Summary Report

A summary investigation, in accordance with Article 45 of the Ordinance on the Safety Investigation of Transport Incidents from 17 December 2014 (OSITI), as amended 1 February 2015 (SR 742.161), was carried out with regards to the following serious incident. This report was prepared to ensure that lessons can be learned from the incident in question.

Aircraft	SF50 Vision Jet	N474CG		
Operator	I-Fly AG, c/o Aximos Treuhand AG, Baarerstrasse 11, 6300 Zug, Switzerland			
Owner	Southern Aircraft Consultancy Inc Trustee, Office 3, Earsham Hall, Bungay Norfolk, England			
Flight instructor	Swiss national, born 1961			
Licence	Airline Transport Pilot Licence Aeroplane (ATPL(A)), issued by the American Federal Aviation Administration (FAA)			
Flying hours	**Total** 27,610 h		**during the last 90 days**	246:30 h
	on the aircraft type 99:31 h		**during the last 90 days**	32:34 h
Student pilot	German national, born 1978			
Licence	Commercial Pilot Licence Aeroplane (CPL(A)) according to the European Aviation Safety Agency (EASA), issued by the Federal Office of Civil Aviation (FOCA).			
Flying hours	**Total** 478 h		**during the last 90 days**	4:29 h
	on the aircraft type 0:59 h		**during the last 90 days**	0:59 h
Location	Zürich airport (LSZH)			
Co-ordinates	-		**Altitude**	-
Date and time	22 September 2018, 20:17 (LT = UTC + 2 h)			
Type of operation	Flight training			
Flight rules	Instrument Flight Rules (IFR)			
Departure airport	Mainz-Finthen airport, Germany			
Destination airport	Zürich (LSZH)			
Flight phase	On the ground/taxiing			
Nature of the serious incident	Smoke development in the avionics compartment			

Injuries to persons	**Crew members**	**Passengers**	**Third parties**
Minor	0	0	0
None	2	3	0

Damage to aircraft	Slightly damaged
Other damage	None

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Factual information

General

The serious incident occurred on 22 September 2018 at approximately 20:15 at Zürich airport (LSZH). The Swiss Transportation Safety Investigation Board (STSB) was not informed of the incident by the Zurich airport authority until 25 September 2018. The STSB opened an investigation on the same day and informed the following countries of the serious incident: USA and Great Britain. The USA appointed an authorised representative who participated in the investigation.

The statements of the crew members and airport staff were used for the following description of the background and the course of events.

Background

On 22 September 2018 the Pilot-in-Command (PIC) of the Cirrus Aircraft SF50 Vision Jet single-engine business jet aircraft, registration N474CG, made a ferry flight from Zurich (LSZH) to Mainz-Finthen (EDFZ), where he landed at 18:07.

At Mainz-Finthen, 4 persons boarded the aircraft. One person, who held a commercial pilot's licence but not a type rating for the SF50, took the left pilot's seat and assumed the function of a student pilot, and the other three persons sat in the rear seats of the aircraft. The PIC, who held a flight instructor qualification, took the front right seat. For the student pilot, this was his second flight in an SF50. He had made his first flight in the course of a demonstration flight with representatives of Cirrus Aircraft.

Take-off at Mainz-Finthen took place at 19:21. Both the subsequent flight, which attained a flight level (FL) of 230 and was carried out under instrument flight rules (IFR), and the landing on runway 28 at Zurich 20:09, were uneventful.

Course of events

After landing, N474CG taxied to General Aviation (GA) apron 1 at the east of Zurich airport. The crew stated that during this taxiing phase they became aware for the first time of an unusual faint smell in the cabin. After N474CG had come to a halt at its planned parking position and the engine had been shut down 2 minutes later, the smell became stronger and was described by the student pilot as that of an electrical fire.

The student pilot then disembarked from the aircraft and noticed white smoke emanating from the underside of the fuselage at the undercarriage bay and from the edges of an access panel on the right of the nose fuselage. The smoke was cold and had a similar smell to that noticed in the cabin earlier. The student pilot detected considerable heat generation at the side access panel with his hand.

The PIC determined from the display on the system screen in the cockpit that battery 1 was still outputting 56 amps, although all the electrical consumers had already been switched off. This did not comply with his expectations. There were no associated warnings or alerts. He switched off battery 1 approximately 3 minutes after shutting down the engine, which deactivated the entire electrical system. The smoke development outside the aircraft then decreased, and stopped completely after a while.

The aircraft was then towed into the hangar by airport workers. Approximately one hour later an airport worker noticed an unusual smell emanating from N474CG. After a gel-like substance began to run out of the nose wheel bay approximately 3 hours later, N474CG was moved back on to the apron in front of the hangar and the airport authority was informed.

Two days later, the PIC commissioned an avionics company to troubleshoot the aircraft. After the engineer removed the access panel on the right of the nose fuselage, he noticed severe burn marks at the air-conditioning compressor and substantial soot deposits over the entire fuselage interior (see Figure 1 and Figure 2).

Figure 1: N474CG with the access panel removed from the right of the nose fuselage.

Findings

Both the fuselage interior in the vicinity of the air-conditioning compressor and the interior of the access panel were heavily coated with soot. The compressor itself exhibited severe burn marks at the electrical terminals (cf. Figure 2). A white burn mark was found above the terminal screw of the positive pole, and a metallic melting bead was found immediately next to this. The area around the negative pole had only been subjected to minor thermal loads.

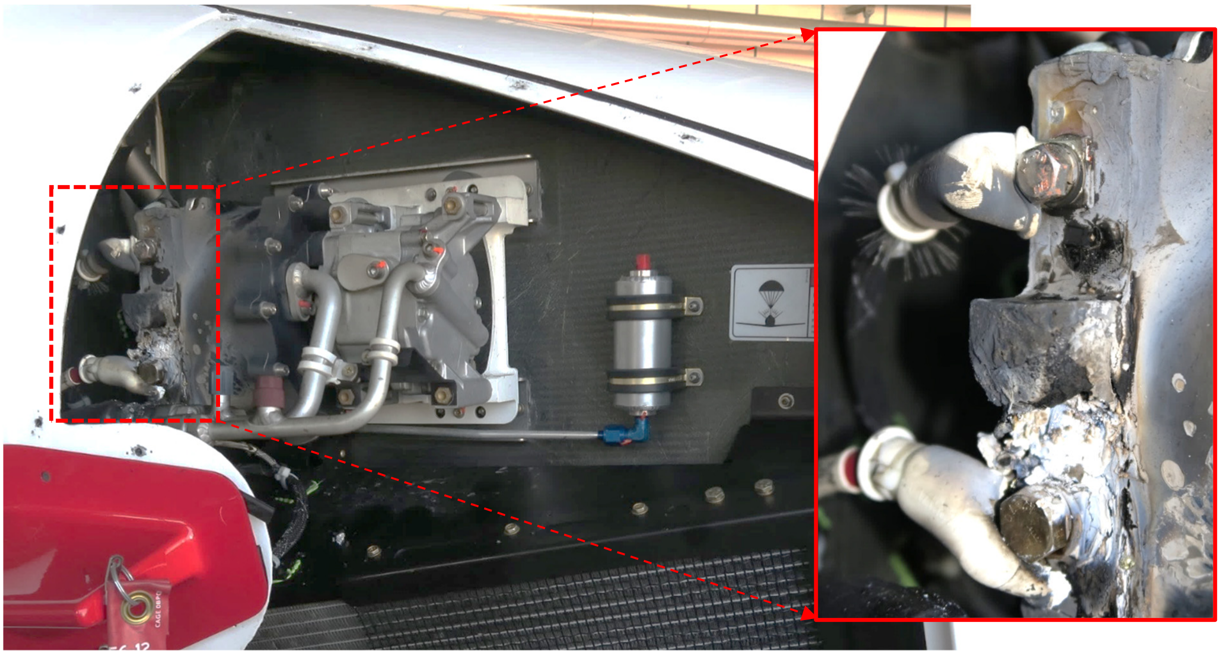

Figure 2: Interior of the right of the nose fuselage: Air-conditioning compressor with burn marks on the electrical terminals (top: negative pole, bottom: positive pole) and fire residues throughout the fuselage interior.

A viscous mass with granular inclusions was found below the electrical terminals. Traces of an oily substance could be seen running down the nose wheel strut.

None of the Circuit Breakers (CB) had tripped. Nor were any warnings or alerts shown on the Crew Alert System (CAS), which generates visual and aural alerts for the crew.

The locking pin of the Cirrus Airframe Parachute System (CAPS) in the activation handle in the cockpit was not inserted.

Aircraft system and equipment

Air-conditioning

The Environmental Control System (ECS) controls both the cabin air supply and temperature, and the cabin pressure. The Air Conditioning System (ACS) is a subsystem of the ECS. The cooling unit operates on the vapour-compression principle. The compressor and condenser of the ACS are located at the front right of the fuselage and are accessible from outside via an access panel.

The ACS is operated from the ECS control panel on the right of the instrument panel.

Electrical system

The SF50 is fitted with a 28 V Direct Current (DC) system, fed from two Generators (GEN) driven off the engine and two lead Batteries (BAT) (cf. Figure 3). BAT 1, BAT 2, GEN 1 and GEN 2 are switched on by switches in the cockpit. The electrical distribution paths, namely the main bus, the essential bus and the emergency bus, and the diodes, are each housed in their own Master Control Unit (MCU) in the front (forward) and rear (aft) fuselage areas respectively.

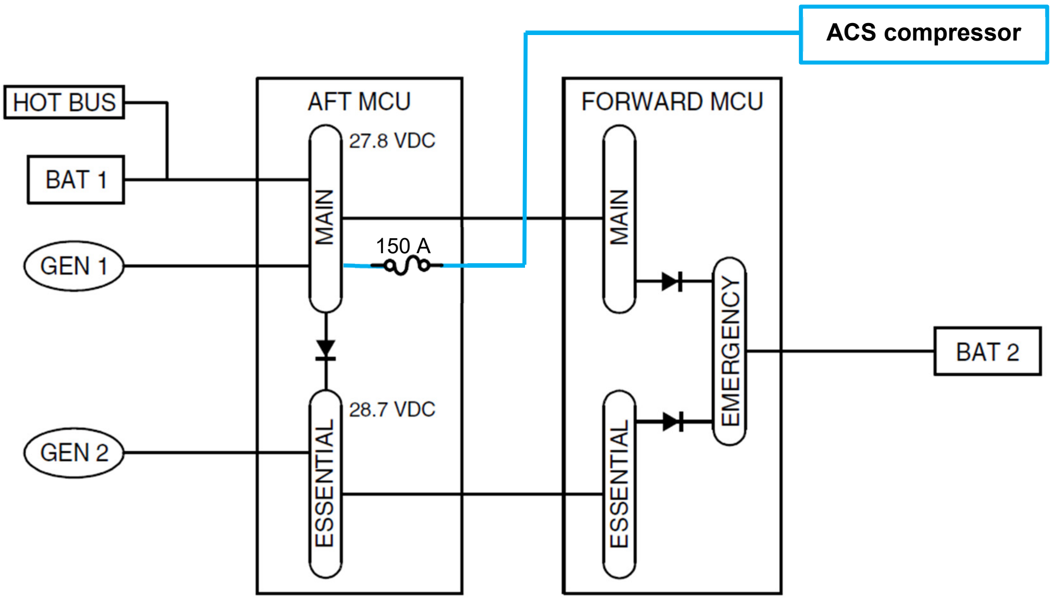

Figure 3: SF50 electrical system block diagram from the Aircraft Flight Manual (AFM), amended by the STSB.

An additional electrical distributor, the hot bus, is permanently connected to BAT 1 and supplies the cabin lighting and one of the two signal channels for triggering the CAPS.

The ACS compressor is supplied from the rear (AFT) MCU. The power cable to the compressor runs through the aft bulkhead under the cabin floor and through the forward bulkhead as far as the nose fuselage. It is protected in the AFT MCU by a 150 A fuse (shown in blue, cf. Figure 3). The compressor is controlled by a controller mounted directly on the compressor.

Display system

The current between BAT 1 and the AFT MCU main bus is shown on the Multi-Function Display (MFD). If the discharge current is greater than 5A, the displayed value and the analogue display are shown as amber in colour.

Cirrus Airframe Parachute System

The parachute package and deployment rocket of the CAPS are accommodated in the middle of the front part of the fuselage. The deployment opening is located in front of the cockpit windscreen on the upper part of the fuselage (cf. Figure 4).

Figure 4: CAPS deployment opening (red dashed line) on the upper part of the front fuselage and direction of deployment of the rocket for the rescue parachute (red arrow).

The CAPS is activated by pulling the handle on the cockpit ceiling. The handle can be secured by a locking pin, which is removed as part of the checklist before starting the engine and re-inserted after the flight after the engine has been shut down. The CAPS can be activated at any time, since one of the two signals to trigger the CAPS is supplied permanently from BAT 1 via the hot bus.

Flight recorder

An Aircraft Data Logger (ADL) was installed in N474CG but no Cockpit Voice Recorder (CVR). Installation of these devices was not mandatory. The ADL records data into a module, the Recoverable Data Module (RDM), which is part of the integrated avionics unit. The RDM data was downloaded and evaluated.

The data from the MFD memory card was also downloaded and read.

After the engine shutdown in Zurich, the RDM recorded a discharge current from BAT 1 to the AFT MCU main bus which immediately rose to 62 A and persisted until the battery was switched off.

Further information

The ACS compressor was removed from N474CG and subjected to further examination. The electrical contacts were checked before the compressor was removed to ensure they were seated firmly. The bolts were fully tightened and no erosion caused by arcing due to an inadequate electrical contact was found on either the bolt threads or the holes in the cable lugs.

Figure 5 shows the damage to the controller of the compressor in its removed state. Figure 6 shows the controller compared to an undamaged unit, the plastic cover of which has been removed.

Figure 5: Side view of the compressor controller with the positive pole (red arrow) and the negative pole (black arrow).

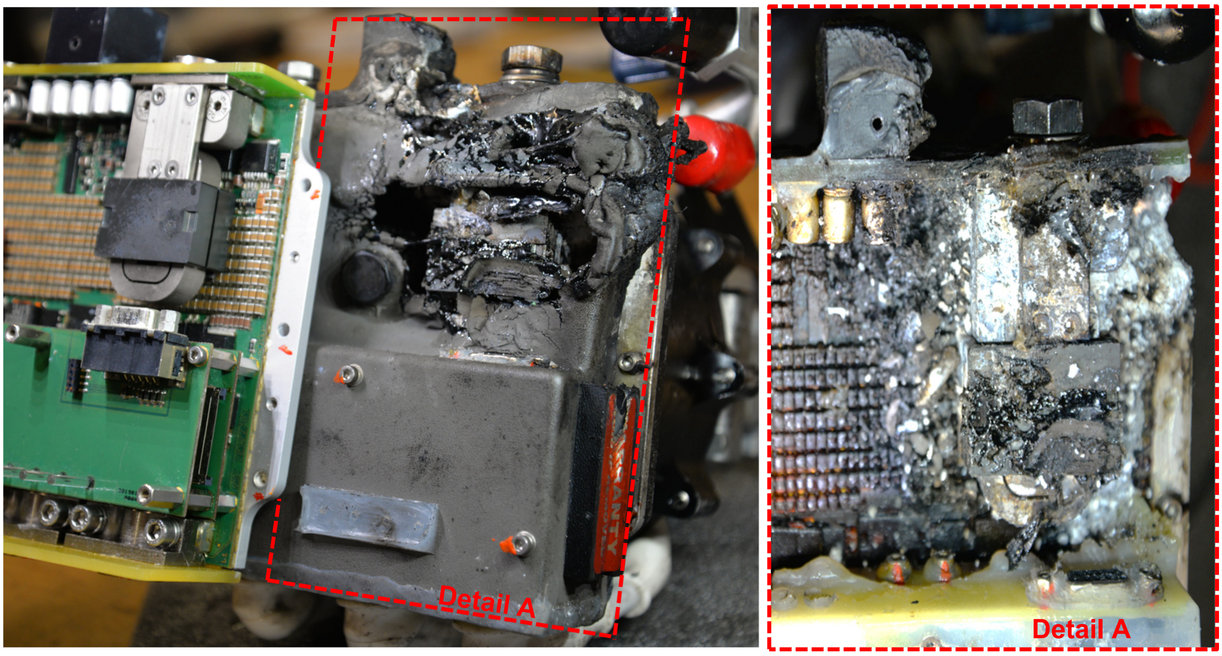

Figure 6: Damaged controller compared to an undamaged controller without the plastic cover (left) The detail on the right shows the damaged controller with the plastic cover removed.

The compressor was fitted with a serviceable controller and subjected to a test procedure. The results showed that the compressor itself and its drive operated within the specified normal limits.

A more detailed inspection of the damaged controller showed that the Printed Circuit Board (PCB) had become detached from the heat sink at the main current input. This part of the PCB exhibited severe damage, which indicated both local heat generation of over 900 °C and corrosion damage.

The effect of an insufficient tightening torque on the electrical connections was evaluated by a test on a serviceable controller. The damage pattern that resulted from tightening torques of 50 % and 0 % respectively only partially matched that of the present serious incident. In particular, large thermal loads at the electrical supply cables to the compressor occurred during this test, which had not occurred at the original terminals of the electrical supply cables.

A hypothesis that water might have penetrated between the PCB and the heat sink and caused corrosion damage and/or short-circuits was tested in a further experiment. A serviceable controller fitted to the compressor was damaged intentionally so that an applied saltwater solution could seep between the PCB and the heat sink at the main power terminal. The controller and compressor were then supplied with electricity at different current levels from different power sources.

- After switching the low-current power source (max. 0.5 A) on and off, a permanent leakage current of approximately 0.5 A was measured. At the same time, small bubbles, a greenish fluid discharge and slight steaming occurred at the damaged PCB. After the test the resistance between the positive and negative poles of the controller was only 0.7 ohms. On a serviceable controller, this is in the region of 25,000 ohms.
- When the higher current power source was switched on (maximum 150 A), severe arcing occurred briefly at the PCB every time. The current value then settled back to its expected value. On the fifth power-up cycle, the controller caught fire spontaneously and the current increased abruptly to 150 A. After the power source was switched off, the fire died out of its own accord after a few seconds.

The damage inflicted to the controller by this fire was very similar to the damage that occurred on the compressor components of N474CG.

Aircraft flight manual

The aircraft flight manual (AFM) includes checklists for emergencies. The checklist for smoke removal includes the following items, among others:

“[…]
11. All Other Switches (except BAT 2) .... off
[…]
12. Land as soon as possible.
[…]”

The checklist for excessive generator 1 current includes the following:

“[…]
If message persists:
a. GEN 1 Switch .... off
b. BAT 1 Switch .... off
c. Land as soon as practicable, avoiding IMC or night flight as able (reduced power redundancy).
[…]”

There is no checklist for an excessive discharge current from BAT 1.

According to the checklist, the locking pin of the Cirrus airframe parachute system is inserted after shutting down the engine:

“[…]
9. CAPS Pin... replace
[…]”

Service bulletins

The aircraft manufacturer issued two Service Bulletins (SB) following this serious incident.

SB5X-21-02 "2 Nov 2018, 21-50 Cooling – Air Conditioning Compressor Bolts Inspection" states that on aircraft with the applicable serial numbers, the electrical terminals on the compressor must be checked once and the tightening torques of the terminal bolts checked and corrected.

SB5X-21-03 "27 Dec 2018, 21-50 Cooling – Air Conditioning Compressor Electrical Power Input Ports Inspection" states that on aircraft with the applicable serial numbers, the electrical voltage and resistance between the terminals (positive and negative poles, see Figure 5) must be measured at regular intervals to rule out any possible ingress of moisture or water in the compressor controller. If specific limit values are exceeded, the compressor must be replaced.

Reports

No immediate report of the serious incident was made to the reporting office of the STSB, although this is mandatory in accordance with Article 17 OSITI. The STSB has designated Swiss Air Rescue (REGA) as the reporting office in accordance with Article 10(e) OSITI. Accidents and serious incidents must therefore be reported immediately after they occur to the REGA alarm centre (telephone number 1414) in accordance with the Swiss Aeronautical Information Publication (AIP).

Analysis

Technical Aspects

The data from the aircraft data logger shows conclusively that the Air Conditioning System (ACS) compressor operated normally during all phases of the outward flight from Zurich to Mainz-Finthen on 22 September 2018. For the subsequent return flight to Zurich, the Environmental Control System (ECS), which also controls the ACS, was correctly switched on after the engine was started, in accordance with the checklist. The data shows beyond doubt that the compressor did not start up at any time during the return flight, although the ECS had output the appropriate start signal and a sufficient speed command to the ACS compressor controller.

The damage pattern on the compressor showed clearly that an electrical short-circuit was present between the power supply to the compressor controller and the potential-free ground, in this case the housing or the heat sink of the controller. The direct-current arc this produced generated immense heat and burned or scorched all the adjacent components. The short-circuit was not broken until the pilot deactivated the power supply to the compressor after the engine shutdown.

A more detailed investigation revealed that an insufficient tightening torque on the electrical supply cables to the compressor controller could be ruled out, since no erosion marks caused by arcing due to inadequate electrical contact could be seen, among other things. On the other hand, it is conceivable that an excessive tightening torque on the electrical supply cables could have caused damage to the controller PCB, contributing to the occurrence of the electrical short-circuit. In this case, for example, the bonding between the PCB and the heat sink could have become detached in places, resulting in the ingress of moisture and/or the loss of electrical insulation.

Tests in a test rig showed that such an ingress of water between the PCB and the heat sink resulted in a short-circuit in the controller after a certain time, and ultimately to the damage pattern that was found in the case of N474CG.

How or why the water or moisture entered the controller could not be definitively established. In addition to excessive tightening torques when fitting the electrical cables, damage of this kind can also occur as a result of production errors, or some other incorrect handling, such as dropping the compressor.

In summary, it can be stated that it is highly probable that the ingress of water or moisture into the compressor controller was the cause of the serious incident. The smoke development, which can only be the result of scorching or burning in the components adjacent to the direct current arcing, was clearly visible after disembarking from the aircraft on the ground. It is therefore probable that the controller was already unserviceable during the return flight, but that by chance the short-circuit and the associated arcing and outbreak of fire did not occur until during the end phase of the flight, possibly not until the aircraft was on the ground after landing.

Human and operational aspects

The compressor failure and the outbreak of fire in the forward avionics compartment could not be predicted or detected by the crew of N474CG. The first indication of this that was noticed was the unusual smell after landing at Zurich. Since the smell was only slight during taxiing and its origin could not be identified, it is understandable that the crew taxied to the planned stand on the apron and did not immediately stop and work through the smoke removal checklist. The fact that this was an electrical problem only became clear after an unusually high discharge current from the battery persisted after the engine shutdown, when the unusual smell was identified as an electrical fire smell and the smoke development from the right forward avionics compartment was noticed. Switching off the battery and the associated entire electrical power supply was therefore appropriate and targeted.

Working through the smoke removal checklist would have resulted in all the electrical consumers being switched off apart from battery 2, which only feeds the emergency bus (cf. Figure 3) with electrical power. The ECS, ACS and the ACS compressor would also have been deactivated in this case.

After disembarking from the aircraft, the origin of the smoke and heat generation was still unknown. The fact that no immediate report was made to a central body of the airport, for example to the airport authority, shows a lack of safety awareness. Since no notification was made to the STSB either, which is mandatory in accordance with Article 17 OSITI and should be made without delay, the airport ground staff remained unaware of the danger posed by N474CG.

This manifested itself in the fact that N474CG was then towed into the hangar and the ground staff were subsequently very surprised when an undefined gel-like fluid ran out of the nose wheel bay of the aircraft. Since the technical condition of N474CG and consequently the hazard it presented were not known, the failure to monitor the aircraft and moving it into the hangar were subject to risk.

The locking pin of the Cirrus airframe parachute system had not been inserted by the crew, as prescribed in the engine shutdown check list, and was not installed until 10 days after the serious incident. This showed a lack of safety awareness as regards the consequences of inadvertent activation of the rescue system, especially as by that time various persons had carried out work on the aircraft and in the aircraft cabin due to the technical fault in the air conditioning.

Conclusions

The serious incident, in the course of which a fire broke out in the forward avionics compartment towards the end of the flight, was caused in all probability by the ingress of water or moisture into the controller of the air conditioning compressor, which resulted in an electrical short circuit with arcing and the generation of intense heat.

The cause of the ingress of water or moisture could not be definitively established.

The measures taken by the aircraft manufacturer, published in the form of two service bulletins the implementation of which was mandatory on all affected aircraft, seem appropriate for addressing the likely technical causes identified in the present serious incident. The STSB is therefore refraining from further investigations and is closing this investigation with this summary report, in accordance with Article 45(1) of the OSITI.

The definitive version of this report is the original in the German language.

Bern, 10 December 2019 Swiss Transportation Safety Investigation Board