

Human error in aviation maintenance: the years to come

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Introduction

The retrospective analysis of actions and inactions by operational personnel involved in accidents and incidents has been the traditional method utilized by aviation to assess the impact of human performance in regard to safety. The established safety paradigm, and prevailing beliefs about what constitutes safe and unsafe acts, guide this analysis in such a way that it traces back an event under consideration until a point in which investigators find a behaviour that did not produce the results. At such point, human error is concluded.

This conclusion is generally arrived to with limited consideration of the processes that could have led to the 'bad' outcome. Furthermore, when reviewing events, investigators know that the behaviours displayed by operational personnel were 'bad' or 'inappropriate', because the negative outcomes are a matter of record. This is, however, a benefit the operational personnel involved did not have when they selected what they thought at the time were good or appropriate behaviours, and which would lead to a good outcome. In this sense, it is suggested that investigators examining human performance in safety occurrences enjoy the benefit of hindsight.

Furthermore, conventional safety wisdom holds that, in aviation, safety is first. Consequently, human behaviours and decision-making in aviation operations are considered to be one hundred percent safety oriented. This is not true, and a more realistic approach is to consider human behaviours and decision-making in operational contexts as a compromise between production-oriented behaviours and decisions, and safety-oriented behaviours and decisions. The optimum behaviours to achieve the actual production demands of the operational task at hand may not always be fully compatible with the optimum behaviours to achieve the theoretical safety demands.

All production systems, and aviation is no exception, generate a migration of behaviours: under the imperative of economics and efficiency, people are forced to operate at the edges of the system-safety space. Consequently, human decision-making in operational contexts lies at the intersection of production and safety, and is therefore a compromise. In fact, it might be argued that the trademark of experts is not years of experience and exposure to aviation operations, but rather how effectively they manage the compromise between production and safety. Operational errors do not reside in the person, as conventional safety knowledge would have aviation believe. Operational errors primarily reside in latency within task and situational factors in the context, and emerge as consequences of mis-managing compromises between safety and production goals, largely influenced by the shared attitudes across individuals (i.e., culture).

This compromise between production and safety is a complex and delicate balance and humans are generally very effective in applying the right mechanisms to successfully achieve it, hence the extraordinary safety record of aviation. Humans do occasionally mis-manage task and/or situational factors and fail in balancing the compromise, thus contributing to safety breakdowns. However, since successful compromises far outnumber failures, in order to understand human performance in context the industry needs to capture, through systematic analyses, the mechanisms underlying successful compromises when operating at the edges of the system, rather than those that failed. It is suggested that understanding the human contribution to successes and failures in aviation can be better achieved by monitoring normal operations, rather than accidents and incidents. The Line Operational Safety Audit (LOSA), discussed in this paper, is the vehicle endorsed by the International Civil Aviation Organization (ICAO) for this purpose.

Strategies to understand operational human performance

Accident investigation

The most widely used tool to document and attempt to understand operational human performance in aviation, and define remedial strategies, is the investigation of accidents. However, in terms of human performance, accidents yields data mostly about behaviours that failed to achieve the balance compromise between production and safety discussed in the previous section. It is suggested that positive outcomes provide a more sensible, supplemental foundation upon which to define remedial strategies and subsequently reshape them as necessary, than do negative ones.

From the perspective of organizational interventions, there are limits to the lessons that may be extracted from accidents that might be applied to reshape remedial strategies. It might for example be possible to identify the type and frequency of external manifestations of errors in each of these generic accident scenarios, or discover specific training deficiencies that are particularly conspicuous in relation to identified errors. This, however, provides only a tip-of-the-iceberg perspective. Accident investigation, by definition, concentrates on failures, and in following the rationale advocated by LOSA, it is necessary to better understand the success stories to see if their mechanisms can somehow be bottled and exported. This can better be achieved through the monitoring of normal line operations and associated successful human performance.

Nevertheless, there remains a clear role for accident investigation within the safety process. Accident investigation remains the appropriate tool to uncover unanticipated failures in technology or bizarre events, rare as they may be. More important, and in extreme terms, if only normal, daily operations were monitored, defining assumptions about safe/unsafe behaviours would prove to be a task without a frame of reference. Therefore, properly focussed accident investigation can reveal how specific behaviours, including errors and error management, can resonate with specific circumstances to generate an unstable and most likely catastrophic state of affairs. This requires a focussed and contemporary approach to the investigation. Should accident investigation restrict itself to retroactive analyses as discussed above, its only contribution in terms of human error would be increase industry databases, the usefulness of which in regard to contemporary safety remains dubious. Even worst, it could provide the foundations for legal action, the allocation of blame and punishment.

Incident investigation

Incidents are more telling markers than accidents, if not of operational human performance, at least on system safety, because they signal weaknesses within the overall system *before* the system breaks down. There are, nevertheless, limitations on the value of the information on operational human performance obtained from incident reporting systems.

First, incidents are reported in the language of aviation and therefore capture only the external manifestations of errors. Furthermore, incidents are self-reported, and because of reporting biases, the processes and mechanisms underlying error as reported may or may not reflect reality. Second, and most important, incident reporting systems are vulnerable to what has been described as normalization of deviance. Over time, operational personnel develop informal and spontaneous group practices and shortcuts to circumvent deficiencies in equipment design, clumsy procedures, or policies incompatible with operational realities, all of which complicate operational tasks. In most cases normalized deviance is effective, at least temporarily. However, since they are normal, it stands to reason that neither these practices nor their downsides will be reported to, nor captured by, incident reporting systems.

Normalized deviance is further compounded by the fact that the most willing reporters may not be able to fully appreciate what are indeed reportable events. If operational personnel are continuously exposed to substandard managerial practices, poor working conditions, or flawed equipment, how could they recognize such factors as reportable problems? While these factors would arguably be reported if they generate incidents, there remains the difficult task of evaluating how they can create less than safe situations, and thus overcome the temptation to postulate that deviations explain incidents simply because they are deviations.

Incident reporting systems are certainly better than accident investigations to begin understanding system and operational human performance, but the real challenge lies in taking the next step - understanding the processes underlying human error rather than taking errors at face value. It is essential to move beyond the visible manifestations of error when designing remedial strategies. If such interventions are to be successful in modifying system and individual behaviours, errors must be considered as symptoms that suggest where to look further. In order to understand the mechanisms underlying errors in operational environments, flaws in system and human performance captured by incident reporting systems should be considered as symptoms of mismatches at deeper layers of the system. The value of the information generated by incident reporting systems lies in the early warning about areas of concern, but it is suggested that such information does not capture the concerns themselves.

Training

The observation of training behaviours, such as for example during flight crew simulator training, is another tool to which aviation has ascribed inordinate value in helping to understand operational human performance. However, the production component of operational decision-making does not exist under training conditions. While operational behaviours during line operations are a compromise balance between safety and production objectives, training behaviours are heavily biased towards safety. In simpler terms, the compromise between production and safety is not a factor in decision-making, and operational behaviours exhibited are 'by the book'.

Therefore, behaviours under monitored conditions can provide an approximation to the way operational personnel may behave during line operations, and such observation may contribute to flesh out major operational questions, such as for example significant procedural problems. However, it would not be correct - and it might lead an organization into a risky path - to assume that observing personnel under training provides the key to understand human decision-making and error in unmonitored operational contexts.

Fight data recorder information

Digital Flight data recorder (DFDR) and Quick Access Recorder (QAR) information from normal flights can also be a valuable diagnostic tool (although the expense may prohibit its use in many airlines). There are, however, considerations about the data acquired through these tools. DFDR/QAR readout does provide information on the frequency of exceedences and the locations where they occur, but these data cannot yield information on the human behaviours that were precursors of the event. While DFDR/QAR data tracks potential systemic problems, pilot reports are still necessary to provide the context within which to fully diagnose the problems.

Nevertheless, DFDR/QAR data hold high cost/efficiency ratio potential. Although probably underutilised because of both cultural and legal reasons, DFDR/QAR data can assist in filtering operational contexts within which migration of behaviours towards the edge of the system takes place.

Normal operations monitoring

The supplemental approach proposed in this chapter to uncover the mechanisms underlying the human contribution to failures and successes in aviation safety, and therefore to the design of countermeasures against human error and safety breakdowns, focuses on the monitoring of normal line operations.

Any typical line flight - a normal process - involves inevitable, yet mostly inconsequential errors (selecting wrong frequencies, dialling wrong altitudes, acknowledging incorrect read-backs, mishandling switches and levers and so forth). Some errors are due to flaws in human performance, others are fostered by systemic shortcomings; most are a concatenation of both. The majority of these errors have no damaging consequences because (a) operational personnel employ successful coping strategies and (b) system defences act as containment net. It is about these successful

strategies and defences that aviation must learn to shape remedial strategies, rather than continuing to focus on failures as the industry has historically done. Monitoring normal line flights, utilizing a validated observation tool, allows to capture these successful coping strategies.

There is emerging consensus within aviation that the time has come to adopt a positive stance and *anticipate* the damaging consequences of human error in system safety, rather than regretting its consequences. This is a sensible objective and a cost-effective way (in terms of dollars *and* human life) to achieve it is by pursuing a contemporary approach rather than updating or over-optimizing methods of the past. After fifty years of investigating failures and monitoring accident statistics, the relentless prevalence of human error would seem to indicate -unless it is believed that the human condition is beyond hope- a somewhat misplaced safety emphasis in regard to operational human performance and error.

A contemporary approach to operational human performance and error

Progressing to normal operations monitoring, and thus to the implementation of LOSA, requires revisiting and adjusting prevailing views of human error. In the past, safety analyses in aviation have viewed human error as an undesirable and wrongful manifestation of human behaviour into which operational personnel somehow willfully elect to engage. In recent years, a considerable body of practically oriented research, based on cognitive psychology, has provided a completely different perspective on operational errors. This research has substantiated in practical terms a fundamental concept of human cognition: error is a normal component of human behaviour. Regardless of the quantity and quality of regulations the industry might promulgate, regardless of the technology it might design, and of the training humans might receive, error will continue to be a factor in operational environments because it simply is the downside of human cognition. Error is the inevitable downside of human intelligence; it is the price human beings pay for being able to think on our feet. Error is a conservation mechanism afforded by human cognition to allow humans to flexibly operate under demanding conditions for prolonged periods without draining their mental batteries.

There is nothing inherently wrong or troublesome with error itself, as manifestation of human behaviour. The trouble with error in aviation lies with the *negative consequences* it may generate in operational contexts. This is a fundamental point: in aviation, an error the negative consequences of which are trapped before they produce damage is inconsequential. In operational contexts, errors that are caught in time do not produce damaging consequences and therefore, for practical purposes, do not exist. Countermeasures to error, including training interventions, should not be restricted to attempt to avoid errors, but rather to make them visible and trap them before they produce damaging consequences. This is the essence of error management: human error is unavoidable but manageable.

Error management is at the heart of LOSA and reflects the previous argument. Under LOSA, flaws in human performance and the ubiquity of error are taken for granted, and rather than attempting to improve the human condition, the objective becomes improving the context within which humans perform. LOSA aims ultimately - through changes in design, certification, training, procedures, management and investigation - at defining operational contexts which introduce a buffer zone or time delay between the commission of errors and the point in which their consequences become a threat to safety. The buffer zone/time delay allows to recover the consequences of errors, and the better the quality of the buffer or the longer the time delay, the stronger the intrinsic resistance and tolerance of the operational context to the negative consequences of human error. Operational contexts should be designed in such a way that allows front-line operators second chances to recover the consequences of errors.

An approach to human error from the perspective of applied cognition furthers the case for LOSA. Accident and incident reports, and existing database analyses may provide some of the answers, but it is doubtful that they will answer the fundamental questions regarding the role of human error in aviation safety. To what extent do flight crews employ successful coping strategies? To what extent do successful remedial strategies avert incidents and accidents? These are the questions for which a *systematic* answer is imperative in order to ascertain the role of human error

in aviation safety, prioritize the issues to be addressed by remedial strategies, and reshape remedial strategies as necessary.

Managing change once LOSA data is collected

LOSA is but a data collection tool. LOSA data, when analysed, are used to support changes designed to improve safety. These may be changes to procedures, policies, or operational philosophy. The changes may affect multiple sectors of the organization that support flight operations. It is essential that the organization has a defined process to effectively use the analysed data, and to manage the change the data suggests.

LOSA data should be presented to management in at least operations, training, standards and safety, with a clear analysis describing the problems related to each of these areas as captured by LOSA. It is important to emphasize that while the LOSA report should clearly describe the problem the analysed data suggest, it should not attempt to provide solutions. These will be better provided through the expertise in each of the areas in question.

LOSA directs organizational attention to the most important safety issues in daily operations, and it suggests what are the right questions to be asked; however, LOSA does not provide the solutions. The solutions lie in organizational strategies. The organization must evaluate the data obtained through LOSA, extract the appropriate information, and then deploy the necessary interventions to address the problems thus identified. LOSA will only realize its full potential if the organizational willingness and commitment exist to act upon the data collected and the information such data support. Without this imperative step, LOSA data will join the vast amounts of untapped data already existing throughout the international civil aviation community.

Conclusion

There is no denying that monitoring normal operations through LOSA on a routine basis and worldwide scale poses significant challenges. Significant progress has been achieved in tackling some of these challenges. For example, from a methodological point of view, some early problems in defining, classifying, and standardizing the data obtained have been solved; and consensus has been developed regarding what data should be collected. From an organizational perspective, there is a need to consider using and integrating multiple data collection tools, including line observations, more refined incident reporting and Flight Data Analysis (FDA) systems. This in turn poses a challenge to the research community, to assist airlines by developing analytic methods to integrate multiple and diverse data sources. But most importantly, the real challenge for the large-scale implementation of LOSA will be overcoming the obstacles presented by a blame-oriented industry, that will demand continued effort over time before normal operations monitoring is fully accepted by the operational personnel, whose support is essential.

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