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Bureau d'Enquêtes et d'Analyses
pour la sécurité de l'aviation civile

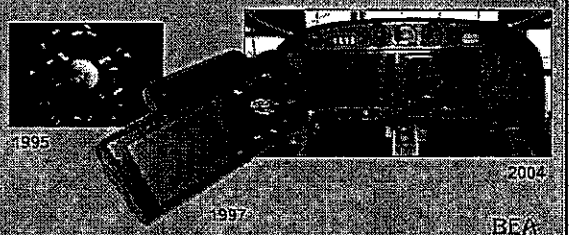
Finding Nuggets:
Cooperation vital in efforts to recover buried data

Christophe MENEZ
Jérôme PROJETTI

www.bea.aero

Introduction

- New technologies and more widespread GPS use
- New challenges for investigators
- Applying lessons learned to other onboard devices



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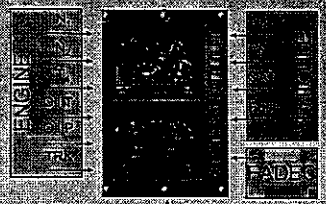
Vehicle Engine Multifunction Display (VEMD)

EC120 B cockpit

VEMD integration



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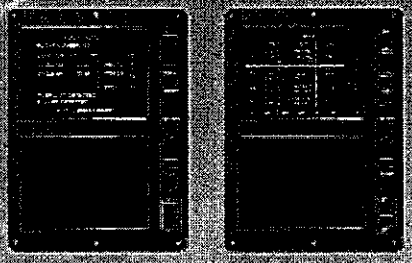
VEMD data for investigation



Flight report page Overlimit page

Maintenance pages

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Limits of direct memory card readout

- Such direct readout at the manufacturer facilities has limits
- Decision to perform the physical examination of the systems, as well as the reading of the memory chips at the BEA
- A very challenging work due to the variety of systems

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A wide variety of data

GPS COMPUTERS	AVIONIC AND PANEL MOUNTED COMPUTERS	OTHER DATA STORAGE DEVICES
Portable GNSS 2D & 3D flight track Waypoint database Flight routes	ECU Failure & flight reports Overlimit, warning	Cameras Photos & videos
Logger IGC 3D flight track [illegible] Noise, IAS, [illegible], etc	EFIS Screen & periphal failures (VOR, radar, FAN, etc.)	PDA Flight track Computer's files
Panel mount GNSS No flight track Flight routes, user waypoints Last position, configuration	PA Failures	ACAS Flight tracks
	VHF Last selected frequency	

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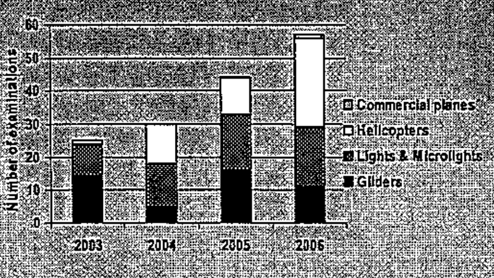
Various fields of application



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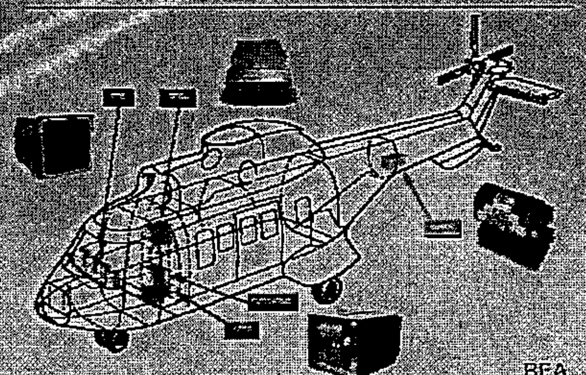
AS332 L2 Super Puma Helicopter



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General outline methodology

- To identify the potential source of information,
- To remove the corresponding systems from the wreckage,
- To identify and extract the electronic cards and memories associated with data recording,
- To read out the contents of the memory chips,
- To decode the raw data,
- To validate the results.

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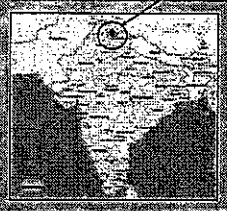
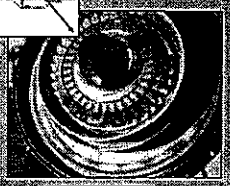
Case 1 : EC120 accident





- EC120 – March 31, 2005
- Engine failure en route
- No mandatory FDR
- VEMD manufacturer based in France

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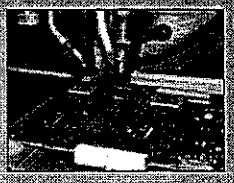
Case 1 : EC120 accident

- Electronic card extraction
- Cleaning and varnish removal
- Memory chip unsoldering
- Memory chip cleaning
- Memory chip inspection & electrical diagnostic
- Memory chips readout



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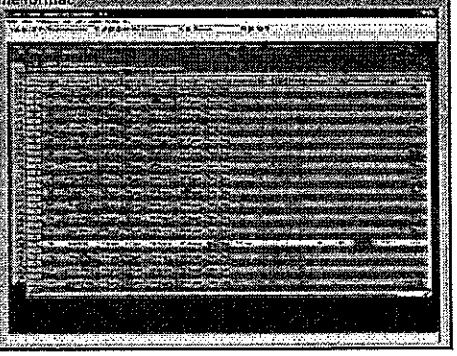
Case 1 : EC120 accident

Binary raw data → Memory mapping Data frame format



Human readable values

Case 2 : Glider accident

- ASW15 – March 22, 2007
- State of occurrence
- Radio transmitter unserviceable

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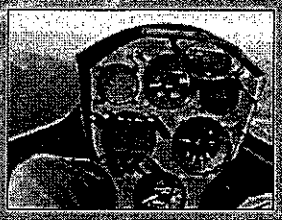
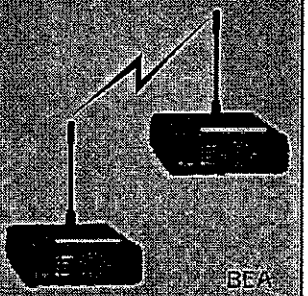
Case 2 : Glider accident



- Low power ACAS based on GPS positioning and VHF
- Equipment manufacturer based in Switzerland



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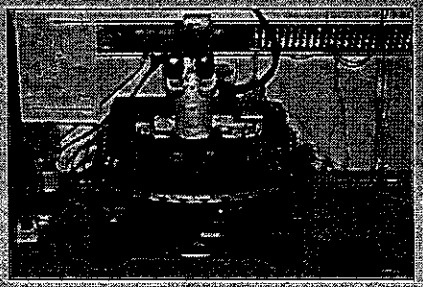
Case 2 : Glider accident
How to find nuggets



Flash memory chip readout with probes

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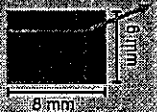
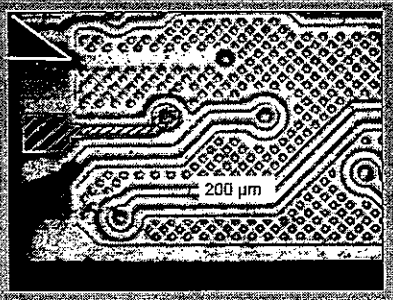
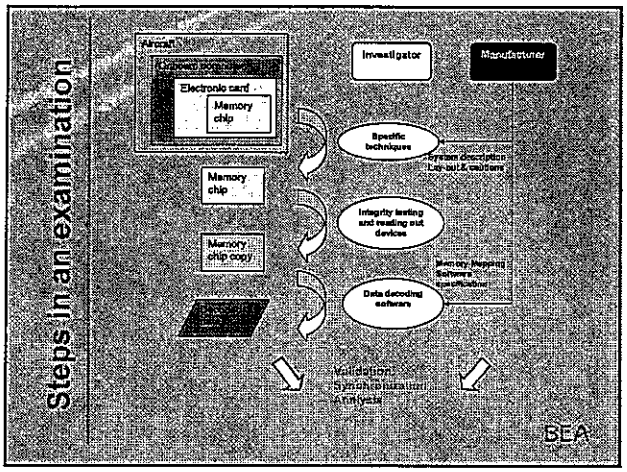
Case 2 : Glider accident
How to find nuggets





Flash memory chip readout with probes

BEA



Conclusion

- Very challenging work
- No guarantee of successful readout
- Win-win cooperation
- Building cooperation from national working relationships to foreign counterparts could enhance the efficiency of investigations

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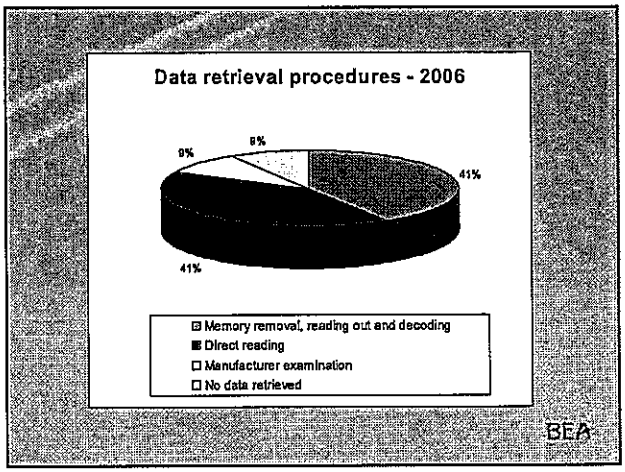

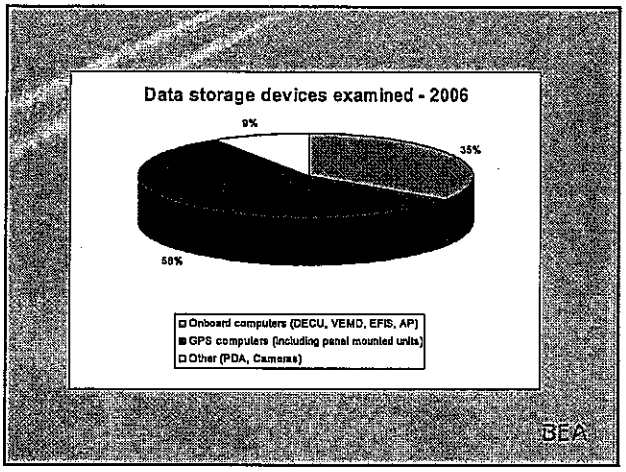
Data storage devices examined - 2006
9%
35%
56%
Onboard computers (DECU, VEMD, EFIS, AP)
GPS computers (including panel mounted units)
Other (PDA, Cameras)
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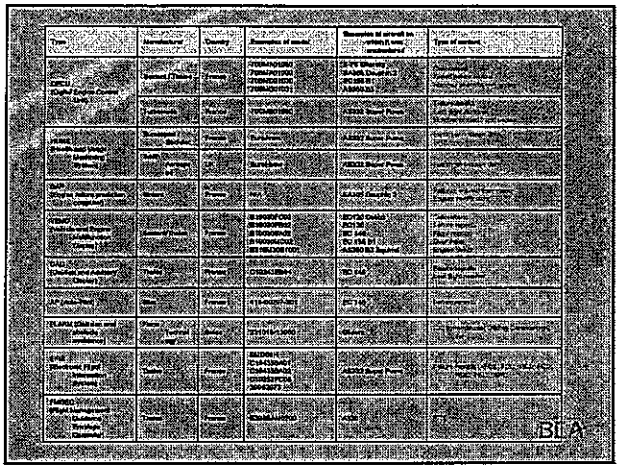
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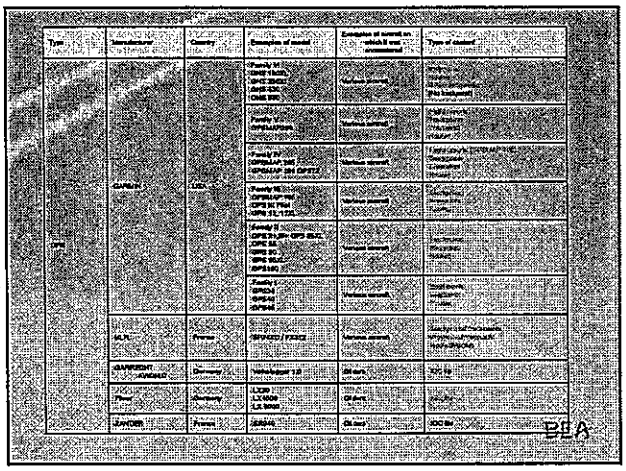
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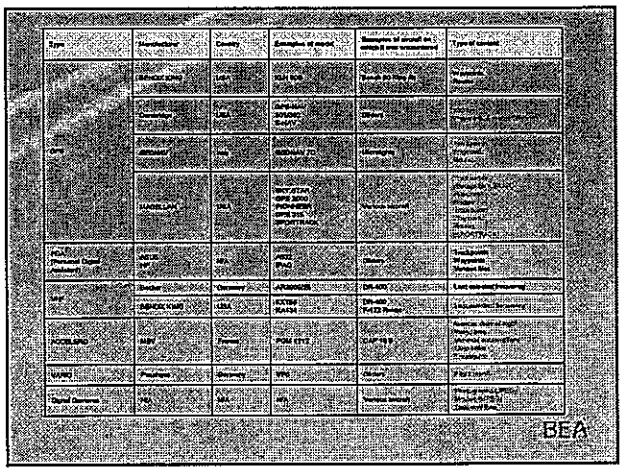
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CIDER Software
Status Update and Demonstration

Presented by: Greg Smith
AIR Meeting 2007

Overview

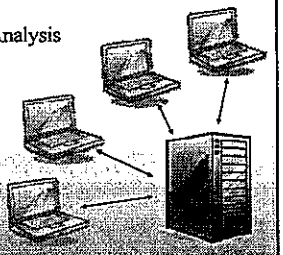
- Design Goals
- General Configuration
- Development Status
- Future Development
- Demonstration

Design Goals

- Backup/Replacement For Existing System
- Workflow Management
- Configuration Control
  - Investigative Data
  - Configuration Data
- Portability
- Data Mining

Client - Server Configuration

- Client
  - Java Application
  - Stand Alone Processing & Analysis
- Server
  - MS SQL Server
    - Searchable Info
    - Parameter Definitions
    - Plot Definitions
  - WebDAV Server
    - Bulk Data



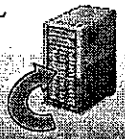
Workflow Management

- 3 Levels of Data
  - Scratch – Working Level Initial Data
  - Production – Preliminary Data Released Within Investigation
  - Release – Final Data Released To The Public

Configuration Control

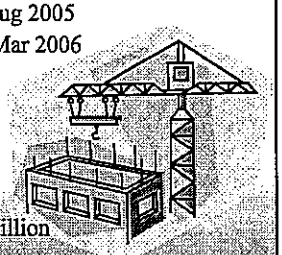
- Automated Email Creation When Promoting

- Parameter Definitions Stored In SQL Database
- Plot Definitions Stored In SQL Database
- Template Files Stored On WebDAV Server



Development Status

- Started – Sep 2004
- First Stand-Alone Beta – Aug 2005
- First Client-Server Beta – Mar 2006
- Latest Beta – Aug 2007



- Development Continuing Thru Feb 2008
- Spending To Date ~$2.3 Million

Future Development

- Upgrading Permissions Handling
- Adding Tape Digitization
- Additional Enhancements

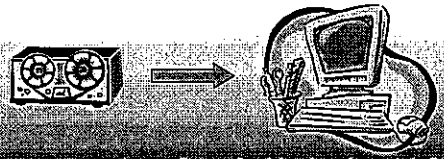
Permissions Handling

- FDR Specialists Put Validated Parameters In A Production Level

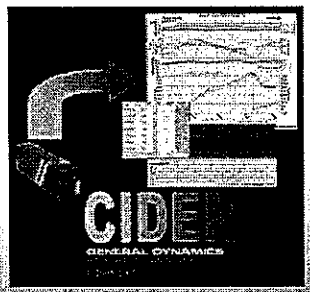
- Other Users Retrieve Production Data Do Their Own Plotting & Analysis

Tape Digitization

- Using Data Translation A/D Converter
- Cover Multiple Types Of Waveform Algorithms
- Should Work With Any Tape Deck



DEMONSTRATION



TSB

TSB Experience with Damaged Honeywell SSFDR and SSCVR

AIR Meeting

4 – 6 September 2007

Canberra

TSB

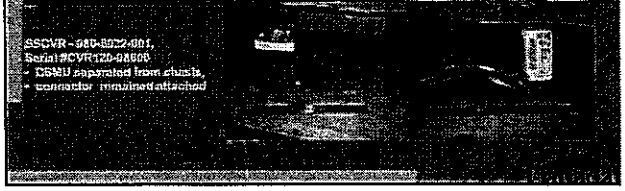
GOL Airlines, 29 Sep 2006
Boeing 737-800, PR-GTD

- Boeing 737-800, PR-GTD, operated by Gol Airlines of Brazil, and an Embraer Legacy 600 business jet, N600XL, owned and operated by Excelaire of Long Island NY, collided in flight over the Amazon Forrest approximately 100 miles southeast of the Cachimbo Air Base, Brazil.
- The Boeing 737 was destroyed by in-flight breakup and impact forces, all 154 occupants were fatally injured. The Legacy N600XL experienced damage to the left wing and left horizontal stabilizer, and performed an emergency landing at the Cachimbo Air Base.

GOL Airlines, 29 Sep 2006

Boeing 737-800, PR-GTD

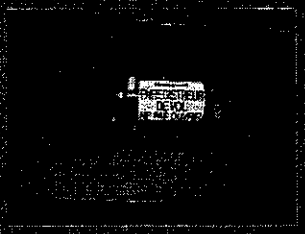
SSFDR - 980-4700-042,
Serial#12552



SSCVR - 980-6022-001,
Serial#CVR120-04606
- CSMU separated from chassis,
- connector remained attached

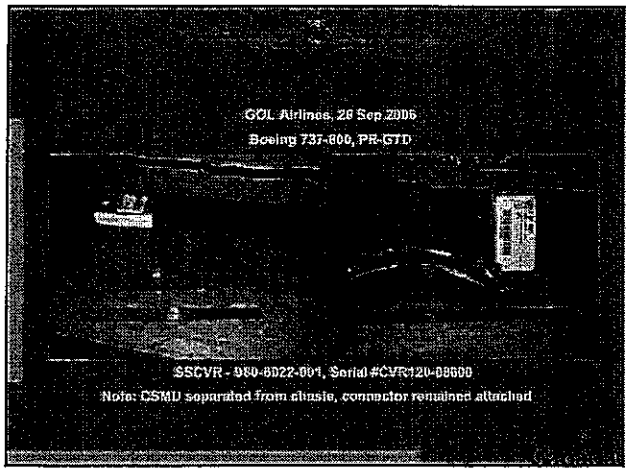
GOL Airlines, 29 Sep 2006

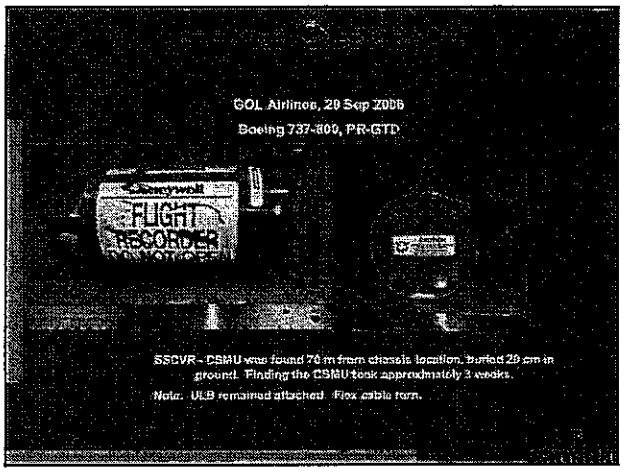
Boeing 737-800, PR-GTD

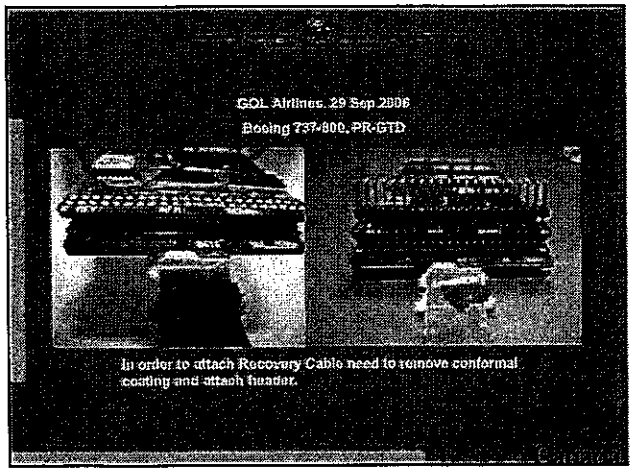


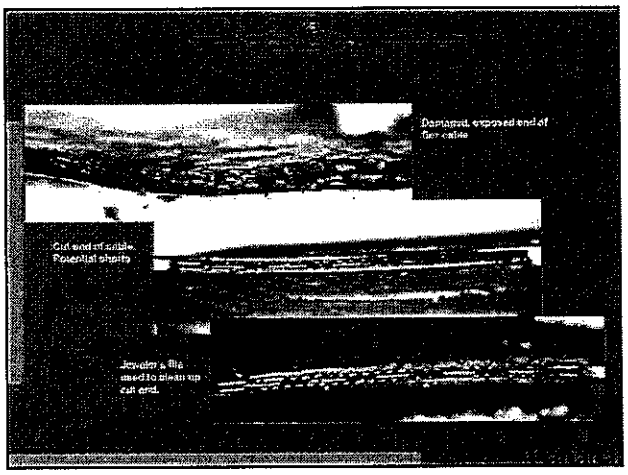
There was no damage to the SSFDR CSMU flex cable.

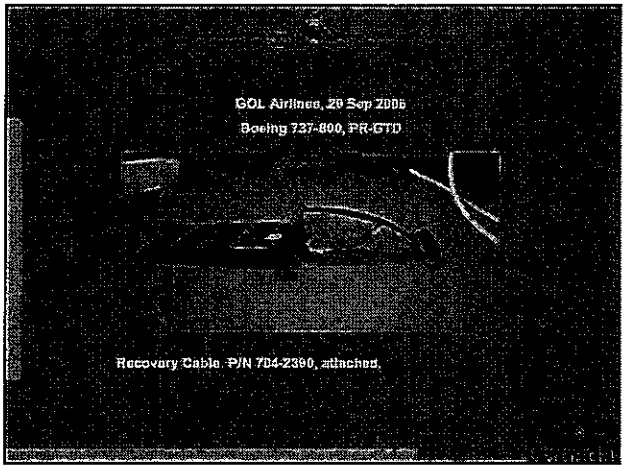
The CSMU was installed on a bench unit and successfully downloaded using PATS workstation.


GOL Airlines, 29 Sep 2006
Boeing 737-800, PR-GTD
SSCVR - 980-6022-001, Serial #CVR120-08600
Note: CSMU separated from chassis, connector remained attached


GOL Airlines, 29 Sep 2006
Boeing 737-800, PR-GTD
FLIGHT RECORDER
SSCVR - CSMU was found 70 m from chassis location, buried 20 cm in ground. Finding the CSMU took approximately 3 weeks.
Note: ULB remained attached. Flex cable torn.

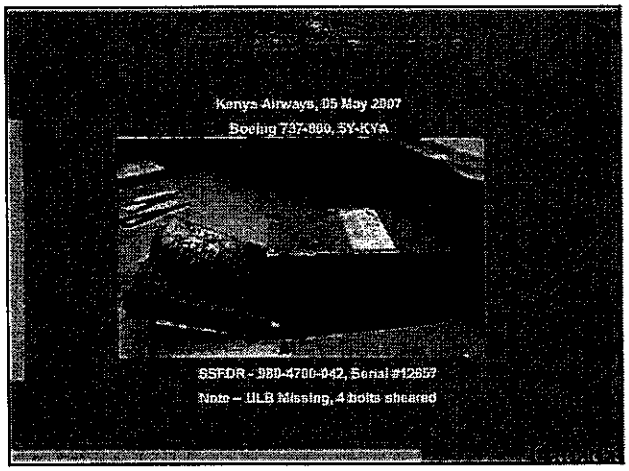

GOL Airlines, 29 Sep 2006
Boeing 737-800, PR-GTD
In order to attach Recovery Cable need to remove conformal coating and attach header.

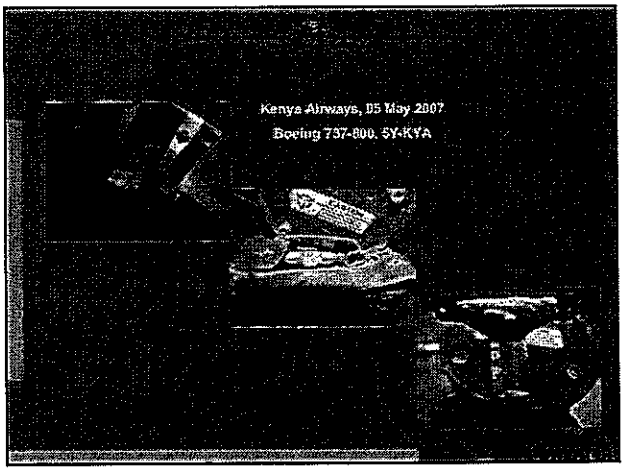

Damaged, exposed end of flex cable
Cut end of cable. Potential shorts
Jeweler's file used to clean up cut end.

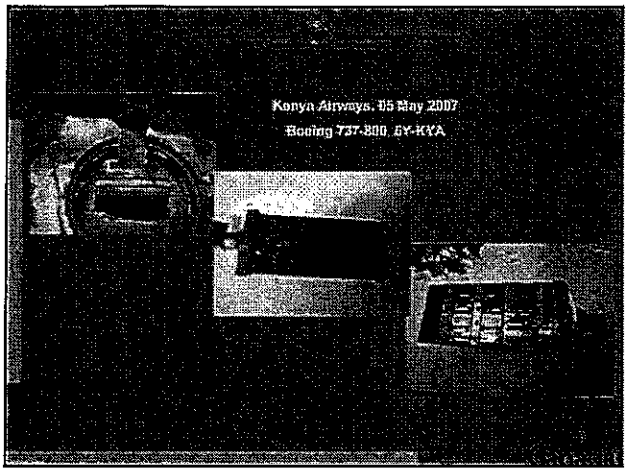


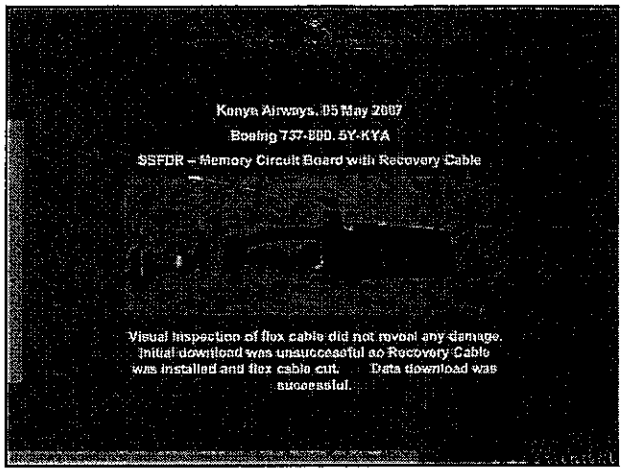
Kenya Airways, 05 May 2007
Boeing 737-800, 5Y-KYA

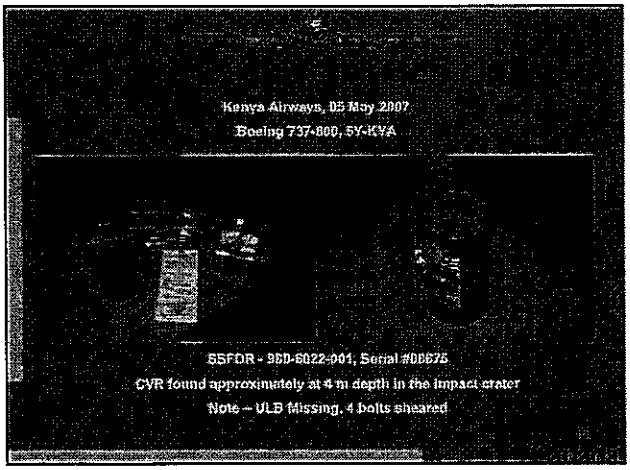
- The Kenya Airways B737-800 was taking off from Douala, Cameroon on a scheduled flight to Nairobi, Kenya. The aircraft crashed shortly after take-off from runway 12 in a swampy area about 2 nm from the airport. All 114 persons on board were fatally injured and the aircraft was destroyed

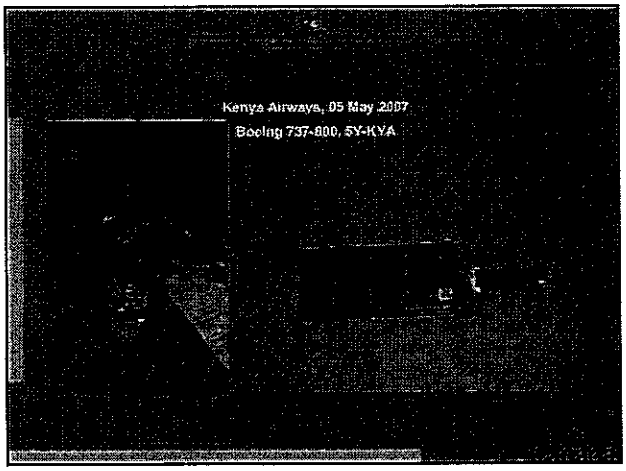





Kenya Airways, 05 May 2007
Boeing 737-800, 5Y-KYA


Kenya Airways, 05 May 2007
Boeing 737-800, 5Y-KYA
SSFDR – Memory Circuit Board with Recovery Cable
Visual inspection of flex cable did not reveal any damage. Initial download was unsuccessful so Recovery Cable was installed and flex cable cut. Data download was successful.


Kenya Airways, 05 May 2007
Boeing 737-800, 5Y-KYA
SSFDR - 980-6022-001, Serial #00676
CVR found approximately at 4 m depth in the impact crater
Note – ULB missing, 4 bolts sheared


Kenya Airways, 05 May 2007
Boeing 737-800, 5Y-KYA

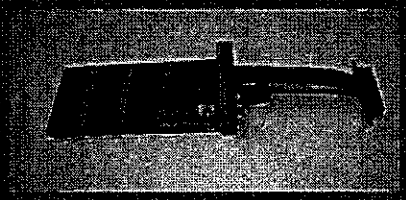
Kenya Airways, 05 May 2007

Boeing 737-800, 5Y-KYA

SSCVR – Memory Circuit Board with header installed

Kenya Airways, 05 May 2007

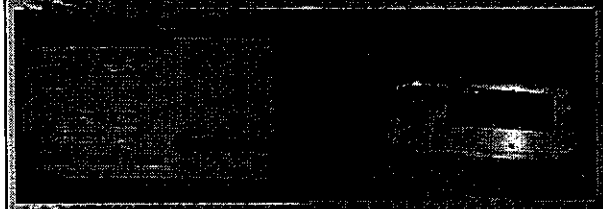
Boeing 737-800, 5Y-KYA



SSCVR – Memory Circuit Board with recovery cable installed and flex cable cut.

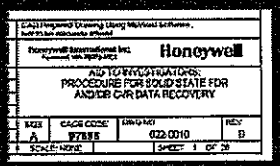
Kenya Airways, 05 May 2007

Boeing 737-800, 5Y-KYA



SSCVR – Memory Circuit Board installed on SSCVR chassis for data recovery.

Honeywell documentation Rev B, dated 1/09/07, has been released and is available from Honeywell.



Honeywell Contacts:

- Michael Thompson – Product/Customer Support Manager
  Email: Michael.H.Thompson@honeywell.com
- Paul Gipson – Product Integrity Group
  Email: Paul.Gipson@honeywell.com

Lessons Learned

- Flex cable can be damaged with no visible damage
- Installation of Recovery Flex Connector
  - SSFDR Memory board does not require installation of header
  - SSCVR Memory board requires installation of header (44 pin)
    - Time consuming and difficult
- Cutting Flex cable can cause shorts between layers
- Bench unit must be compatible with memory config (1X, 2X, 4X)
- Honeywell documentation is useful but not complete
- Honeywell very helpful

Australian Government
Australian Transport Safety Bureau

Issues with retrieval of data from Honeywell SSCVR

March 2007

Michael HILL

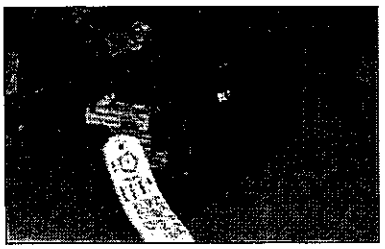
Overview

- Garuda Indonesia Flight 200, Boeing 737-497, PK-GZC
- Recorder was recovered from accident site and transported safe-hand to the Australian Transport Safety Bureau (ATSB) Technical Analysis Facilities in Canberra, Australia.
- Recorder arrived in Canberra on Friday 09 March 2007

Australian Government
Australian Transport Safety Bureau

Cockpit Voice Recorder (CVR)

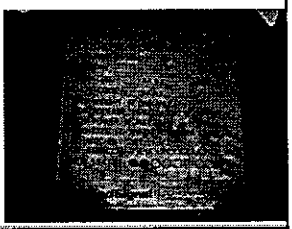
- Cockpit Voice Recorder (CVR) had been subjected to fire - sooted but relatively undamaged



Australian Government
Australian Transport Safety Bureau

Cockpit Voice Recorder Description

- SSCVR
  - Manufacturer: Allied Signal (Honeywell)
  - Model: Solid State Cockpit Voice Recorder (SSCVR)
  - Part Number: 980-6020-001
  - Serial Number: 1193
  - Date Code: 9532
  - Modification Status: 1 and 2



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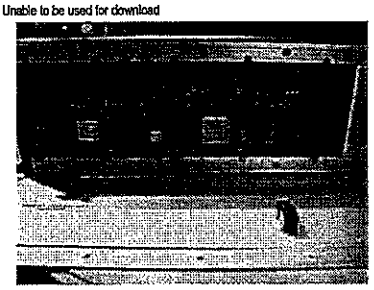
Cockpit Voice Recorder

- Records 4 channels of audio for 30 minutes
  - Pilot
  - Co-pilot
  - Spare / Intercom
  - Area Microphone
- Normal recovery would be the download of a single .DLU file of about 27MB which is then decompressed / segregated into four .wav files using Honeywell software
- For a damaged recorder a dedicated download chassis is required, the ATSB owns a 980-6022-001 SSCVR for this purpose.

CVR Controller Card

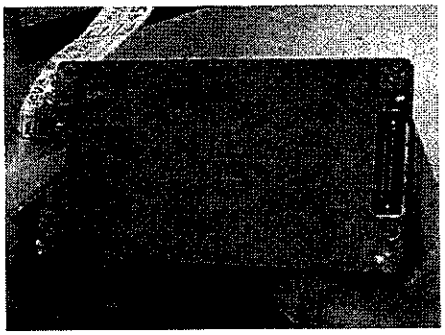
- P/N 97896 Assy 22-4052-003 Rev. F1. S/N 952A
- Heat damage (melted solder)
- Unable to be used for download



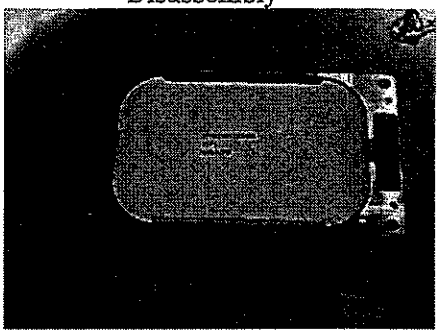
CVR recovery steps taken - 09 Mar

- Step 1: Crush survivable memory unit (CSMU) disassembly and removal of memory card from accident CVR

CVR base



Crash Survivable Memory Unit Disassembly



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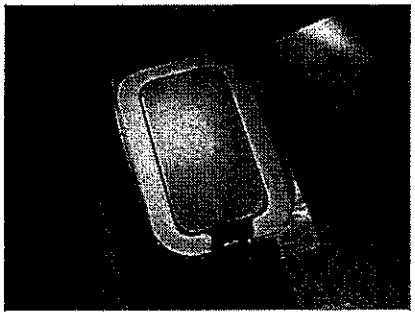
Disassembly of CSMU



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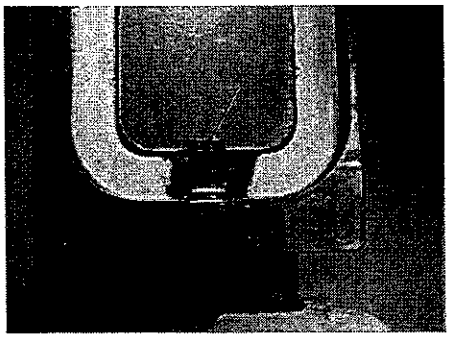
Disassembly of CSMU



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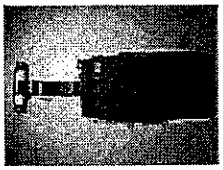
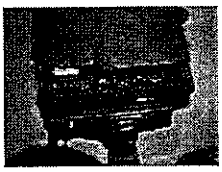
Australian Transport Safety Bureau

CVR recovery steps taken - 09 Mar

- Step 2: Inspection of memory card, flex cable and connector





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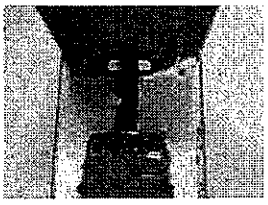
CVR recovery steps taken - 09 Mar

- Step 3: Successful check of download equipment, ATSB SSCVR (980-6022-001 - 2 hour), using Honeywell Recorders Portable Ground Support Equipment (RPGSE) before attempting the download of the memory board from the damaged SSCVR.
- Step 4: Installed accident memory card, including accident CVR flex cable, on ATSB SSCVR chassis (980-6022-001 - 2 hour). Did not use a new flex cable as the board contained 3 lumps of epoxy coating which prevented the ATSB CVR flex cable from being attached.



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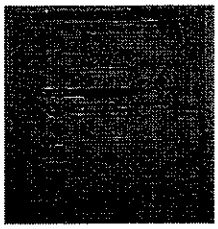
CVR recovery steps taken - 09 Mar

- Step 5: Attempted download of accident memory card using accident CVR flex cable, ATSB SSCVR chassis and RPGSE (Playback 32 software). Download unsuccessful, only 8k of the 27 k of data download



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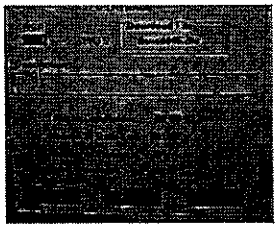
CVR recovery steps taken - 09 Mar

- Step 6: Attempted download of accident memory card using accident flex cable, ATSB SSCVR chassis and AlliedSignal Playback and Test Station (PATS) software. Download unsuccessful, only 8k of the 27 k of data download.



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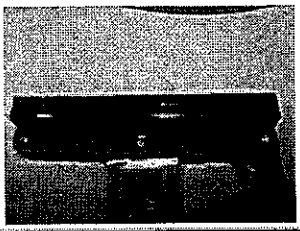
CVR recovery steps taken – 10 Mar

- Step 7: Following advice from Honeywell carefully removed the epoxy and cut the existing flex cable. Inspected flex for shorts between tracks and connected ATSB flex cable between accident memory card and ATSB SSCVR chassis (980-6022-001 - 2 hour). ATSB flex cable had to be modified to allow insertion.



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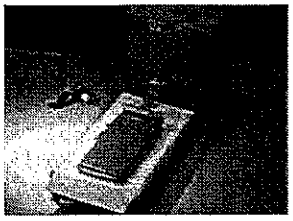
CVR recovery steps taken – 10 Mar

- Step 8: Attempted download of accident memory card using ATSB flex cable, ATSB SSCVR chassis (980-6022-001 - 2 hour) and RPGSE (Playback 32 software). Download unsuccessful. Error messages identical to initial download.



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CVR recovery steps taken – 10 Mar

- Step 9: Point-point continuity check of flex cable connector and check of 5V and MEM0 address lines.
- Step 10: Attempted download of accident memory card using ATSB flex cable, Qantas SSCVR chassis (980-6020-002) and RPGSE (Playback 32 software). Download unsuccessful, only 8K download. Error messages identical to initial download.

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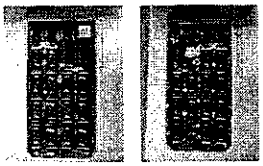
CVR recovery steps taken – 11 Mar

- Step 11: Removal of RTV memory card coating, inspection and careful cleaning of pins and sockets with alcohol



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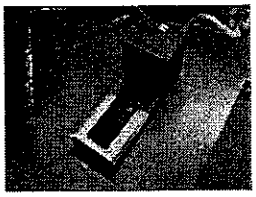
CVR recovery steps taken – 11 Mar

- Step 12: Attempted download of accident memory card using ATSB flex cable, QANTAS CVR and RPGSE (Playback 32 software). Download unsuccessful download. Error messages identical to initial download.



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CVR recovery steps taken – 11 Mar

- Step 13: ATSB investigator to Honeywell with memory card with pre-arranged escort through X-ray security during transit (i.e. no X-raying of memory card)

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Honeywell

- The memory board was electrically checked on the header. There were no shorts to ground, +5 volts or adjacent pins

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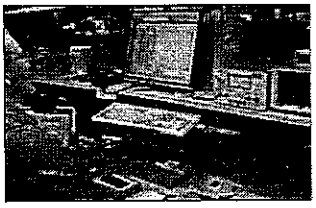
Honeywell

- The memory board was installed on a chassis assembly and connected to PATS



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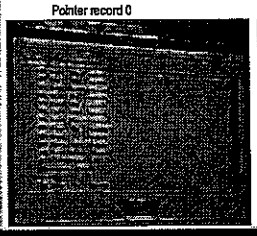
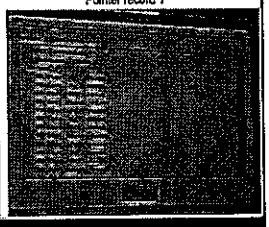
Honeywell

- The Electrically Erasable Programmable Read Only Memory (EEPROM) contents were read

Pointer record 0



Pointer record 1



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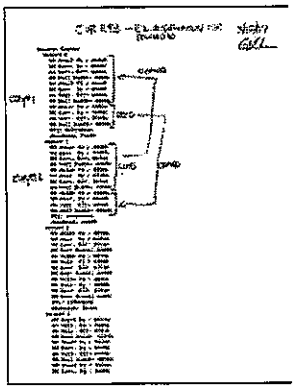
Honeywell

- The EEPROM contained the following information of interest:
  - Record 0 Narrow Band (NB) and Wide Band (WB) pointers were 'eeeeh' indicating invalid pointers. The Mixed Band (MB), Elapsed Time Indicator (ETI) and checksum were valid.
  - Record 0 ETI was 169AF hexadecimal (46295.5 hours of operation)
  - Record 1 NB and WB pointers were valid. The MB was 'eeeeh' indicating an invalid pointer. The ETI was 'eeeeeeeeh' and the checksum was 'eeeeh' indicating they were invalid.
  - Record 2 and 3 had default information
- Record 0 and 1 must have the same pointers for all audio data to be downloaded. This was not the case for the CVR.

Honeywell

- A download was commenced to verify the results observed by the ATSB. Only 8 kilobytes of data was available for download. This was the same result as observed by the ATSB in Canberra. The download was stopped.
- The memory board was then installed on the emulator chassis assembly. The first byte in every memory chip contains the chip number, 00 to 1A hexadecimal. The first byte of memory chip 00, 01, 02, 03, 0F, 19 and 1A were verified correct. This test verified that the memory board was functioning electrically.
- The memory board was then placed on base connected to PATS. The EEPROM was read and saved to file 'e21193.ee'.The EEPROM file was edited using Ultraedit to correct the pointers. The checksum was verified.

- EEPROM modifications

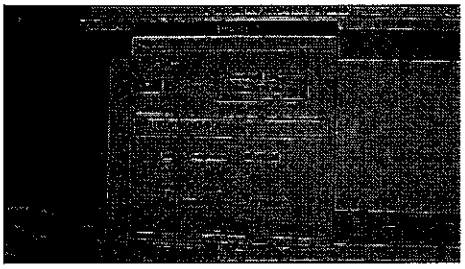


Honeywell

- The edited EEPROM file was then saved as file 'e21193b.ee'. This edited file was then loaded into the EEPROM on the memory board. It should be noted that the EEPROM does not contain any audio data. No audio was changed by editing the EEPROM file.
- The EEPROM was read from the memory board. The pointers were verified to be as edited.

Honeywell

- A download was commenced. There were 27,912,526 bytes of data available for downloading. The download was completed successfully.



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Honeywell

- Honeywell stated this was the first time they had seen a problem like this.
- Possible reasons for the EEPROM corruption are:
  - The EEPROM has a limited number of write cycles. The SSCVR had operated for over 46,000 hours. This is approximately when the EEPROM maximum number of writes would occur.
  - During the accident a combination of environmental (example high temperature) and electrical conditions (example power spikes, low voltage) may have created a condition were the EEPROM was incorrectly written to or erased.

Australian Government
Australian Transport Safety Bureau

FRED format editor
FREDitor

Jim Cash

National Transportation Safety Board

FRED Standard

- Electronic documentation standard
- ARINC 647A standard
- ICAO FLIRECP Recommendation
- FAA adoption

National Transportation Safety Board

SOFTWARE

- Joint FAA - NTSB funding
- 8 months development cycle
- Beta for demo
- Full working copy for Oct EUROCAE mtg
- Final release in DEC 2007

National Transportation Safety Board

Software Features

- Full feature editor
- Input
  - Existing FRED file
  - ASCII, CSV import
  - 3rd party definition files
- Save FRED format
- Validate against FRED schema

National Transportation Safety Board

Beta Demonstration

- Opens – exports FRED files
- Basic features mandatory-optional
- Both 717 – 767 data frames
- Does not validate output
- Does not have ASCII or CSV importer

National Transportation Safety Board

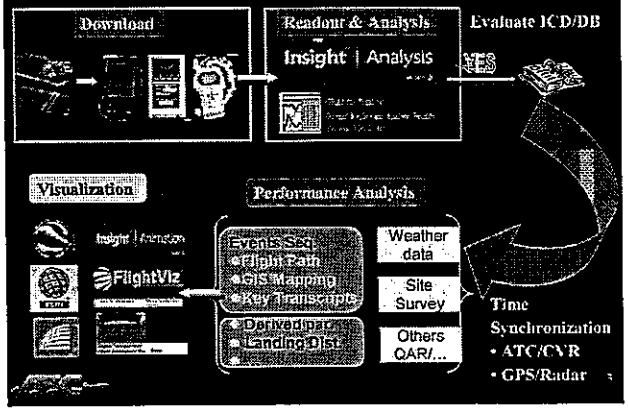
Applying combined data sets for performance analysis

Dr. Michael Guan
Director of Investigation Lab
Aviation Safety Council, Taiwan

Content

- Performance Analysis at ASC
  - Procedures
  - Available tools
  - Self-developing programs
- Cases Study
- Lessons Learned

Procedures at ASC LAB



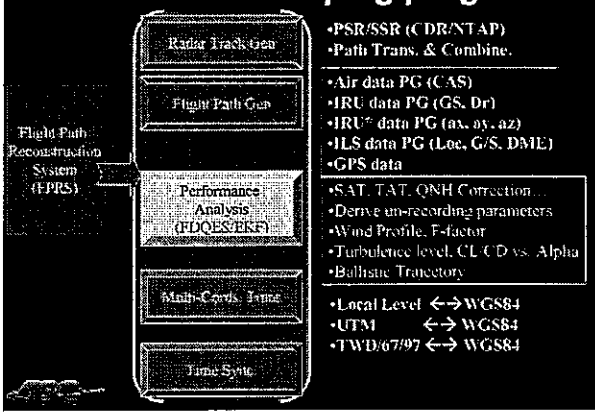
Aircraft Performance Analysis at ASC (Available tools)

- Dante/NTSB
- RAPS/Insight Building Functions
- *Commercial Matlab toolboxes*
  - Inertial Navigation Systems,
  - Flight Dynamics and Control
  - Aircraft Control & Handling Qualities (HQPACK)
- *Advanced Aircraft Analysis V2.4* (AAA)
- *ASC self-developing programs*
  - Flight Path Reconstruction System (FPRS)
  - Flight Data Quality Enhancement System (FDQES)

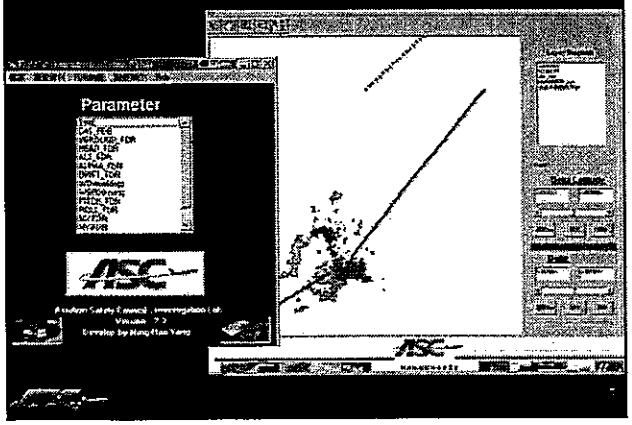
ASC self-developing programs

- Flight Path Reconstruction System
  - Flight path calculation (VB 6.0, GUI)
  - Multi data plotting (similar to Dante)
  - GIS mapping interface (MapInfo API)
- Flight Data Quality Enhancement System
  - Evaluate data kinematics consistence (Matlab v7)
  - Correct recorded parameters (bias, wrong data)
  - Derive unrecorded parameters
  - Perform performance analysis
  - Two modules: ASPD and GSPD

ASC self-developing programs



Demo: FPRS



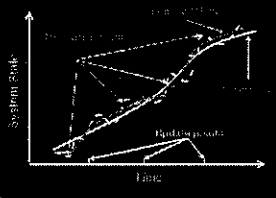
Background Information

- Incorrect FDR data will affected the performance analysis, reasons:
  - Sensors calibration
  - Data recording resolution
  - Incorrect signal source into FDAU
  - Wrong data location/bits
- Using Kinematics and optimization method to processing FDR data (FDQES)
  - ensuring the flight data consistency
  - Obtain performance related flight data
  - FDQES is based on estimation theory of the Extended Kalman Filter (EKF)

Introduction of EKF (1/2)

- EKF is a sub-optimal extension of the original KF algorithm, it allows for estimation of non-linear processes or measurement relationships. (i.e. first order Taylor series approximation)
- Nonlinear Dynamic Model:
  - $x_k = f(x_{k-1}, k-1) + w_k$
- Measurement Model:
  - $z_k = h(x_k, k) + v_k$

f & h are nonlinear
Jacobian matrix



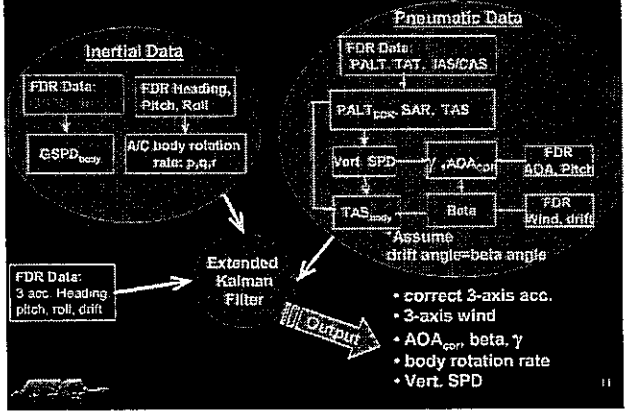
W_k: process noise
V_k: measurement noise

Introduction of EKF (2/2)

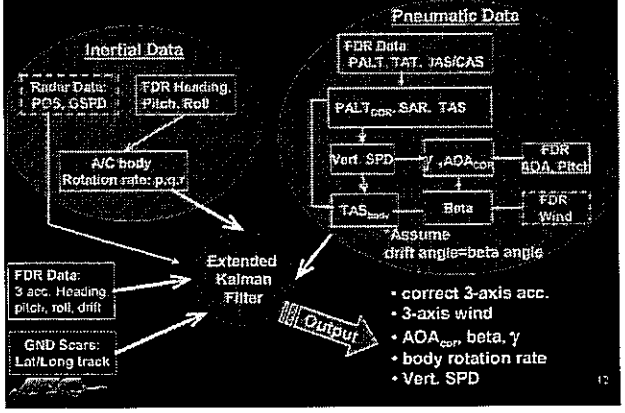
- Prediction: sys. states
  - $x_k = f(x_{k-1}, k-1) + w_k, w_k \approx N(0, Q_k)$
- Prediction: measurement states
  - $z_k = h(x_k, k) + v_k, v_k \approx N(0, R_k)$
- Prediction: error covariance matrix
  - $P_{k-1} = \Phi_{k-1} P_{k-1} \Phi_{k-1}^T + Q_{k-1}$
- Update: Kamlan Gain
  - $K_k = P_k H_k^T (H_k \bar{P}_k H_k^T + R_k)^{-1}$
- Update: estimate states
  - $\hat{x}_k^+ = \hat{x}_k^- + K_k (z_k - \hat{z}_k)$
- Update: error covariance matrix
  - $P_k = (I - K_k H_k) P_k^-$

- Taylor approx. of f is done at previous epoch estimate
  - $\Phi_{k-1}(\hat{x}, k-1) \approx \frac{\partial f(x, k-1)}{\partial x}\Big|_{\hat{x}_{k-1}}$ + higher order terms
- Taylor approx. of h is done at corresponding predicted position
  - $H_k(\hat{x}, k) \approx \frac{\partial h(x, k)}{\partial x}\Big|_{\hat{x}_{k-1}}$ + higher order terms

FDQES: GSPD Module



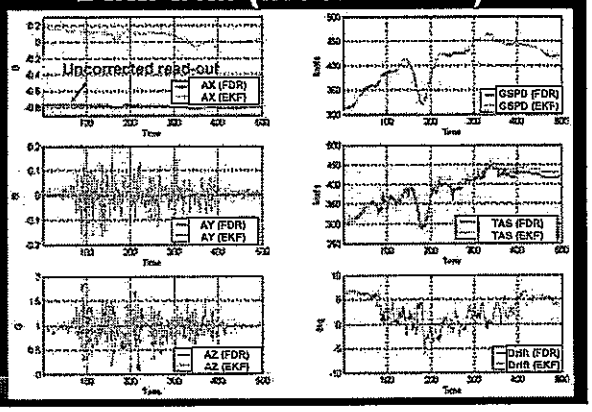
FDQES: ASPD Module



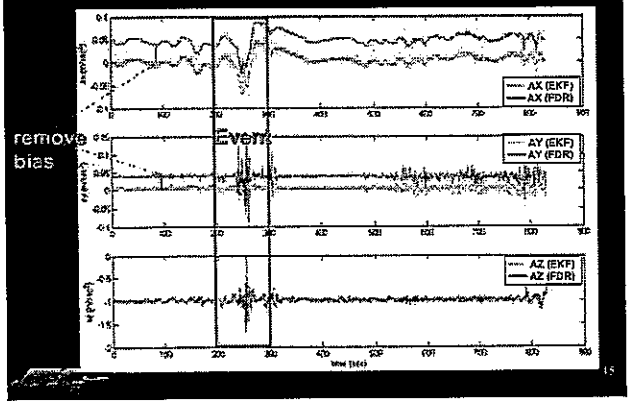
Cases Discussion

- 1. A/C encountered Turbulence
- 2. Limited FDR & Radar Data
- 3. A/C runway veer off
  - Limited FDR data
  - Multi data sets

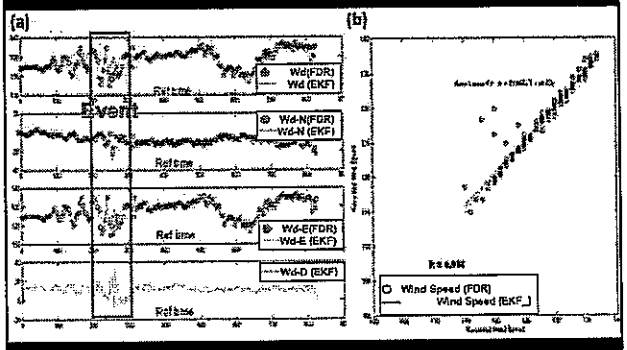
Data trial (incorrect ax)



2. A/C encountered Turbulence

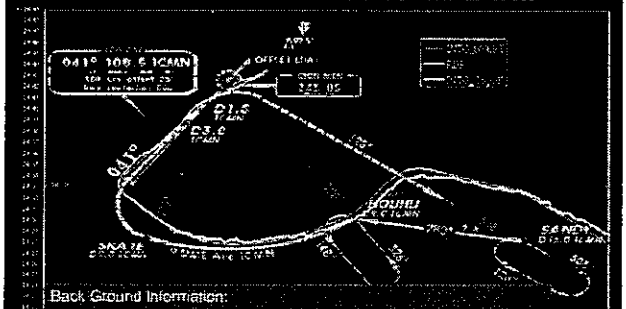


2. A/C encountered Turbulence



A/C encountered "strong" turbulence.
downdraft 10~ 30 knots

2. Limited FDR & Radar Data



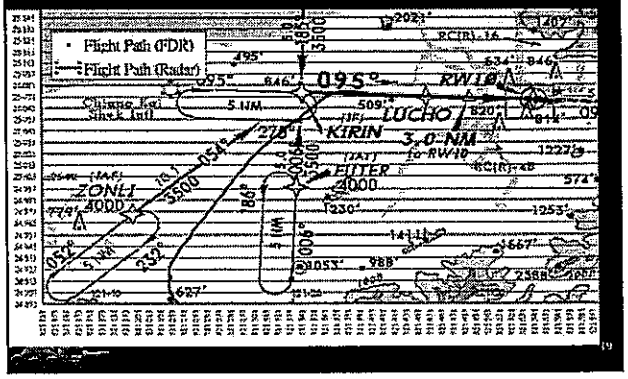
Back Ground Information:

- MD-82 runway veeroff (wet runway, cross wind environment)
- Below 3000 ft AGL, Radar data is not available
- FDR without recording Drift, GS, wind, IVV

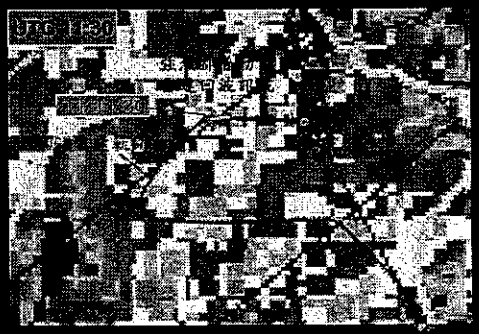
3. A/C runway veer off: history of flight

Occurrence Time	14, July, 2006	A/C Type	MD-83
Phase of Flight	demonstic transport operation, during landing at RCSS		
Weather System	affected by typhoon (just pass through TPE FIR)		
Surface Wind Observations	1109 : Wind direction varied, 3 knots, RVR 3,000 m. 1114: Wind direction varied, 3 knots, RVR 2,000 m. 1117: wind 020 deg, 4 knots, RVR 1,200 m.→ 800 m		
History of Flight	The FLT066 applying the ILS approach to runway 10, during the final approach until 100 ft AGL is normal. About 11:14:55 touched ground with normal speed, moderate break, IDLE REV and full left rudder. Six sec later, the Rt. MLG veer off runway 10. About 11:15:11, FLT066 re-entry the runway10. A/C Rt. Main tires suffered minor damage, no injury. Five runway edge lights were damaged.		

Flight Path Vs. Radar Track



Flight Path Vs. Doppler WXR Chart

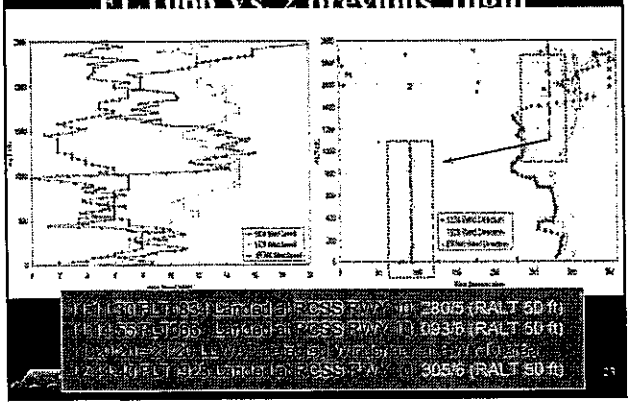


Flight Path Vs. Events

FDQES in the FLT066

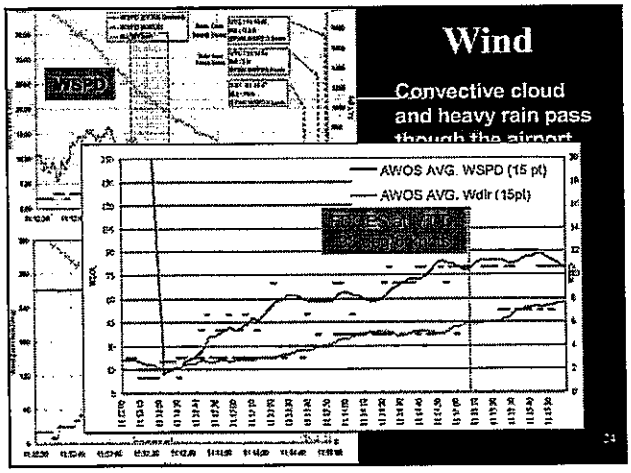
- **Limited FDR data, it did not recording**
  - Ground speed, drift, wind, lat/long position, ..
- **Airport Surveillance Radar track is available**
  - Scanning rate 4.62 sec, below 200 ft no data (blind area)
- **Other useful factual data**
  - Ground tracks, surface wind, two previous flight data
- **Performance problems**
  - Evaluate the ILS path , touched down pt.
  - Calculate the wind

Wind Profile Comparison
FLT066 Vs. 2 previous flight

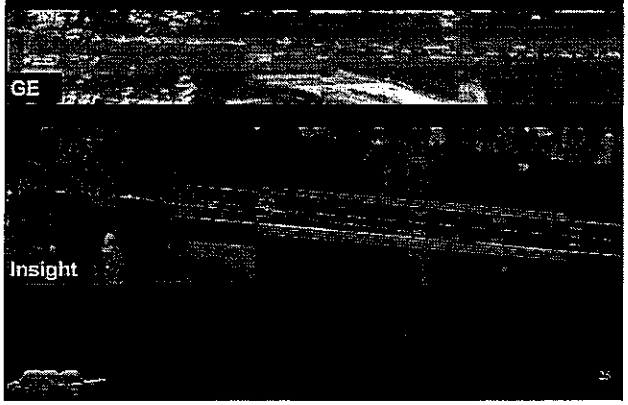


Wind

Convective cloud and heavy rain pass though the airport



Flight Path Visualization: FLT066



Conclusion Remarks

- In order to analyze the combined data sets, the "engineering known-how" is key elements to conquer those challenges
- Flight Path reconstruction is the essential procedure to determinate the sequence of events. Superpose of GIS layers will easier to understand "what and how" happened
- FDQES is useful tool to processing FDR data, and derive interesting parameters

Next step at ASC LAB

Developing the engineering simulator to study the hazard weather conditions

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