

3. CONCLUSIONS

3.1 Findings

Airplanes

- Both airplanes were properly certificated for air transport.
- The investigation did not determine any technical defects on the two airplanes.
- Both airplanes were approved for RVSM.
- Both airplanes had been retrofitted with TCAS II Version 7 (ACSS TCAS 2000). A VSI/TRA indicator was used as optical display.
- In both airplanes there was no evidence of a TCAS malfunction.
- The B757-200 TCAS computer was destroyed by impact forces so that an evaluation was not possible any more. It was possible to analyse essential data of both airplanes from the TCAS computer of the TU154M.

Accident

- At the time of the accident visual meteorological conditions at dark night prevailed.
- Due to the high closure rate of 702 kt - 718 kt (361 -369 m/s) and the darkness, a visual avoidance manoeuvre was for neither of the flight crews a possibility to prevent the collision.
- The flight paths crossed at right angles. The B757-200 had a northern heading (004°) and the TU154M a western heading (274°). The collision occurred at an altitude of 34 890 ft.
- The first contact took place between the vertical tail of the B757-200 and the left wing succeeded by the left fuselage side of the TU154M in the area of the emergency exits.
- The damage to the fuselage of the TU154M resulted in an explosive decompression.
- Due to the structural damage, the TU154 was no longer controllable after the collision. It suffered an in-flight break-up and some of the components caught fire.
- During the collision approximately 80% of the B757-200's vertical tail were destroyed. Afterwards the airplane became uncontrolled and crashed into a forest at a negative pitch angle of approximately 70°.
- The accident was non-survivable for the occupants of the two airplanes.

Flight crews

- The flight crew members of both airplanes held the required valid licences and medical certificates.
- The autopsies of all flight crew members did not indicate any impairments of health. The examinations for medicine, drugs and alcohol produced negative results.

Flight operations

- Both operators had provided training programmes for TCAS and the flight crews had, as far as necessary, completed the corresponding training.
- Practical TCAS training of the flight crew of the TU154M in the flight simulator was not possible, as the simulators were not appropriately equipped.
- The flight operations manuals of both operators contained provisions for the handling of TCAS. The flight operations manuals of both operators did not contain detailed descriptions of the tasks of the individual flight crew members in the case of TCAS occurrences.
- In the operations manual of the TU154M the TCAS description wording was such that ATC had the highest priority in collision avoidance.

Air traffic control (ATC)

- The accident occurred over German territory. In accordance with a letter of agreement (LoA), ACC Zurich was responsible for the air traffic control in this area.
- The management of the air navigation service company had implemented a new safety policy dated 23 October 2001. These principles show that a safety culture was to be evolved in which managers and employees were aware of their critical importance for safe operations. Organisational steps to implement these principles were also taken. The process to realise the new safety culture was, however, still under way.

- Sectorisation work was carried out within ACC Zurich in order to re-arrange the control sectors in the night from 1 to 2 July 2002. During this time the radar system was operated in the “fallback mode“ and the separation minimum had been increased from 5 to 7 NM. In doing so the MV9800 radar computer was not available to the controllers, therefore
 - no automatic correlation of the flight targets was possible and
 - the optical STCA was not displayed anymore.
- The direct phone connections with the adjacent ATC units were not available to the controller of ACC Zurich during the time from 21:23 hrs until 21:34:37 hrs. An automatic change-over of incoming calls to the bypass system was not in existence. At 21:34:44 hrs the first of a total of four calls, three calls from UAC Karlsruhe and one call from Friedrichshafen, was registered. These calls had not been answered.
- There were written directives concerning the accomplishment of the work, however, they did not include explanations about the effects the work would have on the availability of technical equipment.
- The CoC did not know about the sectorisation work. An assessment to minimise risks did not take place.
- Besides the technicians three additional colleagues were present in the CIR.
 - One of the managers to support the ATCO
 - One SYMA
 - One controller to support the technicians

The ATCO did not know about the tasks of these colleagues.

- The sectorisation work had not been coordinated with the adjacent ATC units.
- According to the duty schedule, two controllers were responsible for the control of the entire airspace of ACC Zurich during the night shift. They had to assume the tasks of radar planning (RP), radar executive (RE) and to a limited extent also the functions of the supervisor (DL) and the system manager. Therefore, a continuous management of the different tasks was not ensured. An assessment to minimise risks during the night shift did not take place.
- The controllers were obliged to read the directives concerning the accomplishment of the system work. But they did not read them. The supervisor (DL) had merely given them general information about the work.
- Two assistants were at the disposal of the controllers to support them with routine and coordination tasks, however, they had no authorization to assume any traffic control functions.
- After the air traffic flow had decreased one controller retired to rest at about 21:15 hrs and approximately 10 minutes later one assistant retired to rest. Normally they would not return to the control room until early in the morning.
- It had been known to and tolerated by the management and the quality assurance of the air navigation service company for years that during the night at periods of low traffic flow only one controller performed all traffic control tasks whereas the other controller had a rest.
- Both controllers were qualified and licensed in accordance with the regulations in force.
- The controller remaining in the control room was examined after the accident for medicine, drugs and alcohol which produced negative result.
- At the time of the accident the controller had to control three airplanes:
 - the B757-200 in direct approach to Tango VOR at FL 360
 - the TU154M in direct approach to Trasadigen VOR at FL 360 and
 - a delayed Airbus A320 approaching Friedrichshafen.

The Airbus was controlled on 119.920 MHz and the two other airplanes on 128.050 MHz. Therefore they could not hear each other which resulted in simultaneous transmissions. For all flights the control strips were available to the controller in time. From the control strips the impending conflict situation (B757-200 and TU154M) was only recognisable in combination with the radar display.
- The controller was solely responsible for the entire ATC within ACC Zurich. For this he had to fill two adjacent workstations with different frequencies and worked with two radar monitors. In order to control flights in the upper airspace and the approach in the lower airspace to Friedrichshafen. Radar charts with different ranges were displayed on the monitors.

- The controller was not aware that in the fallback mode the optical STCA was not available. The system did not provide an automatic indication that the optical STCA was not available.
- During the last five minutes prior to the collision, the controller paid more attention to the Airbus A320 in approach to Friedrichshafen.
- The bypass telephone system had temporarily a technical defect so that the necessary coordination with Friedrichshafen could not take place by phone.
- At 21:33:24 hrs the radar controller of UAC Karlsruhe was alerted by his STCA of the conflict situation. His attempts to warn the controller of ACC Zurich by phone were not successful as a telephone connection could not be established.
- The controller did not notice the imminent separation infringement in time. He instructed the TU154M crew at 21:34:49 hrs (43 seconds prior to the collision) to descend to FL 350 which was too late to ensure the required separation to the B757-200. The phraseology used did not correspond with the urgency of the situation.
- At 21:34:56 hrs the prescribed separation of 7 NM was infringed.

ACAS/TCAS

- The TU154M crew followed the ATC instruction immediately and initiated the descent.
- At 21:34:56 hrs (35 seconds prior to the collision) TCAS generated RAs in both aircraft simultaneously.
 - The B757-200 crew received an RA to descend. The copilot was not in his seat at the time. The PIC followed the RA and initiated the descent.
 - The TU154M crew had already initiated the descent when they received the RA to climb. The RA did not change the decision and the descent was continued. This decision did not take into account that very likely simultaneously with this RA the other airplane involved would receive a complementary RA.
- The copilot of the TU154M questioned the continuation of the descent twice. But he could not gain anybody's ear. A comment that TCAS has priority over ATC did not come from any of the crew members.
- The B757-200 crew reported 23 seconds after the RA the "TCAS descent" to ACC Zurich. The copilot had taken his seat again at that time and the frequency was free.
- According to his statement the controller did not notice the message of the B757-200 crew. The first part of the message was incomprehensible due to the simultaneous transmission of both crewmembers. The second part coincided with a message at the adjacent workstation (RE) transmitted by the A320.
- At 21:35:00 hrs the MV9800 computer of ACC Zurich released an aural STCA warning to the workstation of the controller. This warning had not been noticed in the control room.
- Once the controller noticed that the TU154M had initiated the descent he again turned to the A320 whose crew had already called him twice. He did not continue to observe the developing situation.
- An automatic downlink, integrated in the TCAS equipment, carrying information about issued RA's to the respective ATC units has not been introduced worldwide yet. It was determined that with the prescribed reports via radio delays and loss of information may occur.
- The ACAS/TCAS related international regulations and national procedures valid on the day of the accident were not sufficiently clear or incomplete and misleading and did not fully correspond to the system philosophy.

3.2 Causes

The following immediate causes have been identified:

- The imminent separation infringement was not noticed by ATC in time. The instruction for the TU154M to descend was given at a time when the prescribed separation to the B757-200 could not be ensured anymore.
- The TU154M crew followed the ATC instruction to descend and continued to do so even after TCAS advised them to climb. This manoeuvre was performed contrary to the generated TCAS RA.

The following systemic causes have been identified:

- The integration of ACAS/TCAS II into the system aviation was insufficient and did not correspond in all points with the system philosophy.
The regulations concerning ACAS/TCAS published by ICAO and as a result the regulations of national aviation authorities, operational and procedural instructions of the TCAS manufacturer and the operators were not standardised, incomplete and partially contradictory.
- Management and quality assurance of the air navigation service company did not ensure that during the night all open workstations were continuously staffed by controllers.
- Management and quality assurance of the air navigation service company tolerated for years that during times of low traffic flow at night only one controller worked and the other one retired to rest.