الهيئة العامة للطيران المدني
GENERAL CIVIL AVIATION AUTHORITY

Air Accident Investigation Sector

Serious Incident

- Final Report -

AAIS Case Nº: AIFN/0003/2015

Detachment of Canopy During a Roll Manoeuvre

Operator: Team Chambliss
Aircraft Type: Zivko EDGE 540
Nationality and Registration: USA/N14KN
Place of Occurrence: Abu Dhabi, UAE
State of Occurrence: United Arab Emirates
Date of Occurrence: February 14 2015

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GENERAL CIVIL AVIATION AUTHORITY

United Arab Emirates

Air Accident Investigation Sector
General Civil Aviation Authority
The United Arab Emirates

Incident Brief

GCAA AAI Report No:	AIFN/0003/2015
Operator:	Team Chambliss
Aircraft Type	EDGE 540 V3
Registration	N14KN
Engine [s]	Lycoming AEIO-540-EXP
Location	Corniche, Abu Dhabi
Category	Experimental
Persons on Board	1
Injuries	1

Investigation Objective

This Investigation is performed pursuant to the United Arab Emirates (UAE) Federal *Act 20 of 1991*, promulgating the *Civil Aviation Law, Chapter VII- Aircraft Accidents*, Article 48. It is in compliance with *Part VI, Chapter 3 of the UAE Civil Aviation Regulations*, in conformity with *Annex 13* to the Convention on International Civil Aviation and in adherence to the *Air Accidents and Incidents Investigation Manual*.

The sole objective of this Investigation is to prevent aircraft accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

Investigation Process

The Accident was notified to the Air Accident Investigation Sector (AAIS) Duty Investigator on 14 February 2015.

In accordance with ICAO *Annex 13*, the State of Manufacture was notified.

The AAIS is leading the Investigation, as the United Arab Emirates (UAE) is the State of Occurrence.

ADREP Classification[1]

Primary	SCF-NP: System/component failure or malfunction (non-powerplant)
Secondary	AMAN: Abrupt Manoeuvre

[1] The Accident/Incident Data Reporting (ADREP) system is operated and maintained by ICAO. The ADREP Occurrence category taxonomy is a set of terms used by ICAO to categorize aircraft accidents and incidents and allow safety trend analysis on these categories. The ADREP Occurrence category taxonomy is part of the ICAO accident reporting system (ADREP).

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Abbreviations and Definitions

ACCREP	Accredited Representative
ADREP	Accident/Incident Data Reporting
AAIS	Air Accident Investigation Sector
ANS	Air Navigation Service
ATC	Air Traffic Control
OMAD	Al Bateen Airport
BASA	Bilateral Aviation Safety Agreement
CAVOK	Ceiling and Visibility are OK
FAA	Federal Aviation Administration
FAI	Fédération Aéronautique Internationale
GCAA	General Civil Aviation Authority
IPA	Implementation Procedures for Airworthiness
ICAO	International Civil Aviation Organization
LED	light-emitting diode
SMS	Safety Management Systems
TA	Technical Advisors
GmbH	Type of legal entity: Austria
RBAR	Red Bull Air Race
UAE	United Arab Emirates

Synopsis

A Zivko EDGE 540, a high performance aerobatic Aircraft participating in the 2015 Abu Dhabi Red Bull Air Race, was on the approach to the race entry point and the race box.[2]

The race box, the defined area where the race course and pylons are located, is the general area between the Corniche and the opposite side of the island and the causeway bridge.

As the Aircraft approached the race box, the Pilot executed the G-warm-up manoeuvers at approximately 200 kts. These were a series of high roll rate manoeuvres to prepare the Pilot physiologically for the high g demands and to test the Aircraft response prior to accelerating to racing speed and beginning the race.

During the roll manoeuvres, the canopy separates from the Aircraft striking the pilot, causing injury and displacing the pilots head protection which also contains the communications system.

The Pilot aborts the race entry, reduces speed and climbs to the designated safety height.

With the high ambient slip stream noise preventing normal voice communication, and as the Pilot could not access the boom microphone to communicate with the race control tower, the Pilot selected the emergency transponder code 7700 and returned to Al Bateen Airport (OMAD) along the defined corridor over Abu Dhabi city.

The landing was uneventful.

The canopy separation was the result of a tolerance gap between the canopy and the forward glare shield opening, this allowed the into wind gap[3] to lift the front edge of the canopy.

As the canopy forward edge was lifted, the locking mechanism moving parts and the locking lever moved into the unlocked position.

When the lever moved aft into the unlocked position during the high roll rate manoeuvres, the canopy separated.

Based on previous experience of this type of event, the manufacturer has designed an optional modification that installs a red light connected to a micro switch on the locking lever. This will alert the pilot if the locking lever moves from the locked to unlocked position.

2 The defined area where the pylons are located and from which the FAI considers the race to begin and terminate
3 This is the ram air effect of the airflow getting between the canopy and the glare shield lifting the canopy edge up.

1. Factual Information

1.1. History of the Flight

For the 2015 Red Bull Air Race in Abu Dhabi, the operating base for all of the participating teams was Al Bateen Airport (OMAD) in Abu Dhabi.

A Zivko EDGE 540, high performance aerobatic Aircraft, registration N14KN, participating in the air race event departed the OMAD on the 14th February 2015 to position at the holding area prior to starting the run in to the Red Bull air race.

The Pilot advised that after start-up, due to the high ambient temperatures, that the canopy was slightly opened to keep cool in the Aircraft while idling. When given a taxi clearance, the canopy was lowered down and locked.

The Aircraft, following the departure from OMAD, headed along the approved departure route arriving at the holding position to the north west of the race box[4], the Aircraft was holding north of Lulu Island until cleared to commence the race run in.

No problems with the canopy were observed on the on-board camera.

The race course was planned to for pilots to complete a series of high speed turning and climbing manoeuvres over a timed circuit. The manoeuvring was to be performed between floating pylons.

As the Aircraft approached the race box, the Pilot executed the G-warm-up manoeuvers at approximately 200 kts.[5]

As the Pilot completed the second roll manoeuvre, the canopy latch mechanism was observed on the on-board camera to move autonomously aft into the unlocked position.

The canopy then lifted on the left hand side and separated, contacted the Pilot's face and protective helmet, continued towards the rear of the Aircraft, and impacted the empennage as it travelled aft in the slip stream.

The Pilot's protective helmet was partially displaced due to the canopy contact. The Pilot also received facial injuries as the canopy separated.

The pilot assessed the aircraft was controllable and then proceeded to return to the Race airport

The Pilot was unable to communicate with either the race controller or OMAD ATC as the helmet and boom microphone were unusable. Accordingly, and based on the emergency briefing, the Pilot tuned the transponder to the emergency frequency of 7600, alerting the controllers and race coordinators of the problem.

The Aircraft was controllable for the duration of the return flight and returned uneventfully to OMAD where a technical onsite inspection was conducted and the Pilot was referred to a medical examiner.

[4] The Race box is the defined area where the competitors are consider to be competing around the course

[5] The G-warm-up manoeuvers were a series of high roll rate manoeuvres to prepare the pilot physiologically for the high G demands and to test the aircraft response prior to accelerating to racing speed and beginning the race.

1.2. Injuries to Persons

The Pilot was treated for minor injuries by a Red Bull physician and released with no further action.

Table1. Table of injuries

Injuries	Flight Crew	Cabin Crew	Other Crew on Board	Passengers	Total on Board	Others
Fatal	0	0	0	0	0	0
Serious	1	0	0	0	1	0
Minor	0	0	0	0	0	0
None	0	0	0	0	0	0
Total	**1**	**0**	**0**	**0**	**1**	**0**

1.3. Damage to Aircraft

1.3.1. Aircraft structure damage

Figure 1. Missing canopy

Following the return to OMAD, a technical safety inspection was conducted and concluded the following:

- The canopy was detached and had separated from the airframe
- No damage was found to the flight control systems
- The canopy controls were intact and functional. The emergency release handle was still set to safety with break-away wire intact
- The right front hinge was still attached to the Aircraft
- There was impact damage to the glare shield on the right hand side
- There was minor damage to the right hand wing upper surface and some scuffing of the paint
- The turtle deck had scuffing and a small puncture on the left hand side
- The right hand horizontal stabilizer leading edge had 5 to 6 small chips in the paint
- The underside of the 'D' section (on the leading edge) has a puncture heading fore to aft (front to back)

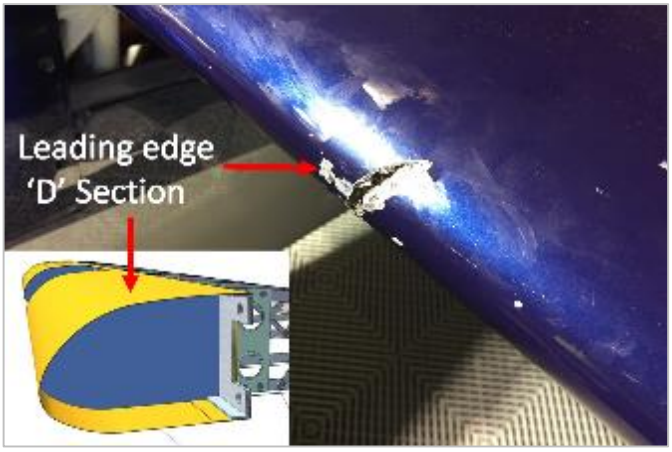
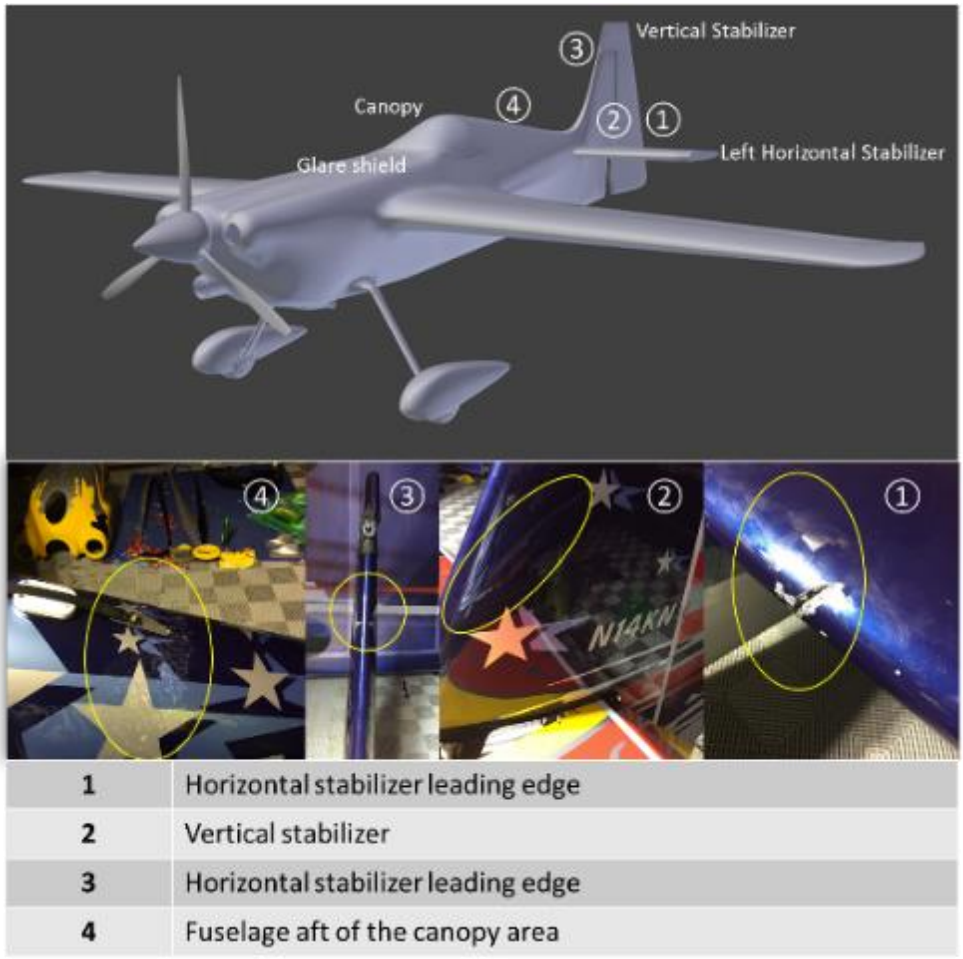


Figure 2. Horizontal leading edge damage

- The left hand horizontal stabilizer had scuffs and chips on the upper and lower surfaces.
- The leading edge suffered a deep cut in the inner 1/3rd section. No spar damage seen
- The vertical fin had a deep cut in the lower 1/3rd of the assembly, numerous scuffs and paint chips also were noticed

1.3.2. Aircraft damage location mapping



1	Horizontal stabilizer leading edge
2	Vertical stabilizer
3	Horizontal stabilizer leading edge
4	Fuselage aft of the canopy area

Figure 3. General damage

1.4. Other Damage

No other damage

1.5. Personnel Information

1.5.1. Pilot Information

Pilot and engineer information.

Table 2. Qualifications of the flight crew

Crewmember	Pilot
Age	56
Type of license	ATPL
Issued	19 November 2008
Rating	Airplane - Single/Multi
Issuing State	USA
Medical class	Not Provided
Valid to	Not Provided
Total flying time (hours)	Not Provided

Total commands on all types	Not Provided
Total on type	Not Provided
Total last 30 days	Not Provided
Total last 24 hours	Not Provided
Total on type last 30 days	Not Provided
Total on type last 24 hours	Not Provided
Last line check	Not Provided
Last proficiency check	Not Provided
English language proficiency	Not Provided

1.5.2. Engineer/mechanic

The engineer held a mechanic certificate issued by the Federal Aviation Administration (FAA) of the United States on 15 December 2007.

1.6. Aircraft Information

1.6.1. Zivko Edge 540

The Zivko Edge 540, manufactured by Zivko Aeronautics, is an advanced, Unlimited Class aerobatic aircraft, capable of a 420 degree per second roll rate and a 3,700 foot per minute climb rate.

Figure 4. General views of the Aircraft

1.6.2. Aircraft assembly on-site

The Aircraft was assembled and tested in accordance with the Red Bull Air Race OM-E Technical Regulations

Table 3. Aircraft general data			
Serial Number	0049V3	Status	Valid
Manufacturer Name	ZIVKO AERONAUTICS INC	Certificate Issue Date	3/9/2011
Model	EDGE 540	Expiration Date	3/31/2017
Type Aircraft	Fixed Wing Single-Engine	Type Engine	Reciprocating
Engine Manufacturer	LYCOMING	Classification	Experimental
Engine Model	IO-540-EXP	Category	Exhibition
Airworthiness Date	6/29/2011		
Pending Number Change	None	Dealer	No

Date Change Authorized	None	Mode S Code (base 8 / oct)	50120505
MFR Year	2011	Mode S Code (base 16 / hex)	A0A145
Type Registration	Corporation	Fractional Owner	NO

1.6.3. Canopy locking mechanism

The canopy latching/locking mechanism is a simple mechanical lever system.

The pilot pushes the lever forward to engage the catch guides, which locate the canopy under tension, securing the canopy in position.

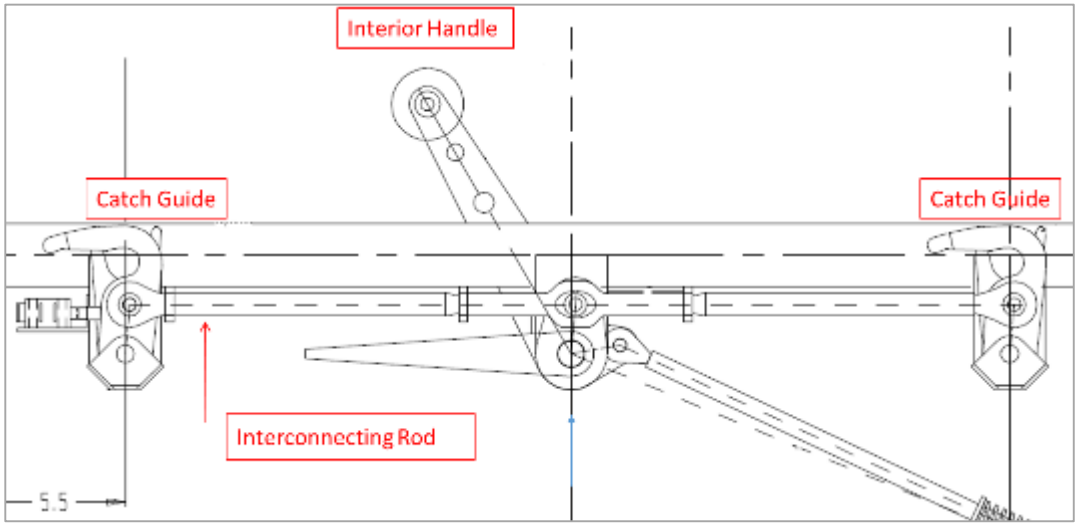


Figure 5. Canopy Latch Mechanism

1.7. Meteorological Information

Weather for the 14 February 2015 was CAVOK[6], with a light variable winds and unlimited visibility.

1.8. Aids To Navigation

Not a factor in the investigation.

1.9. Communications

The Aircraft was equipped with standard VHF radios and transponder. The transponder was operational during the event.

The pre-race safety briefing for radio failure or problems with VHF radio communication was to proceed to the departure aerodrome and select the transponder to code 7760.

As the VHF radio communication was not possible due to the slipstream noise following the canopy separation, the transponder code was selected, detected and the mode S[7] transponder functioned normally.

[6] CAVOK means **C**eiling **a**nd **V**isibility are **OK**

[7] Mode S is a Secondary Surveillance Radar process that allows selective interrogation of aircraft according to the unique 24-bit address assigned to each aircraft.

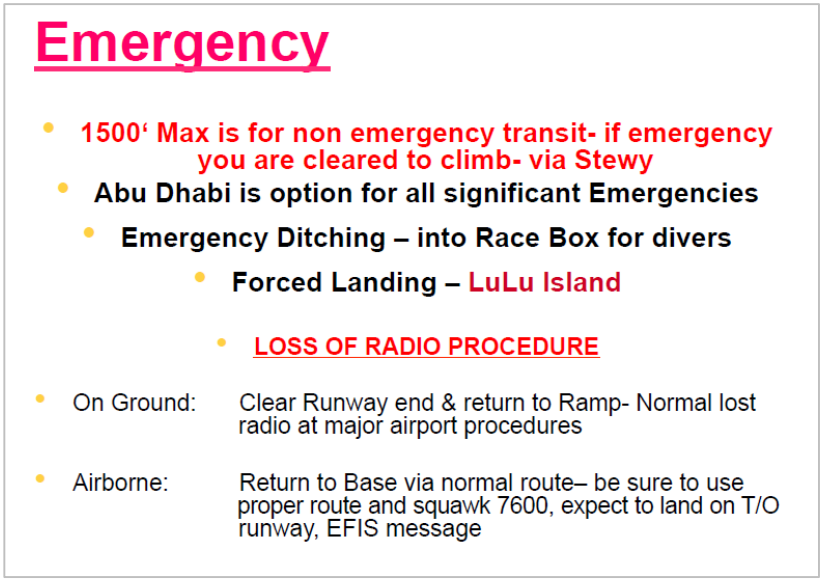


Figure 6. Excerpt - Pilots Briefing/Emergency Procedures

1.10. Aerodrome Information

1.10.1. Race area/Race Box

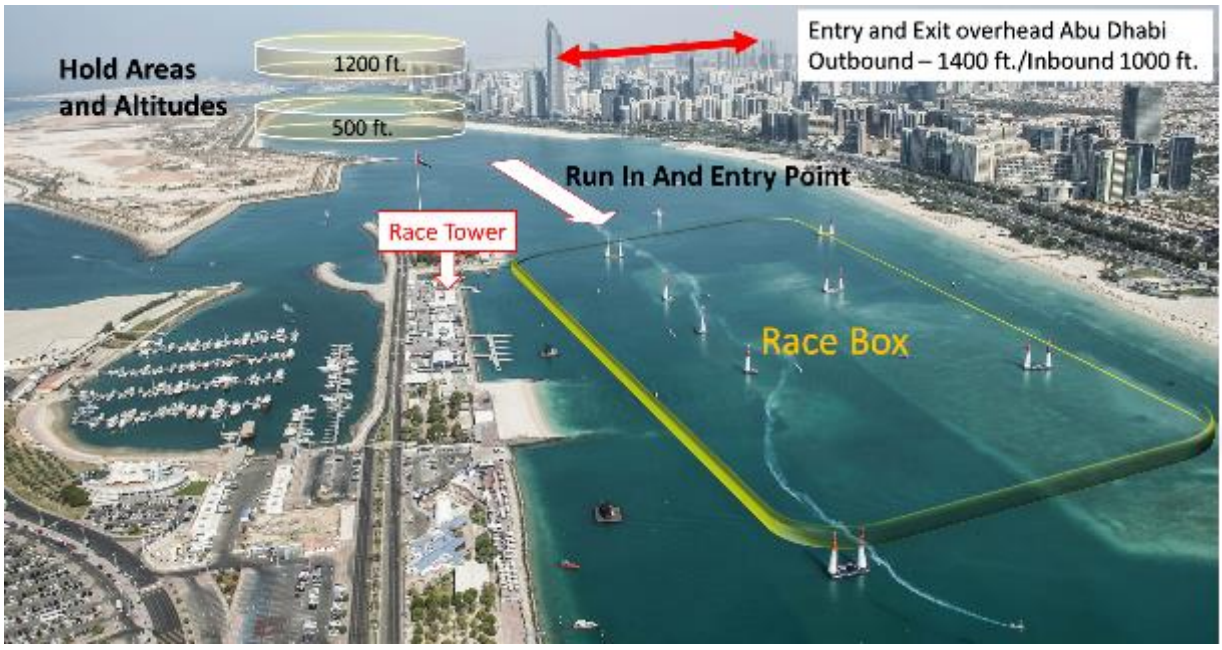


Figure 7. Abu Dhabi Race Box and holding point

Aircraft hold position and Race Box entry was controlled for departure and arrival at OMAD in accordance with the *Civil Aviation Regulation (CARs)* of the United Arab Emirates, *CAR Ops- Air Navigation Service*, standard procedures.

The Aircraft departed OMAD, transit over Abu Dhabi to the first of two holding points.

There was a temporary control tower set up adjacent to the Race Box. This function of the control tower was to manage aircraft from the holding positions to the race entry point

and then clear aircraft from the Race Box back out to the departure transit route back across Abu Dhabi at 1000 feet.

When the Aircraft was cleared to begin the race sequence, the Aircraft descended and at the Pilot's discretion performed a series of high G manoeuvres before the run in to the entry point and the commencing of the race.

During this run in phase, the canopy detached during the second of two snap roll manoeuvres and left the Aircraft.

1.11. Flight Recorders

No flight data recorder (FDR) or cockpit voice recorder (CVR) were fitted on the Aircraft nor were they required by the *Federal Aviation Regulations (FARs)* to be fitted on this category.

The Aircraft was equipped with onboard cameras which capture the cockpit view.

1.12. Wreckage and Impact Information

The canopy fell into the shallow waters of the Corniche breakwater and was recovered.

1.13. Medical and Pathological Information

No blood or alcohol test was conducted on the pilot as specified by *CAR OPS* following an accident or incident.

1.14. Fire

No fire was reported.

1.15. Survival Aspects

1.15.1. Aircraft

The Aircraft design and certification safety protections worked as designed.

1.15.2. Crew survivability

Pilots were not required to wear lightweight buoyancy vests when operating over water. The Pilot's protective helmet was dislodged from his head with the microphone damaged as a consequence of the impact.

The pilot’s eye protection, attached to the helmet, was damaged in the helmet to canopy contact.

1.15.3. Water rescue and Pilot recovery

The event organizer had a comprehensive water rescue support team on standby during the entire time an aircraft is operating.

In order to manage an aircraft incident on water within the display area, the organizer had a comprehensive water rescue support team on standby during the entire time an aircraft is operating with specially trained rescue and intervention divers to respond to any occurrence within racing areas.

1.15.4. Aircraft disintegration, pilot incapacitation and crowd protection

The event organiser's safety team provided a ballistic trajectory analysis which covers all aspects of crowd safety including the likely outcome of the Aircraft trajectory should an Aircraft have a structural failure, and engine failure or the pilot becomes incapacitated.

Internationally accepted trajectory and ballistic analysis requires the debris field safety line to be a minimum of 150 meters from the crowd line.

The analysis models Aircraft events including catastrophic structural failures. The race course can then be modified to adjust to changing conditions.

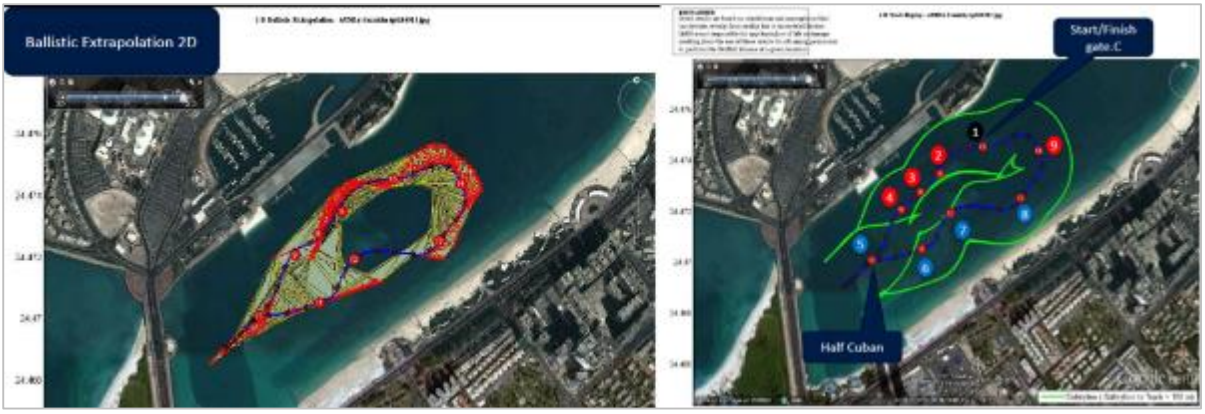


Figure8. Plan view of the trajectory analysis (left) and the Race Box safety line (right)

1.16. Tests and Research

Background review of other similar canopy separations and a comparison with standard operating procedures of operators of similar aircraft provided an opportunity to review current and accepted structural tolerance maintenance practice.

Information and feedback from the aircraft manufacturer was constructive in determining the canopy alerting modifications available.

Based on in-service feedback, the manufacturer had designed a retrofit modification that installs a micro switch into the door opening mechanism to alert to the pilot of the handle moves from the locked position. The modification is optional and at the discretion of the owner as it is not mandated by the FAA.

1.16.1. Manufacturers canopy latch modification

The lock light modification installation and pilot alerting system is a modification to alert the pilot via an LED[8] light if the canopy is open.

The instrument panel mounted red LED is wired to the normally-closed terminal of a micro switch. This illuminates the LED when there is no contact (canopy handle open) with the switch. When the canopy handle is in the closed and locked position, the switch is activated, turning off the LED.

[8] LED: light-emitting diode

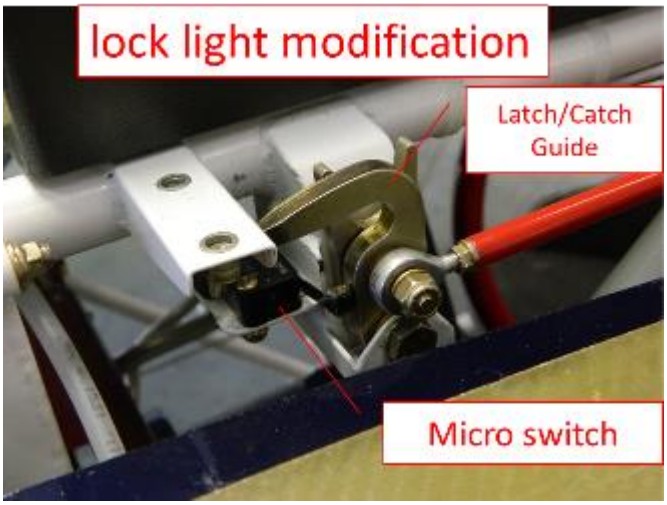


Figure 9. Lock light modification

1.17. Organisational and Management Information

1.17.1. Race event organiser - Red Bull GmbH representative

Red Bull GmbH is the event organiser and has an appointed representative to manage the race preparation, organisation, and coordination.

The representative is the designated signatory for all approvals and compliance documentation related to the race preparation related to the local department of transport, federal civil aviation and air navigation services waivers and compliance.

1.17.2. Red Bull local representative

Red Bull GmbH's appointed representative appoints a local representative contractor to coordinate and manage the liaison with the local and federal UAE aviation authorities.

This contractor manages the practical day to day coordination with the ANS providers, the aerial camera platforms, filming permission permits and coordination with the GCAA.

1.17.3. GCAA waiver

Based on the Red Bull risk assessment, the GCAA issues a Certificate of Waiver to Red Bull Air Race GmbH to conduct the air race within defined criteria:

> *"Low level aerobatic flight over water within minimum height of 33 feet up to 1500 feet including formation.*
>
> *Area: within the proposed area of the Red Bull Air Race 2015 Box, Abu Dhabi Corniche.*
>
> *VMC (Visual Meteorological) Day Flight only."*

1.17.4. Aircraft Transit and ATC clearances coordination

The race aircraft transit along two predefined corridors from OMAD to the Corniche Race Box. One corridor is used for the inbound transit, another for the return to base.

The inbound and outbound corridors were de-conflicted by the route separation and the differing transit altitudes for the two corridors.

Extra mitigation was in place with the ability to coordinate throughout the race with the Grid Control Tower which was located in the Race Box, onsite in the race coordination control tower.

An air traffic control representative at Grid Control Tower was able to pass the details onto OMAD tower when coordination from the Race Box is relayed regarding any circumstances of an incident or operational event requiring mitigation.

Having an air traffic control representative onsite ensures incidents are managed safely and the reason why an ANS representative is on site at both Race and Grid Tower to liaise with OMAD Tower and Approach units prior to and during the event.

1.17.5. Red Bull *Operations Manual – Engineering (OM-E)*

The Red Bull Air Race GmbH *Operating Manual, Engineering, Appendix A- Pre-Race and During Race Inspection Sheet, Task #6* states:

"Check canopy for Latching and Locking."

This task was signed off on 8 February 2015, six days prior to the Accident, and there was no indication from the Operator's Technical Log that any additional inspections of the canopy fit, form and function were performed.

1.18. Additional Information

1.18.1. FAA Experimental Class Aircraft/ Bilateral Aviation Safety Agreement (BASA)[9]

FAA Oversight for United States manufactured and assembled aircraft in the Experimental category as in the Bilateral Aviation Safety Agreement (BASA) with Implementation Procedures for Airworthiness (IPA) does not apply to experimental aircraft, and in fact, there is no bilateral between the United States and the UAE.

Within the United States, oversight of the manufacture and assembly of experimental aircraft is very light when compared to that conducted on a type-certificated product.

Concerning the certification of the design for an experimental aircraft, there is none.

However, these aircraft can be found eligible for a Special Airworthiness Certificate[10] in the Experimental Category, for various purposes including Air Racing.

Such aircraft do not meet ICAO *Annex 8*, and one critical element of the operating limitations for their experimental certificate is that if operated outside the United States, they must comply with all of the rules of the country over which they will be operated.

The FAA term 'Condition for Safe Operation' is normally an initial determination by an FAA inspector or authorized Representative of the Administrator that the overall condition of an aircraft is conducive to safe operations. This refers to the condition of the aircraft relative to wear and deterioration, e.g., skin corrosion, window delamination/crazing, fluid leaks, tire wear, etc.

When operated outside of FAA oversight, for example in a foreign country, the aircraft owner or operator is the cognizant authority.

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9 https://www.faa.gov/aircraft/air_cert/international/bilateral_agreements/overview/

10 A special airworthiness certificate in the experimental category is issued to operate an aircraft that does not have a type certificate or does not conform to its type certificate and is in a condition for safe operation. Additionally, this certificate is issued to operate a primary category kit-built aircraft that was assembled without the supervision and quality control of the production certificate holder.

Refer to FAA Special Airworthiness Certificates Regulations & Policies/Title 14 Code of Federal Regulations

1.18.2. Liability and operational responsibility

Red Bull GmbH assume legal responsibility for liability when the aircraft enter the Race Box.

This liability is distinct from the operational safety responsibility implicit with the GCAA waiver to operate that requires all aircraft to be airworthy in accordance with their respective airworthiness authorities.

Operationally, all aircraft are required to comply with the UAE CAR- OPS requirements for operational safety regardless of the conditions described in the GCAA waiver for low altitude operations.

In the case of N- registered aircraft (United States nationality) , the FAA specifically states that "All 'N' registered experimental Aircraft must comply with the *'rules of the country over which they will be operated."*

1.18.3. Red Bull GmbH risk assessment matrix

Red Bull GmbH provides the GCAA with a risk matric identifying all potential risk factors. This document is a standard pro forma document used at all events.

This document forms part of the overall risk assessment for the approval of the GCAA waiver.

Red Bull GmbH signs this waiver on behalf of Red Bull GmbH and it is assumed on behalf of the participants, who are the individual teams participating in the event.

1.18.4. Safety management systems (SMS)

There was no requirement for an SMS[11] approach to the race event where risk can be assessed and managed in a proactive process as opposed to the risk matrix approach which is based on a reactive process and is not specific to the individual challenges of the specific venues used during the race series.

With the different racing events, changing risk assessments and operating environments it is difficult to determining a generic SMS risk assessment that is relevant to a multiple set of different and altering conditions.

Standard SMS performance management identifies four primary areas - Management of Safety Accountabilities; Hazard identification; Risk assessment and mitigation; Safety performance monitoring and measurement:

- Identify safety hazards
- Ensure the implementation of remedial action necessary to maintain agreed safety performance criteria
- Provide for continuous monitoring and regular assessment of the safety performance
- Aim at continuous improvement of the overall performance of the safety management system.

A modified or adapted version of an aviation SMS specific to the Red Bull GmbH operating and organizational structure would be beneficial to all parties as a race safety and risk assessment tool.

[11] A Safety Management System (SMS) provides a systematic way to control all processes relating to the management of safety for a system or organisation. The International Civil Aviation Organisation (ICAO) *Safety Management Manual* (ICAO, Document 2009)

1.19. Useful or Effective Investigation Techniques

No additional information

2. Analysis

2.1. Safety Risk Analysis, Oversight and Waiver Review

The safety and risk analysis provided by Red bull GmbH was based on a standard pro forma document applied to all race venues.

This risk assessment covers all areas of risk that can be predicted and mitigated for.

The event organiser used consequences and consequence controls, in accordance recognizing risk and hazard identification process, for example, the Bow Tie concept.

Most of the consequences and related controls were similar, which is normal due to the specific nature of the event.

Each risk event and applied controls to manage the risk and the consequences.

There were areas of risk specific to the Abu Dhabi area which should be factored into the risk matrix regarding various environmental, security and noise abatement procedures.

The Red Bull GmbH representative was the signatory to the document, however the document was applicable to risk only and not to overall responsibility for the flight safety and operational compliance of the teams.

Due to the complex nature of the operation of experimental aircraft in countries outside the designated oversight of their respective registered entities, there was no clear compliance guarantee provided to the GCAA to cover this point.

The Red Bull signatory signed an agreement that implied full acceptance of all teams regarding their respective airworthiness although there was no specific documentation from the individual teams that provides verification.

2.2. Red Bull SMS

A modified or adapted version of an aviation SMS specific to the Red Bull GmbH operating and organizational structure would be beneficial to all parties as a race safety and risk assessment tool.

The current method, as mentioned above, was that each risk event is assessed and the applied controls to manage the risk and the consequences are listed. This was a reactive process.

It would be useful for the safety management process to have an evolving risk assessment and mitigation process in an SMS format.

This would provide a method of capturing all relevant risk factors, the mitigation strategies employed to manage the risk factors while avoiding duplication of redundant processes.

This process also has the additional benefit providing a qualitative risk assessment methodology which is easily adaptive and exported in an aviation safety context for all parties.

2.3. Canopy Installation and fit, form and function tolerances

The canopy is manufactured from Carbon Fibre Composite Materials and installed aft (to the rear) of the engine cowling assembly.

The tolerance for the canopy fit when assembled can be within the assembly tolerance, however, due to the high temperatures in Abu Dhabi and the high airframe demands

imposed on the airframe during the race, this tolerance can be affected and remain undetected.

Figure 10. Example the canopy edge on an exemplar airframe

If a gap allows the airflow to lift the canopy forward edge, there is the possibility that the lifting of the forward edge can cause the mechanical locking device to move the catch guides and the locking lever to move backwards to the unlocked position.

2.4. In-service feedback – tolerance testing

Technical teams have developed a simple canopy check which is used during the pre-flight inspection.

An indicating mark is placed on the canopy and the glare shield. The mark is used to align with the fully latched position with the canopy closed and the lever in the locked position. Providing the indicating marks align, the gap is with tolerance.

All pilots are required to check the latched canopy for looseness by applying pushing pressure vertically to the canopy to check that the gap tolerance is within the recommended guide lines.

2.5. Canopy Separation Sequence

As the Pilot approached the Race Box, the Aircraft performed two rapid roll manoeuvres in preparation for the race time trial.

Figure 11. Photo showing the latch position (Source: on-board camera)

In figure 11A, the canopy locking lever can be seen in the forward (locked) position, and in figure 11B above the locking lever can be seen in the aft or unlocked position.

Figure 12. Photo showing canopy opening and separation (Source: on-board camera)

Figure 13. Photo showing canopy detached and helmet and boom microphone pushed back (Source: on-board camera)

In figure 12A the canopy has opened and rotated around the right hand hinge line. In figure 12B the forward edge of the canopy separates contacting the pilots face and head.

In figure 13, he canopy is detached and the Pilot's helmet and boom microphone are pushed back due to the impact and the air stream.

The Pilot then aborted the race entry, followed the emergency procedures briefing ad returned to OMAD.

2.6. Manufacturers Modification

The root cause of the canopy separation was the tolerance on the gap between the canopy leading edge and the fixed installation of the glare shield. If the gap is protruding into wind, the canopy will move, allowing the canopy locking lever move from locked to unlocked.

Based on in-service feedback from similar events and other teams' procedures, the manufacturer's modification alerts pilots to the latch guide moves from locked to unlocked via a micro-circuit.

Given the challenging race conditions, loads imposed on the airframe and the high ambient temperatures of the UAE, the lock light modification installation and pilot alerting system modification designed to alert pilots via LED light if the canopy is open, should be a mandatory modification for competitive sport aircraft.

3. Conclusions

3.1 Findings

The findings are statements of all significant conditions, events or circumstances in the accident sequence. The findings are significant steps in the accident sequence, but they are not always causal or indicate deficiencies

(a) According to race organiser policy, aircraft that participate in the Red Bull Air Race shall operate under the oversight of the authority of the Aircraft State of Registration.

(b) The Aircraft was airworthy according to the experimental aircraft class of operation as defined by the *Federal Aviation Regulations (FARs)*) of the United States.

(c) The Pilot was appropriately licensed to operate the Aircraft.

(d) The oversight of the Federal Aviation Administration (FAA) of the United States of the experimental class of aircraft is limited.

(e) Red Bull GmbH provided a comprehensive Aviation Incident Action Plan - Single Aircraft incident in race track covering all contingencies during the event that relates to Red Bull Air Race assets

(f) Individual teams were not required to verify the current state of airworthiness to the General Civil Aviation Authority (GCAA) of the United Arab Emirates prior to the event.

(g) The Red Bull GmbH risk assessment required the addition of a component that verifies the airworthiness of the individual team participants.

(h) Red Bull GmbH did not employ an aviation safety management systems approach for the series of race events that could capture risk and mitigate according to the operational environment.

(i) The Red Bull *OM-E Technical Regulations in task #4*, was a general fit, form and function check for the overall airframe. There was no specific canopy check performed during assembly and there was no requirement for a regular fit/form check.

(j) If the assembly tolerance is not checked on a regular basis, the canopy forward edge can lift when into wind, moving the interconnecting rod releasing the canopy latches.

(k) Other operators of the same type of Aircraft in the Red Bull Air Race event, who were aware of the risk of the inadvertent canopy opening, had developed a pre take-off check of the pilot pushing the canopy up from inside the cockpit and the engineer/mechanic observing from the outside checking for a leading edge gap.

(l) The Red Bull GmbH risk assessment to the GCAA for the waiver to operate does not include all relevant risk factors.

(m) Pilots are not required to wear life vests when operating over water.

(n) Red Bull GmbH and/or the team affected did not comply with the *Civil Aviation Regulations (CARs)* of the United Arab Emirates relating to mandatory testing for drugs and alcohol following an incident.

3.2 Causes

[Are actions, omissions, events, conditions, or a combination thereof, which led to this Accident].

The Air Accident Sector Determines that the causes of the inflight canopy detachment were:

(a) Inadequate pre-flight inspection to check the canopy tolerance for gaps prior to getting airborne.

(b) Lack of requirement in the *OM-E* for daily or pre-flight inspection of the canopy tolerances

(c) Ineffective SMS or safety oversight to capture in-service events relating to canopy separation risk of occurrence.

(d) There were no sufficient advisories issued by the FAA to advise operators of a potential canopy structural problem following various canopy related events.

(e) The limited employment of FAA oversight for experimental aircraft which allowed various operating process to evolve with the additional complication of not having a safety and risk process to capture in-service events.

4. Safety Recommendations

The Air Accident Investigation Sector recommends that:

4.1 Operators of Zivko Edge 540

SR11/2016

Install the manufacturer's modification of a micro switch into the door opening mechanism to alert the pilot if the handle moves from the locked position.

SR12/2016

In conjunction with the manufacturer install an indicating mark on the canopy and glare shield to align with the fully latched position. All Edge 540 crews can then check the latched canopy for looseness by applying positive pushing pressure vertically to the canopy to assure no looseness exists.

4.2 The General Civil Aviation Authority of the United Arab Emirates:

SR13/2016

Require all individual teams to provide evidence of compliance with the airworthiness standards of the authority that is responsible for oversight of the Aircraft prior to issue of the GCAA air race waiver.

SR14/2016

Clarify with the Red Bull GmbH representative the areas of responsibility concerning flight safety covered by Red Bull GmbH during the race.

Specifically, Red Bull GmbH are required to clarify the operational areas of the race that are directly the responsibility of Red Bull GmbH and those areas that are the direct responsibility of the participating teams. Reference should be made to areas of liability by all parties regarding a worst case scenario involving death or injury to race crew or spectators.

Ensure that Red Bull GmbH employ a modified or adapted version of an aviation SMS specific to the Red Bull GmbH operating and organizational structure for the air race safety management, be beneficial to all parties as a race safety and risk assessment tool.

SR15/2016

Ensure that Red Bull GmbH, as being the race organiser, complies with all requirements of the *Civil Aviation Regulations* following an event and provide a clear investigation evidence collection process in line with *GCAA CAAP 15/11.3- The Emergency Plan*, including the mandatory testing for alcohol and drugs by a licensed medical practitioner.

This Report is issued by:

The Air Accident Investigation Sector

General Civil Aviation Authority

The United Arab Emirates.