FINAL REPORT

ACCIDENT INVOLVING A DA42 AIRCRAFT

47NM SOUTH EAST OF LARNACA

ON THE 22ND OCTOBER 2014

Αχαιών 28, 1424 Λευκωσία, Τηλ:.00357-22800208/209/210/211 Φαξ: 00357-22800212, Ιστοσελίδα: www.aaiib.gov.cy
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ΚΥΠΡΙΑΚΗ ΔΗΜΟΚΡΑΤΙΑ

ΕΠΙΤΡΟΠΗ ΔΙΕΡΕΥΝΗΣΗΣ ΑΕΡΟΠΟΡΙΚΩΝ ΑΤΥΧΗΜΑΤΩΝ & ΣΥΜΒΑΝΤΩΝ ΚΥΠΡΟΥ

AIRCRAFT ACCIDENT & INCIDENT INVESTIGATION BOARD CYPRUS

File no.: 16.15.01.16/14

Tel. no.: 22-800210

Fax. no.: 22-800212

19 November 2015

SUBJECT: FINAL REPORT ON AN ACCIDENT INVOLVING A DA42 AIRCRAFT 47 NM SOUTH EAST OF LARNACA ON THE 22ND OCTOBER 2014

OBJECTIVE OF THE INVESTIGATION

"The Investigation of this Accident has been conducted by the AAIIB in accordance with Annex 13 of the Chicago Convention, European Regulation 996/2010 and Cyprus Aircraft Accident & Incident Investigation Law 2015.

In accordance with Annex 13 to the Convention on International Civil Aviation, EU Regulation 996/2010 and the Cyprus Aircraft Accident & Incident Investigation Law 2015 [N.73(I)/2015], the sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

Any judicial or administrative proceedings to apportion blame or liability should be separate from any investigation conducted under the provisions of ICAO Annex 13.

Consequently the use of this report for any other purpose except for the prevention of accidents in the future could lead to wrong interpretations."

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ΣΚΟΠΟΣ ΤΗΣ ΔΙΕΡΕΥΝΗΣΗΣ

«Η διερεύνηση του συγκεκριμένου ατυχήματος διενεργήθηκε από την ΕΔΑΑΣ σύμφωνα με το Παράρτημα 13 της Σύμβασης για τη Διεθνή Πολιτική Αεροπορία, τον Κανονισμό (ΕΕ) 996/2010 και τον περί Διερεύνησης Αεροπορικών Ατυχημάτων και Συμβάντων Νόμο του 2015 [Ν.73(Ι)/2015].

Σύμφωνα με το Παράρτημα 13 της Σύμβασης για τη Διεθνή Πολιτική Αεροπορία, τον Κανονισμό (ΕΕ) 996/2010 και τον περί Διερεύνησης Αεροπορικών Ατυχημάτων και Συμβάντων Νόμο του 2015 [Ν.73(Ι)/2015], η διερεύνηση αεροπορικών ατυχημάτων και συμβάντων δεν έχει σκοπό στην απόδοση υπαιτιότητας ή ευθύνης. Ο μοναδικός σκοπός της διερεύνησης και του πορίσματος είναι η πρόληψη των ατυχημάτων και συμβάντων.

Οποιαδήποτε δικαστική ή διοικητική διαδικασία για απόδοση υπαιτιότητας ή ευθύνης, θα πρέπει να είναι ξεχωριστή από οποιαδήποτε έρευνα η οποία διεξάγεται σύμφωνα με το Παράρτημα 13 του Διεθνούς Οργανισμού Πολιτικής Αεροπορίας (Δ.Ο.Π.Α).

Κατά συνέπεια, η χρήση αυτού του πορίσματος για οποιοδήποτε άλλο σκοπό εκτός από την πρόληψη των ατυχημάτων στο μέλλον θα μπορούσε να οδηγήσει σε λανθασμένες ερμηνείες»

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Aircraft Operator:	GRIFFON AVIATION
Aircraft Type and Model:	DIAMOND AIRCRAFT DA42
Registration:	5B-CLI
Serial no.:	42.217
Location:	47NM SOUTH EAST OF THE COAST OF LARNACA
Date and Time:	22.10.2014, 14:02 UTC

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CONTENTS:

Αχαιών 28, 1424 Λευκωσία, Τηλ:.00357-22800208/209/210/211 Φαξ: 00357-22800212, Ιστοσελίδα: www.aaiib.gov.cy
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ABREVIATIONS:

AAIIB	AIRCRAFT ACCIDENT AND INCIDENT INVESTIGATION BOARD
(A)	AEROPLANE
ACC	AREA CONTROL CENTRE
ATC	AIR TRAFFIC CONTROL
DOC	DOCUMENT
FADEC	FULL AUTHORITY DIGITAL ELECTRONIC CONTROL
FCL	FLIGHT CREW LICENSE
FL	FLIGHT
FT	FEET
HP	HORSE POWER
hPa	HECTOPASCAL
JRCC	JOINT RESCUE COORDINATION CENTRE
ICAO	INTERNATIONAL CIVIL AVIATION ORGANISATION
ICS	INTEGRATED COCKPIT INSTRUMENT SYSTEM
i.e	FOR EXAMPLE
IR	INSTRUMENTS RATING
KG	KILOS
KIAS	KNOTS INDICATED AIR SPEED
Kt	KNOT
KW	KILOWATT

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(L)	LAND
LBS	LIBRES (POUNDS)
LT	LOCAL TIME
LTRS	LITRES
M	METRE
ME	MULTI ENGINE
MEA	MIDDLE EAST AIRLINES
MEP	MULTIENGINE PISTON
N	NORTH
NM	NAUTICAL MILES
OAT	OUTSIDE AIR TEMPERATURE
O/H	OVERHEAD
PAX	PASSENGERS
PIC	PILOT IN COMMAND
PPL	PRIVATE PILOT LICENCE
Rpm	REVOLUTION PER MINUTE
SATCO	SENIOR AIR TRAFFIC CONTROL OFFICER
SEP	SINGLE ENGINE PISTON
SP	SINGLE PILOT
TAE	THIELERT AIRCRAFT ENGINES
UNIFIL	UNITED NATIONS INTERIM FORCE IN LEBANON
UTC	COORDINATED UNIVERSAL TIME
Vmca	MINIMUM CONTROL SPEED IN THE AIR SINGLE ENGINE
Vyse	BEST SINGLE ENGINE RATE OF CLIMB VELOCITY
VOR	VERY HIGH FREQUENCY OMNI RANGE

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SYNOPSIS

On the 22nd October 2014 the AAIIB was notified by the JRCC of an aircraft accident which occurred 47 NM south east, off the coast of Larnaca, involving a twin aircraft (DA42), registration 5B-CLI. This aircraft departed Paphos Airport with destination Beirut Airport.
Last communication with Nicosia ATC was at 16:02:25 UTC and then disappeared from the radar screen.

1. FACTUAL INFORMATION

1.1. HISTORY OF THE FLIGHT

On October 22nd 2014, a Diamond DA 42 aircraft, registration 5B-CLI, operated by Griffon Aviation Ltd, an approved training organisation, departed from Paphos airport at 15.20 UTC on an IFR flight plan with destination Beirut International Airport.

On board the aircraft were two aircrew members, the pilot in command and another pilot.
The aircraft was in contact with Nicosia ATC.

At time 16:02:25 UTC at night while the aircraft was flying at 9000' about 47 NM south east of the Larnaca coast the Nicosia ATC lost contact with the aircraft. Two minutes later the aircraft disappeared from the radar screen crashing in to the sea killing both pilots.
The sea depth at this point is 2000 metres. Important parts of the wreckage, engines and cockpit could not be recovered from the seabed.

The investigation was based on the aircraft tracks obtained by three different radars operating at the time of the crash as well as the ATC transcript.

This information was analyzed and used in a Diamond DA42 simulator as part of the ongoing investigation.

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1.2. **INJURIES TO PERSONS**

INJURIES	CREW	PAX	OTHERS
FATAL	2	———	———
SERIOUS	———	———	———
MINOR/NONE	———	———	———

1.3. **DAMAGE TO AIRCRAFT**

The aircraft was completely destroyed on impact with the sea. Main parts of the aircraft i.e. engines, cockpit ended up on the seabed from where they were not retrieved. Only small pieces of the aircraft, the largest about a metre were collected from the sea and were stored in the approved area at Larnaca airport.

1.4. **OTHER DAMAGE**

No other damage

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1.5. **PERSONNEL INFORMATION**

PILOT IN COMMAND	CYPRIOT CITIZEN, BORN IN 1960
LICENCE	COMMERCIAL PILOT CPL (A), AND PPL (A) ISSUED BY THE UK CIVIL AVIATION AUTHORITY
RATINGS	SEP (Land), VALID TILL 31 AUGUST 2016 IR-SP-ME CLASS 5E, VALID TILL 31 OCTOBER 2015 MEP (Land), VALID TILL 31 OCTOBER 2015
FLIGHT INSTRUCTOR RATINGS	FCL.905.F1 APPLIES AS In/(a)/(b)/(d)/(e)/(f)/A/(g)/(h)/(i)
TOTAL FLIGHT HOURS	8556
TOTAL HOURS SINGLE PILOT S/E SINGLE PILOT M/E	 6392 1771
TOTAL HOURS MULTI PILOT	 393
TOTAL INSTRUCTION HOURS	6060
TOTAL FLIGHT HOURS ON DIAMOND DA42	 134.5

Limited flying experience at night on the type DA42

MEDICAL FITNESS	CLASS 1, OTHER COMMERCIAL OPERATORS END VALIDITY 7 JANUARY 2015 LAST MEDICAL EXAMINATION 7 JANUARY 2014

Αχαιών 28, 1424 Λευκωσία, Τηλ:.00357-22800208/209/210/211 Φαξ: 00357-22800212, Ιστοσελίδα: www.aaiib.gov.cy
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COPILOT	NATIONALITY LEBANESE WITH GREEK PASSPORT BORN IN 1965
LICENCE	PRIVATE PILOT LICENCE PPL (A), ISSUED BY THE DEPARTMENT OF CIVIL AVIATION OF CYPRUS
RATINGS	SEP (L), VALID TILL 30 SEPTEMBER 2015 MEP (L), VALID TILL 31 MAY 2015
TOTAL HOURS	239 hrs & 25min.
TOTAL HOURS ON DIAMOND DA42	33 hrs & 40min.
PI/C	20 hrs & 10min.

No night flying experience on the type DA42

MEDICAL FITNESS	CLASS 2, VALID TILL 11 SEPTEMBER 2015
LAST MEDICAL EXAMINATION	11 SEPTEMBER 2013

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1.6. **AIRCRAFT INFORMATION**

The Diamond DA42 (called twin star) is a twin engine, four-seated cantilever low wing airplane composite construction, retractable tricycle landing gear, T-tail. The power plant of the aircraft is the Centurion 2.0 TAE 125-02-099 engine. The engine is a 4 stroke Diesel turbo charged direct injection fuel system using common rail technique, oil cooled, burns jet A1 fuel.

The engine is controlled by a Full Authority Digital Electronic FADEC system. The engine is equipped with a constant speed propeller with three blades.
The DA42 is equipped with a Garmin G1000 integrated cockpit instrument system (ICS) and an autopilot system the KAP 140. The autopilot is a digital flight control system that provides roll, pitch and pitch trim steering with altitude preselect.

Αχαιών 28, 1424 Λευκωσία, Τηλ:.00357-22800208/209/210/211 Φαξ: 00357-22800212, Ιστοσελίδα: www.aaiib.gov.cy
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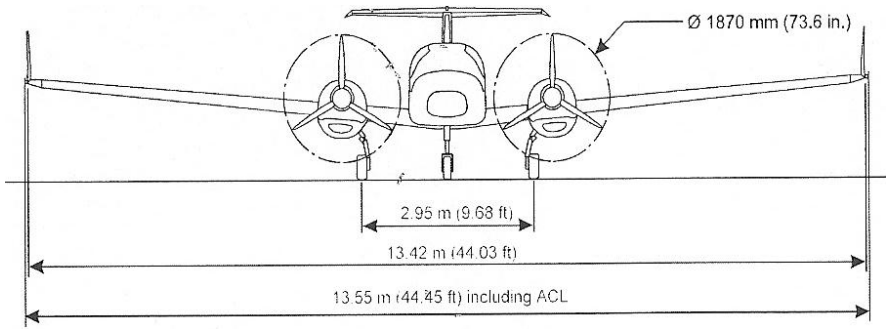
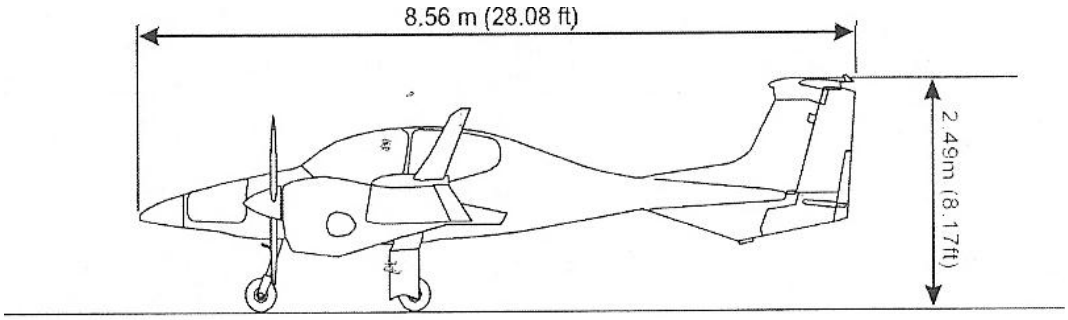
DIMENTIONS:



Span	13.42m
Length	8.56m
Height	2.49m
Wing Area	16.29m^2



Αχαιών 28, 1424 Λευκωσία, Τηλ:.00357-22800208/209/210/211 Φαξ: 00357-22800212, Ιστοσελίδα: www.aaiib.gov.cy
28 Achaeon str.1424 Nicosia, Tel: 00357-22800208/209/210/211 Fax: 00357-22800212, Website: www.aaiib.gov.cy

AIRCRAFT TYPE:	DIAMOND DA42	REGISTRATION: 5B-CLI
MANUFACTURER:	DIAMOND AIRCRAFT INDUSTRIES GMBH N.A. OTTO-STR-S A-2700 WIENER NEUSTADT AUSTRIA	
YEAR OF MANUFACTURER:	2007	
OWNER:	TD The Market Publishers Limited	
OPERATOR:	Griffon Aviation (Cyprus) Limited	
AIRCRAFT SERIAL No:	42217	
CURREN FLIGHT HOURS:	2162.42	

ENGINE TYPE:	THIELERT AIRCRAFT ENGINES TAE 125-02-099	
ENGINE SERIAL No.:	(1) 02-02-02546	(2) 02-02-02547
ENGINE HOURS:	(1) 1164.06	(2) 1164.06
ENGINE LAST O/H:	(1) 20/07/2009	(2) 20/07/2009

PERFORMANCE DATA:

MAX TAKEOFF POWER	99Kw AT 2300 rpm
MAX CONTINOUS POWER	99kw AT 2300 rpm

VARIABLE PROPELLERS TYPE:	MTV-6-A-C-F/CF187-129	
SERIAL NO.:	(1) 06758	(2) 06759
HOURS:	(1) 555.06	(2) 238.41
DATE OF O/H:	(1) 07/2010	(2) 08/2013

Αχαιών 28, 1424 Λευκωσία, Τηλ:.00357-22800208/209/210/211 Φαξ: 00357-22800212, Ιστοσελίδα: www.aaiib.gov.cy
28 Achaeon str.1424 Nicosia, Tel: 00357-22800208/209/210/211 Fax: 00357-22800212, Website: www.aaiib.gov.cy

CERTIFICATE OF REGISTRATION:	ISSUED BY DCA OF CYPRUS ON 4 OCTOBER 2013
AIRWORTHINESS REVIEW CERTIFICATE:	ISSUED BY DCA OF CYPRUS ON 28 JULY 2014 VAILID
MAXIMUM TAKE OFF MASS:	1785Kg
MAXIMUM ZERO FUEL MASS:	1730Kg
MAXIMUM LANDING MASS:	1758Kg
DEPARTURE FUEL:	160LT JET A-1

MAINTENANCE: The aircraft was maintained by an approved maintenance organization at Larnaca Airport. Last 100/200 hour annual check was carried out on 31 July 2014.

All maintenance records have been scrutinized and indicated that the aircraft was equipped and maintained in accordance with existing regulations and approved procedures.

Aircraft departed Paphos with no known defects in the technical log book.

Αχαιών 28, 1424 Λευκωσία, Τηλ:.00357-22800208/209/210/211 Φαξ: 00357-22800212, Ιστοσελίδα: www.aaiib.gov.cy
28 Achaeon str.1424 Nicosia, Tel: 00357-22800208/209/210/211 Fax: 00357-22800212, Website: www.aaiib.gov.cy

1.7. METEOROLOGICAL INFORMATION

The Department of Meteorology does not allocate meteorological instrument in the region of 40NM east of the coast of Larnaka.

The report of the weather situation is based on the analysis of the synoptic charts and on the surface and upper air observations at the Meteorological Office at **Larnaca** Airport.

Analysis of surface charts (06Z, 12Z, 18Z 22/10/2014)
Based on the analysis of the above surface charts, the area of the Eastern Mediterranean was affected by a slack pressure gradient. The area of the accident was affected by a weak north-easterly airflow.

Analysis of the upper air charts (12Z 22/10/2014, 00Z 23/10/2014)
At the level of 700 hPa, a southwest airflow affected the area of the Eastern Mediterranean, with intensity of 25 knots.
At the level of 500 hPa, a southwest airflow affected the area of the Eastern Mediterranean, with intensity of 35 knots.

Surface Observations of the Meteorological Office at Larnaca Airport
The recorded meteorological parameters between 1500-1630UTC at the Meteorological Office at Larnaca Airport, were:

Surface Wind: 080-090 degrees with intensity 9-11kt
Visibility: Above 10000meters
Cloud: from 1500 to 1600UTC, (1-3)/8 with base 200ft and at 1630UTC (1-2)/8 with base 2500ft and (5-6)/8 with base 3500ft.
Temperature: 23° Celsius
Pressure: 1015 hPa

Upper air data at 12 UTC 22/10/2014, recorded at the Meteorological Office at Larnaca Airport
The recorded upper air data were:

1000 ft: 100 degrees 8 knots
2000 ft: 105 degrees 8 knots
3000 ft: 140 degrees 7 knots
5000 ft: 285 degrees 3 knots
7000 ft: 195 degrees 7 knots
10000 ft: 215 degrees 17 knots

Αχαιών 28, 1424 Λευκωσία, Τηλ:.00357-22800208/209/210/211 Φαξ: 00357-22800212, Ιστοσελίδα: www.aaiib.gov.cy
28 Achaeon str.1424 Nicosia, Tel: 00357-22800208/209/210/211 Fax: 00357-22800212, Website: www.aaiib.gov.cy

1.8. **AIDS TO NAVIGATION**

Both Larnaca and Beirut VORs were serviceable and operating normally.

1.9. **COMMUNICATIONS**

All VHF frequencies were operating normally. Two way communication was good on all frequencies used and transcripts were obtained after the accident.

1.10. **FLIGHT RECORDERS**

Not applicable

1.11. **WRECKAGE AND IMPACT INFORMATION**

Pieces of wreckage were scattered in a relatively small radius from the impact point. Satellite images inserted. See Appendices 1 and 2.

1.12. **MEDICAL AND PATHOLOGICAL INFORMATION**

The Official Translation of the Coroner's Report states:

"From the examination of the very limited number of tissue fragments, the kind of anatomical origin of these fragments and their small size, no obvious data of injury due to explosion are recognized. In addition and due to the limited forensic data we have today before us, it is not possible to extract a safe conclusion as to the exact causes of death of the persons on board the aircraft, although the occurrence of these fragments is in accord with extensive polytraumatism due to a plane accident."

Αχαιών 28, 1424 Λευκωσία, Τηλ:.00357-22800208/209/210/211 Φαξ: 00357-22800212, Ιστοσελίδα: www.aaiib.gov.cy
28 Achaeon str.1424 Nicosia, Tel: 00357-22800208/209/210/211 Fax: 00357-22800212, Website: www.aaiib.gov.cy

2. ANALYSIS

Aircraft departed Paphos at 15:20 UTC on an IFR flight plan with destination Beirut Airport.

On board were the pilot in command and another crew member on a private flight in accordance with flight plan submitted.

At 15:24:32 5B-CLI established contact with Nicosia Control while passing 5000' and was cleared by Nicosia Control to climb to the requested FL090 and to route direct to KUKLA point.

Nicosia at 15:25:38 in order to facilitate traffic in bound to Larnaca asked 5BCLI to turn right 20° degrees for spacing on a heading of 110° degrees.

At 15:28:10 5BCLI was asked to turn further right heading 130° for 5 minutes.
At 15:36:43 ATC Officer was replaced. Three minutes later he cleared 5BCLI direct to KUKLA point releasing the aircraft to Nicosia Control on frequency 126.3.

At 16:02:14 Nicosia Control requested 5BCLI to confirm that he was proceeding to KUKLA point because the radar indicated that the aircraft was orbiting.
The response from 5BCLI was: Eh, ok Sir we are setting now back to KUKLA, we had a small problem we are sorting it out now.

The ATC replied: in Greek saying the following translated to English: Ok boys, if you need anything tell us we are here.

The response from 5BCLI was in Greek, again translated to English: "No problem".

At this time MEA 202 established contact with Nicosia Control Centre reporting that it was flying at FL370 and squawking 4777 estimating VESAR at 16:18.

Αχαιών 28, 1424 Λευκωσία, Τηλ:.00357-22800208/209/210/211 Φαξ: 00357-22800212, Ιστοσελίδα: www.aaiib.gov.cy
28 Achaeon str.1424 Nicosia, Tel: 00357-22800208/209/210/211 Fax: 00357-22800212, Website: www.aaiib.gov.cy

While this transmission was in progress a noise is heard at 16:04:05. The 5BCLI sound analysis of the audio recordings from the ATC prior to the crash, revealed loud ambient sounds and human moaning from the pilot's microphone.

After this, several attempts were made to contact 5BCLI from both the Nicosia Control Centre as well as a Royal Jordanian 126, aircraft flying in the area, without any success.

Following the loss of contact and the disappearance from the radar screen of 5BCLI, full emergency was declared. Nicosia ATC played back the tapes in order to establish the last position of the lost aircraft and to pass these coordinates to the JRCC as requested.

After informing JRCC, a full emergency was declared by ACC SATCO.

The JRCC was informed at 19:08 local time from the Air Traffic Control Centre of the disappearance of the twin aircraft from their radar screen at 45 NM south of Larnaca.

Immediately, JRCC implemented plan "NEARCHOS" to deal with the disappearance of the aircraft by sending a military helicopter and 3 vessels from the Harbour Police and the Navy to locate the disappeared aircraft in area 10X10 nautical miles.

During the night, in addition to the above mentioned helicopter and naval vessels two helicopters CH53 from UNFIL, two C130 from Israel, a German corvette Braunschweig F260, a Brazilian frigate contitu ICAO F42 and a Brazilian helicopter type LYNX from UNIFIL were also participating in the operation. The Israeli C130 fired flares in order to illuminate the area and assist the naval vessels to locate the aircraft.

Αχαιών 28, 1424 Λευκωσία, Τηλ:.00357-22800208/209/210/211 Φαξ: 00357-22800212, Ιστοσελίδα: www.aaiib.gov.cy
28 Achaeon str.1424 Nicosia, Tel: 00357-22800208/209/210/211 Fax: 00357-22800212, Website: www.aaiib.gov.cy

The first debris of the aircraft was located at 21:34 local time by the army helicopter.
The search for the two pilots continued through the night. During the morning hours of 23 October human remains were located and were picked up. Pieces of the wreckage with the visible registration number of the aircraft were also picked up.

At 11 o'clock in the morning of the 23th October 2014, in the presence of psychologists from the Ministry of Health, the families of the victims were informed of the results of the search.

All the pieces of the retrieved wreckage were delivered to the Aircraft Accident & Incident Investigation Board of Cyprus for their investigation.

Four radar images (Appendices 3, 4, 5, 6) are attached.

Αχαιών 28, 1424 Λευκωσία, Τηλ:.00357-22800208/209/210/211 Φαξ: 00357-22800212, Ιστοσελίδα: www.aaiib.gov.cy
28 Achaeon str.1424 Nicosia, Tel: 00357-22800208/209/210/211 Fax: 00357-22800212, Website: www.aaiib.gov.cy

3. CONCLUSIONS

3.1. General

a. Considering the limited access to the aircraft wreckage and after the inspection of raw materials (RADAR data and ATC audio recordings) from the flight of the Diamond DA42 Twin Star aircraft, and after running various and time-coordinated flight scenarios of the last minutes of the flight in an advanced simulation environment, as part of a prompt investigation, the possible pilot actions and flight path geometry of the event lead to a single plausible scenario.

b. The plausible scenario for the accident is a spatial disorientation of the pilot, which resulted in a spiral dive and a crash into the sea.

i. Following the reporting of the "small problem" to the ATC and the correction by the pilots back on track, seconds later the aircraft commenced a right bank with minor variations to speed and altitude. Thereafter the bank was increased resulting in to a spiral dive. This correlates with the plausible scenario of spatial disorientation without excluding instrument failure.

ii. Inflight engine malfunction is a low probability scenario due to aircraft performance characteristics, its actual flight path and pilot actions, as described below.

3.2. Aircraft single engine performance:

a. Aircraft's performance specification data is based on the Airplane's Flight Manual (AIRPLANE FLIGHT MANUAL DA42, Doc. No.:7.01.05-E, issued at: 29 April 2004, Engine designation TAE 125-01 or TAE 125-02-99).
b. One engine inoperative minimum control speed (Vmca) is 68 KIAS.
c. One engine inoperative speed for best rate of climb (Vyse) is 82 KIAS.

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d. Maximum engine restart altitude is 8000 ft (TAE 125-02-99 engine stalled), and restart airspeed is 110 to 120 KIAS.
e. One engine inoperative climb/descent (for ~8800 ft, OAT 5 degrees Celsius) is about positive 170 ft/min.

3.3. **Flight path and pilot actions analysis in relation to an engine malfunction situation:**

a. On a single engine and at altitude of ~8800 feet, the aircraft may maintain it' s flying altitude or even climb at a low but positive rate of climb. Operating speed for maintaining its flying altitude is Vyse or slightly above, which is 82 KIAS.

At all times, the aircraft never decelerated to low values of airspeed and around Vyse, nor Vmca, while maintaining its altitude with a ~500 feet amplitude. The probability of flying with a single engine during the last minutes of the flight, at ~8800 feet is very low, giving the aircraft flight performance and characteristics. Real time flight simulation trials for a single engine operation scenario supported the theoretic analysis and demonstrated a mismatched flight path.

b. No report of engine malfunction, emergency, flight direction request or flight level change request for descent (in order to reach the Maximum engine start altitude, which is 8000 feet) were initiated by the pilot. During the flight, radio communication with the pilot was established without noticeable problems, as analysed from the ATC radio recordings.

c. Giving the pilot's proficiency and experience, the probability of flying the aircraft in a single engine emergency, over the sea and at night, without declaring emergency or without contacting the ATC in an engine emergency situation is very unlikely.

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3.4. **Spatial Disorientation FAA document entitled "Spatial Disorientation" available at:**

https://www.faa.gov/pilots/safety/pilotsafetybrochures/media/SpatialD.pdf

Spatial Orientation

Defines our natural ability to maintain our body orientation and/or posture in relation to the surrounding environment (physical space) at rest and during motion. Genetically speaking, humans are designed to maintain spatial orientation on the ground. The three-dimensional environment of flight is unfamiliar to the human body, creating sensory conflicts and illusions that make spatial orientation difficult, and sometimes impossible to achieve. Statistics show that between 5 to 10% of all general aviation accidents can be attributed to spatial disorientation, 90% of which are fatal.

Spatial Orientation in Flight

Spatial orientation in flight is difficult to achieve because numerous sensory stimuli (visual, vestibular, and proprioceptive) vary in magnitude, direction, and frequency. Any differences or discrepancies between visual, vestibular, and proprioceptive sensory inputs result in a sensory mismatch that can produce illusions and lead to spatial disorientation. Good spatial orientation relies on the effective perception, integration and interpretation of visual, vestibular (organs of equilibrium located in the inner ear) and proprioceptive (receptors located in the skin, muscles, tendons, and joints) sensory information.

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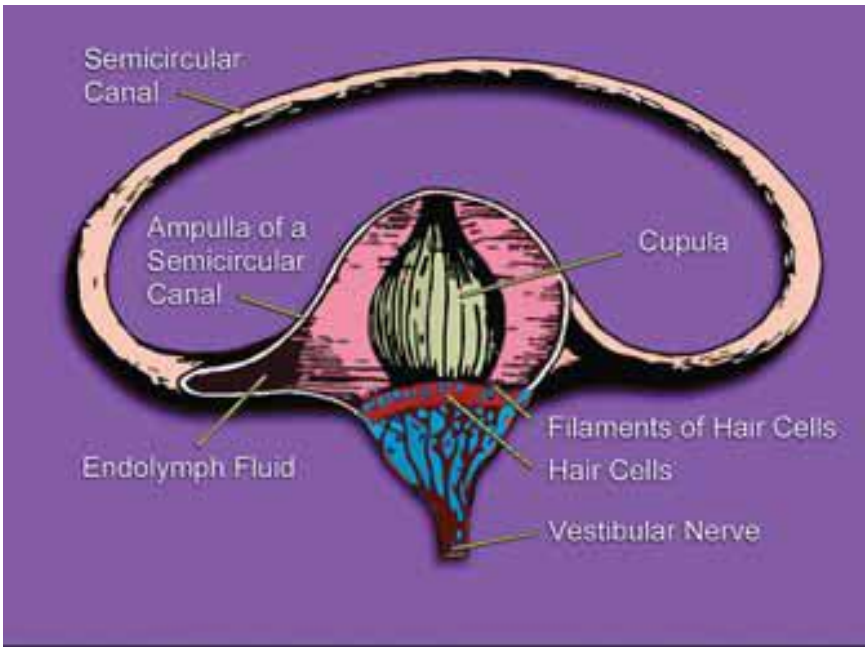

Vestibular Aspects of Spatial Orientation

The inner ear contains the vestibular system, which is also known as the organ of equilibrium. About the size of **a** pencil eraser, the vestibular system contains two distinct structures: the semicircular canals, which detect changes in angular acceleration, and the otolith organs (the utricule and the saccule), which detect changes in linear acceleration and gravity.

Both the semicircular canals and the otolith organs provide information to the brain regarding our body's position and movement.

A connection between the vestibular system and the eyes helps to maintain balance and keep the eyes focused on an object while the head is moving or while the body is rotating.

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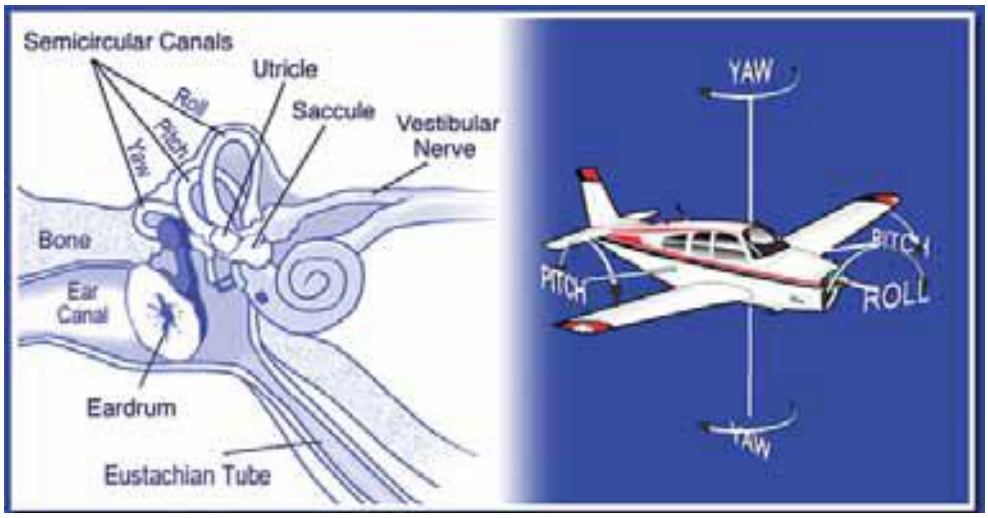
The Semicircular Canals

The semicircular canals are three half-circular, interconnected tubes located inside each ear that are the equivalent of three gyroscopes located in three planes perpendicular (at right angles) to each other. Each plane corresponds to the rolling, pitching, or yawing motions of an aircraft.



Each canal is filled with a fluid called endolymph and contains a motion sensor with little hairs whose ends are embedded in a gelatinous structure called the cupula. The cupula and the hairs move as the fluid moves inside the canal in response to an angular acceleration.

The movement of the hairs is similar to the movement of seaweed caused by ocean currents or that of wheat fields moved by wind gusts. When the head is still and the airplane is straight and level, the fluid in the canals does not move and the hairs stand straight up, indicating to the brain that there is no rotational acceleration (a turn).

If you turn either your aircraft or your head, the canal moves with your head, but the fluid inside does not move because of its inertia. As the canal moves, the hairs inside also move with it and are bent in the opposite direction of the acceleration by the stationary fluid (A). This hair movement sends a signal to the brain to indicate that the head has turned. The problem starts when you continue turning your aircraft at a constant rate (as in a coordinated turn) for more than 20 seconds.

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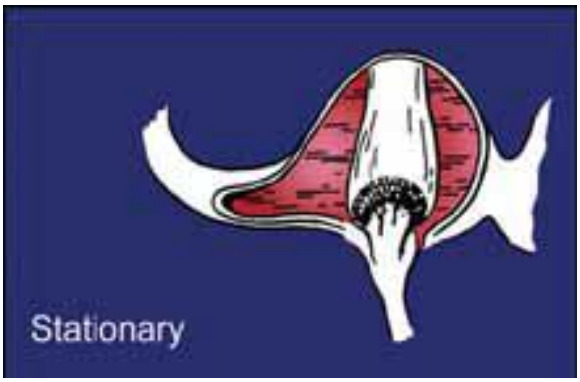
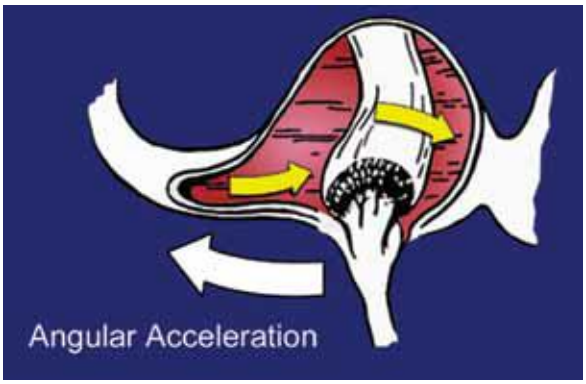
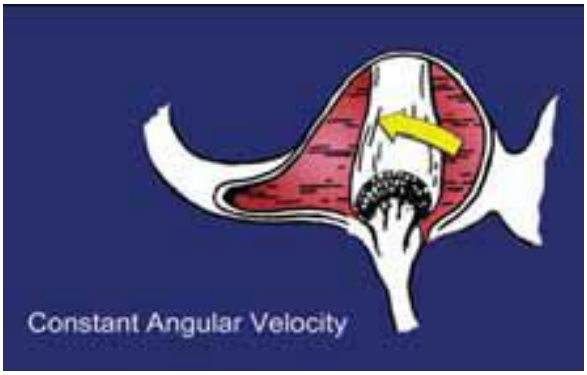
A



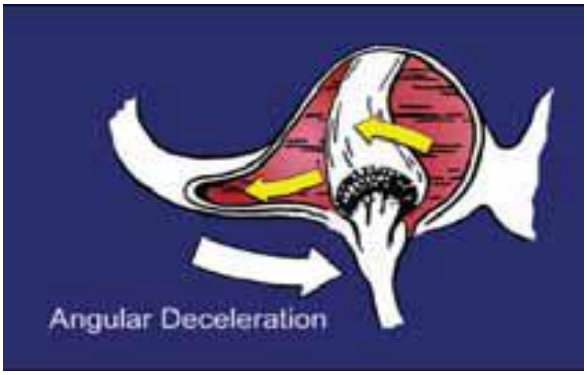


In this kind of turn, the fluid inside the canal starts moving initially, then friction causes it to catch up with the walls of the rotating canal (B). When this happens, the hairs inside the canal will return to their straight up position, sending an erroneous signal to the brain that the turn has stopped–when, in fact, the turn continues.

B



C



If you then start rolling out of the turn to go back to level flight, the fluid inside the canal will continue to move (because of its inertia), and the hairs will now move in the opposite direction (C), sending an erroneous signal to the brain indicating that you are turning in the opposite direction, when in fact, you are actually slowing down from the original turn.

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Vestibular Illusions
(Somatogyral - Semicircular Canals)

Illusions involving the semicircular canals of the vestibular system occur primarily under conditions of unreliable or unavailable external visual references and result in false sensations of rotation.
These include the Leans, the Graveyard Spin and Spiral, and the Coriolis Illusion.

The Leans. This is the most common illusion during flight and is caused by a sudden return to level flight following a gradual and prolonged turn that went unnoticed by the pilot.
The reason a pilot can be unaware of such a gradual turn is that human exposure to a rotational acceleration of 2 degrees per second or lower is below the detection threshold of the semicircular canals. Leveling the wings after such a turn may cause an illusion that the aircraft is banking in the opposite direction. In response to such an illusion, a pilot may lean in the direction of the original turn in a corrective attempt to regain the perception of a correct vertical posture.

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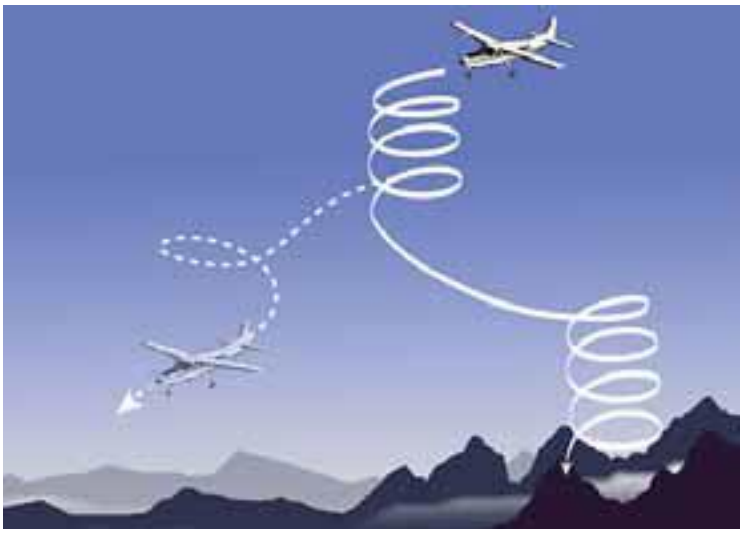
The Graveyard Spin is an illusion that can occur to a pilot who intentionally or unintentionally enters a spin. For example, a pilot who enters a spin to the left will initially have a sensation of spinning in the same direction. However, if the left spin continues the pilot will have the sensation that the spin is progressively decreasing.

At this point, if the pilot applies right rudder to stop the left spin, the pilot will suddenly sense a spin in the opposite direction (to the right). If the pilot believes that the airplane is spinning to the right, the response will be to apply left rudder to counteract the sensation of a right spin. However, by applying left rudder the pilot will unknowingly re-enter the original left spin.



If the pilot cross checks the turn indicator, he/she would see the turn needle indicating a left turn while he/she senses a right turn.

This creates a sensory conflict between what the pilot sees on the instruments and what the pilot feels. If the pilot believes the body sensations instead of trusting the instruments, the left spin will continue.

If enough altitude is lost before this illusion is recognized and corrective action is taken, impact with terrain is inevitable.

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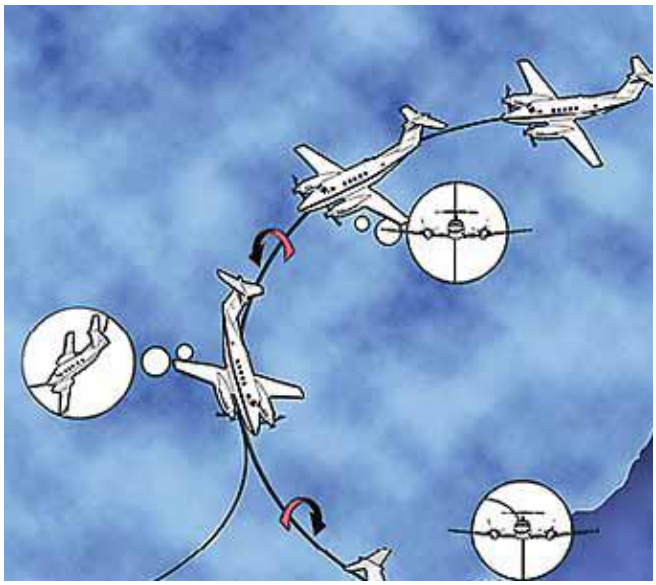
The Graveyard Spiral is more common than the Graveyard Spin, and it is associated with a return to level flight following an intentional or unintentional prolonged bank turn.



For example, a pilot who enters a banking turn to the left will initially have a sensation of a turn in the same direction. If the left turn continues (~20 seconds or more), the pilot will experience the sensation that the airplane is no longer turning to the left. At this point, if the pilot attempts to level the wings this action will produce a sensation that the airplane is turning and banking in the opposite direction (to the right).

If the pilot believes the illusion of a right turn (which can be very compelling), he/she will reenter the original left turn in an attempt to counteract the sensation of a right turn.
Unfortunately, while this is happening, the airplane is still turning to the left and losing altitude. Pulling the control yoke/stick and applying power while turning would not be a good idea–because it would only make the left turn tighter. If the pilot fails to recognize the illusion and does not level the wings, the airplane will continue turning left and losing altitude until it impacts the ground.

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The Coriolis Illusion involves the simultaneous stimulation of two semicircular canals and is associated with a sudden tilting (forward or backwards) of the pilot's head while the aircraft is turning. This can occur when you tilt you head down (to look at an approach chart or to write a note on your knee pad), or tilt it up (to look at an overhead instrument or switch) or tilt it sideways.

This produces an almost unbearable sensation that the aircraft is rolling, pitching, and yawing all at the same time, which can be compared with the sensation of rolling down on a hillside.
This illusion can make the pilot quickly become disoriented and lose control of the aircraft.

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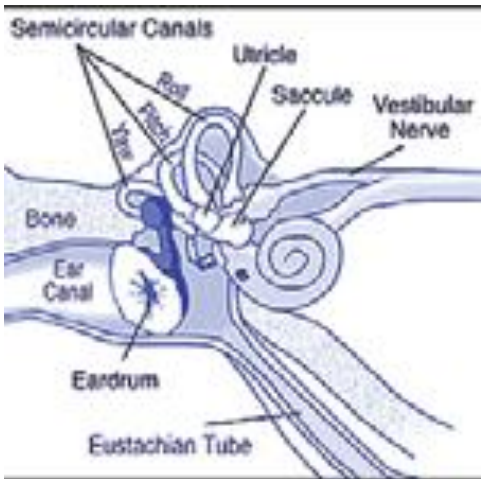
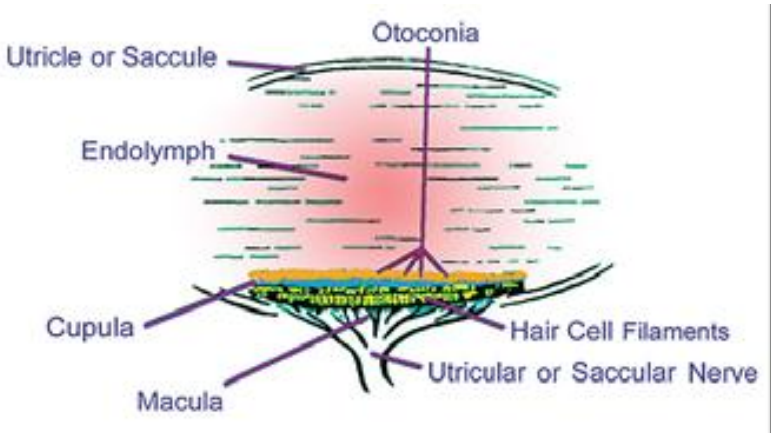
The Otolith Organs





Two otolith organs, the saccule and utricle, are located in each ear and are set at right angles to each other. The utricle detects changes in linear acceleration in the horizontal plane, while the saccule detects gravity changes in the vertical plane.
However, the inertial forces resulting from linear accelerations cannot be distinguished from the force of gravity; therefore, gravity can also produce stimulation of the utricle and saccule.

These organs are located at the base (vestibule) of the semicircular canals, and their structure consists of small sacs (maculas) covered by hair cell filaments that project into an overlying gelatinous membrane (cupula) tipped by tiny, chalk-like calcium stones called otoconia.

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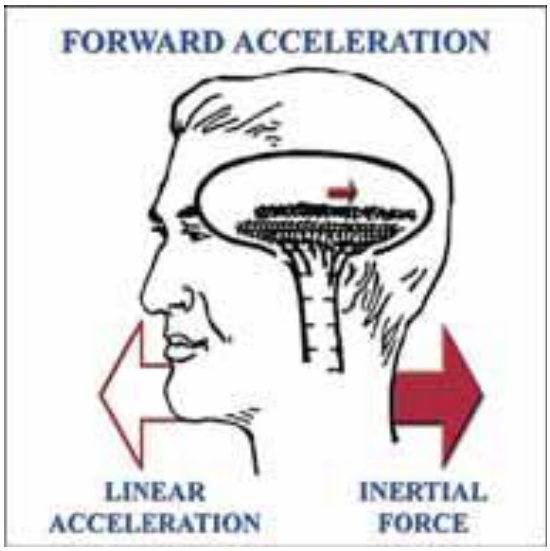
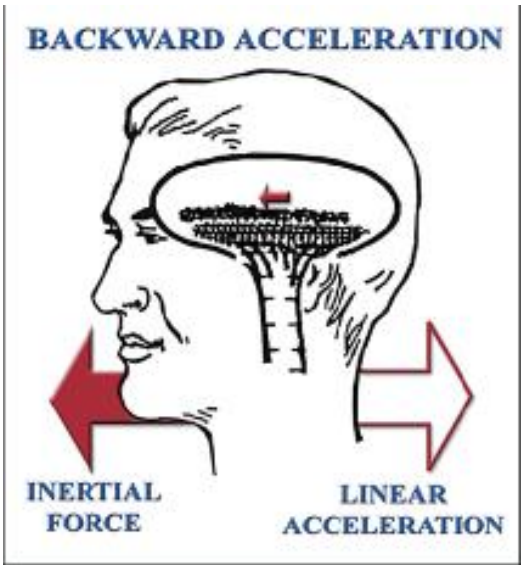
Change in Gravity

When the head is tilted, the weight of the otoconia of the saccule pulls the cupula, which in turn bends the hairs that send a signal to the brain indicating that the head has changed position. A similar response will occur during a vertical take-off in a helicopter or following the sudden opening of a parachute after a free fall.





Change in Linear Acceleration

The inertial forces resulting from a forward linear acceleration (take-off, increased acceleration during level flight, vertical climb) produce a backward displacement of the otoconia of the utricle that pulls the cupula, which in turn bends the hair cell filaments that send a signal to the brain, indicating that the head and body have suddenly been moved forward.

Exposure to a backward linear acceleration or to a forward linear deceleration has the opposite effect.

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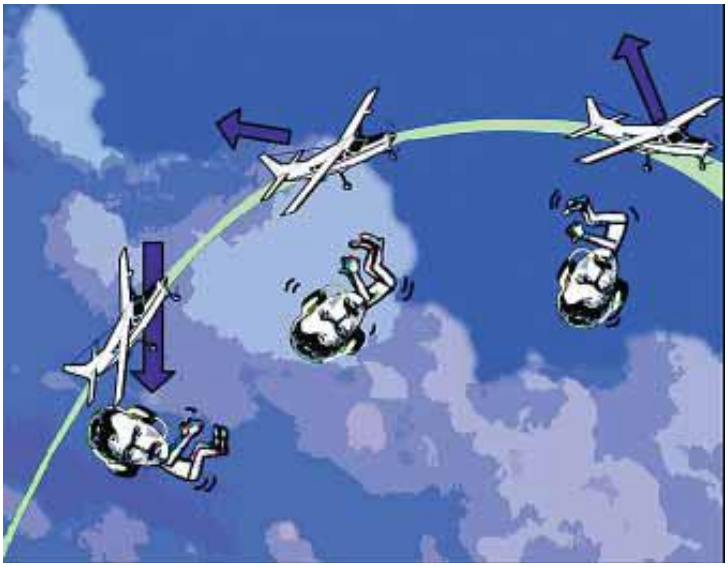
Vestibular Illusions

(Somatogravic - Utricle and Saccule) Illusions involving the utricle and the saccule of the vestibular system are most likely under conditions with unreliable or unavailable external visual references. These illusions include: the Inversion Illusion, Head-Up Illusion, and Head-Down Illusion.



The Inversion Illusion involves a steep ascent (forward linear acceleration) in a high-performance aircraft, followed by a sudden return to level flight. When the pilot levels off, the aircraft's speed is relatively higher. This combination of accelerations produces an illusion that the aircraft is in inverted flight. The pilot's response to this illusion is to lower the nose of the aircraft.

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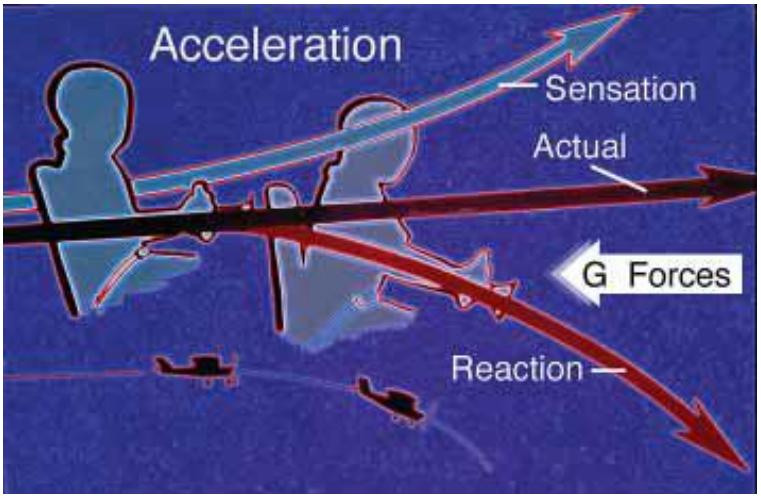
The Head-Up Illusion involves a sudden forward linear acceleration during level flight where the pilot perceives the illusion that the nose of the aircraft is pitching up.

The pilot's response to this illusion would be to push the yolk or the stick forward to pitch the nose of the aircraft down. A night take-off from a well-lit airport into a totally dark sky (black hole) or a catapult take-off from an aircraft carrier can also lead to this illusion, and could result in a crash.



The Head-Down Illusion involves a sudden linear deceleration (air braking, lowering flaps, decreasing engine power) during level flight where the pilot perceives the illusion that the nose of the aircraft is pitching down. The pilot's response to this illusion would be to pitch the nose of the aircraft up. If this illusion occurs during a low-speed final approach, the pilot could stall the aircraft.

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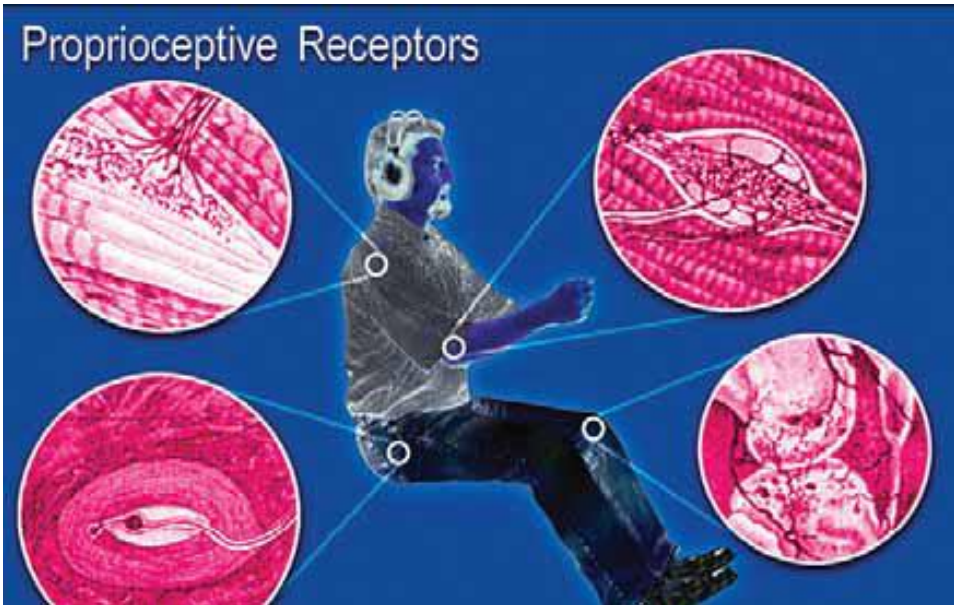
The Proprioceptive Receptors

The proprioceptive receptors (proprioceptors) are special sensors located in the skin, muscles, tendons, and joints that play a very small role in maintaining spatial orientation in normal individuals. Proprioceptors do give some indication of posture by sensing the relative position of our body parts in relation to each other, and by sensing points of physical contact between body parts and the surrounding environment (floor, wall, seat, arm rest, etc.).



For example, proprioceptors make it possible for you to know that you are seated while flying; however, they alone will not let you differentiate between flying straight and level and performing a coordinated turn.

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3.5. **General conclusions of the investigation:**

a. The flight took place at night and above the sea. Few minutes before the crash, the aircraft flight track changed repeatedly, without correlation with its original flight plan.
There is a high probability that the changes of track were the beginning of an escalating state of spatial disorientation of the pilot with the possibility that both pilots trying to establish the cause of the continuous changes of track which probably accounts for the pilots reporting the "small problem" they were encountering.

b. During these changes of flight track, after completing a ~30 seconds right turn from east to south and as a reasonable response to it, the ATC confirmed with the pilot that he was "orbiting", The pilot answered that he "had a small problem and sorting it out now…" without specifying or calling emergency. The pilot answered to the ATC that "… we are setting now back to KUKLA…".
The vague description of the pilot regarding a "small problem" was in high probability referring to the conflict regarding the aircraft attitude and spatial orientation. This is a known and familiar pilot response in spatial disorientation conflicts at it's first stages, when the pilot tends to think that there are minor problems with the aircraft's instruments.

c. After performing two 90 degrees changes of flight track, and as a result of the escalating loss of spatial orientation (and the conflicts involving in flying the aircraft in such situations), the pilot probably reacted to the conflict by flying the aircraft based on his incorrect spatial sensation to fix the aircraft's attitude, rather than using the flying instruments (there is a probability of instruments failure, which could not conclusively be determined due to the limited data available).

d. The last right hand turn before the crash was in a steep bank (over 45 degrees). The pilot probably noticed a loss of altitude, and pulled back on the controls in an attempt to keep his altitude. While banking to the right and descending, this action tightened the turn into a spiral dive and increased the loss of altitude and airspeed of the aircraft.

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The pilot entered a state of "Graveyard spiral" mechanism in the accident. "Graveyard Spirals" are most common in night time or poor weather conditions where no horizon exists to provide visual correction for misleading inner- ear cues.

The "Graveyard spiral" is associated with a return to level flight following an intentional or unintentional prolonged bank turn (~20 seconds or more), without any external use.

e. Analysis of the audio recordings from the ATC prior to the crash, revealed loud ambient sound and human moaning from the pilot's microphone.

The loud ambient sounds are the internal cabin noise caused by the rapid acceleration during the steep descent of the spiral dive. The human moaning sounds can be referred to pilot's response to unfamiliar accelerations (G forces) during the tight spiral, and/or as a fear response.

f. Advanced physical and aerodynamic real-time simulation and flight path recreation of this scenario demonstrated a very high match between the resulted simulated geometry of the flight, and all the available data (RADAR flight path, ATC time-tables and audio recordings).

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4. SAFETY RECOMMENDATIONS

1) EASA to re-examine the required minimum hours of night flying training.

2) When the pilots report any problem to ATC, ATC should attempt to establish the nature of the problem.

(Captain Ioannis (John) Loizou)
Chairman of Cyprus Aircraft Accident &
Incident Investigation Board

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5. APPENDICES 1-6

APPENDIX 1

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APPENDIX 2

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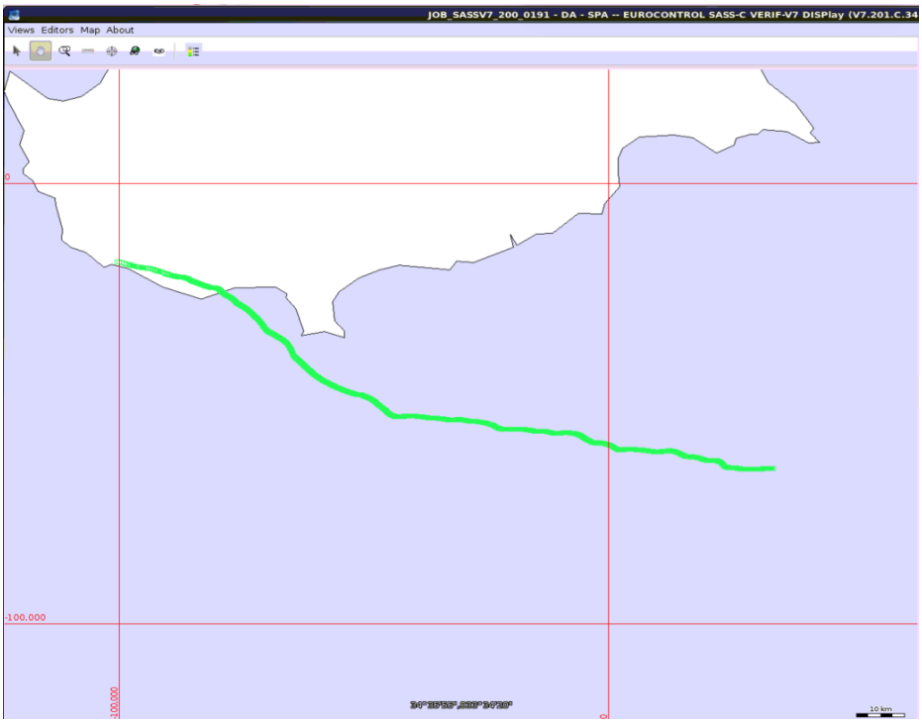
APPENDIX 3

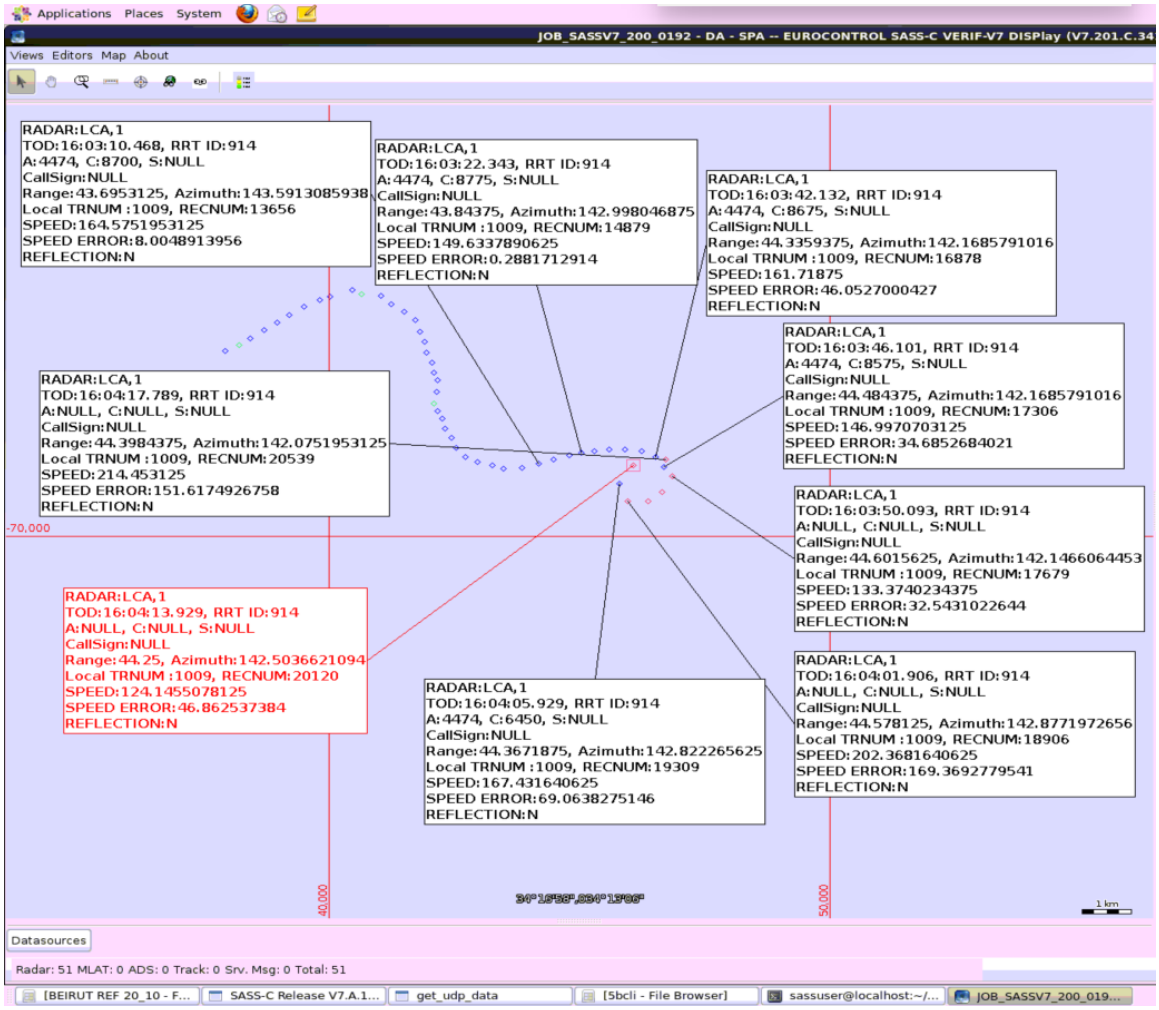
Chronological Narrative and observations based solely on the radar data and without taking into consideration any conversations the PIC may have had with ATC.



The above image displays the reconstructed track of 5BCLI departing from Paphos up to 16:00 UTC at which point the recording continues, as illustrated by the analysis on the next pages.

Αχαιών 28, 1424 Λευκωσία, Τηλ:.00357-22800208/209/210/211 Φαξ: 00357-22800212, Ιστοσελίδα: www.aaiib.gov.cy
28 Achaeon str.1424 Nicosia, Tel: 00357-22800208/209/210/211 Fax: 00357-22800212, Website: www.aaiib.gov.cy

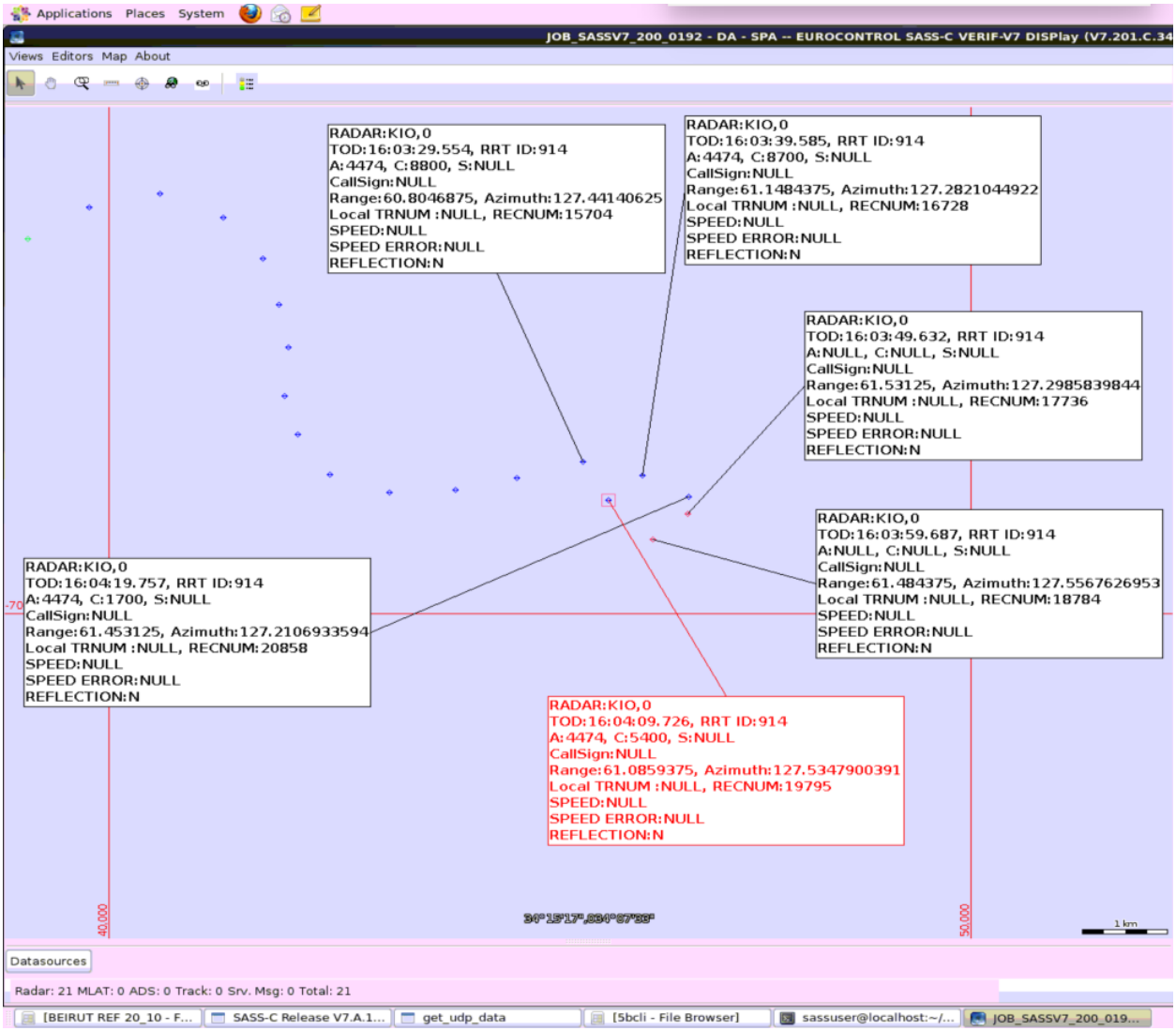
APPENDIX 4



Above image displays the reconstructed track of 5BCLI based on Larnaca Radar readings.

Αχαιών 28, 1424 Λευκωσία, Τηλ:.00357-22800208/209/210/211 Φαξ: 00357-22800212, Ιστοσελίδα: www.aaiib.gov.cy
28 Achaeon str.1424 Nicosia, Tel: 00357-22800208/209/210/211 Fax: 00357-22800212, Website: www.aaiib.gov.cy

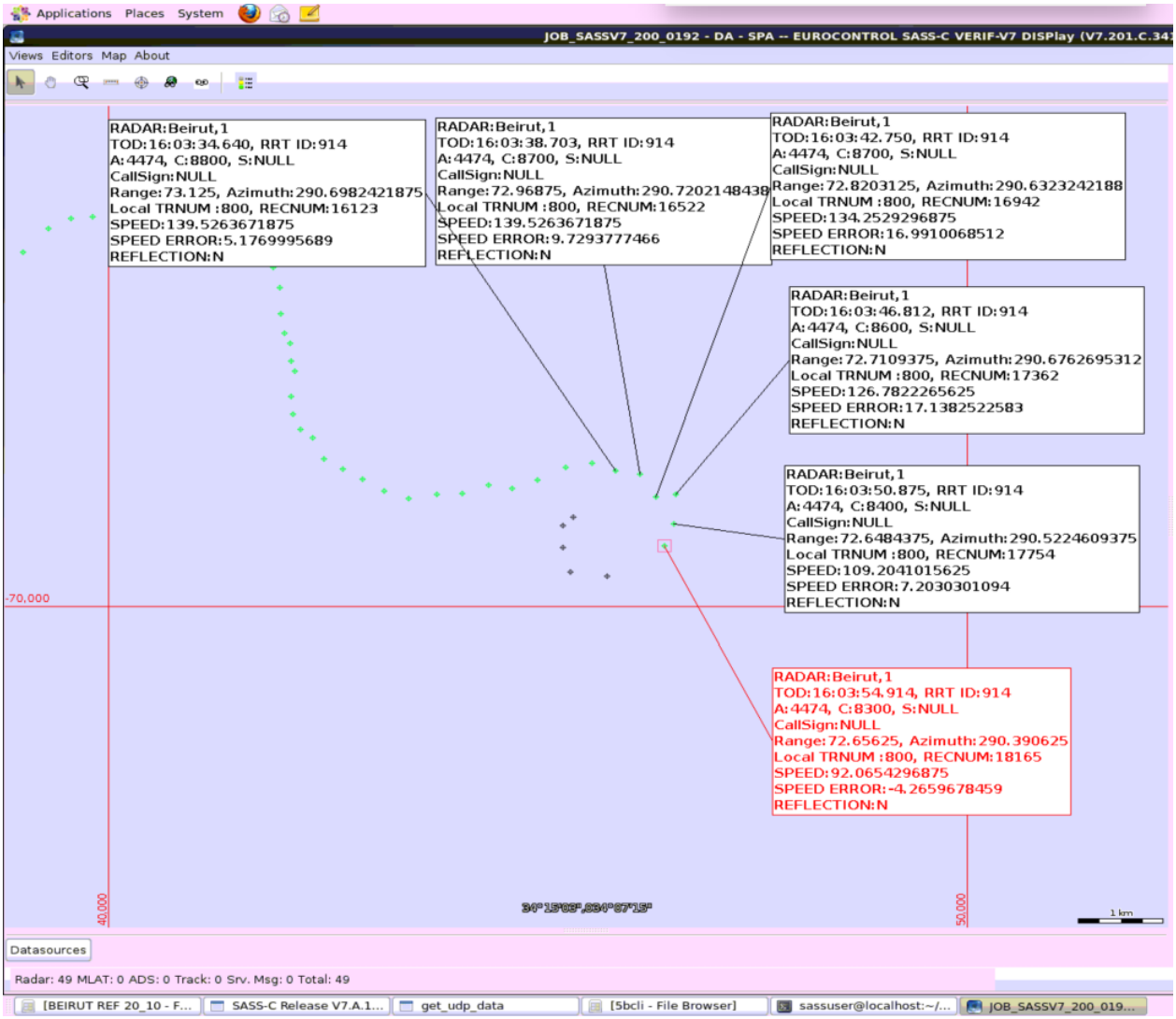
APPENDIX 5



Above image displays the reconstructed track of 5BCLI based on Kionia (In Cyprus) Radar readings.

Αχαιών 28, 1424 Λευκωσία, Τηλ:.00357-22800208/209/210/211 Φαξ: 00357-22800212, Ιστοσελίδα: www.aaiib.gov.cy
28 Achaeon str.1424 Nicosia, Tel: 00357-22800208/209/210/211 Fax: 00357-22800212, Website: www.aaiib.gov.cy

APPENDIX 6



Above image displays the reconstructed track of 5BCLI based on Beirut Radar readings.

Αχαιών 28, 1424 Λευκωσία, Τηλ:.00357-22800208/209/210/211 Φαξ: 00357-22800212, Ιστοσελίδα: www.aaiib.gov.cy
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