Weather Hazards in ATM: Designing for Resilient Operations

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Abstract

Motivation – To improve the quality of collaborative work in approach Air Traffic Management through the design of displays to support pilot-controller decision-making with operational weather minimas.

Research approach – A Resilience Engineering approach is taken which centres on an air-ground team as an un-dissociable unit of work. The air-ground team is constituted of the pilot flying and non-flying while the ground team is made up of the tactical controller. The human-human relationships within the air-ground team form the basis of a collaborative analysis while the scope of work is defined organisationally.

Findings/Design – An initial verification exercise made use of aviation occurrence databases to statistically confirm the incidence of weather on navigation in approach flight phases. 348 air-ground collaborative exchanges were then analysed and indicated a complex re-distribution of crew resources, categorised, under four emergent themes.

Research limitations/Implications – Only US-based accident information from readily-transcribed verbal exchanges was used which limited the generalisation of the findings.

Keywords
Resilience, CSCW, Weather, ATM

Introduction

The purpose of this discussion paper is to explore an identified problem in Air Traffic Management with the variability of expert human performance during the approach phases of flight. It is observed that pilots who attempt to make approaches and landing in adverse weather conditions have largely varying reactions to the prevailing conditions at a moment in time, despite being governed by the same aviation rules and navigation regulations. We initially hypothesize that the large system variability is due to an adaptive interaction of reduced efficiency between the airborne crew and ground controllers. This research exercise will try to identify a probable reason for co-operative actions of reduced effectiveness and to provide a design framework for producing hazard displays as a means of helping air-ground teams in performing safe and effective approaches through concerted decisions. The first part of this paper introduces the problem identification and analytical approach while the latter part explicates the research methodology and work already accomplished.

Millions of large air-carriers face adverse weather conditions and survive it thanks to an Air Traffic Management (ATM) system which can be qualified as being ultra-safe (Amalberti, 2001). When aviation occurrences (incidents and accidents as qualified by the International Civil Aviation Organisation, ICAO) take place in the presence of adverse weather and the absence of mechanical failures, it is not uncommon to situate the problem at the level of the flight crew. Indeed, with the large number of defences built into ATM systems as a means of safely guiding the paths of pilots faced by adverse weather, any systemic error not directly arising from mechanical failure is often said to be human in nature (Dismukes, Berman, & Loukopoulos, 2007). However, the abilities which make humans error-prone also allow them to be the most creative decision-makers when facing unexpected situations and coming up with sensible decisions at that point in time (Hemreich, 1994). Regarding safety, ATM systems can dictate a range of procedural rules of operation as well as accept a number of flexible, critical decision steps to take place.

The analytical approach taken in this research is one with holistic properties, where the unit of work is an interaction which can take place among any pair of system entities. More specifically, a functional pair is identified as being critical in the approach phase of flight and consists of the controller-team and airborne team. The functionality of those two dislocated groups is characterised primarily by a physical relationship which takes place as verbal, radio communications and which occurs mainly between the PNF (Pilot Non Flying or commonly, co-pilot) and the tactical controller.

On Collaboration in Complex Systems

Human to human co-operation in ATM is an instance of collaboration. According to Game Theory in economics,
co-operation arises between two individuals when they perceive their own limitations with regards to certain goals and also perceive the ability for the other person to help them achieve that goal – thereby giving a very individualistic view of the motives behind co-operative actions. Schmidt’s modes of co-operation (Schmidt, 1994) are grounded in a similar view of individualistic needs which are however devoid of the altruistic aspect of co-operation, or the ability for certain natural entities to co-operate without any perceived gains or returns (Roberts, 2005; Worden & Levin, 2007).

The co-operative aspects of entity behaviour can also be explained from the perspective of skill-specialisation and division of labour (Deutsch, 1949). In a complex system, it is virtually impossible for any single entity to master all system functionalities – hence, many entities are needed. The least number of entities needed to provide the most system functionality (or its operating efficiency) relies partly on the ability to minimise skill overlap, and therefore maximise specialisation. This approach for handling complexity requires a large overhead in the form of an integration or management efforts and this reduces the effectiveness of the system; this is a recurrent compromise faced by many complex organisations (Perrow, 1961).

This document regards system co-operation as a non-altruistic exchange of information between functionally adaptive entities – this holistic interaction can be hypothetically understood by analysing the group’s behaviour arising from its goals and motives at a moment in time.

**Dynamic Teams with Dynamic Behaviour**

Air-ground teams in approach ATM have particular forms of collaborative activities since they are structurally de-constructed and re-constructed according to the crew which is in communication with the controller at a point in time. Although bound by the same international aviation regulations, airborne crews as well as air traffic controllers often undergo behaviour modification programmes such as regular company training. For this reason, air-ground teams in civil aviation are to be differentiated from other more physically cohesive and uniformly trained teams in alternate work domains.

When faced with the onset of unpredicted changes in their plans, crews react as a means of trying their best to preserve the global objectives of making a safe and efficient landing. Safety and efficiency are said to be competing objectives since the increase of one often leads to a decrease in the other – hence, operators aim at achieving the best compromise, more often as a synthesis of their reflexes than by explicitly abiding to an organisational directive (O’Hare, 1992). As a means of aiding pilots and controllers in their jobs, practitioners have attempted to explain expert behaviour under stress from the perspectives of numerous decision-making models. The rational decision making model variants presume that humans generate a number of logical alternatives and choose the best one based on their situation at a moment in time (Tversky & Fox, 1995). The recognition primed model takes into consideration the speed and experience of experts while making decision in naturalistic settings and presumes a pattern-matching strategy with similar, past situations (Ross, Klein, Thunholm, Schmitt, & Baxter, 2004).

However, some workers do not seem to abide by, what in hindsight are qualified as rational or even naturalistic decisions. Despite the ample presence of environmental cues to indicate a high risk for navigation, crews attempt to perform approaches and landings, most of the time while aided by controllers. Although very few results in accidents, research indicate that a significant number of incidents occur under the same conditions. The decisions made in those cases are blamed on cognitive limitations because of time pressures, lack of adequate information, lack of expertise, inadequate training and so forth (Hastie, 2001; Hunter, Martinussen, & Wiggins, 2003; O’Hare & Smitharam, 1995; Tversky & Fox, 1995).

**METHODOLOGY**

This paper poses the theoretical question: “How are team decisions made in structurally dynamic and dislocated teams?”

To understand the decisions of air-ground teams on approach, this research analyses the collaborative actions of the air-ground team, namely the controller, the PF (Pilot Flying) and PNF (Pilot Non-Flying). A statistical verification stage is followed by ethnographic methods as a means of explaining the behaviour of structurally dynamic teams.

- Statistical analysis of existing occurrence databases to verify the incidence of hazardous approaches due to the onset of adverse weather.
- Thematic analysis of cooperative activity patterns on approach through verbal exchanges and occurrence investigation reports.
- Interview of air-ground teams to elicit expert information namely:
  - Individual perception and usage of navigation weather minimums.
  - Air-Ground team perception of navigation weather minimums.
  - Air-Ground team weather-related decisions relative to company regulations.

An initial review of occurrence databases (NTSB Accident database, AIDS incident database as well as WAAS global accident database) indicated that weather-related occurrences are frequent – this was confirmed by official statistical reports from safety agencies (NTSB, 2004). A preliminary statistical analysis of accidents occurring with air-carriers on US soil indicated that occurrences peaked during en-route phases and on approach – however, when turbulence-related occurrences are excluded, approach phases of flight constitute the largest source of occurrences.
The apparent significance of occurrences during en-route phases of flight due to turbulence is confirmed by a recent study by the FAA on the same phenomenon (FAA, 2004).

The next step of the research exercise was to focus on the approach phase of flight. A systemic view treats any occurrences as a normal outcome in the system – the distinction between different critical levels of incidents and accidents is an economical and ethical imposition. Hence the term normal accidents (Perrow, 1984) denotes a systemic view of the more critical occurrences as viewed from an organisational perspective. This stage analysed the co-operation of air-ground teams by identifying emergent themes of work. The preliminary results indicate a complex redistribution of work activities among the crew and controllers on approach and when faced with weather hazards (Joyekurun, Amaldi, & Wong, 2007a). The complex redistribution of work, attention and risks has also been observed in critical activities involving patient safety in clinics (Vikkelsø, 2005).

The current state of this doctoral research exercise is focusing on expert interviews both as individuals and as a critical working group. An initial un-structured interview of an airline pilot (unpublished) indicates company rules which, although grounded in the same international flight regulations, are applied to varying degrees. For instance, the usage of standard phraseology within the cockpit is not an obligation for certain crews while the pilot interviewed indicated a strict adherence to formalised language both within-cockpit and to ground services.

CONCLUSION
The approach taken with this research has given a particular view of collaborative activities within air-ground approach ATM. For strategic situations which indicate a planned incidence of weather on approach (for instance, as indicated by a flight dispatcher), the verbal exchanges within the team increases noticeably and it might be construed that the crew’s resource management (CRM) is intensely dynamic thereby leading to the resource delegations observed. For tactical situations during the final approach stages involving what Dismukes (2007) refers as being an action-reaction-evaluation sequence of events, the team retains the largest variations in verbal exchanges within the cockpit while initial analyses are finding ground communications to remain largely constant.

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REFERENCES


