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AO-2008-070, In-flight upset 154 km west of Learmonth, WA 7 October 2008, VH-QPA Airbus A330-303

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Overview

- Occurrence sequence of events
- On-site phase
- Cabin safety
- Systems
- Investigation lessons

Based on ATSB *Interim Factual Report* (6 March 2009) available at www.atsb.gov.au

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Sequence – prior to anomalies

- 0132 UTC: QF72 left Singapore (to Perth)
  - 3 flight crew, 9 cabin crew, 303 passengers
- 0201: established FL370
  - weather clear, no turbulence
- Flight deck:
  - 0433: Capt returned from break
  - 0439: FO left for break
- Cabin:
  - meal service completed, carts in galley
  - 4 cabin crew in crew rest area

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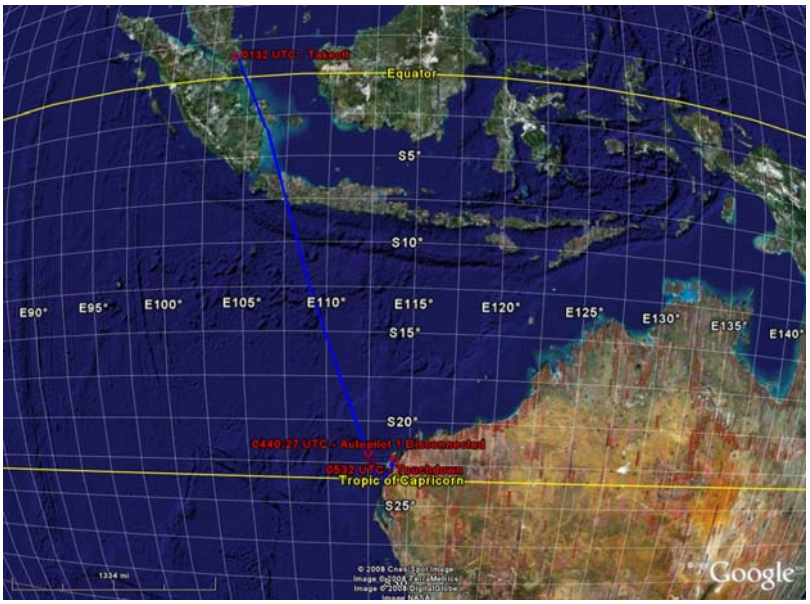

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Sequence – initial anomalies

- 0440.28:
  - ADIRU 1 data spikes started
  - AP1 disconnected (Capt took manual control)
  - ECAM messages, master caution chimes, stall / overspeed warnings, fluctuations on Capt's primary flight display
- Crew evaluating situation
  - 0441.12: AP2 attempted, disengaged
  - asked cabin crew to send FO back to flight deck

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Sequence – first upset

- 0442.27: pitch nose-down
  - max pitch angle 8.4 degrees, *g* loading -0.80
  - many injuries in cabin
- Capt promptly applied back pressure
  - initially no response
- Descended 650 ft before return to FL370
- SO put seatbelt light on, made PA
- Crew commenced ECAM actions
  - NAV IR1 fault – switch to Capt on 3
  - PRIM 3 fault – OFF then ON

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Sequence – second upset

- 0445.08: pitch down
  - max pitch angle 3.5 degrees, *g* loading 0.20
- Capt promptly applied back pressure
  - initially no response
- Descended 400 ft before return to FL370
- Reviewing ECAM
- Captain made PA
- 0447.39: FO returned

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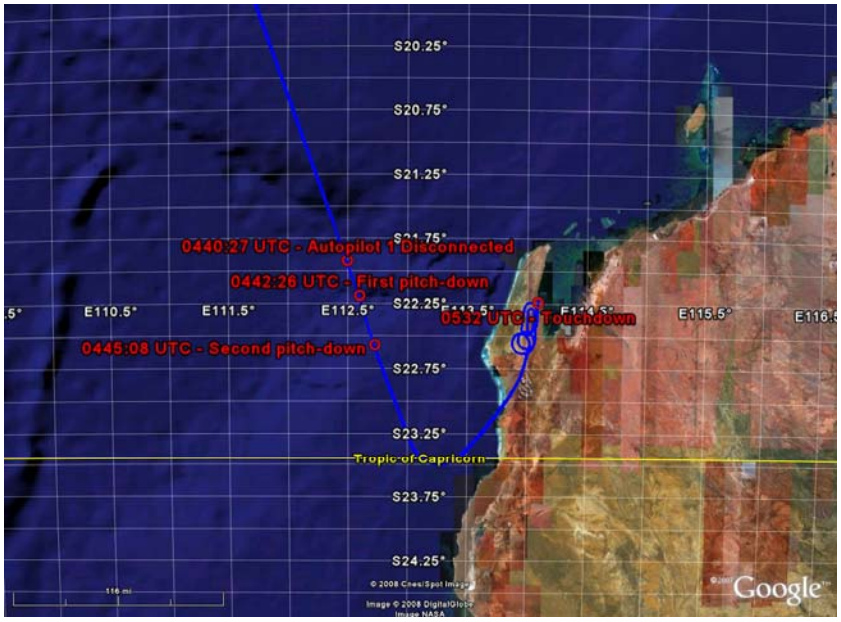

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Sequence – post-upsets

- ECAM messages scrolling and could not action, frequent warnings and cautions
- Decided to land ASAP
  - unsure whether would reoccur
  - aware had some injuries
  - 0449.06: PAN call
- Received advice of serious injuries
  - 0454.26: MAYDAY
- Frequent communications with ATC, cabin, maintenance watch

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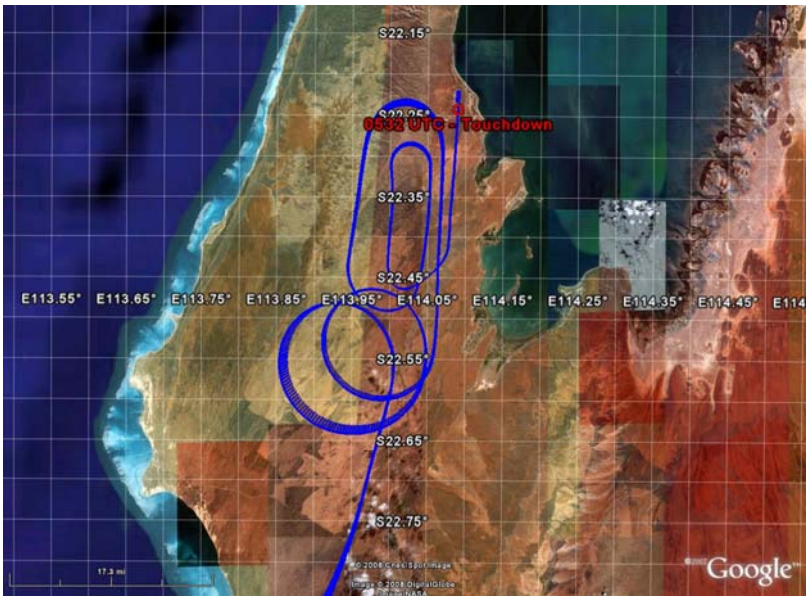

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On-site phase

- Cabin inspection (impact damage)
- Aircraft inspection (no damage)
- Cargo / loading (no problems)
- Recorded data
  - preliminary FDR, QAR, CVR analysis
  - post flight report (PFR), maintenance data
  - (indicated ADIRU 1 problem)
- Functional testing
  - ADIRU 1 removed
  - (no problems found with other systems)

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Injury information

- Obtained from operator, interviews, survey, WA Dept of health
- WA Dept of health
  - 53 attended hospital, 12 of these ‘admitted’
- Serious injury:
  - ATSB definition: admitted to hospital
  - ICAO Annex 13: different definition, same result (though not all the same people)
- Due to serious injuries, was an ‘accident’

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Passenger survey

- Difficulties with names, contact details
- Initial batch sent out 28 Oct 2008
- Questions about events, seatbelts, injuries, PEDs
- 95 responses (+ 6 children) and 29 interviews / email (+11 children)
  - in total information from 47%
- Nothing unusual prior to upset

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Injury information

	Crew	Passengers	Total
Fatal	-	-	-
Serious	1	11	12
Minor	8	95	103
None	3	197	200
Total	12	303	315

- All injuries at time of first in-flight upset
- Severity of injuries varied considerably

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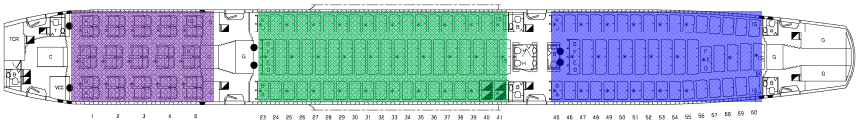
Passenger injuries by location



	Front	Centre	Rear
Passengers	33	150	120
Total injuries	7	55 (37%)	44 (37%)
Attended hospital	-	32 (21%)	19 (16%)
Serious injury	-	7 (5%)	4 (3%)
Damage above seat		~10%	~20%

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Passenger injury details

	Seatbelts on	Seatbelts off	Standing	Toilet
Total responses	82	61	18	2
Injured	35%	91%	100%	100%
Attended hospital	13%	38%	67%	100%
Serious injury	2%	5%	22%	50%
Common injuries	Strain, sprain of neck, back	Head, neck due ceiling impact; bruising to back, legs landing on seats, floor	Multiple (including spinal)	Multiple (including spinal)

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Seatbelt inspections

- 4 passengers said had seatbelt fastened, but were not restrained
- Inspected sample of 51 seatbelts
  - including for those attended hospital and unsure whether seatbelt on or not
- No problems with condition of belts examined
- Potential design problem of lift-latch mechanism

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Cabin safety summary

- Key findings:
  - most injuries to people standing, or seated without seatbelts fastened
  - seatbelts have potential for inadvertent release (never been noted before)
- Ongoing investigation:
  - passenger survey analysis
  - further examination of inadvertent release
  - review of industry seatbelt requirements
- Safety action to date:
  - seatbelt reminders

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Systems: key findings

- ADIRU 1 provided erroneous data (spikes) on many parameters to other aircraft systems
  - other 2 ADIRUs functioning correctly
- Spikes in angle of attack (AOA) data were not filtered by flight control computers (PRIMs)
  - computers subsequently commanded pitch-down movements

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Air data inertial reference unit

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Air data inertial reference unit (ADIRU)

- Air data part (ADR)
  - barometric altitude, speed, Mach, angle of attack (AOA), temperature
- Inertial reference part (IR)
  - attitude, flight path vector, track, heading, accelerations, angular rates, ground speed, vertical speed, aircraft position

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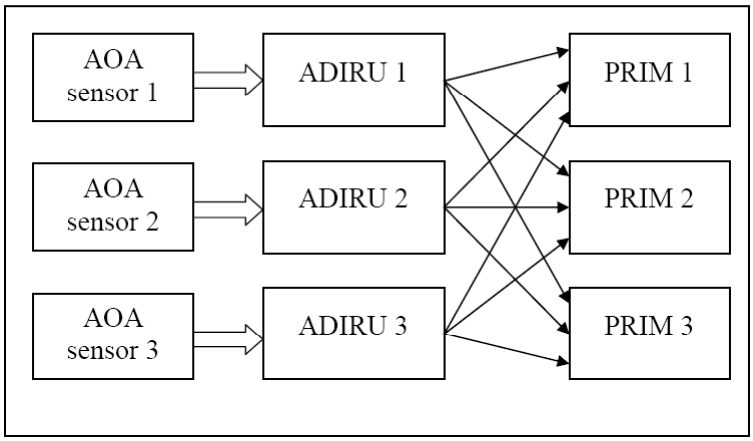
AOA inputs to ADIRUs and PRIMs



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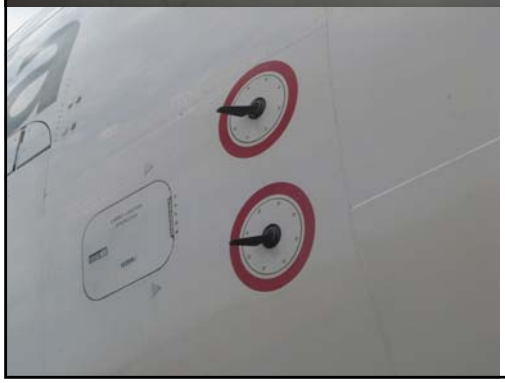
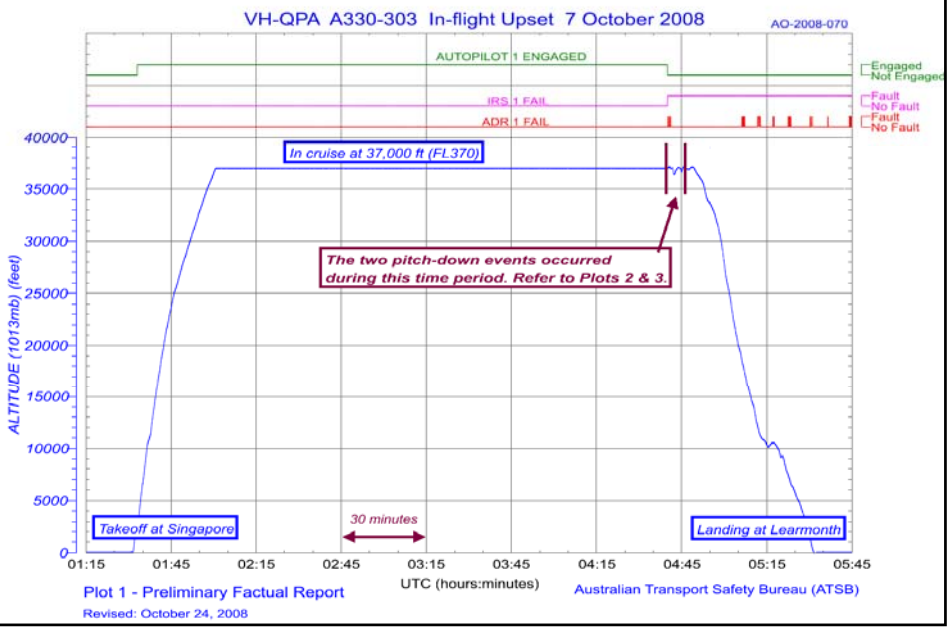
Left AOA Vane (AOA1)

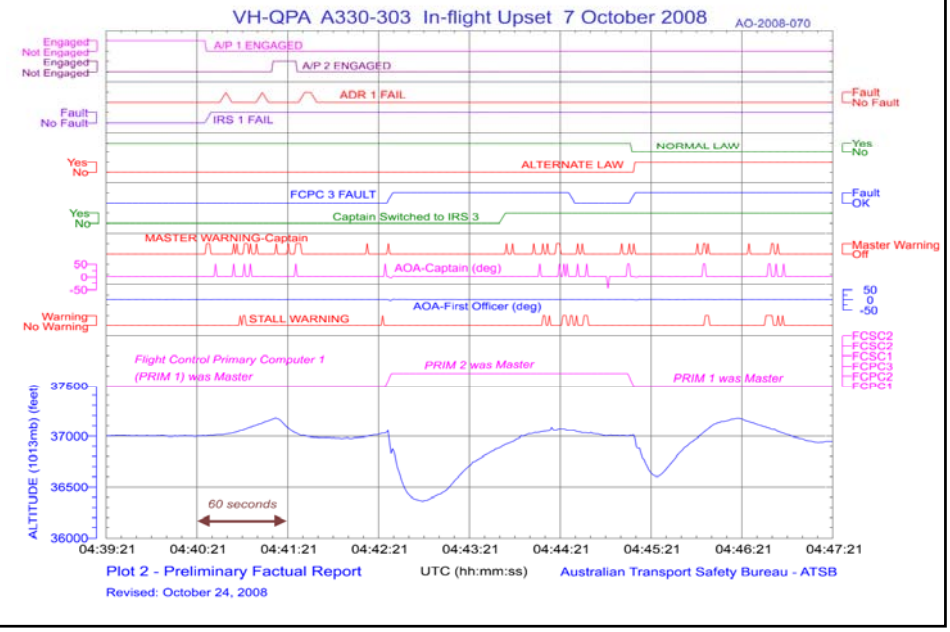


Right AOA Vanes (AOA2 and AOA3)

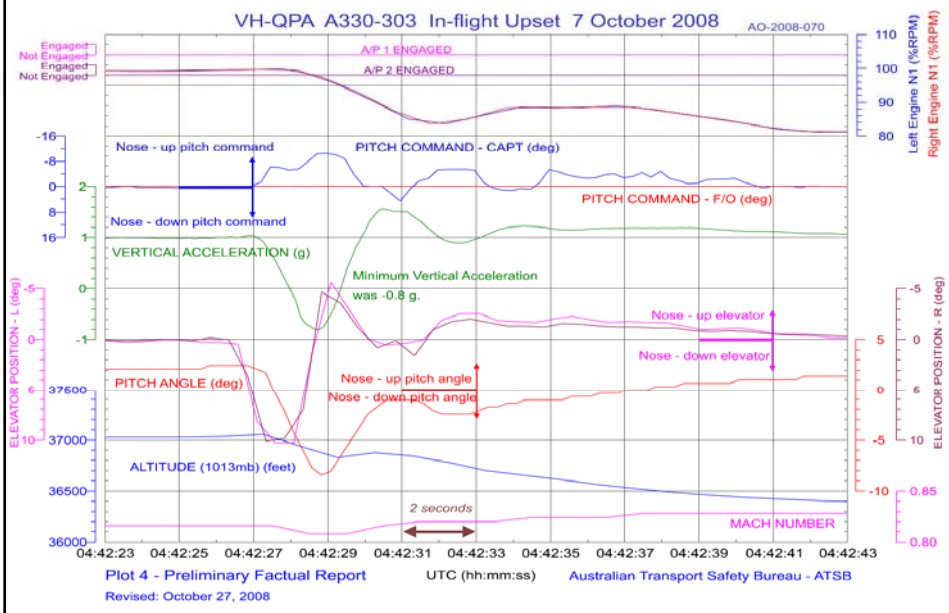
FDR Data (whole flight)



FDR Data (both pitch downs)



FDR Data (first pitch down)



ADIRU testing

- ADIRUs 1, 2, 3 sent to Northrop Grumman
- Test plan and protocols developed
- Initial testing (November 2008) attended by all parties:
  - ATSB, Qantas
  - NTSB, NG, FAA
  - BEA, Airbus

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ADIRU testing

- ADIRUs 1, 2, 3
  - Physical inspection
  - Manufacturer test program (MTP)
  - OFP test (software verification)
  - BITE (test) data download
- ADIRU 1:
  - Ground integrity test
  - Bus tests
  - Internal visual inspection
  - Environmental tests (vibration, temp, EMI)
  - Level III (component) testing

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ADIRU test results

- BITE data:
  - ADIRU 2 and 3 BITE data showed anomalies with ADIRU 1
  - ADIRU 1 had no BITE data from relevant time, several routine messages not stored
- No testing to date on ADIRU 1 has reproduced any faults related to ADIRU behaviour on accident flight
- Summary: even though ADIRU producing spikes, do not yet know why

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PRIM data processing (general)

- Variety of redundancy and error-checking mechanisms to prevent erroneous ADIRU data affecting flight controls
- 3 different values of same parameter, each from different sensor and processed by different ADIRU

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PRIM data processing (general)

- Parameter monitoring:
  - voting process – if any value differed from median by more than threshold for period of time, relevant part of ADIRU ignored
- Calculation of flight control commands:
  - median value used by PRIMs to calculate flight control commands

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PRIM data processing (AOA)

- Parameter monitoring:
  - voting process – if any value differed from median by more than threshold for more than 1 second, relevant ADR ignored
- Calculation of flight control commands:
  - average value used (AOA1 + AOA2 / 2)
  - average value passed through rate limiter
  - if difference between AOA1 or AOA2 and median > threshold, PRIMs memorised last valid average for 1.2 seconds (then used current average)

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PRIM data processing (AOA)

- AOA processing algorithms prevent most types of erroneous AOA inputs influencing flight controls
- However, problem if:
  - 2 or more high amplitude spikes
  - first spike < 1 second duration
  - second spike present 1.2 seconds after detection of first spike
- At least 42 AOA spikes on accident flight

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Flight envelope mechanisms

- In normal law, computers prevent exceedance of predefined flight envelope
- High AOA protection (alpha prot):
  - if AOA too high, PRIMs command nose-down elevator command
  - only available in normal law
- Anti pitch-up compensation:
  - available when Mach > 0.65 and aircraft in clean configuration
  - maximum authority was 6 degrees

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Flight envelope mechanisms

- First upset was close to worst possible scenario:
  - 4 degrees alpha prot, 6 degrees anti pitch-up
- AOA processing algorithm using just two sensors only on A330 and A340
  - different algorithms used on other Airbus aircraft

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Related events

- ADIRU failures occur but rare (mean time between failure of 17,500 hours)
- Extremely rare for ADIRU failures to have an effect on aircraft flight controls
  - Boeing 777 August 2005, 240 km NW Perth (different ADIRU manufacturer and type)
  - no previous case reported involving Airbus aircraft
- Two other cases where ADIRUs exhibited similar anomalous behaviour

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12 September 2006, VH-QPA

- QF68, Hong Kong – Perth
  - same aircraft, same ADIRU
- Tech log
  - ADR 1 fault and numerous ECAM messages
- Pilot report (after accident)
  - night, smooth conditions
  - numerous ECAMs, constantly changing
  - weak and intermittent ADR1 fault light, turned ADR1 off
- Maintenance action as per manual
  - ADIRU re-alignment, system test - nil faults

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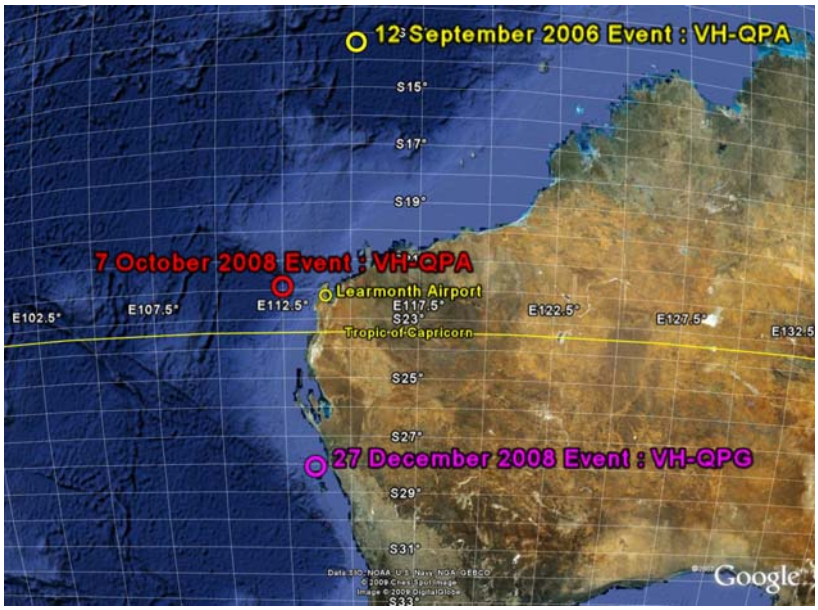

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27 December 2008, VH-QPG

- QF71, Perth - Singapore
  - different aircraft, different ADIRU
- Sequence:
  - 0749.55: takeoff
  - 0814.01: FL360
  - 0828.55: IR1 fault indication
  - 0828.56: AP1 disconnect
  - multiple, scrolling ECAM messages
  - IR1 and ADR switched off (as per new procedure), though IR still provided erroneous data to systems

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Search for other events

- 3 known events had similar PFR messages
- Airbus searched AIRMAN database for similar PFRs
  - covered most of world A330/340 fleet using same model ADIRUs (248 of 397 aircraft)
  - only one similar PFR: VH-EBC, 7 Feb 2008 (Sydney to Saigon) (not confirmed whether this flight had similar event)
- Summary: only 3 known events, same operator, same general area

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Harold E Holt VLF transmitter

- Information from defence:
  - transmitting at time of all 3 events (transmits most of the time)
  - no equipment malfunctions, no changes in nature of transmissions
  - in operation since 1967 (similar transmitters in several other countries)
- Field strengths at event locations well below levels of ADIRU certification tests
- ADIRU tests examined VLF (no problem)

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Systems – ongoing activities

- ADIRU problem:
  - ADIRU testing
  - theoretical analysis of ADIRU failures
  - configuration comparisons
  - review of technical records
  - aircraft testing
- AOA processing algorithm limitation
  - review of PRIM software development cycle

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Systems – safety action

- Airbus
  - Operational Engineering Bulletin (OEB) (operational procedures in response to such events)
  - PRIM software modifications
- Qantas
  - FSO incorporating OEB
  - simulator training
  - Q&A sessions for pilots, memo
- EASA / CASA
  - ADs based on OEBs

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Investigation lessons (1)

- Team composition:
  - go with numbers
  - IIC not involved in data collection
- On-site communications:
  - regular team meetings, briefings
  - access to email
- Difficult decisions:
  - take time, keep asking questions, give explanations
- OH&S: beware of benign sites

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Investigation lessons (2)

- Passenger contact details and injury information
- External communications:
  - face-to-face > conference calls > emails (until relationship established)
  - provide regular updates
  - understand different organisations' approach to investigations (and how protect information)

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