

Final Report

T-50 RUNWAY EXCURSION DURING TAKE-OFF FROM CHANGI AIRPORT

6 February 2018

AIB/AAI/CAS.156

Transport Safety Investigation Bureau
Ministry of Transport
Singapore

17 October 2018

The Transport Safety Investigation Bureau of Singapore

The Transport Safety Investigation Bureau (TSIB) is the air and marine accidents and incidents investigation authority in Singapore. Its mission is to promote aviation and marine safety through the conduct of independent investigations into air and marine accidents and incidents.

The TSIB conducts air safety investigations in accordance with the Singapore Air Navigation (Investigation of Accidents and Incidents) Order 2003 and Annex 13 to the Convention on International Civil Aviation, which governs how member States of the International Civil Aviation Organization (ICAO) conduct aircraft accident investigations internationally.

The sole objective of TSIB's air safety investigations is the prevention of aviation accidents and incidents. The safety investigations do not seek to apportion blame or liability. Accordingly, TSIB reports should not be used to assign blame or determine liability.

Table of Contents

SYNOPSIS	3
1 Factual information	4
1.1 History of the flight	4
1.2 Injuries to persons	6
1.3 Damage to aircraft	6
1.4 Other damage	7
1.5 Personnel information	7
1.6 Aircraft information	8
1.7 Meteorological information	9
1.8 Aerodrome information	9
1.9 Recorded Information	9
1.10 Medical and pathological information	10
1.11 Additional information	10
2 Analysis	12
2.1 Cause of initial right veer during take-off	12
2.2 Pilot's actions after aircraft's initial veering	12
3 Conclusion	14
4 Safety Actions	15
5 Safety recommendation	16

SYNOPSIS

At about 13:23 hours on 6 February 2018, one of the eight T-50 aircraft of the flying display team from the Republic of Korea Air Force participating in the Singapore Airshow veered to the right of Runway 20R in Changi Airport during take-off for an aerial display. Subsequently, the aircraft zigzagged on the runway for about 750 metres before skidding off the left edge of the runway. It then flipped over and came to rest on the grass turf beside the runway. Shortly after, the tail section of the aircraft caught fire, which was extinguished by Changi Airport's airport rescue and firefighting service.

The pilot, who was the sole occupant of the aircraft, extricated himself and was not injured.

The Transport Safety Investigation Bureau classified this occurrence as an accident.

AIRCRAFT DETAILS

Aircraft type	:	T-50 Golden Eagle
Operator	:	Republic of Korea Air Force
Date and time of incident	:	6 February 2018 approximately 13:23 hours
Location	:	Changi Airport, Singapore
Type of flight	:	Aerial display
Persons on board	:	One

1 FACTUAL INFORMATION

All times used in this report are Singapore Local Time (LT). Singapore Local Time is eight hours ahead of Coordinated Universal Time (UTC).

Information pertaining to pilot's action during the occurrence and aircraft systems were provided by the Republic of Korea Air Force (ROKAF) Safety Investigation Board (SIB).

1.1 History of the flight

1.1.1 A flying display team of eight ROKAF T-50 aircraft participated in the Singapore Airshow 2018. The team was scheduled to perform an aerial display in the afternoon of 6 February 2018.

1.1.2 The team received clearance at 13:18 hours from Changi Tower to line up on Runway 20R of Changi Airport, in preparation for take-off. The team planned on a formation take-off in three groups. The first two groups comprised three aircraft each, while the last group comprised two aircraft (see **Figure 1**).

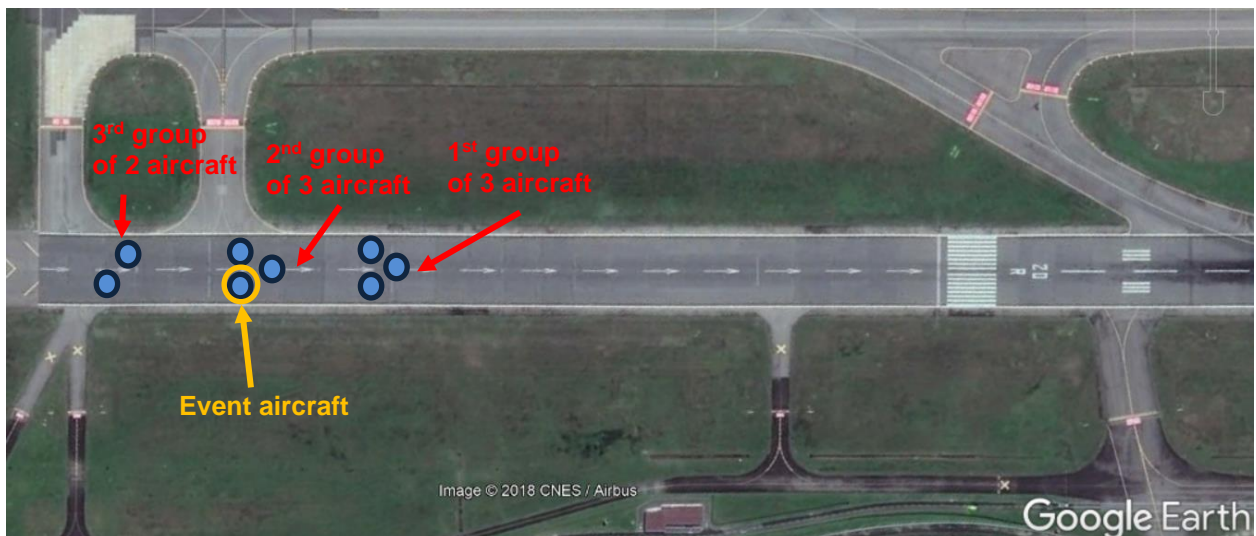


Figure 1: Approximate position of aircraft before take-off

1.1.3 At about 13:21 hours, Changi Tower issued a take-off clearance to the team. Thirty seconds after receiving the clearance, the first group of aircraft commenced take-off roll followed by the second group of aircraft eight seconds later.

- 1.1.4 The three aircraft in the second group were able to stay in formation during the initial take-off roll. After rolling for approximately 350 metres, the pilot of the aircraft on the right of the formation disengaged the nose wheel steering (NWS) system (**Point A in Figure 2**) to switch to using the rudder for directional control¹. The aircraft started to veer towards the right edge of the runway.



Figure 2: Path of event aircraft along runway

- 1.1.5 Shortly after, the pilot reduced the engine thrust to idle, deployed the speed brakes and provided full left rudder pedal input to attempt to steer the aircraft back towards the runway centreline (**Point B in Figure 2**).
- 1.1.6 As the aircraft approached the right edge of the runway, the pilot re-engaged the NWS and stowed the speed brakes (**Point C in Figure 2**). As the aircraft started to move to the left (back towards the runway centreline), the pilot applied full engine thrust (**Point D in Figure 2**) to resume the take-off.
- 1.1.7 Thereafter, the aircraft skidded along the runway in a zigzag manner for approximately 750 metres (see **Figure 2**). The aircraft eventually skidded off the left edge of the runway and flipped over, coming to rest on the grass turf beside the runway (see Error! Reference source not found.). Shortly after, the tail section of the aircraft caught fire.

¹ The directional control of an aircraft on ground can be achieved using either the rudder or the NWS. Typically, a pilot would use NWS at low speed and rudder at higher speed. This is because at low speed (as is the case during taxiing or initial take-off roll), the rudder is ineffective for directional control as the aerodynamic force on the rudder is not large enough. Only after the aircraft has gained speed would the pilot switch to using the rudder for directional control.



Figure 3: Final position of the aircraft

- 1.1.8 The first foam tender from the airport rescue and firefighting service (ARFF) arrived on scene in about 90 seconds and extinguished the fire.
- 1.1.9 The pilot managed to extricate himself from the aircraft.
- 1.1.10 Meanwhile, the remaining two aircraft of the second group continued with their take-off while the third group of aircraft aborted their take-off.

- 1.2 Injuries to persons
 - 1.2.1 There was no injury in this occurrence.

- 1.3 Damage to aircraft
 - 1.3.1 The aircraft was destroyed.
 - 1.3.2 The TSIB investigation team, together with the ROKAF SIB investigators², performed a preliminary inspection of the aircraft on 8 February 2018 before

² Ten ROKAF SIB investigators arrived in the night of 7 February to provide support to TSIB's field investigation. Separately from the TSIB investigation, the ROKAF SIB also conducted an inquiry into the occurrence and shared its findings with the TSIB (see paragraph 1.11).

the aircraft was freighted back to the Republic of Korea on 12 February 2018 for further examination.

Examination of the cockpit

1.3.2.1 The ROKAF SIB investigators did not find any anomaly in the cockpit.

Examination of the aircraft tyres

1.3.2.2 There were wear marks on the aircraft's tyres, consistent with the aircraft's skidding motion.

1.3.2.3 There were no burst tyres. Pressures of the aircraft's three tyres were read. According to the ROKAF SIB investigators, they were within the acceptable range.

1.3.2.4 The nose and left tyres were found to rotate normally. The right brake piston on the right gear was in contact with the brake disc, restricting the free movement of the right tyre. This was assessed to be due to mud that had been compressed within the brake assembly. The mud had probably been stuck to the brake assembly during the aircraft crash sequence.

1.3.2.5 The aircraft was further examined by the ROKAF after it was freighted back to the Republic of Korea. The ROKAF SIB subsequently informed the TSIB investigation team that it could not find any defect in the aircraft.

1.4 Other damage

1.4.1 A runway edge light on the left of Runway 20R was damaged.

1.5 Personnel information

1.5.1 Pilot's information

Gender	Male
Age	32
Total Flying Experience	923 hours
Total on type	177 hours

Flying in last 24 hours	None
Flying in last 7 days	3 sorties
Flying in last 28 days	17 sorties
Flying in last 90 days	53 sorties

1.5.2 The pilot of the accident aircraft, as well as the other pilots in the flying display team, had taken off from Runway 20R previously during their practice sessions for the Singapore Airshow.

1.5.3 According to the ROKAF SIB, the pilot was sufficiently rested and had slept for approximately 9 hours prior to the flying display duties on the day of occurrence.

1.5.4 The pilot was selected as one the flying display pilot in February 2017. He had completed the required training by ROKAF by December 2017.

1.6 Aircraft information

1.6.1 The T-50 aircraft was manufactured by Korea Aerospace Industries (KAI).

Nose wheel steering (NWS)

1.6.2 For the directional control of an aircraft on ground, a pilot would first use NWS, when the aircraft speed was low, and use the rudder at higher speed, as the rudder would be ineffective at low speed.

1.6.3 The pilot would disengage the NWS and start using the rudder for directional control by pushing a switch on the control stick. Before the pilot did so, he had to manually align the nose wheel with the aircraft's nose³. If the nose wheel was not properly aligned with the aircraft's nose at the time of NWS disengagement, the nose wheel would be cocked in this unaligned condition.

1.6.4 If rudder input was made after the disengagement of the NWS and if the NWS was re-engaged, the nose wheel would reset itself at the time of the NWS re-

³ The aircraft did not have a system that could align the nose wheel with the aircraft's nose automatically for the pilot.

engagement to an angle corresponding to the last rudder pedal input.

1.7 Meteorological information

1.7.1 When issuing the take-off clearance, Changi Tower informed the ROKAF flying display team that the surface wind speed was between 16 and 23 knots and wind direction was 30 degrees and that there was a tail wind of about 10 knots.

1.8 Aerodrome information

1.8.1 The aerodrome operator had an optical detection system which provided real-time detection for the presence of foreign object debris (FOD) on the runways in Changi Airport⁴. There was no FOD detected on the runway at the time of the incident.

1.8.2 The aerodrome operator performed a runway friction test after the occurrence and found no anomalies.

1.9 Recorded Information

1.9.1 The TSIB investigation team were provided with the following:

- Video footages from surveillance cameras around the runway provided by the aerodrome operator
- Weather information provided by the local meteorological service
- Recorded air traffic control transmissions
- Aerodrome information provided by the aerodrome operator
- Analysis of the following aircraft recorders by the ROKAF SIB:
 - Voice and Data Recorder (VDR)
 - Airborne Video Solid-state Recorder (AVSR)

1.9.2 The VDR recorded voice and flight data during a flight. The ROKAF SIB reviewed the VDR data⁵ and concluded that there was no evidence of any

⁴ The detection system used an array of cameras to constantly monitor the runway surface. When the system detected a suspected FOD, it would send an alert to the aerodrome personnel on duty, who would check out the suspected FOD and arrange for its removal as necessary.

⁵ Data reviewed included the following:

- Aircraft heading

aircraft system malfunctions, including NWS malfunction, at the time of the occurrence.

1.9.3 The AVSR recorded the aircraft head-up display and audio environment of the cockpit. Parameters that were useful for the TSIB investigation team included:

- Aircraft heading
- Aircraft speed
- Course

1.9.4 The TSIB investigation team was also provided with the AVSR data from an aircraft in the third group taking off, that is, the aircraft behind the occurrence aircraft. The data included video footage of the occurrence aircraft's path during the attempted take-off.

1.10 Medical and pathological information

1.10.1 The pilot underwent medical examinations and toxicological tests after the occurrence. There was no evidence of any medical or toxicological factors that could have affected his performance.

1.11 Additional information

1.11.1 The ROKAF SIB conducted a separate inquiry into the occurrence. It made its findings public on 28 March 2018. The key findings included the following:

- The pilot had disengaged the NWS prematurely when the nose wheel was not perfectly aligned with the aircraft's nose. This resulted in the aircraft veering towards the right initially.
- The pilot attempted unsuccessfully to bring the aircraft under control and eventually lost control of the aircraft.
- The pilot was fixated on the successful completion of the team's flying

-
- Rudder pedal forces
 - Indicted airspeed
 - Engine power
 - Power lever angle
 - Control stick force
 - Acceleration forces
 - Nose wheel steering disengagement switch

display, He should have aborted the take-off, in line with ROKAF's procedures.

1.11.2 The ROKAF SIB also informed the TSIB investigation team of the following:

- The VDR data showed that the NWS was disengaged when the aircraft speed was 51.4 knots and the nose wheel was pointing 1.31° to the right.
- The pilot re-engaged the NWS when the aircraft veered past the right edge line of the runway. The NWS system remained engaged until the aircraft flipped over.

2 ANALYSIS

2.1 Cause of initial right veer during take-off

2.1.1 The aircraft started to veer towards the right edge of the runway as soon as the NWS was disengaged. This was because the nose wheel was not perfectly aligned with the aircraft's nose, having been set at 1.31° to the right at the time of NWS disengagement.

2.1.2 The ROKAF flying display team experienced a tail wind during the take-off⁶. According to the ROKAF SIB, the pilot in the event aircraft has no prior experience taking off with a tail wind in this aircraft type.

2.1.3 As part of the formation take-off procedure, the pilot was maintaining visual reference to the lead aircraft of his group. Even though the actual aircraft speed was approximately 51.4 knots due to the tailwind, the pilot estimated the aircraft speed to be more than 60 knots at the point of disengaging the NWS, based on his previous take-off experience in head wind conditions. As such, there was insufficient aerodynamic forces to correct the direction of travel, when the pilot attempted to correct the veering of the aircraft to the right by applying full left rudder.

2.2 Pilot's actions after aircraft's initial veering

2.2.1 The pilot managed to prevent the aircraft from veering further off the right edge of the runway by re-engaging the NWS. When he re-engaged the NWS, he was providing full left rudder input. This caused the aircraft to swing abruptly towards the left of the runway (see paragraph 1.6.3) after NWS re-engaged.

2.2.2 With the NWS remaining engaged, the pilot's subsequent directional control inputs resulted in over-correction of the aircraft's path of travel, which led eventually to the zigzag motion of the aircraft before it exited the left side of the runway.

2.2.3 According to the ROKAF SIB, the pilot was fixated on the successful completion of the team's flying display, instead of aborting the take-off. This view of the ROKAF SIB was supported by the evidence that the pilot stowed the speed

⁶ According to ROKAF SIB, the aircraft is capable of taking off in such conditions. Five other aircraft in the flying display team had taken off successfully moments earlier.

brakes and applied full engine thrust, consistent with an attempt to continue with the take-off.

3 **CONCLUSION**

From the information gathered, the following findings are made. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

- 3.1 The aircraft veered right initially during the take-off roll, due to the NWS being disengaged when the nose wheel was not aligned with the aircraft's nose and at lower aircraft speed.
- 3.2 The pilot attempted to continue with the take-off instead of aborting it.
- 3.3 The pilot's subsequent inputs over-corrected the motion of the aircraft, resulting in the aircraft becoming uncontrollable and eventually veering off the runway and flipping over.

4 **SAFETY ACTIONS**

During the course of the investigation, the following safety actions were initiated by the ROKAF.

- 4.1 The ROKAF reminded its pilots to comply with the relevant procedures for abnormal situations as stipulated in its standard operating procedures.
- 4.2 The ROKAF also conducted simulator training sessions replicating conditions similar to this occurrence, to remind its pilots of the need to abort a take-off when there is a loss of directional control.

5 **SAFETY RECOMMENDATION**

A safety recommendation is for the purpose of preventive action and shall in no case create a presumption of blame or liability.

As a result of the safety actions undertaken by ROKAF, the TSIB investigation team does not have any safety recommendation to propose at the conclusion of this investigation.