

Investigation Report

Identification

Type of Occurrence:	Accident
Date:	23 June 2014
Location:	Near Olsberg-Elpe
Type of aircraft:	1.) Airplane 2.) Airplane
Manufacturer / Model:	1.) Learjet Corporation / Learjet 35 A 2.) Eurofighter GmbH / Eurofighter
Injuries to Persons:	1.) Pilot and co-pilot fatally injured 2.) None
Damage:	1.) Aircraft destroyed 2.) Aircraft severely damaged
Other Damage:	Crop damage
Information Source:	Investigation by BFU
State File Number:	BFU 1X002-14

This investigation was conducted in accordance with the regulation (EU) No. 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and the Federal German Law relating to the investigation of accidents and incidents associated with the operation of civil aircraft (*Flugunfall-Untersuchungs-Gesetz - FIUUG*) of 26 August 1998.

The sole objective of the investigation is to prevent future accidents and incidents. The investigation does not seek to ascertain blame or apportion legal liability for any claims that may arise.

This document is a translation of the German Investigation Report. Although every effort was made for the translation to be accurate, in the event of any discrepancies the original German document is the authentic version.

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Abbreviations

AAL	Above Aerodrome Level
AIP	Aeronautical Information Publication
AMC	Acceptable Means of Compliance
AMSL	Above Mean Sea Level
AOC	Air Operator Certificate
ARC	Airworthiness Review Certificate
ARO	Authority Requirements for Air Operations
BFU	German Federal Bureau of Aircraft Accident Investigation
BMVI	Bundesministerium für Verkehr und digitale Infrastruktur (Federal Ministry for Transport and Digital Infrastructure)
CAS	Calibrated Airspeed
CRC	Control and Reporting Centre
CRM	Crew Resource Management
CSMU	Crash Survivable Memory Unit
CVR	Cockpit Voice Recorder
DV	Durchführungsverordnung (executive order)
DWD	Deutscher Wetterdienst (German Meteorological Service)
EASA	European Aviation Safety Agency
EFB	Electronic Flight Bag
FAA	Federal Aviation Administration
FOH	Flight Operations Handbook
FDR	Flight Data Recorder
FL	Flight Level
hPa	Hectopascal
ICAO	International Civil Aviation Organization

IMC	Instrument Meteorological Conditions
KIAS	Knots Indicated Airspeed
LBA	Luftfahrt-Bundesamt (German civil aviation authority)
LufABw	Luftfahrtamt der Bundeswehr (Military Aviation Authority)
LuftBO	Regulation on Operation of Aircraft
NATO	North Atlantic Treaty Organization
NfL	Nachrichten für Luftfahrer
NM	Nautical Mile
NTSB	National Transportation Safety Board
OAT	Operational Air Traffic
OM-A	Operations Manual Part A
PF	Pilot Flying
PIC	Pilot in Command
PMDS	Portable Maintenance Data Store
PNF	Pilot non Flying
POB	Persons On Board
QRA	Quick Reaction Alert
SAR	Search and Rescue
SMS	Safety Management System
SSP	State Safety Programme
VMC	Visual Meteorological Conditions

Synopsis

On 23 June 2014 at 1522 hrs¹ the Bundeswehr (German Armed Forces) informed the German Federal Bureau of Aircraft Accident Investigation (BFU) that a collision involving a civil Learjet 35 A (Learjet) and a German Air Force Eurofighter had occurred during aerial target demonstrations.

According to the Law Relating to the Investigation into Accidents and Incidents Associated with the Operation of Civil Aircraft (FIUUG) accidents and incidents involving civil and military aircraft will be investigated under the responsibility of the BFU.

The BFU immediately deployed a team of five investigators to the accident site. The BFU was supported by the Directorate Aviation Safety of the German Armed Forces (AbtFISichhBw).

The Learjet, operated by a civil operator specialising in manned aerial target demonstrations, had taken off at Hohn Airport and had initially been flying with a southern heading in accordance with Instrument Flight Rules (IFR). At the time of the accident the Learjet had changed to Visual Flight Rules (VFR) and was flying in airspace E with a northern heading.

A formation consisting of two Eurofighters had taken off from Nörvenich Air Base with the order to conduct a so-called Renegade mission, i.e. the unknown civil aircraft had to be intercepted, identified, and accompanied to a military airport.

After the collision with a Eurofighter, the Learjet crashed to the ground. The pilots of the Learjet suffered fatal injuries and the aircraft was destroyed. The pilot of the Eurofighter could land the severely damaged airplane at Nörvenich Air Base.

¹ All times local, unless otherwise stated.

The causes of the flight accident were:

Immediate Causes:

- During positioning for the intervention the collision risk due to unexpected manoeuvres of the intercepted airplane was not sufficiently taken into consideration.
- The Learjet crew did not take into account the risks due to possible limitations of the field of vision and the distraction by using the computer when deciding about the task distribution.

Due to insufficient situational awareness during the intervention, the Learjet crew continued the turn with an excessive bank angle despite the loss of visual contact with the Eurofighter flying at the inside of the turn.

Systemic Causes:

- The operator had not specified in detail how the crew should distribute their tasks during Renegade exercises.
- Neither the operator commissioned to conduct the aerial target demonstration nor the Air Force had sufficiently described the Renegade training nor had a commensurate risk analysis been done.

To prevent the occurrence of future accidents, the BFU issued a total of six safety recommendations. These safety recommendations are addressed to the operator, the Luftfahrt-Bundesamt (German civil aviation authority, LBA), the European Aviation Safety Agency (EASA), and the Luftfahrtamt der Bundeswehr (Military Aviation Authority, LufABw).

1. Factual Information

1.1 History of the Flight

At 1304 hrs the Learjet, with two pilots on board, had taken off from runway 26 at Hohn Airport. The plan was to conduct a military interception and identification exercise (Renegade exercise). According to the recordings of the Cockpit Voice Recorder (CVR) the co-pilot was Pilot Flying (PF) whereas the Pilot in Command (PIC) as Pilot Non Flying (PNF) conducted radio communications and the navigation. He used a portable computer to determine positions and distances.

The Flight Data Recorder (FDR) of the Learjet showed that after take-off the airplane had turned south and climbed to Flight Level (FL) 350. After about 15 minutes in FL350 the airplane descended and at 1356 hrs levelled off in 5,000 ft AMSL.

In the area of Ramstein Air Base, the airplane flew three full circles and then headed north. At 1400:27 hrs the co-pilot said: "Du sagst dann Bescheid, wenn du übernehmen willst ja? (You are going to let me know if you want to take over, yes?)". The PIC answered: "Du, das lass uns mal nach Büchel machen (Let us do that after Büchel). Solange mach ich hier weiter. (Until then I will continue)".

During the exercise, taking place in airspace E, the aircraft involved were in radio contact with aircraft controllers of a military Control and Reporting Centre (CRC) but used different frequencies. The work stations of the aircraft controllers in the CRC were adjacent to each other.

At 1419:45 hrs the aircraft controller instructed the Learjet crew: "[...] climb to eight-thousand feet". The Learjet began the climb. After about one minute the aircraft controller instructed the crew: "[...] start a right-hand delay turn" and informed them that the Eurofighters had just taken off at Nörvenich Air Base. This was affirmed. At about 1422 hrs the aircraft reached 8,000 ft AMSL after one full circle.

According to the radar recordings the formation of the two Eurofighters had taken off at Nörvenich Air Base at 1420 hrs. After take-off the formation established contact with the CRC. The aircraft controller took over radar guidance of both airplanes. The initial flight direction was east. Five minutes after take-off the aircraft controller instructed the Eurofighter formation to simulate transponder selection to standby.

On enquiry by the aircraft controller the pilot of the Eurofighter leading the formation reported at 1426:31 hrs he had visual contact with the target aircraft (standard brevity word "TALLY"). At that time, the two airplanes were approximately 6 NM away from the Learjet in about 3,300 ft AMSL. The aircraft controller issued the clearance to climb to the altitude of the target aircraft and instructed a left-hand turn to 030°.

At 1427:00 the Learjet crew was informed that the Eurofighter pilots had reported to have visual contact with them.

At 1427:26 hrs the pilot of the Eurofighter leading the formation acknowledged the course instruction and reported that he would conduct the approach without radar guidance by the aircraft controller ("JUDY"). The aircraft controller acknowledged this and added information regarding the target aircraft: "[...] is a declared probable renegade. You can expect three POB, two pilots, and one probable hijacker."

According to the CVR recordings the Learjet PIC said at 1427:56 hrs: "Airspace, alles gut (Airspace, all good)." The co-pilot confirmed.

At 1428 hrs the Eurofighter leading the formation approached the Learjet from astern. The second Eurofighter followed by approximately 2 NM, and about 1,000 ft deeper. At 1429:14 hrs, after the aircraft controller had been asked "[...] ready to copy ID?" the pilot of the Eurofighter leading the formation began to describe the characteristics of the target aircraft such as colour and registration as well as his observations. He also reported that the blind on the first window behind the door of the Learjet was closed, the pilots in the cockpit were wearing caps and drinking something, and he could not detect any indication for a third person on board. This report lasted for about two and a half minutes. The aircraft controller replied: "[...] copy all, stand by for follow on task."

According to the CVR recordings the Learjet PIC said to the co-pilot at 1429:21 hrs: "Da kommt er links" (here he comes, left). Speed up zwei fünfzig (Speed up two fifty)." In this phase, the FDR recorded an increase in engine thrust and indicated airspeed to approximately 250 kt. At 1434:10 hrs the aircraft controller informed the crew: "[...] for your information the QRA will perform an obey-check on your left side and after three minutes you should obey". The PIC answered: "That's copied. And so far no calls heard on sim guard."

At 1434:10 hrs the aircraft controller instructed the Eurofighter pilot to check if the Learjet pilot was obeying instructions (obey check), following him toward the southwest. The Eurofighter pilot stated that subsequently he flew to a position slightly

higher and to the left in front of the Learjet. The FDR data showed that the Eurofighter was flying towards 030°, rocked the wings several times, turned left to approximately 018°, and then returned to 025°. At 1435:04 hrs the pilot answered: "Aircraft is not obeying he is not turning". He added: "[...] only waving at me they are not following left-hand turn".

At 1435:30 hrs the Learjet crew reported to the aircraft controller: "We received a first wing-rock, we're waiting three minutes and then obey". The aircraft controller acknowledged this information. According to the CVR recordings the Learjet PIC said at 1436:43 hrs: "Airspace ist noch gut (Airspace is still good). Nach Paderborn wollen wir natürlich nicht rein (We do not want to go into Paderborn airspace). Anderthalb Minuten sind rum (One and a half minutes have passed). Nicht dass wir uns hier in die Ecke fahren mit dem Airspace gleich (Not that we drive us into the corner with the airspace soon). Aber das passt noch, zwei Minuten dann sind wir da (But it still fits, two minutes then we are there). Eine Minute haben wir noch, das wäre hier und dann haben wir noch genügend Raum überall irgendwas zu machen (We still have one minute that would be here and then we still have enough space everywhere to do something)."

At 1437:25 hrs the Eurofighter pilot began to radio the Learjet crew using the frequency specified for the exercise.

At 1437:27 hrs the PIC said: "So, zwei Minuten rum (So, two minutes are over). Jetzt zweieinhalb (Now two and a half). Das heißt, wenn er nochmal wackelt, dann reagieren wir (That means if he rocks the wings again we will react)." The co-pilot answered: "In Ordnung (okay)".

At 1438:00 hrs the aircraft controller issued the following instruction to the Eurofighter pilot: "Try again if the aircraft is obeying your orders and again heading is south-west I authenticate at minute three eight [...]". The Eurofighter pilot stated he once again positioned his airplane slightly higher and in front of the Learjet.

At 1438:02 hrs the Learjet PIC said: "So, jetzt kommt er noch mal'n bisschen nach vorne (So now he comes a little forward again). Vielleicht macht er noch mal was [...] (Maybe he will do something again)."

At 1438:10 hrs the aircraft controller radioed the Learjet crew: "[...] for your information, you overwhelmed the hijacker and now you will obey the orders of the QRA and call them on the guard". This radio communication ended at 1438:22 hrs.

According to the FDR, at 1438:10 hrs the Eurofighter began again to alternately roll about its longitudinal axis and at 1438:16 hrs the pilot commenced a left-hand turn. Two seconds later the bank angle reached approximately 20° and within two more seconds increased to approximately 27°.

According to the FDR of the Learjet, the autopilot was disengaged at 1438:13 hrs and one second later the aircraft had a bank angle to the right of approximately 5°. After about one second the bank angle decreased to approximately 3° and until 1438:16 hrs increased again to approximately 5° right. The pilot commenced a left-hand turn, and at 1438:18 hrs the airplane had a left bank angle of 4° when the co-pilot said: "Kannst du mal nehmen, ich kann den nicht mehr sehen" (Can you take over; I can no longer see it). One second later, at 1438:19 hrs, N1 of both engines was increased from approximately 73% to about 88%. At this time, the left bank angle had reached 13° and increased still further.

At 1438:22 hrs the Eurofighter pilot said: "Now the aircraft is responding by rocking wings and following in a left-hand turn". During this radio communication lasting four seconds, and the subsequent two seconds until the collision, altitude, indicated airspeed, and bank angle of the Eurofighter remained almost constant.

At 1438:23 hrs the Learjet PIC had answered the radio transmission of the aircraft controller with: "Roger". In the following three seconds the engine thrust N1 was reduced to approximately 80%. At 1438:26 hrs the PIC said: "Nimm mal den Computer (Take over the computer)." At this point the bank angle to the left was 52°. At 1438:28 hrs the CVR recorded dull sounds before the recording stopped after one second.

At the time of the collision the FDR of the Learjet recorded a heading of 358° and a left bank angle of 46°. The FDR of the Eurofighter recorded a heading of 001° and a left bank angle of 26°.

Twenty seconds after the collision, at 1438:48 hrs, the radio transmission of the Eurofighter pilot was recorded: "Mayday, mayday, mayday".

The Learjet crashed to the ground in the area of Olsberg-Elpe. The two pilots suffered fatal injuries and the aircraft was destroyed.

At 1439:09 hrs the pilot of the Eurofighter leading the formation informed the aircraft controller: "[...] crashed with Learjet probably [...] left-hand turn direct inbound Nörvenich declaring emergency." The aircraft controller instructed the pilot to set the emergency transponder code. This was confirmed.

At 1442:45 hrs the pilot of the second Eurofighter radioed the aircraft controller and transmitted the coordinates of the accident site of the Learjet. At 1443:25 hrs the pilot of the second Eurofighter requested the aircraft controller to issue a clearance for a direct approach to Nörvenich Air Base. The aircraft controller asked the pilot of the Eurofighter leading the formation if he still needed the support of the second airplane.

The aircraft controller asked the pilot of the second Eurofighter if he could fly to the accident site. The pilot answered "[...] currently doing a structural damage check [...] severely damaged on the right-hand side he needs my assistance right now." Then he added: "Able to come back to downed aircraft position once he is save down in Nörvenich."

At 1445:56 hrs the aircraft controller instructed the Eurofighters to change frequency to Nörvenich military air traffic control.

The pilot of the Eurofighter leading the formation stated that after take-off the two aircraft had accelerated to approximately 450 KIAS as instructed by the aircraft controller. The two aircraft had approached the Learjet from the lower left. By flying turns and using the air brake the pilot had reduced the speed of the Eurofighter. He had come from behind with a slight exceedance of speed, and flown left of the Learjet conducting an identification. Subsequently, he had conducted the obey check. Initially the Learjet crew had not responded. He tried to contact the Learjet using the frequency specified for the training, but the crew had not responded. Then the Learjet responded to the obey check. Subsequently, he had commenced a left-hand turn with a bank angle of 15 - 25°. He had been looking into the cockpit when he felt the jolt. The other airplane had disappeared. In the mirror he saw black smoke. Subsequently, he made the distress call and discontinued the exercise. He stated that the right engine thrust control had been jammed at 75 - 85% NH and therefore he shut down the engine right before the landing.

At 1458 hrs the Eurofighter landed on runway 07 at Nörvenich Air Base.

The pilot of the second Eurofighter stated that he flew 1.5 - 2 NM behind the other two aircraft as intended. The pilot of the Eurofighter leading the formation had steered the airplane left of the Learjet. From his position he could not see if the airplanes had rocked their wings. After checking his instruments he noticed a "small explosion". The video recordings of the head-up display showed reflections of fire lasting about two seconds and then black smoke. A short while later he heard the distress call of the Eurofighter leading the formation. After he had escorted the

damaged Eurofighter to Nörvenich Air Base, the pilot flew to Köln-Bonn Airport and landed there at 1505 hrs.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Third Party
Fatal	2	-	-
Serious	-	-	-
Minor / None	1	-	

1.3 Damage to Aircraft

The Learjet was destroyed.

The Eurofighter was severely damaged.

1.4 Other damage

Crop damage occurred.

1.5 Personnel Information

1.5.1 Learjet 35 A Crew

1.5.1.1 Pilot in Command

The 50-year-old PIC held an Air Transport Pilot's License (ATPL(A)) of the European Union issued in accordance with Part-FCL. It was first issued on 11 December 2013 by the Luftfahrt-Bundesamt (LBA) and valid until 16 February 2015. The type rating for the Learjet 20/30 and the Instrument Rating (IR) were also valid until 16 February 2015.

His class 1 medical certificate was last issued on 25 September 2013 and valid until 15 October 2014.

His total flying experience was about 7,505 hours; of which 3,554 hours were on the type. He had acquired about 3,935 hours of his total flying experience on military jet aircraft. Among other things, the pilot had been a flight instructor for military jet pilots in the USA during his military service with the Bundeswehr. According to the

operator's reports, the pilot's last flight prior to the accident was on 16 June 2014. Within the last 30 days he had flown approximately 21 flight hours (about 10 hours as PIC and about 11 hours as co-pilot). Within the last 90 days he had flown approximately 62 flight hours (about 41 hours as PIC and about 21 hours as co-pilot).

The pilot had been employed by the company since 1 January 2004. Initial he flew as co-pilot and since May 2007 as PIC. The entry of 22 May 2014 showed his last proficiency check according to JAR-FCL 1.965 and JAR-FCL 1.968. According to the operator's documentation, within the last five years, the pilot had attended Crew Resource Management (CRM) recurrent trainings of one day each on 16 December 2013, 28 February 2013, 11 January 2012, and on 18 December 2010.

The operator stated, prior to the accident the pilot had last flown a so-called Renegade/QRA-Mission on 8 November 2010. A Renegade/QRA-Mission is a military exercise in which a civil aircraft operates such that suspicion of a terrorist attack is triggered.

1.5.1.2 Co-pilot

The 43-year-old co-pilot held an Air Transport Pilot's License (ATPL(A)) of the European Union issued in accordance with Part-FCL. It was first issued by the Luftfahrt-Bundesamt (German civil aviation authority, LBA) on 22 January 2014 and valid until 30 June 2015. He had the rating as co-pilot on Learjet 20/30, and the IR and they too were valid until 30 June 2015.

His class 1 medical certificate was last issued on 05/05/2014 and valid until 19/05/2015.

The co-pilot had a total flying experience of about 3,560 hours; approximately 745 hours of which were on the type. He had acquired 2,814 flying hours on military jet aircraft. The operator stated that the pilot had, among other things, served as flight instructor for jet pilots in the USA during his military service. The co-pilot had been employed by the company since 1 July 2012. The pilot had last flown on 19 June 2014. In the last 30 days he had flown approximately 39 flight hours and in the last 90 days 92 flight hours. Including the accident flight, the co-pilot had conducted a total of 10 flights with approximately 22 flight hours together with the PIC.

On 3 April 2014 he had attended his most recent Operator Proficiency Check in accordance with OPS 1.965. The operator's documentation showed that he had

attended a one-day CRM recurrent training on 16 December 2013, and on 12 December 2012.

According to the operator, the co-pilot had participated in another co-called Renegade Mission on 25 November 2013.

1.5.2 Eurofighter Pilot

The 33-year-old pilot held a Military Pilot's License. It was initially issued on 2 July 2004 and valid until 17 December 2014. He had the type rating for Eurofighter and the instrument rating.

His total flying experience was about 1,465 hours, approximately 406 hours of which were on the type. Within the last 60 days he had flown 12 hours and in the last 90 days 17 hours on the type. In 2013 the pilot had acquired approximately 167 flying hours and 34 hours in the simulator.

In 2014 he had flown 17 and in the previous year 42 interception and identification missions. The pilot stated that these missions often ended after the identification without intervention.

1.6 Aircraft Information

1.6.1 Learjet 35 A

The Learjet 35 A is a twin-engine business jet in all-metal construction. It is a low-wing airplane with T-tail configuration. The aircraft had a valid German certificate of registration.

Manufacturer:	Learjet Corporation
Type:	Learjet 35 A
Manufacturer's Serial Number (MSN):	35A-612
Year of manufacture:	1986
Total operating time:	about 8,259 hours
MTOM:	8,890 kg
Fuselage length:	14.84 m
Wing span:	12.07 m

Engines: Honeywell TFE731-2-2B

The latest Airworthiness Review Certificate (ARC) was issued on 19 February 2014 and valid until 27 January 2015. The front fuselage up to about the wings was painted white, and the aft part dark blue.

Each pilot of the operator had a company-owned computer (usable as notebook or tablet) which was taken on board the airplane. Among other things, the Operations Manual (OM) of the operator, and navigation software with moving map function were installed on the computer. The computer manufacturer stated, that the device had been 271 mm wide, 49 mm high, and 216 mm deep, and weighed approximately 2.3 kg (including battery).

From the National Transportation Board (NTSB) the BFU received the Federal Aviation Administration (FAA) documentation regarding the determination of the field of vision from the cockpit of the Learjet 35.

1.6.2 Eurofighter

The Eurofighter is a single-seat, twin-engine, multi-role fighter in composite construction. It has a canard foreplane / delta wing configuration.

The aircraft had a German military certificate of registration.

Manufacturer: Eurofighter GmbH

Type: Eurofighter

Manufacturer's

Serial Number (MSN): GS0070

Year of manufacture: 2012

MTOM: more than 23,500 kg

Fuselage length: 15.96 m

Wing span: 10.95 m

Engines: Eurojet EJ200

Total operating time of the aircraft was approximately 329 hours.

The airplane was equipped with two external fuel tanks (tank capacity 1,000 litres each) fitted below the wings at the centre wing station. Below the left wing the outboard wing pylon carried an air-to-air training missile fitted to a rail launcher.

Below the right wing a multi-function rail launcher was fitted to the outboard wing pylon.

1.7 Meteorological Information

Visual Meteorological Conditions (VMC) prevailed at the time of the accident. According to the statement of the Deutscher Wetterdienst (German meteorological service provider, DWD) the following weather conditions prevailed:

Clouds: 3-4 oktas Cumulus in 4,500 ft AMSL, 5-7 oktas
Cirrus in FL180

Visibility: More than 10 km

Barometric air pressure (QNH): 1,018 hPa

1.8 Aids to Navigation

Not applicable.

1.9 Radio Communications

Radio communications and the phone calls of the aircraft controllers were recorded and made available to the BFU for evaluation.

1.10 Aerodrome Information

Not applicable.

1.11 Flight Recorders

The Learjet and the two Eurofighters were equipped with cockpit voice recorders and flight data recorders. These and the video recordings of the head up displays of the two Eurofighters were read out and available for the investigation.

The L-3com F1000 FDR of the Learjet (p/n: S703-1000-00, s/n: 2257) recorded 19 parameters. Recording time was approximately 100 hours. A total of 35 flights, including the accident flight, had been recorded. The analysis of the recordings showed that during 22 of the 35 flights bank angles of approximately 60° were reached.

The CVR of Universal Avionics, Type CVR 120 (s/n: 550) had a recording time of two hours.

The Eurofighter was equipped with: A Crash Survivable Memory Unit (CSMU), and a combined CVR/FDR which recorded voices and sounds for about 46 minutes and 514 technical parameters.

In addition, the system failure messages recorded in the Portable Maintenance Data Storage (PMDS) of the Eurofighter were analysed. At 1438:35 hrs the messages that one wing pylon was no longer electronically registered in the system and the loss of one outboard tank were recorded. At 1438:59 hrs the system recorded a failure message regarding the failures of the right engine's accessory gearbox and the right alternating current generator. At 1454:45 hrs a failure message concerning the right engine control (problems with the mass flow) was recorded.

The flight paths of the three aircraft were recorded by radar equipment of military and civil air navigation service providers and made available for the investigation.

1.12 Wreckage and Impact Information

1.12.1 Accident Site Learjet 35 A

The Learjet impacted a slope, which declines to the west, in an inverted attitude with large nose-down pitch angle. The distance between several buildings and the place of impact was approximately 100 m.

At the impact site the left wingtip tank stuck in the ground. In the area surrounding the impact site the elevator and the vertical tail of the airplane were found. The FDR was found about 20 m and the CVR about 30 m to the north.

The right engine had fractured between compressor and turbine and was found about 75 m downslope from the impact site. In this area the right wingtip tank was found.



Dimension of the accident site of the Learjet 35 A

Photo: Police

The left engine was found about 1.3 km south of the main wreckage. Parts of the cowlings of the right engine and pieces of luggage of the two Learjet pilots were found about 2.7 km south of the main wreckage.



Left engine (left) and the cowling of the right engine (right)

Photos: BFU

A 2.5 m long piece of the interior cabin panelling of the Learjet was found about 2.9 km away from the main wreckage.

The right fuselage emergency exit door of the Learjet was found approximately 2.7 km south of the main wreckage. The inside of the door showed traces of fire.

1.12.2 Findings on the Eurofighter

The Eurofighter was examined at Nörvenich Air Base. It was determined that the rail launcher at the outboard wing pylon below the right wing was fractured in the front third and bent towards the fuselage. In the rail a white part of the Learjet's fuselage was found. At the aft part of the rail launcher, parts of the insulating material from the Learjet's fuselage were found.



Deformed rail launcher (left). Fragment of the Learjet's fuselage (right)

Photos: BFU

The lower surface of the inner flaperon and parts of the nozzle of the right engine showed blue paint transfer.

The entire right engine was deformed towards the longitudinal axis of the airplane.



Damages on the tail of the Eurofighter

Photo: BFU

The outboard tank of the Eurofighter had been torn off and was found in two pieces. One of the pieces still carried the jettison and was found 2.1 km and the other 2.3 km south of the main wreckage of the Learjet.



Parts of the outboard tank of the Eurofighter



Photos: BFU

Approximately 2.4 km south of the Learjet's main wreckage the following parts of the Eurofighter were found: pieces of the nozzle of the right engine, carbon composite pieces of the aft fuselage, and the cowling of the inner flaperon track and carriage of the right wing.



Parts of the nozzle (left); carbon composite structure of the Eurofighter

Photos: BFU

The braking parachute of the Eurofighter was found in a tree approximately 4.5 km south of the main wreckage of the Learjet.

1.13 Medical and Pathological Information

The autopsy report did not provide a clear cause of death, and potential pre-existing illnesses could not be determined.

1.14 Fire

The recordings of the head-up display of the second Eurofighter and the traces on wreckage parts of the Learjet show that the collision resulted in fire.

1.15 Survival Aspects

According to the mission report, the Search and Rescue (SAR) services in Münster was informed by the CRC at 1443 hrs that in the area of Winterberg a collision involving a Eurofighter and a Learjet 35 had occurred. The Learjet had crashed and the Eurofighter was severely damaged.

Two minutes later, at 1445 hrs, it was recorded that a fire-fighting vehicle of the fire brigade had arrived and a SAR helicopter was on approach to the accident site.

At 1447 hrs and 1450 hrs the SAR received reports describing the position of the accident in more detail.

1.16 Tests and Research

Not applicable.

1.17 Organisational and Management Information

1.17.1 Operator Procedures

The Learjet was operated by a German operator.

Since 1989 the company held an Air Operator Certificate (AOC). The predecessor of the company was founded in 1966. At the time of the accident the operator operated 13 Learjet 31, 35 and 36 airplanes. The operator held an Air Operator Certificate (AOC) valid until 30 June 2015 issued by the Luftfahrt-Bundesamt. The AOC carried the entry commercial transport of passengers and freight as operating mode of the company.

1.17.1.1 Operations Manual of the Operator

The Operations Manual Part A (OM-A) of the operator stipulated the tasks of the company. According to which the operator was service provider during the trainings of the armed forces. In different configurations the airplanes served as targets either clean, or with additional equipment mounted beneath the wings, or towed targets. During the so-called aerial target demonstrations either the airplane served as target for radar or visual recognition, including interception training, or the airplane had a target in tow for live firing.

Chapter 8 Operating Procedures 8.3 Flight Procedures 8.3.0 Target Demonstration Flights of the OM-A described that conducting flights for the armed forces was the main task of the company. This also included aerial target demonstrations in low altitudes and formation flights.

Chapter 8.3.0 was divided into six segments:

- I General*
- II Low Level Flying below Minimum Safe Altitude*
- III Formation Flying*
- IV Combined Air Operations*
- V Scheduling*
- VI Speed Restriction below FL100*

According to segment *I General* the special tasks of the company required pilots to have a flying experience of many years on military jet airplanes. Therefore it was stipulated: "In the interest of safety and customer needs, some restrictions have to be observed for [...] pilots without a long-term military jet flying experience." Therefore the restrictions signify that flights described in segments II - IV should be conducted by pilots with many years of flying experiences on military jet airplanes.

Segment *III Formation Flying* included the stipulations:

To be allowed to rejoin during daytime on another aircraft closer than 500 ft vertically or ½ mile horizontally, at least one crew member must have a military jet pilot background. If the PNF is the pilot with the military background, he must not only observe any formation flying very closely, but he must be ready to take control of the aircraft at any time, even if he is in the SIC position.

Standard military formation procedures always apply. Any deviation from these standard shall be briefed or called on the radio. Cross-cockpit close formation flying should be avoided.

During nighttime all crew members shall maintain a minimum of 500 ft vertical separation.

Excerpt from Chapter 8.3.0 OM-A

Source: Operator

In the Operations Manual Part B (OM-B) Chapter 2.1 Appendix 2 *Standard Workload Distribution* included stipulations regarding the use of the pilots' computers. It stipulated:

When flying by hand, the PF shall concentrate on handling the aircraft. Systems, switches, Tablet PC etc. shall be operated by the PNF at the PF's command or request.

The operator stated that one of the computers was connected with the on-board power supply during the flight. If the computer was not used it was either stored in

the cockpit behind the middle console or in the cabin on a seat (toilet) secured with a belt.

The operator stated that originally the device was intended as mission computer with moving-map function. In combination with the reorganisation of the changes stipulated by EASA and the subsequent increase in documentation the Operations Manual (OM) had been loaded on the device and replaced the printed version.

The operator's operations manual did not define the term Renegade. According to the operator an average of approximately eight Renegade Missions per year were conducted. The operator stated that a Renegade Mission could without difficulty either be flown manually or with engaged autopilot. The operator had not made any stipulations for it. The company had not set up special trainings for Renegade Missions.

1.17.1.2 Safety Management System

On 1 July 2012 the operator had put into effect a Safety Management Handbook which had been valid at the time of the accident. It stipulated, among other things, that the hazard and risk evaluation had to cover the following points:

- Hazard identification and evaluation
- Risk analysis and evaluation
- Identification of defence and control options for hazards and risks and possible effects of incidents
- Evaluation of the hazard and risk control and defence actions

The post-holder operations and the post-holder maintenance should identify the hazards. To determine the potential risk these hazards should be analysed together with the safety manager and/or the safety committee. The following steps were described for the risk management:

- Identification of hazards
- Analysis of the risks
- Decision about the risks

The handbook described the tasks of the safety manager. These included the development, the organisation and implementation of the Safety Management System (SMS), conduct of safety audits, processing of safety reports within the

company, the supervision of the implementation of regulations by the aviation authorities, and the conduct of trainings regarding the correct application of the SMS.

The safety manager stated that up until the time of the accident a concrete hazard and risk analysis had not been conducted in the company.

1.17.2 Certification and Supervision of the Operator

The Luftfahrt-Bundesamt was responsible for the certification and operational supervision of the operator.

The LBA issued the last AOC on 14 June 2013. It certified that in accordance with Council Regulation (EEC) No 3922/91 Appendix III (OPS 1) in combination with the respective German regulations commercial air traffic is conducted. The AOC form allowed the entries of different operating modes for passengers, freight and others. The AOC of the operator carried the entry commercial transport of passengers and freight.

The LBA stated that the operating modes passengers and/or freight were always entered in the AOC. The entry possibility others had not been used. An AOC can only be issued if the requirements of Regulation (EC) No 1008/2008 are met; i.e. it stipulated general, financial and other requirements. At the time of the accident the operating mode aerial work did not require permission by an aviation authority because up until 21 April 2017 the European regulations regarding Specialised Operations do not have to be applied in Germany.

The LBA flight operations inspector responsible for the operator involved, which he had been supervising since December 2010, stated that he had also been responsible for eight other companies. One audit required one day. He had conducted audits in the company on 16 June 2011, 23 April 2013, and finally on 12 March 2014. During the last audit prior to the accident in March 2014 the focal point had been the infrastructure of the company. According to the LBA checklist no irregularities had been found. The flight operations inspector stated that during the three audits he had conducted, during the time span he was responsible for the company he had never conducted an inspection flight.

He further stated that with the implementation of Commission Regulation (EC) No 965/2012 operators had to revise their operations manuals due to the changes of all legal references. In 2014 the operators had submitted their revised operations manuals for assessment. The workload required for assessment of the

documentation was comparable to the workload needed for the certification process of a newly-founded company.

The LBA stated it had no application of the operator regarding the use of Electronic Flight Bags (EFB).

The Federal Ministry for Transportation, Building and Urban Affairs established a plan by stages with four implementation phases regarding the implementation of SMS in German operators and on 4 December 2008 published a circular to that effect. The four implementation phases provided the following steps:

1. 1 January 2009 - Designation of responsible persons, safety strategy, gap analysis, implementation plan
2. 1 October 2010 at the latest - Strategies and processes, reactive risk management, training and communication
3. 1 January 2011 at the latest - Proactive and predicative hazard identification and risk management, initial performance values
4. 1 January 2012 at the latest - Proof of a complete SMS, determination of safety status, determination of safety indicators and target values, continuous improvement of the SMS

In regard to the SMS it was the task of the LBA to assess the documentation provided by the operators and to review the implementation in the scope of flight operations supervision.

The end of March 2014 the flight operations inspector attended a four-day seminar in regard to Commission Regulation (EC) No 965/2012. One topic of the seminar was the safety management system.

Four months after the accident, October 2014, an audit with the focus on the management system was conducted. According to the checklist filled in by the LBA no irregularities were determined. The checklist item "Gibt es ein funktionierendes SMS? (Is there a functioning SMS?)" was assessed as "Satisfactory". The flight operations inspector stated that this audit aimed at assessing the conformity with the regulations taking effect in Germany on 28 October 2014 regarding the new management system, but not assessing the functionality of the safety management system.

At the time of the BFU interview, in February 2015, regarding the safety management the flight operations inspector did not have: gap analysis, implementation plan,

reactive risk management, proactive and predicative risk analysis. He did also not have any information regarding the operator's determination of safety indicators and target values. After the interview, the LBA requested documentation from the operator and received a SMS gab analysis, an implementation plan, and the documentation of various internal audits.

The LBA stated that in the past years, in the department flight operations positions of flight operations inspectors either leaving or retiring fell away to reduce costs. This resulted in shortage of staff.

The European Aviation Safety Agency (EASA) had determined during their audits of the LBA conducted in 2009, 2010, 2012, and 2013 that the department flight operations lacked 14.8 full-time positions. Additional personnel had been requested for the federal budget of 2013 and in 2014 four persons had been employed.

1.17.3 German Air Force Procedures

The home base for the Tactical Air Force Wing 31 "Boelke" was Nörvenich Air Base. The wing operated Eurofighters. The German Air Force stated that the Tactical Air Force Wing 31 "Boelke" has been providing the Quick Reaction Alert (QRA) since 1 July 2013.

1.17.3.1 Renegade Procedures

The word Renegade is the term for a scenario in which a civil aircraft operates such that the suspicion of a terrorist attack is triggered. Based on the information provided about the civil aircraft there were three different escalation levels during a Renegade scenario: The suspected, the probable, and the confirmed Renegade.

The Bundeswehr stated that there were three different phases during a Renegade procedure which also had to be trained:

In the first phase *Intercept* the aircraft functioning as target should basically choose its flight path freely. The first of the Eurofighters should approach the target to be able to conduct identification. The pilot of the Eurofighter had control of the distance to the target and the flight path. The second Eurofighter should follow the target in a trail position.

In the second phase *Interrogation* the aircraft functioning as target should basically still choose its flight path freely. The first Eurofighter should fly parallel with the target, conduct the identification, and, if requested by the aircraft controller, the cockpit

check without pressuring the target. The second Eurofighter should remain in the trail position.

In the third phase *Intervention* the first Eurofighter should request the target to obey by signs and signals. Once the request is confirmed it should turn into the intended direction. The target should confirm to follow the request by signs and signals and follow into the turn. The second Eurofighter should remain in the trail position.

1.17.3.2 Planned Training Procedure

According to the schedule of 13 June 2014 provided by the Zentrum Luftoperationen der Luftwaffe (Air Operations Command), the Eurofighter formation (QRA) should intercept and identify the Learjet on its northern trajectory, and then accompany it to Wunstorf Air Base. The exercise should have ended with an overflight of Wunstorf Air Base. The exercise was to be conducted under Visual Flight Rules (VFR).

The schedule stipulated safety measure for the participants. These stipulations included that the CRC would handle the coordination with air traffic control and all participants should select a certain ultra-high frequency (UHF). Should a safety hazard arise the standard brevity word KNOCK IT OFF should be used to terminate the training.

On the morning of the accident day it was established that the training should be conducted as planned. Instead of flying to Wunstorf Air Base as intended, Büchel Air Base should be the airport of destination. This was discussed by phone with the operator and the Tactical Air Force Wing. The Eurofighter pilot involved in the accident stated that he had phoned the officer at the Zentrum Luftoperationen der Luftwaffe (Air Operations Command) responsible for planning and coordination of the training. They had discussed the general process of the training and exchanged information regarding the flight. They had not talked about which aircraft type (Douglas A-4, Learjet, or Pilatus PC-9) would be deployed during the training to ensure an appropriate training effect for the Eurofighter pilots.

The pilots involved did not have a shared briefing. The Bundeswehr stated that the training had taken place several times a year in a standardised fashion which made direct arrangements between the pilots involved unnecessary.

1.17.3.3 Flight Operations Manual

The stipulations of the Flight Operations Manual (FOM) Kommando Einsatzverbände Luftwaffe (German Airforce Operational Forces Command) Volume III/1 dated

1 February 2014 had to be applied for flight operations with jet engine fighter planes of the German Air Force.

The FOM III/1 did not contain a description of the Renegade procedure.

Chapter 10 *Aerial Combat* made several stipulations.

Paragraph *Requirements for Aerial Combat* stipulated, among other things, a pre-flight meeting regarding the kind and process of the mission with all persons involved including the responsible part of the tactical control centre. If possible, this should be a face-to-face briefing. Everyone involved should explicitly be made aware of the regulations such as target grades, or manoeuvring categories in accordance with Fighting Edge, FOM Volume III/1 and IV.

For interception missions under Visual Meteorological Conditions (VMC) and Instrument Meteorological Conditions (IMC) it was stipulated, among other things, that so-called intercepts should generally be flown against military targets. In the scope of this regulation, civil aircraft, deployed on behalf of the Ministry of Defence, should be treated as military aircraft.

The following requirements have to be met, in order to infringe the stipulated minimum distance of 1,000 ft slant range during air combat:

- Conduct of visual identification in accordance with the mission
- Visual contact
- Target aircraft "non-manoevring"
- Radio contact with the same air traffic control unit

Infringement of the minimum distance of 500 ft slant range can only occur if the pilots involved have agreed on and determined a minimum distance.

Flight Operations Manual Chapter 6 *Formation Flights* included stipulations as to the procedure if visual contact with the formation leader is lost.

In case visual contact is lost during straight flight the formation leader shall be informed and for 15 seconds a turn with a bank angle of 15° be flown. Subsequently the old heading should be resumed, and a special clearance obtained.

If the visual contact is lost during a turn different actions were stipulated depending on the position either on the inside or the outside of the turn. From the position on the outer side of the turn a contrary turn with a bank angle of 15° should be flown for 15 seconds, and the formation leader informed accordingly. Then a sufficient distance

should be ensured before the turn is continued. A special clearance should be obtained.

In addition to the regulations of the FOM, the NATO-wide effective handbook *AM 75-2-1 Fighting Edge Air to Air Training Rules* contained basic rules for the conduct of aerial combat training. Chapter 3 *Training Rules* stipulated, among other things, that everyone involved should adhere to the See-and-Avoid Rules. The brevity words TERMINATE or KNOCK IT OFF were stipulated as standard radio transmissions for immediate termination. The chapter listed a number of termination criteria for the termination of aerial combat training and the loss of situational awareness is one of them.

1.17.4 Air Traffic Organisations and Procedures

The guidance of military aircraft during peace flight operations is conducted by air traffic control units and tactical air command and control services, respectively.

The local military air traffic control was responsible for the respective air base and the approach and departure sectors. In the scope of the civil - military cooperation the civil air traffic control service was responsible for the en-route part. The air traffic service provider stated that the Operational Air Traffic (OAT) applied:

- Air traffic control services for en-route military air traffic
- Air re-fuelling en-route and in the orbit
- Support of major military exercises
- Assistance of NATO AWACS during surveillance and training missions in German airspace
- Monitoring of military training air space

The Einsatzführungsdienst der Luftwaffe (EinsFüDstLw; tactical air command and control service) was subordinated to the Kommando Einsatzverbände Luftwaffe (German Airforce Operational Forces Command). The tactical air command and control service was responsible for the military airspace surveillance above the Federal Republic of Germany and for the coordination and control of protection, and defence actions. The military tactical control service was conducted by aircraft controllers of the tactical air command and control service.

The tactical air command and control service was divided into two different areas. The flights of the Learjet and the two Eurofighters occurred in the area of the tactical

air command and control service 2 (EinsFüBer 2). The CRC coordinated and monitored the flights.

Different radar surveillance and guidance procedures were stipulated for the conduct of the tactical air command and control service.

The two Eurofighters were supported by Close Advisory Control. According to this procedure the aircraft controller gave specifications for headings, speeds, and altitudes, assigned the target, and issued hazard information. The pilots of the Eurofighters were responsible for the adherence to minimum distances to other air traffic, to lateral and vertical boundaries of allocated air space, and the minimum safe distances between fighter/fighter and fighter/target.

The radar supporting procedure for the Learjet during the training was Radar Monitoring. The tactical air command and control personnel supports the crew by giving hazard information applying to the adherence of lateral and vertical airspace limits and minimum distances to other air traffic.

1.17.5 German Armed Forces Aerial Target Demonstrations Procedures

At the time of the accident, the Kommando Territoriale Aufgaben der Bundeswehr (KdoTerrAufgBw, Bundeswehr Territorial Tasks Command) as technical coordinator was responsible for the complete planning of aerial target demonstration missions as was stipulated in the Bereichsrichtlinie (Regulation) Flugzieldarstellung Bundeswehr dated 8 April 2014. The KdoTerrAufgBw was in charge of the process management for the planning, commanding, conduct, and control of manned and unmanned aerial target demonstrations at the Bundeswehr.

The army, air force and navy of the Bundeswehr use aerial target demonstrations. The German Air Force used it for the training of aircraft controllers, or the ground-based air forces, the anti-aircraft defence, the training of special tasks (e.g. escort, intervention, renegade), and the proof of operational readiness in Air Policing and Renegade, respectively. The military airspace control (Air Policing) safeguards the airspace, e.g. by identifying unidentified aircraft, to the point of protection against air attacks, or helping aircraft in distress.

For years the Bundeswehr has been contracting civil companies to conduct various aerial target demonstrations. For manned target demonstrations these were companies who operated Pilatus PC-9, Learjet, or Douglas A-4 airplanes. The selection of the company was based on the speed range of the target required for the training task. Not all contracted civil companies were certified air operators.

The Bundeswehr stated that only civil companies were contracted who met the regulations applying for them. The Bundeswehr did neither specifically certify nor supervise the civil companies, nor conduct any flight safety hazards analysis at the civil companies. Neither were these proceedings mandatory.

1.18 Additional Information

1.18.1 National Aviation Regulations

The Luftverkehrs-Ordnung (LuftVO, Air Traffic Order) §12 Avoidance of collisions stipulates:

- (1) 1) In order to avoid collisions, the pilot shall maintain sufficient distance from aircraft as well as vehicles and other obstructions. When in flight, except for take-off and landing, a minimum distance of 150 m (500 feet) from single constructions or other obstructions shall be maintained; § 6 paragraph 1 shall remain unaffected. Sentence 2 shall not apply to gliders, hang-gliders, paragliders and manned free balloons; for other aircraft the competent aeronautical authority of the Federal State concerned may grant exemptions in individual cases. The requirements according to sentences 1 and 2 shall also remain unaffected in the case of an operating ATC unit.*
- (2) (2) Aircraft shall not be flown in formation except by pre-arrangement among the pilots.*

The Aeronautical Information Publication (AIP) Chapter ENR 1.12 *Interception of Civil Aircraft* states:

1. Signals initiated by the intercepting aircraft and action to be taken accordingly by the intercepted aircraft:

Signals from the intercepting military or police aircraft

1. (a)

– Day:

Rocking wings alternately from a position slightly above and ahead of and, normally, to the left of the intercepted aircraft. After acknowledgement of the signal, a slow level turn, normally to the left, onto the desired heading.

Meaning:

Follow me.

[...]

Action to be taken by the intercepted aircraft

Aeroplanes

– Day:

Rock wings alternately and follow

Meaning:

Understood, will comply.

[...]

1.18.2 European Aviation Regulations

The Commission Regulation (EU) No 965/2012 of 5 October 2012 lays down technical requirements and administrative procedures regarding commercial air traffic. In addition it also makes stipulations as to how the member states have to conduct the certification and supervision of persons and organisations.

Appendix II Authority Requirements for Air Operations (ARO) makes stipulations which the national aviation authorities must adhere to. The ARO.GEN.305 Oversight programme stipulates: [...] *(b) For organisations certified by the competent authority, the oversight programme shall be developed taking into account the specific nature of the organisation, the complexity of its activities, [...] and shall be based on the assessment of associated risks.*

The Acceptable Means of Compliance to Part ARO, AMC2 ARO.GEN.300(a);(b);(c) *Evaluation of Operational Safety Risk Assessment* stipulates that the national oversight authority should evaluate the operator's risk assessment process. In addition, the responsible authority should, as part of its continuing oversight, evaluate the risk assessment as part of the operator's management system. Therefore the responsible authority [...] *should establish a methodology for evaluating the safety risk assessment processes of the operator's management system.*

On the European level Acceptable Means of Compliance (AMC) and Guidance Material (GM) to Annex VIII, Part Specialised Operations (SPO) should make stipulations for commercial air traffic with airplanes and helicopters other than transport of persons, freight and mail.

The appendix contained explanations as to which operating modes would be summed up under the term Specialised Operations. GM1 SPO.GEN.005 Scope (a) listed 21 operating modes such as parachute operations and skydiving, calibration flights, helicopter external load operations, and survey operations. GM1 SPO.GEN.005 Scope: *(b) For other operations, the operator can apply the criteria specified in AMC1 SPO.GEN.005 to determine whether an activity falls within the scope of specialised operations.*

These criteria were described as follows:

[...]

- (a) *The aircraft is flown close to the surface to fulfil the mission;*
- (b) *Abnormal manoeuvres are performed;*
- (c) *Special equipment is necessary to fulfil the mission and which affects the manoeuvrability of the aircraft;*
- (d) *Substances are released from the aircraft during the flight where these substances are either harmful or affect the manoeuvrability of the aircraft;*
- (e) *External loads or goods are lifted or towed; or*
- (f) *Persons enter or leave the aircraft during flight.*

The Federal Republic of Germany issued on 17 October 2013 in the German Language Publication for Aviation (NfL I 217/13) an opt-out regulation that the Commission Regulation (EU) No 965/2012 Appendices I - V should not be applied until 28 October 2014. The changes in appendices III and V in accordance with Regulation 800/2013, and the stipulations of the appendices VI and VII should not be applied until 25 August 2016. This opt-out regulation published in the NfL I 217/13 applied also to Appendix VIII Special Operations.

Some weeks after the accident, on 30 July 2014, another publication (NfL 1-192-14) announced that the regulations in Appendices II, III, IV, and VIII in regards to paragraphs 4 and 5 will not be applied in Germany until 21 April 2017.

1.18.3 Other International Aviation Regulations

ICAO Annex 2 *Rules of the Air* contained basic aviation regulations as standards or recommendations which the member states had to apply. Appendix 2 Interception of Civil Aircraft stipulated:

- 1.2 Contracting states shall publish a standard method that has been established for the manoeuvring of aircraft intercepting a civil aircraft. Such method shall be designed to avoid any hazard for the intercepted aircraft.*

Attachment A contained other detailed requirements and the suggestion of a standard method for the interception of civil aircraft.

The ICAO Manual Concerning Interception of Civil Aircraft (Doc 9433-AN/926) summed up the stipulations of the different ICAO documentation. Two terms were described: "strayed aircraft" (An aircraft which has deviated significantly from its intended track or which reports that it is lost.); "unidentified aircraft" (An aircraft which has been observed or reported to be operating in a given area but whose identity has not been established.).

The manual also described the standard interception method in more detail and explained it with graphs:

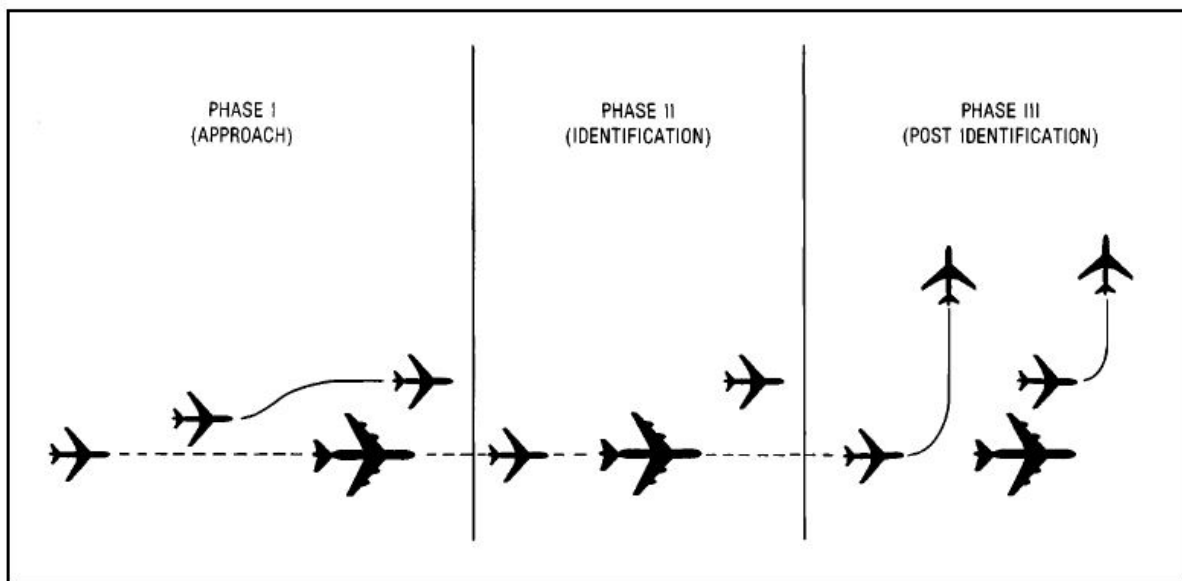


Figure 1. Manoeuvres for visual identification
(Annex 2, Attachment A, 3.2)

Phase I

The intercepting aircraft should approach the intercepted aircraft from astern. The element leader or the single intercepting aircraft should normally take up a position on the left (port) side, slightly above and ahead of the intercepted aircraft, within the field of view of the pilot of the intercepted aircraft, and initially not closer to the aircraft than 300 metres. Any other participating aircraft should stay well clear of the intercepted aircraft preferably above and behind. After speed and position have been established, the aircraft should, if necessary, proceed with Phase II of the procedure.

Phase II

The element leader, or the single intercepting aircraft, should begin closing in gently on the intercepted aircraft, at the same level, until no closer than absolutely necessary to obtain the information needed. The element leader, or the single intercepting aircraft, should use caution to avoid startling the flight crew or the passengers of the intercepted aircraft, keeping constantly in mind the fact that manoeuvres that are considered normal to an intercepting aircraft maybe considered hazardous to passengers and crew of civil aircraft. Any other participating aircraft should continue to stay well clear of the intercepted aircraft. Upon completion of the identification the intercepting aircraft should withdraw from the vicinity of the intercepted aircraft as outlined in Phase III.

Phase III

The element leader, or the single intercepting aircraft, should break gently away from the intercepted aircraft in a shallow dive. Any other participating aircraft should stay well clear of the intercepted aircraft and re-join their leader.

The part *Manoeuvres for navigational guidance* described a manoeuvre for interference of the navigation of the intercepted aircraft in case that during phases I and II this becomes necessary.

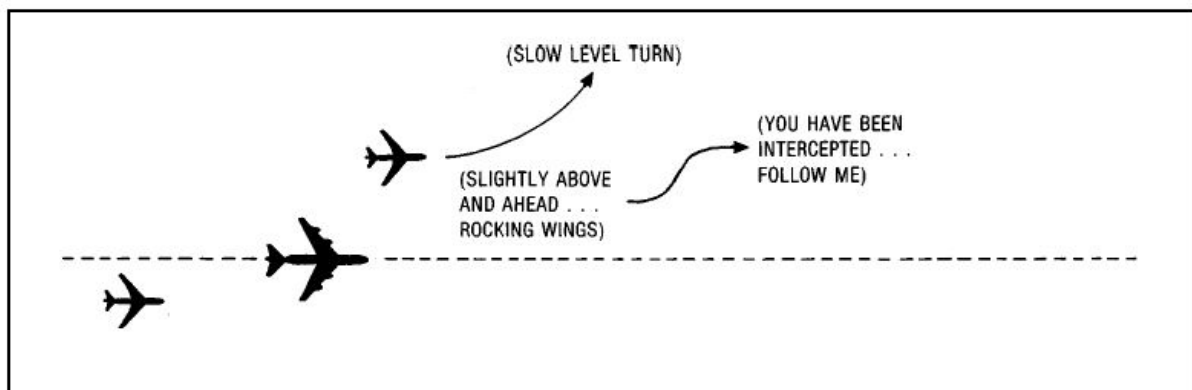


Figure 2. Manoeuvres for navigational guidance
(Annex 2, Attachment A, 3.3)

The Safety Management Manual of ICAO (Doc 9856, 3rd Edition) stated requirements for the State Safety Programme (SSP) the member states had to implement.

4.1.2 An SSP is a management system for the regulation and administration of safety by the State. The implementation of an SSP is commensurate with the size and complexity of the State's civil aviation system and requires coordination among multiple authorities responsible for the aviation functions of the State. The objectives of the SSP are to:

- a) ensure that a State has the minimum required regulatory framework in place;
- b) ensure harmonization amongst the State's regulatory and administrative organizations in their respective safety risk management roles;
- c) facilitate monitoring and measurement of the aggregate safety performance of the State's aviation industry;
- d) coordinate and continuously improve the State's safety management functions; and
- e) support effective implementation and interaction with the service provider's SMS.

4.1.3 Safety management principles provide a platform for parallel development of the SSP by the State and the SMS by its service providers. In developing the State safety legislative framework, the State promulgates SMS requirements requiring service providers to implement their safety management capabilities allowing for the effective identification of systemic safety deficiencies and the resolution of safety concerns.

4.1.4 The service provider's SMS requires effective regulatory oversight. Additionally, SMS is a largely performance-based system requiring the appropriate exchange of safety information with internal and external stakeholders. The State, through its SSP functions, both provides the oversight functions and facilitates implementation of appropriate data aggregation and information-sharing initiatives.

Excerpt Safety Management Manual

Source: ICAO

The Federal Ministry of Transport and Digital Infrastructure (BMVI) stated that due to the ICAO requirements the Federal Republic of Germany should have developed and implemented a State Safety Programme by the end of 2013.

At the time of the accident such a programme was still being developed.

1.18.4 Electronic Flight Bags Stipulations

According to EASA AMC 30-25 Airworthiness and operational consideration for Electronic Flight Bags defined an EFB as follows:

Any information system for flight deck crew members which allows storing, updating, delivering, displaying, and/or computing digital data to support flight operations or duties.

EFBs were considered either to be installed or portable EFBs depending on their hardware. Installed EFBs were considered part of the aircraft and therefore part of the airworthiness certificate. Portable EFBs were not considered part of the certified aircraft.

The applications installed on the EFB were divided in Type A and Type B.

Type A applications were: *"[...] applications whose malfunction or misuse have no safety effect"*.

Type B applications were defined as: *[...] applications*

(a) whose malfunction or misuse are limited to a minor failure condition; and

(b) which do neither substitute or duplicate any system or functionality required by airworthiness regulation, airspace requirements, or operational rules

Appendix B contained a list of possible Type B applications. This list included:

- Operations Manual
- Aircraft Flight Manual
- Operational Flight Plan
- ATS flight plan
- Electronic aeronautical chart applications including en route, area, approach and airport surface maps

1.19 Useful or Effective Investigation Techniques

The Institut für Flugsysteme der Universität der Bundeswehr München conducted a reconstruction of the flight path of the two aircraft using radar, GPS, and FDR data of the Learjet and the Eurofighter. The calculation determined that about 10 seconds prior to the collision the slant range between the two airplanes at the beginning of the turn was approximately 30 m. Two seconds later the slant range was approximately 50 m.

2. Analysis

2.1 Accident / General

Generally, there is a higher collision risk if two aircraft fly in close proximity to each other than if they adhere to larger distances. During a flight in accordance with Instrument Flight Rules (IFR) the safety distances are stipulated. Pilots conducting a flight under Visual Flight Rules (VFR) are required to ensure safe distances to other air traffic. For military pilots on Renegade missions it can become necessary to approach the unidentified aircraft very closely in order to be able to visually identify it. In order to ensure that the stipulated procedures can be applied effectively and safely by the different military organisations (tactical air command and control service, pilots) they have to be trained.

ICAO has made stipulations in its documentation regarding interception of civil aircraft. The assumption was that the civil aircraft had either lost orientation or could not be contacted by radio. Interception of an unidentified aircraft is therefore the last possible option.

The military term Air Policing includes activities concerning national defence. The military interception procedures do not differentiate which intentions the aircraft occupants might have. According to the training scenario the Learjet was to pose as civil aircraft which could not be contacted by radio. Eurofighters would therefore intercept and identify it and then accompany it to a military air base.

Focal points of the analysis of this accident were: The actions of the persons involved the procedural requirements, and the risk analysis.

The investigation did not determine any technical defects on the aircraft involved.

2.1.1 Damage Analysis

The damages found on the two airplanes show that the initial contact occurred between the rail launcher of the outboard wing station and the front fuselage upper surface of the Learjet. Subsequently, the Learjet fuselage collided with the outboard tank of the Eurofighter. The impact forces affected the Eurofighter's right-hand wing rail launcher and the outboard tank sideways and resulted in the deformation of the rail launcher and the outboard tank being torn off. The dark-blue paint transfer on the Eurofighter's lower surface of the inner flaperon, and parts of the right engine nozzle

originated from the Learjet's right engine cowling. During the collision the following parts of the Eurofighter were severed: Right engine nozzle, parts of the carbon fibre structure of the aft fuselage and the cowling of the inner flaperon track and carriage of the right wing, and the braking parachute. The Learjet lost parts of the right engine cowling during the collision. The fact that parts of the interior cabin panelling, the luggage of the pilots, and the emergency exit door were found in great distances from the main wreckage shows that the fuselage was heavily damaged during the collision. The fire traces found on the inside of the emergency exit door correspond with the fire observed by the two Eurofighter pilots and the video recording of the head-up display.

2.1.2 Flight Data Analysis

The analysis of the radar data showed that, for approximately nine minutes, the airplanes were flying parallel to each other with narrow lateral distance.

During this time period the Eurofighter pilot identified the Learjet, requested the Learjet crew to follow by rocking his aircraft's wings, and then commenced a left-hand turn. The Learjet did not follow this first request. The Eurofighter aborted the turn and approached the Learjet once more.

The FDR analysis of the two airplanes showed that at 1438:10 hrs, i.e. 18 seconds prior to the collision, the Eurofighter commenced to alternately roll about its longitudinal axis. Three seconds later, the Eurofighter had rolled once to the left, and once to the right, and was just about to pass the neutral position, the Learjet's autopilot was disengaged, and after another second it also commenced to roll about its longitudinal axis. The Learjet's bank angle changed slightly from 0° to 5° right, decreased by about 2° and then increased again to about 5° right. Subsequently, the Learjet changed its rotating direction, passed the neutral position and entered a left bank angle. Ten seconds prior to the collision as the Learjet had a bank angle of approximately 4° left, the bank angle of the Eurofighter was 20° left. Within one second it decreased by 2 - 3° and increased again after another second up to about 25° and then to approximately 27°.

Nine seconds prior to the collision as the Learjet's bank angle increased, the engine thrust was increased to approximately 88%, and subsequently speed and altitude increased. The recorded vertical acceleration was partly due to the increase in engine thrust and was not only owed to control inputs. Approximately 4 seconds prior to the collision the engine thrust was reduced, and about 1.5 seconds prior to the

collision reached approximately 80%. Two seconds prior to the collision the flight altitude began to decrease slightly.

The table below shows the comparison of some movement parameters of the two airplanes in the last ten seconds prior to the collision.

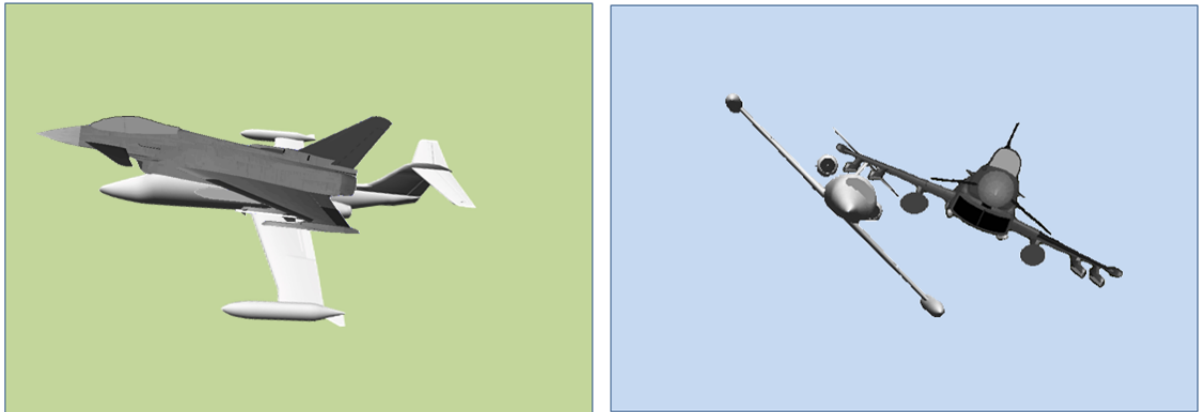
Time to collision (s)	Learjet				Eurofighter			
	Bank to the left (°)	Δ Bank (°/s)	Heading (°)	Δ Heading (°/s)	Bank to the left (°)	Δ Bank (°/s)	Heading (°)	Δ Heading (°/s)
-10	2		024		19		020	
-9	15	13	023	1	17	-2	019	1
-8	22	7	022	1	25	8	017	2
-7	28	6	019	3	26	1	014	3
-6	37	9	016	3	25	-1	012	2
-5	45	8	013	3	25	0	011	1
-4	46	1	010	3	25	0	009	2
-3	50	4	007	3	26	1	007	2
-2	51	1	004	3	26	0	005	2
-1	51	0	001	3	26	0	003	2
0	46	-5	358	3	26	0	001	2

Comparison of selected FDR data of Learjet and Eurofighter

Source: BFU

During the last 8 seconds prior to the collision, altitude, indicated airspeed, and bank angle of the Eurofighter remained almost constant. In the last seven seconds prior to the collision the bank angle of the Learjet was larger than the one of the Eurofighter and increased to a maximum of 52° one and a half seconds prior to the collision.

At the time of the collision, at 1438:28 hrs, the CVR recorded dull sounds. The Learjet had a heading of 358° and a bank angle of 46° to the left. The Eurofighter had a heading of 001° and a bank angle of 26° to the left.



Reconstruction of the collision in side view (left image) and front view (right image)

Source: BFU

That the recordings of the Learjet's FDR and CVR stopped approximately one second after the collision was due to the damages of the fuselage causing the interruption of the power supply.

2.2 Individual Actions

2.2.1 Eurofighter Pilot

The analysis of the radar and FDR data showed that the Eurofighter pilot had approached the Learjet from below and behind. He manoeuvred into a position left of the other airplane in order to identify it. This process corresponded with internationally common procedures. Among other things, it served the purpose to allow the PIC in the left-hand seat, which is the seating position in airplanes with adjacent pilot seats, a clear view of the Eurofighter.

The formation leader had reported having the aircraft in sight with the brevity word "TALLY". At 1427:26 hrs the brevity word "JUDY" was recorded which indicated that, in accordance with military procedures, the pilot had taken over the responsibility of further approaching the Learjet and his distance to it.

In the radio communications with the CRC the descriptions such as the pilots waving, the drinking, and the description of the caps are very detailed observations. From these and the radar data it can be deduced that in the identification phase the two aircraft flew in very short lateral distance to each other and that the pilot put his attention to a large extent on the Learjet. In the identification phase it is necessary to describe the observed special features, and the characteristics of the intercepted

airplane. This includes details such as the blind in one of the windows, a description of the persons in the cockpit and their actions, and possible indications for another person on board.

Due to the instruction to conduct an obey check the Eurofighter pilot flew in a position slightly higher than and to the left of the Learjet. He rocked the wings of his aircraft and commenced a left-hand turn, requesting the Learjet crew to obey his instructions. The Learjet crew did not obey. Therefore the Eurofighter pilot reported to the aircraft controller that the Learjet was not following into the turn and resumed his flight next to the Learjet.

After the aircraft controller had instructed the Eurofighter pilot 28 seconds prior to the accident to try again, the pilot positioned the aircraft once again slightly higher and to the left of the Learjet and rocked the wings again. Because the Learjet changed its attitude the pilot realised it was responding to his signal. Ten seconds prior to the collision the Eurofighter had a left bank angle of 20° , and as he was reducing it the pilot observed that the Learjet, having a bank angle of approximately 4° left, would follow him into the left-hand turn. He then increased the bank angle of the Eurofighter. With the words "Now the aircraft is responding by rocking wings and following in a left-hand turn" the Eurofighter pilot reported his observation to the aircraft controller six seconds prior to the collision. During the radio communication lasting four seconds, he was concentrating on controlling the aircraft, navigating, and passing on information to the aircraft controller. The fact that the indicated airspeed and the bank angle of the Eurofighter remained almost constant during the last eight seconds prior to the collision shows that the Eurofighter pilot had not observed the Learjet and its increasing bank angle during this time period.

The Eurofighter pilot flew the turn with constant altitude and a turn rate about the longitudinal axis of approximately two degrees per second; i.e. a significantly slower rotary rate as during a so-called standard rate turn (3 degrees per second). The BFU is of the opinion that this corresponded with the stipulation "slow level turn" of the ICAO requirements.

He had noticed the collision due to some jolting while he was looking into the cockpit. The jolting had been recorded by the FDR and the video head-up display. In the mirror he had seen black smoke. The pilot could no longer see the Learjet. Twenty seconds after the collision the pilot declared emergency by radio, and terminated the exercise using the respective brevity word. He informed the aircraft controller of the collision, and reported he would fly with a left-hand turn towards Nörvenich Air Base.

This shows that due to the damages on the Eurofighter he had promptly decided to conduct an emergency landing.

The pilot of the second Eurofighter stated that because of the distance he could not observe if the aircraft had rocked their wings or which manoeuvres the Learjet had been flying. From a distance of 1.5 - 2 NM the apparent object size of the Learjet was 3 - 4 mm taking into account its wing span. The indications of the head-up display further limited the direct view towards the Learjet. After he had been checking his instruments he noticed a "small explosion". After the collision, the pilot of the second Eurofighter initially supported the CRC by reporting the accident site coordinates, and later informed the aircraft controller that he would conduct a visual inspection of the damages on the other Eurofighter, and then accompany it to the home base. He offered to fly back to the accident site once the Eurofighter had safely landed at Nörvenich Air Base.

Because the right engine thrust control had been jammed at 75 - 85% NH the pilot shut down the engine right before the landing and landed on runway 07 in single-engine operation.

Nörvenich Air Base had a cable arresting gear at the end of the runway, and the air base fire brigade was familiar with the characteristics of the Eurofighter. The BFU is of the opinion that Nörvenich Air Base was the closest suitable airport for the damaged Eurofighter and the decision of the pilot understandable.

Due to the landing of the damaged Eurofighter the runway at Nörvenich Air Base was blocked for some time. The BFU is of the opinion that the pilot of the second Eurofighter had acted congruently by choosing to deviate to Köln-Bonn Airport where he landed without further incident.

2.2.2 Learjet 35 A Crew

The CVR recordings show the general task distribution of the crew. The co-pilot was Pilot Flying (PF) during the entire flight; the PIC was Pilot Non Flying (PNF). The CVR recordings show that the PIC used his computer to stay up-to-date on the position and distance of the airplane to the airspace around Paderborn Airport and to estimate the remaining time.

At 1400:27 hrs the co-pilot said "Du sagst dann Bescheid, wenn du übernehmen willst ja? (You are going to let me know if you want to take over, yes?)". The BFU views this remark as an indication that the co-pilot thought the PIC would fly the exercise. The PIC answered: "Du, das lass uns mal nach Büchel machen (Let us do

that after Büchel). Solange mach ich hier weiter. (Until then I will continue)". He let the co-pilot know that he should control the airplane until they reached Büchel Air Base and he would continue to handle radio communications and navigation. Except for this conversation neither of the pilots said anything any more about the task distribution. The procedures in the operator's operations manual did not contain any detailed stipulations as to who should be PF or PNF during a Renegade exercise. Therefore the decision regarding the task distribution rested with the two pilots and ultimately with the PIC.

With the words "da kommt er links (here he comes, left). Speed up zwei fünfzig (Speed up two fifty)" the PIC informed the co-pilot that he had one of the Eurofighters in sight and instructed him to increase speed. The FDR recorded in this phase an increase in engine thrust and the respective indicated airspeed.

In accordance with procedures the Eurofighter pilot flew left of the Learjet. Therefore the co-pilot in the right-hand seat could not see the Eurofighter well.

In accord with the exercise plan the Learjet crew did not respond to the Eurofighter pilot's first attempt to establish contact. At 1435:30 hrs the Learjet PIC acknowledged to the aircraft controller that the Eurofighter had tried to establish contact and that they would wait for three minutes and then obey.

Twenty-six seconds prior to the collision the PIC remarked: "So, jetzt kommt er noch mal'n bisschen nach vorne (So now he comes forward again). Vielleicht macht er noch mal was [...] (Maybe he will do something again)" proves that he had observed the Eurofighter coming from abeam and flying forward at that time.

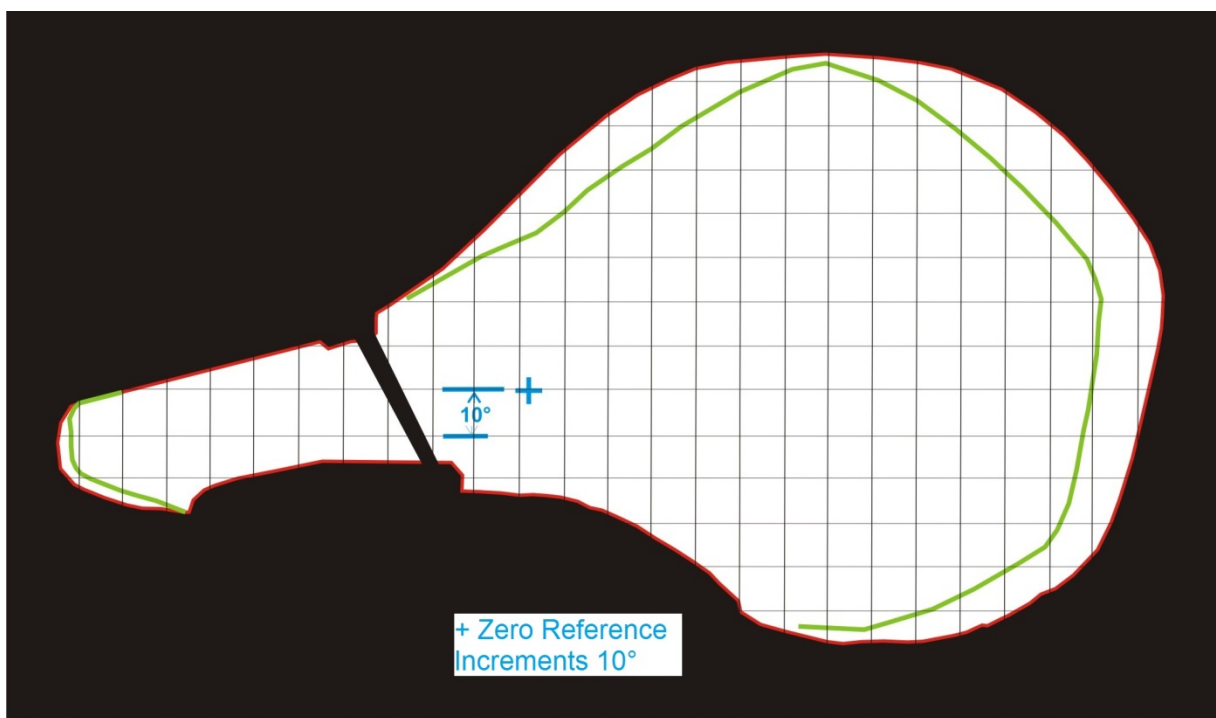
Eighteen seconds prior to the collision the aircraft controller began a radio communication with the Learjet crew: "[...] for your information, you overwhelmed the hijacker and now you will obey the orders of the QRA and call them on the guard". The Learjet's PIC concentrated on the radio contact which he acknowledged with "Roger" at 1438:23 hrs, i.e. five seconds prior to the collision.

The BFU is of the opinion that the commencing rocking of the Eurofighter's wings, and the instruction of the aircraft controller to now obey the instructions, prompted the co-pilot at 1438:13 hrs, i.e. 15 seconds prior to the collision, to disengage the autopilot, and by rocking the wings signalling they would now follow instructions. The co-pilot changed the bank angle 5° to the right, then to approximately 3° and then again to about 5°. The BFU is of the opinion that the likely explanation for this hesitant rocking of wings exclusively to the right is that even in this phase the co-pilot

had only a limited field of vision towards the Eurofighter flying on his left side and wanted to keep the airplane in sight, and prevent getting even closer.

The co-pilot's remark ten seconds prior to the collision "Kannst du mal nehmen, ich kann den nicht mehr sehen (can you take over, I can no longer see it)" shows that he had lost visual contact with the Eurofighter shortly before and asked the PIC to take over controls. At the time of this remark the Learjet had a bank angle of 4° to the left.

The following graph shows that the field of vision from the right-hand pilot's seat towards the left and upward was clearly limited. It is highly likely that for the co-pilot in the right-hand seat the Eurofighter flying at that time slightly above and to the left of the Learjet was hidden by the fuselage structure (cockpit roof) even at the low bank angle to the left. In this phase the Learjet's bank angle increased and the obstruction of the field of vision did too.



Field of vision from the co-pilot's seat

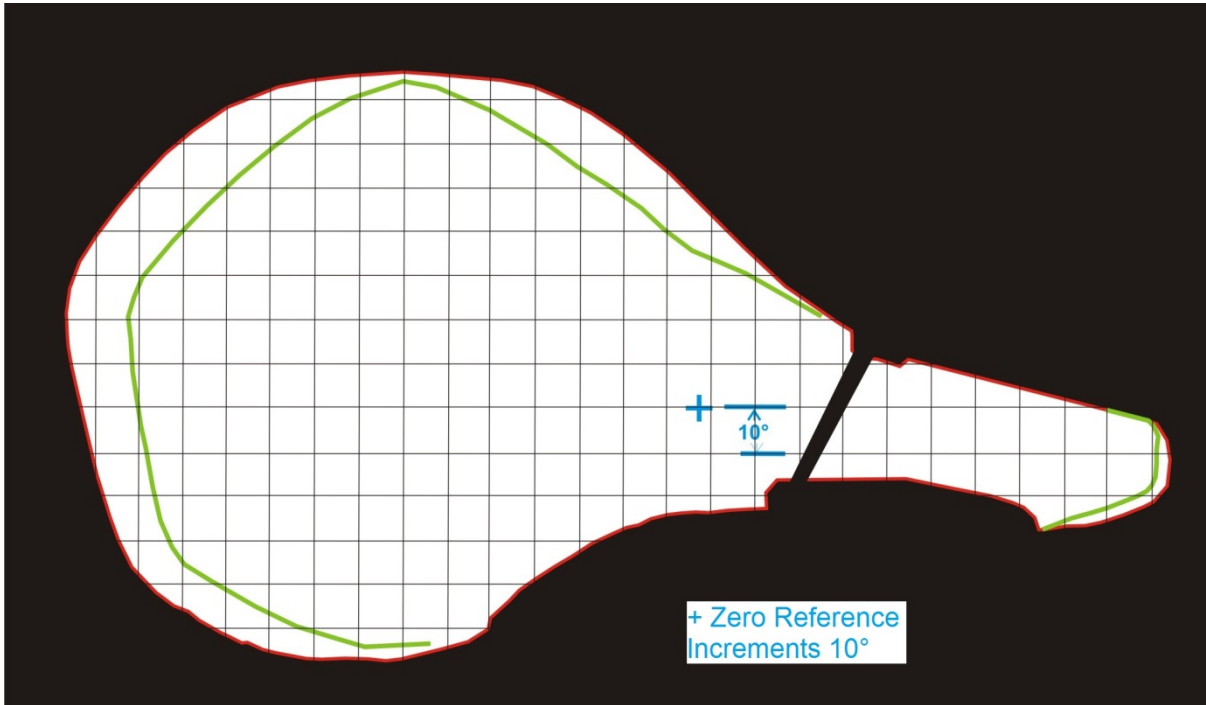
Source: Gates Learjet/BFU

The co-pilot's remark "Kannst du mal nehmen, ich kann den nicht mehr sehen (can you take over, I can no longer see)" took two seconds. The CVR recordings did not contain any definite proof which of the two pilots controlled the airplane for the subsequent six seconds. Coming to a clear conclusion which of the two pilots made control inputs was not possible because the FDR of the Learjet only recorded a

limited number of parameters which did not allow for a clear reconstruction of the control inputs and rudder deflections. The recordings do show, however, that even though the co-pilot did not have the Eurofighter in sight any more at least ten seconds prior to the collision - according to the CVR - the left-hand turn was continued, the increase in altitude allowed, and the bank angle actually increased further.

At 1438:26 hrs the PIC said to the co-pilot: "Nimm mal den Computer (Take the computer)". The BFU is of the opinion that this proves that even though he had concentrated on the instructions of the aircraft controller he had heard and understood the co-pilot's request and had prepared to hand over the computer in order to have more liberty of action. At that time, two seconds prior to the collision, the Learjet's bank angle was approximately 52°.

Within the last one and a half seconds the Learjet's bank angle decreased by about 7°. The BFU views this as a probable consequence of a respective control input by the PIC. It is likely that the Eurofighter was in the upper left part of the left cockpit window and therefore at the edge of the PIC's field of vision.



Field of vision from the PIC's seat

Source: Gates Learjet/BFU

2.2.3 Tactical Air Command and Control Personnel

In accordance with its responsibility for the military airspace surveillance and the coordination and control of protection and defence actions, the military tactical control service was conducted by aircraft controllers of the tactical air command and control service.

The two Eurofighter participating in the exercise were guided by one aircraft controller; the Learjet was guided by another aircraft controller. Direct and even non-verbal communication between the aircraft controllers benefited from the fact that the workstations of the aircraft controllers were next to each other.

The analysis of the radio communications showed that during the approach and identification phases, the Learjet crew received immediate information from the aircraft controller regarding the intended actions of the Eurofighter pilots. The BFU is of the opinion that the heading and altitude instructions the Learjet crew received corresponded more with the Close Advisory Control procedure than with the Radar Monitoring procedure briefed before the exercise began.

After the Eurofighter formation had established radio contact with the CRC the aircraft controller guided the two airplanes to the Learjet using Close Advisory Control.

Six minutes after take-off, about 6 NM from the Learjet in approximately 3,300 ft, the formation leader reported the unidentified aircraft in sight ("TALLY"). Subsequently, the aircraft controller instructed a left-hand turn to 030° and climb. At 1427:26 hrs the first Eurofighter pilot reported the brevity word "JUDY" which signalled the aircraft controller that in accordance with stipulated procedures the pilot would conduct further approach without the controller's support. In accordance with the exercise scenario, the aircraft controller informed the Eurofighters by radio that the aircraft had been declared a probable Renegade and a hijacker- third person - could be on board. From 1429:14 hrs on, in accordance with procedures stipulated for the identification phase, the aircraft controller received the description of the approached airplane's characteristics, and detailed information regarding the pilot's observations. This information should enable the air force personnel to decide on the further course of action.

As intended in the exercise process, the aircraft controller instructed the Eurofighter pilot to conduct the Obey Check. Twenty-eight seconds prior to the collision, after he had learned the Learjet was not obeying, he issued the instruction to repeat the obey

check, and to lead the Learjet to the south-west. Since the Learjet changed its attitude, the Eurofighter realised that it was responding to his signals and informed the aircraft controller of attitude change.

In accordance with the exercise process, the Learjet crew received the instruction to now obey the Eurofighter pilot's request.

The aircraft controller received the information that the Learjet was obeying through the words of the Eurofighter pilot: "Now the aircraft is responding and following in a left-hand turn". Immediately afterwards the collision occurred. In accordance with procedures, after he had received the emergency call the aircraft controller instructed the Eurofighter pilot to set the emergency transponder code.

Approximately four minutes after the collision the CRC received the coordinates of the accident site from the second Eurofighter pilot and informed SAR accordingly.

2.3 Specific Conditions

At the time of the accident good visual conditions prevailed. This was confirmed by weather data and the fact that the Eurofighter pilot reported having the Learjet in sight in a distance of approximately 6 NM (about 11 km).

Prior to being employed by their current employer the two Learjet pilots had gathered great experience on military procedures by flying fighter planes for the German Armed Forces. Both had been flight instructors for military jet pilots and therefore had repeatedly conducted student training flights in the areas Renegade missions and formation flights. On average, the two pilots had flown approximately 350 hours per year for their company. Including the accident flight, PIC and co-pilot had only flown 22 hours together. The Renegade exercise as it was performed on the day of the accident was a rather rare task compared to other forms of aerial target demonstrations. This was especially true for the two pilots. The PIC had participated in a Renegade exercise three and a half years before. The co-pilot had only participated in one other such exercise. Compared to the co-pilot the PIC was clearly more experienced in regard to his total flying experience and the experience with aerial target demonstrations. It cannot be ruled out, that this might be the reason why he did not question the PIC's decision to let him conduct the exercise. The CVR recordings did not indicate that either of the two pilots had any uneasiness or misgivings during the entire flight, especially during the approach of the Eurofighters

and the identification phase, regarding the task distribution in the cockpit as to who is PF and PNF.

The CVR recordings show that the PIC used the portable computer during the entire flight very intensely. He also used the computer during the interception and identification phases and the subsequent flight manoeuvre. It cannot be proven with sufficient certainty that a delay during the transfer of control occurred. It is likely however that the PIC's attention was distracted from the observation of the Learjet's attitude, and the distance and position in regard to the Eurofighter. This observation would have been very important in this critical flight phase. The operator had only stipulated that if the PF was flying the airplane manually the PNF should handle the tablet PC on instruction by the PF. There were no detailed stipulations in which operating phase it was permitted or forbidden to use the tablet PC.

The autopsy did not provide a clear cause of death for the two Learjet pilots, and prior illnesses could not be rule out. Neither the CVR nor the FDR data showed any indication that one of the Learjet pilots suffered any health impairment.

The Eurofighter pilot was experienced. In accordance with the Bundeswehr regulations his annual flight hours were sufficient. Interception missions were routine for the pilot. He had flown such missions on average approximately every other week for the last year and a half. In general, interceptions are terminated after the identification phase. Therefore the pilot had little experience with the intervention, i.e. the intrusion of the flight path of another airplane.

2.4 Defences

In the scope of this investigation, the term "Defences" means technical systems, actions, procedures and institutions which shall minimise the effects of technical and human errors to protect flight safety.

2.4.1 Operator Procedures

The stipulations of the operator's OM-A that cross-cockpit flying was to be avoided applied for formation flights and especially for close formations. The reason was the very close distances of the aircraft involved in a close formation, and the limitations to the field of vision of the respective pilot to the other aircraft. No such stipulations existed for aerial target demonstrations and especially not for Renegade missions.

The operator had also stipulated that during aerial target demonstrations the airplane had to be controlled by a pilot with long-time experience as pilot of military jets. Based on the military experience such a pilot was familiar with tactics, safety measures, and trained in formation flights, among other things. Generally, both Learjet pilots met these requirements. The stipulation to deploy ex-military pilots was designed as safety measure, among other things, and was generally correct. The BFU is of the opinion that in this case it could have had an adverse effect, because military pilots are used to more resolute manoeuvres compared to their civil colleagues.

The flight operations manual of the German Air Force made stipulations for formation flights in case a pilot loses visual contact with the leading airplane. These measures included heading and attitude stipulations as well as instructions regarding communication. The operator did not have similar detailed stipulations in the operations manual. Where formation flights were concerned it stipulated that the military standard procedure always had to be applied and each deviation had either to be briefed beforehand or announced via radio.

2.4.2 Learjet Crew – Crew Resource Management

The BFU is of the opinion that the assessment of the Learjet's CVR recordings showed deficiencies in regard to the application of crew resource management principles. These deficiencies become noticeable in: cooperation, communication, leadership behaviour, situational awareness, and the decision making process.

Close to Ramstein the airplane was flying circles waiting for the exercise to begin when the co-pilot asked: "Du sagst dann Bescheid, wenn du übernehmen willst ja? (You are going to let me know if you want to take over, yes?)" This question aiming at the task distribution in the cockpit answered the PIC as follows: "Du, das lass uns mal nach Büchel machen (Let us do that after Büchel). Solange mach ich hier weiter. (Until then I will continue)". Thus, the PIC had decided the co-pilot should also be PF during the Renegade mission. During this conversation the pros and cons of the PF being the one in the right-hand seat were not discussed. Neither did the PIC ask the co-pilot's opinion or enquire about his condition. It was never discussed which expectations the PIC had regarding the co-pilot conducting the exercise.

Between 1429:21 hrs and 1438:10 hrs, according to the CVR recordings, the PIC was intensively involved in observing the outside environment, i.e. observing the movements of the Eurofighter, the distances to the airspace of Paderborn Airport,

and the time left for the exercise. He kept the co-pilot informed accordingly. In addition, he talked with the aircraft controller. Not one of the remarks made by PIC or co-pilot indicated that details or possible hazards of the impending exercise were discussed.

Neither the co-pilot as PF nor the PIC as PNF questioned the use of the computer during the identification and intervention phases.

Even though 10 seconds prior to the accident the co-pilot had made the PIC aware of the fact that he had lost visual contact with the Eurofighter did this not result in the termination of the turn. The operator's OM-A did not make any stipulations as to what to do in case a pilot loses visual contact with another aircraft during formation or target demonstration flights or any other operating mode. By continuing the turn the crew acted contrary to the stipulations in the FOM of the German Air Force regarding formation flights and loss of visual contact with the leading aircraft. They also acted contrary to the stipulations of the operator's OM-A stating that during formation flights the valid military standard procedures have always to be applied.

The BFU is of the opinion that the turn would have had to be aborted immediately once visual contact was lost. Instead, the co-pilot asked the PIC to take over controls. It is highly likely that in this phase the co-pilot was convinced the PIC in the left-hand seat would have the Eurofighter in sight and would continue the left-hand turn. Neither pilot mentioned the increasing bank angle during the turn or took corrective action.

2.4.3 Eurofighter Crew – Crew Resource Management

Approximately 10 seconds prior to the collision, the Eurofighter pilot saw the Learjet was now following, commenced a turn, and radioed: "Now the aircraft is responding by rocking wings and following in a left-hand turn". In the remaining 8 seconds the values for flight altitude, indicated airspeed, and bank angle of the Eurofighter remained almost constant. This indicates that during this time period he focused his attention mainly on control input, navigation, and communication. He did not observe the increasing bank angle of the Learjet. This concurs with his statement that he had realised the collision because of the jolting while he had just been looking into the cockpit.

The BFU is of the opinion that this process shows on the one hand that the demands on a pilot of a single-seat Eurofighter are higher in this phase compared with the two-seaters formerly used by the Bundeswehr. On the other hand, the BFU is convinced

that his expectations resulting from his experience acquired during similar exercises, and his trust in the line of action of his training partners contributed to the Eurofighter pilot's attention distribution.

Due to the distance to the other two airplanes during the identification and intervention phases, the pilot of the second Eurofighter could not effectively support the other Eurofighter pilot by observing the Learjet or warn the other pilot about the flight manoeuvres during the last eight seconds. After the collision he checked the other Eurofighter for damages. Until the damaged Eurofighter had landed, he supported the other pilot during the decision making process and the communication.

2.5 Organisational Aspects

2.5.1 Organisational Aspects Operator

Since the middle of the 1960s the company had been operating in the challenging area of aerial target demonstrations, and had been able to guarantee a high flight safety level. The operator formally met the official requirements in regard to the safety management system. A SMS handbook had been compiled and approved by the LBA. The BFU is of the opinion that since, at the time of the accident, a concrete hazard and risk assessment had not been conducted the SMS had still been in the development phase and had not yet been fully implemented. A particular effect had the fact that until the accident a risk analysis of flight operations had not been conducted in all areas.

The BFU is of the opinion that a comprehensive risk analysis would have given the company the additional option to analyse certain procedures in regard to Renegade missions, such as cross-cockpit procedures, turning with increased bank angles in close proximity to interceptor aircraft, and the potential distraction of a pilot through the use of a tablet computer, and to determine actions to minimize the risks.

The stipulations in the operator's operations manual stated that cross-cockpit procedures had to be avoided during formation flights and especially close formations and was not applicable for Renegade missions. The accident shows, however, that at close distances between aircraft involved the visual contact with a fighter plane flying on the other side of the airplane can be lost during small position and attitude changes due to the limited field of vision. This is also true for the Learjet which has only one strut in the cockpit window and therefore offers a comparatively good field of vision.

The BFU is of the opinion that the extreme bank angle of more than 50° does not realistically match the exercise scenario. Crew of "normal" civil airplanes would probably fly such a turn with a bank angle of 10° - 15°, or up to 30° at the most.

Video recordings about the operator available on the internet, and observations of a BFU investigator show that bank angles of more than 45° were flown during other formation and target demonstration flights conducted by the company. The analysis of the Learjet's FDR showed that a bank angle of 60° was recorded by approximately 63% of the 35 recorded flights. This proves that these proceedings were common within the company and were therefore not unusual for the PIC or the co-pilot. This is supported by the fact that the PNF made no comments about the control inputs of the PF and the resulting strongly increasing bank angle of the Learjet.

According to EASA AMC 30-25 the computer used in the cockpit met the description of a portable EFB. Some of the installed applications such as Moving Map and the Operations Manual were listed as Type B software.

The BFU is of the opinion that part of the risk analysis should be to which extent the use of portable EFBs results in distraction and which flight phases, in general and in regard to the characteristics of the operator's operating modes, have to be considered critical flight phases.

2.5.2 Organisational Aspects Air Force

The BFU is of the opinion that a flight safety risk analysis regarding Renegade missions conducted by the Bundeswehr has to consider two levels.

The first level has to consider the training scenario. The exercise has to be examined in regard to the reality and risk ratio. Everyone involved in the exercise is in general familiar with civil and military procedures and tactics and is interested in a successful and safe training. The BFU is of the opinion that the process of the exercise shows that the organisations involved had great confidence in the knowledge of the procedures and the correct application of standards. Furthermore, the flight manoeuvres conducted during such trainings are used frequently and in general are considered not very demanding for military pilots with the appropriate training. Nevertheless, possible erroneous control inputs and human errors have to be taken into account. The German Air Force had made arrangements concerning various safety measures during the planning phase of the Renegade mission. During similar training scenarios these general safety measures had always been given and range between basics of coordination to radio frequencies to brevity words such as KNOCK

IT OFF and TERMINATE for immediate termination. The BFU is of the opinion that during the planning phase and the order, it would have been possible to make more exact provisions as to the role of the Learjet during the exercise. For example, if the role of the Learjet would have been to pose as transport aircraft, it could have used the autopilot to simulate limited manoeuvrability.

Contrary to a real Renegade situation it would have been possible to come to an agreement for a certain training scenario. In this case it was done on one hand on long-term basis during the planning phase and on the other hand on the morning the exercise was to take place when phone calls with the operator and the Tactical Air Force Wing were conducted to finalise detailed definitions for the course of the exercise. There was, however, no direct agreement between the Eurofighter and Learjet pilots. Third parties such as the Zentrum Luftoperationen (Air Operations Command) made the arrangements.

The FOM stipulation that infringement of the minimum slant range of 500 ft can only occur if the parties involved have agreed on and determined a minimum distance was formally not complied with. Even without defined minimum slant range, everyone involved knew, based on their experience, that especially during the identification phase the airplanes would fly in close proximity to each other.

The second level of the necessary risk analysis has to consider the real Renegade mission with the escalation levels suspected, probable and confirmed. The BFU is of the opinion that in such a scenario it must be assumed the civil airplane is not familiar with military procedures and tactics. Possible control errors and unintentional erroneous reactions of pilots have to be taken into account. The situation of a suspected Renegade can already occur if a civil aircraft loses radio contact. In such cases it often happens that radio contact can be established again and the interception can be terminated after the identification phase without having to go to the intervention phase. There are cases, however, where the interception mission has to be carried forward beyond the identification phase. Even though the aircraft fly in close proximity to each other during the identification phase and are flying in a sort of formation during the intervention, from the legal point of view it is not considered to be formation flight, because the pilots have not made previous arrangements. Furthermore, pilots of civil aircraft usually do not have formation flight training. The BFU is of the opinion that sudden and unexpected flight manoeuvres of the intercepted aircraft are likely in cases where the situational assessment based on the available information results in either suspected or confirmed Renegade.

2.5.3 Organisational Aspects Extern

The investigation revealed that the flight operational practices of the operator were very specialised. This was also demonstrated by the stipulations in the operator's operations manual. Nevertheless, the flight operations of the company had nothing to do with the operating modes the LBA had approved with the AOC. Due to the tasks and organisational form the operator operated between commercial civil aviation and the military requirements as service provider for the armed forces.

Oversight and support of the company through the LBA were insufficient. Contributing factors were on one hand the staff shortage at the LBA department flight operations and the additional workload resulting from the implementation of Commission Regulation (EC) No 965/2012 and on the other hand the fact, that in Germany at the time of the accident aerial work was not subject to approval. The BFU is of the opinion that oversight by the LBA should include the flight operational practices of the company in order to have a general view and come to a conclusion whether the company has an effective safety management system.

The investigation revealed that until the accident the safety management system of the operator had not been a focal point of the LBA's oversight duties. An audit with the focal point on safety management system was conducted four months (October 2014) after the accident but even then did not reveal any irregularities. During the audit it was not inquired whether there were any results of an internal investigation of the accident or possible results of an internal safety audit. In order to meet the requirements of overseeing an operator in regard to safety management, to assess the presented documentation, and to check the implementation, the LBA employees responsible for the flight operations oversight should be trained sufficiently.

The BFU is of the opinion that flight operations of a company which conducts aerial target demonstrations on behalf of the Bundeswehr is mainly geared towards the requirements and needs of the armed forces. This, for example, is shown by the conduct of the flight, the flight profile, the necessary equipment, and the necessary knowledge of military procedures and tactics. At the time of the accident, the Bundeswehr planned, supervised and conducted manned and unmanned aerial target demonstrations but oversight and auditing of such companies in regard to military flight safety did not take place. Only one of the three contracted companies conducting manned aerial target demonstrations for the Bundeswehr had an AOC and was therefore subject to oversight by the Luftfahrt-Bundesamt. At that time in Germany aerial work was not subject to approval and therefore the activities of the

LBA did not focus on the core area of the operator's flight operations. In case of the other two companies conducting manned aerial target demonstrations the LBA was not responsible for flight operations approvals and oversight, because they were not operators. In order for flight safety finding more consideration during aerial target demonstration flights conducted on behalf of the Bundeswehr the expertise of the Bundeswehr in regard to flight safety issues should be incorporated more.

At the time of the accident up until this investigation report was published, the Federal Republic of Germany (FRG) had not prepared a State Safety Programme. The BFU is of the opinion that the FRG shows deficits in all five areas mentioned in the ICAO Safety Management Manual regarding the State Safety Programme. These areas were: Legal framework, harmonisation, implementation of monitoring and measurement of the safety performance in national aviation, the coordination and continued improvement of the safety management system, support of communication and interaction of organisations which operate in the area of flight safety.

The BFU is of the opinion that it would be of great importance for the sustainment of the high level of flight safety in general and with manned aerial target demonstrations conducted by civil companies in particular if the information exchange between civil (Luftfahrt-Bundesamt) and military organisations (Luftfahrtamt der Bundeswehr responsible since October 2014) responsible for flight safety were improved.

The Commission Regulation (EC) No 965/2012 Appendix VIII Part Specialised Operations (SPO) listed parachute operations or towing of objects as examples. Air to air refuelling and aerial target demonstrations were not part of this list, however. The BFU is of the opinion that such operating modes should also be part of the list.

3. Conclusions

3.1 Findings

- The pilots of both airplanes were experienced and held the required licenses and ratings to conduct the flight.
- The two Learjet pilots had accumulated many years of flying experience on military jet airplanes prior to their work for the operator.
- The Learjet PIC did not fly any Renegade exercises in the last three and a half years. For the co-pilot the accident flight was the second flight as part of a Renegade mission.
- No indications for technical irregularities on the aircraft were found.
- The aircraft controllers involved had the required licenses and ratings.
- The post-mortem examination of the two pilots was possible only to a limited extent, but it did not show any indications of performance limitations.
- The weather conditions had no causal effect on the course of events.
- At the time of the accident the airplanes were in airspace E in approximately 8,000 ft AMSL.
- Both airplanes were in contact with the same CRC but on different frequencies and with different aircraft controllers.
- During the course of the flight, the PIC decided that the co-pilot should also fly the airplane during the interception while he continued as PNF.
- During the entire time of the flight the PIC used a portable computer for navigation purposes.
- Approximately 15 seconds prior to the collision the autopilot was disengaged, the co-pilot controlled the airplane manually in an alternating roll about the longitudinal axis and followed the Eurofighter in a left-hand turn.
- The investigation showed that the slant range of the two airplanes at the beginning of the turn was approximately 30 m.
- The turn was continued, even though the co-pilot had lost visual contact with the Eurofighter once the Learjet had a bank angle of 4°. The Learjet turned

more sharply around the yaw and longitudinal axis as the Eurofighter. The speed of the Eurofighter remained almost constant. The speed of the Learjet increased.

- Immediately prior to the collision, the PIC was distracted by the portable computer when taking over controls.
- The Eurofighter reported via radio that the Learjet would obey his instructions.
- During the last 8 seconds prior to the accident he had focused on the control inputs, the navigation, and the communication and had not observed the Learjet.
- At the time of the collision the Learjet had a heading of 358° and a left bank angle of 46°. The Eurofighter a heading of 001° and a left bank angle of 26°.
- The initial point of impact was between the upper surface of the Learjet's fuselage and the Eurofighter's right side of the rail launcher of the outboard wing station, and then with its right outboard tank. The cowlings of the right engine of the Learjet then collided with the area of the right engine on the fuselage underside of the Eurofighter
- The Learjet was destroyed by the collision and subject to in-flight fire. The accident was non-survivable for the occupants.
- The Eurofighter was severely damaged by the collision. The pilot was able to land the aircraft safely at the home base.
- The pilot of the second Eurofighter could not observe the flight manoeuvres of the preceding airplanes in detail due to the distance.
- The investigation determined deficiencies regarding Crew Resource Management of the Learjet crew.
- At the time of the accident the operator's safety management system was still under development and not yet completely implemented. No risk analysis of the flight operations in general and the Renegade exercises in particular had been conducted.
- The used computer had to be considered an EFB Type B due to his type of use and applications.
- The operator's safety management had not sufficiently analysed the use of the computer, and the cross cockpit procedure in regard to flight safety risks.

- The operating modes stipulated in the AOC and approved by the LBA did not correspond with the flight operations practices of the operator. At the time of the accident aerial work in Germany was not subject to approval.
- No documentation was found showing that the LBA had specifically supervised the implementation of the operator's safety management system.
- The Bundeswehr procedures concerning interception of unidentified aircraft (Renegade) were neither described in detail nor assessed by way of risk analysis.
- There was no information exchange between the Bundeswehr and the Luftfahrt-Bundesamt regarding the specialities and flight safety aspects of aerial target demonstrations.
- At the time of the accident the Federal Republic of Germany had not met the ICAO requirement for implementation of a State Safety Programme in all member states.

3.2 Causes

The causes of the flight accident were:

Immediate Causes:

- During positioning for the intervention the collision risk due to unexpected manoeuvres of the intercepted airplane was not sufficiently taken into consideration.
- The Learjet crew did not take into account the risks due to possible limitations of the field of vision and the distraction by using the computer when deciding about the task distribution.

Due to insufficient situational awareness during the intervention, the Learjet crew continued the turn with an excessive bank angle despite the loss of visual contact with the Eurofighter flying at the inside of the turn.

Systemic Causes:

- The operator had not specified in detail how the crew should distribute their tasks during Renegade exercises.
- Neither the operator commissioned to conduct the aerial target demonstration nor the Air Force had sufficiently described the Renegade training nor had a commensurate risk analysis been done.

4. Safety Recommendations

The BFU issued the following safety recommendation to prevent future accidents:

Recommendation No 03/2015

The operator should ensure that during aerial target demonstrations a high level of flight safety is reached. Therefore such flights should be investigated in regard to latent flight safety risks and actions be determined to minimise these risks.

For aerial target demonstration flights as part of Renegade mission trainings, the following points should especially be considered during risk analysis:

- Applicability of cross cockpit procedures
- Use of portable computers during critical flight phases
- Procedures for loss of visual contact
- Application of flight manoeuvres suitable for the kind of target represented during the training.

Recommendation No 04/2015

The Luftfahrtamt der Bundeswehr (LufABw) should ensure that during interception of civil aircraft a high degree of flight safety is guaranteed.

The Renegade procedure should be sufficiently described and rendered more precisely so that the collision risk of aircraft involved is minimised even in the event of unexpected flight manoeuvres of the intercepted aircraft. Therefore the requirements of single-seat military aircraft should be taken into account more strongly when describing the procedures. The demand on the pilots in regard to the attention and task distribution in individual phases of the procedure should be rendered more precisely and the pilot of the second military aircraft should be more involved in the support to guarantee continued observation of the intercepted aircraft.

Recommendation No 05/2015

The Luftfahrtamt der Bundeswehr (LufABw) (Military Aviation Authority) should ensure that companies acting as civil contracting partners for the Bundeswehr conducting aerial target demonstrations meet the highest Bundeswehr standards in regard to their flight operations and flight safety organisations.

In case the civil contracting partner does not hold an Air Operator Certificate (AOC) issued by a civil aviation authority, the LufABw should ensure that the civil contracting partner is organised such that hazard analyses are conducted in regard to their aerial target demonstrations operations which are suited to ensure a high degree of operational safety.

In case the civil contracting partner is a civil air operator certified by the Luftfahrt-Bundesamt (LBA), regular information exchange should take place between the LufABw and the LBA in regard to special operational and flight safety issues in order to support the LBA.

Recommendation No 06/2015

The Luftfahrt-Bundesamt should effectively supervise the service providers working for the armed forces in terms of their operation.

Therefore the Luftfahrt-Bundesamt should cooperate with the Luftfahrtamt der Bundeswehr in order to better understand the military special features. Therefore, regular information exchange should take place between the Luftfahrt-Bundesamt and the Luftfahrtamt der Bundeswehr (Military Aviation Authority) in regard to special operational and flight safety issues.

Recommendation No 07/2015

The Luftfahrt-Bundesamt (LBA) should ensure that operators have an effective Safety Management System.

It should especially guarantee that the Safety Management System analyses the essential operating modes of an operator in regard to flight safety risks and, if applicable, take actions to minimise the risks.

Recommendation No 08/2015

The European Aviation Safety Agency (EASA) should add the term aerial target demonstrations to the list of examples mentioned in Commission Regulation (EC) No 965/2012 Part Specialised Operations (SPO) SPO.GEN.005 Scope (a).

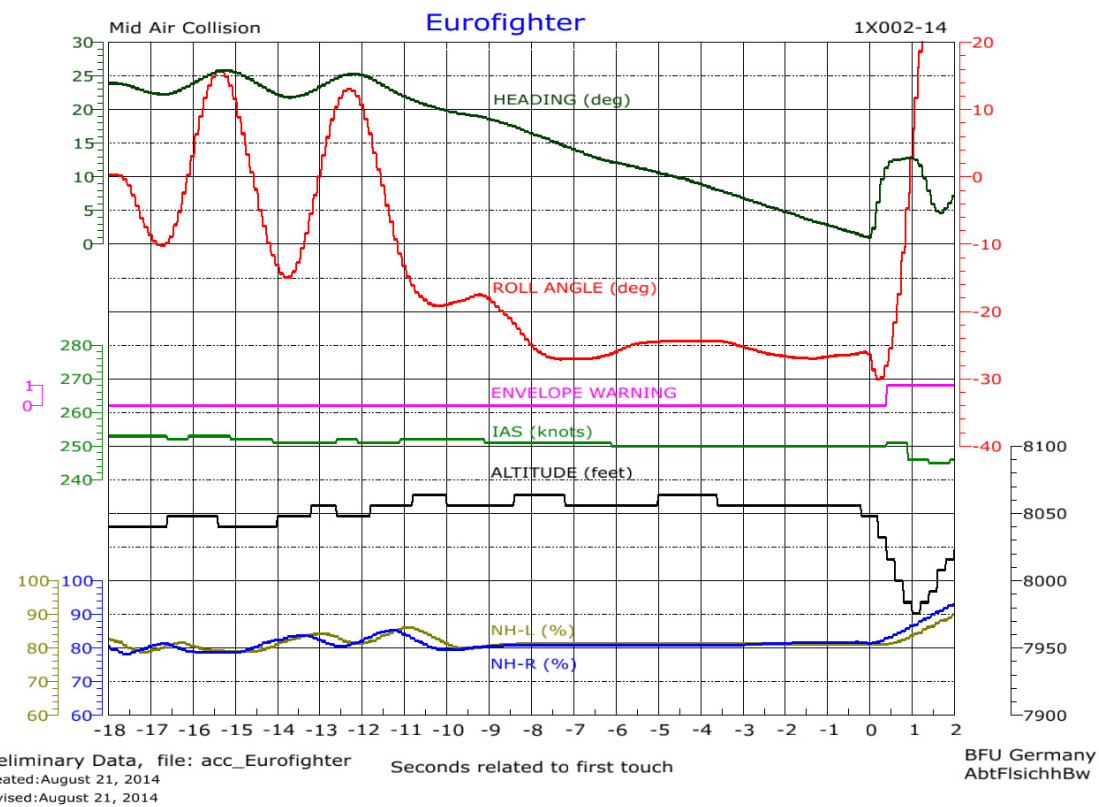
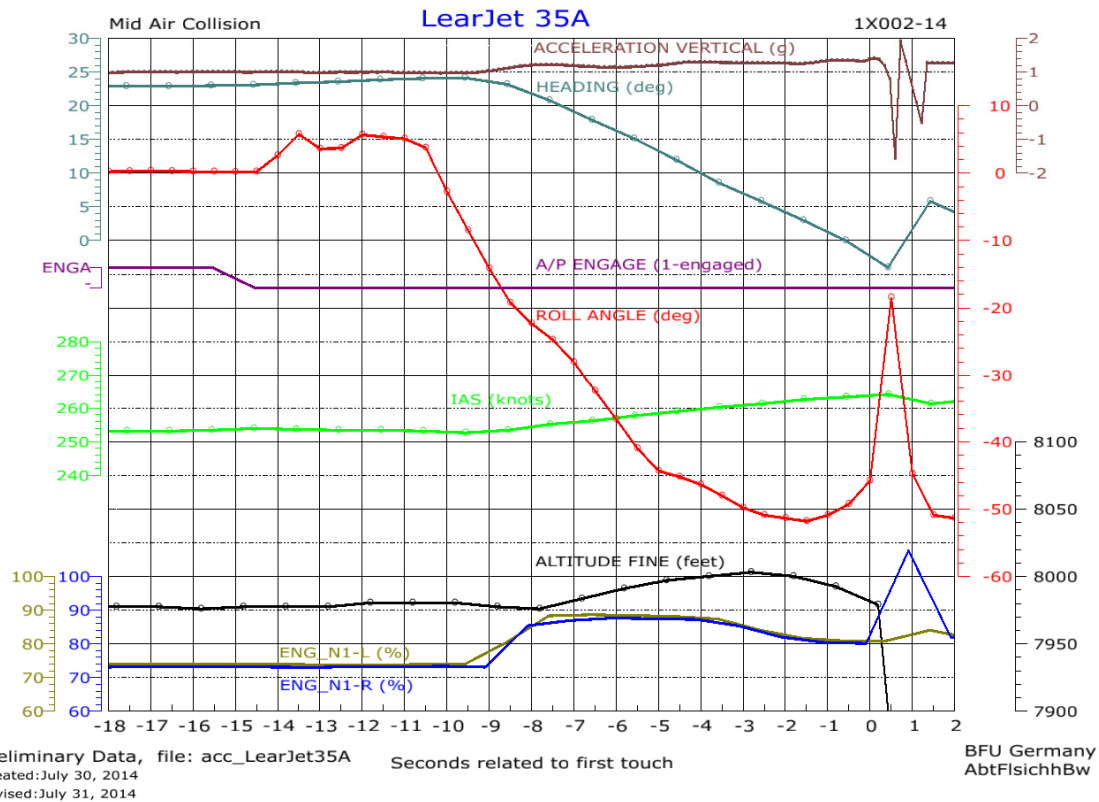
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Braunschweig, 13 August 2015

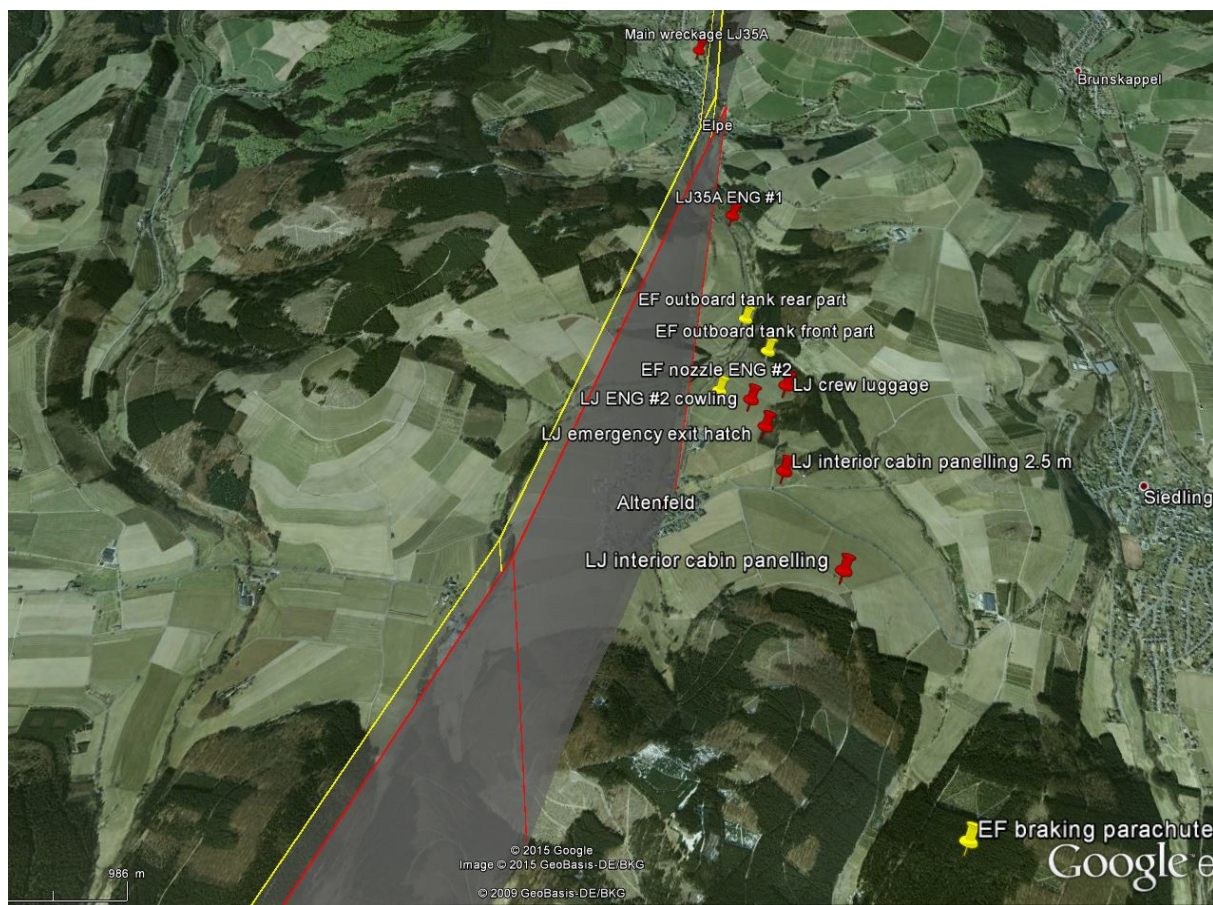
5. Appendices

Appendix 1 Excerpt flight data recorder Learjet 35 A and Eurofighter

Appendix 2 Flight path reconstruction and distribution of the wreckage



Flight path reconstruction based on radar data and the distribution of the wreckage



Flight path reconstruction and distribution of the wreckage Learjet (red) and Eurofighter (yellow)

Source: Google Earth/BFU