AIRCRAFT ACCIDENT REPORT AND EXECUTIVE SUMMARY

			Reference:	CA18/2/3/10091			
Aircraft Registration	**ZU-MDA**	**Date of Accident**	11 December 2021	**Time of Accident**	0930Z		
Type of Aircraft	Slick-360		**Type of Operation**	Private (Part 94)			
Pilot-in-command Licence Type	ATPL (Aeroplane)		**Age**	66	**Licence Valid**	Yes	
Pilot-in-command Flying Experience	**Total Flying Hours**	± 16 300	**Hours on Type**	± 170			
Last Point of Departure	Baragwanath Aerodrome (FASY), Johannesburg, Gauteng Province						
Next Point of Intended Landing	Baragwanath Aerodrome (FASY), Johannesburg, Gauteng Province						
Damage to Aircraft	Destroyed						
Location of the accident site with reference to easily defined geographical points (GPS readings if possible)							
Open area adjacent the taxiway at FASY at GPS co-ordinates: 26°20'56.1" South 027°46'37.7" East, at an elevation of 5 426 feet (ft)							
Meteorological Information							
Number of People On-board	1+0	**Number of People Injured**	0	**Number of People Killed**	1	**Other (On Ground)**	0

Synopsis

On Saturday, 11 December 2021, a pilot on-board a Slick-360 aircraft with registration ZU-MDA departed Kitty Hawk Aerodrome (FAKT), east of Pretoria in Gauteng province, to participate in the Ace of Base 2021, an aerobatic display competition. The flight was conducted under visual flight rules (VFR) by day and under the provisions of Part 91 of the Civil Aviation Regulations (CAR) 2011 as amended.

The air show was organised by the Sport Aerobatic Club (SAC) and was held at Baragwanath Aerodrome (FASY) in the south of Johannesburg in Gauteng province. According to eyewitnesses, during the last display sequence abeam FASY, the pilot performed a manoeuvre at high speed and at low height; the aircraft entered an uncontrolled descent from which he was unable to recover.

The aircraft was destroyed, and the pilot was fatally injured during the accident sequence.

The cause of the accident was attributed to the initiation of an aerobatic manoeuvre below the minimum height required for safe execution.

Probable Cause

The aircraft entered an aerobatic manoeuvre at a height below the minimum required for safe execution. The aircraft crashed, and the pilot was fatally injured.

Contributory Factors

(1) Pilot not attending briefing and practising exercises before the actual show at FASY.
(2) The air show organisers allowing the pilot, who has not attended a briefing, to partake in the air show.

SRP date	12 September 2023	Publication date	26 September 2023

Occurrence Details

Reference Number	**:** CA18/2/3/10091
Occurrence Category	**:** Accident (Category 2)
Type of Operation	**:** Private (Part 94)
Operator Type	**:** Private
Aircraft Registration	**:** ZU-MDA
Aircraft Make and Model	**:** Slick 360
Nationality	**:** South African
Place	**:** Open area adjacent to taxiway at Baragwanath Aerodrome (FASY)
Date and Time	**:** 11 December 2021 at 0930Z
Injuries	**:** Fatal
Damage	**:** Destroyed

Purpose of the Investigation

In terms of Regulation 12.03.1 of the Civil Aviation Regulations (CAR) 2011, this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and not to apportion blame or liability.

All times given in this report are Co-ordinated Universal Time (UTC) and will be denoted by (Z). South African Standard Time is UTC plus 2 hours.

Investigation Process

The Accident and Incident Investigations Division (AIID) of the South African Civil Aviation Authority (SACAA) was notified of the occurrence on 11 December 2021 at 0930Z. The occurrence was classified as an accident according to the CAR 2011 Part 12 and ICAO STD Annex 13 definitions. Notifications were sent to South Africa as the State of Registry and Operator in accordance with CAR 2011 Part 12 and ICAO Annex 13 Chapter 4. The State of Registry and Operator did not appoint an accredited representative and advisor. Investigators were dispatched to the accident site.

Notes:

1. *Whenever the following words are mentioned in this report, they shall mean the following:*
   Accident — this investigated accident
   Aircraft — the Slick 360 involved in this accident.
   Investigation — the investigation into the circumstances of this accident
   Pilot — the pilot involved in this accident.
   Report — this accident report

2. *Photos and figures used in this report were taken from different sources and may have been adjusted from the original for the sole purpose of improving clarity of the report. Modifications to images used in this report were limited to cropping, magnification, file compression; or enhancement of colour, brightness, contrast; or addition of text boxes, arrows, or lines.*

Disclaimer

Table of Contents

Abbreviation	Description
°	Degrees
°C	Degrees Celsius
%	Percent
AIID	Accident and Incident Investigations Division
AGL	Above Ground Level
AMSL	Above Mean Sea Level
AP	Approved Person
ATF	Authority to Fly
ATPL (A)	Airline Transport Pilot Licence (Aeroplane)
CAR	Civil Aviation Regulations
C of R	Certificate of Registration
CPL	Commercial Pilot Licence
FAKT	Kitty Hawk Aerodrome
FASY	Baragwanath Aerodrome
ft	Feet
g-force	Gravitational Force
GPS	Global Positioning System
hp	Horsepower
hPa	Hectopascal
kg	Kilograms
km	Kilometres
kt	Knots
L	Litres
m	Metres
MEA (L)	Multi-Engine Aircraft (Land)
METAR	Meteorological Routine Aerodrome Report
MHz	Megahertz
Mph	Miles per Hour
NTCA	Non-type Certified Aircraft
PPL	Private Pilot Licence
QNH	Altitude Above Mean Sea Level
RPM	Revolutions per Minute
SAC	Sport Aerobatic Club
SACAA	South African Civil Aviation Authority
SAWS	South African Weather Service
SEA (L)	Single-Engine Aircraft (Land)
TBD	To Be Determined
TBO	Time Between Overhaul
VHF	Very High Frequency
VNL	Correction for Defective Near Vision
Z	Zulu (Term for Universal Co-ordinated Time - Zero Hours Greenwich)

1. FACTUAL INFORMATION

1.1. History of Flight

1.1.1. On Saturday, 11 December 2021, a pilot on-board a Slick-360 aerobatic aircraft with registration ZU-MDA departed Kitty Hawk Aerodrome (FAKT), east of Pretoria in Gauteng province, to participate in the Ace of Base 2021 air show, an aerobatic display competition. The air show was organised by the Sport Aerobatic Club (SAC) and was held at Baragwanath Aerodrome (FASY) in the south of Johannesburg in Gauteng province.

1.1.2. The pilot was one of the 10 participants in the air show. He had chosen and designed his own aerobatic display sequence which consisted of 10 manoeuvres, and had submitted his display sequence for the aerobatic competition the night before the competition to the aerobatic competition registrar via email.

1.1.3. According to the eyewitness (a judge), during the pilot's last aerobatic display sequence, which was the half Cuban-8 manoeuvre (Illustration 1) and includes a one-and-a-half snap roll (Illustration 2), the aircraft's left wing stalled. The pilot recovered from the stall and shortly afterwards, the aircraft stalled again but this time the aircraft continued to descend towards the ground.

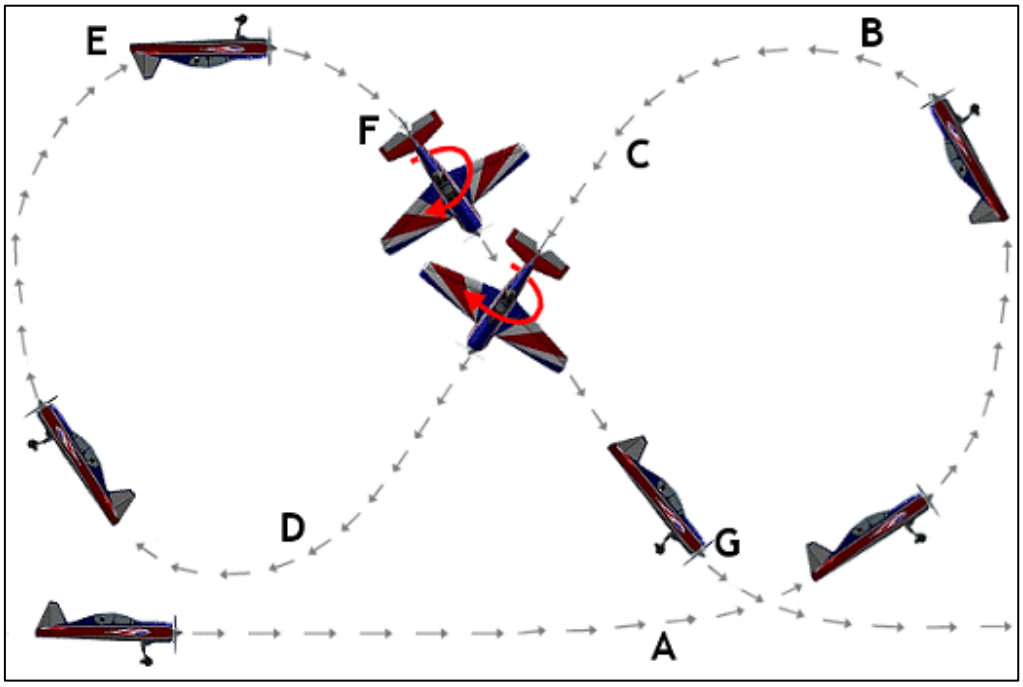

Illustration 1: The Cuban-8 manoeuvre.
(Source: https://www.rc-airplane-world.com/cuban-8-rc-airplane-aerobatics.html)

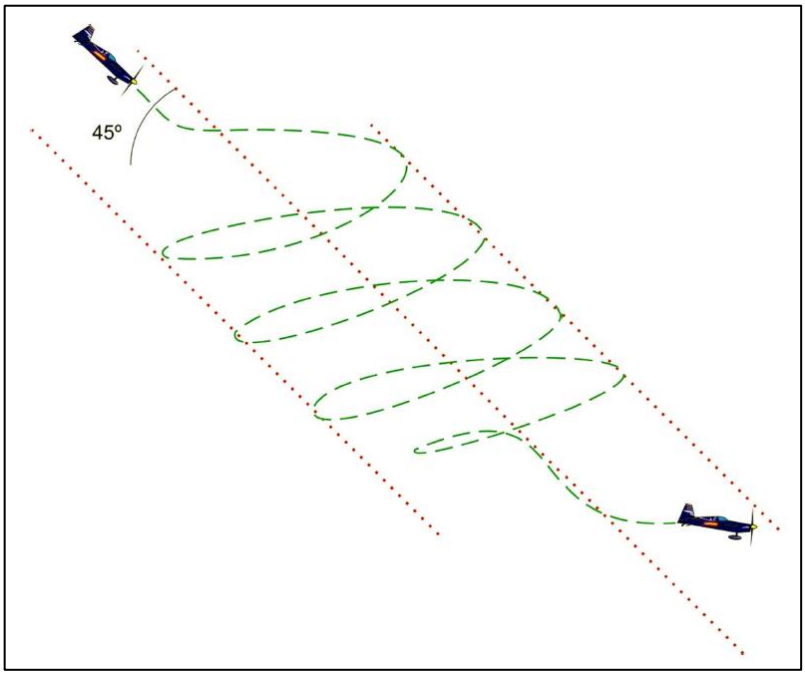

Illustration 2: Snap roll manoeuvre with four consecutive turns at 45° descending and positive. (Source: ZIVKO EDGE 540 aircraft accident report, 2010)

1.1.4. The eyewitness stated that the attitude of the aircraft during the high-speed descent seemed as if the pilot was attempting to recover from the manoeuvre; however, due to insufficient height available, the aircraft impacted the ground in a wings-level tail-high attitude and at a 10º to 20º nose-down angle.

1.1.5. According to most eyewitnesses who were also aerobatic display pilots, the aircraft was approximately 700 feet (ft) above ground level (AGL) when the pilot initiated the last manoeuvre and was below 400 ft AGL when he attempted to pull out or recover the aircraft.

1.1.6. The aircraft impacted the ground and was destroyed; the pilot was fatally injured.

1.1.7. Eyewitnesses stated that fine weather conditions with a few high-level clouds prevailed at the time leading to the accident.

1.1.8. The aircraft crashed on an open field in the vicinity of FASY at Global Positioning System (GPS) co-ordinates determined to be 26º20’56.1” South 027º46’37.7” East, at 5 426 ft above mean sea level (AMSL).

Figure 1: Aerial view of the accident site. (Source: Google Earth Pro)

1.2. Injuries to Persons

Injuries	Pilot	Crew	Pass.	Total On-board	Other
Fatal	1	-	-	1	-
Serious	-	-	-	-	-
Minor	-	-	-	-	-
None	-	-	-	-	-
Total	**1**	**-**	**-**	**1**	**-**

Note: Other means people on the ground.

1.3. Damage to Aircraft

1.3.1. The aircraft was destroyed.

Figure 2: The wreckage post-accident.

1.4. Other Damage

1.4.1. None.

1.5. Personnel Information

Nationality	South African	Gender	Male	Age	66
Licence Type	Airline Transport Pilot Licence (ATPL)				
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Instrument, Instructor Grade 2, Test Pilot (Class 2)				
Medical Class	Class 2				
Medical Issue Date	27 May 2021	Medical Expiry Date	31 May 2022		
Restrictions	Correction for defective near vision (VNL)				
Previous Accidents	None				

Note: Previous accidents refer to past accidents the pilot was involved in, when relevant to this accident.

Flying Experience:

Total Hours	± 16 300
Total Past 24 Hours	± 0.75
Total Past 7 Days	± 1.25
Total Past 90 Days	± 25
Total on Type Past 90 Days	± 25
Total on Type	± 170

Note: The information entered in the table above was obtained from the pilot's last instructor licence renewal with hours as of 2 September 2021, as well as the last page of the flight folio.

1.5.1. The pilot completed an ATPL proficiency check on 22 April 2021 and was certified competent.

1.5.2. The pilot conducted his revalidation check for flight instructor rating Grade II on 3 November 2021 and was certified competent.

1.5.3. The pilot had a valid Recreational Aviation Administration of South Africa (RAASA) display rating endorsement on his licence.

Maintenance Personnel Information

1.5.4. The ZU-MDA aircraft was maintained in line with Part 43 of the Civil Aviation Regulations (CAR) 2011 and the aircraft's maintenance schedules were carried out by the same approved person (AP) since 2019 (the last three annual inspections).

1.5.5. The AP's approval certificate was reissued on 4 June 2020 with an expiry date of 3 June 2022.

1.5.6. The AP was rated and certified to carry out repairs and maintenance on the Slick-360 aircraft and Lycoming series engine types.

1.6. Aircraft Information

Figure 3: The file picture of the Slick-360 aircraft, ZU-MDA. (Source: http://www.surfacezero.com/)

1.6.1. Aircraft Description (Source: Slick-360 Aerobatic Aircraft Pilot's Operating Handbook [POH])

The Slick-360 is a high-performance aerobatic aircraft with a one-seater and enclosed cockpit. The aircraft's wings are constructed of moulded glass-fibre composite sandwich with a carbon composite main wing spar. The fuselage features carbon fibre longerons and a Kevlar encased cockpit.

Ailerons are of composite design with counter-balance mass in the horn. The horizontal stabiliser is also constructed of moulded glass-fibre and the elevator is mass balanced for aerodynamic balancing and the right elevator has an electronically controlled trim tab that is operated from the cockpit. The vertical stabiliser is manufactured with carbon fibre and the rudder is aerodynamically balanced with a balancing horn comprising 15 percent (%) of the rudder.

The Slick-360 is approved for all aerobatic manoeuvres. During take-off, flight and landing the aircraft reacts as any other aerobatic approved taildragger. The aircraft reacts normally during stalling and spinning. The aircraft is designed to resist very high gravitational-forces (g- forces) (positive 10g, negative 10g).

The Aero Sport Lycoming AEIO 360 angle valve engine fitted to the Slick-360 develops 227 horsepower (hp) at 2700 revolutions per minute (rpm). The engine has a compression ratio of 10,5:1 and uses Avgas LL100aviation fuel.

The Slick-360 is fitted with an electronic ignition system, a cold air induction system and a lightweight starter. To offset historically low oil pressure in four-cylinder aerobatic engines, a deeper oil sump is fitted to the Lycoming AEIO 360 engine.

The propeller fitted to the Slick-360 is a 3-blade Muehl Bauer MTV-9-B, variable pitch, composite, fitted for maximum cooling and performance efficiency, especially during ground operations at hot and high elevations. The wooden core is reinforced by layers of epoxy fibreglass and sealed by several coatings of acrylic-polyurethane paint.

Airframe:

Manufacturer/Model	Aerocam (Pty) Ltd; Slick-360	
Serial Number	360-0604	
Year of Manufacture	2006	
Total Airframe Hours (At Time of Accident)	269.1	
Last Annual Inspection (Date & Hours)	30 July 2021	252.9
Airframe Hours Since Last Inspection	16.2	
CRS Issue Date	30 July 2021	
ATF (Original Issue Date & Expiry Date)	2 August 2019	31 August 2022
C of R (Issue Date) (Present Owner)	26 June 2018	
Operating Category	Part 94 (Operation of Non-type Certificated Aircraft)	
Type of Fuel Used	Avgas 100LL	
Previous Accidents	None	

Note: Previous accidents refer to past accidents the aircraft was involved in, when relevant to this accident.

Engine:

Manufacturer/Model	Lycoming AI-IO360-AIB6
Serial Number	0644-SP
Hours Since New	269.1
Hours Since Overhaul	TBO not yet reached

Propeller:

Manufacturer/Model	Muehl Bauer MTV-9-B
Serial Number	06995
Hours Since New	269.1
Hours Since Overhaul	TBO not yet reached

1.6.2. Post-accident investigation found no technical defects with the airframe, engine, propeller, systems and components that were recorded in the logbooks or flight folio.

1.6.3. All applicable Airworthiness Directives (AD) and Service Bulletins (SB) were reviewed; they had all been complied with.

1.7. Meteorological Information

1.7.1. The weather information on the table below was provided by the South African Weather Service (SAWS) recorded at Zuurbekom Automatic Weather Station (AWS) on 11 December 2021 at 0930Z. Zuurbekom AWS is located 5 kilometres (km) from FASY. The wind was from a northly direction at 5.6 knots at the time of the accident flight.

Wind Direction	350 °	Wind Speed	5.6 kt	Visibility	9999 m
Temperature	26 °C	Cloud Cover	Scattered	Cloud Base	6000 ft
Dew Point	15 °C	QNH	1026 hPa		

1.7.2. Satellite Image

The SAWS satellite image (below) was taken at 0930Z on the day of the accident; it shows *south Gauteng region with a few broken and scattered clouds and with no turbulence; and visible high-level cloud and thunderstorms in the Free-State*, which had no effect on Gauteng region.

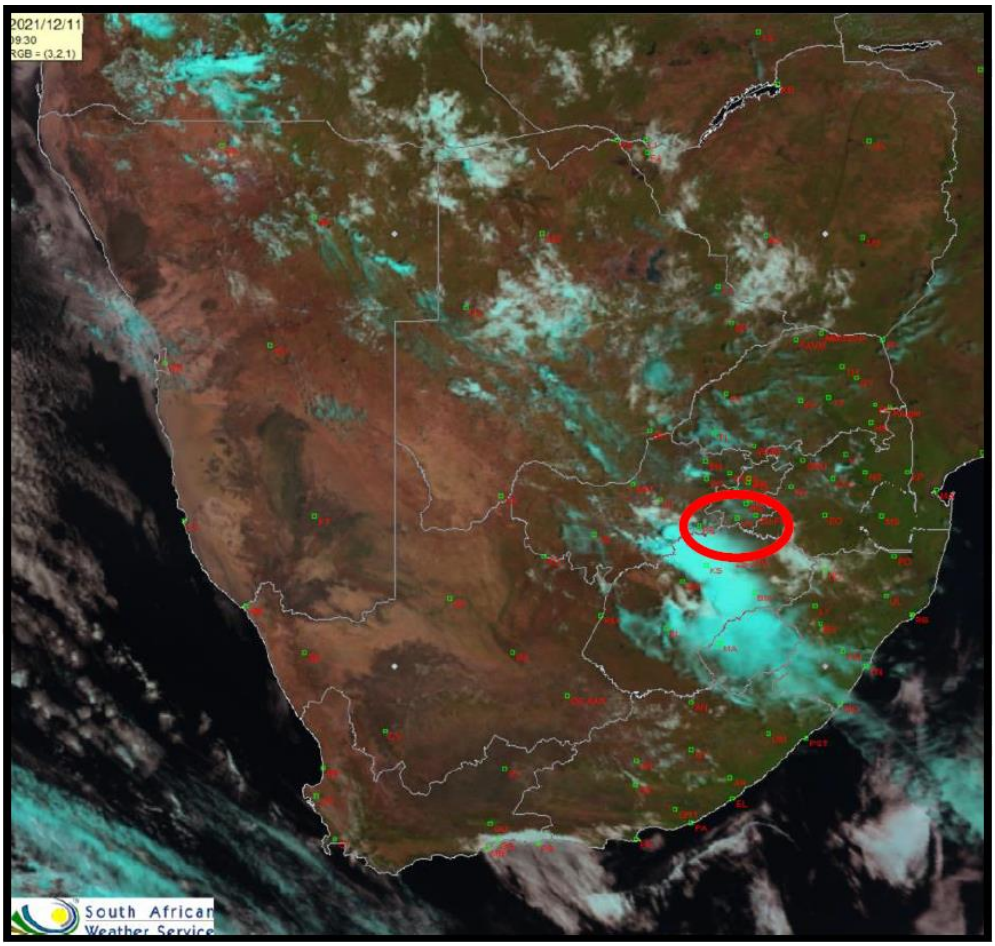

Figure 4: Satellite image at 0930Z on 11 December 2021. (Source: SAWS report)

1.7.3. Density Altitude (Source: https://www.skybrary.aero/articles/density-altitude)

Density altitude is pressure altitude corrected for temperature. In layman's terms it directly affects the performance parameters of any aircraft, and in effect it is the equivalent altitude of where, performance-wise, the aircraft "thinks" it is at. The higher the density altitude, the lower the aircraft performance, and vice versa.

As pressure increases, with temperature constant, density increases. Conversely when temperature increases, with pressure constant, density decreases. Air density will decrease by about 1% for a decrease of 10 hPa in pressure or 3 ºC increase in temperature.

A decrease in density results in an increased density altitude, whereas an increase in density results in a decreased density altitude. Considering the notion that the aircraft performs based on density altitude, at higher elevations with high temperatures the aircraft performance is greatly reduced compared to its relative performance at that level with standard temperatures. Conversely, at lower altitudes with colder temperatures aircraft performance is greatly increased compared to its relative performance at that level with standard temperatures.

The density of air decreases more rapidly with height in warm air than in cold air. The commonly accepted value for density altitude decrease with height is 120 ft ºC-1, and in some publications, articles may even be simplified to 100 ft ºC-1.

1.7.3.1. The density altitude at the time of the accident was calculated at 7 590 ft. (Source: https://e6bx.com/density-altitude/)

1.8. Aids to Navigation

1.8.1. The aircraft was equipped with a Garmin Aera 500 GPS navigation unit. There were no recorded defects with the navigational equipment prior to the flight.

1.9. Communication

1.9.1. The aircraft was equipped with a very high frequency (VHF) radio communication system. There were no recorded defects with the communication system prior to the flight.

1.9.2. On the day of the aerobatic competition, the SAC's chief judge was the designated safety officer. The safety officer communicated with pilots prior to take-off via a two-way radio (a walkie-talkie). According to the safety officer, the pilot of ZU-MDA did not make a Mayday call at any point of the flight prior to impacting the ground.

1.10. Aerodrome Information

Aerodrome Location	Baragwanath Aerodrome (FASY), Gauteng Province
Aerodrome Status	Unlicensed
Aerodrome GPS coordinates	26°20'47" South 027°46'31" East
Aerodrome Elevation	5 393 ft
Runway Headings	13/31
Runway Dimensions	1 113 m x 11 m

Runway Used	13
Runway Surface	Asphalt
Approach Facilities	None
Radio Frequency	122.350 MHz

1.10.1. Within the aerodrome's airspace is a designated aerobatic box consisting of an imaginary cube of 1 kilometre (km) by 1 km (1 km x 1km) diameter in which aerobatic manoeuvres are performed. The aerobatic box is used as a reference by judges during the aerobatic competition. The box is intended to ensure the safety of the spectators, the aircraft performing aerobatic manoeuvres and other traffic using the aerodrome (Figure 5). Aerodrome procedures define the method to be used by traffic at the aerodrome to make approaches, take-offs and landings when there are activities in the aerobatic box (blue square).

Figure 5: Aerial view of the Baragwanath Aerodrome with the imaginary aerobatic box in blue. (Source: Google Earth Pro)

1.11. Flight Recorders

1.11.1. The aircraft was not equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR), nor was it required by regulation to be fitted to the aircraft type.

1.12. Wreckage and Impact Information

1.12.1. The aircraft approached from the south (flying towards a northerly direction) at low height. The aircraft's first point of impact crater (impressed by the bottom part of the fuselage and the main landing gears) was measured at 3 metres (m) length by 1.5m width. During the

aerobatic sequence, it was established that the aircraft impacted the ground in a wings-level attitude at a 10º to 20º nose-down angle and at high speed.

1.12.2. The ground scars showed that the aircraft cartwheeled and bounced on its nose about 15m high before it came to rest approximately 40m from the initial point of impact. The wreckage distribution consisted of numerous fragments of the wings and fuselage (Figure 6) in a 40m radius of the main wreckage, indicative of the aircraft disintegrating after impacting the ground at high speed.

1.12.3. The aircraft's fuselage, canopy, propeller, undercarriage, wings and engine were extensively damaged during impact. The examination revealed that the entire structure of the aircraft sustained impact damage. The aircraft crashed on a grass-covered terrain about 15m south of the taxiway at FASY.

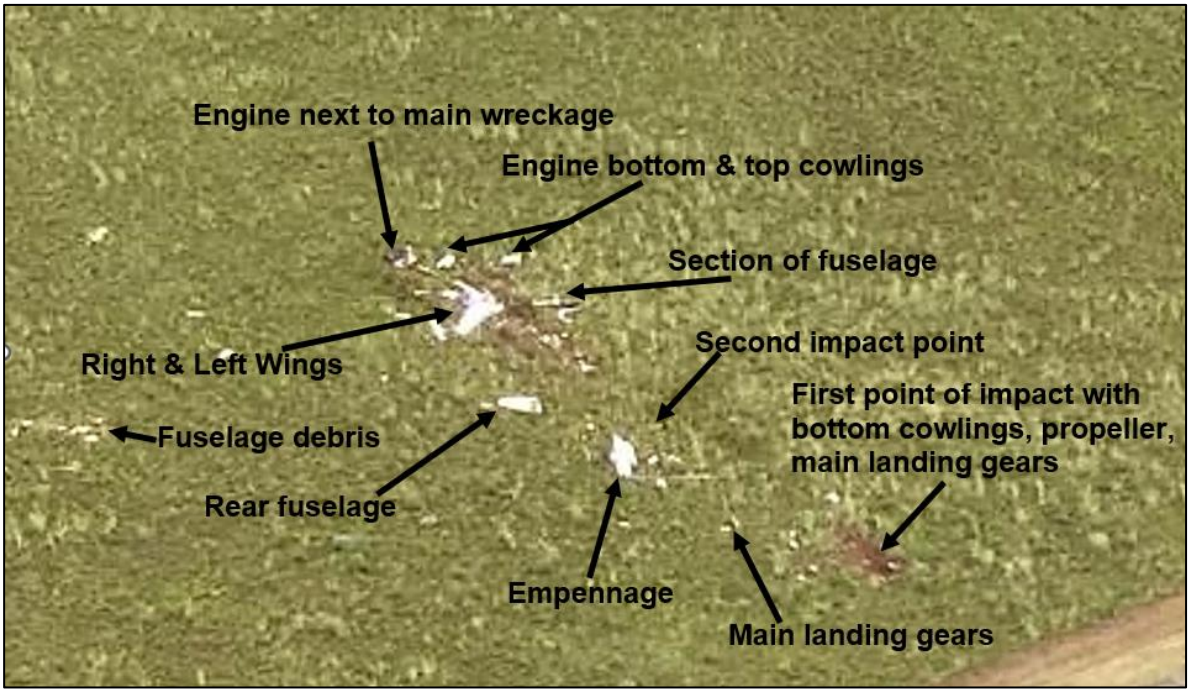

Figure 6: Wreckage distribution. (Source: Insurance Assessor)

1.12.4. Although the control surfaces had been destroyed, the rudder and elevator on the empennage were found still attached; they moved without obstruction when examined at the accident site. Due to the extensively damaged wings, aileron continuity could not be established.

Figure 7: The empennage at the accident site.

1.12.5. The engine had dislodged from its mounting point and the impact mark on the ground indicated that it had separated before it bounced. It was found 3m from the main wreckage. The inspection of the engine on site indicated that it was running at a high-power setting at the time of impact; this was verified by the destruction of all three composite propeller blades at the roots.

Figure 8: The condition of the engine and its proximity to the wreckage.

Figure 9: The propeller hub assembly.

1.12.6. The fuel selector was found selected to the main tank. The fuel amount could not be established as the fuel tanks had ruptured due to impact forces; however, there was still a small amount of Avgas LL100 fuel in the carburettor fuel bowls. The throttle and mixture control levers were found in the fully in/forward (open) position.

Figure 10: The throttle and mixture control/selector levers.

1.12.7. Most of the aircraft's instruments and avionics were not found as they had dislodged from their mounting brackets. The aircraft's rudder pedals were found 4m from the main wreckage. The pilot's helmet was found under the aircraft's wings. The airspeed indicator was found intact and stuck at 180 miles per hour (mph), which is equivalent to 160 knots.

Figure 11: Airspeed indicator (left) and accelerometer (right).

1.13. Medical and Pathological Information

1.13.1. A post-mortem examination was conducted by the South African Department of Health forensic pathologists. According to the pathology report, there were no signs of pre-existing medical conditions which might have contributed to the accident; the pilot was in good health prior to the accident. The pathological report revealed that the cause of death was due to multiple blunt force injuries.

1.14. Fire

1.14.1. There was no evidence of a pre- or post-impact fire.

1.15. Survival Aspects

1.15.1. The accident was considered not survivable as the aircraft impacted the ground with its nose section first, which led to the destruction of the cockpit area and, thus, fatal injuries to the pilot.

1.16. Tests and Research

1.16.1. Description and Execution of a Cuban-8 Manoeuvre
(Source: https://www.rc-airplane-world.com/cuban-8-rc-airplane-aerobatics.html)

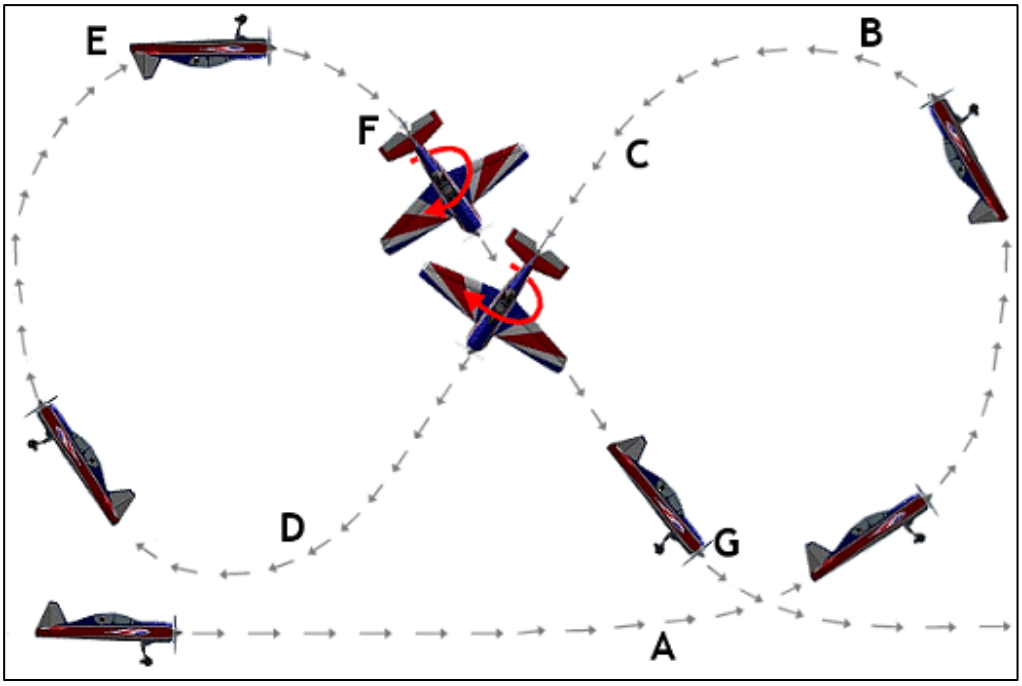

Illustration 3: The Cuban-8 manoeuvre.
(Source: https://www.rc-airplane-world.com/cuban-8-rc-airplane-aerobatics.html)

*How to fly it: Fly straight and level in to wind and at point '**A**', in the picture above, apply full power and up elevator to initiate a climb, as if starting an inside loop.*

*Let the airplane go in to its vertical climb and roll over on to its back at the top of the loop, point '**B**'.*

*Continue with the loop but at point '**C**' apply aileron to smoothly roll through 180 degrees, bringing the airplane right side up. Reduce power slightly and use elevator to maintain a 45-degree dive.*

Continue the brief dive and level out at the altitude at which you entered the manoeuvre.

*As soon as you've levelled out, point '**D**', increase power and begin a second loop and repeat the process of letting the airplane roll over on to its back, point '**E**', before applying aileron at the start of the dive, point 'F', to roll through 180 degrees.*

*Continue the 45-degree dive and start to recover at point '**G**', to resume straight and level flying at your original altitude. To test your accuracy successive Cuban 8s can be flown while trying to keep the cross-over point in the same place in the sky, and both loops equal size.*

1.16.2. Description and Execution of a Snap Roll Manoeuvre
(Source: ZIVKO EDGE 540 aircraft accident report, 2010)

This manoeuvre starts with quick pitch and yaw motions that cause one wing to momentarily stall while the other maintains lift. The manoeuvre is performed under power. There are different types of rolls, depending on the combination: vertical, horizontal or at 45°, climbing or diving, from positive or negative and turning left or right. Several rolls and turns can also be stringed into a single manoeuvre to make it more spectacular. In this case, the manoeuvre involved a 45° dive while turning to the right.

This is performed as follows: the stick is pulled back to cause a stall and the aircraft is placed at 45° up angle. This is normally initiated at 3000ft and ends at 1000ft, depending on the number of turns to be made, with approximately 150ft being lost per roll. This manoeuvre involves mainly the use of the rudder, with the pedal on the side to which the turn is to be executed being fully depressed.

To recover from the manoeuvre, the opposite pedal is applied, with the angle of attack being maintained with the stick. If the smoke system is used, the manoeuvre looks like a coiled telephone cord (see Illustration 3). The aircraft nose comes out on the same trajectory. This manoeuvre is performed very fast, and the amount of inertia accumulated by the aircraft because of the turns can result in the aircraft rotating an additional ¼ roll approximately.

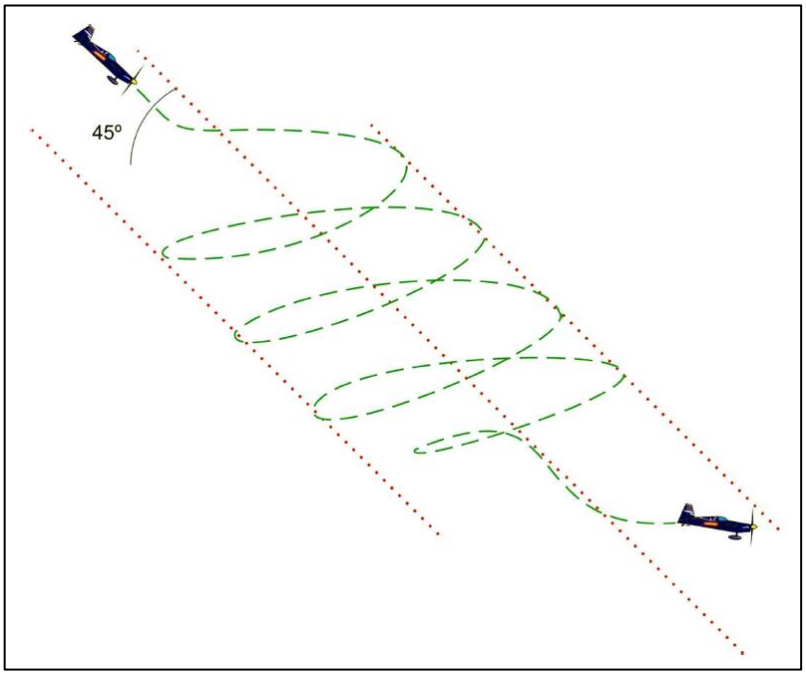

Illustration 4: Snap roll manoeuvre with four consecutive turns at 45º descending and positive. (Source: ZIVKO EDGE 540 aircraft accident report, 2010)

1.17. Organisational and Management Information

1.17.1. At approximately 21:00 (local time) the night before the aerobatic competition, the pilot had emailed his personally designed aerobatic display sequence consisting of 10 manoeuvres to the registrar of the aerobatic competition. According to the email, the pilot had not planned on competing due to work commitments, however, a friend and a fellow aerobatic pilot had asked him to enter the aerobatic competition. The entry form was accompanied by a "cobbled" (i.e., scribbled) sequence.

1.17.2. According to the safety officer on duty, the pilot of ZU-MDA arrived late for the aerobatic competition; as a result, the pilot missed the safety briefing held prior to the commencement of the aerobatic competition. During the meeting, the safety officer had highlighted key aerobatic competition rules, one of the rules being that pilots were allowed breaks during their sequence.

1.18. Additional Information

1.18.1. None.

1.19. Useful or Effective Investigation Techniques

1.19.1. None.

2. ANALYSIS

2.1. General

From the available evidence, the following analysis was made with respect to this accident. This shall not be read as apportioning blame or liability to any organisation or individual.

2.2. Analysis

Pilot

2.2.1. The pilot had an Airline Transport Pilot Licence (ATPL) that was issued on 22 April 2021 with an expiry date of 30 June 2022. According to the pilot's logbook as of 2 September 2021, the pilot had flown a total of 16 282.5 hours on various aircraft types.

2.2.2. The pilot had a Grade 2 flight instructor rating as well as a valid Recreational Aviation Administration of South Africa (RAASA) display rating endorsement on his licence.

2.2.3. The pilot was issued a Class 1 aviation medical certificate on 27 May 2021 with an expiry date of 31 May 2022. The pilot was required to wear suitable corrective lenses.

2.2.4. Based on the autopsy and medical reports, there was no evidence that suggested the pilot suffered any sudden illness, physiological factors or incapacitation which might have affected his ability to control the aircraft.

Aircraft

2.2.5. The Certificate of Registration (C of R) was issued to the present owner on 26 June 2018.

2.2.6. The aircraft was issued an Authority to Fly (ATF) on 2 August 2019 with an expiry date of 31 August 2022.

2.2.7. The last annual maintenance inspection conducted on the aircraft prior to the accident flight was on 30 July 2021 at 252.9 total airframe hours. The next annual maintenance inspection was due on 30 July 2022 or at 354.3 airframe hours, whichever comes first. The aircraft had accumulated a further 16.2 airframe hours since its last inspection.

2.2.8. The Non-type Certified Aircraft (NTCA) was operated as a private flight in terms of Part 94 under visual flight rules (VFR) by day.

2.2.9. The maintenance records indicated that the aircraft was equipped and maintained in accordance with the existing regulations and approved procedures.

2.2.10. The AP who maintained the ZU-MDA since 2019 was rated and certified to conduct maintenance on the Slick-360 aircraft and Lycoming engine types in line with the provisions of Part 24, 44, 66.4, 94 and 96 of the CAR 2011 as amended.

2.2.11. The pilot sent a copy of his chosen display sequence to the registrar of the aerobatic competition the night before the competition. It is possible that the pilot had not flown the sequence before he submitted it.

Weather

2.2.12. The density altitude at the time of the accident was calculated to have been 7 590 ft. Considering that the aircraft performs based on density altitude at higher elevations with high temperatures, the aircraft's performance is greatly reduced compared to its relative performance at that level at standard temperatures.

Aircraft Wreckage Information

2.2.13. After the accident, the AIID investigators examined the aircraft's construction and the components of the control system, but the aircraft was extensively destroyed, and no useful information could be recovered. However, the airspeed indicator dial was found, and its examination thereof showed that the speed was about 160 knots at the time of impact.

2.2.14. Based on the impression marks on the ground, it was determined that the aircraft impacted the ground in a wings-level attitude at a 10º to 20º nose-down angle and at a very high speed.

2.2.15. Several eyewitnesses had seen the aircraft before it hit the ground; they mentioned that the aircraft was perpendicular to the ground and the engine was revving high, which was indicative that the pilot was trying to pull up from the descent, however, the aircraft had exited the last manoeuvre at low altitude to recover safely.

2.2.16. Based on the engine and propeller damage, it was determined that the engine was running at high power. This resulted in the destruction of the propeller blades on impact with the ground.

2.2.17. Although the fuel amount on-board the aircraft at the time of the accident could not be established as the fuel tanks had ruptured due to impact forces, there was still some fuel remaining in the carburettor fuel bowl.

2.2.18. The fuel selector was found selected to the main tank, which was consistent with the aircraft's operation manual. Due to the destruction of the fuel tanks, it was not possible to sample fuel for the correct grade, condition and contamination. The only possible checks that could be conducted with the fuel found in the bowls were for contamination and positive feed/supply.

2.2.19. The aircraft was destroyed during the accident. The pilot's seat and the safety belts were damaged. Although the pilot had a parachute on, he was unable to use it. The parachute deployed due to impact force. The accident was considered not survivable due to high-impact force.

2.2.20. The aircraft impacted the ground hard and was destroyed; the force exerted on the pilot during impact resulted in fatality.

Aerobatic Flight Operations

2.2.21. The aircraft had no recording equipment on-board to reconstruct the manoeuvres undertaken by the pilot. There was also no video footage that was recorded by the attendees or participants of the aerobatic competition. The known information about the final phase of the flight was provided by eyewitnesses' statements.

2.2.22. According to *Report A-027/2010*, the turn rate during a snap roll could be very high (over 400 degrees per second), which means that the pilot would not be able to look outside the aircraft with ease and that the ground reference would be hard to judge. Also, whilst performing downward rolls, the descent rate would be hard to judge.

2.2.23. It is possible that the pilot did not notice the reference altitude at the start of the last manoeuvre in relation to the number of rolls/turns planned. According to the eyewitnesses, after performing several manoeuvres, the pilot started the snap roll manoeuvre which was included in the last half of the Cuban-8 at about 700 feet, which was the 10th and last display sequence. Therefore, a drop in altitude would have gone unnoticed by the pilot, as the sequence was not practised prior to the aerobatic competition. The Cuban-8 manoeuvre picks up speed as it progresses, thus, it would be impossible to determine the altitude lost with each roll the pilot completes.

2.2.24. Based on the email the pilot had sent to the aerobatic competition registrar after 21:00 (local time) the night before the competition, the pilot indicated that the submitted aerobatic display sequence was "cobbled" together that same evening. Based on this statement, it was determined that the pilot had not practised the display sequence prior to the aerobatic competition. Therefore, the pilot would not have known that the last sequence would have required more altitude to be completed safely.

2.2.25. Based on the analysis of the wreckage and impact marks, as well as the eyewitnesses' statements, it could be concluded that ZU-MDA was flown towards the ground from a low altitude in a strong vertical motion (after a roll whilst in a transition from vertical to horizontal flight). Although during this transition the rate of descent was reduced (by the attempted pull up), this was not enough to fully stop the descent and proceed in a horizontal or climb path. The aircraft hit the ground at a speed of about 160 knots at an angle of about 10º to 20º. The

heaviest part of the aircraft, the engine, penetrated the ground and the aircraft disintegrated; its parts spread in various direction. It could be concluded that the manoeuvre to change from vertical movement to horizontal flight was initiated at an altitude that timely recovery was not possible. The pilot had managed to get the aircraft into a climbing attitude; however, the aircraft was already too close to the ground.

3. CONCLUSION

3.1. General

From the available evidence, the following findings, causes and contributing factors were made with respect to this accident. These shall not be read as apportioning blame or liability to any organisation or individual.

To serve the objective of this investigation, the following sections are included in the conclusion heading:

- **Findings —** are statements of all significant conditions, events, or circumstances in this accident. The findings are significant steps in this accident sequence, but they are not always causal or indicate deficiencies.
- **Causes —** are actions, omissions, events, conditions, or a combination thereof, which led to this accident.
- **Contributing factors —** are actions, omissions, events, conditions, or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the accident occurring, or would have mitigated the severity of the consequences of the accident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil, or criminal liability.

3.2. Findings

3.2.1. The pilot was properly licensed and medically fit for the aerobatic flight in accordance with the existing regulations and approved aerobatic competition procedures. Competition and briefing procedures were not followed.

3.2.2. The aircraft had a valid Authority to Fly (ATF) certificate, and aircraft logbooks showed that it had been maintained in compliance with the existing regulations.

3.2.3. There was no mechanical defect with the aircraft that could have caused or contributed to the accident. The aircraft was airworthy prior to the flight.

3.2.4. The aircraft was destroyed on impact, and the pilot was fatally injured during the accident.

3.2.5. Weather conditions at the time of the accident had a bearing on the accident as there was a high-density altitude of 7 590 ft prevalent at the time of the flight which would have degraded the aircraft's performance.

3.2.6. The maintenance records indicated that the aircraft was equipped and maintained in accordance with existing regulations. The aircraft was airworthy when it dispatched for the flight.

3.2.7. After performing several manoeuvres, the pilot started the snap roll manoeuvre which was included in the last half of the Cuban-8 at about 700 ft, which was the 10th and last display sequence. Therefore, a drop in altitude would have gone unnoticed by the pilot as the sequence was not practised prior to the aerobatic competition.

3.2.8. The pilot "cobbled" the display sequence the night before the aerobatic competition.

3.2.9. The aircraft hit the ground at a high speed of about 160 knots and at an angle of about 10º to 20º.

3.2.10. The manoeuvre to change from vertical movement to horizontal flight was initiated at an altitude that timely recovery was not possible. The pilot had managed to get the aircraft into a climbing attitude; however, it was already too close to the ground.

3.3. Probable Cause

3.3.1 The accident was attributed to the pilot's improper estimate and planning of the starting altitude for conducting a descending half Cuban-8 manoeuvre, followed by a descending one-and-a-half snap roll manoeuvre below the minimum attitude required to conduct the number of rolls the pilot planned to execute.

3.4. Contributory Factors

3.4.1 Poor planning by not attending briefing, and not practising exercises and manoeuvres before the show.

4. SAFETY RECOMMENDATIONS

4.1. General

The safety recommendations listed in this report are proposed according to paragraph 6.8 of Annex 13 to the Convention on International Civil Aviation and are based on the conclusions listed in heading 3 of this report. The AIID expects that all safety issues identified by the investigation are addressed by the receiving States and organisations.

4.2. Safety Actions

4.2.1. Safety actions implemented immediately after the accident of ZU-MDA by the SAC committee to mitigate any safety risks at their aerobatic competitions:

(1) ***Sequence checking.*** *While we already require all competitors to have their sequences checked by a senior judge or pilot, it has clearly not been happening. This is in place to check the legality of the sequence only; however, the spinoff is that it offers another set of eyes that could possibly pick up a potential safety problem.*

(2) ***Buddy system.*** *This is a process practised by many other aerobatic organisations across the globe. This ensures that any competitor is ready and prepared for his flight. Prior to an aerobatic competition flight, pilots force their 'buddy' to walk their sequence*

on the ground; they check their card; ensure a proper pre-flight is conducted; confirm the official wind direction; confirm frequencies; where a break is to be taken and if a weather break is permitted, etc. In a club environment, no competitor should be left to deal with this kind of preparation on his own. A checklist is being prepared for this purpose. We want the buddies to be identified at the briefing.

(3) ***Indicating a break on sequences.*** *Competitors will, from now on, be required to indicate the point in their sequence where they will take a break, for either a weather break or a compromised altitude situation. Our rules do allow a competitor to take a weather break at any point in the sequence, at their own discretion and not exactly where they have indicated it on the sequence sheet. Marking this point on their sequence sheet however forces a competitor to be consciously aware of the lowest point in their sequence and hopefully encourages heightened spatial awareness during their flight.*

(4) ***Density altitude.*** *SAC aerobatic competitions held on the Highveld have always implemented a free break to compensate for density altitude in the Advanced and Unlimited categories. The CIVA regulations now permit this for Intermediate class too and we will follow this regulation. It goes without saying though that any aerobatic competitions held at lower altitudes / sea level will consider any density altitude implications.*

(5) ***Sample known sequences.*** *A set of prepared known sequences for each category will be published for each year and any competitor is free to fly this sequence, however, we do encourage members to design their own sequences and, of course, have someone knowledgeable check them out.*

(6) ***Assessing mental preparedness.*** *It is a fact that we practise a high-risk sporting activity so it goes without saying that every competitor must be mentally prepared to compete. We should all recognise where a fellow competitor is distracted by personal or business matters and suggest to the competitor that they should consider stepping aside until the distraction is no longer a factor. Late arrivals at an aerobatic competition should only be possible under special circumstances, and sufficient time allocated to the competitor to properly prepare for his aerobatic competition flight (at least an hour).*

The above items are merely some of the options that SAC considered as being appropriate to further improve safety at aerobatic competitions. As a club, the SAC has been fortunate to have had many years of safely run aerobatic competitions and we will certainly strive to continue this.

4.3. Safety lesson

Starting an acrobatic figure at very low height constitutes risk-taking which goes against the rules of the aerobatics discipline. Indeed, aerobatics is governed by several rules including the definition of an aerobatic box.

4.4. Safety Recommendation

4.4.1. As the pilot of ZU-MDA submitted an entry for the aerobatic competition the night before the aerobatic competition, the safety systems such as sequence checking and using the buddy system designed by the SAC aerobatic competition committee were by-passed. This led to

the pilot of ZU-MDA flying a display sequence which was not practised before the aerobatic competition. The submitted sequence did not include a break in the sequence which would have taken into consideration density altitude and the starting altitude for the last sequence. The sequence was submitted a few hours before the aerobatic competition and was accepted despite the pilot's indication that the sequence was only designed the night before the aerobatic competition.

The accident could have been prevented if the sequence was practised prior to being submitted and if it was checked by a fellow aerobatic pilot. Based on this, the AIID recommends that the SAC aerobatic competition committee adopts the following safety measures:

(1) The SAC aerobatic competition committee should adopt a system to verify that pilots have practised their sequence before submitting their entries by producing proof of practise flights.
(2) The SAC aerobatic competition committee should adopt a system to verify that pilots have gotten their sequence by submitting proof of review by a fellow aerobatic pilot on the same level.
(3) The SAC aerobatic competition committee should impose a cut-off date for entries for aerobatic competitions.

5. APPENDICES

5.1. None.

This report is issued by:
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