

THE UBERLINGEN MID-AIR COLLISION: LESSONS FOR THE MANAGEMENT OF CONTROL ROOMS IN THE PROCESS INDUSTRIES

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Synopsis

The mid-air collision which occurred over Uberlingen in 2002 was one of the worst aviation accidents in Europe in recent years, the resulting lessons having been applied in the aviation industry.

No hardware failures contributed to the accident which occurred at a time of very low operational loading. Systemic failings of management systems led to an experienced air traffic controller failing to act in a timely manner. This together with actions on the flight deck of one of the aircraft resulted in the collision. Many of the factors which contributed to the accident could also arise in the control rooms of process plants.

This paper draws on the official investigation by the BFU (Bundesstelle fur Flugunfalluntersuchung, German Federal Bureau of Air Accidents Investigation) In addition input from a workshop organised by the PRISM Human Factors Network has been used to draw lessons for the process industries.

These include

- The need to define minimum manning levels for all states of operation and ensuring that these are complied with.
- The need to assess the impact of maintenance work and of revising risk assessments and operational procedures when necessary to maintain integrity.
- The need to ensure that when senior staff are present in the control room they do not inhibit open discussion and decision making.

INTRODUCTION

As noted above the accident which occurred over Uberlingen on the 1July 2002 was one of the worst in Europe in recent years. Mid air collisions are very rare and in this incident a Russian Tupolev passenger aircraft on a flight from Moscow to Barcelona collided with a Boeing freighter enroute from Bergamo, Italy to Brussels. Both aircraft were less than 15 years old, they where equipped with modern navigational and collision avoidance systems and were manned by experienced aircrews. The accident occurred under good weather conditions, at a time of low traffic density with both aircraft under the control of an experienced air traffic controller at the Swiss air traffic control centre, Zurich. All those on the aircraft lost their lives, 2 crew members on the Boeing and 9 crew and 60 passengers on the Tupelov. A particularly tragic aspect of the accident was that the passengers on the Russian aircraft were a party of school children making a special visit to Barcelona, their first trip outside of Russia.

The official report prepared by the Bundesstelle fur Flugunfalluntersuchung (BFU) (ref1) identifies a number of failings in both the air traffic control centre and in the training in and use of collision avoidance systems which contributed to the accident. The report details 21 recommendations to improve safety in the aviation sector.

The incident was discussed at a meeting of the EU funded PRISM Human Factors Network, (ref 2) where it was agreed that many aspects of the incident were relevant to the process industries and needed to be more widely circulated and appreciated. In preparing this paper this paper the author has consulted a number of sources on the internet particular attention has been given to the section of the BFU report on Human Factors.

The author would like to make it clear that this paper has been prepared solely to communicate the lessons to the process industries and does not attempt to allocate blame or to comment on the lessons appropriate to the aviation industry.

The incident involved interactions between the air traffic control centre and the cockpits of both aircraft. For simplicity this paper starts with a description of the sequence of events in each location followed by an analysis of the factors which contributed to the accident.

EVENTS AT THE AIR TRAFFIC CONTROL CENTRE

At the time of the accident both aircraft were under the control of the Zurich air traffic control centre. This was a long established installation although in the year prior to the accident the centre had been transferred from federal to private control (It should however be noted that the report does not identify any way in which this change contributed to the accident). The centre was equipped with modern radar and computer systems which included ‘short term conflict alert’ which provided both an audible and a visual indication of potential mid-air collision.

The manning of the centre was based on two Air Traffic Control Officers (ATCO) assisted by two support staff. Both of the ATOC’s rostered for duty on the night of the accident were fully qualified and experienced. During the night shift

the traffic load was generally very low and it had been accepted practice for a number of years for one of the ATOC's to leave the control room and retire to a nearby lounge together with one of the assistants, out of immediate contact with the controller who remained on duty. To quote the report (ref 1) *'Even though it was an unofficial procedure it was known to and tolerated by the management.'*

One the night in question modification work had been planned on the radar and computer systems used by the controllers. This required the system to be operated in 'fall-back' mode from 21:00 hrs for a period of 6 hours, normally a period of low traffic density. In 'fall-back' mode the visual indication of potential collision would no longer appear on the screens although the audible alarm would still be operational. A description of this modification work had been provided in two 'Official Instructions' which were issued and made available in the briefing room and the office of the supervisor, however none of the staff on duty claimed knowledge of these instructions. In addition the work required that the ATCO use a back-up telephone system to contact other air traffic control centres. This was not detailed in the instructions.

At 21:00 hrs a group of about 6 technicians entered the control room and requested permission to start the modification work which was granted. No mention was made of the fact that the visual indication of potential collision would be out of operation.

At 21:21:56 the Boeing en-route from Bergamo to Brussels entered the airspace of ACC Zurich and requested permission to climb to a flight level of 360 which was granted.

At about this time a delayed Airbus bound for Friedrichshaven entered the airspace. This required the ATCO to alert Friedrichshaven control staff. The normal telephone link had been disconnected for the modification work and the controller tried the back-up system without success. He made repeated attempts to contact the control staff and also asked his assistant to try and find another number.

At 21:30:33 the Tupelov entered the airspace of ACC Zurich at a flight level of 360 and was given permission to proceed. The ATCO then returned to the problem of contacting Friedrichshaven.

At 21:34:49 the ATCO became aware of the potential conflict between the Tupelov and the Boeing and instructed the Tupelov to ". . . .descend to flight level 350, expedite, I have crossing traffic." He then returned to the problem with the telephone contact.

At 21:35:03, having received no acknowledgement from the Tupelov, the ATCO repeated the instruction ". . . .descend to flight level 350, expedite, descend." This was acknowledged by one of the pilots and, having seen that the plane was starting to descend, the ATCO once again turned his attention to the Airbus approaching Friedrichshaven.

Having transferred control of the Airbus to Friedrichshaven the ATCO returned to the other planes and found that the signal for the Tupelov had been replaced by a red dot indicating that radar contact had been lost. Attempts to contact both the Tupelov and the Boeing failed.

EVENTS ON THE TUPELOV FLIGHT DECK

Since the captain of the Tupelov was not experienced with the flight to Barcelona the flight crew of the aircraft had been increased by the addition of an instructor. It therefore comprised, the instructor, (Pilot in Charge), the captain (Pilot Flying), a co-pilot (no specific duties), a navigator and an engineer.

Both the Tupelov and the Boeing were equipped with TCAS, a Traffic Alert and Collision Avoidance System. This system acts independently of other control systems in the aircraft and on the ground to detect any other aircraft with which a collision is likely. It provides a visual indication of other aircraft in the vicinity together with two warnings, firstly a 'Traffic' warning followed by an instruction to either 'Climb' or to 'Descend', the advice being coordinated between the two aircraft involved so that they receive the appropriate instruction. At the time of the accident the system was mandatory for all aircraft using European airspace but was generally not in use within the Russian federation. The flight crew had undergone training in the use of TCAS but this did not include simulator training.

Shortly after entering the Zurich airspace the crew noticed that the system indicated another aircraft in the vicinity and at 21:34:36 made visual contact. At 21:34:42 the 'Traffic' warning was received. 7 seconds later at 21:34:49 the system issued the instruction 'Climb'. Before the pilots had time to act they received the instruction from the Zurich ATOC to '. . . descend, expedite'.

Faced with this dilema the Instructor (Pilot in Charge) called on his experience and followed the instruction of ATC, issuing the order to descend which was followed by the captain.

There then appears to have been some discussion between the three pilots, with the copilot stating, "It (TCAS) says climb" and the instructor replying "He (the controller) is guiding us down". The disagreement prevented the crew from acknowledging the instruction and at 21:35:03 it was repeated by the Zurich ATCO.

EVENTS ON THE BOEING FLIGHT DECK

The Boeing was manned by two pilots, the captain with over 11,000 hrs flying experience and a copilot with over 6000 hrs. As is normal the plane was equipped with TCAS, both pilots having had simulator training involving TCAS exercises.

Shortly after entering Zurich airspace, when the aircraft had reached its new flight level of 360, the copilot left the flight deck to go to the lavatory. Within 12 seconds TCAS gave the "Traffic" alert and the captain started the routine of searching for the other aircraft. 14 seconds later at 21:34:56 TCAS issued the instruction "Descend, descend" which was acted on 2 seconds later. After another 14 seconds at 21:35:10, by which time the copilot was back in his seat, TCAS issued a second instruction "Increase descent, increase descent" which was again acted upon.

At 21:35:32 the two aircraft collided. The Boeing lost its tailfin, lost stability and crashed. The Tupelov lost a wing and disintegrated on its way to the ground. Nobody survived.

ANALYSIS

Aircraft flight crew and air traffic control officers are highly trained and are expected to make rapid decisions and work in a situation with clearly defined rules. With such experienced crews and air traffic control, with modern aircraft fitted with collision avoidance system such an accident should not have happened. Clearly there were places where different actions by the staff concerned would have prevented the accident. However there were other systemic factors which were in place well before the two planes entered Zurich airspace which lead to high demands being placed on the staff. These are considered in the 'Human Factors' section of the BFU report.

ZURICH AIR TRAFFIC CONTROL

Modifications

- The work being carried out on the radar and telephone systems clearly reduced the safeguards in place and needed more detailed consideration. The 'Official Instructions' had not been prepared in a way which highlighted the features which would be unavailable and the effect on the operations. The loss of the telephone system was not mentioned at all.
- The report (ref. 1) makes no mention of a risk assessment having been carried-out on the effects of the temporary 'downgrading' the system nor of attempts to put in place measures to maintain safety integrity. Before going off duty the supervisor drew attention to the work but did not specify that a higher manning level should be maintained until the work was complete.
- Although not highlighted in the BFU report there is an indication that nobody had taken overall responsibility for the safety aspects of the work, which had been planned over a significant period of time.

Work load

- The report notes that the work levels at night were low and normally well within the capacity of one ATCO. In fact the report states that". . the controller was at risk of losing situational awareness due to the low workload. . .". However the combination of the loss of the direct telephone link together with the late arrival of Airbus drastically increased the work load on the single ATCO. To quote the report "*At the conscious level humans have limited attention resources. When these limited resources are time shared between multiple demanding tasks, as in the case of the controller, the continuous detailed analysis of all incoming information is not possible. In such conditions much of what is consciously perceived may in fact be inferred.*"
- Outside of the night shift the manning of the air traffic control centre included a supervisor whose role included the assessment of the load on individual ATCO's and the reallocation of tasks where appropriate. On the night shift the ATCO was supposed to undertake this role himself. However in this case under a high work load: "*The ATCO attempted to manage the air traffic situation using the resources that were available and familiar to him. He did not recognise in the deteriorating situation that the system had become less error resistant*".
  In simple terms the high work load prevented him from recognising that he was becoming over-loaded and that events were going out of control.
- As noted earlier the practice of one controller going to the lounge was not official policy but was know to and tolerated by management. The last independent audit which was carried out late in 2000 had not produced any critical safety issues due to non-compliance. There is no indication that the audit had detected this important failing.

Safety culture

- The above together with the fact that the notice had not been read by the staff certainly raises a question mark over the 'safety culture' of the organisation.

Working environment

- The working environment increased the problems of the ATCO. The ATCO had to work on two work stations using two radar screens with different scales, with two separate radio facilities and an additional, non-functioning, phone system.
  This was inconsistent with the very short time scales and rapidly changing situation which the controller was required to manage.

TUPELOV

- Although the Tupelov was equipped with TCAS its use was not normal in the Russian Federation at the time. Whilst the instructions prepared by western authorities on the use of TCAS make it clear that it must be followed those for Russia were ambiguous.
  "*The ATC (air traffic control system) to be the basis for collision avoidance. Nevertheless, in case of no link with ATC, the TCAS will help the crew to avoid a collision*"
- In addition although the Russian pilots had received training in the use of TCAS this did not include simulator training. The instructor had little experience of TCAS and had made only 4 flights using TCAS during 2002. For the above reasons the instructor may have had reservations regarding TCAS and his authorisation to depart from ATC.
- The presence of the instructor in the cockpit interrupted the normal hierarchy and working relationships. As the report notes this may have both beneficial and negative effects. However it is noted that *"The autocratic way in which the decision was made (by the instructor) could have affected the other crewmembers in their willingness to communicate relevant information or any discomfort they felt with the situation"*

APPLICATION TO THE PROCESS INDUSTRIES

To assist the process industries in improving both its understanding of and application of human factors the European Process Safety Centre took the initiative of creating PRISM. This was a 'Thematic Network' aimed at creating an extensive European forum within which industry, universities, research centres and practitioners could collaborate to improve the flow of practical experience and fundamental knowledge in human factors.

The network was established in 2001 with financial support from the European Union Department for Research and Development under its Programme for Competitive and Sustainable Growth. It lasted for 3 years and had the support of organisations from 14 countries in Europe. These included many major chemical producers as well as universities and research organisations.

Since Human Factors is a very broad field four separate 'Focus Groups' were established within the network covering

- *Cultural and organisational factors*
- *Optimising human performance*
- *Human factors in high demand situations*
- *Human factors as part of the engineering design process*

Each of the focus groups held seminars and produced guidance which is available at www.prism-network.org. The work of the network has also been described in a number of papers (refs. 2 and 3).

In November 2003 the 'Focus group- Human factors in high demand situations' held a meeting in Brussels attended by over 30 experts on human factors in the process industries. Together with papers on alarm management and crisis management attendees viewed a video reconstruction of the Uberlingen accident. They then used 'brainstorm' sessions to identify key lessons from the incident emphasising those of relevance to the process industries. The results of the whole meeting are available after registration on the PRISM website. In Appendix I the results of the brainstorming session, which were produced before the results of the BFU investigation were made public, are shown.

Whilst there are some differences between control rooms in the aviation and process industries the similarities are more important. The factors which contributed to the Uberlingen accident are clearly relevant to the process industries and need to be considered by all those with responsibility for the operation of control rooms.

- The need to define minimum manning levels for all states of operation and ensuring that these are complied with.
- The need to assess the impact of maintenance and modification work and of revising risk assessments and operational procedures when necessary to maintain integrity.
- The need to ensure that when senior staff are present in the control room they do not inhibit open discussion and decision making.

FINAL CHAPTER

As already stated the passengers on the Russian airline were predominately children leaving many bereaved parents. In 2004 the distraught father of one of the girls who was killed sought out and murdered the air traffic controller. It is hoped that by publicising some of the lessons from the incident further pain and loss will be avoided.

REFERENCES

1. Bundesstelle fur Flugunfalluntersuchung, Investigation Report AX001-1-2/02, May 2004, www.bfu-web.de.
2. Turney, RD and Alford, L, 'Improving Human Factors and Safety in the Process Industries, the 'PRISM' project, Loss Prevention 2004, Prague.
3. PRISM Project, www.prism-network.org.

APPENDIX 1

UBERLINGEN MID-AIR COLLISION

Results of 'brainstorming' at PRISM seminar, 'Human Factors in High Demand Situations', held in Brussels, November 2003

Factors which may have contributed to or prevented the accident.

1. Control Room (ATC) Management System Issues
   - The management decision to carry-out maintenance work which downgraded 2 systems (radar and telephone) at the same time.
   - Did the system for work planning/ permit consider this?
   - Was any consideration given to measures to offset the loss of integrity caused by transfer to back-up radar and telephones?
   - Were the controllers consulted in this decision?
   - Did the controller have sufficient authority to block work which significantly downgraded system integrity?
   - Insufficient testing of back-up telephone system before switch-off
   - Were staff fully trained in the use of the back-up system?
   - The controller had to work between two screens and was not able to respond to calls from pilots when at the other console, was this the design intent?
   - Were controllers trained in the operation of TCAS?
2. Control Room (ATC) Management: Staffing Issues
   - Was it official policy for controllers to take a prolonged break?
   - If not was there 'silent approval' of this reduction in the effective staffing level?
   - Who was in overall operational control of the ATC at the time of the accident?
   - Were they working as a team or as individuals?

3. Individual Factors (ATC)
   - Reluctance of controller to recall colleague when work load increased.
   - Controller's ability to recognise and assess his own workload when under stress. (Tunnel vision?)
   - ATC pride in being able to do job without need for assistance.
   - Controller working with partial information.
4. Control Room (Russian Cockpit) Management
   - Possible conflict between pilots (reversal of normal management hierarchy)
   - Crew resource management.
   - What training was provided in how to respond to TCAS.
   - What training was provided in how to assess and respond to conflict situations.
5. International Standards
   - Were Russian standards compatibly with those of the west?
   - Acceptance of conflicting same height routes.

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