particular threat type definitions for other single-pilot operators (e.g., rotary-wing EMS operations).

Experience has shown that in a typical airline operation, a sample size of around 60 flights is needed to capture enough errors, threats, and UASs to undertake valid quantitative data analysis. Larger samples would facilitate cross-tabulating threat source and flight phase, as in a full LOSA evaluation. Such an analysis would normally show that a large proportion of threats and errors are encountered in the preflight and approach/landing flight phases.

Sexton and Klinect (2001) stated that an airline's safety culture combines individual members' practices, attitudes, and competencies against a backdrop of organizational policies and procedures. The current study demonstrated practices and competencies under normal flying circumstances for both pilots and the system, highlighting the effectiveness of safety culture in contributing to improvements. Rayner (1992) distinguished safety from safeness. Defining an organization as safe because it has a low rate of errors or incidents has limitations comparable with defining health in terms of not being sick. A LOSA has been likened to a health check – by identifying potential problems (e.g., high cholesterol), a patient can engage measures to prevent an adverse health event (e.g., heart attack; Klinect, 1995). Safeness is the story that a group or organization tells about itself and its relation to the risk environment. A LOSA aims to capture data that can point to problems in the system and, together with a positive safety culture, make changes to improve safety within an organization's operations.

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Appendix A

Error Management Worksheet

			Error Description				*Error Response/Outcome*		
Error ID	Describe the error and any associated undesired aircraft states	**Phase of Flight** 1. Pre-depart/ Taxi 2. Takeoff/ Climb 3. Cruise 4. Descend/ Approach/ Landing 5. Taxi-in	**Was the error proficiency based?** (Yes or No)	**Error Type** 1. Intentional Noncompliance 2. Aircraft Handling 3. Procedural 4. Communication	**Error Code & altitude error occurred**	**Who committed the error?**	**Who detected the error?**	**Error Response** 1. Detected & action 2. Detected and ignored 3. Undetected	**Error Outcome** 1. Inconsequential 2. Undesired state 3. Additional error
E1					——				

		Error management			*Undesired aircraft states*		
	Associated with a threat? (If Yes, enter threat ID – e.g., T2)	**How did the pilot manage or mismanage the error?** (Describe the response to the error and the outcome) Also describe the response to any associated UAS and the outcome	**Was there an undesired aircraft state (Y/N)**	**UAS code and altitude UAS occurred**	**Who detected the UAS?**	**UAS response** 1. Detected & action 2. Detected and ignored 3. Undetected	**UAS outcome** 1. Inconsequential 2. Additional
E1				——			

Who Committed/Detected Codes				
Flight crew 1 Pilot 3 Other crew member 4 All crew members	5 Nobody 6 Observer (only complete if observer had to intervene for safety)	**Other people** 8 ATC 9 Dispatch	10 Ground crew 11 Maintenance	**Aircraft** 20 Aircraft systems **Other** 99 Detected by any other means

Q6 *Note*. ATC = air traffice control; UAS = undesired aircraft state. With acknowledgement to the LOSA Collaborative.

Appendix B

Threat Management Worksheet

Threats – Events or errors that originate outside the influence of the pilot but require active management to maintain safety					
Threat ID		***Threat description***		***Threat management***	
	Describe the threat	**Threat code & altitude that threat occurred**	**Phase of flight** 1. Predepart/taxi 2. Takeoff/climb 3. Cruise 4. Descend/approach/landing 5. Taxi-in	**Effectively managed?** (Yes / No)	**How did the pilot manage or mismanage the threat?** (Describe the response to the threat and the outcome)
T1					
T2					
T3					
T4					
T5					
T6					