Layers of influence on human-alarm interaction: A case study

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Abstract. This work documents a case study in a safety critical domain where human-alarm interaction is shown to be subjected to safety policies developed and modified by the Management in response to safety critical events. A working hypothesis is formulated drawing on recent studies in the safety management areas, like resilience engineering Hollnagel, Woods, & Leveson, 2006), according to which the "unit of analysis" in human alarm interaction has to reach for organizational and societal layers. Recent developments in the health care settings suggest the proposed framework applies well beyond the present case study.

Historical-Organisational shift in human-alarm interaction paradigm

Consistent with recent development in the safety management literature (Xiao, Seagall, Nieves-Khouw, Barczak, & Perkins, 2004), we argue that the process of developing and the integration of a safety device into a practice has to be conceptualized in relation to organizationally/societally (and historically determined) values. While this organizational-historical perspective has already received some attention by the literature on alarm design and resource management in medical settings (Cook & Rasmussen, 2005; Miller & Xiao, 2006; Xiao, et al 2004), its role in shaping the integration process of a tool into the practice has not been much explored yet. We intend to provide evidence to a framework of analysis where *interaction* within the different layers including regulators, safety engineers, managers, and front line operators, is a central

construct and it implies that whatever happens in one layer, cannot be made full sense of unless goals, constraints and pressures operating within other layers are taken into account. We refer to this as the *systemic-interactional* framework of analysis. The domain of reference is Civil Aviation and the role played by a safety device introduced on board of civilian aircraft in order to prevent mid air collisions, once other safety barriers have failed. The tool, called Traffic Collision and Avoidance System (**TCAS**) is composed of two "Advisories": while "Traffic Advisory" provides a warning that the situation could evolve in a loss of standard separation, it is only the "Resolution Advisory" that requires pilots to act according to the maneuver announced by the alarm.

To clarify the nature of the interactions among TCAS/pilots/air traffic controllers, we have analysed a number of Technical Reports, Operational evaluations, Accident Reports, Training Material and found that TCAS played different roles not always overlapping with those defined by the safety regulators. Further, interviews with safety managers, and airline pilots (to be detailed elsewhere), have highlighted that the "nature" of the alarm, its scope, and roles are dynamically defined and re-defined not only by the "front line" practitioners, but also by the safety managers and engineering communities.

Our analysis suggests quite a drastic shift has been made by safety management in response to the recent midair collision in near Überlingen in 2002 (BFU, 2004). These "view-shifts" are then historically determined and while the safety management community has introduced recommendations leading to an increased number of compliant responses of pilots to the TCAS alarm, there remain concerns about certain "unsafe" pilots' reactions (RTCA, 2006).

Methods and findings

In this section we illustrate the domain of reference, the method and data analyzed, and the findings. The domain of reference is Civil Aviation and the role played by a safety device introduced on board of civilian aircraft in order to prevent mid air collisions, once other safety barriers have failed.

Methods: (i) Review of Accident Reports of a mid air collision occurred over Uberlingen (Swiss-German border) in July 2002; (ii) Review of over 15 Technical Reports drawn in the past thirteen years and covering Operational Evaluation and Training material, issued by major Research and Development Centers in Civil Aviation; (iii) interviews with safety managers, regulators, airline pilots (ongoing, detailed results to be reported elsewhere).

An in-depth analysis of the documents prepared by safety managers in the course of the last thirteen years has highlighted a number of "view shifts" occurred over time concerning in particular the integration of TCAS into the existing Air Traffic Management settings, and the re-definition of TCAS-Flight Crews-ATC interactions. These highlight that the scope and role of the alarm is dynamically re-defined reflecting *systemic interactions* among different layers within the Air Navigation activity system.

Two situations have been historically analyzed: (a) the TCAS-pilots interaction before and after the Überlingen mid air collision and (b) the issue of military-civilian air traffic coordination. Early European operational evaluations revealed that the engineering and safety management community recognized the "situated" nature of TCAS by giving pilots the "final say", i.e., the authority to override the Resolution Advisory (RA) (Vallauri, 1995). As shown by the quotes below, the high rate of pilots' non-compliance (25%) to the alarm was justified by the pilots' ability to:

- visually acquire the intruder;
- integrate traffic information received from controllers;
- assess the seriousness of the situation;
- judge that safety is not compromised.

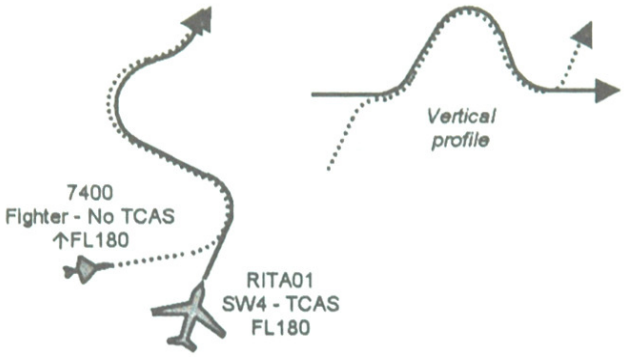
In the following quotes from an early operational evaluation Report (Vallauri, 1995), the author is willing to provide reasons for pilots non compliance to the alarm annunciation:

> "The main reason why pilots do not react to RAs [Resolution Advisories] is that there's visual acquisition of the threat […] They might also have received traffic information from controllers. In these […] circumstances, pilots might *consider* that the safety of the aircraft is not jeopardized and that there is *not a risk* of collision. [italics added]
> [……..]
> We can thus conclude that pilots rely on their TCAS and follow RAs whenever they cannot *assess* the seriousness of the situation themselves" (pg. 28-29).

Both quotes admit that pilots are not only in a position of "considering" or "assessing" the parameters of the situation they control, but their judging skills can *overrule* TCAS decisions. However, there is *no trace* of such a view in the Reports we reviewed and written after the mid air collision. Rather, these indicate that both pilots and controllers are required to *unconditionally* follow TCAS as shown by the following quotes extracted from an Operational Evaluation prepared after the Überlingen accident.

> "Pilots must follow all RAs even if they have visual acquisition"
> (CENA/EUROCONTROL, 2002)

While compliance requirements have been enforced more rigidly, other issues such as military/civilian air traffic coordination have "softened out". The following category of events, i.e., military interceptions of civil aircraft has been illustrated in several Reports, but commented differently at different times. Early Evaluation Reports highlighted the potential risks of military traffic flying outside their zone without informing either the controllers or the aircraft being intercepted.



- The aircraft Rita01 is flying at Flight Level18000 feet (short FL180). It receives a "Climb" Resolution Advisory (RA) that the pilot follows.
- However, the RA does not cease (intending a loss of standard separation is still possible) and is followed by many other RAs. After a climb to FL197 and a descent back to FL180, the pilot initiates some horizontal maneuvers.
- The intruder detected by the TCAS alarm is a military aircraft, which is performing an interception on RITA01.

Figure 1. Event_1: Military interception as a source of nuisance (EUROCONTROL/CENA 2002)

This event caused a lot of discomfort to pilots and controllers. The military aircraft ignored that they were being "intercepted" by the alarm TCAS. On the other hand, civilian pilots and controllers did not see the intruder and were surprised by the TCAS alarms. The following recommendation is made by the Eurocontrol Report (Bisiaux, 1996):

> This [*Event_1*] underlines the requirement to maintain efficient co-ordination between civil and military ATC. (pg. 42/33).

Even more emphatically, the CENA Report (Vallauri, 1995) stated:

> "[…] it is *hazardous* for civil aircraft to react to RAs during conflict with military aircraft since military aircraft approaching civil aircraft do not expect the civil aircraft to react. (pg. 47).
>
> "TCAS is effective for resolving conflicts between civil aircraft, but military aircraft maneuvers impair its performance" (pg. 46).

Later Reports, however seem to have mitigated the risk of intercepting traffic not known to neither pilots nor controllers. In fact a training manual stated that

> "When *practicable*, a good coordination between military and civilian controllers may help to prevent unnecessary RAs […] (RITA2, 2002, pg 51, italics added)

Recommendations for avoiding unnecessary stress is made, but the acknowledgement of the safety risk seems gone.

> "If the tracks are not displayed to ATC, this may cause surprise to the controllers. [….] The aircraft being intercepted should be informed, if possible, about the interception, to minimise the surprise to the pilot" (RITA2, 2002, pg 51/79)

Interestingly enough this shift is reminiscent of the one operated by the NASA Management leading to the (tragic) decision of launching the Columbia space shuttle (CAIB, 2003; Woods, 2005). In case analysed here, minimizing operational inadequacy of TCAS seemed to be functional to increasing trust in the alarm device so to further reduce non-compliant responses to TCAS.

Conclusions

While we have no compelling evidence that the shift in risk assessment, reinforced compliance requirements and role of the alarm tool have been consequential to the Überlingen mid air collision, some changes have been documented. They point to the fact that the "identity" of a safety device is not only the result of decisions made neither by the designer's team, nor by the National and Trans-national Safety Policy makers and regulators, nor is it exclusively defined by the frontline practitioners' use of it but it is interwoven across these layers. Our analysis of the operational data (of which only a tiny sample is reported here) suggests that TCAS has strengthened dependencies among actions taken by different crews and between pilots and controllers; further TCAS has unexpectedly violated certain organisational boundaries like those around military/civilian air traffic. All of this has created new needs for coordination. How are these needs interpreted within the different organisational layers and what is the link between these different interpretations and practitioners' actions? Our hypothesis is that while the focus of investigation can opportunistically shift from one layer to another, ultimately it is the interplay among these layers that accounts for the ways in which TCAS become progressively integrated into the activity of Air Traffic Management.

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