AIRCRAFT SERIOUS INCIDENT

FINAL REPORT

SI 02/17

Air Accident Investigation Bureau

Ministry of Transport, Malaysia

Final Report on the Serious Incident involving

Fixed wing aircraft Airbus A330 Registration 9M-XXS

En-route from Taipei to Kuala Lumpur

on the 03rd May 2017

AIR ACCIDENT INVESTIGATION BUREAU (AAIB)

MALAYSIA

ACCIDENT REPORT NO. : SI 02/17

OPERATOR	**:**	**AIRASIA X BERHAD**
AIRCRAFT TYPE	**:**	**AIRBUS A330-343**
NATIONALITY	**:**	**MALAYSIA**
REGISTRATION	**:**	**9M-XXS**
PLACE OF OCCURRENCE	**:**	**EN-ROUTE TPE-KUL**
DATE AND TIME	**:**	**03.05.2017 17:47:25hrs (UTC)**

This report contains a statement of facts which have been determined up to the time of issue. It must be regarded as tentative, and is subjected to alteration or correction if additional evidence becomes available.

This investigation is carried out to determine the circumstances and causes of the accident with a view to the preservation of life and the avoidance of accident in the future: It is not the purpose to apportion blame or liability (Annex 13 to the Chicago Convention and Civil Aviation Regulations 2016).

INTRODUCTION

The Air Accident Investigation Bureau of Malaysia

The Air Accident Investigation Bureau of Malaysia (AAIB) is the air accidents and incidents investigation authority in Malaysia and is responsible to the Ministry of Transport. Its mission is to promote aviation safety through the conduct of independent and objective investigation into air accidents and serious incidents.

The AAIB conducts the investigations in accordance with Annex 13 to the Chicago Convention and Civil Aviation Regulations of Malaysia 1996.

In carrying out the investigations, the AAIB will adhere to ICAO's stated objective, which is as follows:

"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."

Accordingly, it is inappropriate that AAIB reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

AIRCRAFT ACCIDENT/SERIOUS INCIDENT REPORT

Aircraft Type	**:**	**AIRBUS A330**
Model	**:**	**A330-343**
Owner	**:**	**AirAsia X Berhad**
Nationality	**:**	**Malaysia**
Year of Manufacture	**:**	**2014**
Aircraft Registration	**:**	**9M-XXS**
Serial Number	**:**	**1533**
State of Registration	**:**	**Malaysia**
State of Operator	**:**	**Malaysia**
Place and State of Occurrence	**:**	**En-route TPE-KUL**
Date and Time of Occurrence	**:**	**03.05.2017 17:47:25hrs (UTC)**

All times in this report are Local Time (LT) (UTC +8 hours)

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SYNOPSIS

During cruise at FL390, aircraft encountered severe turbulence. Autopilot and Autothrust were manually disconnected and Captain took over control. Subsequently, a PAN call was made to Ho Chi Minh control due to the strong updraft encountered. As aircraft recovered, pilots requested climb back to FL390. Pilots were directed to point MAPNO and the PAN call was cancelled. Captain was informed by Purser that five passengers were reported injured during the event. Cabin Crew managed to page for medical personnel on board to attend to the injured passengers.

1.0 FACTUAL INFORMATION

1.1 History of the flight

During cruise at FL390 in Ho Chi Minh airspace, while maintaining M0.81, Airbus A330-300 registration 9M-XXS encountered moderate to severe turbulence.

Captain took over the controls and disconnected the Autopilot to control the abrupt manoeuvres caused by the weather, which appeared as green patches on the weather radar display. The aircraft bank more than 30 degrees and pitched up more than 10 degrees. During the event, ECAM triggered F/CTL PRIM 1 FAULT and flight crew proceeded to reset the PRIM 1 as per ECAM actions. PAN call was declared to Ho Chi Minh Air Traffic Control (ATC).

After recovering the aircraft, flight crew requested to climb to FL390. ATC directed the flight to position MAPNO and continue as per flight plan route. Flight crew were informed that five passengers were injured with one requiring medical assistance on arrival. Cabin crew managed to page for medical personnel on board to attend to the injured passengers. Medical support was provided upon arrival at Kuala Lumpur.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	Nil	Nil	Nil
Serious	Nil	01	Nil
Minor	Nil	04	Nil
None	11	286	Nil

1.3 Damage to aircraft

1.3.1 During the event, the following load factor excursions were observed Based on the FDR recording):

- Vertical (VRTG): +2.094g / -0.23g.

• Lateral (LATG): -0.15g / +0.30g.

1.3.2 Some cabin ceiling panels were found damaged.

1.3.3 Based on the DFDR readout, the final load analysis concluded that no exceedances of limit loads were found on the airframe.

1.3.4 In addition, the following aircraft inspections were performed:

• AMM task 05-51-17 Inspection after Flight in Excessive Turbulence or in Excess of VMO/MMO.

• AMM task 05-51-44 Inspection After a Flight with High Lateral Loads.

1.3.5 As a result of those inspections, 2 fasteners were found with sign of rotation at LH Wing Bottom Surface, MLG Reinforcement Skin, at between Rib 5LH to Rib 6LH and at Rear Spar.

1.3.6 However, after analysis, those findings are most probably not related to the event (e.g. were present beforehand).

1.4 Other damage

Nil.

1.5 Personal Information

1.5.1 Captain

Status	Commander
Designation	Captain
Date joined AirAsia X	01st July 2012
Nationality	Indonesian
Date of Birth	24th April 1973
License Type	Malaysian ATPL – Class 1 with no limitations
License Number	3430
Current Aircraft Rating	Airbus A330

Previous experience

Previous Employer	AirAsia Berhad
Designation	Captain
Previous Aircraft Rating	Airbus A320
Other Experience	Fokker F27 : 3,560:25hrs

	B737-300 : 2,389:55 hrs A 320. : 4,432:04 hrs A 330. : 4,222:57 hrs Total hours as of 07/11/17: 14605:21 hrs.

The following is a summary of training received while in AirAsia X Berhad. Points highlighted are related to reports by instructors/examiners specifically on the pilot's manual handling skills as well as avoidance of weather.

Training Received In AirAsia X Berhad

	Training Type	Details of Training
1.	Cross Crew Qualification (CCQ) training from A320 to A330	- Completed Aircraft system (type tech) exam in July 2012 - Completed Theoretical ground studies and examination in July 2012 - Completed Safety Emergency Procedures (SEP) training in July 2017 - Completed Conversion Full Flight Simulator (FFS) training in August 2012 - Recommended for Final Line Check at 8 sectors of line training. - Completed Line Flying under supervision & cleared for operational duties on the 7th October 2012

2.	Summary of CCQ training	- Overall performance during training indicate satisfactory to good performance.
		- Simulator training and checks indicated that Captain had good aircraft handling.
		- Line Training discussion items were completed as per the TS2 form.
		- Among items discussed are:
		  - Turbulence Penetration
		  - Usage of Weather Radar
		  - En-route weather monitoring.

3.	Other Training	- Completed NAT HLA (North Atlantic High Level Airspace) Training, previously known as MNPS in January 2015 - Completed RNP APCH training and qualification in January 2015.
4.	Safety Emergency Procedure (SEP) Recurrent Training and Check	- Passed all annual Recurrent SEP exams and drills.
5.	Annual Line Check	- Passed all annual line checks with reports indicating good standards.

		• Instructor's report - 23rd Feb 2016 – Good climb management with due weather avoidance. - Overall satisfactory to good CRM points were noted.
6.	Instrument Rating Check	- Passed all annual Instrument rating checks as part of the License Proficiency checks
7.	Line Oriented Flight Training (LOFT)	- Completed all bi-annual LOFT recurrent simulator training sessions with satisfactory to good standards. - Jul-Dec 2013 syllabus: received simulator training on overspeed at high altitude. - Jan-Jun 2014 syllabus: received simulator training in Unanticipated Moderate turbulence - Jan-Jun 2015 syllabus: received simulator training on Jet Upset scenario - Jan-Jun 2016 syllabus: received theoretical classroom training on aircraft stall prevention and recovery manoeuvres. - Jul-Dec 2016 syllabus: received simulator training on Jet Upset recovery techniques. - Jan-Jun 2017 syllabus: received simulator training on Jet upset recovery in Normal Law at high angle of attack.
8.	License Proficiency Check (LPC) / Operator Proficiency check (OPC) Regulatory Certificate of Tests	- Passed all bi-annual recurrent checks with satisfactory to good standards as reported by examiners. - Satisfactory to good CRM also noted in check forms.

1.5.2 Co-Pilot

Status	Co-Pilot
Designation	First Officer
Date joined AirAsia X	01st July 2015
Nationality	Malaysian
Date of Birth	14th April 1988
License Type	Malaysian ATPL – Class 1 with no limitations
License Number	4980
Current Aircraft Rating	Airbus A330

Previous experience

Previous Employer	AirAsia Berhad
Designation	First Officer
Previous Aircraft Rating	Airbus A320
Other Experience	Airbus A320: 2,286:00 hrs Airbus A330: 1,130:00 hrs

The following is a summary of training received while in AirAsia X Berhad. Points highlighted are related to reports by instructors/examiners specifically on the pilot's manual handling skills as well as avoidance of weather.

Training Received In AirAsia X Berhad

	Training Type	Details of Training
1.	Cross Crew Qualification (CCQ) training from A320 to A330	- Completed Aircraft system (type tech) exam on 24th July 2015 - Completed Theoretical ground studies and examination on 16th July 2015 - Completed Safety Emergency Procedures (SEP) training in July 2015 - Completed Conversion Full Flight Simulator (FFS) training in August 2015 - Recommended for Final Line Check at 12 sectors of line training. - Completed Line Flying under supervision & cleared for operational duties on the 11th September 2015

2.	Summary of CCQ training	- Overall performance during training indicate satisfactory performance.
		- Simulator training and checks indicated that manual flight handling and anticipation of flight parameters were satisfactory and safe with room for refinement.
		- Line training reports indicated a need to improve knowledge as well as some issues with take-off and landing handling issues that were eventually addressed as part of the training progress.
		- Line Training discussion items were completed as per the TS2 form.
		- Among items discussed are:
		  - Turbulence Penetration
		  - Usage of Weather Radar
		  - En-route weather monitoring

3.	Other Training	- Completed NAT HLA (North Atlantic High Level Airspace) Training, previously known as MNPS in August 2015 - Completed RNP APCH training and qualification in August 2015
4.	Safety Emergency Procedure (SEP) Recurrent Training and Check	- Passed all annual Recurrent SEP exams and drills.
5.	Annual Line Check	- Passed all annual line checks with reports indicating satisfactory to good standards. • Instructor's report - Overall satisfactory CRM points were noted.
6.	Instrument Rating Check	- Passed all annual Instrument rating checks as part of the License Proficiency checks.
7.	Line Oriented Flight Training (LOFT)	- Completed all bi-annual LOFT recurrent simulator training sessions with satisfactory to good standards. - Jan-Jun 2016 syllabus: received theoretical classroom training on aircraft stall prevention and recovery manoeuvres. - Jul-Dec 2016 syllabus: received simulator training on Jet Upset recovery techniques. - Jan-Jun 2017 syllabus: received simulator training on Jet upset recovery in Normal Law at high angle of attack.
8.	License Proficiency Check (LPC) / Operator Proficiency check (OPC) Regulatory Certificate of Tests	- Passed all bi-annual recurrent checks with satisfactory standards as reported by examiners. - Satisfactory CRM also noted in check forms.

1.6 Aircraft Information

Manufacturer and model	:	Airbus A330-300
Registration	:	9M-XXS
Operator	:	AirAsia X Berhad

1.7 Meteorological Information

No significant weather was reported on the forecast en-route weather, but the satellite IR image supplied by Airbus (dated 03-MAY-2017, 17:50 UTC) showed a very local air column / build-up close to the turbulence encounter. Such meteorological phenomena may generate high vertical air velocities.

Weather information attached in Appendix 1.

1.8 Aids to navigation

Not Applicable.

1.9 Communications

No significant issues.

1.10 Aerodrome information

Departure Airport- RCTP. Taipei Taiyoan International Airport, Taiwan

Destination Airport-WMKK, Kuala Lumpur International Airport, Sepang, Malaysia.

1.11 Flight Recorders

Data from on board recorders were used to assist investigation.

1.12 Wreckage and impact information

Nil.

1.13 Medical and pathological information

Nil.

1.14 Fire

Nil.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

Nil.

1.17 Organisational and management information

Not applicable.

1.18 Additional information

1.18.1 Pilot Report

An Air Safety Report (reference Air Safety Report 9039) was available for this event. (Refer Appendix 5).

1.18.2 Action Taken

As demonstrated by in-service experience (one sole reported occurrence over 66 million Flight Hours on the A330/A340 Family), the combination of the factors that led to this event is remote. However, Airbus performed an in-depth analysis into this event to understand the contribution of weather, technical and operational factors. As a result, in order to supplement the existing operational prevention means, Airbus has introduced enhancements of the Flight control system (lateral normal law, robustness to PRIM FAULT) for the A330 NEO Type Certificate. The feasibility of these enhancements for the A330 NEO is under review. EASA has been made aware and is kept informed of the progress.

1.19 Useful or effective investigation techniques

Not applicable.

2.0 ANALYSIS

2.1 SEQUENCE OF EVENTS

2.1.1 **General information**

The analysis is based on the data extracted from the DFDR (256 words/s).
A standard calibration file (p256farr10.ffd) was used for decoding.
The associated flight data plots are available in Annex 2.
All times are provided in UTC reference.

2.1.2 **Initial conditions (17:46:30 UTC)**

17:46:30 UTC: A/C was in Cruise at FL390 (REC MAX = FL415) with:
- AP2 and both FD engaged in ALT CRZ / NAV modes (SALTFCU = 39000ft).
- ATHR was engaged in MACH mode. Mach target was managed at 0.82 and Mach number was following its target.

- The weather radar (WXR) display was selected on both sides, and WXR mode was "Weather and Turbulence".
- Both ND were configured in ARC mode, with a selected range of 320NM on Captain and F/O sides.
- GW = 169.5t, CG = 38.8%.
- Slats/Flaps were in configuration CLEAN.
- FCPC1 ("PRIM1") was Master-in-law (FCPC1CL=1).
- The F/O reported being the Pilot Flying (PF).

Analysis:

The weather radar mode was adequate, but the chosen ND ranges (320 NM on both sides) were not the optimum ones to provide good weather awareness in cruise. The tilt and gain of the weather radar are not recorded in the DFDR, therefore it was not possible to determine if these settings were adequate to properly scan the weather. To be noted that *"few patches of weather displayed in green colour on the weather radar"* were reportedly overflown previously. The FCTM (section Aircraft Systems / Weather Radar / Weather detection) provides the following recommendations for the use of the weather radar in cruise:

Manual Weather Radars (or Automatic Weather Radars in Manual Tilt Mode)		
Flight Phase	**Tilt Control**	**Comments**
LEVEL FLIGHT/CRUISE	1. Adjust ND range as required 2. Regularly modify the tilt to scan the weather ahead of the aircraft 3. When the weather scan is completed, adjust the tilt so that the ground returns appear on the top of the ND [(2)(3)].	In cruise, the combination of the following ND ranges provides good weather awareness[(1)]: - 160 NM on the PM ND - 80 NM on the PF ND. Use shorter ND ranges to track/avoid short-distance weather.

1) *For aircraft equipped with a manual weather radar that has only one tilt control knob, use an average tilt value to suit both ND ranges.*

OPTIMUM USE OF THE WEATHER RADAR

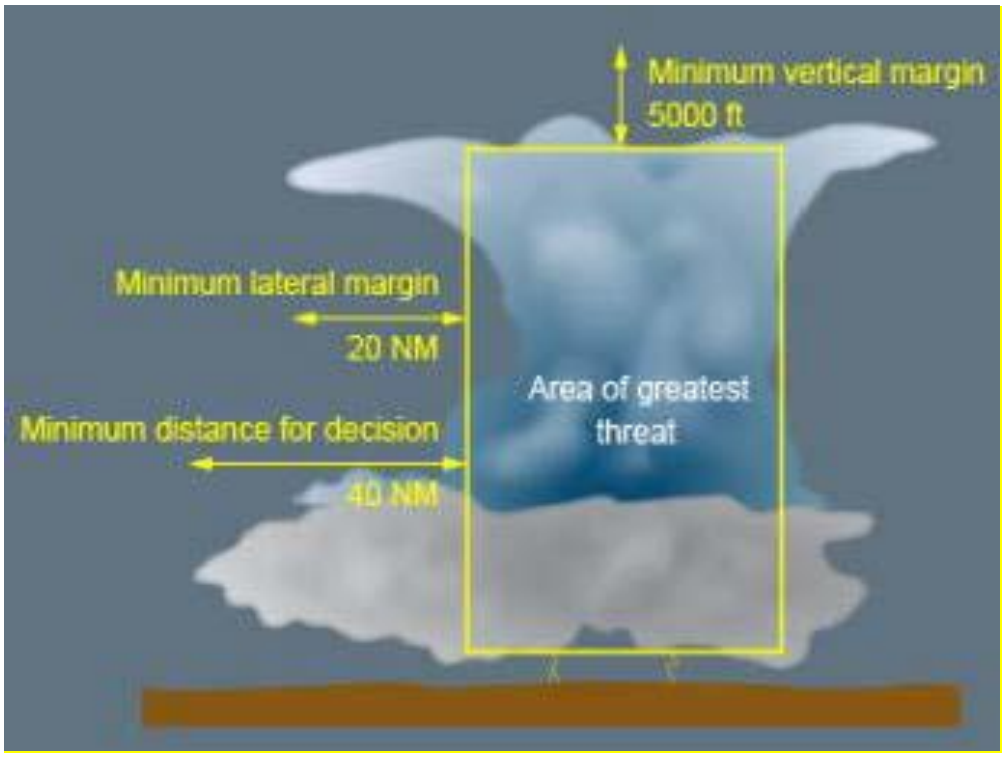
Relevant procedures and best practices:

• Regularly scan the weather ahead of the aircraft
• Use manual tilt to have the real shape of the cell
• Adjust the gain: reduce gain to identify zones with highest precipitation and increase gain to improve long-term accuracy or for deeper analysis of a cell
• Recommended ND ranges for weather awareness in cruise: 80 NM on PF ND and 160 NM on PM ND
• Use shorter ND ranges to track/avoid short-distance weather
• Analyse shapes combined to colours (and not only colours)

Operational documentation:
• FCOM section DSC-34-20-30 – Aircraft Systems – Weather radar
• FCTM section AS-WXR – Aircraft Systems – Weather radar

Relevant procedures and best practices:

- Avoidance decision: define the "Area of greatest threat" based on:
  - Location and shape of the strongest weather radar echoes
  - Meteorological knowledge of the flight crew.
  - zone where the flight crew estimates that the weather conditions are too dangerous to fly in
- Avoidance technique
  - Take margins around the "area of greatest threat"
  - Increase the margin if the cloud is very dynamic



Operational documentation:
• FCOM section DSC-34-20-30 – Aircraft Systems – Weather radar
• FCTM section AS-WXR – Aircraft Systems – Weather radar

2.1.3 **Phase 1: start of turbulence, AP disconnection and nose-up orders (17:47:25 to 17:47:55 UTC)**
(Refer Appendix 2: Phase 1 Longitudinal and Lateral Axis)

2.1.3.1 **Phase 1 overview – Longitudinal axis**

As illustrated in the plots in Appendix 2, during this time period:

- The turbulence started – it is considered as moderate to severe (maximum vertical load factor (VRTG) of 1.82G, lateral load factor (LATG) of -0.15G).
- CAS and Mach first increased quickly from 252 Kts/0.81 to 266 Kts/0.85, before decreasing towards 200 Kts/0.70.
- The AP was voluntary disconnected (using the sidestick P/B). Master warning triggered accordingly during 3s.
- The Captain began applying significant nose-up stick inputs (STKPC) and took the priority (STKFINOP=1) during 1s (using the sidestick P/B).
- Dual inputs started in pitch: The F/O applied mostly moderate nose-down stick inputs (STKPF). Dual input boolean (DUAL INPUT) was consistently recorded at 1 during most of this time period.
- Pitch angle (PTCH) and AoA (CAOA1&2) started to increase. Vertical speed (VSPD) reached +7100ft/min. Altitude (ALT) started to increase
- A/THR was involuntary disconnected, resulting in a Thrust Lock condition, at the climb thrust (THRLKD=1).

Analysis:
The first AP2 disconnection corresponds to a voluntary disconnection via the sidestick P/B (APOFF VLTRY=1).
The flight crew interview confirmed that the Captain took over the controls and disconnected the AP.

QUOTE
During the deviation, the aircraft entered an updraft and Captain decided to take over control by disengaging the autopilot.
Captain announced taking over control, but it was not heard by the First officer.
However, the First officer understood the handling over control to the captain when he heard the PRIORITY LEFT twice.

UNQUOTE
Two (2) additional AP2 disconnections are recorded during the Phase 1. They are involuntary disconnections due to the Captain sidestick inputs, respectively in roll and pitch. The PFR consistently indicated that the ECAM warning AUTO FLT AP OFF was generated at 17:48 UTC.
This aircraft was fitted with both visual and aural dual input warnings. The triggering of the DUAL INPUT boolean is consistent with the activation of these warnings.

<u>MANUAL TAKE-OVER, PF/PM DUTIES TRANSFER AND DUAL INPUTS</u>
Relevant procedures and best practices:

• As on any aircraft, simultaneous inputs by both PF and PM on sidestick (or yoke must be avoided.
• Only one pilot flies at a time.
• The flight crew should keep in mind that sidestick inputs are algebraically added. Therefore, dual inputs must be avoided, and will trigger aural and visual alerts.
• If the PM wants to act on the sidestick, he/she must:
    • Clearly announce "I have control"
    • Press and maintain his/her sidestick pushbutton, in order to get full control of the Fly-By-Wire system.
    Note: priority is latched after 40s

Operational documentation:
• FCTM AOP-10-30-20 Airbus Operational Philosophy – Design Philosophy – FBW Use of Sidestick
• FCOM DSC-27-20-30 Aircraft Systems – 27 Flight Controls – Flight Control System
• FCOM NOR-SOP-90 Normal Procedures – SOP – Standard Callouts – PF/PM duties transfer

The wind reconstruction provided by Airbus highlighted a significant headwind gradient (24kt in 2s) prior to AP2 voluntary disengagement, which contributed to the airspeed/Mach increase.

The characteristic speeds provided by Airbus shows that the current CAS remained below VMAX (e.g. VMO/MMO in the event's configuration), but the Speed Trend transiently exceeded VMAX.

There was no overspeed warning triggering: the maximum Mach number reached was 0.85 whereas the Maximum Operating Mach number (MMO) is 0.86 on the A330.

Turbulence management and overspeed prevention during the event are further discussed in the "Operational considerations"

<u>TURBULENCE MANAGEMENT</u>
Relevant procedures and best practices:
• In case of severe turbulence:
    • Reduce speed to VRA/MRA
    • SIGNS ON
    • AUTO PILOT: KEEP ON
    • A/THR: DISCONNECT (only if thrust changes excessive)
    • DESCENT … CONSIDER (in order to increase the margin to buffet)
    • FOR APPROACH: A/THR in managed speed … USE

• Unanticipated turbulence:
    • SIGNS ON
    • PA to Passengers and Cabin Crew: "Fasten Seatbelts Immediately"

• In addition, if manual flight is required: adopt a calm, flexible flying attitude without aggressive inputs

Operational documentation:
• FCOM PRO-ABN-MISC-10 / QRH 22.08A / FCTM PR-NP-SP-10-10 Adverse Weather – Severe turbulence
• CCOM 09-065 ABNORMAL/EMERGENCY PROCEDURES – TURBULENCE MANAGEMENT

OVERSPEED PREVENTION

Relevant procedures and best practices:
    • Keep AP and A/THR
    • Select a lower speed
    • Monitor speed trend
    • Speedbrakes (as required)

Operational documentation:
• FCTM PR-AEP-MISC-B ABNORMAL AND EMERGENCY PROCEDURES – MISC –OVERSPEED

Both sidesticks inputs being algebraically added, the equivalent stick input (STKP-EQ) of the two pilots was globally nose-up. This was combined with a significant updraft (~42kt in 4s). As a result, pitch angle and AoA started to increase, with 2 noticeable peaks (+12.7°/+8.4° (αMAX+2.4°) at 17:47:43 UTC, then +23.2°/+11° (αMAX+4.2°) at 17:47:55 UTC). The pitch angle reached very high values, which are unusual for the cruise phase.
The aircraft was flown at high AoA, and the High Angle-of-Attack protection was triggered several times during this phase, in accordance with its phase in/phase out activation logics.

Notes:
- In the Mach range of 0.76-0.86, αPROT varies between 5° and 4°, and αMAX varies between 6° and 5°.
- αPROT and αMAX are defined and detailed in the FCOM section DSC-27-20-10-20. Flight Control System / Normal law / Pitch control / Protections.
- αfloor function did not activate during this flight phase as the Mach number remained above the activation threshold of Mn=0.53.

2.1.3.2 **Phase 1 overview – Lateral axis**

As illustrated in the plots in Appendix 2, during this time period:

- Just after the AP disconnection, the aircraft started rolling to the right (8° RH) **1.**
- Roll stick inputs were applied by the Captain to target wings level. Maximum roll excursions were limited to 12°, and aircraft shortly returned wings level at 17:41:51 UTC. **2.**
- The aircraft then rolled rapidly to the right (reaching 20° RH). **3.**
- This was counteracted by both pilots (dual input in roll) applying a full LH lateral stick input, which was followed by an opposite full lateral RH input. **4.**
- Roll angle increased on the LH side, up to 33°. **5.**
- Roll rate increased, reaching ~20-24°/s (in absolute values). **6.**

Analysis:
The wind reconstruction and the engineering simulations that have been performed confirmed an important lateral (LH) wind gust leading to the initial aircraft departure to the RH side (20° RH bank angle was reached at 17:47:56 UTC). 3.

2.1.3.3 **Phase 1 – additional details**

17:47:47 UTC: A/THR was disconnected. TLAs were still on CL notch. Thrust Lock mode activated.

Analysis:
A/THR disconnection is described in the FCOM (section DSC-22_30-90) as follows:

A/THR DISCONNECTION

Applicable to: ALL

Ident.: DSC-22_30-90-B-00011490.0001001 / 18 AUG 10

GENERAL

When the A/THR is disconnected, it is neither armed nor active.

The A/THR can be disconnected in two ways:
- Standard disconnection:
  - The flight crew pushes the instinctive disconnect pb on the thrust levers (which immediately sets the thrust corresponding to the lever positions), or
  - The flight crew sets all thrust levers to IDLE detent.
- Non-standard disconnection:
  - The flight crew pushes the A/THR pb on the FCU while A/THR is armed/active, or
  - The system loses one of the arming conditions.

A non-standard disconnection is also called 'involuntary' disconnection.
The THRUST LOCK function is activated when the thrust levers are in the CL detent, and:
- The flight crew pushes the A/THR P/B on the FCU
  or
- The A/THR disconnects due to a failure.

The PFR consistently indicated that the ECAM caution AUTO FLT A/THR OFF was generated at 17:47 UTC.

The most probable cause is the A/THR disconnection via the FCU P/B, as there was no failure message associated to this cockpit effect in the PFR.

As a result of this Thrust Lock mode, thrust was frozen at the current value, which corresponded to the climb thrust (EPRA~1.67), until the reduction of the thrust levers to IDLE, at 17:48:38 UTC.

2.1.4 Phase 2: roll oscillations (17:47:55 to 17:48:53 UTC) (Refer Appendix 3: Phase 2 Longitudinal and Lateral Axis)

2.1.4.1 Phase 2 overview – Longitudinal axis

As illustrated in the plots in Appendix 3, during this time period:

- Dual input in pitch, lasting ~ 1 min 30s. Dual input boolean (DUAL INPUT) was consistently recorded at 1 during most of this time period.
- The sum of the Captain and F/O pitch stick inputs (STKP-EQ) remained between half and full back stick during the whole phase.
- AoA remained around αMAX with transient overshoots up to 11-12° in the same time as right bank angle excursions were progressively increasing above 60°.
- CAS and Mach number reduced, down to 181 Kt / 0.64.
- Thrust levers were reduced to IDLE. Thrust Lock mode was exited (THRLKD=0) and the actual thrust reduced to IDLE (EPRA reduced towards 0.8).
- The maximum altitude reached was 42000 ft. (REC MAX = FL415).

2.1.4.2 Phase 2 overview – Lateral axis

As illustrated in the plots in Appendix 3, during this time period:

- Dual inputs in roll, lasting ~1 minute.
- Full lateral orders (LH stop to RH stop) from Captain and F/O sides (frequency ~0.15Hz / Period ~7s), roughly synchronous.
- Progressive increase of lateral parameters: roll rate from ~30°/s to 40°/s, bank angle up to 98° RH, sideslip up to 9°.

Analysis (longitudinal & lateral):

The High Angle-of-Attack protection was activated during the most part of Phase 2 in accordance with its phase in/phase out activation logics.

Note: in the Mach range of 0.65-0.76, αPROT varies between 6° and 5°, and Amax varies between 7° and 6°.

The flight crew dual inputs maintained the sidestick in the aft sector. With the High Angle-of-Attack protection being active, this resulted in a permanent command of AoA between αPROT and αMAX. The aircraft was therefore maintained in a condition of

high AoA, low speed and high altitude, which corresponds to a zone of lower natural dutch-roll damping.
This aircraft was fitted with both visual and aural dual input warnings. The triggering of the DUAL INPUT boolean is consistent with the activation of these warnings.
The maximum recorded altitude during the event was 42000ft, above the recommended maximum altitude (REC MAX) of FL415, which corresponds to maximum certified ceiling of the A330.
Dual inputs, high altitude manual handling and High Angle-of-Attack protection triggering during the event are further discussed in the "Operational considerations" section.

MANUAL TAKE-OVER, PF/PM DUTIES TRANSFER AND DUAL INPUTS

Relevant procedures and best practices:

- As on any aircraft, simultaneous inputs by both PF and PM on sidestick (or yoke) must be avoided.
- Only one pilot flies at a time.
- The flight crew should keep in mind that sidestick inputs are algebraically added. Therefore, dual inputs must be avoided, and will trigger aural and visual alerts.

- If the PM wants to act on the sidestick, he/she must:
  - Clearly announce "I have control"
  - Press and maintain his/her sidestick pushbutton, in order to get full control of the Fly-By-Wire system. Note: priority is latched after 40s

Operational documentation:

- FCTM AOP-10-30-20 Airbus Operational Philosophy – Design Philosophy – FBW – Use of Sidestick
- FCOM DSC-27-20-30 Aircraft Systems – 27 Flight Controls – Flight Control System
- FCOM NOR-SOP-90 Normal Procedures – SOP – Standard Callouts – PF/PM duties Transfer

HIGH ALTITUDE MANUAL HANDLING

Relevant procedures and best practices:

- If a Pilot has to fly manually at high altitude, he/she will not find the characteristics he/she is familiar with at low altitude.
- The pilot must anticipate to a greater extent the changes in the trajectories both vertically and horizontally.
- Over the normal operating domain of commercial flying, simulators are perfectly representative of reality and utmost confidence can be placed in them, for both low and high altitude manual flight.
- At high altitudes and high Mach numbers, it is very important to adopt an especially calm, flexible flying attitude without aggressiveness.

Operational documentation:
• OTT 999.0012/17 *Undesired Aircraft State - Training Recommendations*
• OTT 999.0161/15 *Training for aircraft handling at high altitude* (supersedes FOT 999.0077/09)

HIGH ANGLE OF ATTACK PROTECTION

Relevant procedures and best practices:
• One of the PF's primary tasks is to maintain the aircraft within the limits of the normal flight envelope. Typically, he should target a pitch attitude consistent with the flight phase.
• When flying at the αMAX (e.g. current speed stabilised around VαMAX), the PF can make gentle turns, if necessary.
• If the pilot flies into αPROT, he should leave it as soon as other considerations allow, by easing forward on the sidestick to reduce alpha below the value of αPROT, while simultaneously adding power (if the αfloor has not yet been activated, or has been cancelled)

Operational documentation:
• FCOM DSC 27-20-10-20 Flight Control System – Normal law – High Angle-of-attack Protection
• FCTM AOP 10-30-10 Fly-By-Wire – Design Principles – Flight Control Protections

The behaviour of the lateral normal law and the bank angle protection have been analysed in detail.

Lateral normal law behaviour

As discussed in the factual description of the event, the High Angle-of-Attack protection was activated during the most part of this event in accordance with its phase in/phase out activation logics.
When the High Angle-of-Attack protection is activated, the maximum commanded roll rate is 7.5°/s and the bank angle limit is 45° (respectively 15°/s and 67° when out of the protection).
It has been checked that the lateral normal law orders (commanded ailerons, spoilers and rudder deflections) were consistent with the pilots' inputs. Nevertheless, the lateral normal law limitations have been exceeded during the Phase 2 of this event.

The following elements contributed to this situation:

- Dual and cyclic full LH and RH roll inputs were applied at the frequency of the dutchroll and generated a very dynamic lateral response
- Aft stick input was maintained such that the aircraft remained in the zone of high AoA / low speed condition where natural dutch-roll damping is lower.
- In addition, the altitude increased above the REC MAX, which is detrimental to the dutch-roll natural damping (reduced air density).

The bank angle protection is computed by the lateral normal law as a roll rate order which takes precedence on the pilot's order when the aircraft is approaching the bank angle limit.
Both orders (e.g. from the pilot and from the protection) are then limited to the maximum commanded roll rate value.

During the event, the roll rate reached ± 40°/s. This was counteracted by the bank angle protection at its full authority of 7.5°/s (High Angle-of-Attack protection being active), but the lateral dynamic was so high that the bank angle limit of 45° was exceeded. Some possible design enhancements on the lateral normal law or bank angle protection are under review.

2.1.4.3 **Phase 2 – additional details**

17:48:05 UTC: FD1&2 disengaged

Analysis:
The involved FD disengagement logic in the AFS is as follows: when AP is OFF and FD is ON, and Open Descent mode is engaged:

- FDs are automatically disengaged if CAS < VLS-2kts.
- FDs P/B are set to OFF on the FCU, to prevent automatic re-engagement.

In the DFDR recording, Open Descent mode was activated (OPDESD=1) at 17:48:04 (e.g. one sample before FD1+2 are recorded OFF). CAS was ~195 kts and VLS was ~214 kts, therefore the 'CAS<VLS-2 kts' condition was fulfilled.
The AFS logic described above activated and both FDs were automatically disengaged. The engagement conditions of the Open Descent mode are recalled below (extract from FCOM section DSC_22_30-70-60).

ENGAGEMENT CONDITIONS

Ident.: DSC-22_30-70-60-00010287.0001001 / 18 AUG 10
Applicable to: ALL

The OPEN DES mode can only be engaged, if the following conditions are met:
- The aircraft has been in flight for more than 5 s
- LAND mode is not engaged
- The FCU selected altitude is lower than present altitude.

The OPEN DES mode is engaged by:
- Pulling out the ALT knob.

Note: *When OP DES is engaged:*
- *The FMA displays "OP DES"*
- *The managed LVL/CH dot on the FCU goes out*
- *The system arms the ALT mode.*

17:48:38 UTC: Both TLAs were set on IDLE notch

Analysis:
As both thrust levers were reduced to IDLE, the Thrust Lock mode was exited (THRLKD=0) and the actual thrust reduced to IDLE (EPRA reduced towards 0.8).

2.1.5 Phase 3: upset and recovery (17:48:53 to 17:49:35 UTC)

2.1.5.1 Phase 3 overview – Longitudinal axis

As illustrated in the plots in Appendix 4, during this time period:

- An upset condition is observed:
  - When reaching the maximum bank angle of 98° on RH side, pitch angle had already progressively decreased to ~-13° after engines throttles were pulled back to idle.
  - Pitch angle further reduced down to -27° and AoA reduced from ~+12° down to ~-2°.
  - A strong elevator movement is observed, reaching -19° (nose-up), then +15° (nose-down stop) over 3s.
  - FCPC1 became faulty (FCPC1F=1); FCPC2 took over and became Master-in-law (FCPC2CL=1).
  - CAS and Mach number started to increase, reaching 284 Kt / 0.82.

- A recovery manoeuvre was performed:
  - A pull-up action was conducted by the Captain, with a pitch stick input close to full back stick. AoA increased towards αPROT and vertical load factor was ~2.2g. There was no overshoot of αMAX during this phase.
  - Pitch angle increased to +20°.
  - Dual inputs stopped in pitch.
- The minimum altitude reached was 34000ft.

2.1.5.2 Phase 3 overview – Lateral axis

As illustrated in the plots in Appendix 4, during this time period:

- Roll order was mainly to the left (cyclic inputs stop), with progressive return to wings level in the following 20s.
- At the same time roll rate was reduced from ~-30°/s to +14°/s and contained to lower values.
- Dual inputs stopped in roll.

Analysis (longitudinal & lateral):
As per the "Nose Low Actions" from the Upset recovery technique described in the FCTM (section Procedures / Abnormal and Emergency Procedures / MISC / Upset

Prevention and Recovery), the flight crew adjusted the roll in the shortest direction to wings level and recovered the level flight.

During the whole upset and its recovery:

- Normal law remained active (NLAW=1).
- No Stall Warning was triggered (STALLW=0).
- No overspeed VMO/MMO warning was triggered (VMOW=0).
- There was no rudder pedal input from the crew (RUDP=0).

Upset recovery is further discussed in the "Operational considerations" section (Refer to Airbus report §7, Updated standards are available for implementation: ICAO Airplane Upset Prevention and Recovery Training Aid AUPRTA Rev 3 (Feb. 2017)).

2.1.5.3 **Phase 3 – additional details**

17:48:53 UTC: a strong elevator movement is observed over 3s, starting from +4° (nose-down) down to -19° (nose-up), increasing to +15° (nose-down stop), then reducing to -9° and towards lower absolute values.

Analysis:

The first nose-up elevator order (-19°) was generated by the pitch flight control law when crossing 90° of bank angle. The resulting AoA increase was counteracted by the High Angle-of-Attack protection, which applied the full nose-down order (+15°). At that time, the important bank angle was leading to a reduced vertical lift force component, which was no more sufficient to compensate the weight force. As a result, pitch angle was reducing. The nose-down elevator movement contributed to further decrease the pitch angle (from -13° down to -27°).

17:48:58 UTC: FCPC1 became faulty (FCPC1F=1); FCPC2 became Master-in-law (FCPC2CL=1); Spoilers 5 (LH & RH) became not available (SP5V=0).

Analysis:

The PFR consistently confirm the failure of the FCPC1 ("PRIM1"):

- the ECAM caution F/CTL PRIM 1 FAULT was generated at 17:48.
- this is correlated with the Class 1 failure message "FCPC1 (2CE1)".

This PRIM fault has been analysed thanks to the available EFCS TSD, and was linked to a COM/MON disagreement seen on the elevator orders by PRIM1. A specific analysis has been conducted on this topic and is detailed below. The unavailability of the spoiler pair #5 was the consequence of the PRIM1 fault as it is the flight control computer in charge of the associated servoloop.

<u>PRIM 1 FAULT analysis</u>

The PRIM 1 FAULT which occurred during the event was analysed to understand the root cause of this failure.

After analysis of the EFCS TSD, it was confirmed that the PRIM 1 FAULT was linked to a COM/MON disagreement seen on the elevator orders at the time of a strong deflection of the elevator, which was generated by the pitch flight control law when crossing 90° of bank angle.
This COM/MON monitoring on the elevator order is active only in the PRIM Master-in-law (e.g. PRIM1 in nominal configuration). After the PRIM1 FAULT, PRIM2 became Master-inlaw, and the aircraft conditions changed (bank angle reduced below 90°), therefore no COM/MON discrepancy was triggered by PRIM2. Following the reset of PRIM1, the fault cleared, and PRIM1 became Master-in-law again.

Despite this PRIM 1 FAULT, normal law was maintained during the event.

17:49:30 UTC: AP2 was recorded engaged during 1 sample and immediately involuntarily Disengaged.
Analysis:
The AP2 disconnection corresponds to a voluntary disconnection via the sidestick P/B (APOFF VLTRY=1).

17:49:32 UTC: dual inputs stopped (DUAL INPUT=0).

2.1.6 **Post-recovery (after 17:49:35 UTC).**

2.1.6.1 **Phase 4 – overview**

During this time period:

- Pitch angle was reduced first to ~+15°, then progressively returned to the nominal cruise range (e.g. below 5°).
- AoA increased up to ~10°, then progressively reduced and returned to the nominal cruise range (e.g. ~2-3°).
- Both TLAs were set back on CL notch; A/THR was re-armed and re-engaged.
- Altitude reached FL380 with reducing airspeed / Mach.
- FCPC1 fault was cleared and FCPC1 became Master-in-law again.
- Descent was initiated to FL340, A/C accelerated to M=0.82.
- AP1 was re-engaged and target altitude set back to FL390.

2.1.6.2 **Phase 4 – additional details**

17:49:41 UTC: Both TLAs were set back on CL notch; A/THR was re-armed and re-engaged.
17:50:17 UTC: Selected altitude was changed from 39000ft to 38000ft.
17:50:31 UTC: FCPC1 fault was cleared, FCPC1 became Master-in-law. Spoilers 5 became available again (SP5V=1).

Analysis:
The FCPC1 fault being cleared is consistent with the PRIM 1 reset reported by the crew in the ASR.
QUOTE
During the event, ECAM showed F/CTL CONTROL PRIM 1 FAULT and ***flight crew proceeded to reset the PRIM 1****.*
UNQUOTE
The reset was successful, with PRIM1 becoming Master-in-law again and recovering the control of the spoiler's pair #5.

17:50:58 UTC: Selected altitude was changed from 38000ft to 35000ft.
17:51:21 UTC: AP1 was re-engaged in V/S / HDG mode.
17:51:32 UTC: Selected altitude was changed from 35000ft to 37000ft.
17:51:47 UTC: FD1&2 were re-engaged.
17:53:42 UTC: Selected altitude was changed from 38000ft to 39000ft. Mach reached 0.82.

Analysis:
This was the end of the event, the aircraft had returned to its nominal cruise conditions.

The end of the flight was performed uneventfully.

3.0 CONCLUSION

3.1 Findings

3.1.1 Both Navigation Displays were configured in ARC mode, with a selected range of 320NM on CPT and F/O.

3.1.2 Turbulence encountered was moderate to severe, accompanied with significant wind variations on three axes.

3.1.3 Due to these wind variations, the airspeed initially increased close to VMO/MMO, the AP was disconnected by the crew and the Captain took-over control of the aircraft. A lateral (LH) gust caused the aircraft to roll rapidly to the right.

3.1.4 During the next 90 seconds, the flight crew inputs (dual inputs in pitch and roll, pitch inputs maintained in the aft sector, and cyclic inputs in roll applied at the frequency of the Dutch-roll) induced a very dynamic situation on the lateral axis.

3.1.5 As a result of this lateral dynamic and the turbulence:

a. Overshoots of αMAX are observed, which are consistent with the buffet reported by the crew. However, the High Angle-of-Attack protection prevented the aircraft from stalling.

b. The bank angle limit was overshot.

3.1.6 The event evolved into an upset, with the bank angle reaching 98° (RH) which exceeded the bank angle limit and associated with a nose-down pitch angle of -27°.

3.1.7 The upset was recovered by the flight crew and the rest of the flight was uneventful.

3.2 Probable Cause

3.2.1 Selection of weather radar to a higher range than recommended may have resulted the adverse weather ahead of the aircraft not being displayed clearly on the Navigation Display (ND).

3.2.2 Early disengagement of autopilot and the dual sidestick inputs may have possibly contributed to the over control of the aircraft.

4.0 SAFETY RECOMMENDATIONS

It is recommended that:

	Items	Action Owner
1.	**Air Asia X is:** 1. To re-introduction of the Upset Prevention and Recovery Training into the current LOFT syllabus. 2. To develop an Upset Prevention and Recovery Training Program. This will enhance pilot skills and awareness to prevent and if required, recover from such situations. 3. To highlight the importance of ND range selection in accordance to FCTM during BCCR classes.	CPTS
2.	**Air Asia X Flight Safety Department is:** 1. To share with all pilots during recurrent BCCR classes with the focus on the lessons learnt. 2. To emphasize the importance of ND range selection in accordance to FCTM during BCCR classes to all pilots.	CPFS

Chief Inspector

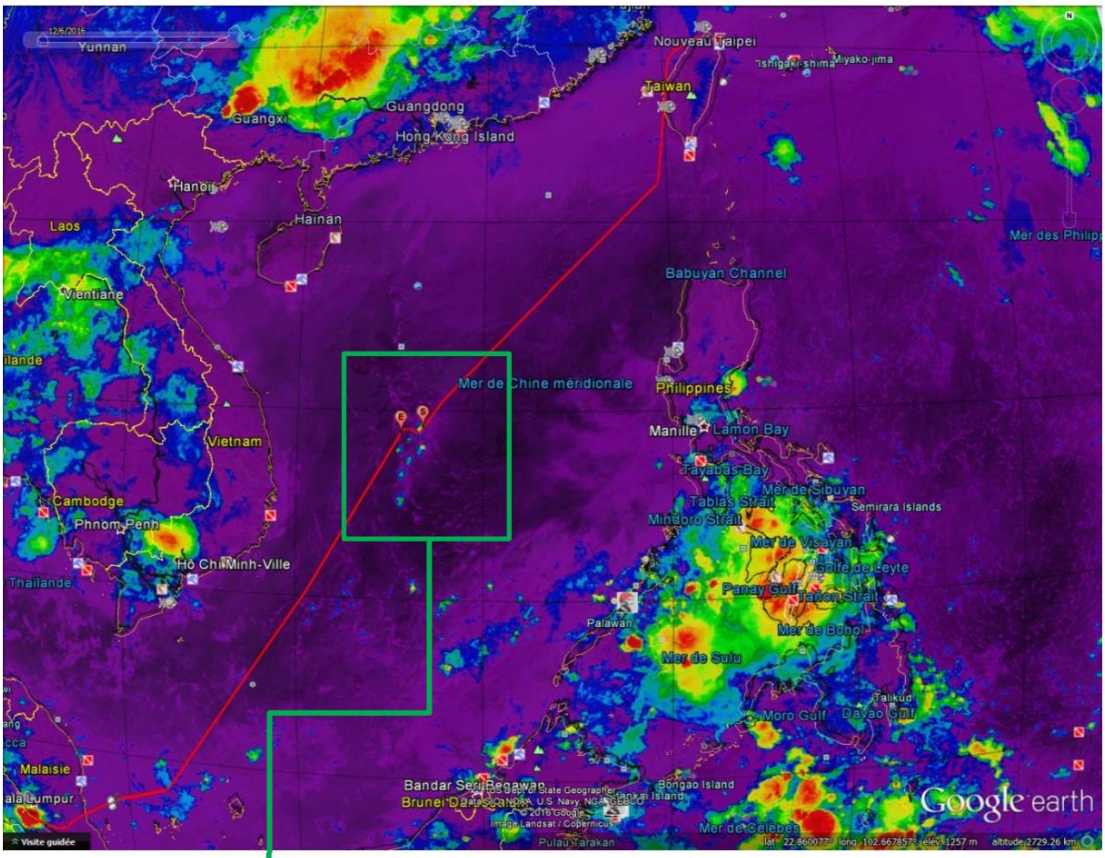
Air Accident Investigation Bureau (AAIB)

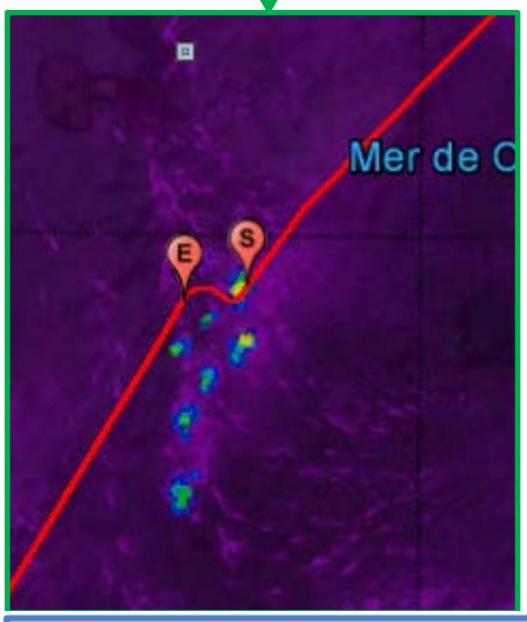
MALAYSIA

18th March 2019

APPENDICES

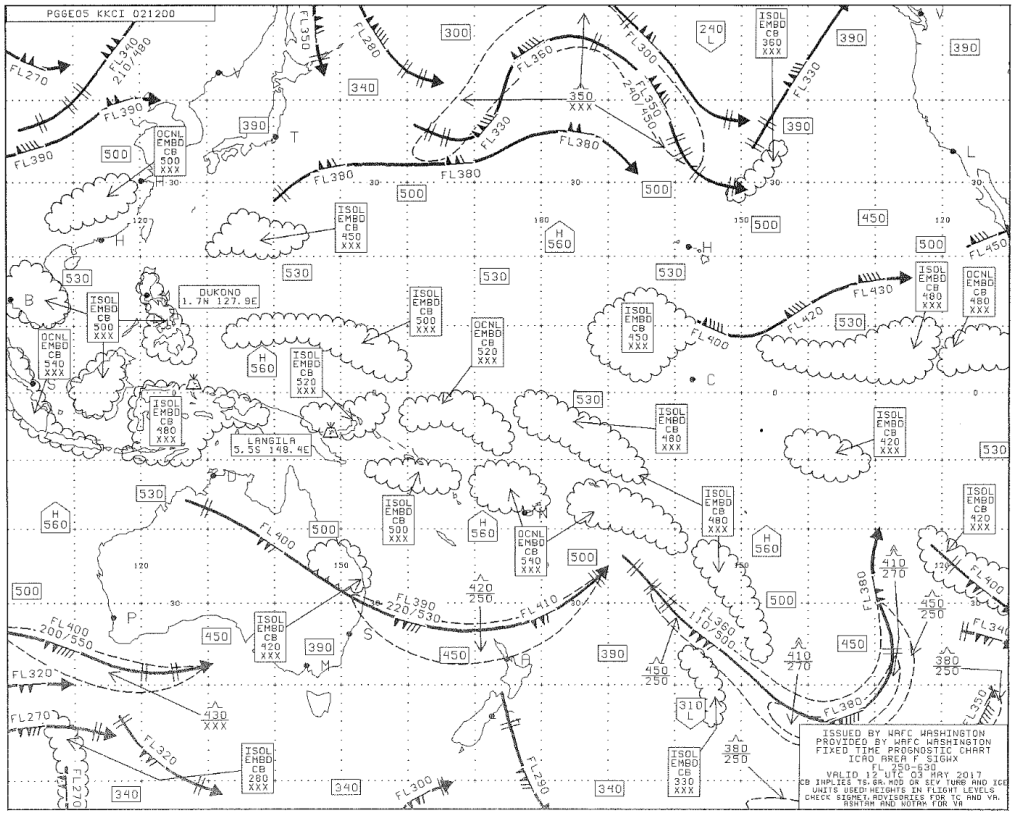
Appendix 1: Weather Information

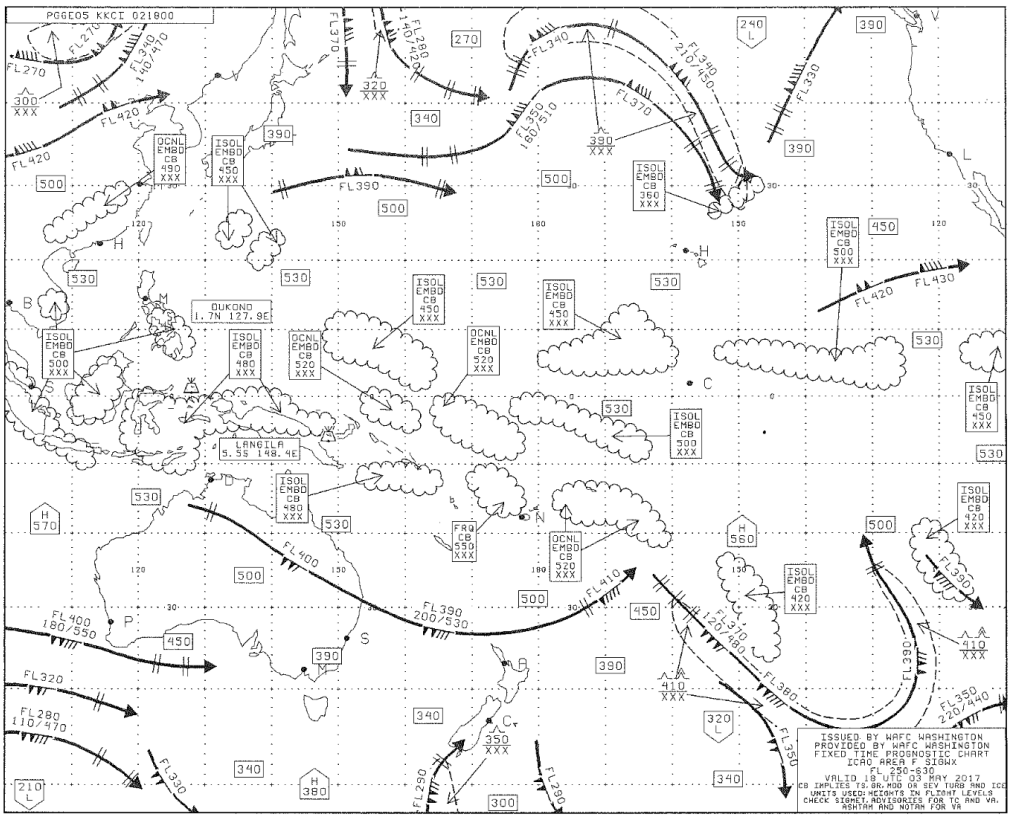




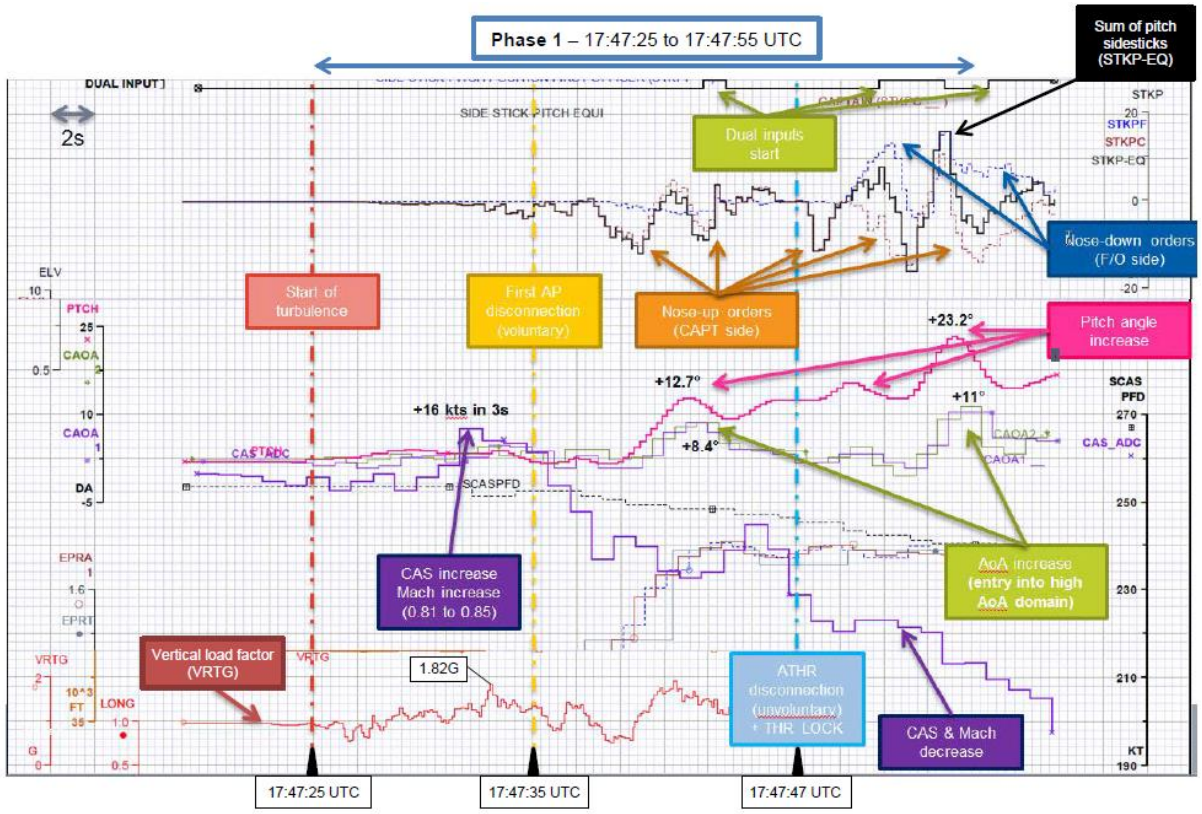
S = Start of event *(17:47:25 UTC)*
E = End of event *(17:53:42 UTC)*

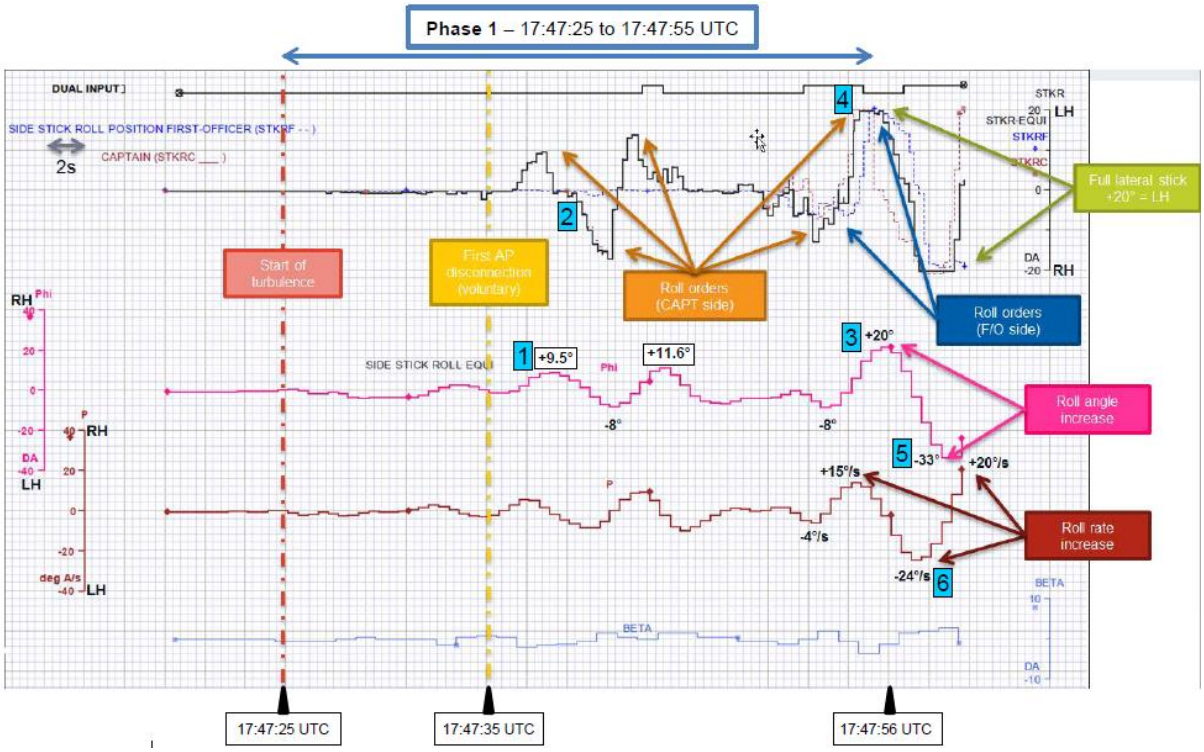
Weather Forecast





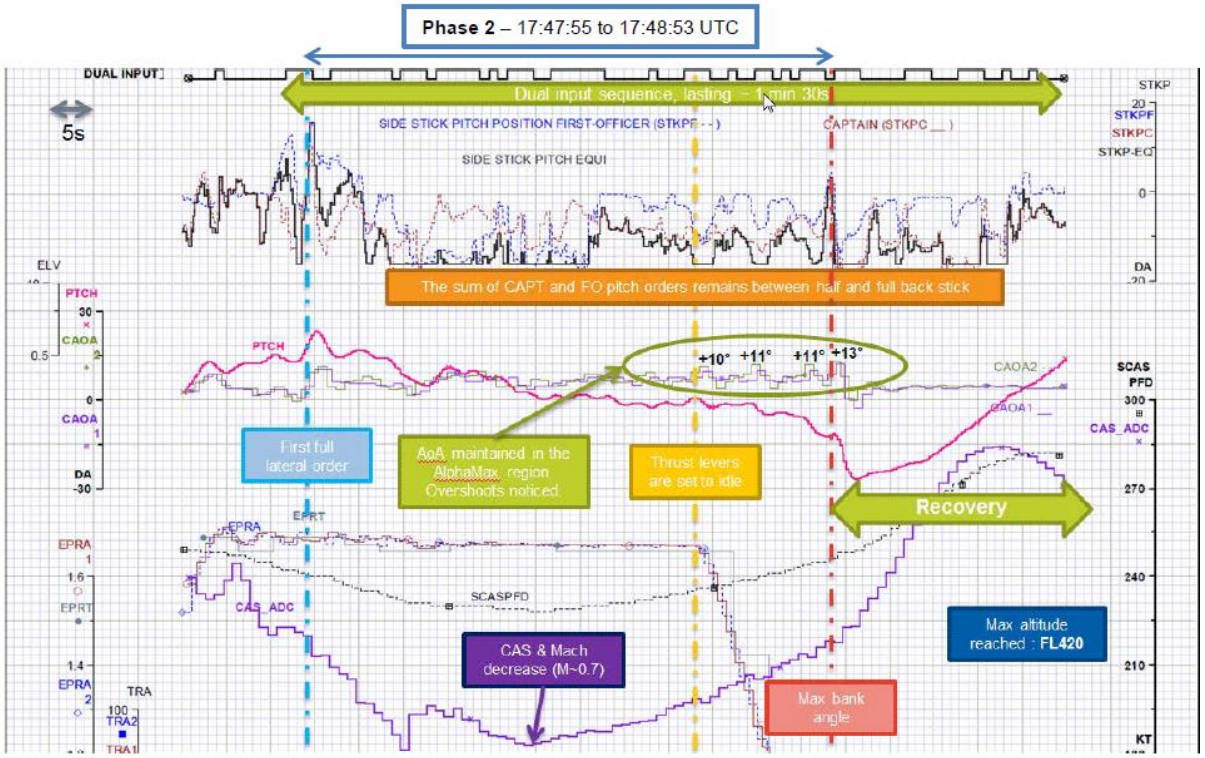
Appendix 2: Phase 1 Longitudinal and Lateral Axis



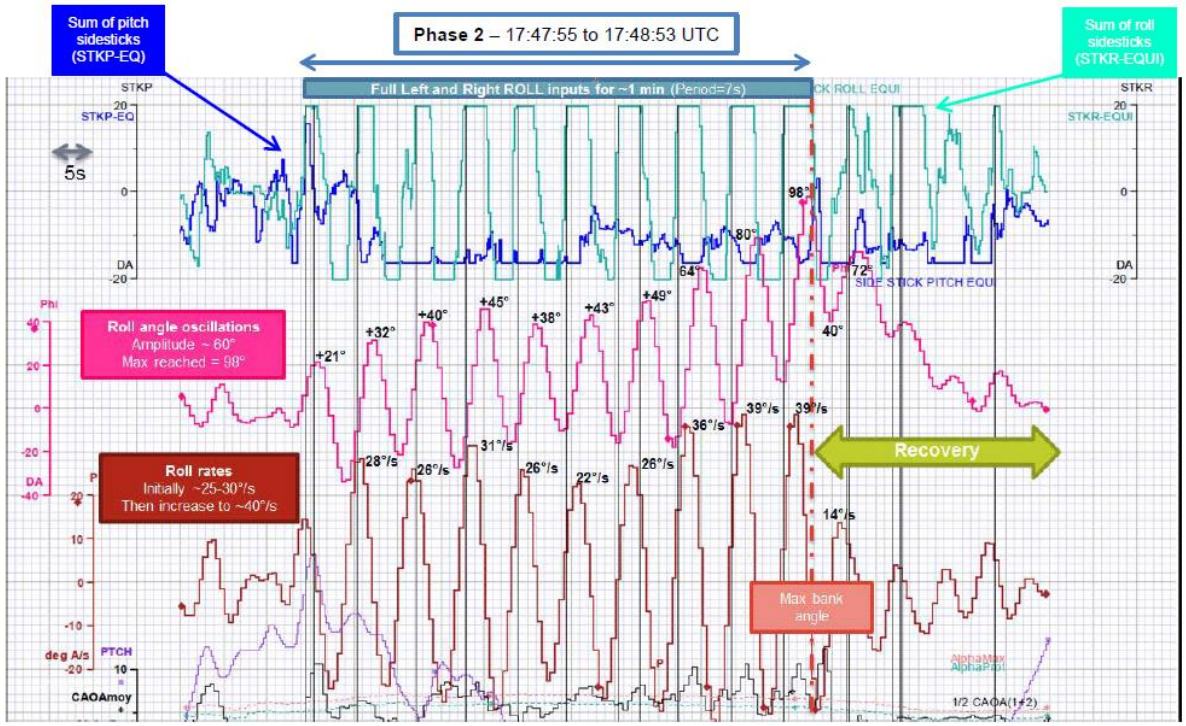


Appendix 3: Phase 2 Longitudinal and Lateral Axis

Longitudinal

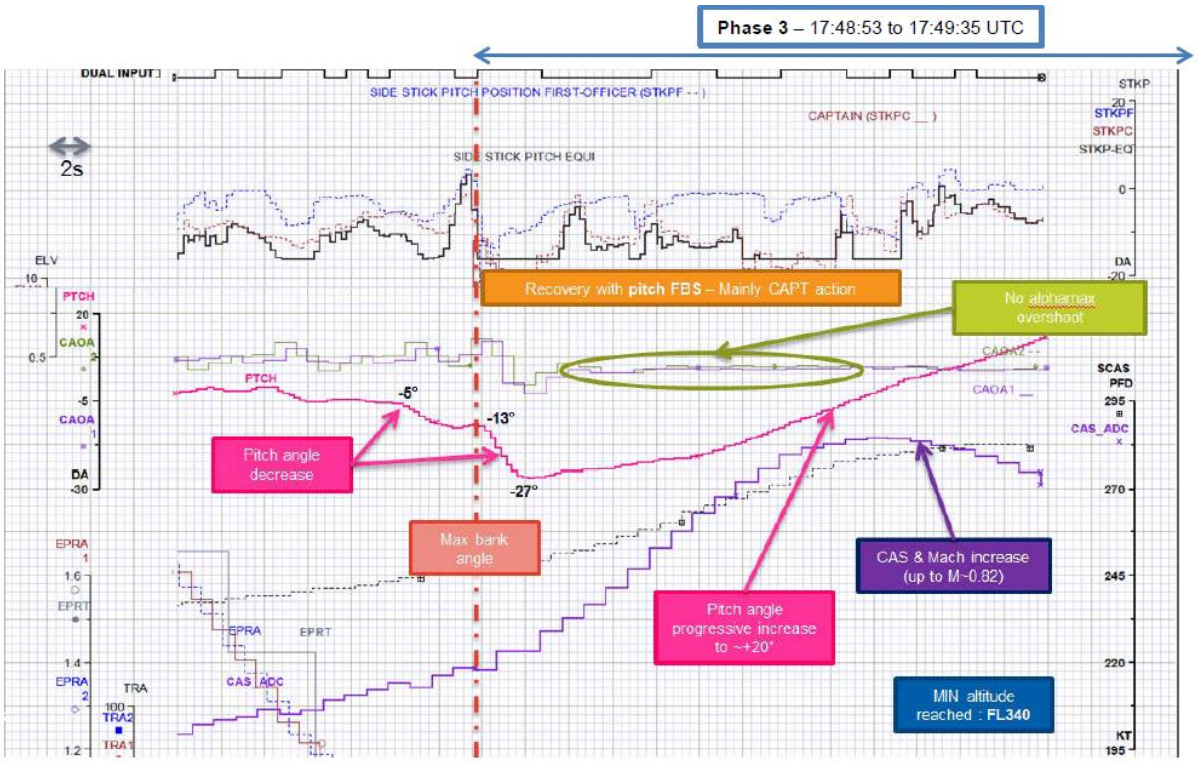


Lateral Axis

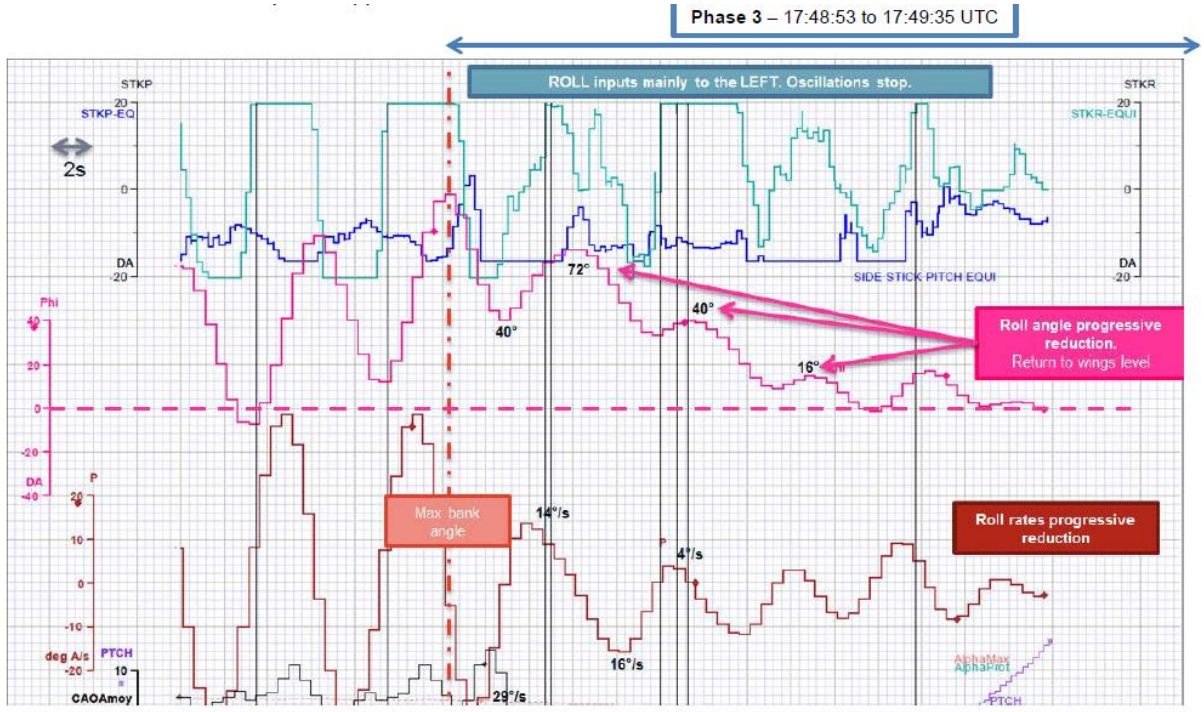


Appendix 4: Phase 3 Longitudinal and Lateral Axis

Longitudinal



Lateral



Appendix 5: Air Safety Report (ASR/9039)

Investigation

Air Safety Report (asr/9039)

Report Info

Report Title	encounter severe turbulence					asr/9039	
Report Status	Safety Data			Date of Occurrence		*****	
Reported Date	*****			Reported Event Descriptor		Environment-Weather-Turbulence	
Investigation Due Date	-			Initial ERC score		0	
Investigation Close Date	-			Final ERC score		0	
MOR Sent to	- -			Reported by		*****	
Opened by	*****			For Info Alert Groups			
Lead Investigator	-			Report flagged Confidential	N	Red flag Alert	N
Recommendations	N	Peer Review	N	Quality Review	N	External Agency Review	N

Event Description

Principal Safety Report	asr/9039

During cruise at FL390, while maintaining M0.81, aircraft encountered severe turbulence which appeared as green patches on the weather radar. The aircraft banked more than 30 degrees and pitched around 10 degrees and the aircraft lost approximately 5000ft as a result of the turbulence. Captain took over the controls, disconnected the Autopilot to avoid the weather. At the same time, Captain disconnected the Autothrust and set the thrust lever to idle. During the event, ECAM showed FLIGHT CONTROL PRIM 1 FAULT and flight crew proceeded to reset the PRIM 1. Due to strong updraft, aircraft entered STALL buffet twice and flight crew managed to recover from the stall by setting the thrust lever back to CLB detent and Autothrust on. PAN call was declared to Ho Chi Minh control. As the aircraft recovered, flight crew requested climb back to FL390. ATC directed flight to point MAPNO and the PAN call was cancelled. Flight crew were informed that 5 passengers were injured during the event with one of them sustaining serious injuries. Cabin crew managed to page for medical personnel onboard to attend to the injured passengers. Medical support was provided immediately upon arrival.

Air Safety Report (asr/9039)

Air Operator Certificate (AOC)

Air Operator Certificate (AOC)
AirAsia X

Reporter Details

Name	*****
Confidential Report	N
Rank	Senior First Officer
Date Reported	*****

Event Details

Title	encounter severe turbulence		
Red Flag Event	N		
Event Date & Time			
Event Date	03/05/2017	Event Time	1755 UTC
Light Condition	Night		

Flight	
Flight Number	D7-377
Departure Date	03/05/2017
Departure Airport	TPE
Arrival Airport	KUL
Diverted To	-

Location	
Flight Phase	Cruise
Airport	-
Stand No.	-
Rwy Ident.	-
FIR	-
Altitude/Flight Level	39000
Altitude Ref.	FL = Flight Level
Speed (Kts)	-
Mach No.	0.81

Aircraft	
Aircraft Registration	9MXXS

Type	A330
Weight (Kg)	168100

No. On Board			
Pax	285	Infants	0

Event Description
During cruise at FL390, while maintaining M0.81, aircraft encountered severe turbulence which appeared as green patches on the weather radar. The aircraft banked more than 30 degrees and pitched around 10 degrees and the aircraft lost approximately 5000ft as a result of the turbulence. Captain took over the controls, disconnected the Autopilot to avoid the weather. At the same time, Captain disconnected the Autothrust and set the thrust lever to idle. During the event, ECAM showed FLIGHT CONTROL PRIM 1 FAULT and flight crew proceeded to reset the PRIM 1. Due to strong updraft, aircraft entered STALL buffet twice and flight crew managed to recover from the stall by setting the thrust lever back to CLB detent and Autothrust on. PAN call was declared to Ho Chi Minh control. As the aircraft recovered, flight crew requested climb back to FL390. ATC directed flight to point MAPNO and the PAN call was cancelled. Flight crew were informed that 5 passengers were injured during the event with one of them sustaining serious injuries. Cabin crew managed to page for medical personnel onboard to attend to the injured passengers. Medical support was provided immediately upon arrival.

Questions Regarding The Event

Was anyone on board injured during turbulence?	Yes
Repo ed Event Severi	High
Immediate Operational Outcome	Ai¨ra¨ Damage Emergency Declaration Pan call Medical Assistance In Airpo ˙ Medical Procedure On-Board Medically Quali¨ed Pax Assisted

Tech Log

De˙ect Entry Made in Tech Log			
Entry Made	Yes	Technical Log Ref.	-

Weather Conditions

MET	
IMC/VMC	IMC
Vis/RVR (KM)	-

Wx Actual	
Wind Degrees°/KTS	-
Cloud/Cloud Base	-
Temp. (°C)	-
QNH	-

Runway State	-

Wx Condition	
Icing	-
Snow	-
Hail	-
Rain	-
Fog	-
Turbulence	SEVERE
Windshear	-

Crew Details

Pilots			
	LHS	RHS	Jump Seat
Name	*****	*****	*****
Qualification Rank	*****	*****	*****
Crew Number	*****	*****	*****
Base	KUL	BDO	-
Pilot Flying	*****	*****	*****
Total Hours	Over 5000 hours	3000-5000 hours	-
Hours On Type	-	-	-
Hours In Command	-	-	-
Duty Day of Block	-	-	-
Number of sectors operated during duty day	-	-	-
Sector No. of event	-	-	-

Training Flight	N

Other Crew			
Position	Name	Base	Crew Number
*****	*****	*****	*****
*****	*****	*****	*****
*****	*****	*****	*****
*****	*****	*****	*****
*****	*****	*****	*****
*****	*****	*****	*****
*****	*****	*****	*****
*****	*****	*****	*****

*****	*****	*****	*****
*****	*****	*****	*****

Person 1

Personal Details			
Involvement	-	Other Involvement	-
Medical Profession	-	Other Profession	-
Name	*****	Contact Number	*****
Email Address	*****	Address	*****
Seat Number	-	Booking Ref	*****
Sex	-	Age	-
Nationality	-	Passport No.	*****
Travelling With	-		

Staff 1

Personal Details			
Involvement	-	Other Involvement	-
Medical Profession	-	Other Profession	-
Name	*****	Contact Number	*****
Email Address	*****	Address	*****
Company Name	*****	Job Title	*****
Crew/Staff Number	*****		