Australian Government
Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT
External Investigation – AE-2010-024

Flight Data Recovery

Collision with Terrain – RNZAF Base Ohakea
14 January 2010
CT-4 Airtrainer, NZ1990

Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

AE-2010-024
Final

Flight Data Recovery

Collision with Terrain
RNZAF Base Ohakea – 14 January 2010
CT-4 Airtrainer, NZ1990

Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

Published by: Australian Transport Safety Bureau
Postal address: PO Box 967, Civic Square ACT 2608
Office: 62 Northbourne Avenue Canberra, Australian Capital Territory 2601
Telephone: 1800 020 616, from overseas +61 2 6257 4150
Accident and incident notification: 1800 011 034 (24 hours)
Facsimile: 02 6247 3117, from overseas +61 2 6247 3117
Email: atsbinfo@atsb.gov.au
Internet: www.atsb.gov.au

ISBN and formal report title: see 'Document retrieval information' on page 5.

DOCUMENT RETRIEVAL INFORMATION

Report No.	Publication date	No. of pages	ISBN
AE-2010-024	March 2011	15	978-74251-185-6

Publication title

Flight Data Recovery – Collision with terrain, Airtrainer CT-4, RNZAF Base Ohakea, 14 January 2010

Prepared By

Australian Transport Safety Bureau
PO Box 967, Civic Square ACT 2608 Australia
www.atsb.gov.au

Reference Number

ATSB- June11/ATSB58

Acknowledgements

Appareo Systems assisted the investigation by providing information and hardware for testing the recovery procedure.

Abstract

On 14 January 2010, a Royal New Zealand Air Force (RNZAF) *Red Checkers* aerobatics team CT-4 Airtrainer aircraft collided with terrain while practicing for an upcoming aerobatics display. The pilot was fatally injured in the accident and the aircraft was destroyed by a post-impact fire.

An *Appareo Systems GAU1000* data recorder was fitted to the aircraft to gather performance data as part of a fatigue monitoring programme. Although the recorder was severely fire damaged, it was recovered from the aircraft wreckage by RNZAF investigators, who subsequently requested assistance from the Australian Transport Safety Bureau (ATSB) in the recovery of any stored data on the recorder that may have survived the accident and fire.

Following preparatory research into the nature of the recorder's design and operation and the subsequent non-destructive examination to evaluate the physical condition of the damaged unit, a number of attempts were made to recover data from the removable secure digital/multimedia memory card (SD/MMC) – all of which were unsuccessful. Further examination of the recorder, however, located an on-board NAND flash memory device, which subsequently yielded a large quantity of valid recorded data after its removal from the primary circuitry and interrogation in a universal reader/programmer unit. The data was provided to the RNZAF on 12 August 2010.

FACTUAL INFORMATION

Introduction

On 14 January 2010, a Royal New Zealand Air Force (RNZAF) *Red Checkers* aerobatics team CT-4 Airtrainer aircraft collided with terrain while practicing for an upcoming aerobatics display. The pilot was fatally injured in the accident and the aircraft was destroyed by a post-impact fire.

The aircraft was fitted with an *Appareo Systems GAU1000* data recorder; used to gather performance data as part of a fatigue monitoring programme. The recorder was severely fire damaged, but was recovered from the aircraft wreckage by RNZAF investigators.

On 26 March 2010, the RNZAF flight safety office requested assistance from the Australian Transport Safety Bureau (ATSB) in the recovery of any data stored on the recorder.

On 30 March 2010, the fire damaged recorder was hand carried to Canberra Airport by an RNZAF flight safety officer, from where it was transferred to the ATSB's Technical Analysis facilities.

Recorder information

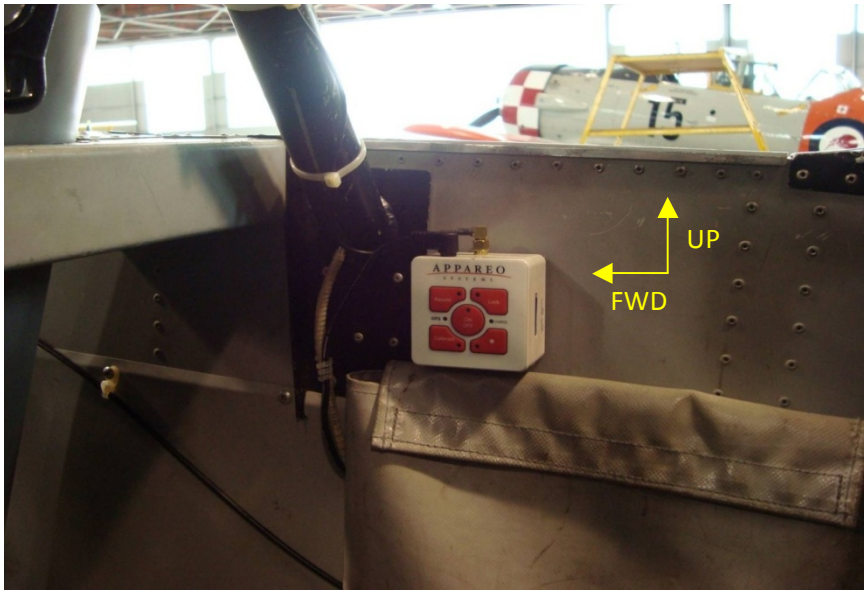
Appareo Systems GAU1000 recorder

The Appareo Systems GAU1000 data recorder (Figure 1) was a non-crash protected flight data recorder mounted to the aircraft with hook-and-loop fasteners (Figure 2). The recorder contained gyroscopes, accelerometers, barometric pressure sensors, and a solid state compass. It also recorded Global Positioning System (GPS) data[1]. Data was recorded to a Secure Digital (SD) card or Multimedia Card (MMC) fitted in the side of the recorder (arrowed in Figure 1) as well as to on-board NAND flash memory.

Figure 1: Example Appareo Systems GAU1000 recorder

[1] http://www.appareo.com/products/gau_1000.php , as at 6 September 2010

Figure 2: GAU1000 fitted to a RNZAF CT-4 Airtrainer



Data recovery

On 31 March 2010, the recorder was unpacked (Figure 3) and disassembled in the ATSB's Canberra technical facilities. The initial approach to recovering data from the unit focussed on the removable SD/MMC card.

Figure 3: Contents of the box from the RNZAF. (GAU1000 is circled)

SD/MMC card data recovery

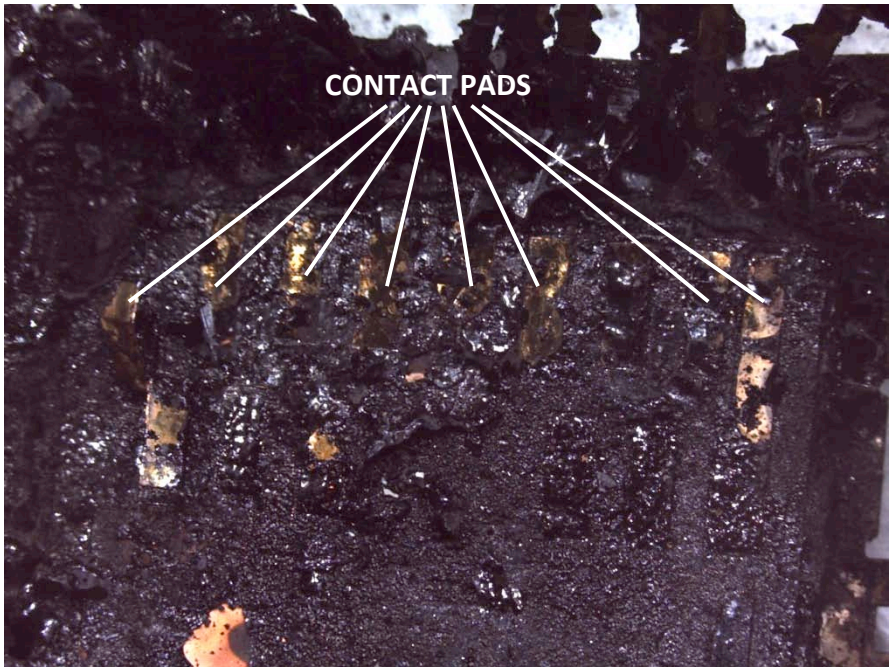
The SD/MMC card and socket were removed from the recorder (Figure 4). Removal of the card from its socket was obstructed by thermally-induced deformation of the surrounding material (Figure 5).

Figure 4: SD/MMC card removed from the recorder

Figure 5: SD/MMC enclosed in its socket (reverse)

The charred material was carefully removed from the front face of the card exposing the pin contacts (Figure 6).

Figure 6: SD/MMC card with contact pads visible



The SD/MMC was identified (by the part number visible at the base of the front side of the card, Figure 7) as an *Imation* 512 megabyte (MB) multimedia card (MMC) (Figure 8).

Figure 7: Part number of SD/MMC card visible at base of card

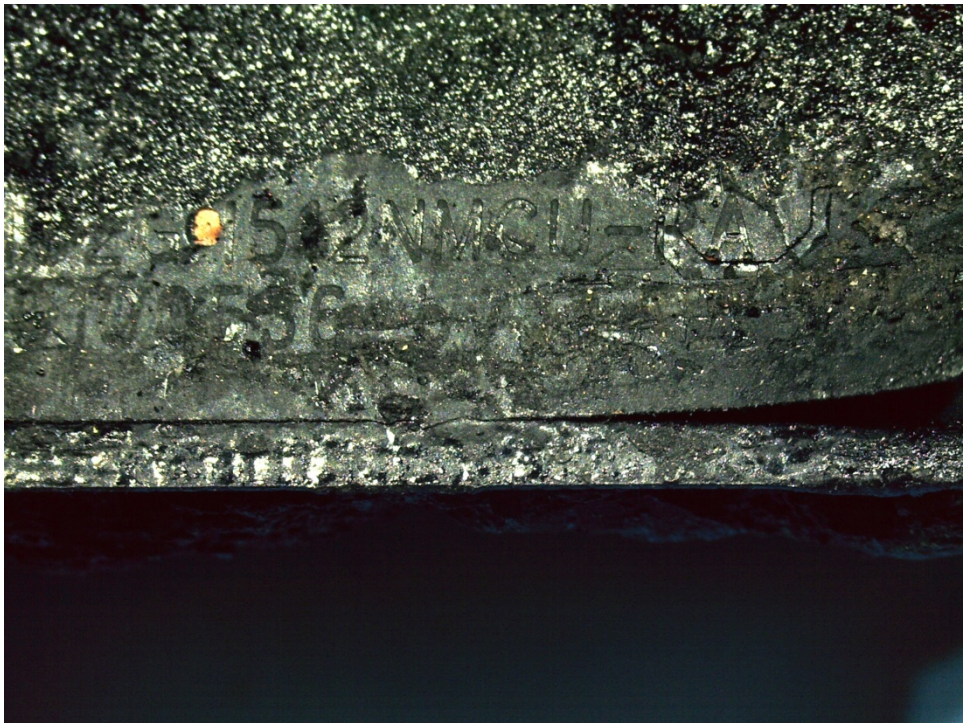
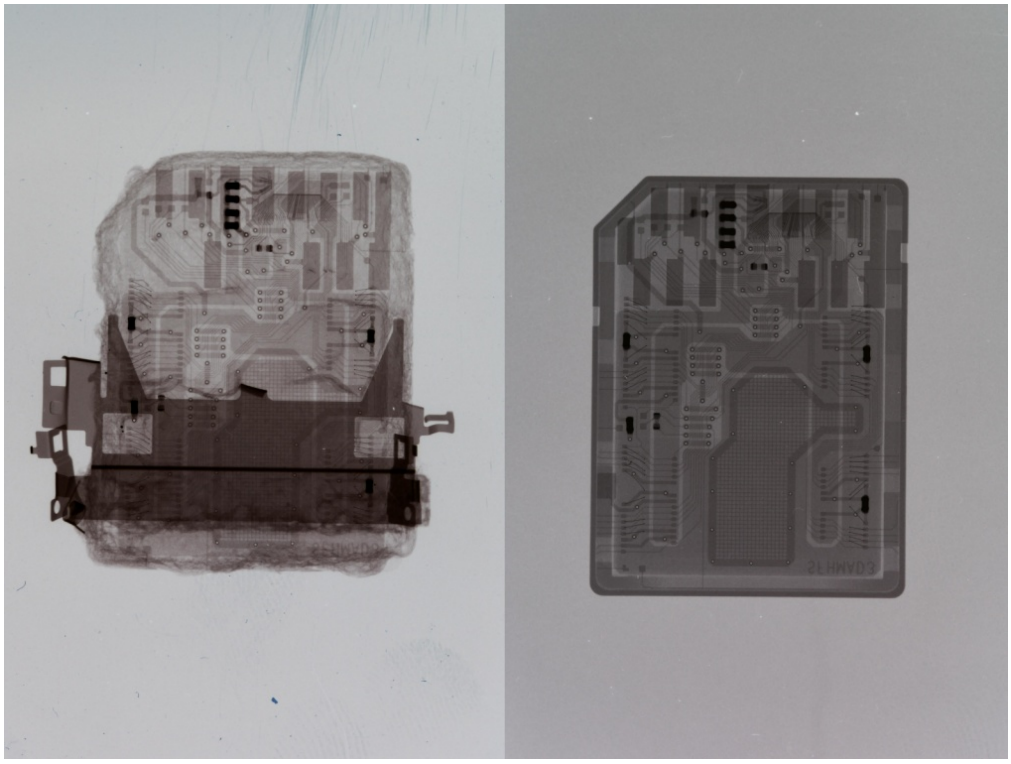


Figure 8: Example MMC card provided by RNZAF flight safety

The MMC was manufactured with its electronics encapsulated in plastic. X-ray images (Figure 9) were taken to non-destructively identify damaged circuit tracks. For comparison, an identical, undamaged card was x-rayed.

Figure 9: X-ray comparison of undamaged card (right) and accident card (left)



Comparison of the x-ray images revealed no substantial damage to the circuit tracks. However, these images gave no indication of the condition of other key components within the card or the integrity of any stored data.

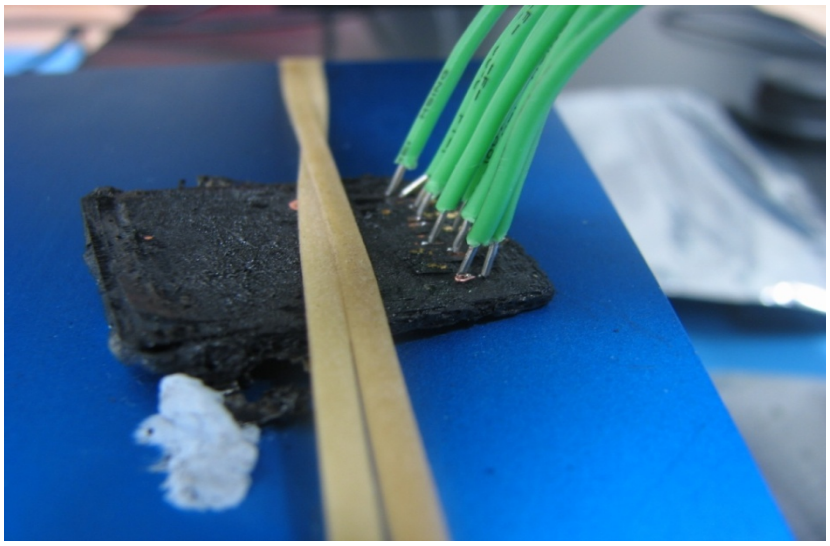
Download Attempts

A MMC/SD card reader was setup with fly-leads to enable connection to the accident card without inserting the card into a socket. The reader and fly-lead setup was tested successfully with several SD cards and MMCs, including the example MMCs provided.

Due to the external damage to the card, the fly-leads made direct contact to the board, bypassing the damaged contact pads.

Numerous attempts were made to access the data on the accident card using the card reader setup (Figure 10). The card was not recognised by the computer in use and no data was recovered.

Figure 10: Accident MMC in contact with fly-leads from the card reader



NAND Flash memory recovery

Flash memory is a specific type of non-volatile[2], electrically erasable programmable read only memory (EEPROM).

There are two major types of flash memory; NAND flash and NOR flash, with the key differences relating to the specific manner of data storage. The flash memory device used in the Appareo Systems recorder was the NAND type. There are a large variety of NAND flash memory device sizes and package types[3], however the architecture/structure of the memory appears common throughout; a device is made up of data blocks, which in turn are made up of multiple data pages. In each page, there are spare bytes that can be used to store an error correction code (ECC) checksum[4]. The size of the page and number of blocks is dependent on the memory density[5].

---

2 Non-volatile memory retains the data when power is removed from the device.

3 Refers to the shape and type of connection of the memory device (examples are thin small outline package (TSOP) and ball grid array (BGA))

4 Method used for detecting errors in data, introduced by transmission or storage.

5 Density refers to the size in bits of the useable memory in the flash memory device.

Accident NAND flash details

Manufacturer: *ST Electronics*

Part number: NAND01GW3B2AN6

Package type: TSOP-48

Dimensions: 12mm x 20mm

Density: 1 Gigabit (equivalent to 128 megabytes (MB))

Figure 11: NAND01GW3B2AN6 flash memory device

The accident NAND flash memory was structured as 1024 blocks; each block contained 64 pages of 2048 bytes and 64 spare bytes[6]:

- *1 [illegible] =2048 [illegible]+64 [illegible] [illegible] [illegible]*
- *1 [illegible] =64 [illegible]=64×2048+64 [illegible]*

  =131,072+4096[illegible]=128+4[illegible]
- *1 [illegible]=1024 [illegible]=1024 ×(128+4)[illegible]*

  =(128+4)[illegible]

  =132[illegible] ([illegible] [illegible] [illegible])

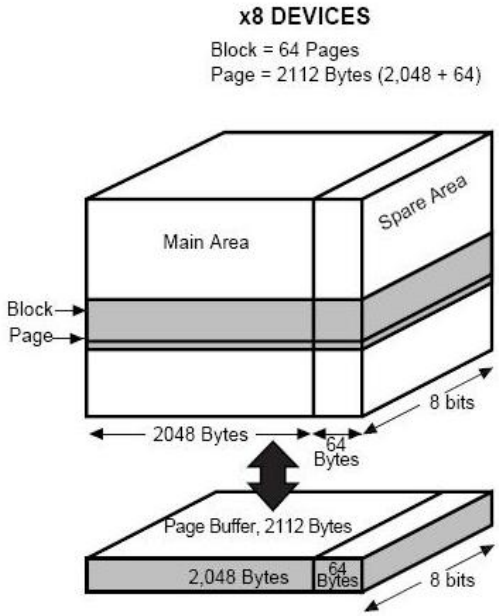
As such, a successful, complete, download of the flash memory device should yield a binary data file of 132MB in size. Figure 12 is a graphical representation of the structure of the NAND flash memory[7].

---

[6] 8 bits = 1 byte, 1024 bytes = 1kilobyte (KB), 1024 KB = 1 megabyte (MB)

[7] ST Electronics, NAND01/2G-B Datasheet, February 2006, Revision 4.0.

Figure 12: Architecture of flash memory device family NAND01G-B



On-board flash device

The NAND flash device was identified on the circuit board during the disassembly (Figure 13). Typically, the removal of a flash device from a circuit board would be performed using a rework or hot-air station. For the accident board, heat exposure had caused the device pins to separate and lift away from the circuit board. The device was held in situ by solidified charred plastic. Once this material was removed, the device was easily lifted away from the board (Figure 14). The pins of the flash memory device were found to be in good condition.

Figure 13: Left - NAND flash on undamaged GAU1000 recorder, Right - NAND flash as seen on accident board indicated by screw driver tip.

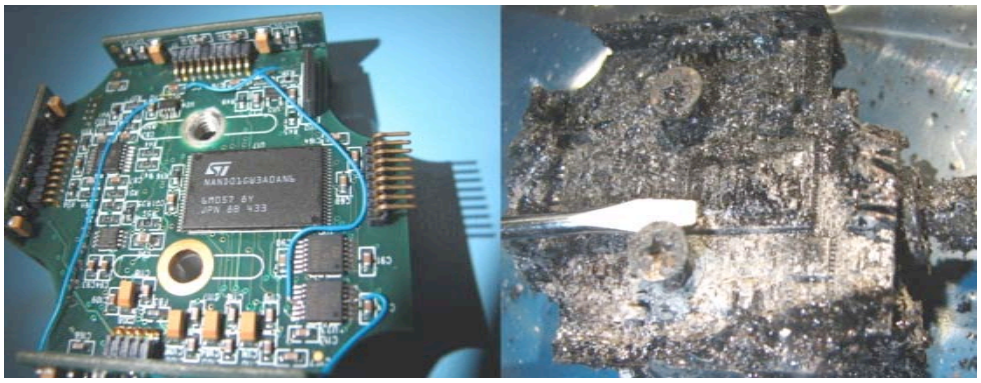
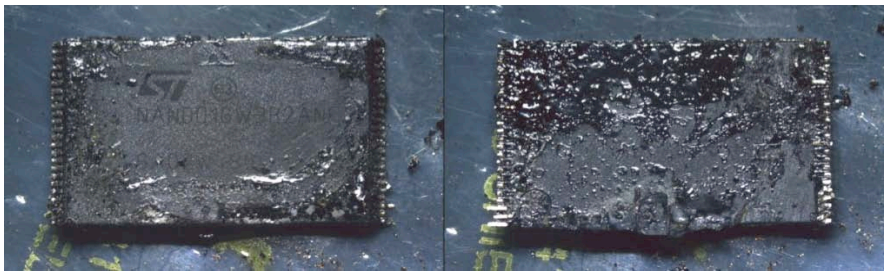


Figure 14: NAND device as removed from circuit board (top and bottom views)



The device was manually cleaned and tinned[8] in preparation for mounting within the reader/programmer device (Figure 15).

Figure 15: NAND device after inspection and cleaning

Download

On 10 August 2010, the NAND flash device was downloaded successfully using the *Xeltek Superpro 5000* universal reader/programmer with CX1004 adapter and the *Superpro USB 2.0 Series Version 3.0* software, in accordance with the Xeltek and ATSB procedures[9]. As expected, the downloaded binary file was 132MB in size.

Data processing

The initial downloaded binary file was a 'raw image copy' or direct representation of the data contained on the NAND flash memory device. To extract the individual data files from this large binary file and thus enable the interrogation and analysis of the information, instances of the header were identified and located within the data file. When using the header string as a marker for the data extraction, 47 different files were recovered. Each was subsequently validated using the *Appareo Systems Flight Evaluator*™ software and named sequentially, according to the date and time metadata information. The accident flight (identified chronologically as the latest flight among those recovered) was identified as *File_47.dat*.

On 12 August 2010, all 47 data files were provided to the RNZAF safety officers via the ATSB's secure web storage and transfer site.

---

[8] Tinning is a method of preparing electrical contacts for connection by coating them with a layer of solder.

[9] ATSB Procedure - Xeltek SP5000 procedures Revision 0.docx

SUMMARY

On 14 January 2010, a Royal New Zealand Air Force (RNZAF) CT-4 Airtrainer aircraft collided with terrain during practice for an air display event. The pilot was fatally injured and the aircraft destroyed by fire.

Following the accident, the RNZAF flight safety office requested the assistance of the Australian Transport Safety Bureau (ATSB) in recovering the flight data from the GAU1000 recorder fitted to the aircraft.

On 30 March 2010, the recorder was transferred by safe-hand to the ATSB's Canberra Technical Analysis facilities.

The manufacturer of the recorder, *Appareo Systems*, advised that data should be available from the multimedia card (MMC) and the NAND flash memory device mounted on the recorder circuit board.

The MMC was identified as an *Imation* 512 megabyte (MB) card. Numerous attempts were made to download the card however no data was recovered.

The NAND flash memory device was identified as *ST Electronics* 128 MB NAND flash device, part number NAND01GW3B2AN6. The device was removed from the circuit board and downloaded using the ATSB's *Xeltek Superpro 5000* reader/ programmer.

A file of 132MB in size was recovered, from which 47 flight data files were subsequently extracted. The accident flight was identified as *File_47.dat* using the *Appareo Systems Flight Evaluator*™ software.

On 12 August 2010, the 47 flight data files were provided to the RNZAF safety officers via the ATSB secure web storage and transfer site.