

# Designing for the Resilience of Flight Approach Operations

Ronish Joyekurun<sup>†‡</sup>, Paola Amaldi<sup>†</sup> and William Wong<sup>†</sup>

<sup>†</sup>Interaction Design Centre, Middlesex University, London NW4 4BT, UK;

<sup>‡</sup>EUROCONTROL Experimental Centre, F-91222 Bretigny Sur Orge, France.  
*Ronish.joyekurun.ext@eurocontrol.int; {p.amaldi-trillo; w.wong}@mdx.ac.uk*

**Abstract.** We propose a design approach grounded in the analysis of civil air traffic occurrences for tackling normal system errors. This proposal argues that the work of air traffic controllers and airborne crews on approach to an airport can be qualified by collaborative interactions. Such interactions are shaped by a number of factors namely: a) divisions of labour inherent to a complex socio-technical system, b) the distributed availability of traffic and atmospheric information on approach. Finally, we propose that design solutions which attempt to tackle normal system errors by augmenting the psycho-physical limitations of human are limitedly applicable to the improvement of that system's functional resilience.

## Introduction

On the 1<sup>st</sup> of June, 1999, American Airlines flight 1420 crashed after it overran the runway 4R at Adams airfield, in Little Rock, Arkansas. A detailed analysis of the accident by the National Transportation Safety Board (NTSB) indicated as a probable cause, the flight crew's failure to discontinue the approach when a thunderstorm had moved into the area of the airport. Among the human factor causes mentioned were a) impaired performance due to fatigue, b) continuing an approach despite a maximum crosswind component which exceeded company crosswind minimas, and c) the use of reverse thrust 1.3 engine pressure ratio after landing (NTSB, 2001). Dismukes, Berman and Loukopoulos (2007b) studied the limits of expertise in 19 aviation accidents, including the American Airlines 1420 occurrence at Little Rock. They recommended that airline could safeguard against error by implementing periodic revisions of procedures, establishing firm "bottom line" limits for navigation procedures such as stabilised approaches and training crews to proactively assess situations.

The accident of American 1420 leading to the loss of 11 lives is often seen as an example of human cognitive limitations and biases and used for crew training. In hindsight, the causes of this accident seem clear cut. However, further analysis indicates that a) the knowledge of a thunderstorm threat was available during the planning stages of the flight, b) the flight dispatcher

conveyed that information to the crew and advised that they took off as soon as possible to “beat the storm”, c) the thunderstorm was perceptible to the crew before attempting their approach, d) the ground controllers were also aware of the weather and yet helped the crew to plan their approach, and e) the cockpit recorder does not indicate any discussions for diverting to another airport at any moment during the scenario. These facts provide an insight on expert decision-making which cannot be satisfactorily explained by a theory grounded in the variability and limitation of human performances – adequate planning time was available, weather information sources were accurate during relatively non-stressful time periods, but the participants in this scenario pressed on into a hazardous situations.

## Normal Accident Theory

Normal Accident Theory (Perrow, 1984; Sagan, 1993) considers the complexity inherent to our socio-technical systems as being beyond the complete control of tools and preventive barriers. In fact, Amalberti (2001) argues that trying to “fix” the system based on a number of localised causes might only lead to a paradoxical decrease in safety, in an otherwise ultra-safe system. Normal Accident Theory takes a holistic, systemic approach to analyse occurrences in complex systems, by stepping away from the limited view of targeting only individuals as the main contributors to system errors. It proposes a pro-active means of increasing system resilience which differs from the reactive design solutions targeted at mitigating human errors. Moreover, the theory proposes to consider expert decision-making as inherently re-shaped by the overarching objectives of an organisation, such as ever-increasing demands on operational efficiency.

The American Airlines flight 1420 accident reviewed at the start portrays operational decisional conditions which are not uncommon on a routine basis. Dismukes, Berman and Loukopoulos (2007a, p. 271) observe that landing approaches conducted in adverse navigation conditions are potentially hazardous, but nonetheless common practice in the airline industry – therefore, it would be unreasonable to expect no vulnerability from accidents, unless more conservative approach procedures are enforced by the airline industry. Ironically, as long as such situations end in a favourable outcome, they are seen as being routine – one might also assume that such situations are not recorded into aviation occurrence databases, and thus remain invisible to the eyes of safety reviewers and commissions.

Hollnagel, Woods and Leveson (2006) propose the Resilience Engineering paradigm as a proactive means of designing for the risk of failure. At the functional level of a complex system, operations might be enabled by a large number of entities such as regulatory procedures, automated machine functions as well as human performances, all motivated by organisational goals of safety

and efficiency. Therefore, an approach which addresses the improvement of a system function should hypothetically target those critical entities as a whole, by first analysing their complex interactions. While this holistic or systemic approach is gaining more recognition in human factor-based analytical exercises, the transition to design solutions still tends to be focused on correcting and modifying the variability of human beings. Although this approach retains its value, it is seen to be targeted at a class of problems which do not necessarily extend to the type of aviation occurrences known as normal incidents and accidents, originating from Normal Accident Theory.

## Identifying a Critical Unit of Work

Operators in High Reliability Organisations are often organised according to a division of labour where individual specialist skills are integrated into a collective mind as a means of resolving complex organisational objectives (Weick, Sutcliffe, & Obstfeld, 1999). Air-ground teams in approach ATM are also seen to have an added particularity in the form of a structurally de-constructed and re-constructed group – indeed, the team is reconstituted according to the crew which is in communication with the ground controller at a point in time. Despite this dynamicity, the air-ground teams are bound by the function of planning an approach and performing a landing, thereby requiring that a stable functional relationship be preserved. Moreover, airborne crews as well as air traffic controllers often undergo behaviour modification programmes such as regular company training (e.g. Helmreich, Merritt, & Wilhelm, 1999; Maurino, 1999; Rogalski, 1996). For this reason, air-ground teams on approach are to be differentiated from other more structurally stable and uniformly trained teams in alternate work domains (e.g. Entin & Serfaty, 1999).

A detailed study of 348 instances of collaborative verbal exchanges from five occurrences due to hazardous weather has provided four co-operative themes of air-ground team interaction namely, 1) Monitoring of activities, 2) Attention redirection to perceived priorities, 3) Implicit delegation of responsibilities, and 4) Explicit verbal assignation of activities (Joyekurun, Amaldi, & Wong, 2007). The study concluded that a complex re-distribution of activities occurred among the air-ground team during the hazardous approach situations analysed.

We propose that normal occurrences during the approach flight phase in Air Traffic Management (ATM) constitute a systemic error which can be understood by the analysis of a functional team. An “aircraft approach” function is determined by the system goal of landing an aircraft safely and efficiently. The functional goal is accomplished by humans engaged in collaborative activities due to the divided labour strategies adopted in ATM. The human entities in this air-ground team are the Pilot flying (PF), Pilot Non-

flying (PNF) and the Executive controller (EC). The collaborative group behaviour and decisions of the team follows prescribed aviation procedures but can be re-shaped by organisational goals and objectives.

## Design of Safety Boundaries

The performance demands of certain complex systems are said to drive operators to progress closer to dynamic safety boundaries (Leveson et al., 2006). The availability of such boundaries in an explicit form is believed to provide a feedback control mechanism as a means of achieving a self-corrective interaction between air-ground teams and their organisational work setting. We made use of navigation hazards on approach due to adverse weather conditions to inform our study on the boundary limits of operations.

We have analysed a number of accident reports and found that there is a tendency in "normalising" risky actions/decisions on the ground (Joyekurun et al., 2007). While contributing to the effectiveness of the whole system those decisions generally do not have fatal consequences. The tendency to normalise decisions that are on the boundary of the safety envelope has eloquently been demonstrated by the Columbia space shuttle accident (CAIB, 2003) and more generally in the aviation domain (Dismukes et al., 2007b; Woods, 2005). It appears then, that the issue is to support practitioners to recognise when they are pushing towards the safety boundaries while attempting to comply with organisational pressures.

Flight navigation approaches are regulated by an interaction of atmospheric minimas (visibility conditions, precipitation rates, wind speeds and direction, icing probabilities, pressure variations, dew points, etc.), ground conditions (runway conditions, approach landing equipment availability, etc.) and traffic geometries in the area (FAA, 2001, 2003; ICAO, 2006a, 2006b). The ability to manage the complex combination of those factors during decision-making is an expert skill of air-ground teams. We hypothesize that the decisions of air-ground teams in approach sectors is further shaped by the demands of efficiency in certain parts of the ATM system – the air-ground team re-adapts progressively to this added set of organisational conditions. This is seen to constitute what Reason (1990) qualifies as being a latent condition for active failures to result in adverse operational outcomes.

## Conclusion

Designs aimed at resolving isolated causes of aviation occurrences risk introducing even more latent conditions for failure (Amalberti, 2001). A design approach grounded in the analysis of normal occurrences as a means of

providing air-ground teams with a feedback of the system's safety boundaries during navigation flight approaches in adverse weather is proposed.

## Acknowledgement

This study is part of an ongoing doctoral research programme at the Eurocontrol Experimental Centre, under the mentoring of Mr Alistair Jackson and Mr Marc Bourgois. I would also like to thank Dr. Barry Kirwan for his kind consideration of this proposal for the Safety R&D Seminar.

## References

- Amalberti, R. (2001). The Paradoxes of Almost Totally Safe Transportation Systems. *Safety Science*, 37, 109-126.
- CAIB. (2003). The CAIB Report - Volume I, *Columbia Accident Investigation Board* (Vol. 1): National Aeronautics and Space Administration.
- Dismukes, K., Berman, B., & Loukopoulos, L. (2007a). American 1420 - Pressing the Approach. In K. Dismukes, D. Maurino & S. Dekker (Eds.), *The Limits of Expertise: Rethinking Pilot Error and the Causes of Airline Accidents* (pp. 247-273): Ashgate.
- Dismukes, K., Berman, B., & Loukopoulos, L. (2007b). *The Limits of Expertise: Rethinking Pilot Error and the Causes of Airline Accidents*: Ashgate.
- Entin, E., & Serfaty, D. (1999). Adaptive Team Coordination. *Human Factors*, 41(2), 312-325.
- FAA. (2001). *Instrument Flying Handbook* (manual): Department of Transportation: Federal Aviation Administration.
- FAA. (2003). *Pilot's Handbook of Aeronautical Knowledge* (manual): Department of Transportation: Federal Aviation Administration.
- Helmreich, R., Merritt, A. C., & Wilhelm, J. A. (1999). The Evolution of Crew Resource Management Training in Commercial Aviation. *The International Journal of Aviation Psychology*, 9(1), 19-32.
- Hollnagel, E., Woods, D., & Leveson, N. (Eds.). (2006). *Resilience Engineering: Concepts and Precepts*. England: Ashgate.
- ICAO. (2006a). *Aircraft Operations: Volume I - Flight Procedures* (manual): International Civil Aviation Organisation.
- ICAO. (2006b). *Manual of Aeronautical Meteorological Practice* (manual): International Civil Aviation Organisation.
- Joyekurun, R., Amaldi, P., & Wong, W. (2007). *A Functional Collaborative Work Unit for Analysing Hazardous Flight Approaches*. Paper presented at the Human Factors and Ergonomics Society, Baltimore, Maryland.
- Leveson, N., Dulac, N., Zipkin, D., Cutcher-Gershenfeld, J., Carroll, J., & Berrett, B. (2006). Engineering Resilience Into Safety Critical Systems. In E. Hollnagel, D. Woods & N. Leveson (Eds.), *Resilience Engineering: Concepts and Precepts* (pp. 95-123): Ashgate Publishing Limited.
- Maurino, D. (1999). Safety Prejudices, Training Practices, and CRM: A Midpoint Perspective. *The International Journal of Aviation Psychology*, 1999(9), 4.
- NTSB. (2001). *Runway Overrun During Landing - American Airlines Flight 1420* (manual). Washington D.C. 20594: NTSB.
- Perrow, C. (1984). *Normal Accidents: Living with High-Risk Technologies*. New York: Basic Books.
- Reason, J. (1990). *Human Error*: Cambridge University Press.

- Rogalski, J. (1996). Co-operation Processes in Dynamic Environment Management: Evolution Through Training Experienced Pilots in Flying a Highly Automated Aircraft. *Acta Psychologica, 91*, 273-295.
- Sagan, S. D. (1993). *The Limits of Safety: Organizations, Accidents and Nuclear Weapons*. Princeton, New Jersey: Princeton University Press.
- Weick, K., Sutcliffe, K., & Obstfeld, D. (1999). High Reliability: Processes of Collective Mindfulness. *Research in Organizational Behaviour, 21*, 81-123.
- Woods, D. D. (2005). Creating Foresight: Lessons for Enhancing Resilience from Columbia. In B. Starbrook & M. Farjoun (Eds.), *Learning from the Columbia Accident*. Blackwell.