Investigation report

L2012-08

Airliner Veering Off the Runway during the Landing Roll at Helsinki-Vantaa Airport on 19 August 2012

Translation of the original Finnish language report

OH-ATH

ATR 72-212A

Onnettomuustutkintakeskus
Olycksutredningscentralen
Safety Investigation Authority, Finland

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SUMMARY

AIRLINER VEERING OFF THE RUNWAY DURING THE LANDING ROLL AT HELSINKI-VANTAA AIRPORT ON 19 AUGUST 2012

A serious incident occurred at Helsinki-Vantaa airport (EFHK) on 19 August 2012 at 3:42 UTC. An ATR 72-212A type twin-engine airliner, registration OH-ATH, manufactured by Avions de Transport Régional (ATR) and operated by Flybe Finland Oy, veered off runway 22L. It was on scheduled flight FCM992T from Tampere-Pirkkala airport to Helsinki-Vantaa. There were 27 passengers and four members of the aircrew on board.

As the aircraft was approaching Helsinki-Vantaa airport the automatic functioning of the Travel Limitation Unit (TLU), which limits rudder deflection, malfunctioned and the flight crew did not switch on the TLU's standby system. Since the normal landing criteria provided by the Quick Reference Handbook (QRH) for a TLU FAIL situation were met the captain decided to continue the approach and land on RWY 22L. Upon touchdown the captain noticed that the rudder pedals felt as if they were stuck. Since rudder authority was unavailable, the aircraft veered off the runway onto the shoulder strip during the landing roll. The captain, using nose wheel steering, managed to steer the aircraft back onto the runway. The serious incident did not result in any injuries to persons or damage to runway equipment. The aircraft sustained minor damage which was repaired by Flybe Finland Oy's maintenance organisation, Finnish Aircraft Maintenance (FAM), during the subsequent inspection and maintenance.

Working together with the aircraft manufacturer and the operator, the investigation established why the TLU's automatic functioning failed, the flight crew's action during the malfunctioning and the incident, and how Human Factors contributed to the onset of the serious incident.

The serious incident was caused by the mechanically centred rudder's insufficient authority for directional control which resulted in the aircraft veering off the runway. A contributing factor to the serious incident was that the electric motor of the TLU's actuator broke and the TLU remained in the high speed (HI SPD) mode for the approach and landing, thereby jamming the rudder. Another contributing factor was that the flight crew did not switch on the TLU's standby system. This was due to their inadequate system awareness and lack of clarity in Quick Reference Handbook (QRH) instructions with regard to using the standby system during a TLU failure. Yet another contributing factor was the asymmetrical propeller blade angle transition into the BETA zone following the reduction of engine power at landing, which resulted in a strong sideways oscillation.

Safety Investigation Authority, Finland issued four safety recommendations to ATR, the aircraft manufacturer. They pertain to the more detailed instructions concerning the operation of the ATR's Travel Limitation Unit (TLU).

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ABBREVIATIONS

ADC	Air Data Computer
AFM	Aircraft Flight Manual
AIP	Aeronautical Information Publication
ATPL	Airline Transport Pilot Licence
ATR	Avions de Transport Régional
BEA	Bureau d’Enquêtes et d’Analyses pour la Sécurité de l’Aviation Civile
BETA zone	The zone of zero propeller blade angle
CAVOK	Ceiling and Visibility OK
CA	Cabin Attendant
CAME	Continuous Airworthiness Management Exposition
CBT	Computer Based Training
CC	Chief of Cabin
CEV	Centre d'Essais en Vol
CPL	Commercial Pilot Licence
CRM	Crew Resource Management
CS25	Certification Specifications Large Airplanes
CVR	Cockpit Voice Recorder
EASA	European Aviation Safety Agency
EC	European Commission
EEC	Electronic Engine Control
EFHK	Helsinki-Vantaa airport
EFTP	Tampere-Pirkkala airport
FAM	Finnish Aircraft Maintenance
FCOM	Flight Crew Operations Manual
FDAU	Flight Data Acquisition Unit
FDR	Flight Data Recorder
FOCS	Flight Operations Control System
EU	European Union
FL	Flight Level
FLT CTL	Flight Controls

FT	Foot (feet)
HI SPD	High Speed
HF	Human Factors
HMU	Hydro Mechanical Unit
hPa	Hectopascal
ICAO	International Civil Aviation Organization
JAR	Joint Aviation Requirement
KT	Knots
LO SPD	Low Speed
MHz	Megahertz
NM	Nautical Mile
OM A-D	Operations Manual – A-D
PLA	Power Lever Angle
QAR	Quick Access Recorder
QNH	Altitude Above Mean Sea Level
QRH	Quick Reference Handbook
RUD	Rudder
TLU	Travel Limitation Unit
TRTO	Type Rating Training Organisation
TWR	Control Tower
UTC	Co-ordinated Universal Time
V_C	Calibrated air speed
V_{MCA}	Minimum control speed – air

SYNOPSIS

On 19 August 2012, pursuant to Section 2 of the Safety Investigation Act (525/2011), Safety Investigation Authority, Finland (SIAF) categorised the veering off-occurrence as a serious incident and decided to initiate safety investigation L2012-08. SIAF Expert Timo Heikkilä was appointed as team leader for the investigation group, accompanied by SIAF Expert Jukka Harajärvi. Chief Air Safety Investigator Ismo Aaltonen was appointed as Investigator-in-Charge.

SIAF notified the ICAO (International Civil Aviation Organization), the European Commission (EC), the EASA (European Aviation Safety Agency) and the French Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA). Pursuant to ICAO Annex 13 the BEA designated their Accredited Representative (ACC REP) to the investigation.

During the course of the investigation SIAF sent the EASA five safety recommendations for comments. Four of the recommendations concerned further clarifications to the ATR's TLU-related instructions. One recommendation was related to improving flight crews' theoretical instruction and simulator training with regard to TLU systems. Responses to all safety recommendations were received on 6 November 2012.

SIAF Expert Jaakko Kulomäki assisted the investigation group by evaluating the role of Human Factors in the course of events. SIAF Expert Sanna Winberg provided expert assistance to the group in cabin crew-related matters.

All times in the investigation report are in Co-ordinated Universal Time (UTC). The course of events was established by means of information derived from the Flight Data Recorder (FDR), the Cockpit Voice Recorder (CVR), the Air Traffic Control's radiocommunication, telephone and radar recordings, and by interviewing the interested parties.

Comments pursuant to European Union Regulation No 996/2010 were requested from the interested parties, Flybe Finland Oy, the operator, the Finnish Transport Safety Agency, Finavia, the EASA, the BEA and the ATR.

Comments were received by 19.8.2013. The comments were taken into consideration by the in the final report. Appendix 4 contains a précis of the comments.

The investigation was completed on 13.10.2013. The Finnish language version of the investigation report is the official version. The Finnish language investigation report and the material used in the investigation are archived at Safety Investigation Authority, Finland.

1 FACTUAL INFORMATION

1.1 History of the flight

Flybe Finland Oy’s scheduled flight Finncomm 992T was flown on 19 August 2012 from Tampere-Pirkkala airport to Helsinki-Vantaa airport where the flight landed at 3:42 UTC.

Prior to the flight the aircrew stayed overnight at Tampere. The ATR 72-212A aircraft involved in the serious incident, registration OH-ATH, stayed overnight on the apron of Tampere-Pirkkala airport.

Nothing out of the ordinary happened during the stay overnight or the briefing for the flight. The captain performed the pre-flight check; nothing out of the ordinary was noticed.

The flight progressed normally until approximately 6 NM (11 km) from the threshold of Helsinki-Vantaa RWY 22L. When the flight crew reduced airspeed to below 185 KT (342 km/h) for a change of configuration and to begin the approach, the rudder’s Travel Limitation Unit (TLU) automatic functioning malfunctioned.

The meteorological conditions were good and the captain decided to proceed with the necessary checks and procedures without aborting the already ongoing approach. When the fault appeared and the approach was being continued the aircraft was flying by automatic pilot. The flight crew believed that they had enough time to focus on identifying the fault and to complete the required procedures during the approach.

In a normal approach pattern airspeed is reduced to approximately 110 KT (204 km/h) during the approach. When the fault appeared the flight crew had approximately 2min 30sec to identify the fault before the landing. As the approach continued and the co-pilot was searching for the relevant instructions in the Quick Reference Handbook (QRH) the captain realised that they would not have enough time for Crew Resource Management as required. The captain completed the final check for the approach on his own and advised the co-pilot to continue establishing the fault from the QRH.

The flight crew did not have enough time to interpret the QRH’s instructions for a TLU fault. This being the case, they failed to switch on the TLU’s standby system. The QRH was still being read as the aircraft was passing the 1000 ft (300 m) and 500 ft (150 m) altitudes above the threshold elevation. However, despite Company regulations that require in a situation like this the commencement of a go-around at 500 ft, at the very latest, they continued the approach. At 250 ft (75 m) the flight crew noted that the normal landing criteria required by the QRH were being met and continued the approach all the way to the runway. Due to the TLU fault rudder travel was limited to ±4 degrees.

When the captain reduced engine power to below flight idle immediately upon the first contact with the runway, the aircraft rapidly swung 14.5° to the right. The airspeed at that time was still 103 KT (190 km/h). The approach speeds calculated for the weight of the aircraft at the time of the incident were V_{GA} 112 KT and V_{APP} 108 KT. Because of the fault the flight crew used an airspeed which was 10 KT higher than the one specified in the QRH for a landing. The V_{APP} used was 108 KT.

Upon landing the captain, who was controlling the aircraft, could not counter the aircraft's sudden change of direction with the rudder because its travel was limited close to its centre position. The aircraft veered off the runway with both main landing gears rolling onto the grassy runway shoulder strip (Figures 1and 2. Skid marks and track of the aircraft) approximately 550 m from the position of making first contact with the ground.

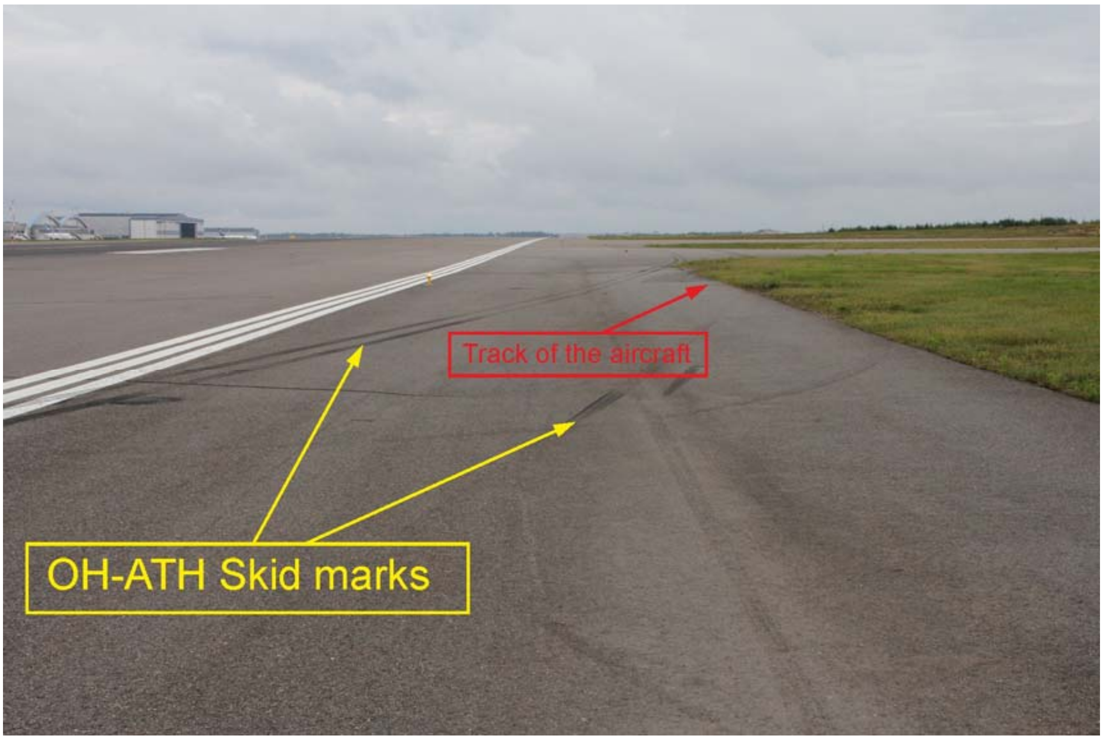

Figure 1. Skid marks and track of the aircraft.

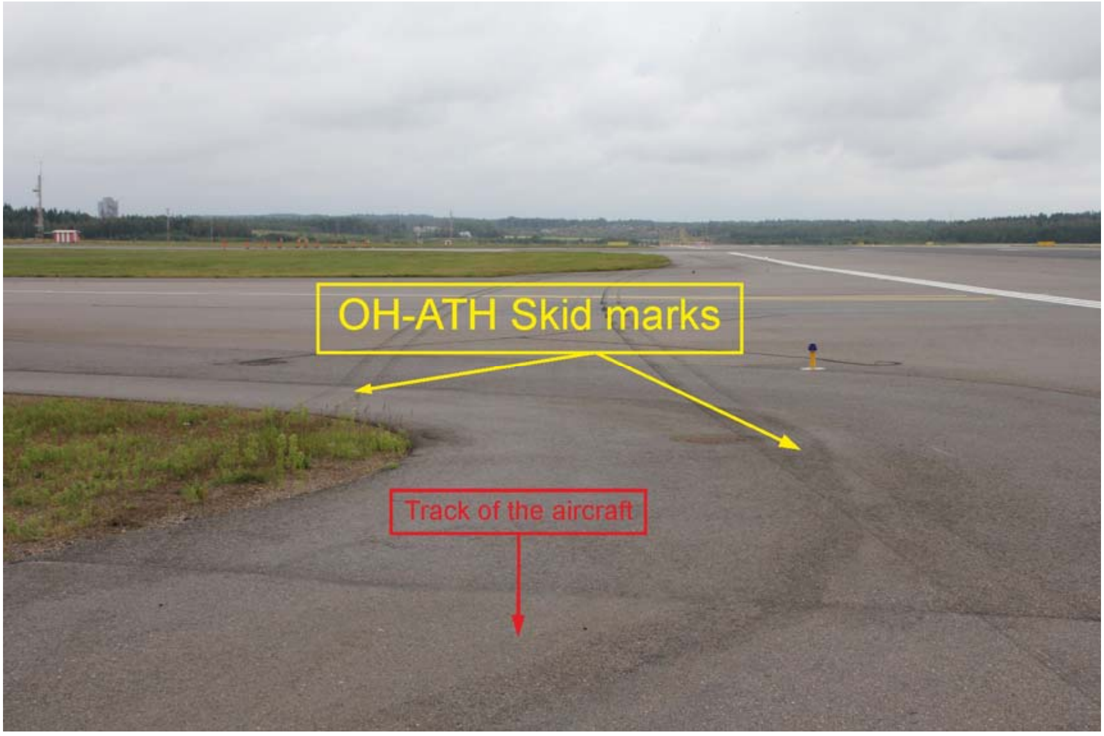

Figure 2. Skid marks and track of the aircraft.

Once the flight crew managed to return the aircraft to the runway they reduced engine power to ground idle and continued to taxi normally in accordance with their ATC clearance. While taxiing the flight crew again checked the instructions associated with a TLU fault. During this check the captain noticed that the FAULT caution light in the TLU panel above was illuminated and that the TLU switch was set to the AUTO mode. The captain set the switch to the low speed (LO SPD) mode. However, after approximately 10 seconds the captain noted that the system was inoperable and switched it back to AUTO. The flight crew did not know that the lag of the TLU's standby system was 33±5 seconds.

There were two members of the cabin crew on the flight: the Chief of Cabin (CC) and a Cabin Attendant (CA). During takeoff and landing the CC was seated at the back of the cabin and the CA at the front.

The cabin crew prepared the cabin for landing in the normal fashion. Judging from the aircraft's oscillation, the shaking and the passengers' reactions the cabin crew noticed that the landing roll was irregular. The captain had given no instructions to the cabin crew as regards the fault with the flight control system. Before the landing roll ended the CC unbuckled the seat belt, left the jump seat behind the cabin and went into the passenger cabin so as to find out what was going on. Having observed the situation the CC returned to the jump seat. The CA remained seated with the seat belt fastened throughout the event.

After the flight the flight crew and the cabin crew held a joint defusing session. Following this meeting the captain and the CC filed their respective occurrence reports.

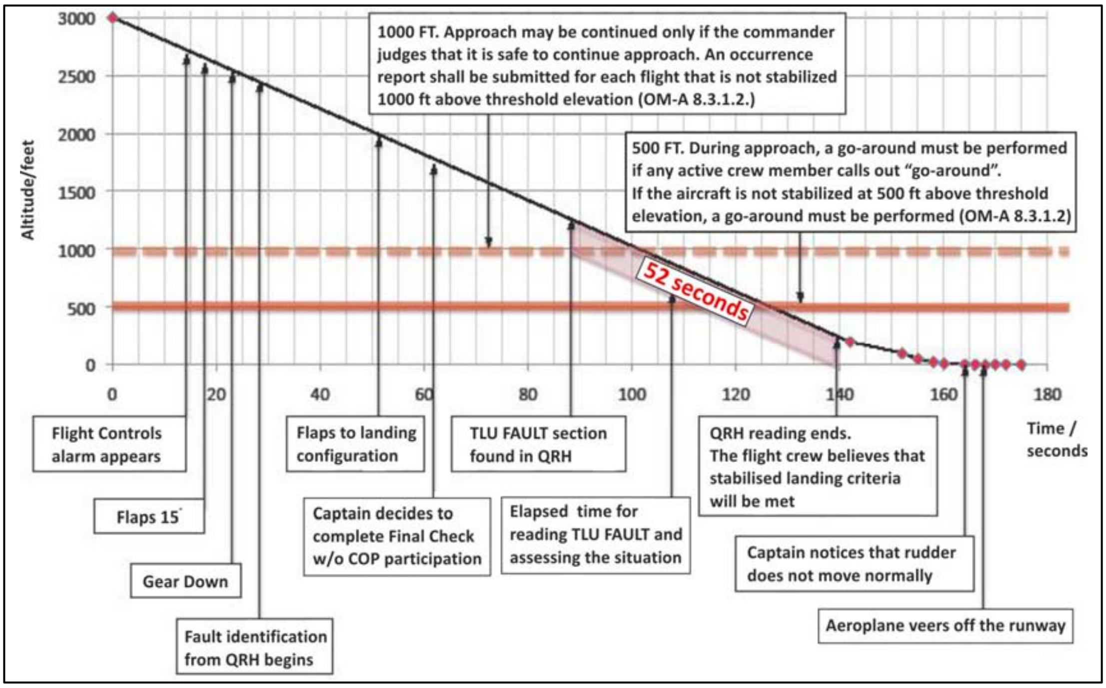

Figure 3. A recordings-based presentation of the course of events that resulted in the serious incident. Altitude information in the graph is approximate. Touchdown point elevation being used as zero altitude.

1.2 Injuries to persons

There were 27 passengers and four members of the aircrew on board the aircraft. The serious incident did not result in any injuries to persons.

1.3 Damage to aircraft

The Travel Limitation Unit's automatic functioning failed because its electric motor (actuator) was broken. As a result of veering off the runway the cockpit avionics equipment cooling fan on the belly of the aircraft, the right hand (RH) main landing gear's fairing and the nose landing gear's RH tyre were damaged. In addition, the dome and the lamp of the red rotating beacon on the bottom of the fuselage were broken. The damage was not extensive because the aircraft veered off in an area where the runway and taxiway intersect and the ground was sufficiently hard and level to support an aircraft of this weight class.

1.4 Personnel information

Captain of OH-ATH Age 38.

Licences Airline Transport Pilot's Licence (A) was valid.

Class 1medical certificate was valid.

Ratings All required ratings were valid.

Flight experience	Last 24 hours	Last 30 days	Last 90 days	Total hours and landings
All types	4 h 44 min 3 landings	20 h 33 min 12 landings	138 h 54 min 79 landings	6580 h 3602 landings
Type	4 h 44 min 3 landings	20 h 33 min 12 landings	138 h 54 min 79 landings	2101 h 1204 landings

Co-pilot of OH-ATH Age 28.

Licences Commercial Pilot License (A) was valid.

Class 1medical certificate was valid.

Ratings All required ratings were valid.

Flight experience	Last 24 hours	Last 30 days	Last 90 days	Total hours and landings
All types	4 h 14 min 4 landings	53 h 59 min 58 landings	151 h 00 min 155 landings	673 h 37 min 872 landings
Type	4 h 14 min 4 landings	53 h 59 min 58 landings	151 h 00 min 155 landings	448 h 21 min 462 landings

1.5 Aircraft information

Figure 4. ATR 72-212A OH-ATH. (Copyright Mika Virolainen – FAP)

Type	Twin-engine turboprop ATR 72-212A
Engines	2 x Pratt & Whitney 127F
Manufacturer	Avions de Transport Régional (ATR)
Registration and Certificate of Registration	OH-ATH, 2017
Airworthiness Certificate	Valid until 14 Nov 2012
Serial Number and Year of Manufacture	no 769, 2007
Maximum Takeoff Mass	22 500 kg
Landing mass	18 000 kg at the end of the flight at Helsinki-Vantaa
Owner	Finncomm Finance Four Oy
Operator	Flybe Finland Oy

1.6 Meteorological information

METAR EFHK 190320Z 23004KT CAVOK 16/15 Q1013 NOSIG=

Observed weather report at Helsinki-Vantaa airport on 19 August 2012 at 3:20 UTC: Wind 230 degrees 4 KT. Visibility over 10 km; no cloud cover below 5000 ft (1500 m). Temperature 16°C, dew point 15°C. Current altimeter setting (QNH) 1013 hPa. No significant change expected to the reported conditions within the next 2 hours.

1.7 Aids to navigation

The aids to navigation functioned normally; they had no bearing on the onset of the serious incident.

1.8 Communications

The communications and the associated recording equipment functioned normally; they had no bearing on the onset of the serious incident. Radio communication and telephone recordings were used to establish the course of events.

1.9 Aerodrome and Air Traffic Control information

1.9.1 Aerodrome information

The serious incident occurred on RWY 22L at Helsinki-Vantaa airport. The runway is 60m wide and 3440 m long. More detailed information of Helsinki-Vantaa airport is available in the Finnish Aeronautical Information Publication (AIP Finland).

1.9.2 Air Traffic Control action

Air Traffic Control action played no role to the onset of this incident. Contacts with different ATC units functioned normally throughout the entire flight. During no phase of the flight did the flight crew inform Helsinki Vantaa APP or TWR of the fault in the TLU’s automatic functioning, or of the aircraft’s limited controllability. In accordance with ATC instructions the air traffic controller must sound a full emergency alarm when the operation of an aircraft is degraded which, in this case, refers to controllability (Appendix 1).

The Helsinki-Vantaa TWR controller was oblivious to any potential incident until having witnessed the aircraft veer off the runway during its landing roll. Immediately after the occurrence the controller asked the captain whether anything happened; the reply was that everything was OK.

The ATC did not alert the rescue service to the scene because the aircraft managed to return to the runway on its own and continued to taxi normally. Immediately after the incident the ATC had the runway inspected and filed the appropriate occurrence reports.

1.10 Flight recorders

Flight Data Recorder (FDR)

The Flight Data Acquisition Unit (FDAU) compiles all parameters and relays them to the Multi Purpose Computer (MPC). The MPC then relays the information to the Flight Data Recorder (FDR) and the Quick Access Recorder (QAR). An investigator from the Safety Investigation Authority, Finland (SIAF) supervised the transfer and downloading of flight data. The flight data were available in both numeric and graphic format. The data were utilised in establishing the course of events.

Cockpit Voice Recorder (CVR)

The Cockpit Voice Recorder, model FA2100, serial number 000532507, was manufactured by L3 Communications. Following the removal of the CVR from the aircraft SIAF took hold of it. The recording was downloaded at Finnair's avionics repair shop under SIAF supervision and analysed at Safety Investigation Authority, Finland. After the downloading the CVR was erased and returned to Flybe Finland Oy.

1.11 Wreckage and impact information

Helsinki-Vantaa maintenance inspected and photographed the site of the incident. SIAF received the photographs in digital format. The runway edge lights and other runway fixtures were positioned in such places that the aircraft did not hit them at any stage of veering off the runway or returning to it. Whereas the investigation group did not inspect the aircraft, Flybe Finland Oy's OM-M maintenance organisation (Finnish Aircraft Maintenance, FAM) completed the required inspections and maintenance. Pressure variation was discovered in the LH brakes' antiskid system during maintenance. Because of this the pressure sensor in the system was replaced.

1.12 Survival aspects

The rescue units were not alerted because the air traffic controller did not have any prior knowledge of the aircraft's flight control system fault or an impending incident. After having seen the aircraft veer off the runway the air traffic controller called the flight crew over the radio in order to make certain that the situation was under their control.

1.13 Tests and research

1.13.1 Information received from the Flight Data Recorder Unit

Using the data downloaded from the FDR (FDR – Flight Data Recorder) the graph (Figure 5, FDR graphs) shows that the aircraft suddenly turned to the right at the point in time when engine power was reduced below flight idle following the initial contact with the ground. Engine power remained between flight idle and ground idle during the time the aircraft veered off the runway and returned to the runway. The recording shows that the flight crew reduced engine power from flight idle to ground idle within 40 seconds from the commencement of reducing power from flight idle to ground idle. Judging by this incident's and previous FDR recordings it appears that the OH-ATH's right engine tends to respond quicker to changes in power setting. This significantly speeds up the rate at which the RH propeller's air drag increases in comparison to that of the LH propeller when propeller blade angles are transitioning to the BETA zone (the zone of zero propeller blade angle).

Figure 5 also shows that during the landing the Rudder Position was at the position of its maximum TLU-limited travel, 4° to the left, before the asymmetrical response of the engines to the use of power levers caused the aircraft to suddenly swing to the right. The recording shows figures exceeding the nominal 4° limit. Nevertheless, they are possibly caused by inaccuracies in the measuring system, mechanical wear or rudder flutter caused by aerodynamic forces.

The information in graphs PLA1 (Power Lever Angle) and PLA2 is provided by the Electronic Engine Controls (EEC) which, in turn, receive it from the Hydro Mechanical Unit (HMU). PLA information is mechanically relayed to the HMUs. The constant difference of approximately 4°–5° in power lever angles represents a systematic error in the FDR's measuring system of this particular aeroplane, authenticated through several recordings. PLA divergence is possibly caused in conjunction with engine replacements or major component replacements.

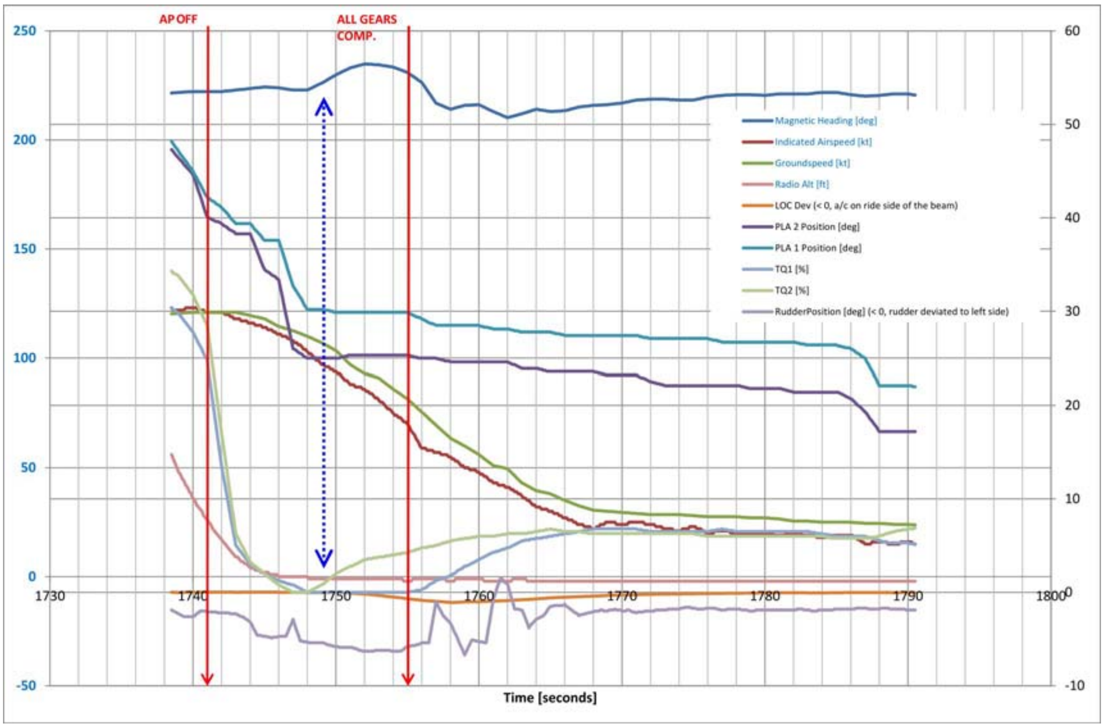

Figure 5. FDR- graphs.

1.13.2 The Travel Limitation Unit (TLU) in an ATR 72-212A type airliner

The Travel Limitation Unit in an ATR 72-212A type airliner protects the structure of the aircraft from the strain of excessive rudder deflections at high airspeeds as such deflections can result in structural damage.

As per its design the TLU automatically activates when airspeed exceeds 185 KT (342 km/h), at which time it limits rudder travel to ±4 degrees. Conversely, when the airspeed falls below 180 KT (333 km/h) this limitation is automatically eliminated, permitting full rudder travel for a landing and takeoff.

On the flight deck the TLU's functioning at airspeeds exceeding 185 KT (342 km/h) can be felt in the restricted (approximately ±10 mm) movement of the rudder pedals. At airspeeds below 180 KT (333 km/h) the mode of the TLU, and the availability of full rudder travel, is indicated by the green RUD TLU LO SPD light (Figure 6) which is positioned next to the landing gear indication lights.

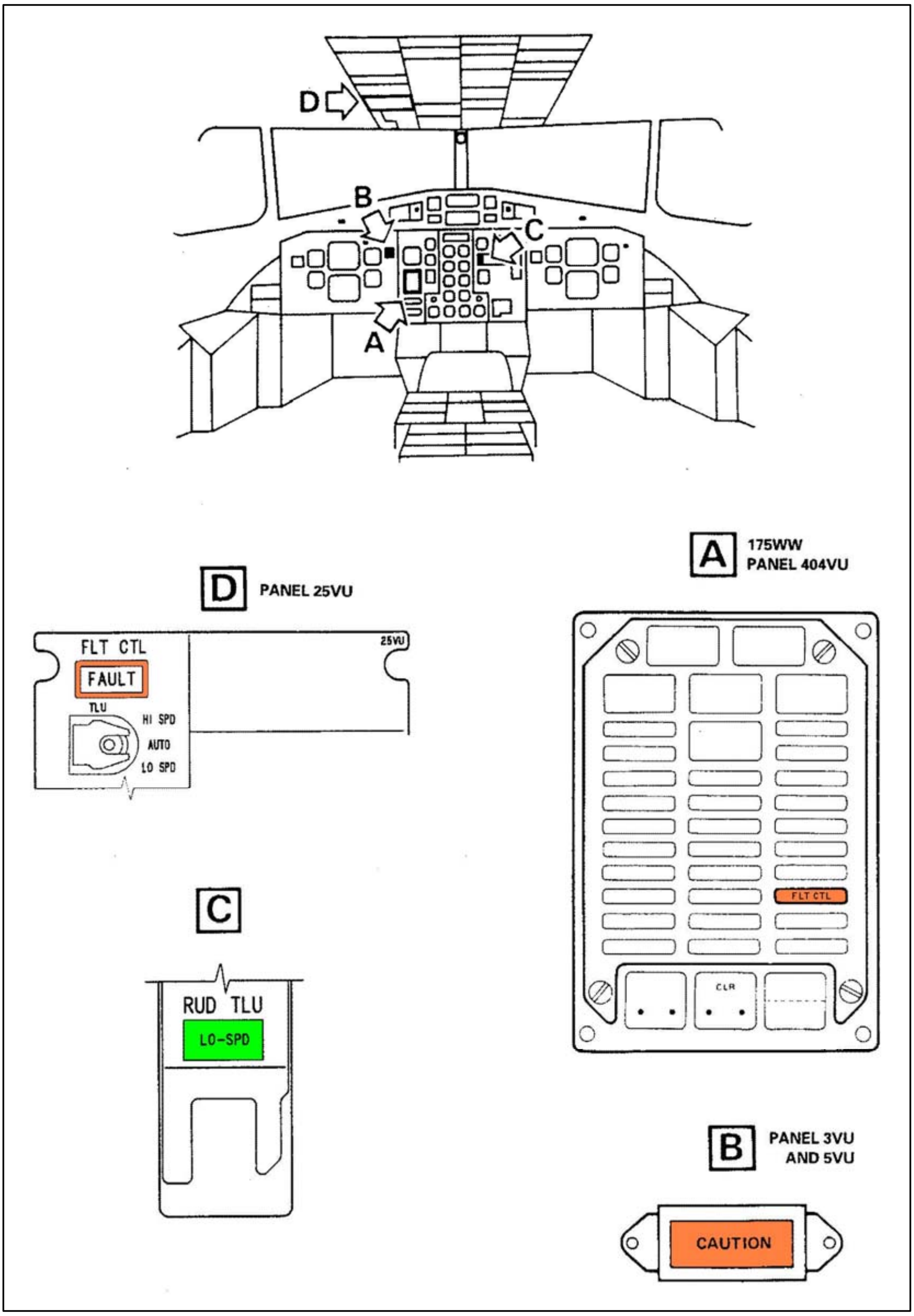

Figure 6. The TLU’s caution lights, switch and displays in the cockpit. (Source: ATR)

In case of a TLU fault there are caution lights, displays and a switch in the cockpit for the purpose of establishing the situation and to switch on the TLU's standby system (Figure 6, The TLU's caution lights, switch and displays in the cockpit). When the TLU's automatic functioning fails, two CAUTION lights [B] illuminates and an aural alarm sounds. In addition, in conjunction with the fault, the FLT CTL (Flight Controls) warning light [A] is illuminated on the crew alerting panel and the FAULT light [D] illuminates in the upper panel next to the TLU switch.

When the automatic functioning of the TLU fails it is possible to manually [D] set the rudder's mechanical travel limiter either to the low speed (LO SPD) mode, which permits full travel, or the high (HI SPD) speed mode, which limits rudder travel to ±4 degrees.

The TLU consists of four main components (Figure 7, The TLU's main components).

1. An electric actuator [A] which moves two separate pushrods [B]. The electric motor operates under predetermined criteria either automatically or manually.

2. Two levers operated by electrically actuated pushrods, attached to rolls [C]. The levers either open, allowing free movement for the rudder's drive shaft, or close, at which time the structurally integrated rolls fall into the V-shaped notches [D] attached to the rudder's drive shaft [E], which mechanically limits rudder travel to ±4 degrees.

3. The coils in the electric actuator [A] operate separately in the automatic mode and the manual mode.

4. Two V-shaped notches [D] attached to the rudder's drive shaft that turn along with the rudder's drive shaft [E].

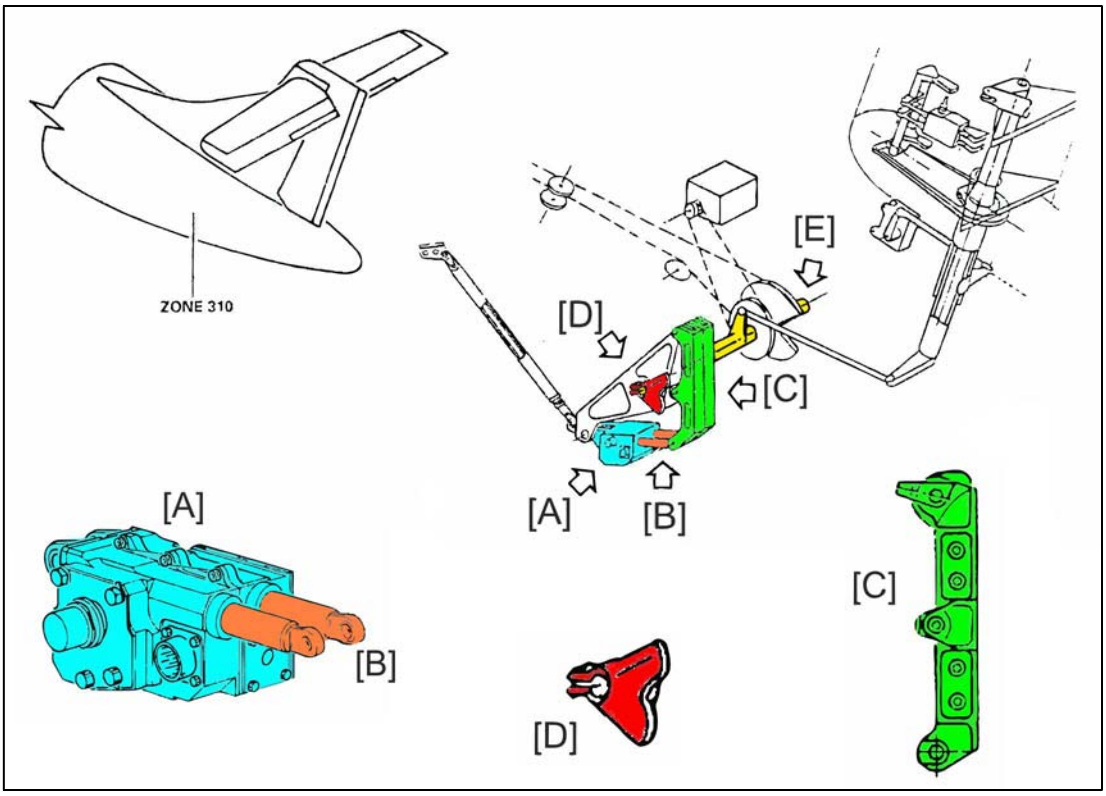

Figure 7. The TLU's main components. (Source: ATR)

When the aircraft accelerates to cruising speed the TLU will function normally if two Air Data Computers (ADC) provide identical information that the calibrated airspeed V_c is greater than 185 KT (342 km/h). At this time the electric motor [A] automatically pulls the two pushrods [B] into a closed position, which also closes the two levers [C] containing the integrated rolls. The rolls then fall into the notches [D] on the rudder's drive shaft [E], which limits rudder travel to ±4 degrees.

When the airspeed decreases the TLU operates normally when at least one ADC says that the airspeed has decreased below 180 KT (333 km/h). At this time the electric actuator moves the two pushrods [B] into the open position, opening the two levers [C]. This releases the notches [D] on the rudder's drive shaft [E], permitting the rudder to travel in its full range of ±28.5 degrees.

1.14 Organisations and management

1.14.1 Manuals and instructions

Airplane Flight Manual (AFM)

The aircraft manufacturer's Airplane Flight Manual (AFM) is an essential element in an aircraft's type certification process. It is within the purview of the European Aviation Safety Agency (EASA) to type-certificate aircraft that operate in Europe. The EASA approves new AFMs per aeroplane type. All flight operation-related documents are based on the content of the AFM which is published by the aircraft manufacturer. AFM-based instructions may include abridged content so long as no ambiguity or risk of misinterpretation ensue from the process of condensing the text. The Finnish Transport Safety Agency manages the manufacturers' AFM-based instructions which are being used by Finnish operators.

FCOM – Flight Crew Operator Manual

The aircraft manufacturer's Flight Crew Operator Manual (FCOM) contains detailed information on aircraft systems, including the procedures related to their operation. ATR, the aircraft manufacturer, has published the FCOM in such a manner that it complements the official AFM. Its purpose is to assist operators in preparing their own Operating Manuals.

Quick Reference Handbook (QRH)

A QRH may be carried on board an aircraft and its content must correspond to the instructions of the approved AFM, aircraft equipment and the flight operations for which the aircraft is certified. The QRH will normally address continually repeated operational procedures or situations requiring immediate attention. The QRH's procedures may include abridged content from the AFM and the OM-B so long as the abridgments result in no ambiguity or risk of misunderstanding.

The QRH can be written in the Finnish language or the language in which the AFM was originally published. In this particular incident the QRH was prepared in the English language. If the AFM does not specifically define the content of the QRH, it must include all required procedures for normal operations, abnormal situations and emergencies.

The QRH and the AFM of the ATR 72-212A state that it is possible to land normally with the TLU set to the HI SPD mode and that this has been demonstrated up to a maximum crosswind of 15 KT. In accordance with the QRH and the AFM, when landing with the TLU in the HI SPD mode one must increase the weight-based, calculated approach speed by 10 KT (V_{APP}+ 10 KT). Therefore, the Landing Distance Required must be multiplied by 1.13 (RWYx1.13).

Operations Manual (OM) Parts A, B C and D

According to the aviation regulatory authority, the Finnish Transport Safety Agency, the Operations Manual shall include the following parts, as applicable:

Part OM-A: The Operations Manual published by the operator contains the principles, instructions and procedures which are required by the safe conduct of flight, independent of any particular aeroplane type. It contains information on keeping the OM-A up-to-date, the operators' organisation and responsibilities, the quality assurance system, crew requirements, safety procedures and, especially, operational procedures and flight rules. Appendix 3 contains an excerpt from Flybe Finland Oy's OM-A as regards a stabilised approach.

Part OM-B: The operator's Airplane Flight Manual contains aeroplane type-specific instructions and procedures required by the safe conduct of flight. It gives the instructions for the aeroplane type being used. Among other things, the instructions include general information, limitations, normal procedures, checklists, emergency procedures, instructions for flight planning, mass and balance calculations, and a description of aeroplane systems. In addition, the OM-B explains how performance requirements are to be met in flight operations.

Part OM-C contains the Route and Aerodrome Instructions which are relevant to the area in which the operator operates.

Part D, the operator's Training Manual, contains the training instructions required by the safe conduct of flight. It includes training and test requirements for the operational personnel that participate in the briefing and/or conduct of flight. The more voluminous the flight operations, the more extensive the training organisation must also be and, hence, the more items the OM-D will cover.

1.14.2 Training

Pilot training in accordance with Flybe Finland Oy's Type Rating Training Organization (TRTO) training manual

Pilots are trained on aircraft systems on type rating courses which are organised in accordance with the instructions given in the Type Rating Training Organization (TRTO) training manual. The flight crew of this flight had received their ATR 72 type training at Finnair's training centre in Vantaa. Finncomm / Flybe Finland Oy have organised their type course-related classroom instruction at their own premises in accordance with their OM regulations.

According to the TRTO the type rating course consists of classroom lessons, independent Computer Based Training (CBT) lessons and training flights flown on the Full Flight Simulator. As per the TRTO classroom lessons are the main instructing method for systems training and theoretical instruction. CBT is used in support of classroom learning.

TLU training through Computer Based Training (CBT)

CBT training is independent, interactive computer based training in which aircraft systems are methodically studied through electronic lessons and animations.

In addition to a simplified schematic of the TLU's structure and functioning, CBT training states that the TLU, installed in the rear quadrant of the aircraft, reduces rudder deflections at high airspeeds. TLU faults are discussed in a little more detail in CBT training by presenting, among other things, the TLU-associated switches and displays on the flight deck. There is much dissimilarity between the generic QRH's procedures and verbiage as regards the CBT's section that addresses a TLU fault and Flybe Finland Oy's OM-B, which is used by the pilots (Appendix 2).

TLU training in the flight simulator

Pilots are trained on aircraft systems as well as aeroplane type-specific action and procedures in the flight simulator. In accordance with the training curriculum the TLU system is introduced on one simulator flight when turns are flown with the TLU set to the HI SPD mode, with limited rudder travel.

Following successfully passed theoretical tests and simulator flights pilots begin to fly on an actual aeroplane, using documents such as the FCOM, AFM, OM-B and the QRH that contain instructions and limitations for controlling the aeroplane. The operational procedures provided by these documents regarding a TLU fault are presented in appendix 2. In addition to these procedures, and a short system description, the limitations caused by a TLU fault are not presented in the manuals' section 'Limitations'.

Cabin crew training – the Cabin Attendant Manual (CAM)

The Company's CAM instructions make no mention of how long the cabin crew should remain seated after the landing. According to interviews the cabin crew's emergency training focuses on the completion of action that follows prepared emergency landings and water landings (ditching). Less training is provided for sudden and non-standard situations. In abnormal situations the cabin crew must for the most part wait for the captain's instructions. Conditions that constitute an exception to this rule include a situation in which the flight crew can be assumed to be incapacitated, a fire in the cabin or an emergency water landing. According to the OM-B it is prohibited to unbuckle the seat belt and leave one's seat before the aircraft has come to a full stop.

1.14.3 Communication with Company personnel

When it comes to new and abnormal situations Flybe Finland Oy inform their personnel with the FOCS system. In order to receive information, on their work schedules for example, the staff must sign into the FOCS system and open the published Alert Bulletins. In addition to these bulletins flight crews have been informed of the TLU's characteristics during extended simulator training and the ATR fleet's annual refresher classroom training.

1.15 Useful or effective investigation techniques

The investigation group visited the ATR full flight simulator so as to validate the TLU's effect on the controllability of the aeroplane. For this purpose static and dynamic directional stability tests (CS 25.149) were conducted with the TLU set to the HI SPD mode. An operational test involved a simulator demonstration of the effect of the TLU's HI SPD mode on the controllability of the aeroplane in a normal crosswind landing when the crosswind component was 15 KT. Another operational test consisted of a simulated engine failure during a go-around with the aeroplane in the approach configuration and the TLU set to the HI SPD mode. Normally, faults do not warrant these kinds of tests, but since the flight crew got the impression from the QRH that, within certain constraints, the aircraft would function normally, the investigation group decided to investigate the behaviour of the aircraft with its rudder locked. The QRH did not provide any warning pertaining to limited directional control of the aircraft when its TLU is set to the HI SPD mode. Due to inherent risks, no engine failure conditions with the TLU set to the HI SPD mode during go-arounds have been flown on test flights.

On the basis of ATR 72 flight simulator tests the investigation group noted that the controllability of the ATR 72 simulator did not meet the EASA's Certification Specifications CS25.143-25.149 when the TLU was in the HI SPD mode in conjunction with a crosswind landing or an engine failure during a go-around. On the basis of the results of simulator flight tests the manufacturer of the ATR aircraft was asked how they had demonstrated a normal landing with the TLU in the HI SPD mode when the limits V_{APP}+ 10 KT, RWYx1.13 and max crosswind component of 15 KT are met, and what the VMCA is with the TLU in the HI SPD mode. In addition, the investigation group requested that the results of the flight tests be made available to them.

The investigation group did not receive the flight test results they requested. However, the aircraft manufacturer invited the investigation group to study the results of the test flight regime at the manufacturing plant in Tolouse. The investigation group was unable to visit the installation. The aircraft manufacturer stated that the ATR 72 models 101, 201, 102 and 202 were flight-tested in order to demonstrate compliance to regulation JAR 25.671c. Flying with the TLU in the HI SPD mode was included in these flight tests. ATR said that during these flight tests two approaches and landings with a 15 KT crosswind component were flown with the French flight test centre CEV [Centre d'Essais en Vol]. The results of these approaches and landings ATR considers to be compliant with JAR 25.671c requirements.

According to the manufacturer of the ATR aircraft, for ATR 72 models 210, 211 and 212 certification, compliance with requirements was demonstrated through a comparative analysis of straight steady sideslip flight test, the results of which were compared with the model ATR 72-200. This analysis was validated by the French CEV.

For ATR 72-212A certification, the French Directorate General of Civil Aviation (DGAC) considered the flight test results provided for the certification of previously certified ATR 72 models, regarding landing in a 15 KT crosswind with the TLU in the HI SPD mode, as sufficient.

During the certification of the ATR 72-212A aircraft, VMCA values were not demonstrated with the TLU in the HI SPD mode. The demonstration of the CS25 VMCA regarding this aircraft type is published in the EASA's Certification Specifications CS25.149. According to the aircraft manufacturer the combination of engine failure and TLU failure is extremely improbable. According to ATR the probability of such an occurrence is less than 10^{-9} per flight hour.

The Bow Tie analysis model was used in assessing the flight crew's action during the approach which resulted in the incident and in assessing the role of Human Factors (HF) to the onset of the incident.

2 ANALYSIS

2.1 Flight crew action

The TLU fault which illuminated the Flight Controls alert in the warning panel appeared during the intermediate approach segment of the instrument approach with there being approximately 6 NM (11 km) to the threshold of the landing runway. The flight crew decided to continue the approach and identify the fault from the QRH. Simultaneously, the pilots had to complete the procedures required by the normal landing routine. When the aircraft passed 1000 ft (300 m) above threshold elevation they were still in the process of establishing the fault. This being the case, the approach was not stabilised. As per the OM-A (appendix 3) in a situation such as this they should have initiated a missed approach procedure from 1000 ft (300 m) in order to clarify the situation. When the aircraft passed 500 ft (150 m) above threshold elevation the approach was still not stabilised, and the go-around should have been initiated at this altitude at the very latest.

The haste caused by the decision to continue the approach allowed too little time for the flight crew to sufficiently explore the difficult-to-read QRH. Since the haste contributed to the situation and the QRH did not make any mention as regards switching on the TLU's standby system, the flight crew left the TLU MANUAL switch set to the AUTO mode. As a result the TLU was in the HI SPD mode during the landing, which limited rudder travel to ±4 degrees.

Instead of finding instructions in the QRH for switching on the TLU's standby system the flight crew found the instructions for a normal landing with the TLU in the HI SPD mode. The captain, who was the pilot flying, was unaware of limited rudder travel before the touchdown because of using the automatic pilot all the way to the minimum decision altitude. The flight crew were not sufficiently informed of the limited rudder travel by only reading the QRH.

The flight crew did not inform the cabin crew of the TLU fault or any potential problems upon landing. Having noticed that the landing was not normal the CC unbuckled seat belt, left the jump seat behind the cabin and went into the passenger cabin so as to find out what was going on. When an aircraft veers off the runway it is likely that the landing roll will end in an abrupt stop or change of direction, in which case people moving about the aisle run a great risk of injury.

2.2 Flight Data Acquisition Unit analysis

Judging by the data recorded by the Flight Data Acquisition Unit (FDAU), and the tests and research, there was remarkable asymmetry between the engines of this individual aeroplane as regards propeller blade angle transition to the BETA zone when engine power is reduced to idle As regards turboprop aircraft, depending on the individual aircraft and situation, it is perfectly normal for the aircraft to slightly swing to the right or left when engine power is being reduced to idle at landing. In a normal situation this directional oscillation can be countered with aerodynamic controls, i.e. the rudder.

The FDAU data indicate that the flare after the first contact with the ground was prolonged as the weight on wheels switch is only activated after 10 seconds from the first contact with the ground. The captain attempted to correct the directional oscillation with nose wheel steering, this, however, did not achieve the desired outcome. The ‘floating in ground effect’ and the prolonged flare prevented the operation of nose wheel steering because the use of the ATR’s nose wheel steering requires the activation of the weight-on-wheels switch for all of the landing gear.

2.3 Instructions and regulations

The OM-B’s section ’Limitations’ does not provide any limitations for flying with a TLU fault. The TLU fault, and it remaining in the HI SPD mode impacts, among other things, the maximum permissible crosswind landing component, the approach speed (V_{APP}) to be used and, due to the limited rudder travel, the minimum airspeed at which a twin engine aircraft is controllable with one engine inoperative (V_{APP}). The crosswind limitation caused by the TLU fault and the non-standard approach speed are presented, among other things, in the QRH’s section ‘TLU FAULT.

While a rudder which is travel-limited close to its centre position substantially impacts the V_{MCA} the operator’s instruction material which was in use makes no mention of this. In a go-around situation with the critical engine inoperative it is normal to use the so-called V_{GA} speed which is the speed for the best rate of climb. Judging by simulator tests it can be estimated that when the TLU limits rudder travel to ±4 degrees airspeed cannot be reduced to the normal V_{GA} speed in a single-engine missed approach procedure because control of the aircraft can already be lost at airspeeds higher than this.

As per the instructions related to a TLU fault the landing was flown at an airspeed which was 10 KT higher than normal. The higher than normal threshold speed and the half-finished engine power reduction prolonged the floating in ground effect. Therefore, nose wheel steering was not available to the captain for directional control right after the landing.

The captain always bears overall responsibility for the entire conduct of flight. Company regulations for flight crews (OM-A and OM-B) point out that the captain must actively take charge of abnormal situations. This also applies to communication between the flight crew and the cabin crew. It is the responsibility of the captain to inform the cabin crew of any potentially abnormal occurrences during the landing. Being informed of potential abnormalities will help the cabin crew to prepare for an eventual emergency and, for instance, mentally summon up the instructions and procedures for a possible cabin evacuation. Such preparations promote adaptation to the situation and shorten reaction time.

2.4 Conditions

Helsinki-Vantaa approach cleared the aircraft for a visual landing for RWY 22L well before the TLU fault appeared. The weather was good and the aeroplane was flying on automatic pilot. According to the flight crew's interviews the good conditions contributed to the decision to continue the approach after the TLU fault appeared.

Despite the fact that Helsinki-Vantaa RWY 22L is 60 m wide, the aircraft veered off the runway at approximately 550 m from the point where the tyres made first contact with the runway. The aircraft veered off the runway to the extent that both of its main landing gears ended up on the grassy runway shoulder strip. The width of the runway and the fact that the aircraft veered off in an intersecting area of the runway and taxiway mitigated the damage to the aircraft. The runway edge lights and other runway fixtures were positioned in such places that the aircraft did not hit them at any stage of veering off the runway or returning to it.

2.4.1 Quick Reference Handbook (QRH) instructions for a TLU fault

According to the Quick Reference Handbook of the ATR 72-212A it is possible to land normally with the TLU in the HI SPD mode, and that this has been demonstrated up to a maximum crosswind of 15 KT. When the incident occurred the prevailing wind was 230°/04 KT, so in effect it played no role in the occurrence. The asymmetrical operation of the engines caused the 14.5° directional oscillation. Such a divergence between the track and the heading at the airspeed of 103 KT (225 km/h), converted to a crosswind component, would amount to approximately 25 KT. This had a critical impact on the serious incident.

2.4.2 Brake system

Pressure variation was discovered in the LH brakes' antiskid system during maintenance. The fault in the brake system had no bearing on the onset of the incident or on the aircraft veering off the runway. When the direction of the aircraft suddenly changed by 14.5° the weight on wheels switch was not activated due to the prolonged flare when the aircraft floated in ground effect.

As the aircraft was, for all practical purposes, still in the air the operation, or non-operation, of the brake system has no bearing on the changes in the aircraft's heading. Moreover, skid marks left by the LH and RH landing gear were found on the runway, which testify to the fact that the fault discovered after the occurrence did not affect the course of events, at least by increasing the swing to the right [figures 1 and 2].

2.5 Flight tests flown in an ATR 72 flight simulator

Judging by the tests conducted by the investigation group it can be said that the ATR 72 simulator's controllability, when a crosswind landing and a simulated engine failure in a go-around were flown with the TLU set to the HI SPD mode, did not meet the EASA's type certification requirement CS25.143-25.149. Aircraft controllability test flights are not normally flown in circumstances where faults limit controllability. In this instance, however, the flight characteristics were measured despite the fault because neither the flight crew nor FlyBe's ATR group, due to insufficient instructions, had sufficient awareness of the effect of the TLU fault on the controllability of the aircraft. The instructions published for such an instance led the crew to believe that the aircraft would behave normally with the TLU in the HI SPD mode so long as the conditions given in the QRH were met. The investigation group does not know how precisely the ATR 72 flight simulator's flight characteristics correspond to the ones of the actual aircraft during a TLU failure.

2.6 Human factors (HF)

2.6.1 The Bow Tie analysis model

A Bow Tie analysis-based model was prepared of the occurrence in order to analyse human factors (Figure 8). The Bow Tie model is used in risk assessment, risk management planning and in risk communication. The Bow Tie analysis illustrates risks associated to an event by presenting them as an interrelationship of hazards, top events, threats and consequences. In addition to these, the model includes preventive and recovery controls that impact the event, and escalation factors which may negate the functioning of preventive controls.

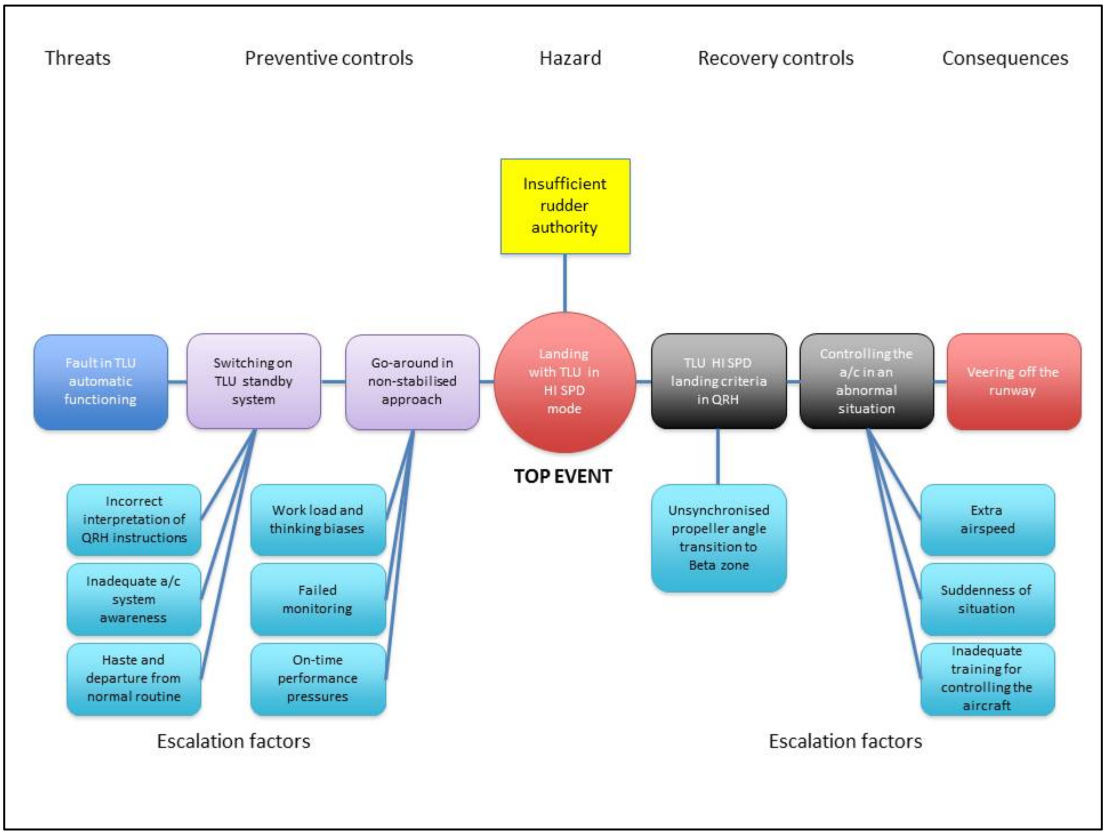

Figure 8. A Bow Tie analysis-based model of this occurrence.

2.6.2 Hazard, Top Event, Threats and Consequences

A hazard is a contributing factor which, uncontrolled, will cause harm. A hazard can be, for example, a material or source of energy, a condition or an object. The missing rudder authority is the hazard in this particular diagram, which at worst can result in the loss of control of the aircraft. It is customary to try to mitigate this hazard by appropriately operating and maintaining the aeroplane.

The threats inherent in the system facilitate the realisation of the hazard. In this diagram the fault in the TLU's automatic functioning was the threat, through which the hazard was able to influence the top event. A top event is a seminal moment which turns the course of events, resulting in an unavoidable incident or accident. A top event unleashes the hitherto-contained hazard. The top event in this diagram is the landing with the TLU in the HI SPD mode.

The chain of events that begins at the top event culminates in consequences. They express the end result of an accident. In this diagram the aeroplane, as a result of the chain of events triggered by the top event, veered off the runway.

2.6.3 Preventive controls

Two preventive controls were in place for this occurrence: switching on the TLU's standby system as per the QRH's instructions and initiating a go-around when the OM-A's criteria for a stabilised approach were not being met. Either preventive control, if employed, could have prevented the situation from escalating to a top event. The following is an analysis of why the preventive controls did not work.

Switching on the TLU's standby system

The QRH's instructions are written in such a manner that they do not explicitly denote whether they refer to setting the TLU's standby system to the LO SPD position or to only checking the status of the mode from the indication light. In the stressful end stage of the flight the pilots do not have sufficient mental resources to contemplate the meaning of ambiguous instructions. Rather, they act upon assumptions which they have developed over time and from previous experience.

During a normal approach, as per the Final Check, the TLU's mode is checked from the TU LO SPD light on the front panel. This is done on every flight. In other words this happens several times during the pilot's work shift and, hence, it is a thoroughly ingrained procedure. On the other hand, using the TLU's standby system is an extremely rare occurrence in day-to-day flight operations, nor is it regularly trained.

Inadequate system awareness may further increase the probability of misinterpreting the instructions due to old habits. If the flight crew do not have proper system knowledge they are ill-equipped to recognise whether a fault is properly rectified by following the instructions. The simultaneously completed landing checks and fault identification measures created extra haste for the flight crew. Furthermore, it raised their stress levels and resulted in the abandonment of the normal checklist completion routine. Both the haste and the departure from normal routine may have resulted in a cursory reading of the instructions. Moreover, it may have led the flight crew to believe that the fault had been corrected and that the approach could be continued in a normal fashion.

A go-around in a non-stabilised situation

The final approach and landing are the most mentally stressful phases of flight for a flight crew. Having to identify a fault in aircraft systems in these phases may push the information processing capacity of the flight crew to the limit. Establishing a total picture of how dangerous the situation is, including its consequences, requires a lot of extra information processing capacity, which is a limited commodity for pilots in stressful phases of a flight. A result of the increased work load is that their action may become reactive, in other words responses to oncoming events are completed as they appear. The situation can no longer be monitored comprehensively, nor is it possible to anticipate or plan for future events. In such a decision-making situation pilots easily resort to different rules of thumb, created through previous experience, and subject themselves to thinking biases. Under high work load the flight crew do not have the mental resources to actively challenge any misconceptions generated by thinking biases.

People are usually reluctant to abort an activity to which they have invested lots of resources towards its completion. This phenomenon is known as Plan Continuation Bias. The closer the completion of the task is, the more unwillingly the action is abandoned. The final approach and landing serve as good examples of such a situation. The closer the end of the flight, the more difficult it becomes to alter the original plan.

Plan Continuation Bias has contributed to many accidents in which the approach was continued even when the criteria for a stabilised approach were not being met. The importance of on-time performance in business aviation, and the many associated penalties from being late, partly explain why it is so difficult to deviate from the original plan. There are, however, also some other factors that play a role in human decision-making which serve to strengthen the Plan Continuation Bias, such as the Confirmation Bias and Availability Heuristic.

As a result of Confirmation Bias any opinion or plan will be strengthened by favouring information that supports it and, respectively, by rejecting any information that calls the plan into question. Therefore, the pilot gives preference to the reasons that support the decision to continue with the plan, such as good weather, the apparently stable flight condition and the significance of meeting the QRH’s criteria for a landing.

Factors that support aborting the approach, such as general confusion or haste, or if the completion of checklists is still in progress, do not receive their due attention in the decision-making process. The stress which is felt in the situation also easily results in failing to seek information that challenges the prevailing view.

Availability Heuristic refers to the significance of previous positive experience when considering the end result of the situation at hand. Possible previously successful non-stabilised approaches may have contributed to the belief that the present situation too would be resolved without problems. After a successful landing the flight crew gets no feedback whatsoever as regards how much they actually compromised flight safety in the situation.

When this happens time and again, the OM-A based criteria for a stabilised approach may begin to seem unduly conservative and it becomes easier and easier to disregard them. The importance of the criteria for a stabilised approach is also diminished if, for example, the captain is permitted to deviate from them as required. This may give the message that it is possible to achieve something even more important than the safe conduct of flight by acting against the criteria.

In accordance with the principle of Crew Resource Management one pilot flies (Pilot Flying, PF) the aeroplane and the other pilot (Pilot Not Flying, PNF) monitors his action. The monitoring pilot is to intervene in any observed errors or incidents as provided for by the OM-A. This includes a call-out for a go-around if a non-stabilised approach continues to 500 ft above the threshold altitude. The very same thinking biases which influenced the captain's situation assessment probably affected the co-pilot, acting as PNF, to such an extent that the co-pilot did not challenge the captain's decision to continue the approach. Moreover, the co-pilot's monitoring may have failed because of the combined stress of the landing and the action required in establishing the fault.

It is also possible that the captain's resolute action to continue the approach increased the co-pilots confidence in the assumption that the captain was in control of the situation. In hierarchical organisations it is typical that members at lower tiers in the hierarchy find it difficult to question the action of their superiors. The 'cockpit authority gradient' may impact action, even if the persons involved were unaware of its presence.

2.6.4 Recovery controls

Two recovery controls were in place as protection from the consequences of the missing rudder authority during the landing: the QRH-defined criteria for landing with the TLU in the HI SPD mode and controlling the aircraft by taking into consideration the abnormal situation's effects on the controllability of the aeroplane. While the purpose of these controls is to mitigate the consequences of a top event, in this case they were unable to prevent the aeroplane from veering off the runway. The following is an assessment of the functioning of the recovery controls.

The QRH's criteria for a landing with the TLU in a HI SPD mode

The Quick Reference Handbook permits a landing with the TLU in the HI SPD mode so long as 10 KT be added to the approach speed (V_{APP}), the Landing Distance Required be 1.13 times the normal and the maximum crosswind component not exceed 15 KT. The manufacturer says that when these criteria are met the aeroplane is controllable during the approach and landing even without rudder control. The pilots flew the approach at the required higher airspeed and assumed that the other QRH criteria were met as well. Nonetheless, they were unaware of the aeroplane's limited directional controllability and could not anticipate the asymmetrical propeller blade angle transition to the BETA zone, or the subsequent sudden change of direction when they reduced engine power to ground idle. When it comes to this fault the QRH does not include any mention of the rudder's mechanically limited travel or reduced directional controllability when the TLU cannot be manually set to the LO SPD mode. When the aeroplane suddenly swung 14.5° to the right the pilots, lacking rudder authority, were unable to keep it on the runway.

Controlling the aeroplane in an abnormal situation

While the captain was familiar with the tendency of the aeroplane to change direction in conjunction with reducing engine power to idle, the captain did not know the reason for this. The captain was also surprised about the fact that the rudder pedals did not move in the usual manner when he attempted to correct the direction after the oscillation. The insufficient rudder authority came out of the blue to the captain, and the captain was unprepared for steering the aeroplane in accordance with the requirements of the abnormal situation.

Had the captain been aware of the insufficient rudder authority and the consequences of the asymmetrical propeller blade angle transition to the BETA zone when landing the aeroplane, the captain might have been able to prepare for the changes in direction and reduce power more gradually. Nevertheless, the captain managed to control the aeroplane with nose wheel steering, which can be seen to have mitigated the consequences of veering off the runway. Still, the extra approach speed required by the QRH degraded the effect of nose wheel steering in the early stage of the landing roll.

The QRH's criteria for a landing with the TLU in the HI SPD mode are apparently intended to act as recovery controls, in other words they lessen the effects of the missing rudder authority on the behaviour of the aeroplane. This, however, is not pointed out in the instructions. Rather, they easily give the impression that a landing can be made in an almost normal fashion when the criteria are met. The QRH's TLU FAULT section makes no mention of the fact that, despite the completion of procedures, the controllability of the aeroplane is critically degraded and that pilots should prepare for a potential loss of control at landing. If this fault is not sufficiently addressed in pilot training, it is highly likely that pilots are completely unaware of the potential danger when they come to a landing.

2.7 Training

As per the TRTO, approved by the regulatory authority, classroom lessons are the main instruction method for systems training and theoretical instruction for pilots. CBT is used to support classroom learning. During the investigation it became evident that CBT, in effect, is Flybe Finland Oy's main instruction method, which classroom lessons are intended to support. If CBT is used as the most important instruction method, the content of CBT lessons should be approved by the authority as the primary means of instruction. *(TRTO: "Main instructing method is classroom lessons. Group workshops (sic), case studies, excursions and exercises are highly recommended. CBT is used to support classroom learning".)*

Judging from discussions and interviews it appears that the flight crews' system awareness is not at an acceptable level with regard to the TLU system. It is the opinion of the investigation group that Flybe's flight crews did not possess sufficient knowledge or awareness of the TLU fault's consequences upon the controllability of the aircraft. Moreover, flight crews have suffered from an evident lack of TLU system awareness as well as its special characteristics when the standby system is switched on.

Computer Based Training (CBT)

In addition to a simplified schematic of the TLU's structure and operation, the CBT states that the TLU, installed in the rear quadrant of the aircraft, reduces rudder deflections at high airspeeds. In view of normal operations or faults there is no mention that if the TLU fails and remains stuck in the HI SPD mode, the TLU limits rudder travel to ±4 degrees from the normal ±28.5 degrees. No training materials or instructions point out the effect of the TLU HI SPD mode on the controllability of the aeroplane.

The CBT addresses TLU faults in slightly more detail by presenting, among other things, the TLU's switches and displays on the flight deck. There is dissimilarity between the generic QRH's procedures and verbiage in the CBT's section that addresses a TLU fault and, among other things, the QRH used by pilots and Flybe Finland Oy's OM-B (Appendix 2). It took 60 seconds to locate the TLU fault in the QRH. Following this, it took 52 seconds to read the five associated checks. The elapsed one minute and 52 seconds for locating the correct section and completing the required checks is a long time.

From the standpoint of learning, it would be beneficial if the training materials were as identical as possible with the instructions used in flight operations. Standardisation would ease the tasks of the pilots and improve their performance when under pressure.

Pilots are trained on aircraft systems and aeroplane type-specific action and procedures on simulator flights. In the training curriculum the TLU system is familiarised once on a simulator flight when turns are flown with the TLU in the HI SPD mode with limited rudder travel.

Following the successfully completed theoretical tests and simulator flights pilots begin to fly on real aeroplanes, using published documents that contain instructions and limitations for controlling the aeroplane, such as the OM-B and the QRH. The procedures provided by the QRH for a TLU fault are presented in appendix 2. In addition to these procedures, and a short system description, the limitations caused by a TLU fault are not presented in the manuals' section 'Limitations'.

3 CONCLUSIONS

3.1 Findings

1. The aircraft's airworthiness certificate and the certificate of registration were valid.
2. The flight crew had valid licences and the required ratings.
3. The flight was a scheduled flight from Tampere-Pirkkala airport to Helsinki-Vantaa airport.
4. The takeoff and the cruise phase were uneventful.
5. The meteorological conditions at the aerodrome of destination were good.
6. Upon approaching Helsinki-Vantaa airport the flight crew received a Flight Controls alert.
7. The Flight Controls alert was caused by a fault in the rudder’s Travel Limitation Unit’s automatic functioning.
8. Despite the Flight Controls alert the flight crew continued the approach.
9. The captain flew the aircraft while the co-pilot was searching for instructions to resolve the TLU fault.
10. The approach was continued even though the criteria for a stabilised approach were not met before passing 1000 ft (300 m) above threshold elevation.
11. The flight crew did not set the TLU’s standby system to the LO SPD so as to correspond with the approach speed.
12. It would have been possible to bypass the TLU fault by using the TLU MANUAL switch. However, this did not become evident for the flight crew from the QRH’s instructions.
13. The flight crew did not initiate a missed approach procedure at 500 ft (150 m) above threshold elevation even though, as per regulations, in a non-stabilised situation they should have done so.
14. From the QRH’s instructions the flight crew got the impression that, despite the TLU fault, they could land normally so long as certain criteria were being met.
15. When the flight condition and the other conditions were met at 250 ft (75 m) above threshold elevation the flight crew decided to land normally.

16. The captain changed over to manual control at the minimum descent height prescribed for instrument approach.

17. The captain reduced engine power to below flight idle immediately after the first contact with the ground.

18. Engine power remained between flight idle and ground idle while the aircraft veered off the runway and returned to the runway.

19. The asymmetrical propeller blade angle transition to the BETA zone in conjunction with reducing engine power to idle caused the aircraft to suddenly swing 14.5 degrees to the right.

20. Rudder travel was limited at landing because the TLU was in the HI SPD mode.

21. Because of the limited rudder travel the flight crew had insufficient rudder authority for correcting the strong directional oscillation.

22. The aircraft veered off the runway.

23. The captain, using nose wheel steering, managed to steer the aircraft back onto the runway.

24. Engine power was reduced to ground idle during taxiing once the aircraft had returned to the runway.

25. The aircraft taxied normally to its stand.

26. The serious incident did not cause any injuries to persons and there was only little damage to the aircraft.

27. The aircrew held the required joint defusing session regarding the occurrence.

28. Pursuant to the ICAO Annex 13 severity classification this occurrence was a serious incident.

3.2 Probable cause and contributing factors

Probable cause and consequence

The serious incident was caused by the mechanically centred rudder's insufficient authority for directional control, which resulted in the aircraft veering off the runway.

Contributing factors

The rudder's Travel Limitation Unit (TLU) electric actuator broke and the TLU was left in the high speed (HI SPD) mode for the approach and landing, jamming the rudder.

Due to inadequate system awareness and the fact that the QRH did not clearly enough provide instructions for using the TLU's standby system, the flight crew did not switch on the TLU's standby system.

The right engine's propeller blade angles transitioned sooner into the BETA zone following the reduction of engine power at landing, which resulted in a large directional oscillation.

4 SAFETY RECOMMENDATIONS

4.1 Action already implemented

Theoretical instruction

During the time of the investigation Flybe Finland Oy have increased and enhanced their classroom instruction as regards the ATR fleet's TLU system.

Simulator training

During the time of the investigation Flybe Finland Oy increased and enhanced their simulator training as regards the ATR fleet's TLU system.

Other action

During the time of the investigation Flybe Finland Oy organised TLU-related training during the ATR fleet's annual refresher classroom training, and on 20 August 2012 they published Safety Alert Bulletin SAB No. 2/2012 in reference to the TLU fault experienced on flight FCM992T, i.e. the occurrence flight of this investigation.

4.2 Safety recommendations

1. When it comes to a TLU fault neither the Quick Reference Handbook nor the FCOM include an instruction for the flight crew to switch on the TLU's standby system by manually setting the TLU to the appropriate mode. Such an instruction is given for an ADC fault and a DUAL GEN fault: "TLU……..MAN MODE LO SPD".

   Safety recommendation 1 (checklists): Safety Investigation Authority, Finland recommends that the manufacturer of the ATR aircraft include instructions for the manual selection of the TLU's standby system in the FCOM and in other relevant instructions.

2. As regards a TLU fault the FCOM states the following: "DISREGARD TLU FAULT ALERT". This can only be done when the green TLU light turns on after the manual switch has been set to the LO SPD mode. When manually controlling the TLU it takes 33 ± 5 seconds for the mode to change and the indicator light to turn on.

   Safety recommendation 2 (checklists): Safety Investigation Authority, Finland recommends that the manufacturer of the ATR aircraft include in the FCOM the length of time it takes for the TLU's standby system to change from the HI SPD mode to the LO SPD mode.

3. On page 56, Section 2 of the ATR 42/72' OM-B (rev. 12/10.5.2011) it is explained what the terms WARNING, CAUTION or Note mean when it comes to the procedure, technique or other matters relevant to the situation at hand. Cautions are used in view of situations which can result in damage to the aircraft if the procedure or instruction is not carefully followed. .

   Safety recommendation 3 (checklists): Safety Investigation Authority, Finland recommends that the manufacturer of the ATR aircraft include in the FCOM and other relevant instructions a TLU FAULT warning [CAUTION] of limited rudder travel and of the considerably reduced directional controllability during the approach and landing when the TLU system is in the HI SPD mode.

4. The flight documents used by the operator are based on the FCOM published by the aircraft manufacturer. Flybe Finland Oy's ATR fleet-specific instructions are superficial as regards the TLU system. The descriptions of normal system operations and the standby system are inadequate, and the limitations caused by a fault are not satisfactorily explained.

   Safety recommendation 4 (documentation/literature): Safety Investigation Authority, Finland recommends that the manufacturer of the ATR aircraft include in the FCOM further information on the TLU system including the limitations on the controllability of the aircraft caused by its malfunctioning.

4.3 Other observations and proposals

The flight crew did not inform the air traffic controller about the limited controllability. Aircraft checklists should include a note that requires the reporting of an emergency when a fault, malfunction or limited functioning calls for the air traffic controller to sound a full emergency.

Because of flying the instrument approach all the way down to the minimum descent height with the automatic pilot the captain did not get any appreciation of the aeroplane's limited controllability before the flair. When the aeroplane's controllability is degraded the approach should not be flown with the automatic pilot to the minimum descent height.

Checklists in the instruction materials of the type rating course differ in structure and appearance from those used in flight operations. If the checklists in instruction materials and flight operations were standardised it would make it easier for the pilots to read them and to comprehend their instructions in stressful situations. Checklists that are used for training purposes should be identical with those used in flight operations.

The Company's CAM instructions contain no mention of how long the cabin crew should remain seated after the landing. According to the OM-B it is prohibited to unbuckle the seat belt and leave one's seat before the aircraft has come to a full stop. Training and instructions should highlight the fact that it is only safe to move about in the cabin after the aircraft has been parked at the stand.

Helsinki 13.10.2013

Ismo Aaltonen

Timo Heikkilä　　　　　Jukka Harajärvi

AIR TRAFFIC CONTROL INSTRUCTIONS FOR A FULL EMERGENCY ALERT

Date:
16.01.2012

RESCUE PLAN

For Air Traffic Control use

2.1 FULL EMERGENCY TWR/APP

a) An aircraft has been cleared to land and fails to land within three minutes of the estimated time of landing and there is no visual or radar contact and no communication has been re-established with the aircraft

b) The operating efficiency of the aircraft has been impaired because of:

- In-flight malfunction or failure of engine, landing gear, hydraulic system or pressurisation system; in-flight fire; aircraft low on fuel
- VFR – the aircraft has entered a cloud
- Other ____

c) The meteorological conditions are below the minima of the pilot/crew and the aircraft must land

d) Runway conditions require closing the runway but the aircraft must land

e) Emergency beacon signal received but its origin is unknown

f) An aircraft is known to be the subject of unlawful interference (Code 7500)

Radio call/Registration/Serial number		Type
Number of persons on board	Owner/Operator	
Weapon system/Ejection seat/ Dangerous goods carried as cargo		
Last point of departure	Time	
Last point of intended landing	Time	
Route		
Last position report	Time	
Altitude	Airspeed	Maximum endurance
Area designated for SAR/Danger area		
Meteorological conditions		

Colour and distinctive marks of aircraft:

☐ Propeller aeroplane	☐ Single-engine	☐ High wing
☐ Jet aeroplane	☐ Twin-engine	☐ Nose wheel
☐ Sailplane	☐ Three-engine	☐ Tailwheel
☐ Amphibious aircraft	☐ Four-engine	☐ Pontoons
☐ Helicopter	☐ Low wing	☐ Skis

Colour of fuselage	Colour of wings
ELBA/Visual distress signals/Rescue equipment	

Reported by________________________Telephone_______________Date_________/20_____at________UTC

Appendix 2

The differences between a generic QRH used in CBT and the one used in flight

Generic QRH CBT

TLU FAULT

- If both ADC are lost
  - IAS above 185 kt
    TLU .... HIGH SPEED
  - IAS below 185 kt
    TLU .... LOW SPEED

DISREGARD TLU FAULT ALERT

- If at least one ADC operates
  - IAS above 185 kt
    TLU .... HIGH SPEED
    - If TLU FAULT alarm persists
      MAX SPEED .... 180 kt
  - IAS below 185 kt
    MAX SPEED .... 180 kt
    TLU .... LOW SPEED

TLU FAULT

- If TLU green light is not lit
  VAPP .... INC by 10 kt
  Landing distance flaps 30 .... Multiply by 1.13
  LAND AT AIRPORT WITH MINIMUM CROSSWIND

NOTE : Maximum demonstrated cross wind on dry runway with TLU in high speed position 15 kt.

QRH used in flight operations

TLU FAULT

- If ADC 1 + 2 are lost
  - If IAS above 185 kt
    TLU .... HI SPD
  - If IAS below 185 kt
    TLU .... LO SPD
  DISREGARD TLU FAULT ALERT
- If at least one ADC operates
  - If IAS above 185 kt
    TLU .... HI SPD
    - If TLU FAULT alarm persists
      SPEED .... 180 KT MAX
      TLU .... LO SPD
  - If IAS below 185 kt
    SPEED .... 180 KT MAX
    TLU .... LO SPD
    DISREGARD TLU FAULT ALERT
    - If TLU green light is not lit
      VAPP .... INCREASE BY 10 KT
      LDG DIST .... MULTIPLY BY 1.13
      LAND AT AIRPORT WITH MINIMUM CROSSWIND

Note: Maximum demonstrated crosswind (dry runway) with TLU HI SPD mode : 15 kt.

Appendix 3

Flybe Finland OM-A's description of a stabilised landing

8.3.1.2 Aeroplane stabilization on approach

Both pilots must monitor approaches. Because of the high workload of PF, a very important duty of PNF is to automatically call out any deviation from the approach procedure, altitude, rate of descent, speed or timing.

A non-stable approach often occurs after delayed TOD or shorter than expected track miles during descent. Need for excessive rate of descend is a clear signal for requiring more miles for achieving stable approach. Therefore maximum rates of descend have been defined for flight phases below 5000 ft.

Approach shall be stabilized no later than when passing 1000 ft above threshold elevation. Approach may be continued only if the Commander judges that it is safe to continue approach. An occurrence report shall be submitted for each flight that is not stabilized 1000 ft above threshold elevation using Company's reporting system.

During approach, a go-around must be performed if any active crew member calls out "go-around", regardless of who is PF/PNF. If the aircraft is not stabilized at 500 ft above threshold elevation, a go-around must be performed.

In every event, the landing runway threshold or displaced threshold should be passed at height of 50 feet AGL, and the aircraft shall be maneuvered to touchdown within touchdown zone. Prolonged flares are prohibited.

The approach is considered stabilised when:

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are necessary to maintain the correct flight path;
3. The airspeed is not more than VREF + 20 kts indicated speed and not less than VREF;
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1000 feet/minute; if an approach requires a sink rate greater than 1000 feet/minute a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for the approach as defined by the OM-B;
7. All briefings and checklists have been completed;
8. Specific types of approaches are stabilized if they also fulfill the following;
   i. ILS approaches must be flown within one dot of the glide-slope and localizer;
   ii. ILS category II and category III approaches must be flown within the 1/3 dot localizer band;
   iii. during a circling approach wings should be level on final when the aircraft reaches 300 feet above airport elevation;

SUMMARY OF THE COMMENTS TO THE DRAFT FINAL REPORT

Non-stabilised approach (1.1)

The comments called attention to the fact that the flight crew decided to continue the approach and land, despite the fact that the normal criteria for a stabilised landing were not met at 500 FT.

Probable cause for veering off the runway (2.2, 2.4.1, 2.4.2, 3.2)

In its comments the aircraft manufacturer held the opinion that the fault in the anti-skid system on the left inner and outer LH main landing gear wheels, discovered during the inspection after the occurrence, also contributed to the aircraft veering off the runway. Furthermore, the manufacturer believes that the engine power asymmetry which contributed to the aircraft veering off was the result of the LH engine malfunctioning, and that when the engines and systems are operating normally there is no need for lateral deviation correction as engine power is being reduced during landing.

Interpreting the graph made of the FDR recording (1.13.1)

The aircraft manufacturer pointed out that the FRD graph shows that the power levers remained between flight idle and ground idle during the entire landing roll.

Flight tests in the simulator (1.15.2.5)

The comments emphasised that a flight simulator is not an approved means of compliance to certification requirements. Moreover, it was stated that the aircraft is not even designed to meet JAR/CS requirements regarding controllability following a failure that critically degrades controllability.

Manuals and instructions (1.14.1, 2.5)

The investigation report points out that the operational documentation (AFM, FCOM and QRH) do not provide information on the controllability limitations caused by the critical TLU FAULT. The aircraft manufacturer stated in its comments, that the manuals and instructions meet the requirements of the national civil aviation authority.

The TLU's standby system (1.1.2.1)

In its comments the aircraft manufacturer pointed out that the manual TLU mode that limits rudder travel, mentioned in the investigation report, is a normally used standby system of the automatic mode.

System descriptions (1.11, 1.13.1, 1.13.2)

In its comments the aircraft manufacturer expressed a desire to have more detailed information regarding propeller control, the TLU and braking systems in the investigation report.

Verbiage and terminology

In addition to the abovementioned comments the interested parties provided remarks on terminology and verbiage. These are taken into account as applicable in the investigation report.

In their comments the Finnish Transport Safety Agency and Finavia stated that they had nothing to comment on regarding the content of the investigation report.

Extract of comments provided by BEA, see appendix 5

<u>Extract of comments provided by BEA:</u>

Comment: Flight data analysis

Thanks to the partial CVR transcript that you had provided us with, we synchronised FDR and CVR. We determine the following radio (and pressure) altitude sequence that is not in line with the draft final report information.

- Flight controls alarm appears ► 1760 ft (1809 ft)
- Flaps 15 ► 1640 ft (1747 ft)
- Flaps to landing configuration ► 1186 ft (1283 ft)
- TLU FAULT section found in QRH ► 716 ft (878 ft)

It results from this analysis that the crew started to apply the TLU FAULT procedure below 1000 ft.

***Comment*:** Operational documentation

Operating manuals are approved (some parts) by the National civil aviation authority of the operator. OM-B is based on AFM and, for some manufacturers which are provided it, FCOM (or FOM). Limitation of the OM-B should be considered as limitations provided in AFM.
The paragraph 1.14.1 “Manuals and instructions” should also include a paragraph related to the Flight Crew Operator Manual (FCOM) provided by ATR to the operators. This manual (not formally approved by the EASA) supplements the Aircraft Flight Manual (AFM) and helps the operators to build their Operating Manual.
The limitation section of the OM-B should be regarded as the limitation section of the AFM which establishes the approved bounds of operation of the airplane in accordance with JAR/CS 25.1581 requirements. Limitations indicated in this AFM or OM-B section are related to Airspeed (VMO, VFE, …), powerplant, weight and loading, etc.…
A TLU failure in high speed position reduces rudder deflection but this is not a condition that is required to appear in the AFM Limitation section.

***Comment*:** Technical information

<u>TLU (Travel limitation unit)</u>

Additional information regarding the TLU should be provided in the report:

There are two control modes for the TLU system: the automatic mode and the manual mode. A guarded switch enables to switch from one to the other. The medium position corresponds to the automatic mode; the upper position to the High speed manual command and the lower position to the Low speed manual command. This switch is installed on Flight control overhead panel (25VU) which also includes the TLU “Fault” light that enables the crew to identify the TLU failure condition. When the switch is on the Auto position, the TLU actuator is commanded by the MFC. It should be noted that the flaps setting or flaps position is not a parameter considered in the TLU logic within MFC.

The monitoring of the TLU system is ensured by the MFC which, in case of disagreement between the actual TLU actuator position and the expected one (based on aircraft airspeed), triggers the following light and sound:

- “FAULT” light on flight control overhead panel (25VU)
- Both master “CAUTION” light on LH and RH instrument panels
- “FLT CTL” amber light on the crew alerting panel (CAP)
- Single chime audio warning

Based on these indications, the philosophy for failure identification is the following:

- The "CAUTION" lights and the single chime alert the crew.
- The "FLT CTL" on the CAP enables the crew to identify the related system.
- The local alert TLU "FAULT" on 25VU notifies the crew on relevant checklist to be performed.

When the TLU is failed in High Speed position, the rudder is not jammed. The rudder deflection is limited to +/- 4° instead of +/- 27°. As a single failure the limitation of rudder deflection has no consequence on landing capability (only the maximum crosswind is impacted) and doesn't lead to a loss of control of the aircraft. Lateral control on ground, during the landing roll can be managed through the use of asymmetric braking and nose wheel steering. This capability was demonstrated during ATR 72 certification through flight tests.

The nose wheel steering

The nose wheel steering system comprises a solenoid valve which inhibits pressurization of the differential control valve until the three landing gears are compressed on ground. The AIR/GROUND signal is provided by MFC1B or MFC2B. The "WOW" (Weight on wheel) information recorded in the FDR is coming from the activation of relays 29GB and 35GB that are commanded by the MFC1B, based on the information received from the proximity switches of WOW system 1.

The FDR data shows that after the touchdown, when the PL's are moved below FI, the WOW parameters (main landing gear and all landing gear) are still at 0 (aircraft in flight). They switch to 1 (aircraft on ground) approximately 7 s after the touchdown. This could be explained by different facts: the touchdown was very smooth, the control column is not pushed forward after touchdown, the pitch attitude of the aircraft remains above the theoretical pitch attitude with nose landing gear compressed, the ailerons are deflected up to 11° (maximum deflection is 13°) and the aircraft roll up to 4° to the left, which prevent the right main landing gear to be properly compressed. Standard practice is to apply nose down input on control column in order to "stuck" the aircraft on the runway after touchdown. This ensures a good contact of the aircraft landing gears and increases the lateral control efficiency. If the Captain tried to use the nose wheel steering just after touchdown, the lack of efficiency was not due to the additional 10kt to the Vapp but to the absence of pressure in the system as all the three landing gears were not compressed.

***Comment*:** Engine functioning analysis

When the aircraft is in flight, the idle gate protection is active and the power levers (PL's) cannot be set below flight idle (FI) due by means of a mechanical stop. The idle gate protection de-activates as soon as one landing gear is compressed allowing the PL's to be set below FI.
After the touchdown, the PL's are moved below FI but not down to GI, contrary to what is written in the report. PL's are kept in this intermediary position until the aircraft turns to enter a taxiway. The FDR data enable to check the dynamic of the engines and propellers when the PL's are moved below FI position.

- One second after the PL's start moving below FI, the low pitch indication is recorded active on engine 2, which means the propeller pitch for engine 2 is at or below 8°. One second later the low pitch indication is recorded for engine 1. Considering that the sampling rate for recording these parameters is 1 pps, the Low pitch threshold of 8° could have been reached within the second before the parameter is recorded active. This difference of 1 second in the recording of low pitch status cannot be considered as significant with regards to the lateral deviation.
- Standard engine behavior, when going to the beta zone, is to have an increase of NP from 82 to 85 or 86%, and then a progressive decrease. The FDR data evidenced thisbehavior on the engine 1, the NP curve is coherent with standard dynamic. However, it can also be observed that NH 1 is dropping to 66% five seconds after PL's moving below FI. Such value is not standard during this phase of flight. It could be due to a temporary PEC Fault with an NP cancel signal sent by the PEC to the EEC. The incorrect PLA rigging could have participated in the scenario leading to this PEC Fault. On engine 2 it can be observed that the NP only increases up to 83% and then decreases very quickly. The behaviour of engine 2 is not nominal. It would have been interesting to look at the FDR data of previous flights and determine if same anomaly on engine 2 was already present.

Regarding the overall engine asymmetry, based on the fact that both propellers pitch angles are below 8° but none is in reverse, the asymmetry in traction is not significant. It is not clear, in the report, if a precise thrust asymmetry was computed or which parameters were analyzed by the investigation group to conclude that the engine power asymmetry was "remarkable".

The report states that a gradual reduction of engine power would have avoid exiting the runway. The manufacturer considers that it is preferable to go from FI to GI at reasonable speed (within 2 or 3s) and not to stay to long in intermediary position.

Comment**:** certification process

The showing of compliance of the ATR 72-212A regarding applicable regulation JAR 25.143 and 149 was performed according to a flight test program that was validated by the certification authority (French DGAC at that time) and the certification flight tests results were also validated by this same authority. Those regulations do not require a demonstration of handling capability for the association of an engine failure and a flight control system failure. The association of an engine failure and a TLU failure in high speed position during a go around has been considered as a potentially catastrophic event in regards to regulation JAR 25.1309 and then not tested in flight. Consequently, it has been demonstrated, as part of the certification, that the probability of occurrence of such failures combination was extremely improbable (below 10^{-9} per flight hour).

The investigation group should consider that the TLU fault has been triggered by the failure of the automatic mode. The manual mode was still available and would allow the crew to recover the total rudder deflection. Moreover both engines were working at the time of the incident. There is no reason to consider such failure.

The ATR certification is based on JAR 25 requirements not on CS25. Such information is available on the Type Certificate Data Sheet of ATR72-212A.

A flight simulator is not an approved means to demonstrate the aircraft compliance to JAR 25.143 and 149 requirements. The simulator characteristics could be different from the actual aircraft behaviour in the failure conditions simulated. The paragraphs dealing with the simulations performed should be removed.

***Comment*: braking system**

ATR informed BEA that the Flybe Finland maintenance operator found out some defects on brakes.
Further to the event, the maintenance organization performed several checks on the aircraft systems. One of the tests run on braking system, the functional test of the antiskid system failed and revealed fluctuation of braking pressure on brakes 1 and 2 (left outer and left inner). Such failure would have led to a lack of efficiency on left brakes. As a corrective action, the metering valve was removed and while the part was being tested in a repair shop, the failure identified on aircraft was confirmed.
We consider that this element is significant with regards to the veering off event and should be included in the report.

***Comment*: Aircraft lateral deviation during this event**

The runway veering off event could not only be due to the limited rudder authority. A combination of multiple causes and contributing factors are at the origin of this event: the TLU failure in high speed, limiting rudder authority associated to a lateral deviation of the aircraft after the touchdown. The lateral deviation was probably due to the association of an engine power asymmetry and a deficiency in left braking system.
The TLU failure, taken as single failure, does not result in an "unavoidable accident". The demonstration of the aircraft capability to land with a TLU in high speed has been performed during certification flight tests. The failure of the braking system, the anomalies of power levers rigging and engine dynamics are failures that were most probably already present on the aircraft before this event.
It would have been interesting to look at FDR data for previous flight to check engines behaviour and any possible lateral deviation under braking action.

***Comment*: Deviation**

The report states that an ATR aircraft "tends to swing to the right or to the left when engine power is reduced to ground idle". This statement seems to rely on "available information".
The manufacturer is not aware of any deviation during landing touchdown or landing roll.
The SIA should provide us with further information on which this statement is based.

The ATR aircraft does not show any tendency to lateral deviation when PL's are moved from FI to GI when engines and systems are operating in their nominal conditions. Any lateral deviation tendency of the aircraft is not a normal behaviour and should be systematically reported by the crews experiencing it to the maintenance organization for troubleshooting and correction of the anomaly.