Statens haverikommission
Swedish Accident Investigation Authority





Final report RL 2020:11e

Accident at Malmö Airport 17 November 2019 involving the aircraft SE-LUX of the type Beechcraft 95, operated by south Sweden Flight Academy AB.

File no. L-164/19

17 November 2020

SHK investigates accidents and incidents from a safety perspective. Its investigations are aimed at preventing a similar event from occurring in the future, or limiting the effects of such an event. The investigations do not deal with issues of guilt, blame or liability for damages.

The report is also available on SHK´s web site: www.havkom.se

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This document is a translation of the original Swedish report. In case of discrepancies between this translation and the Swedish original text, the Swedish text shall prevail in the interpretation of the report.

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Content

General observations

The Swedish Accident Investigation Authority (Statens haverikommission – SHK) is a state authority with the task of investigating accidents and incidents with the aim of improving safety. SHK accident investigations are intended to clarify, as far as possible, the sequence of events and their causes, as well as damages and other consequences. The results of an investigation shall provide the basis for decisions aiming at preventing a similar event from occurring in the future, or limiting the effects of such an event. The investigation shall also provide a basis for assessment of the performance of rescue services and, when appropriate, for improvements to these rescue services.

SHK accident investigations thus aim at answering three questions: *What happened? Why did it happen? How can a similar event be avoided in the future?*

SHK does not have any supervisory role and its investigations do not deal with issues of guilt, blame or liability for damages. Therefore, accidents and incidents are neither investigated nor described in the report from any such perspective. These issues are, when appropriate, dealt with by judicial authorities or e.g. by insurance companies.

The task of SHK also does not include investigating how persons affected by an accident or incident have been cared for by hospital services, once an emergency operation has been concluded. Measures in support of such individuals by the social services, for example in the form of post crisis management, also are not the subject of the investigation.

Investigations of aviation incidents are governed mainly by Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation and by the Accident Investigation Act (1990:712). The investigation is carried out in accordance with Annex 13 of the Chicago Convention.

The investigation

SHK was informed on 17 November 2019 that a serious incident involving one aircraft with the registration SE-LUX had occurred at Malmö Airport, Skåne County, the same day at 16:30 hrs.

The accident has been investigated by SHK represented by Mr Mikael Karanikas Chairperson, Mr Johan Nikolaou, Investigator in Charge, Mr Tony Arvidsson, Technical Investigator (aviation), Mr Mats Trense, Operations Investigator Mr Tomas Ojala, Investigator specializing in Fire and Rescue Services.

Mr Mitchell Gallo from the National Transportation Safety Board (NTSB) has participated as accredited representative on behalf of USA.

Virpi Mikkonen has participated until 25 September 2020 and thereafter Mr Alvaro Nerves as an adviser from the European Union Aviation safety Agency (EASA).

The investigation was followed by Mr Magnus Axelsson and Daniel Wastesson of the Swedish Transport Agency.

The following organisations have been notified: International Civil Aviation Organisation (ICAO), European Aviation Safety Agency (EASA), EU-Commission, NTSB and the Swedish Transport Agency (Transportstyrelsen).

Investigation material

The aircraft and relevant components have been examined. Interviews have been held with the crew as well as students and staff from the flight school, the rescue service and air traffic control. Documents from i.e. the flight school and the rescue service have been obtained and examined.

A meeting with the interested parties was held on 26 May 2020. At the meeting SHK presented the facts discovered during the investigation, available at the time.

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Aircraft:	
Registration, type	SE-LUX, Beechcraft 95
Model	95-B55
Class, Airworthiness	Normal, Certificate of Airworthiness and Valid Airworthiness Review Certificate (ARC)1
Serial Number	TC-1269
Operator	South Sweden Flight Academy AB
Time of occurrence	17 November 2019, 16:30 hrs during darkness Note: All times are given in Swedish standard time (UTC[2] + 1 hour)
Place	Malmö Airport, Skåne county, (position 5532N 01322E, 66 meters (216 feet) above mean sea level)
Type of flight	Schooling
Weather	According to Metar: wind 080 degrees, 6 knots, CAVOK[3], temperature/dewpoint +7/+5°C, QNH[4] 1016 hPa[5]
Persons on board:	2
crew members including cabin crew	2
passengers	0
Injuries to persons	None
Damage to aircraft	Substantially damaged
Other damage	None
Instructor:	
Age, licence	59 years, CPL[6]
Total flying hours	2490 hours, of which 14 hours on type
Flying hours previous 90 days	33 hours, of which 4 hours on type
Number of landings previous 90 days	4, of which 3 on type
Student:	
Age, licence	40 years, PPL[7]
Total flying hours	3166 hours, of which 5 hours on type
Flying hours previous 90 days	45 hours, of which 5 hours on type
Number of landings previous 90 days	65, of which 26 on type

[1] ARC (Airworthiness Review Certificate)
[2] UTC (Coordinated Universal Time)
[3] CAVOK (Ceiling And Visibility OK)
[4] QNH.(Barometric pressure at mean sea level)
[5] hPa (Hectopascal)
[6] CPL (Commercial Pilot License)
[7] PPL (Private Pilot License)

SUMMARY

The intention was to carry out flight training southeast of Malmö Airport and then return and practice instrument approaches. After about sixteen minutes of flying, radar vectors was initiated for approach to runway 17. At the same time, the aircraft lost all electrical power, which i.e. caused all installed navigation equipment, radio communication with air traffic control and intercommunication to cease functioning. It was dark outside under visual flight conditions.

In order to find their way back to the airport, the pilots used external references and a tablet with a navigation program installed. In the absence of electrical power in a noisy environment, the crew had to perform manual landing gear extension, a procedure that neither the student nor the instructor had previously performed.

The crew then tried to check, with the help of their light sources via mirrors on the engine cowlings, whether the nose landing gear was extended. None of the pilots could see anything and the crew decided to continue the approach.

At touchdown, the landing gear collapsed. The plane landed on its belly and skidded over 300 meters before stopping.

It has not been possible to determine the reason why the loss of electrical power occurred.

The accident was caused by the pilots lacking sufficient knowledge about the manual landing gear extension function, which in turn led to the landing gear not being fully extended before landing.

Contributing factors are that the instructions in the aircraft's flight manual for the electrical system did not correspond to how the installed system worked. In addition lack of knowledge for the electrical system and lack of a warning system that clearly indicates that the battery is not charged by the alternators and ambiguities in the training organization's instructions for the operation, risk management and training.

Safety recommendations

EASA is recommended to:

- Evaluate and decide whether a warning system that clearly indicates that the battery is not being charged by the alternators can be introduced as an operational requirement for aircraft operated under instrument flight rules or in darkness. *(RL 2020:11 R1)*

The typecertificate holder Textron Aviation Inc. is recommended to:

- Update the POH so that the function of the ALT OUT warning corresponds to the correct serial number of the aircraft. *(RL 2020:11 R2)*

The Swedish Transport Agency is recommended to:

- Inform operators flying under the instrument flight rules or darkness about the risks of aircraft types that do not have a low voltage warning installed. *(RL 2020:11 R3)*

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Preconditions

The intention was to carry out flight training southeast of Malmö Airport with the aircraft, and then return and practice instrument approaches.

The student had previously flown four hours with the aircraft type and it was the student's first instrument approach session.

The aircraft's checklist was used to assist in preparing the aircraft for flight. Checklist items were checked including circuit breakers and warning lights.

1.1.2 Sequence of Events

When starting the engines, the left engine started on the first try. For the right engine, several start attempts were required, including a rest period of 4 minutes before the engine started. The load meters were then checked according to the checklist. It was difficult to see any change at all, only a few millimeters.

The aircraft took off from runway 17 at 16.07 climbing to 3,000 feet towards the waypoint TIDVU to perform air work southeast of the airport. When the air work were finished, they received radar vectors to fly on heading 020 degrees, with the intention of conducting an approach to runway 17.

Shortly afterwards, the air traffic controller informed the crew that there were interruptions in the aircraft's transponder response. The crew established that the transponder did not have normal indications. Shortly afterwards, a total electrical power loss occurred, and the last instrument that stopped working was the aircraft's distance meter equipment (DME). The pilots had not observed any warning light for alternator failure. No further radio communication took place. However, the air traffic control could see the aircraft on its primary radar during certain parts of the flight.

No checklist or troubleshooting for the electrical failure was performed, which were explained by the crew, that there was no published procedure for the fault. Nor were the load meters or voltmeters checked during any part of the flight. The crew did not observe if any circuit breakers had tripped.

It was dark outside with good metrological visibility and no clouds. The crew used a mobile phone and a tablet as their light sources in the darkness.

The student continued to fly the aircraft and the instructor used the tablet to navigate. As the crew received visual contact with the airport they continued to navigate based on external references.

Due to the electrical failure the intercom system ceased to function. They removed the headset and communicated by shouting to each other. The environment that arose made it hard to communicate.

The crew decided to perform two turns north of the airport to perform the manual extension of the landing gear, a procedure that neither of the crew previously had performed, before commencing the approach. At this point the instructor decided to take over control of the aircraft and to let the student perform the emergency extension of the landing gear.

The student used the aircraft (POH) as a reference to perform the manual landing gear extension. The student rotated the landing gear hand crank counter clockwise until a resistance was felt. The instructor asked the student at least three times if the checklist was completed, which the student confirmed.

The crew tried to assess, with their light sources, if the nose landing gear was extended by looking in the mirrors on the engine cowling. Neither of the crew could see anything and they decided to continue the approach. The pilots did not know that there was a mechanical landing gear indicator below the centre pedestal.

The air traffic control, that lost the radio and transponder contact, found the airplanes position by using the primary radar. After some time the primary echo disappeared completely, but came back when the aircraft were on four nautical miles final to the runway. The crew then received landing clearance by green light signals from Malmö Tower.

At touchdown the landing gear collapsed and resulted in a belly landing. The aircraft skidded approximately 300 meters (984 feet) before coming to a stop. The crew observed smoke and evacuated the aircraft immediately without changing any position of any switches.

The airport emergency service entered the aircraft and turned off the battery master switch and both alternator switches.

The accident occurred at position 5532N 01322E, 66 meters above sea level.

1.1.3 Observations from instructors and students

Students and instructors at the school reacted that the start attempt of the second engine was going on for a long period of time and mentioned it to the Accountable Manager (AM). To try to get an idea of the start-up time and any other information the instructors and students, who were at the school's premises on the day of the event, were contacted by e-mail. The contact details were provided by the school.

The answers do not give a uniform idea of the time required to start the right engine. Most of the interviewd agreed that it took longer time than normal. The time perception was from 5 minutes to 1 hour for the start of the right engine and the number of starting attempts were estimated by most to be at least 3 to 5.

1.2 Injuries to persons

	Crew members	Passengers	Total on-board	Others
Fatal	-	-	0	-
Serious	-	-	0	-
Minor	-	-	0	Not applicable
None	2	-	2	Not applicable
Total	2	0	2	-

1.3 Damage to aircraft

Substantially damaged.

1.4 Other damage

1.4.1 Environmental impact

Some fuel leaked on the runway. The airport emergency service foamed the runway.

1.5 Personnel information

1.5.1 Qualifications and duty time of the pilot/pilots

Instructor

The instructor, were 59 years old and had a valid CPL[8] with flight operational eligibility and medical certificate. At the time the instructor was PM[9] until just before the manual extension of the landing gear were initiated. From that point the instructor operated as PF[10].

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	1	1	33	2490
Actual type	1	1	4	14

Number of landings on class MEP(land) previous 90 days: 33.
Difference training on type was concluded on July 18th 2019.
Latest PC[11] was conducted on September 16th 2019 on type.

The student

The student was 40 years old and had a valid PPL[12] with flight operational eligibility and medical certificate. At the time the student was PF until just before the manual extension of the landing gear were initiated. From that point the student operated as PM[13].

The student had an expired third country ATPL[14].

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	1	5	45	3166
Actual type	1	5	5	5

Number of landings on class MEP(land) previous 90 days: 26.
The student was under training on Type.
Latest PC was conducted on October 31st 2019 on a Piper PA-28R.

1.5.2 Other personnel

None.

[8] CPL (Commercial Pilot License)
[9] PM (Pilot Flying)
[10] PF (Pilot Flying)
[11] PC (Proficiency Check)
[12] PPL (Private Pilot License)
[13] PM (Pilot Monitoring)
[14] ATPL (Airline Transport Pilot License)

1.6 Aircraft information

The aircraft type is a Beechcraft 95 (model 95-B55) which is a six-seater, low-wing two-engine piston engine aircraft. The aircraft is just over eight and a half meters long and has a wingspan of just over eleven and a half meters.

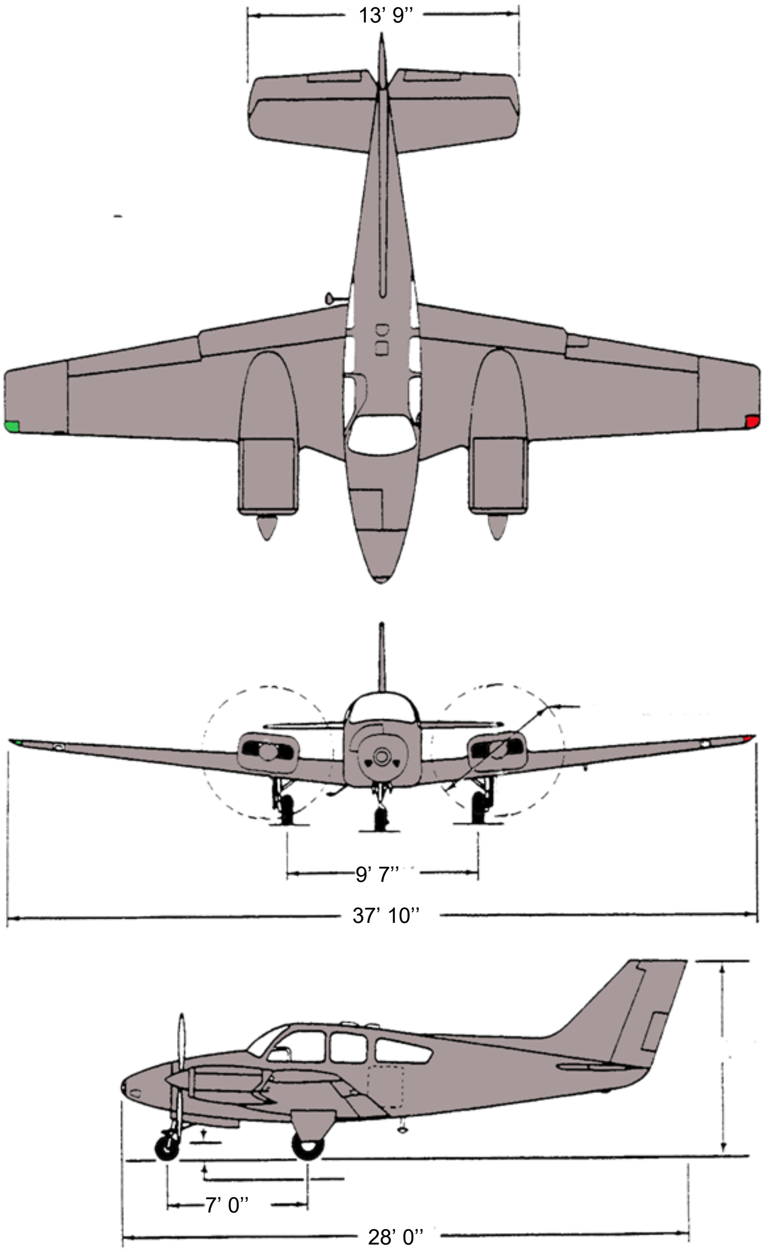

Figure 1. 3D picture of the aircraft type. Picture Baron 95 operating Handbook.

1.6.1 Airplane

TC-holder	Textron Aviation inc
Model	95-B55
Serial number	TC-1269
Year of manufacture	1969
Gross mass, kg	Max mass suspended load 2310 current 2050
Centre of gravity	Within limits.
Total flying time, hours	5537
Flying time since latest inspection	46
Number of cycles	851
Type of fuel uplifted before the occurrence	100LL
Engine	
TC-holder	Continental Motors
Type	IO-470-L
Number of engines	2
Propeller	
TC-holder	Hartzell Proppeller inc
Type	PHC-C3YF-2UF
Number of propellers	2
Deferred remarks	None

The aircraft had a Certificate of Airworthiness and a valid ARC.

1.6.2 Landing gear

The landing gear is an electrically operated tricycle retractable landing gear. The landing gear is operated through push pull tubes by one reversible electric motor and an actuator gearbox under the front seat. The linkage is spring loaded to an over center position.

A two position landing gear switch located on the right hand side of the center console controls the motor. The gearbox has an extendable emergency hand crank located behind right front seat which is used to manually extend the landing gear if an electrical failure occurs. To extend the landing gear the hand crank should be rotated approximately 50 turns counter clockwise.

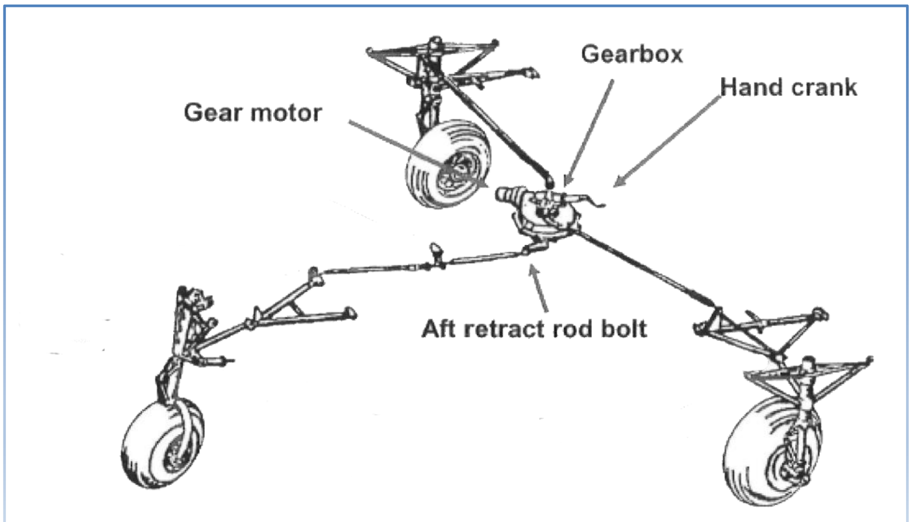

Figure 2. Landing gear mechanism Picture: Beech Baron 55 Shop Manual.

A Mechanical indicator is located at the bottom of the centre console (see Figure 3). This indicator is mechanically linked to the nose wheel actuating mechanism and will show the position of the nose wheel whether electric power is available or not. This indicator does not directly indicate the position of either main landing gear leg, however in the absence of a break in the mechanical linkage between the gearbox and the landing gear legs all three gear-legs must be in the same position.

Figure 3. Mechanical nose wheel position indicator.

1.6.3 *Installed mirrors*

The aircraft had an installed mirror on the left engine gondola that was not described in the aircraft manual or its supplement (see Figure 4). The school also installed a mirror on the right motor gondola so that the instructor visually could check the position of the landing gear. The mirror on the right engine gondola was not present on the aircraft when the SHK investigated the aircraft.

Figure 4. Installed mirror on the left engine cowling to visually verify landing gear position.

1.6.4 *Electrical system*

The electric system is a direct current 24/28 volt electric system. There are two 50 amp alternators and two 12-volt batteries connected in series to act as a single 24 volt 20 amp hour battery. The alternators are belt driven units attached to each engine. One voltage regulator that controls the field of both alternators maintains voltage in the system. The aircraft are equipped with two voltage regulators and the pilot can choose which voltage regulator that is active with a switch on the pilot sub-panel.

Battery is connected to the main bus via a relay that is controlled by the battery master switch. The alternators are activated with switches for the left and right alternators, respectively. All switches are located on the sub panel.

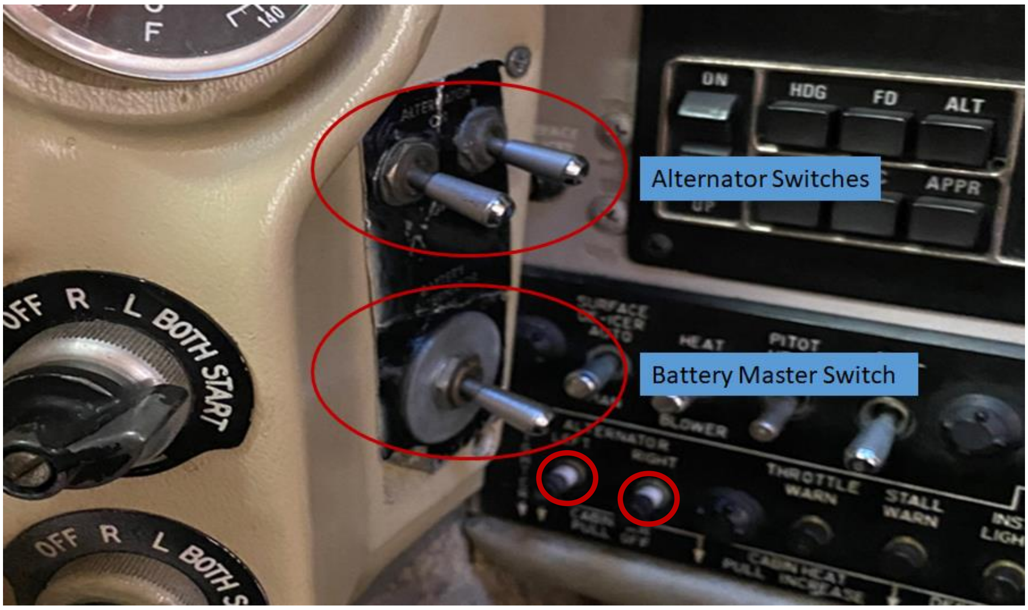

Figure 5. Battery switch, Alternator switches and pulled circuit breakers.

Each alternator has the capacity to provide 50 amps of electricity. The alternators deliver power to the main bus through the two circuit breakers labeled left alternator and right alternator respectively.

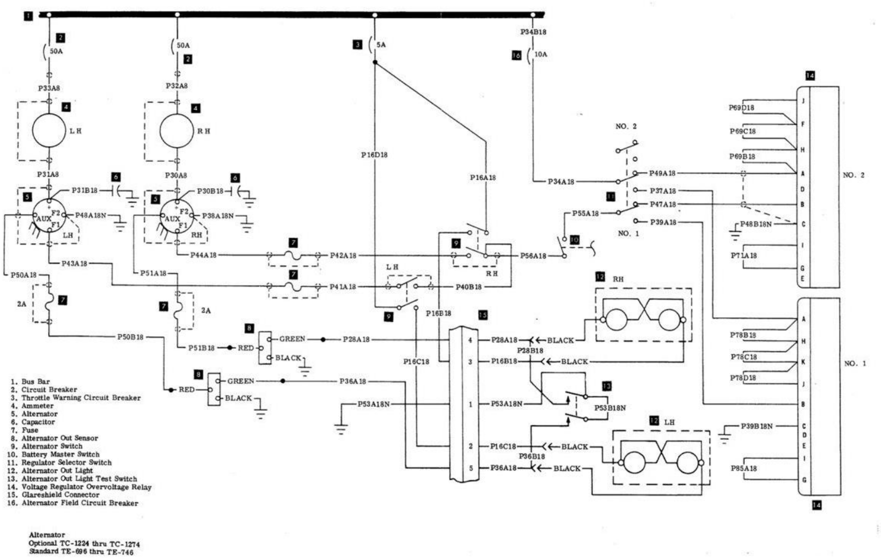

Figure 6. Alternator schematic. Picture: Beechcraft Baron 55 Shop manual.

The voltage regulators draw current from the single circuit breaker labeled alternator field.

The voltage regulators have a built in over voltage protection. Over voltage prevents further output from the regulator thereby shutting down the alternators. There is no over voltage light in the electric system. Following an over voltage, the pilot will notice that both alternators have stopped working by illumination of both “ALT OUT lights.

The aircraft is equipped with two alternator-out lights, which are activated by two relays, one for each alternator. The relays close automatically when the corresponding alternator output is zero. Power for the alternator out lights is provided through the alternator switches, consequently the alternator-out lights will illuminate only if the alternator switch is on. A push to test button for the lights is provided.

Text from the SE-LUX Pilot Operating Handbook (POH):

"On serials TC-1043 thru TC-1607, two annunciator ALT OUT lights are on the instrument panel. They will illuminate whenever their respective alternator is disconnected from the bus by low voltage or an overvoltage condition ***or with the switch in the OFF position****. Any time a failure is detected the appropriate alternator should be turned off".*

According to POH the "ALT OUT" lights will illuminate when the alternate switch is off. According to SHK:s test of the system the alternator out lights did not illuminate when the alternator switches were in the off position (see Figure 7).

Figure 7. The picture shows left "ALT OUT" light not illuminating when the switch is set to OFF.

Individual alternator output is indicated by two loadmeters on the instrument panel (see Figure 8). The loadmeters give a percentage reading of the load on the system.

Figure 8. Loadmeters in SE-LUX. The right indicator shows 0 Amperes.

In the system there was also a voltmeter, located at the top right of the instrument panel. The range was between 24 and 29 volts, with an extra mark for 28.5 volts, which is the mark for normal charging voltage.

Figure 9. Voltmeter in SE-LUX.

1.6.5 *Procedures in the POH*

According to the POH, the aircraft must be operated in accordance with the manual. Relevant procedures are presented below.

Engine start

The procedure after start states the following in the POH:

"CAUTION

lf the total of both loadmeters exceeds .2 after two minutes at 1 000-1 200 rpm, with no additional electrical equipment on, and the indication shows no signs of decreasing, an electrical malfunction is indicated. The battery master and both generator/alternator switches should be placed in the OFF position. Do not take off".

The procedure cannot be checked on the installed load meters with a scale up to 50 amps (see Figure 10).

Figure 10. The loadmeters installed in SE-LUX.

In order to be able to check the value down to 0.2, a load meter with a gradation according to figure 21 is needed.

Figure 11. The loadmeeter described in the POH of SE-LUX.

Electrical Failure

ILLUMINATION OF OVERVOLTAGE LIGHT OR ALTERNATOR OUT LIGHT(S)

In the event af the illumination of a single ALTERNATOR OUT light:

1. *Check the respective loadmeter for load indication.*

    a. *No Load - Turn off affected alternator*
    b. *Regulate load In the event af the illumination af the overvoltage fight ar af both ALTERNATOR OUT fights:*

1. *Check loadmeters for load indication*

    a. *No load indicates failure of regulator*
    (1) Switch regulators
    (2) System should indicate normal

    b. *lf condition recurs*
    (1) Switch to original regulator
    (2) System returns to normal, indicates overload condition causing malfunction
    (3) Reduce load

    c. *lf condition indicates malfunction of both alternator circuits*
    (1) Both ALT Switches – OFF
    (2) Minimize electrical load since only battery power will be available Landing Gear Extension

LANDING GEAR MANUAL EXTENSION

Reduce airspeed before attempting manual extension of the landing gear.

1) *LDG GR MOTOR Circuit Breaker - PULL*
2) *Landing Gear Handle - DOWN*
3) *Remove cover from handcrank at rear of front seats. engage handcrank and turn counterclockwise as far as possible (approximately 50 turns). Stow handcrank.*
4) *Check mechanical indicator to ascertain that gear is down.*
5) *If electrical system is operative, check landing gear position lights and warning horn (check LDG GR RELAY circuit breaker engaged.)*

1.7 Meteorological information

According to Metar: Wind 080 degrees, 6 knots, CAVOK, temperature/dewpoint +7/+5°C, QNH 1016 hPa.

The accident occurred in darkness.

1.8 Aids to navigation

The aircraft was equipped for IFR. All permanently installed electric navigation instruments ceased to function at the power failure. The instructor brought a handheld tablet (iPad) with map function that were used for navigation.

All flight instruments where funktional after the electrical failure except the turn indicator.

1.9 Communications

The communications with Malmö Tower and Air Traffic Control were normal until the total failure of electric power. After the electric failure all communication from the aircraft were lost and Air Traffic Control were transmitting blind.

Malmö Tower and Air Traffic Control were exchanging information and coordinating the aircrafts position during the incident.

1.10 Aerodrome information

Malmö Airport were an approved instrument airport according to AIP [15]Sweden. The airport had two paved runways, 11/29 (799*18m) and 17/35 (2800*45m).

At the time of the accident runway 17 were in use.

The runway was equipped with high intensity approach lights, centre line lights and PAPI[16]. The runway was dry at the time of the incident.

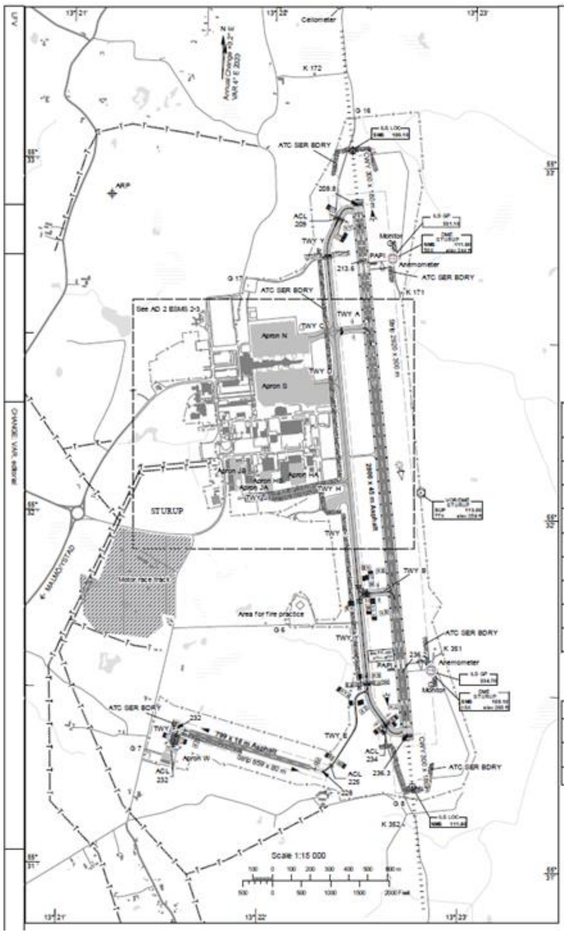

Figure 12. Malmö Airport. Picture AIP Sweden.

1.11 Flight recorders

The aircraft was not equipped with and did not have any requirement to be equipped with any recording device.

A tablet (iPad) with GPS [17] were on-board that recorded the complete flight.

[15] AIP (Aeronautical Information Publication)
[16] APAPI (Precision Approach Path Indicator)
[17] GPS (Global Positioning System)

1.11.1 Flight Recorder (GPS)

The IPad data were analysed together with the primary and secondary radar data and they corresponded to each other.

In the presentation below the flight path is presented to show what radar data that were available at different segments of the flight. The GPS data were available at all times and only fill in the gapes in radar data.

At 15:23:28 (UTC) the secondary radar return ceased which indicate the time when the aircraft suffered the total electrical failure (see Figure 11).

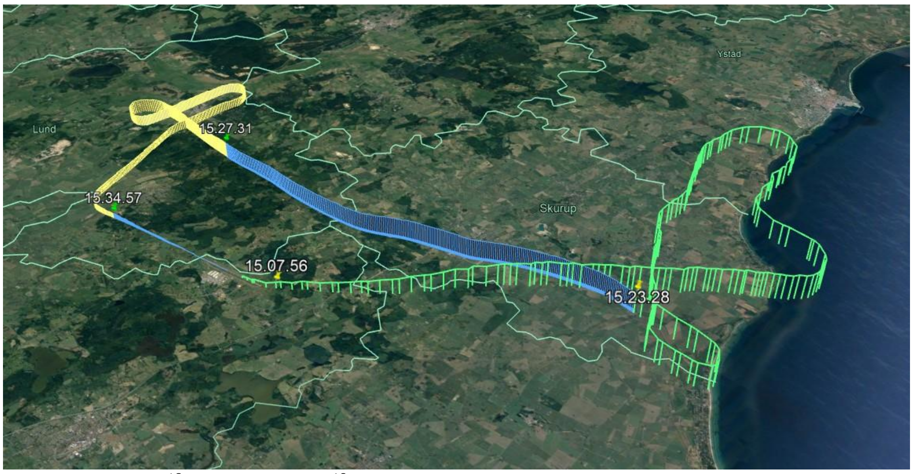

Figure 13. SSR [18]in green, PSR [19]in blue and IPad GPS data in yellow. The coloured line inserted by SHK. Picture: Google Earth.

1.12 Accident site and aircraft wreckage

The accident occurred at Malmö Airport on runway 17. After the landing the aircraft stopped on the belly about 1 000 meters (3 280 feet) into the runway.

Figure 14. The aircraft on the runway together with the rescue services of the airport. Circled added by SHK. Picture: Swedish police.

[18] SSR (Secondary surveillance radar)
[19] PSR (Primary surveillance radar)

1.12.1 *Accident site*

The aircraft belly landed at approximately 700 meters (2 300 feet) into the runway and skidded thereafter 300 meters (984 feet). In the overview image below the aircraft symbol represents were the aircraft stopped.

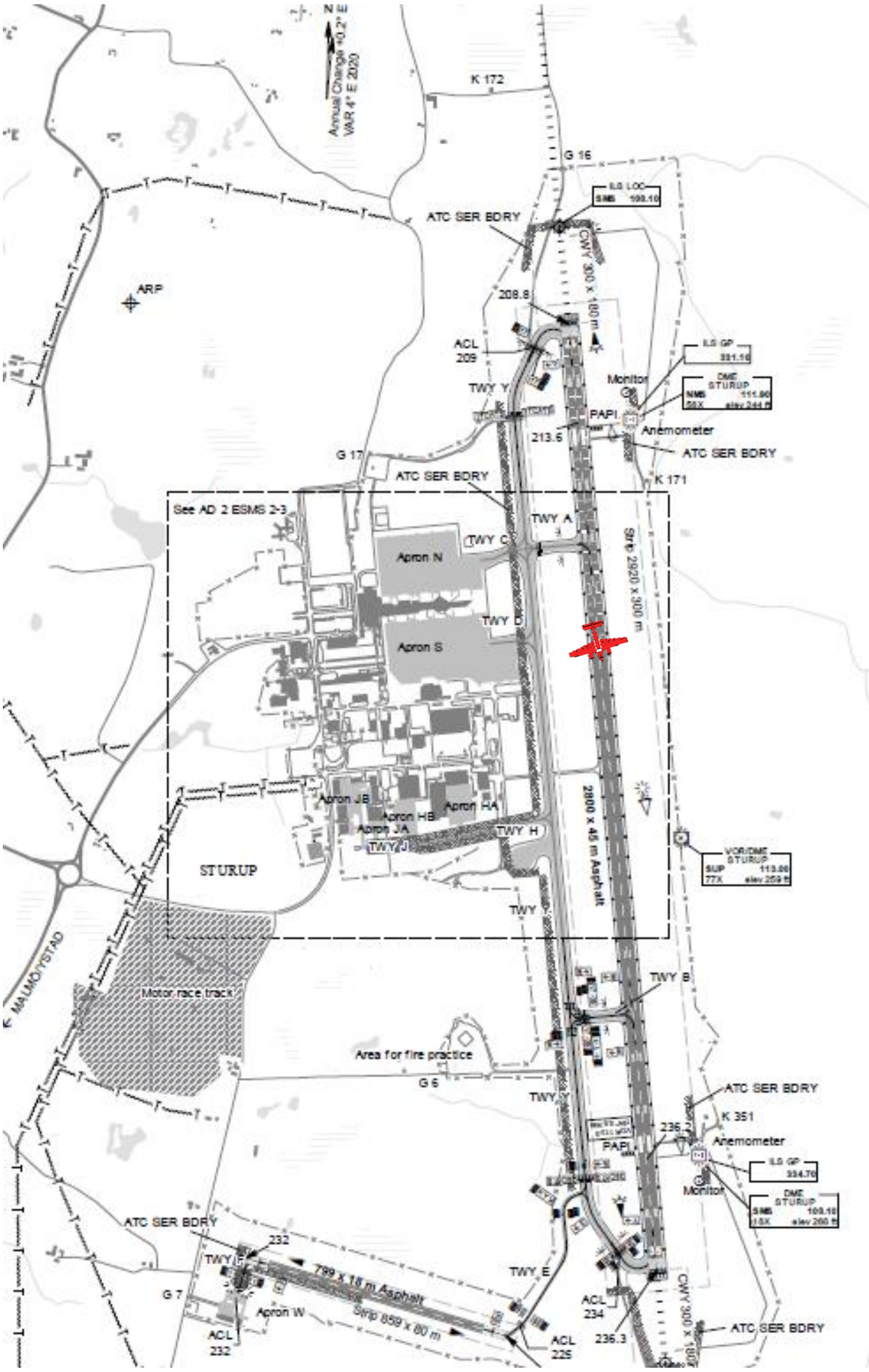

Figure 15. The aircraft symbol (inserted by SHK) shows the final position of the aircraft on the runway. Picture: AIP Sweden.

1.12.2 *Aircraft wreckage*

Damage occurred to both propellers, all landing gear doors and to their attachments. Sheet metal and frame on the underside of the belly, tires, rims, brakes and landing gear had scratches.

1.12.3 *Technical examination of the aircraft*

SHK carried out a first preliminary investigation of the aircraft on 22 November 2019 in a hangar at the airport, where the aircraft had been transported after the accident. The aircraft had been lifted onto jacks and the batteries had been removed for control measurement and charging. After charging, the voltage was normal and the capacity 89 % and 95 %, respectively.

During the initial investigation of the aircraft the following emerged, among other things. The circuit breakers for the left and right alternators were tripped. The switches for both alternators were off. The main battery/alternator switch was off. A fuse between the alternator output “AUX” and the sensor for left fault indication “ALT OUT” had melted, (see Figure 16).

With the main battery/alternator switch and both alternator switches in the “ON” position, both alternator warnings “ALT OUT” were lit. However, one of two light bulbs in the right indicator warning light was broken.

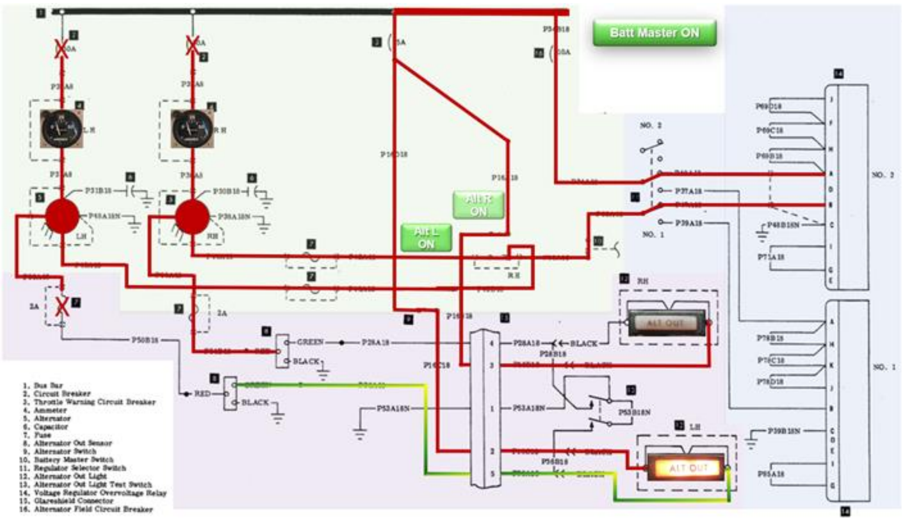

Figure 16. The configuration of the electrical system at the time of SHK:s examination. Red marking illustrates powered wires and components. Yellow-green illustrates wire connecting to ground.

Furthermore, it could be stated that the main landing gear were not in a fully down and locked position. Both push rods between the main landing gear and the landing gearbox were bent. The push rod between the nose landing gear and the landing gear actuator was interrupted.

After the aircraft had been lifted onto jacks, the nose landing gear could be moved to the fully extended locked position, without cranking on the landing gear hand crank. However, the mechanical landing gear indicator did not show the down position, according to the indicator scale. The crank handle for the manual gear extension was in the extended position.

1.13 Medical and pathological information

There is no evidence that the pilot's mental or physical fitness had been impaired before or during the landing.

1.14 Fire

Sparks arouse during landing, but no fire erupted. The crew experienced smoke in the cockpit after landing.

1.15 Survival aspects

1.15.1 Rescue operation

When the air traffic control at Malmö ATCC[20] lost radar and radio contact with the aircraft, an alarm according to the Green-Yellow checklist were activated. The checklist provided support for the handling of suspected accidents or accidents with an unknown accident site. JRCC[21] was contacted at 16.32 and the air rescue leader decided to search for the aircraft, and the SAR[22] helicopter in Kristianstad was alerted. At 16:40 the rescue mission was cancelled just before the helicopter was about to take off as the air rescue leader was informed that the aircraft had landed at Malmö Airport.

When Malmö ATCC lost contact with the aircraft, they also notified the air traffic controllers in the Tower about this. The Tower contacted the rescue service and informed that there was a risk of an accident, but no formal handling started according to any checklist.

When the air traffic controllers in the Tower saw sparks on the runway, they started an emergency alarm according to the red checklist. The accident alarm was started by the air traffic controller pressing a designated button, whereby the airport's rescue service and SOS Alarm were automatically alerted. SOS Alarm then contacted the Tower for information about the accident and in turn alerted the rescue service in Svedala municipality.

Staff from the airport rescue service initially had difficulty seeing the aircraft on the runway as the sparks subsided and the aircraft was completely extinguished. However, the air traffic controllers in the

[20] ATCC (Air Traffic Control Centre)
[21] JRCC (Swedish Maritime Administration's Sea and Air Rescue Centre)
[22] SAR (Search and Rescue)

Tower were able to provide some guidance on where the sparks originated and then disappeared, and the rescue service located the aircraft shortly thereafter.

When the airport rescue service arrived at the aircraft, the crew stood outside the aircraft, physically unharmed. The rescue personnel took care of the crew and cut off the power in the aircraft. Foam extinguishing agents were then applied to reduce the risk of fire when the aircraft was to be moved.

The resources from the Svedala Rescue Service, that were alerted, did not need to respond to the rescue.

The ELT[23] manufactured by Artex ME406 ELT were not activated.

1.15.2 Position of crew and passengers and the use of seat belts

Both pilots used four-point belts during landing.

1.16 Tests and research

1.16.1 Landing Gear

In connection with the landing, the landing gear collapsed, causing damage to the landing gear mechanism. To get the main landing gear to the down and locked position, the landing gear hand crank was cranked 24 turns counter clockwise. During tests, main landing gear could also be extended and retracted with the electric actuator. When the nose landing gear was moved to the up position, the mechanical indicator indicated the position fully up. Apart from the damage that occurred in the accident, no technical fault has been found on the actuator or on the landing gear mechanism.

1.16.2 Electrical system

During inspection and testing of the aircraft's electrical system and components, the following were found:

- Without load, the batteries had a voltage of 10 volts each.
- The indication of the load meters where normal.
- The indicator of the voltmeter was normal.
- Physical verification of wiring behind the instrument panel, engine compartments and from the positive terminal of the battery to the main busbar was performed without remarks.
- No faults on the alternators have been detected.

[23] ELT (Emergency Locator Transmitter)

- During function check of the electrical system, the transponder was stopped functioning when the voltage became less than 9.5 volts and the DME at 7.2 volts.
- During a function check of the battery relay, the connection closed at 12.9 volts and opened at the voltage 3.2 volts.
- Both voltage regulators were tested for function, without remarks.

Test of alternator system fault indication "ALT OUT"

The conditions for the test were as follows. The battery was fully charged, the battery/alternator switch and the switch for each alternator were in the on position. Both alternator circuit breakers were pulled. During the test, the voltage was regulated by means of an external power supply from each alternator's "AUX" line.

On the left side, where a fuse had melted, it could be stated that the "ALT OUT" lamp remained lit up to maximum voltage of 14 volts.

The same test was performed for both sides, but with a functional fuse, which resulted in the "ALT OUT" lamp for the left side was extinguished at a voltage of 9.8 volts and the right side at 9.0 volts.

Test of alternator circuit breakers

The two alternator circuit breakers (50 amps) which were found in the tripped position during the technical examination were dismantled in order to be tested.

The circuit breakers were powered to measure the voltage difference across the circuit breaker, this to calculate the resistance through the breaker at different loads.

Both circuit breakers had at least twice as high resistance compared to the specification for an equivalent fuse. The left breaker had the highest resistance of the two. Some values were more than four times higher than the specification. There were also large variations in resistance after the breaker had tripped and was reset.

Function check was also performed to see at which current each fuse tripped.

At a load of 40 amps, the left alternator breaker tripped just before seven minutes had elapsed. In order for the left breaker to trip, it had to be subjected to vibrations.

At a load of 40 amps for 20 minutes, the right alternator breaker did not trip even when subjected to vibrations. The current was then increased to 45 amps and then the breaker tripped after 40 seconds.

1.16.3 Load calculation

How much capacity a battery has is affected by several factors. One of the factors is the ambient temperature, where a lower temperature reduces the capacity of the battery. Another factor for the battery's capacity is how much load the battery is exposed to. At high loads, such as during engine starts, the capacity drops significantly more than at low loads for a long time. According to the specification, the maximum capacity of the batteries must withstand a load of 20 amps for one hour or 32 amps for half an hour. The capacity of the battery before flight could not be determined.

During the technical investigations of the aircraft, the load was measured for different electricity consumers in the aircraft. From these measurements and information from the manual regarding the electricity consumption of components, calculations have been performed to find out the total electricity consumption for the flight in question, if only the battery has supplied the aircraft with voltage. The calculation is reported in the diagram below and is based on interviews, information from ATC communication and radar tracks.

The fact that the aircraft was inside the hangar with no heating meant that the aircraft's batteries probably had a few degrees higher temperature than if it would have been outdoors, which has been taken into account.

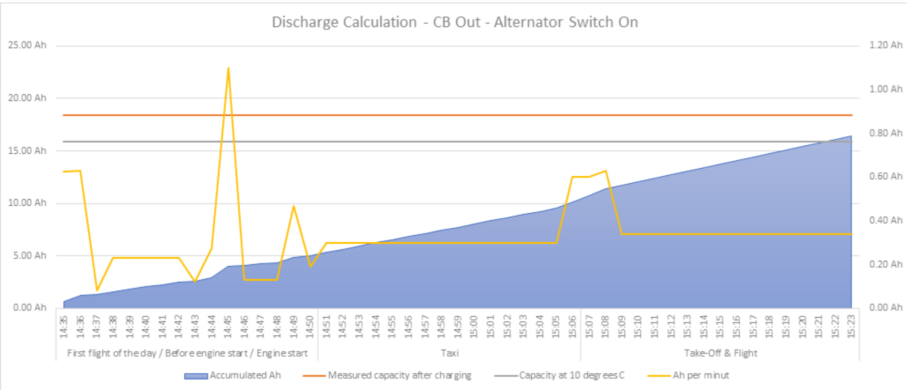

Figure 17. Calculation of discharge for the battery.

1.17 Organisational and management information

1.17.1 Generally

At the time of the accident the school was an approved training organisation with a valid training certificate issued by Transportstyrelsen with the number SE.ATO.030.

The school held a permit to perform training on the actual accident flight and the training were part of the IR[24](A) MEP [25](land) education.

[24] IR (Instrument rating)
[25] MEP (land) – Multi Engine Piston (land)

Different educations were offered by the school in the range from Private Pilot license to Commercial Pilot License and other specialized educations for pilots.

The school started in 2012 and where since 2017 under new management. The Accountable Manager (AM) and Safety Manager (SM) had not previously worked within the framework of a safety management system in the aviation industry.

The instructor for the accident flight where Head of Training (HT) and Chief Flight Instructor (CFI) when SE-LUX were introduced into the business. HT and CFI were replaced with other persons before tha accident during 2019.

1.17.2 The Management System

The management system was described in different manuals:

- OM, Operations Manual, the manual, describing the school.
- SMSM, Safety Management school's Manual, describing the Safety Management System.
- A number of TM, Training Manuals, describing the theoretical and practical courses.

Operational Manual (OM)

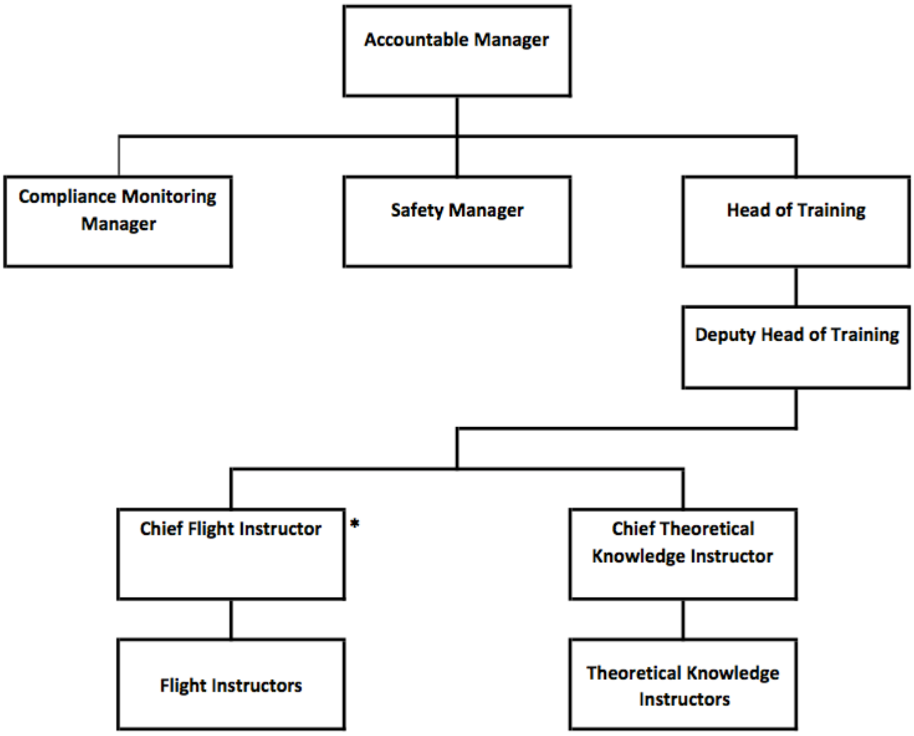

Figure 18. The schools management system structure.

Some positions in the management system were held by the same person. Accountable Manager also held the Chief Flight Instructor position and in addition were the Deputy Head of Training. Safety Manager also held the Compliance Monitoring Manager position. Head of Training had a 50 percent position and worked three weeks at the school and then was absent from school for three weeks, when he flew commercially for another company. This was approved according to current regulations.

With regard to the Commander's responsibilities, the handling of the aircraft and emergency procedures, the following is stated in the operational manual regarding checklists.

A:8 RESPONSIBILITIES OF PIC[26]

> *Be responsible for the normal operation of the flight, including the normal operation of the aircraft, reading of checklists, listening radio watch, etc.*

B:2 AIRPLANE HANDLING

> *Before any flying exercise, Daily Inspection shall be performed. Any pilot shall be well familiar with, and use, pertinent checklists. Respective airplane's POH shall be used.*

B:3 EMERGENCY PROCEDURES

> *For practical aircraft handling procedures, see respective airplane's POH.*

During interview the operations manager has stated that the aircraft's flight manual (POH) took precedence over checklists and SOPs.

Safety Management System Manual

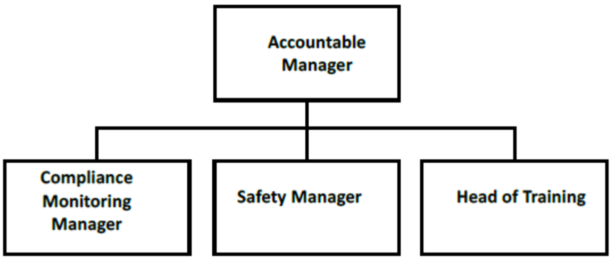

Figure 19. Safety Management structure.

The Safety Review Board was a high-level safety committee composed by the members of the Safety Department. The Safety Review Board meet regularly every 12 months to discuss, evaluate, assess and to find the correct controls and mitigations to the high-level safety concerns discovered in the previous period. Supplementary meetings could be organized if deemed necessary.

[26] PIC (Pilot in Command)

The Safety Manager reported directly to the Accountable Manager and was responsible for the safety management system implementation, administration and maintenance.In the SMSM there was a risk assessment model where risk was assessed in terms of severity and probability and a risk assessment matrix, used to determine the overall level of risk. Risk was also handled in accordance to the method ALARP[27].

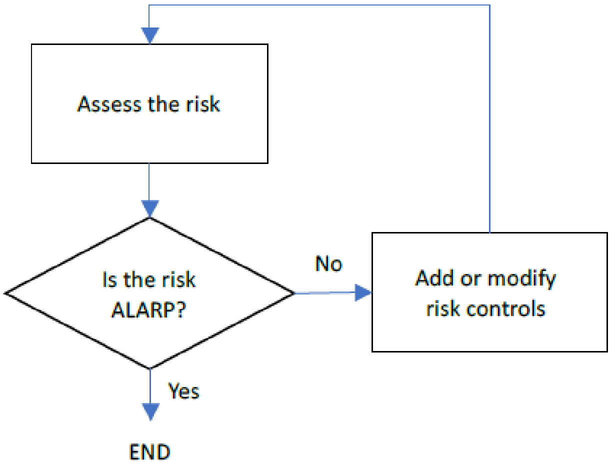

Figure 20. The ALARP process.

When identifying risk control measures, any new risks that may arise from the implementation of such measures (“substitution risks”) should be identified.

The school used a risk management log to document hazards and risks that SRB handled. The log described each identified event or hazard, after which existing routines and barriers that controlled the risk were identified, i.e. a root cause analysis. Finally, the risk was assessed using the school’s risk management model. If the risk was considered to be as low as practically possible (ALARP), the risk was acceptable. If the risk was not considered ALARP, a plan was documented with measures to reduce the risk. When the measures were implemented, this was documented and a new assessment of the risk was performed. If the risk was considered ALARP and accepted, the operation could continue.

In the school’s risk management log, there were two occasions that describe events related to the landing gear on the current aircraft type.

The first incident concerned an occasion where the landing gear could not be extended using normal procedures. Existing routines and barriers were considered to follow emergency procedures using standard procedures (SOP) and the aircraft manual (POH). No root cause could be identified and the level of risk analysis was that further evaluation would take place before the risk was accepted. The plan to reduce the risk was to point out the importance of following emergency procedures

[27] ALARP (As low as reasonable practicable)

and reading the POHs and checklists before flying. The plan also included placing a separate emergency checklist in the aircraft and distributing it to instructors and students via MyWeb log. These measurees were performed and the risk was considered to be ALARP.

The second incident concerned an occasion where a student could not see if the nose gear was in a down and locked with a mirror on the engine gondola. Existing routines and barriers were that there were a mirror installed and the landing gear was working normally. The root cause was considered to be that the student was inexperienced and the flight was performed during night time. The risk was considered acceptable, but as a further risk mitigation action a mirror was installed on the right engine gondola for the instructor and a conversation with the flight instructors would be implemented regarding decisions on the suitability to fly night qualification on the first multi-engine flight. These measures were performed and the risk was considered to be ALARP.

To ensure safety, there were some tools described in SMSM such as safety performance indicators (SPI), safety data from various sources, internal audits, change management (MOC) and continuous improvement.

No documented risk analysis or MOC were performed at the introduction of the aircraft in question at the school. The aircraft used by the school was from 1969 and had a history of problems with the landing gear. The school had not previously used the aircraft type.

All personnel within the organization received safety training related to their safety responsibilities. Security information was provided through security meetings, security reviews, newsletters and security bulletins. Below is a compilation of the safety bulletins sent out to students and instructors with events that historically have been related to the landing gear for the aircraft in question at the school before the accident.

DATE	TITLE	INFORMATION
20180904	GEAR FAILURE LUX	During ME lesson landing gear refused to extend despite attempts to lower + shake it down. Gear extended manually. We wish to stress the importance of following emergency procedures and reading poh and checklists before flight. EMERGENCY CHECKLIST FOR GEAR FAILURE has been aded to the checklist for the aircraft, put in plane and distributed to student and teachers via myweblog. Version 4.4 is now valid.
	NOSE GEAR LUX	During ME lesson a student had trouble seeing if the nose gear was down in the mirror, an extra mirror has been put on the instructors side for extra safety.

Figure 21. The safety bulletin.

1.17.3 The school's standard operational procedures (SOP) and checklists

The school had standard routines described in a document called *"Standard Operating Procedures"* (SOP). This document was not described in the school's manual, but was accepted as one of the school's official documents.

In the SOP, in addition to the Operational Manual (OM), the handling of checklists was described.

- *"Checklists for VFR flights are Read and Do and shall be done with list in hand."*
- *"All items with a "►" are by heart items and shall be performed without delay."*
- *"Checklists shall be read aloud, list in left hand, thumb in text."*
- *"Failures shall be remedied with checklist, no own procedures."*
- *"If no checklist exist, consult POH."*

The plane had a checklist designed by the school. The checklist contained routines for both normal, abnormal and emergency situations.

The "Before Engine Start" checklist (see Figure 22) was applied before engine start. Several points were checked, including *"Warning Lights" and "Fuse Panel"* (Circuit Breaker Panel).

According to the school, the item *"Warning Lights"* tested the; *"ALT OUT"* lamps in the alternator warning system, the *"Tank Selector Valve"* lamp and the *"Cowl Flaps"* lamp.

The test of the "ALT OUT" lights, at this stage could not be performed because the alternator switches were off (see section 1.6.4). According to the checklist, the alternators are switched on after engine start.

BEFORE ENGINE START	
Documents	- ON BOARD
Gear	- DOWN
Battery Switch	- ON
Lights	- AS REQ
Pitot C & Rudder L	- ON BOARD
Instruments	- CHECKED
Warning Lights	- CHECKED
Radios & Autopilot	- SET & OFF
De-Ice Panel	- CHECKED
Fuse Panel	- CHECKED

Figure 22. The checklist before engine start with two items marked with red.

The school's checklist that concerned emergency procedures was marked with a red frame. Figure 23 is the school's emergency checklist for landing gear failures. The checklist does not comply with any procedure in the flight manual.

GEAR FAILURE CHECKLIST

▶ LDG GR MTR CRCT BRKR	- PULL
▶ LDG GR HANDLE	- DOWN
▶ COVER OF HANDCRANK	- REMOVE
▶ MECHANICAL INDICATOR	- CHECK
▶ GEAR POSITION LIGHTS	- CHECK
▶ WARNING HORN	- CHECK
▶ LDG GR RELAY CRCT BRKR	- CHECK
▶ LDG GR RELAY CRCT BRKR	- CHECK

Figure 23. The flight school interpretation of the checklist.

1.17.4 *The ATO:s aircraft training*

The school carried out a theoretical technical training for the aircraft through a instructor-led lesson with the help of a Power Point Presentation which also included certain operational parts. Facts about how detailed the teaching has been cannot be determined with certainty.

In the case of multi-engine single-pilot aircraft, the theoretical test shall be in writing and the number of multiple-choice questions shall be determined by the complexity of the aircraft in accordance with the regulatory requirement of FCL.725. The ATO is required to demonstrate that he/she has the theoretical level of knowledge required to operate the applicable class or type of aircraft safely.

Technical training on type

The theoretical part included information about the mechanical landing gear indicator. However, the mirrors on the motor gondolas were not mentioned, which were part of the school's routines for seeing the position of the nose wheel.

A number of pictures in the presentation dealt with the electrical system. One picture stated that the aircraft would have two 25 a/h batteries in series. However, the aircraft in question had two 20 a/h batteries in series. In the same picture, *"ON/OFF (Alternator still online)"* is indicated next to a picture with the main battery/alternator switch circled. However, if the main battery/alternator switch is switched off, the alternators cannot work.

In another image of the presentation, it was stated that the load meters showed the percentage of load in the system. However, the load meters in the aircraft showed load in amperes (see section 1.6.4). Furthermore, it was stated that the *"ALT OUT"* lights would light up when the alternator switches are switched off or that the current in the system is low, which is not in accordance with the system's function.

After completion of the technical training, a technical test followed which could be performed with the support of the manuals. The test contained 20 questions, and to pass the test it required at least 75 percent correct answers. The student's result was 100 percent.

The test contained two questions related to the electrical system and no questions related to the landing gear system. According to the flight school, one of the two questions regarding the electrical system was deliberately designed so that there was no correct answer. The school's idea was that the student should draw attention to the fact that the question did not apply to the aircraft in question and that there was no correct answer. Only if the student drew the school's attention to the fact that there was no correct answer did the student get the question right.

The question was under what conditions the *"yellow battery charge rate caution light"* was lit, a warning light that was not installed in the aircraft in question. The student chose one of the options on the multiple-choice question.

The instructor did not have a documented technical course for the aircraft type. It was explained, by the school, that the instructor was the Head of Training (HT) and the Chief Flight Instructor (CFI) when SE-LUX was implemented in the organization and that he was involved in the design of the training material.

Operational training on the type

The operational training was integrated into the briefing before each flight lesion

1.17.5 Regulation

Flight operations that are to be undertaken with the EU are governed by the common aviation provisions contained within Regulation (EC) No 2018/1139 of the European Parliament and of the Council on common rules in the field of civil aviation. Compliance with these provisions is supervised at the EU level by the EASA[28], which also supervises the member states' national aviation organization and supervisory authorities.

[28] EASA (European Aviation Safety Agency)

Training operations of the type conducted at the school in question are regulated by Commission Regulation (EU) No 1178/2011, Annex VII, Part-ORA, Subpart ATO. This sets out the requirements that an approved training organization must fulfil in order to receive permission to conduct flight training. In the requirements it is included that the organization has a safety management system (SMS) and compliance monitoring system (CMS).

The management system shall correspond to the size of the organisation and the nature and complexity of its activities, taking into account the hazards and associated risks inherent in these activities.

The training organization are considered as Non-Commercial air operation with other than aircrafts complex motor powered aircraft and is regulated by the Commission Regulation (EU) 965/2012, Annex VII, Part-NCO.

The national supervisory authority for aviation, i.e. the Swedish Transport Agency in Sweden, has to approve the planned operations and also supervise them while operational.

1.17.6 Operational Supervision

According to the regulations in Commission Regulation (EU) No 1178/2011, Annex VI, Part-ARA, Subpart ATO, the national supervisory authority shall conduct regular supervision of flight training operations. The main aim is to monitor the organization’s compliance with both regulations, procedures and systems that the organization describes in its own manuals.

An operational Supervision includes a review of the company’s SMS and CMS. The operator must show how the organization assesses and manages any flight safety risks that may arise in the operation. The operator must also demonstrate a plan for systematic safety work, where operations are continuously monitored and deviations and risks can be captured. The system should minimize the risks in the operation and also address the identified safety deficiencies.

The Operational Supervision is carried out on site at the organization by at least two flight inspectors, one of whom conducted the previous year’s supervision.

During the operational inspections in 2018 and 2019, certain deviations were noted with regard to risk management and risk reduction. Among other things, it was noted that operational risks were not taken into account when introducing a new aircraft and that the risks described in the risk management log could not be demonstrated as implemented, despite the fact that risks were documented as acceptable. These deviations were noted as remedied.

1.18 Additional information

1.18.1 Previously reported landing gear problems with SE-LUX

On two previous occasions, two reports have been received by the Swedish Transport Agency regarding incidents regarding landing gear problems with SE-LUX.

In 2014, the aircraft SE-LUX landed at Dala/Järna Airport. At that time, the pilot had a green indicator light and an audible warning sounded during the flare according to the pilot. SHK did not investigate the incident as there were not sufficient reasons for investigation.

On 26 August 2018, the pilot on SE-LUX reported that the landing gear could not be extended in flight. The crew then managed to extend the landing gear and was able to land at Malmö Airport without further remark.

1.18.2 Low volt warning

In the national regulation LFS 2007: 58 and general advice on private flying with aircraft, there was an operational requirement for operating in IFR and/or darkness, on a warning device (light, sound or flag warning) for a distinct indication if the generator system is not capable of charging the battery or keep it charged. However, LFS 2007:58 was repealed on 1 October 2019.

While this requirement was in force in Sweden, a simple low-voltage warning system was installed to detect if the voltage is less than 13 volts for a 14-volt system or 25 volts for a 28-volt system. When these values fall below, an warning light comes on to clearly alert the pilot that there is a problem with the charging system.

A similar requirement is not included in EASA’s operational regulations and SE-LUX did not have such a warning installed.

The Beech 95 was certified with CAR 3, dated May 15 1956, the US is the State of Design. In the architecture of the electrical system, there was no distinct indication if the alternator system is unable to charge the battery or keep it charged.

Current CS-23 rules do not allow, according to EASA, to certify an architecture of the electrical system that was installed on SE-LUX.

The certification requirements CS23.1351, which are the certification requirements for this aircraft category, state, among other things, the following regarding the alternator system.

> *Generator System. There must be at least one generator/alternator if the electrical system supplies power to circuits necessary for safe operation. There must be a way to immediately give a warning to the crew in the event of a fault in any generator/alternator.*

Each generator/alternator must have a surge protector designed and installed to prevent damage to the electrical system.

In the event of a complete loss of the primary electrical system, the battery must be able to provide 30 minutes of electrical power to the loads necessary for continued safe flight and landing.

The time period of 30 minutes includes the time required for the pilot (s) to detect the loss of generated power and take appropriate load balancing.

These requirements apply to both single and multi-engine aircraft.

1.18.3 Actions taken

None.

1.18.4 Similar events

On December 19, 2002, a Finnish-registered Beechcraft 55 returned ten minutes after take-off from Stockholm/Bromma Airport in darkness due to an electrical fault and belly landed. See accident report RL 2004:01.

1.19 Special methods of investigations

None.

2. ANALYSIS

2.1 Initial starting points

Through the registrations that have been analysed together with information from interviews with e.g. the crew, the course of events has largely been determined. It is clear that the aircraft had a total electrical failure during the flight and that the aircraft landed without the landing gear being fully extended and in a locked position. The questions that SHK primarily has to answer are the reason for the loss of electrical power and the fact that the landing gear were not fully extended, and why this was not noticed. As part of the explanation, there are also reasons to analyse in more detail the training on the aircraft that the crew had received from the flight school and the safety management system's ability to identify risks in the operation.

2.2 Why did the electrical system seize functioning?

From the load calculations that have been made (see section 1.16.3), it appears that the batteries were most likely the only electrical source during most of the flight.

The fact that the batteries have not been charged during the flight can be explained by that both circuit breakers for the alternators had been tripped, whereby the busbar was not supplied with voltage from the alternators which would have charged the batteries. After the circuit breakers tripped, the batteries were the only source of electrical power. When the circuit breakers tripped has not been possible to determine.

The SHK's investigations (see section 1.16.2) show that the circuit breakers did not meet the specification for an equivalent breaker in terms of resistance through the breakers. In addition, both breakers tripped before the specified maximum load was reached. This is most likely due to the formation of oxide on the contact surfaces inside the breakers, which gives a higher resistance, which leads to the breaker tripping before the specification is reached. The fact that the measured values during the tests varied is also most likely due to the oxide formation.

At the start of the right engine, several attempts were made before the engine finally started. These start-up attempts have reduced the capacity of the batteries. How low the capacity has been after these start-up attempts is, difficult to determine. A low capacity of the batteries when switching on the alternators can lead to a high load on the electrical system in the form of high current. This can cause a circuit breaker that does not meet the specification to trip without there being any other fault in the system.

It has not been possible to determine with certainty why the electrical power loss occurred.

2.3 Why did the crew not notice that the batteries were the only electrical source?

During interviews, the crew said that they did not during any part of the flight notice that any of the warning lights *"ALT OUT"* were lit. It seems unlikely that the warning lights were on and that neither the instructor nor the student noticed it.

During an investigation of the electrical system, SHK found that a fuse had melted in the system for the alternators' fault indication *"ALT OUT"*, which would have resulted in the left *"ALT OUT"* warning being lit if the left alternator switch was on (see section 1.12.3).

In the opinion of SHK, there are two alternatives that could explain why the warning light does not come on even though the alternators did not contribute to the aircraft's power supply. One is that the switches for the alternators have been on and the circuit breakers for the alternators were tripped and that the fuse had melted in connection with the power failure. The second is that the switch on the right alternator was on and the switch on the left alternator was off, and that both circuit breakers for the alternators were tripped. SHK has not been able to determine which alternative was available at the time.

The only possibility for the crew to see that the alternator system was unable to charge the batteries was to regularly check the load meters and the voltmeter. The load meters' design of the scale can be difficult to read, as the scale line for 0 could easily be mistaken for 12.5 amperes (see Figure 8 in section 1.6.4). In addition, load meters and voltmeters are not normally included in the instruments that the pilot continuously monitors during an instrument flight. This may explain why the lack of charge was not noticed.

A clear warning system for low battery voltage would probably have notified the pilots that the batteries where not charging.

For this reason, EASA should evaluate and decide whether a warning system that clearly indicates that the battery is not being charged should be introduced as an operational requirement for aircraft's operated under instrument flight rules or in darkness.

2.4 Why was it not possible to manually extend the landing gear to the fully down position?

Due to the electrical power failure, it was no longer possible to use the electric landing gear actuator to extend the landing gear. Instead, the crew had to use the manual hand crank.

After the accident, it was found that the hand crank was 24 turns from the fully extended position. The inertia that the student felt and that he experienced as an end position, was probably the natural mechanical resistance that arose in the landing gear mechanism when it comes to the locking position. The hand crank used to manually extend the landing gear was not stowed after the student felt that the landing gear was fully extended. Since the landing gear was not locked in the fully extended position, it is possible that the hand crank rotated back a number of turns when the landing gear was loaded and compressed during the landing phase.

The checklist was not fully followed. The mirrors fitted to visually check the landing gear were used instead of the visual mechanical landing gear indicator to which the checklist referred to and of which the crew was unaware of.

Why all the necessary measures were not carried out may be due to lack of knowledge about the aircraft's system in combination with a stressed situation in a noisy environment in darkness.

2.5 Aircraft training

As stated above, neither the student nor the instructor had sufficient or correct knowledge of how the electrical and landing gear system worked. The checklist for manual extension of the landing gear was performed, but the crew did not understand the meaning of all items.

There is therefore reason to analyse the flight school's training of the student and the instructor in more detail.

Before starting practical training, the flight school had a technical training of the type for one day. During the training, which was led by a instructor with a PowerPoint presentation as a basis, technical parts of the aircraft and certain operational limitations were presented. The operational part, which describes how the aircraft is to be operated and the handling of emergency procedures, was part of what was to be reviewed before each flight. In retrospect, it can be stated that the handling of the emergency that arose had shortcomings. Handling the aircraft in normal and abnormal operations is a large part of the training. The instructor may miss essential parts if this part is only performed in connection with the flight session.

The technical training that the school conducted had several tasks in the training material that did not correspond to how the electrical system worked (see section 1.17.4). There was also information in the flight manual that was not correct regarding the electrical system. However, it is not possible to say whether these deviations have affected the crew's handling of the electrical system. Based on the information in the training and the flight manual, however, it is reasonable to assume that the crew expected at least one of the warning lights to be lit when the alternators did not contribute to the power supply, which may explain why the fault was not identified.

With regard to instruction and training for manual landing gear extension, neither the instructor nor the student had performed the procedure, nor did they have knowledge of the mechanical indicator that showed the position of the landing gear. Instead, the mirrors on the cowling were used to try to see if the landing gear was fully extended. The system with mirrors is not useful in darkness and is not something that the type certificate holder recommends. The mechanical indication is included in the documentation for the technical course. According to interviews the mirrors on the engine cowlings were discussed for most as the method for seeing if the landing gear was extended. That is in accordance with what appears from the flight school's risk management log and action program. This may be an explanation for the crew not being aware of or remembering the mechanical indicator.

2.6 The safety management system

From the previous section it appears that there were shortcomings in the training both in terms of the electrical system and the handling of the landing gear in an emergency. The basic idea of a safety management system is to proactively identify risks in the business and then take mitigating measures. If events occur, measures must be taken to minimize the risk of a recurrence.

Creating a working safety management system that is both documented and working in practice can be difficult. The fact that few people are involved is not in itself unique in small businesses, but the experience and understanding of safety management systems can be facilitated by previous experience.

The maturity of the management system can be reflected partly in the results of the operational inspections and partly in the internal management of risks documented in, among other things, the flight school's risk documentation risk management log.

In the risk management log, there were two incidents that relate to the accident. The identified risks were identified due to events that occurred. One incident concerned an occasion where the landing gear could not be extended with normal procedures. The second concerned an occasion when a student could not see if the nose landing gear was down using the mirror on the engine cowlings.

The first event resulted in the development of a checklist to reduce risks and increase clarity. However, the checklist did not comply with any procedure in the flight manual and lacked e.g. the essential information in the flight manual on how to handle the hand crank.

There is also a lack of clarity on how the checklists should be handled and how they relate to the flight manual. The operational manual states that both the flight manual and the checklists must be used. The SOP states that the checklist has priority and that if one does not exist, the flight manual must be consulted.

When asked by SHK, the flight school's management has stated that the flight manual must always be used regardless of whether there is a checklist. In the opinion of SHK, the management of the operations in this part is unclear and may explain why the flight manual was used and not the special checklist that was produced as a risk-reducing measure.

In an emergency, it is especially important that there is no doubt for the pilot which instructions to use. There is rarely time to consult and compare the contents of checklists and manuals in such a situation and on that basis decide on what measures to take.

In the second incident, the focus in the risk management log was on mirrors on the engine cowlings as a method of checking that the landing gear was down. The method and barrier specified in the flight manual, i.e. the manual nose landing gear indicator, was not mentioned and was not included in the Safety Bulletin that was communicated. The manual nose landing gear indicator was also not adjusted to show the correct extended position. This may indicate that the nose landing gear indication was either not considered functional, or that one was not aware of or did not understand its function. All in all, this may explain why the crew tried to verify the position of the landing gear with the help of mirrors. A method that did not work in darkness.

In this context, there is also reason to note that there was no documented risk analysis from when the aircraft was taken into operation.

In view of the fact that during the operational inspections it has been noted that no risk analysis was carried out when introducing a new type of aircraft. It would have been appropriate to performed a risk analysis on SE-LUX. At the same time, it is not certain that the operational and technical risks that the investigation highlighted had been found. However, the preconditions for this are greater with a systematic and structured system with documentation of implementation.

2.7 The rescue operation

The investigation has not revealed any indications of shortcomings with regard to the implementation of the rescue operation.

3. CONCLUSIONS

3.1 Findings

a) The instructor were qualified to perform the flight.
b) The aircraft had a Certificate of Airworthiness and valid ARC.
c) The flight school were an approved training organization (ATO).
d) The flight was the fifth training flight for the student, but the first under instrument flight rules (IFR) on type.
e) The intention of the training flight was to practice airwork and instrument approaches.
f) While starting the engines, several start attempts were made on the right engine before it started.
g) After takeoff it became dark.
h) About sixteen minutes after take-off the aircraft gradually lost electrical power.
i) After the electrical power failure the flight were performed with only external references.
j) After the transponder response ended, ATC was able to see the aircraft via primary radar for four minutes before the aircraft dissapeared from the radar.
k) The noise level became high after the electrical power loss when the intercom system seized to function and it became difficult to communicate.
l) The instructor took over the controls of the flight and ordered the student to perform the items for the manual landing gear extention.
m) The item on the checklist that handles the mechanical indicator, to check the position of the landing gear, was not known by the instructor or the student.
n) The mirrors mounted on the engine cowlings were not described in the aircraft manual.
o) The ATC regained radar contact with primary radar when the aircraft were on four nautical miles final.
p) The ATC gave cleard to land in the form of a green light.
q) Upon landing, the air traffic controller in the Tower saw sparks from the aircraft and alerted the rescue service.
r) The instructor and the student left the aircraft without turning any switches off.
s) The rescue service skimmed the runway.

3.2 Causes/Contributing Factors

The accident was caused by the pilots lacking sufficient knowledge about the manual landing gear extension function, which led to the landing gear not being out and locked before landing.

Contributing factors have been:

- The instructions in the aircraft's flight manual for the electrical system did not correspond to how the installed system worked.
- Lack of knowledge about the electrical system.
- Lack of a warning system that clearly indicates that the battery is not being charged by the alternators.
- Ambiguities in the training organization's instructions for the operation, risk management work and training.

4. SAFETY RECOMMENDATIONS

EASA is recommended to:

- Evaluate and decide whether a warning system that clearly indicates that the battery is not being charged by the alternators can be introduced as an operational requirement for aircraft operated under instrument flight rules or in darkness. *(RL 2020:11 R1)*

The typecertificate holder Textron Aviation Inc is recommended to:

- Update the POH so that the function of the ALT OUT warning corresponds to the correct serial number of the aircraft. *(RL 2020:11 R2)*

The Swedish Transport Agency is recommended to:

- Inform operators flying under the instrument flight rules or darkness about the risks of aircraft types that do not have a low voltage warning installed. *(RL 2020:11 R3)*

The Swedish Accident Investigation Authority respectfully requests to receive, **by 17 February 2021** at the latest, information regarding measures taken in response to the safety recommendations included in this report.

On behalf of the Swedish Accident Investigation Authority,

Mikael Karanikas Johan Nikolaou