Aviation Safety Council

Taipei, Taiwan

GE235 Occurrence Investigation
Factual Data Collection
Group Report

Airworthiness Group

July 2, 2015

ASC-FRP-15-07-003

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I. Team Organization

Chairman: David Lee, Aviation Safety Investigator, ASC
Members:
1 Yanni Lee, Aviation Safety Investigator, ASC
2 Carol Horgan, Sr. Air Safety Investigator (Powerplants) NTSB, USA
3 Henri Denis, Investigator, BEA, France
4 Jérome Pfeiffer, Safety Investigator, ATR, France
5 Fabien Darsonval, Powerplant Specialist, ATR, France
6 Chng Seng Piang, Director, Technical Service, ATR, Singapore
7 Nora Vallée, Civil Aviation Safety Investigator, TC, Canada
8 Thomas Berthe, Investigator, P&WC
9 David Barnard, Accessories Investigator, P&WC
10 Mike Huang, Aviation Safety Inspector, CAA
11 Nicolas Liaw, Aviation Safety Inspector, CAA
12 William Lin, Aviation Safety Inspector, CAA
13 Nicolas Hung, Assistant Manager, TNA
14 Wilson Ling, Engineer, TNA
15 Jimm Wang, Engineer, TNA

II. History of Major Activities

Date	Activities
02/04/2015	1. Go team launched. 2. Secured latest 3 months aircraft Technical Log Book, No. 1, 2 Engine Log Books and No. 1, 2 Reduction Gearbox Log Books. 3. Recovered FDR, CVR and QAR. 4. Monitored the recovery of aircraft wreckage. Recovered aircraft wreckage including: fuselage, cockpit and broken debris.
02/05/2015	1. Requested Songshan Air Force Base to provide space for the temporary storage of aircraft wreckage. 2. New Taipei City and Taipei City Emergency Response Center helped to transport all recovered wreckage to Songshan Air Force Base. Those aircraft wreckage was recovered including cockpit, part of front fuselage, aft and part of center fuselage, tail section, left wing and part of right wing, No. 1 and No. 2 engines, chairs and debris.
02/06/2015	1. Removed No. 1 and No. 2 Multi-function computers, flushed and submerged in clean water. 2. Checked No. 1 and No. 2 engine placards. The serial numbers showed on the placards were exactly the same as records. 3. Checked feathering mechanism status of No. 1 propeller. Blades of No. 1 propeller were at feathering positions.
02/07/2015	1. Visited wreckage storage site with specialists from TSB, BEA and PWC representative. 2. Removed No. 1 and No. 2 Propeller Electronic Controls (PECs), Multi-Purpose Computer (MPC), Captain and FO's EDU (Electronic Display Unit), flushed and submerged in clean water. 3. Recovered left wing from downstream of Keelung River and transferred it to Songshan Air Force Base storage site.

02/08/2015	1. Removed Captain and FO's PFD, ND and center DU, ATPCS control panel, 2 CMS computers, flushed and submerged in clean water. 2. Checked No. 1, 2 engines with bore scope, all engine turbine sections showed normal conditions. 3. Checked No. 1 engine torque sensors of No. 1, 2 engines, resistance of sensor connectors were all within specs. AFU electrical harness continuity checks were all passed.
02/09/2015	1. Witnessed by BEA, ATR, TC, TSB and CAA personnel to remove parts from No. 1, 2 engines for further testing/inspection: a. 2 Engine Electronic Controls (EEC) b. 2 Data Collection Units (DCU) c. 2 Auto Feather Units (AFU) d. 2 Propeller Interface Units (PIU) e. 2 Core Avionic Cabinets (CAC) f. 2 AFU electrical harnesses g. 4 torque sensors h. 8 speed sensors (4 Nh, 2 Nl, 2 Np) i. 2 fire handles 2. Measure stick pusher actuator length; the actuator was at retracted position.
02/10/2015	Examined 7 pieces of aircraft wreckage structures. All broken structures were due to overload and post impact damages.
02/13/2015	Sent 22/25 recovered components to TSB/BEA for inspection and / or test. TSB/BEA received those items on Feb. 19, 2015.
02/25/2015	Removed 2 Propeller Valve Modules (PVM) from No. 1, 2 engines and stored in ASC laboratory.

04/08/2015 ~ 04/14/2015	1. Monitored the AFUs (S/N: RT 3077, RT2362, RT2354) tests at Rosemount Aerospace Inc. Participants included representatives from NTSB, TC, BEA, P&WC, ATR, TNA and ASC. 2. Test results showed that the AFU (RT 3077) removed from No. 1 engine of the occurrence aircraft passed all the tests. 3. The continuity failures detected on Pin J and Pin H of the AFU (RT2362) which removed from No. 2 engine of the occurrence aircraft were located inside the 90°connector and the continuity failure might from time to time disappear. 4. The continuity failures detected on Pin J of the AFU (RT2354) which removed from the other aircraft was located inside the 90°connector.
04/20/2015 ~ 04/22/2015	1. Two PECs and 2 EECs NVM data were downloaded at UTAS Windsor Locks, Connecticut, participants included representative from NTSB, TC and P&WC. 2. The PECs and EECs NVM data have been successfully downloaded. No significant faults were found.

III. Factual Description

1.3 Damage to aircraft

The aircraft was destroyed.

1.6 Aircraft information

1.6.1 Aircraft and engine basic information

Basic information of the occurrence aircraft is shown in Table 1.6-1

Table 1.6-1 Aircraft basic information

Aircraft basic information (statistics date: February 04, 2015)	
Nationality	Taiwan, R.O.C.
Aircraft registration number	B-22816
Manufacturer	Avions de Transport Régional
Aircraft model	ATR72-212A
Aircraft serial number	1141
Manufactured date	April 14, 2014
Delivery date	April 14, 2014
Owner	TransAsia Airways
Operator	TransAsia Airways
Number of certificate of registration	103-1271
Certificate of airworthiness, validity date	March 31, 2015
Total time (hours)	1627:05
Total cycles	2356
Last check, date	A4 CHECK / January 26, 2015
Time / cycles since last check	44:50 / 64

Basic information of the two Pratt & Whitney Canada engines is shown in Table 1.6-2

Table 1.6-2 Engine basic information

Engine basic information (statistics date: February 04, 2015)		
Number/position	No. 1/ Left	No. 2/ Right
Manufacturer	PWC	PWC
Model	PW127M	PW127M
Serial number	ED0913	ED0814
Manufacture date	May 09, 2014	November 19, 2013
Installation date	August 16, 2014	February 07, 2014
Time since installation (hours)	829:31	1627:05
Cycle since installation	1240	2356
Last check, date	A4 CHECK / January 26, 2015	A4 CHECK / January 26, 2015
Time / cycles since last check	44:50 / 64	44:50 / 64

1.6.2 Maintenance related information

A review of maintenance record before the occurrence flight showed that there was no defects report or Minimum Equipment List (MEL) item of the occurrence flight when the aircraft was dispatched from Songshan airport to Kinmen airport. The Technical Log Books (TLBs) from aircraft delivery date to the occurrence date, the pre-flight check, daily check, transit check records of the last 6 months and the last periodic check (A4 check) records before the occurrence were reviewed. There was no defect report related to autofeather of the No.2 engine.

The Deferred Defect (DD) records, status of Airworthiness Directive (AD) and Service Bulletin (SB) of the occurrence aircraft were also reviewed. The control of DD records of the occurrence aircraft were in compliance with CAA regulation and no DD item related to autofeather of the No.2 engine was found. The review showed that the occurrence aircraft was in compliance with all applicable AD and SB.

1.6.3 Propellers system

The occurrence aircraft was equipped with HAMILTON STANDARD 568F-1 propellers. The propeller is of the variable pitch

type, hydromechanically controlled, and can be placed in reverse or feathering configurations. According to the Aircraft Maintenance Manual, Description / Operation (AMM D/O) (Revision number = 38, Revision date = Dec 01/14), the propeller's operating modes include propeller in a governing speed mode, synchrophasing, propeller in a governing pitch mode and feathering / unfeathering modes.

Feathering can be performed:

- Manually, by the condition lever in case of engine failure
- Automatically, in case of torque decrease at take-off on one engine
- Manually, by the fire handle in case of engine fire
- Manually, during maintenance operations

When the condition lever is moved past the safety trigger of FTR position, micro switch 5KF (6KF) and 54KF (55KF) are activated which enables the activation of the feather pump, energization of the feather solenoid and indication to the Propeller Electronic Control (PEC) to command pitch increase toward feather.

The Automatic Takeoff Power Control System (ATPCS) is operational if it is armed prior to take-off. Arming of the system is performed when all the following conditions are simultaneously met:

- Power Management (PWR MGT) selector switch is placed in TO (Take-Off) (Figure 1.6-1) position
- ATPCS (pushbutton(Figure 1.6-1) switch is pressed in
- Torques of engines 1 and 2 are higher than 46.2% which corresponds to 5,558 ft.lb
- both power levers are above 55 degrees MFCU (Mechanical Fuel Control Unit) (equivalent to 49 degrees of power lever angle)

When the ATPCS is armed, ARM legend of ATPCS comes on. When the system is armed, a torque lower than 18.5% on one engine causes uptrim of the other engine. The uptrim causes the valid engine increasing its power from TO to RTO (Reserve Take-Off), and 2.15 second later, the propeller of the faulty engine is automatically feathered

by activation of the Propeller Valve Module (PVM) solenoid and increase of the pitch by the PEC. From then automatic feathering of the valid engine is prohibited to ensure both engines are not feathered at the same time.

According to the BEA provided GE235 Answer to Action Log Revision #4 (Attachment 1), once the ATPCS sequence has been triggered, autofeathering of the failed engine can be aborted during the 2.15 seconds if at least one of the following conditions is true:

- PWR MGT selector switch is moved out of TO position
- ATPCS push button is released off
- At least one of the power levers is retarded below 55 degrees MFCU (equivalent to 49 degrees of power lever angle)
- Torque of the engine detected failed increases above 2,229 ft. lb threshold
- Torque of the sane engine drops below 5,558 ft. lb threshold.

The autofeathering and UPTRIM system is disarmed after 2.15 seconds delay when any of the arming conditions is cancelled. The cancellation can only result from one of the following conditions:

- PWR MGT selector other than TO
- ATPCS push button set to OFF
- Both power lever retarded below 55 degrees MFCU (equivalent to 49 degrees of power lever angle).

When the ATPCS is not selected at take-off, an aural warning is triggered and warning lights come on if the autofeathering is not selected during TO CONFIG test.

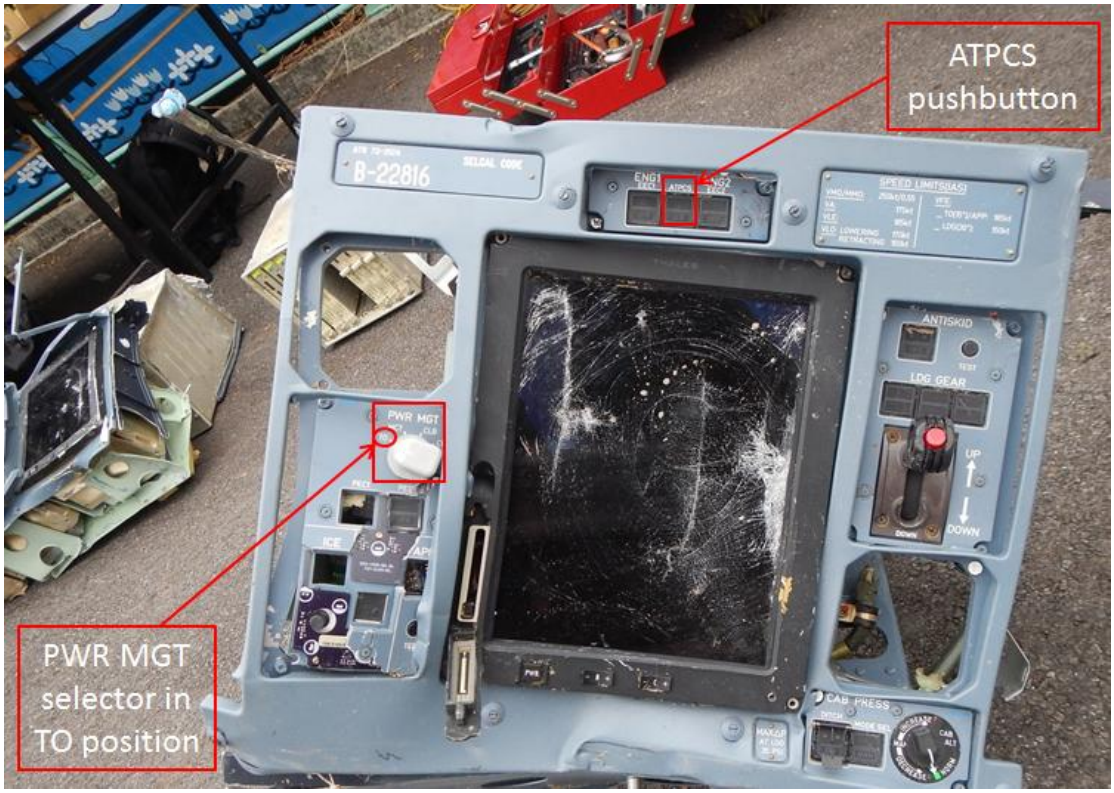

Figure 1.6-1 PWR MGT selector and ATPCS pushbutton

According to Attachment 1, simultaneous autofeathering of both propellers can be prevented by two protections:

- One relay inhibitor per side, installed between MFC1(2) output and PVM1(2) feather solenoid, which prevent autofeathering command propagation to PVM1(2), when propeller 2(1) autofeathering signal is already active (Figure 1.6-2);
- One software protection inside the MFC which prevents an autofeathering signal sent to the propeller when autofeathering signal is active on opposite propeller.

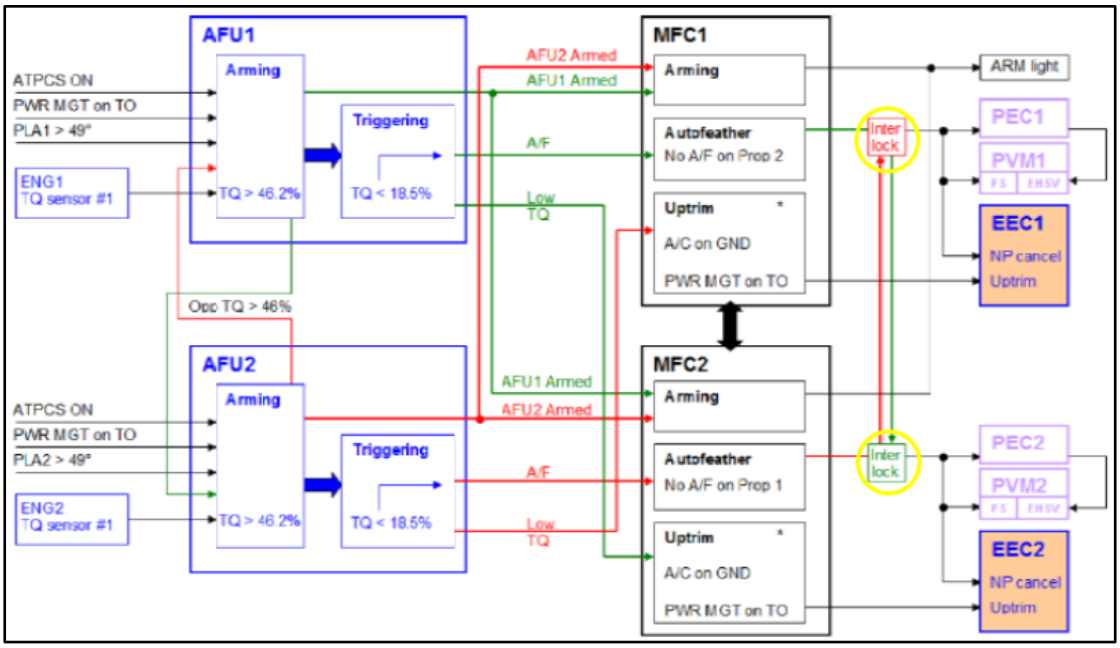

Figure 1.6-2 Functions of the ATPCS system

When the fire handle is pulled, feathering is performed identical to that of the automatic feathering system. Upper two photos of Figure 1.6-3 show that both safety wires of No. 1 and No. 2 fire handles are secured in place. Lower two photos of Figure 1.6-3 show the pointers of two fire bottle pressure gages are in the green ranges.

Figure 1.6-3 No. 1, 2 fire handles and fire bottles

1.6.4 Engine torque sensing and indication

According to the AMM D/O, torque is one of engine parameters associated with power. Each engine contains two torque sensors which located on the reduction gearbox casing at 4 (No. 2) and 8 (No. 1) o'clock approximately when looking forward. Torque sensors are used to measure the torque produced by the engine.

As shown in Figure 1.6-4, the signal sensed by the No. 1 and No. 2 sensors is transmitted to the Auto Feather Unit (AFU) and the Electronic Engine Control (EEC) respectively, where it is converted into engine torque indications. The AFU and EEC transmit the data to the Core Avionic Cabinet 1 (CAC1) and CAC2. The CAC is provided with the 5VDC reference voltage and the signal from the AFU, which are then routed to Display Unit (DU) through ARINC 429 and displays the TORQUE value in analog form. The indication in the digital form is provided in ARINC 429 message from the EEC to DU. The torque value in digital form is also transmitted to the Multi-Purpose Computer (MPC), which is then stored in the Solid State Flight Data Recorder (SSFDR) through ARINC 429.

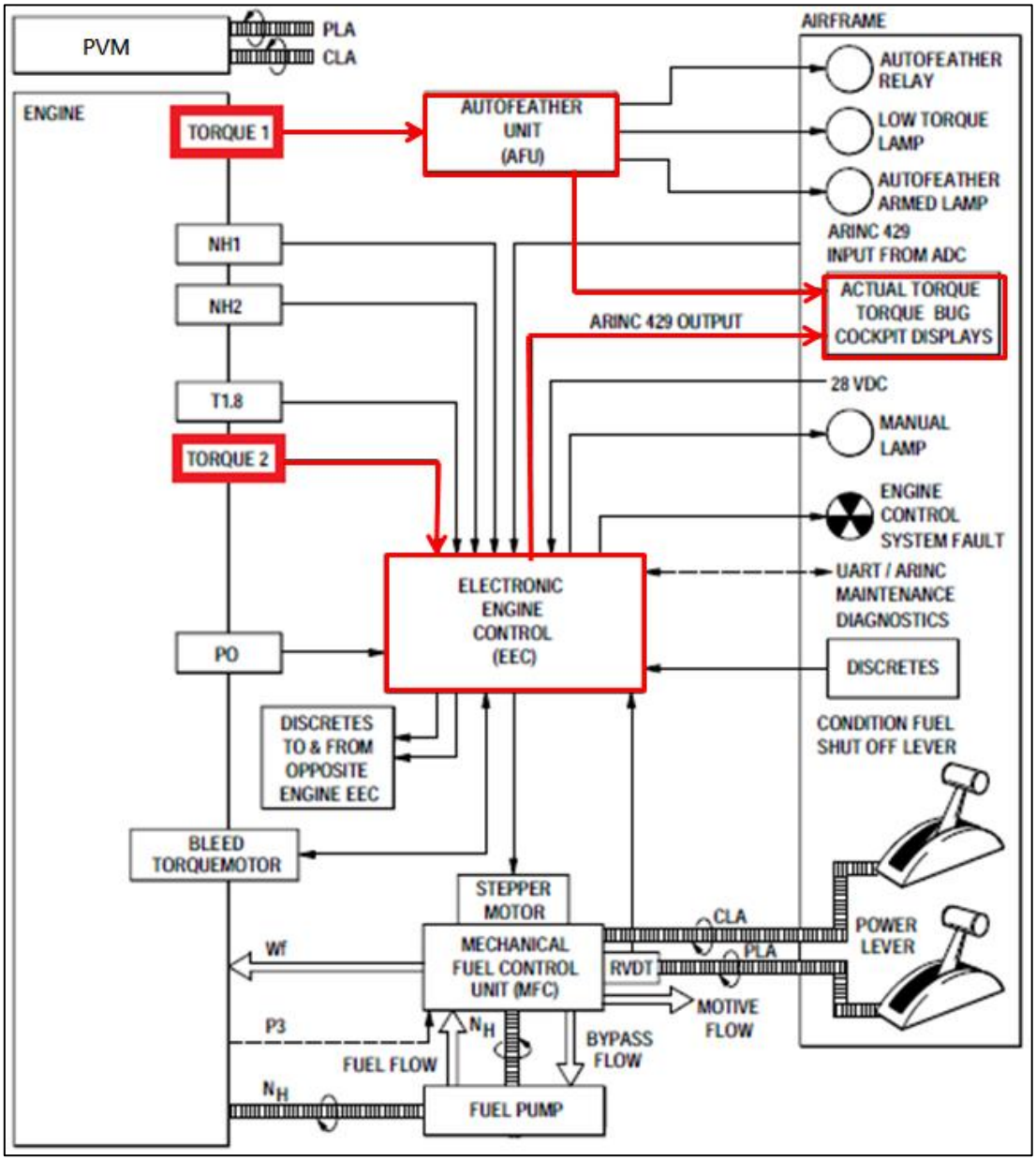

Figure 1.6-4 Engine torque sensing and indication

1.12 Wreckage and impact information

On February 04, 2015, TransAsia Airways (TNA) passenger flight GE235, an ATR72-212A aircraft, crashed into Keelung River of Nankang section at 1054 Taipei time. The Central Aircraft Accident Response Center (CAARC) was setup by the Ministry of Transportation and Communications immediately after the crash. ASC was informed by the CAA, and also established an occurrence investigation command post center in ASC office immediately. With the assistances of New Taipei City and Taipei City Emergency Response Centers, the wreckage salvage

and transportation to storage site operations were finished in one and a half days. This section states recovery of aircraft wreckage, wreckage transfer and wreckage temporary storage (Attachment 2).

1.12.1 Recovery of aircraft wreckage

Upon receiving the occurrence notification, ASC launched go team to the occurrence site right after a pre-investigation meeting. The members of go team included Investigator-in-charge (IIC) and investigators in flight operation, maintenance, flight recorders, survival factors and wreckage recovery.

The aircraft wreckage was broken into the cockpit and middle/aft fuselage two major portions with its nose immersed in the mud of riverbed. A floating bridge and three heavy lift vehicles were deployed by the Army Engineering Corps to facilitate the rescue of the victims and recovery of the aircraft wreckage. While the search and rescue operations were continuously going, the salvage operation of aircraft wreckage was commenced in the late afternoon of the occurrence day. The FDR and CVR of the aircraft were found at 1605 local time and had been delivered to ASC. Figure 1.12-1 showed that those two major portions of the wreckage were lifting up and moved to offshore ground of the river. By the late afternoon of day two salvage operation, the aforementioned two major portions and both engines were all successfully recovered.

Figure 1.12-1 Wreckage recovery operations

Figure 1.12-2 and 1.12-3 show the mappings of recovered aircraft wreckage during salvage operations. Total wreckage recovered is approximately 85% of the whole aircraft. The remaining unrecovered 15% of the whole wreckage is mainly between the after cargo area and forward of the ice shield area as shown in Figure 1.12-2. Larger pieces of aircraft wreckage are listed as follows.

Cockpit and forward fuselage

Radome, left and right sides cockpit skin, FR (frame) 11~16 cargo door surround, cargo door entry structure, fuselage lower skin, left side emergency exit, right side emergency exit and surround, right side fuselage

Middle and aft fuselage and landing gears

FR24-27 lower part with lower faring, center wing box, middle and aft fuselage broken at FR24~25, left and right hand side fuselages, left hand side main landing gear

Tail

Horizontal stabilizer and right hand side elevator, right hand side elevator tip, rudder and rudder tip, right hand side rudder antenna, dorsal fin and vertical stabilizer

Left wing

Outer wing box, aileron, outboard wing skins and panels, outboard and inboard flaps

Right wing

Outer wing box, aileron tab, flap fairing

Engines

No.1 (left) and No.2 (Right) engines

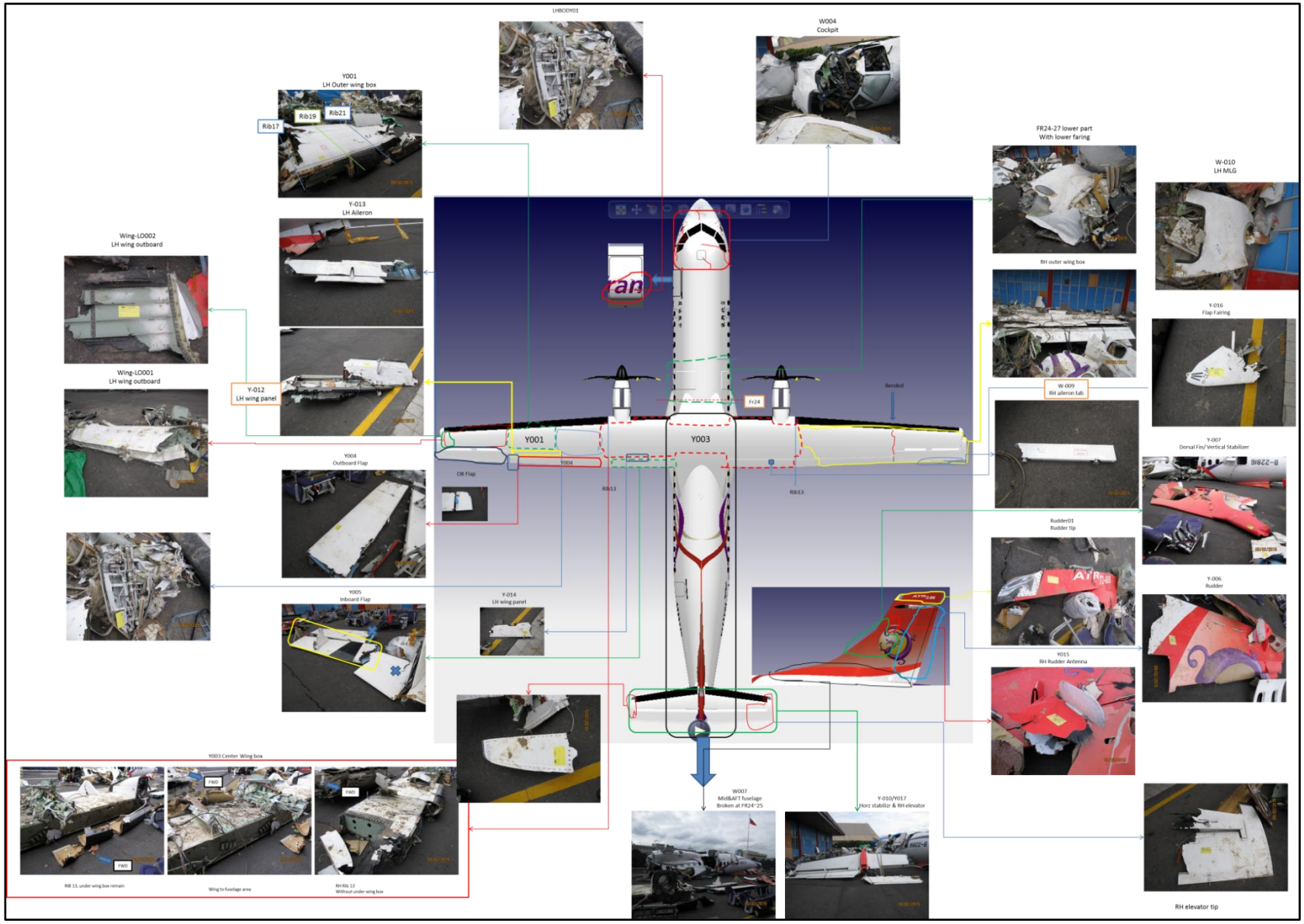

Figure 1.12-2 Recovered aircraft wreckages (1)

Figure 1.12-3 Recovered aircraft wreckages (2)

1.12.2 Wreckage transfer and temporary storage

With the support of the Ministry of National Defense (MND), the recovered aircraft wreckage was transported to the Songshan Air Force Base (SAFB) for temporary storage and subsequent inspections. With the assistances of New Taipei City and Taipei City Emergency Response Centers, all the aircraft wreckages were loaded into five trucks and transported to the SAFB as shown in Figure 1.12-4. The operation of aircraft wreckage transfer was finished in the late night of February 05, the second day after the occurrence.

Figure 1.12-4 Wreckage transferring to storage site by trucks

Figure 1.12-5 shows the aircraft cockpit portion was lifted and moved to the wreckage storage site. The locations of wreckage were arranged as two dimensions reconstruction of whole fuselage. The aircraft emergency locator transmitter (ELT) was deactivated on February 06 after being notified by Songshan airport.

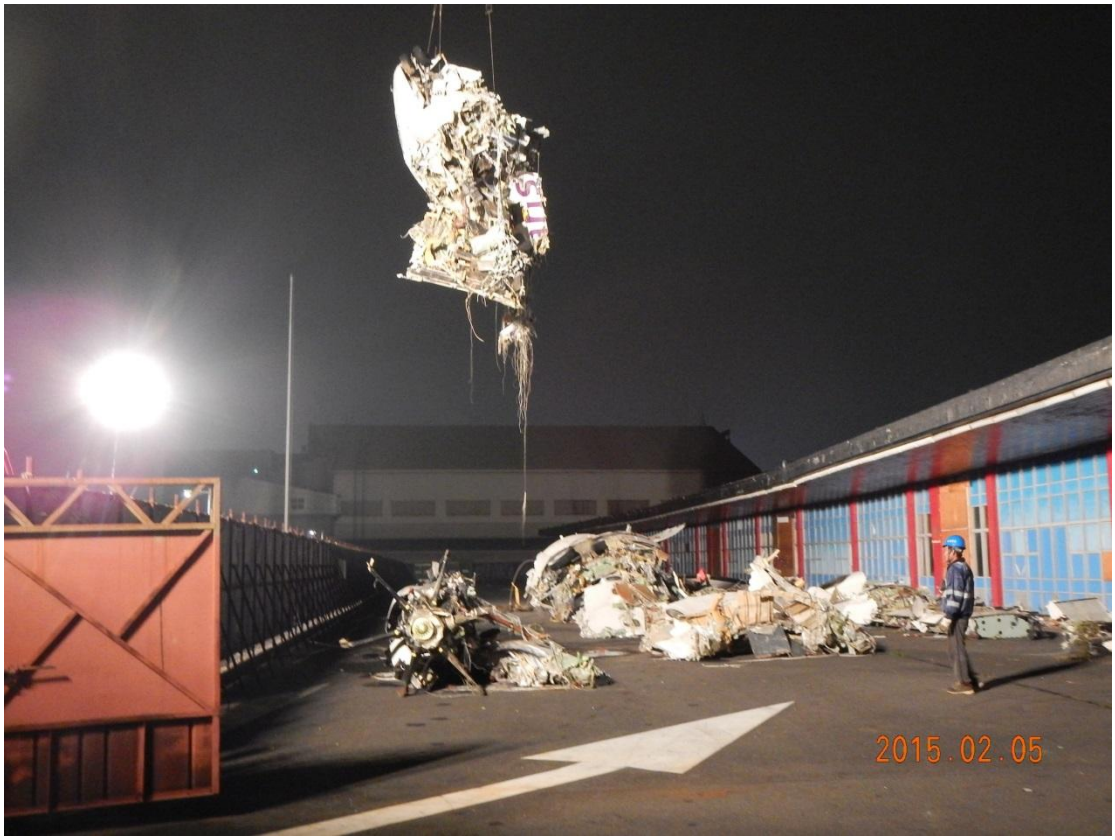

Figure 1.12-5 Temporary wreckage storage site

1.16 Test and research

1.16.1 Aircraft structure examination

The examination of aircraft structure was conducted on February 10, 2015 at the wreckage storage site in SAFB. The examination was finished with joint efforts of ASC, CAA, and TNA structure engineers. Totally 7 aircraft structural pieces were examined. Those fractured surfaces of structural pieces all showed overload and post impact damages. The results of examination were fed into the wreckage structure database which was compiled by ASC during wreckage recovery operation.

1.16.2 Engines examination

The examination of engines was conducted on February 7-9, 2015 at the wreckage storage site in SAFB. Representatives from the following organizations participated in the examination: Transportation Safety Board (TSB) Canada, Transport Canada (TC), ATR, P&WC, CAA, TNA

and ASC. After the examination, the P&WC service investigation provided the factual notes (Appendix 1).

1.16.2.1 No.1 engine

The No. 1 engine is a P&WC Model PW127M, serial number ED0913, total hours 829:31 and total cycles 1240. The engine was installed on the occurrence aircraft following aircraft delivery due to a low oil pressure event with the original installed engine. Review of the engine logbook and reduction gearbox logbook showed no unusual maintenance.

The No. 1 engine was examined in the airframe nacelle as recovered. The external case inspection showed all quick engine change items and airframe nacelle to engine connections appeared to be intact, with water immersion damage. The propeller blade remained attached to the hub with the blade outer spans separated.

The engine turbo machine was borescope inspected in accordance with the PW127 engine maintenance manual. The turbine section components, combustion section components, compressor section components and reduction gearbox components all displayed no indications of any anomalies affecting normal operation, and all components observed showed normal running wear. All components showed immersion damage.

Some control and accessory components of No. 1 engine were removed and shipped to TSB Canada for routing to their respective vendors for investigation and analysis under the oversight of National Transportation Safety Board (NTSB), Transport Canada (TC), BEA, P&WC, ATR, UTAS and ASC. The removed components are as following: Propeller Electronic Control (PEC), Engine Electronic Control (EEC), Auto Feather Unit (AFU), Data Collection Unit (DCU), Torque Sensor No. 1 and No. 2, upper and lower Nh Sensors, Nl sensor and Np sensor.

1.16.2.2 No.2 engine

The No. 2 engine is a P&WC Model PW127M, serial number ED0814, total hours 1627:05 and total cycles 2356. The engine was an original installation on the occurrence aircraft. Review of the engine logbook and reduction gearbox logbook showed no unusual maintenance.

The No. 2 engine was examined in the airframe nacelle as recovered. The external case inspection showed all quick engine change items and airframe nacelle to engine connections appeared to be intact, with water immersion damage. The propeller blade remained attached to the hub with the blade outer spans separated. The nacelle aft section and exhaust duct were separated.

The engine turbo machine was borescope inspected in accordance with the PW127 engine maintenance manual. The turbine section components, combustion section components, compressor section components and reduction gearbox components all displayed no indications of any anomalies affecting normal operation, and all components observed showed normal running wear. All components showed immersion damage.

To troubleshoot the fault of uncommanded autofeather, the continuity check was done on the AFU harness which connecting the AFU and No.1 torque sensor. According to the PW127 engine maintenance manual, all the results are within limits (see Table 1.16-1 and Figure 1.16-1). Upon removal of the harness plugs for the continuity check, both the torque probe and AFU plugs showed slight water ingress to plug retaining collar. The connector pin seats appeared to be dry.

Table 1.16-1 Continuity check of No. 2 AFU electrical circuit

Point-A	**Point-B**	**expected**	**result**
J6 pin A	J6 pin B	553-589 ohms	575 ohms
P16 pin H	P6 pin A	0-0.5 ohms	0 ohm
P16 pin J	P6 pin B	0-0.5 ohms	0 ohm
Insulation resistance (with reference to ground) of torque sensor No. 1 > 2 Mohms			

P16 pin H to P6 pin A | J6 pin A to J6 pin B

Figure 1.16-1 Continuity check of No. 2 AFU electrical circuit

Some control and accessory components of No. 2 engine were removed and shipped to TSB Canada for routing to their respective vendors for investigation and analysis under the oversight of NTSB, TC, BEA, P&WC, ATR, UTAS and ASC. The removed components are as following: PEC, EEC, AFU, DCU, Torque Sensor No. 1 and No. 2, upper and lower Nh Sensors, Nl sensor and Np sensor.

1.16.3 Components test and examination[1]

1.16.3.1 AFUs tests

Two AFUs removed from the occurrence aircraft, and another AFU removed from an ATR72 aircraft that experienced an uncommanded autofeather event after the GE235 occurrence were sent to the manufacturer, UTAS Rosemount Aerospace, in Minnesota, USA for test and examination.

The test was performed at UTAS facility in Eagan/Burnsville, Minnesota USA, during April 8-11, 2015. The attendees of this test included representatives from safety boards (NTSB, BEA and ASC), regulator (Transport Canada), Advisors (UTAS, PWC and ATR) and observer (TransAsia Airways). The test was based on shop test for functional testing and extended to laboratory examination. During the shop test, a field notes (referred to Appendix 2) was made by NTSB which documented key findings and group decisions. BEA also prepared a Meeting Report of this AFUs tests, document no. BEA2015-0039_tec10,

[1] All the tests are conducted on post-impact components.

referred to Attachment 3. The Meeting Report provided more detailed test process and results, but not including laboratory examination. After all necessary tests including laboratory examination finished, NTSB provided ASC a full AFU Investigation Report prepared by UTAS on June 11, 2015, document number D06429311, Non Technical Rev A (referred to Attachment 4). Following paragraphs are excerpts that relevant to occurrence AFUs from the UTAS document and the BEA Meeting Report.

Basic information: Basic information of these 2 AFUs is shown in Table 1.16-2.

Table 1.16-2 AFUs basic information

	AFU #1	AFU #2
		
Manufacturer	UTAS	UTAS
Part Number	30048-0000-28	30048-0000-28
Serial Number	RT3077	RT2362
J2 Connector Reference *	1301	1315
Position	Engine 1	Engine 2
Aircraft ID	B-22816	B-22816
Flight ID	GE 235	GE 235

* Format is year week (YYWW)

Work performed

The following testing protocol for each AFU was agreed for all the units before the meeting:

- Visual inspection

- Perform a continuity check ([Ref 1][2]– page 125 and 126)
- Perform the functional tests manually ([Ref 1] – page 101 and 123)
- Perform the functional tests automatically [Ref 2][3]
- Perform the thermal cycle tests ([Ref 1] – page 124)
- Perform the vibrations tests ([Ref 1] – page 129)

If a device failed a test, then the testing protocol would be adapted.

AFU No. 1

AFU No. 1 passed continuity test, manual functional tests, automatic functional tests, thermal tests and vibration tests.

Findings for AFU No. 1

- AFU No. 1 passed all the tests in accordance with CMM [Ref 1]

AFU No. 2

AFU No. 2 failed to pass continuity test. The measured resistances values for the Pins J and H were fluctuated from 1 to 20 ohms when the ribbon was moved by hand. The resistance was higher than the CMM (Component Maintenance Manual with Illustrated Parts List, 73-20-03, Rev. 11, Oct 01, 2014) values threshold of 0.35 ohms for the Pins J and H. These two pins are the pins connected with the torque sensor. An X-ray examination was performed and no defect was found of this unit. In order to find where the increased resistance occurred between Pin J/H of J2 connector and the A2 board strip contact (contact points No. 34/33), a new test procedure was proposed and agreed by all attendees for this unit.

To perform the new test, three test points were defined to facilitate the isolation of the high resistance.

- X1 – The insulation was removed at the end of the flex to create a testing point
- X2 – The flange on the pin that is soldered between the flex circuit and the circuit card
- X3 – A testing point on the circuit card, instead of the strip contact point defined in the CMM

Detail test results by applying the new test procedure for AFU No. 2 are as follows.

---

[2] 73-20-03 Rev11, Component Maintenance Manual, Part Number 30048-0000-* Part Testing and Fault Isolation

[3] D06409502 Rev C, Acceptance Test Procedure

- The resistance (R_{X1}) measured between pin J and point X1 provided a value consistent with the maximum resistance value provided by the CMM. Moving the ribbon did not affect this value.
- The resistance (R_{X2}) measured between pin J and point X2 provided a value greater than R_{X1}, which was unstable and changed while the ribbon was moved.
- The resistance (R_{X3}) measured between pin J and point X3 provided a value greater than R_{X1}, which was unstable and changed while the ribbon was moved.

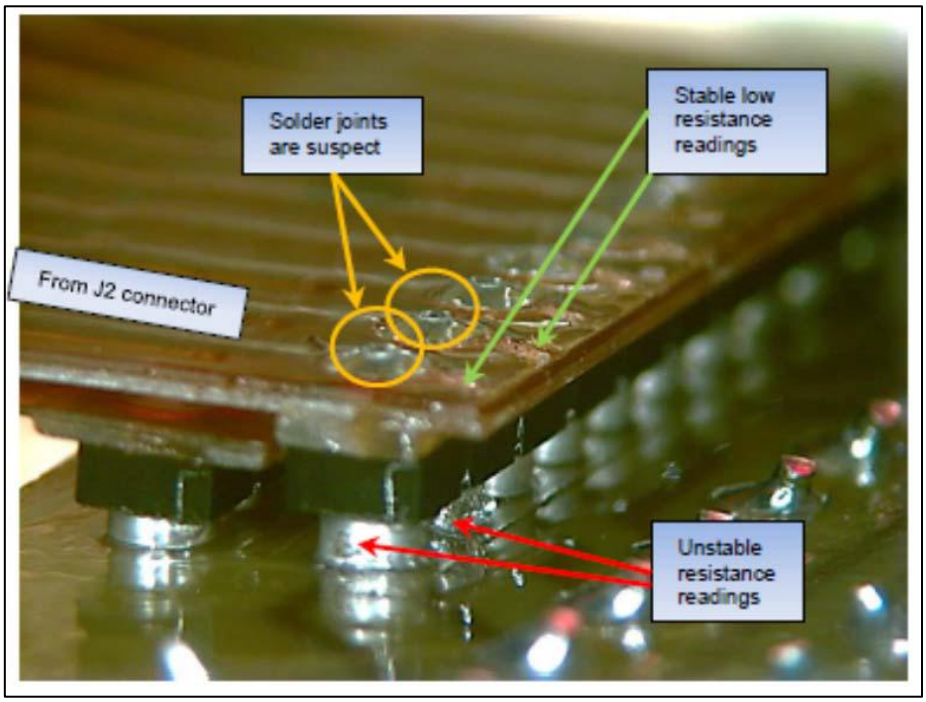

Figure 1.16-2 Continuity check of pin J and A2 board

It was noted that the first time R_{J2} and R_{H2} were measured, both were unstable. As the tests were repeated, from time to time, R_{J2} and/or R_{H2} were stable during one test. The continuity failures detected on pin H and pin J were located inside the header strip connector (end of the ribbon, opposite to the J2 socket). The discontinuity was observed to be intermittent. The test results are summarized in Table 1.16-3.

Table 1.16-3 Test results of AFU No. 2 by applying new test procedure

AFU No. 2			
	X1	X2	X3
Pin J	Stable	Unstable	Unstable
Pin H	Stable	Unstable	Unstable

The functional test of AFU No. 2 was not completed due to a short circuit was detected during the gain tests. An X-ray examination was performed and a possible cause was found on the bounding No. 16 of component U5 of A2 board. As the component replacement could be seen as a destructive choice, it was decided to stop the test with this unit.

A CT-Scan (Computed Tomography) of J2 solder joints was performed and potential solder cracking was identified. A destructive test was performed to find the possible root cause of continuity failures inside the 90°connector of J2 flex circuit. The J2 flex circuit was cut out of the CCA (Circuit Card Assembly) and housing. Pins 33-42 of J2 flex circuit was examined using optical microscope and with the SEM (Scanning Electron Microscope). Figure 1.16-3 shows the photos of Pins 33 and 34 with 40X magnifications and with SEM examination. The Pins 33-42 of J2 flex circuit was cross sectioned to the component centerline and examined. Figure 1.16-4 and 1.16-5 show the photos of cross sectioned pin to flex solder joints of Pins 33 and 34. The Pin-Flex solder joints displayed a coursing of the solder micro structure near the pin on each of the 10 pins in the strip. The condition was most advanced on pins near the end of the strip. In the optical cross-section images the Lead-rich phase are the grey particles dispersed within the white Tin-rich phase. In the SEM images the Lead phase is white and Tin is grey. The solder microstructure is enlarging, coarsening and cracking in a stress zone adjacent to the Pin / Solder interface. Away from this “crack zone” the solder microstructure is very fine.

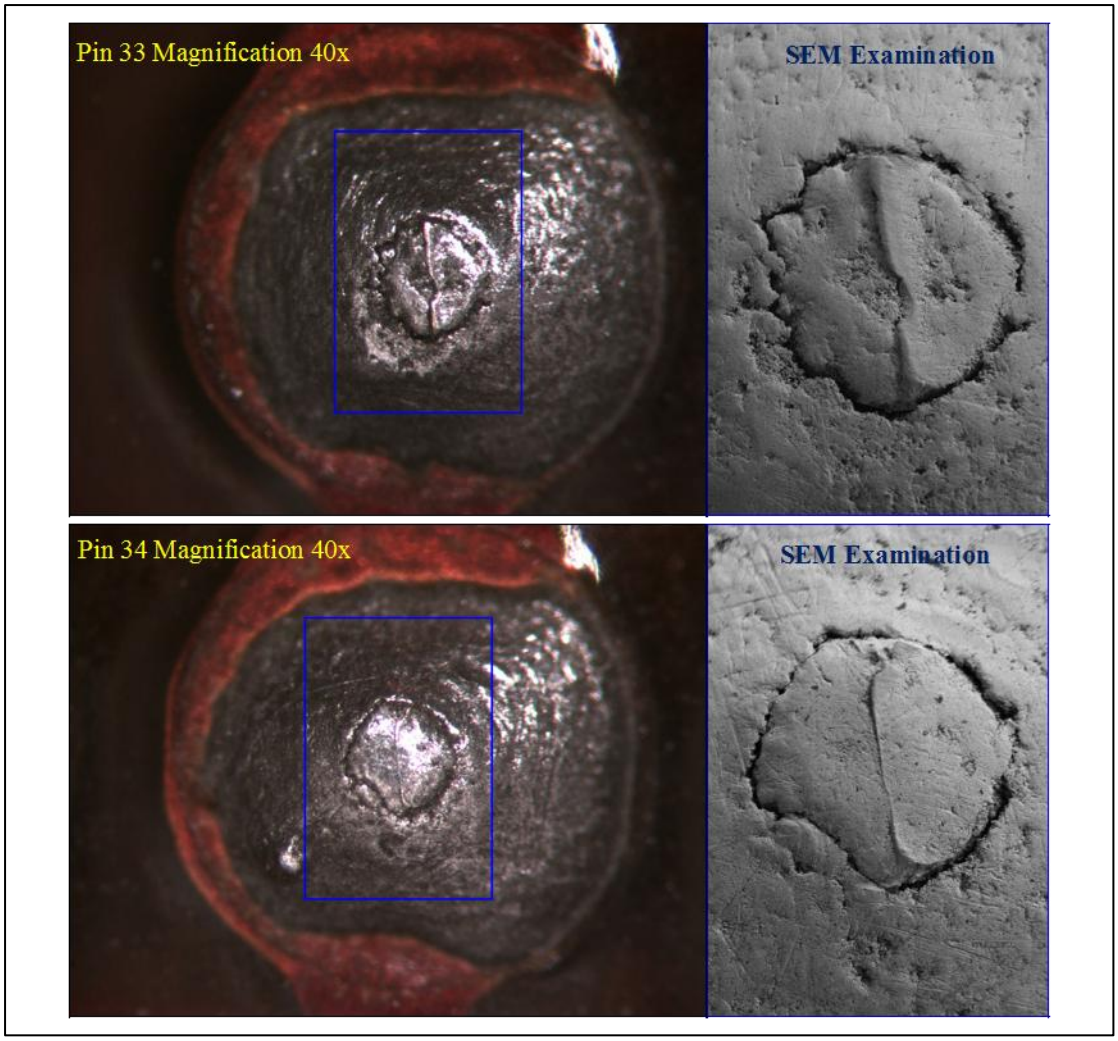

Figure 1.16-3 Pins 33 and 34 with 40X magnifications and with SEM

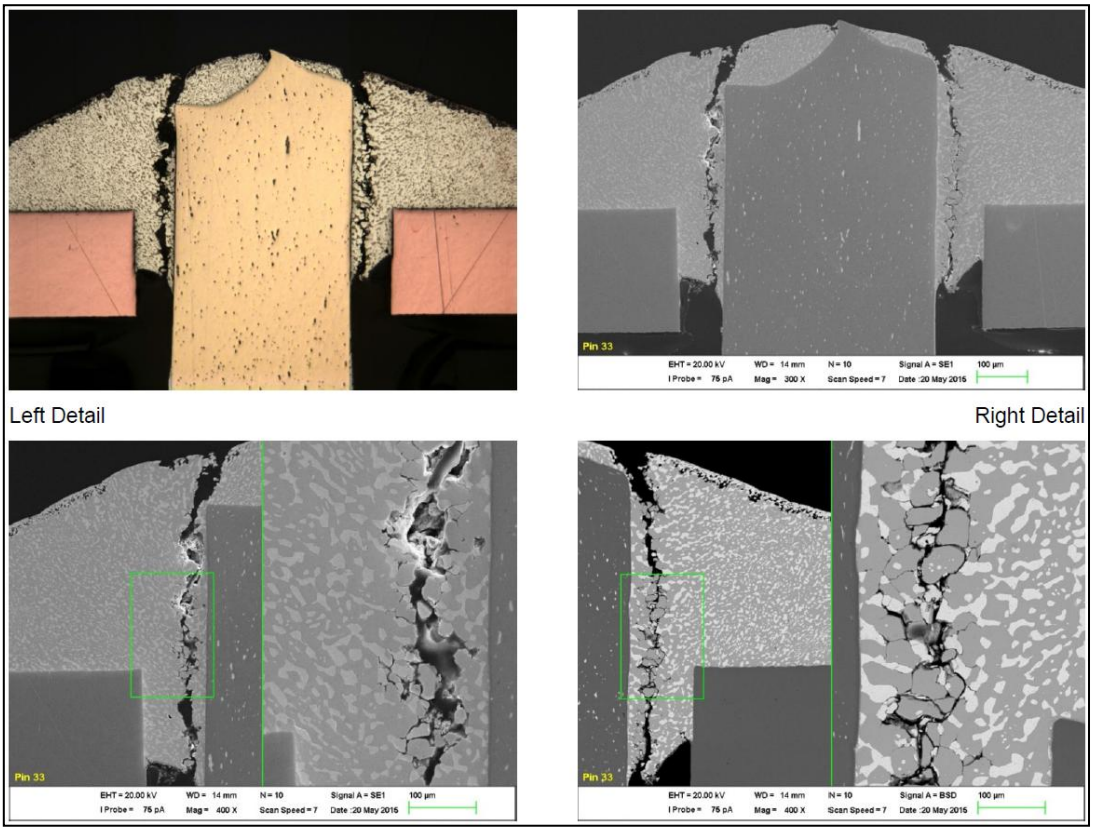

Figure 1.16-4 Cross sectioned pin to flex solder joints of Pins 33

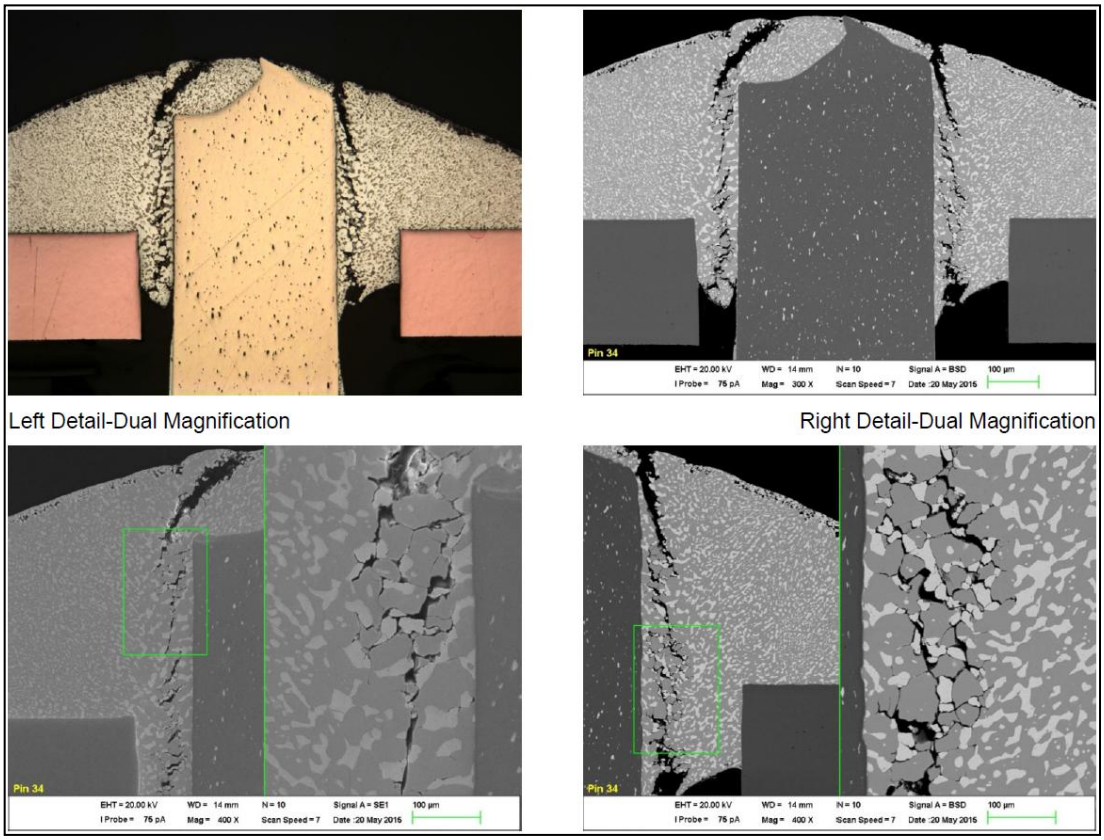

Figure 1.16-5 Cross sectioned pin to flex solder joints of Pins 34

Findings for AFU No. 2

- Continuity failures (resistance values above the CMM threshold) exist between pin H and the circuit board, and between pin J and the circuit board
- Continuity failures (resistance values above the CMM threshold) are located at the solder joint interface between the flex circuit and the header pin
- Continuity failures (resistance values above the CMM threshold) were inconstant
- The solder microstructure is enlarging, coarsening and cracking in a stress zone adjacent to the solder joint interface between the flex circuit and the header pin

1.16.3.2 MFCs NVM data download

Twenty two boards of two Multi Function Computers (MFC 1, 2) were removed from the occurrence aircraft and shipped to BEA for NVM data readout. BEA provided the Final report of the Computer MFC 1 and computer MFC 2 Memories readout, document no. BEA2015-0039_tec11, date of issue 16/04/2015, referred to Attachment 5. Following paragraphs are excerpts of the document.

Four memory chips extracted from boards CPU1 and CPU2 of MFC 1 and MFC 2 were dried and electrically checked before the readout processes. The memories were readout twice to check the correctness of the downloaded binary files. The binary file of each memory was then decoded by BEA and Airbus and the same results were found. Information stored in the memory chips included 3 groups of readout, Basic BITE, Advanced BITE and Super advanced BITE.

The only information provided by the basic BITE memories is that from the CPU2 of MFC 1. The only recorded failure is the code 02 of the system "flight control", no other failure had been detected since the last MFC maintenance action[4], with an erase of the memory.

Advanced BITE and Super Advanced BITE provided following information,

[4] TNA information: TNA checks MFC memory every Wednesday night during weekly check. If only WOW (Weight On Wheel) failure code existed, the memory will be erased. If there were failure code other than WOW, the associated correction will be documented in the TLB. From the maintenance records, the last weekly check of the occurrence aircraft was performed on January 28, 2015 with no fault found.

During the 6 of the 8 previous flights (no event for flight N-1 and N-2), the code 02 appeared in the group “flight control” (advanced BITE). The meaning of this code and the associated action are the following:

- TORQUE 2 FAULT (confirmation delay: 30 s)
- This code appears with the following conditions:
  - right power lever in TO position AND torque below 25%
  - OR right power lever not in TO position AND torque upper 50%
  - AND right ECU not fault
  - AND right engine oil not in low pressure
  - AND MFC1B or 2B valid.
- Action:
  - Check AFU, Torque indicator, microswitch on right power lever and associated wiring.

When this failure occurs, it shall be underlined that:

- the failure concerns a chain composed of {TQ sensor #1 of engine #2, harness, AFU #2}
- it is impossible to know what element of the chain failed.
- the exit of the system is the needle TQ indication displayed on the EPD. This failure has then an impact on the information displayed to the crew.
- the digital TQ indication displayed on the EPD uses another chain and another sensor (TQ sensor #2 of the engine). It is this information, which is recorded by the DFDR.

All those flights were performed the day before the flight of the event (2015/02/04).

The flights N-1 and N-2 were performed the same day than the flight of the event (2015/02/04). It is impossible to know if the crew faced or not the same failure during these two flights:

- no indication of ATPCS sequence exists on the FDR recorded data (no feathering request recorded inside the FDR and the super advanced BITE)
- after the take off, it is impossible to know if the needle TQ indication of the engine #2 was invalid as the information of the torque values recorded by the FDR is provided by

another chain using the TQ sensor #2

- as the confirmation delay for the MFC to record this failure is 30 seconds, this failure might have happened intermittently, for durations lower than 30 seconds.

During the flight of the event, MFC #2 recorded an autofeather request inside the super-advanced BITE, with a signal coming from the AFU No. 2. Both module 2A and 2B recorded the same context:

- A single record
- Code E1: Activation signal for feathering pump 2 status
- Code E3: Auto feathering signal from AFU No. 2

This recording is consistent with the record of the code 02 of the group "flight controls", recorded inside the advanced BITE during the flight of the event (all the MFC modules). As the right power lever was recorded in the take off position by the FDR, the torque indication value was then detected below 25%.

During the flight N-1, the Super Advanced BITE information seems not consistent for the propeller brake recorded context. Both MFC 2A and 2B modules performed the same first record, but the module 2B performed 2 additional records. This has no impact on the investigation of the event. Nevertheless, ATR is investigating these differences.

FINDINGS

- No error other than the invalid needle TQ indication was detected by the MFC since the last erase of the MFC memory (maintenance action)
- AFU #2 reported TQ values of the engine #2 lower than 25% to the MFC during more than 30 s.
- The auto feathering triggered during the flight of the event.

1.16.3.3 PECs and EECs data download

Two EECs and 2 PECs removed from the occurrence aircraft were sent to manufacturer, Hamilton Sundstrand at Windsor Locks, Connecticut, USA, for NVM data download. The work was performed by Hamilton Sundstrand and overseen by the representatives from NTSB, TC and P&WC during the time period April 20-22, 2015. The Shop Findings Report of EECs and PECs, referred to Attachment 6, was

provided to ASC on May 20, 2015. Following is the basic information of the EECs and the PECs,

Table 1.16-4: Basic information of EEC and PEC

	P/N	S/N	Position
EEC	1012974-4-002	14040035	No.1 / left
EEC	1012974-4-002	13100020	No.2 / right
PEC	816332-5-401	13070018	No.1 / left
PEC	816332-5-401	13080013	No.2 / right

The shop finding and data download indicated that both PECs had no induced failures and no fault codes stored during the occurrence flight. Both EEC passed power up test with some stored fault codes. Each of the fault codes occurred on a flight prior to the event and was most probably caused by the power-up sequence of the EEC, DCU, AFU, Air Data Computer.

1.16.3.4 Harnesses

The harnesses connecting No. 1 torque sensors to AFU of both engines were removed from the occurrence aircraft and shipped to BEA for further lab examination. A non-destructive means was performed by using an X-ray and a macroscopic examination (Appendix 3). The connection between the torque sensor and the AFU is made through (Figure 1.16-6):

- Pin No. 1 and pin No. 2 on the torque sensor connector
- Pin H and pin J on the AFU connector

Figure 1.16-6 Torque sensor and AFU connectors

The X-ray examination of both harnesses showed no anomaly. The X-ray pictures of the connectors which connect AFU and the torque sensor of No. 2 engine are shown in Figure 1.16-7.

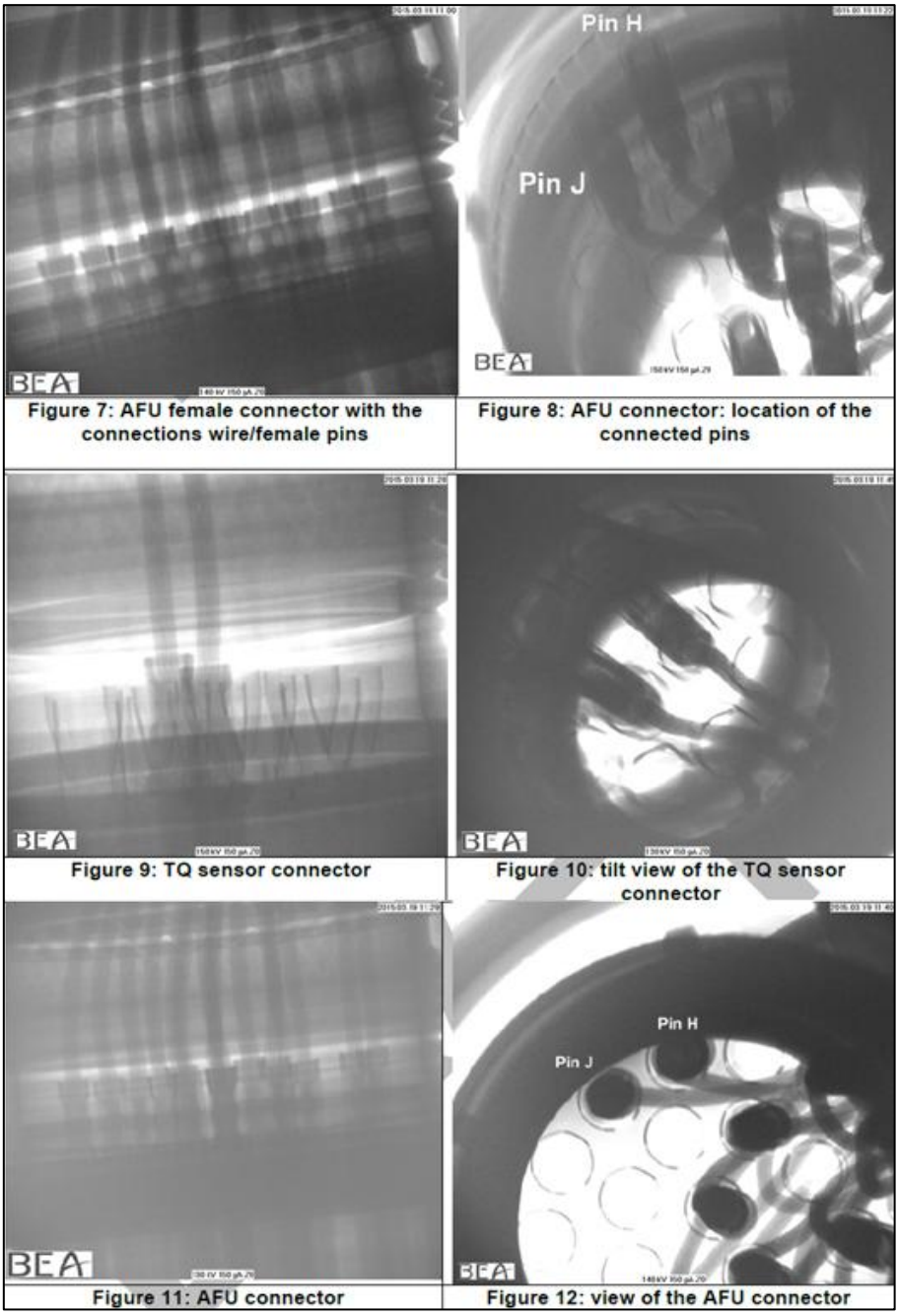

Figure 1.16-7 X-ray examination of AFU and torque sensor connectors

The macroscopic examination showed a difference between the pin H of AFU connector of No.2 engine and the other pins on this connector. A picture of pins H, J of No. 2 AFU connector is shown in Figure 1.16-8.

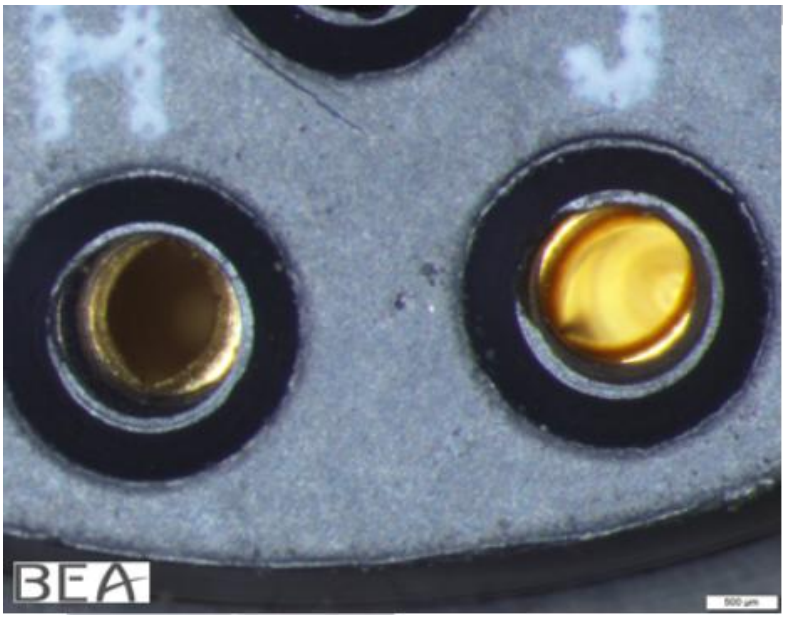

Figure 1.16-8 Pins H and J of No. 2 AFU connector

The harness was brought to UTAS Rosemount Aerospace to combine with the AFU test if situation required. Because of the discontinuity was found in AFU No.2, ASC requested just to perform the continuity check of harness. A continuity check then was done on the pin J and H of harness. The resistances were 0.20 ohms and 0.21 ohms respectively.

1.16.3.5 Accessories tests

Twelve engine sensors including right torque, left torque, Np speed, lower Nh speed, upper Nh speed and Nl speed sensors of No. 1 and No. 2 engines which removed from the occurrence aircraft were sent to P&WC via TSB for testing. After all necessary tests finished, P&WC provided ASC a report on June 22, 2015, document number RFA No 15ECN00082 SI File No: 15-006 (referred to Attachment 7). According to the report, observations recorded from testing of the speed and torque sensors were indicative of immersion in water and impact. Test results are summarized in Appendix 4.

Two Data Collection Units (DCUs) which removed from No. 1 and No. 2 engines of the occurrence aircraft after the crash were sent to the manufacturer, Safran Electronics, via TSB for memory data readout. According to Attachment 7, the readout data from the DCU of both engines did identified engine cycle count and engine run-time data.

1.18 Additional information

1.18.1 Interview summaries

1.18.1.1 Assistant manager of maintenance division

The interviewee first introduced TNA's maintenance difficulty reporting procedures and how the difficulty was reported. TNA's Maintenance Control Center (MCC) collects reported aircraft defects from all stations and compiles them into a daily report each day. These defects might be from pilot report, safety department or maintenance personnel etc. A printed out daily report was prepared and used for reference during TNA's directors meeting. MCC assists directors of each division to review the daily report as necessary. If there were service difficulty item, MCC would report this item to Quality Control Center (QCC). QCC also compulsorily needed to make Service Difficulty Report (SDR) and reporting the difficulty to the Civil Aeronautics Administration (CAA). After the SDR was reported to the CAA, TNA's Reliability Control Board (RCB) would discuss with CAA personnel for solution of the service difficulty case.

Regarding the issues of aircraft diversion resulted from engine problems during B-22816 ferry flight from Bangkok to Taiwan, the interviewee expressed how those engine problems were reported to Taiwan CAA. While the aircraft B-22816 was in cruise from Toulouse to Taipei, a low oil pressure warning on the No. 1 engine occurred. The flight crew shut down the No. 1 engine and diverted to Macau airport. TNA replaced of the No. 1 engine to resume the aircraft delivery flight. During the flight from Macau to Taipei, the No. 1 engine low oil pressure warning appeared again and the flight crew shut down the No. 1 engine. The investigation confirmed that the missing drive shaft / spur gear woodruff key of the No. 1 engine reduction gearbox oil scavenge pump was the cause of the engine low oil pressure warning. When the aircraft B-22816 was diverted to land at Macau airport, TNA on board aircraft personnel with the ferry flight called TNA Flight Control Center (FCC) about the diversion. TNA FCC then reported the event to CAA. Due to

the repeated No. 1 engine low oil pressure warning and commanded in flight shut down events, CAA sent Principal Maintenance Inspector (PMI) to Kaohsiung airport to assist TNA after the aircraft B-22816 landed at Kaohsiung airport.

While being asked what TNA's actions taken and response to those in flight shut down events in the latest 5 years were, the interviewee replied that 2 of those in flight shut down events occurred during aircraft delivery were mentioned earlier. One engine in flight shut down event occurred in May 2, 2012 was resulted from manufacturing defect of engine turbine blades which had been investigated and closed by the ASC. The incident occurred on August 16, 2011 was resulted from defective J1 and J2 connectors of the Auto Feather Unit (AFU). TNA revised ATR Continuous Airworthiness Maintenance Program (CAMP) task number 771362-RAI-10000-TNA to change the inspection of AFU to hard time interval. The last one occurred in October 6, 2010 was due to engine torque fluctuation after take-off. To reduce loss of engine torque signal or torque fluctuations related event, TNA issued Engineering Circular EC-1106-04 requesting the compliance of related documents and procedures to perform electrical connector care.

1.18.1.2 Maintenance personnel stationed in Kinmen airport

The interviewee has worked for TNA since 1995. He has CAA's A/E/AV licenses and stationed in Kinmen airport as a senior mechanics now. The interviewee received ATR72-500 type training and configuration differences course training between the ATR72-500 and -600 aircrafts. The interviewee also received aviation maintenance related recurrent training each year. The interviewee then described how to follow the procedures to authorize and dispatch aircraft after completion of required check and maintenance.

While being asked what work had been done before the aircraft B-22816 was dispatched to service the previous flight of the occurrence flight from Kinmen to Songshan, the interviewee replied that there were two mechanics stationed in Kinmen airport, since the other one had no CAA license, the mechanics with no CAA license performed fueling work and the interviewee did the transit check alone. The interviewee

finished the transit check in 20 minutes with no fault found. Usually, if no fault was found, transit check could be done in about 20 to 25 minutes. The interviewee also checked maintenance records; there was no deferred defect of the aircraft B-22816. The interviewee then signed the Technical Log Book and the aircraft was airworthiness released for service. After the other mechanics finished fueling job, the interviewee walked to the cockpit and gave the fueling form to the Captain. The flight crew did not mention any problem about the engines.

If there were fault found before the aircraft departure, the interviewee never discussed with the flight crew to apply MEL for delay maintenance. Delay of aircraft scheduled departure time would not bring any pressure on him. The interviewee said keeping aircraft airworthiness was the first priority.

1.18.1.3 Maintenance personnel stationed in Songshan airport

The interviewee has worked for TNA since 2005. Before that he had been in the Dragon Air for 2.5 years. He has CAA's A/E/AV licenses, and is stationed in Songshan airport as a mechanic now. The interviewee had received ATR72-500 type training and configuration differences course training between the ATR72-500 and -600 aircrafts. The interviewee also received aviation maintenance related recurrent training each year. The interviewee then described how to follow the maintenance procedures to dispatch aircraft after completion of required check and maintenance.

The transit check before the occurrence flight was done by the interviewee. The transit check was finished in 20 minutes with no fault found. The interviewee expressed that if no fault was found, transit check usually could be done in about 20 minutes. The interviewee also checked maintenance records and no deferred defect record of the aircraft B-22816 was found. The interviewee then signed the Technical Log Book and the aircraft was airworthiness released to service.

The interviewer asked whether or not the flight crew mentioned about engine problem before the occurrence flight from Songshan to Kinmen. The interviewee replied that the first leg of that day was flight

GE231. The interviewee did a pre-flight check while the Captain performed a 360 degree check. The pre-flight check result was normal. Before the leg of flight GE235, the interviewee did the transit check himself. The flight crew did not mention anything about the engine. If there were fault found before the aircraft departure, the interviewee never bargained with the flight crew to apply MEL for delay maintenance. Delay of aircraft scheduled departure time would not bring any pressure on him. The interviewee said keeping aircraft airworthiness was the first priority.

1.18.2 Abnormal engine torque related events/information

1.18.2.1 Chronology of TNA ATR72 aircraft abnormal engine torque related events/information

A review of Taiwan CAA's aviation incident reports revealed that 2 TNA ATR72 abnormal engine torque related events were investigated between October 2010 and the day of GE235 occurrence. One was reted to the connection of the torque sensor to the EEC and the other one event related to the AFU. There was also a TNA ATR72 autofeathering event occurred after the GE235 occurrence. A chronology of these events and information is shown in Table 1.18-1.

Table 1.18-1 TNA ATR72 abnormal engine torque related events

Date	Type of aircraft or Info issued by	Description of event/information
Nov. 17, 2008	P&WC	P&WC issued Service Information Letter SIL No. PW100-125 to operators on proper electrical connector protection and wrapping.
Oct. 06, 2010	ATR72-500	After aircraft takeoff, No. 2 engine torque vibrated between 20% and 100%, the aircraft in flight turned back and landed safely. Or connection between No. 2

		torque sensor and EEC was suspected.
Jun. 28, 2011	TNA	1. TNA issued Engineering Circular EC-1106-04 to Line/Base Maintenance and Training Section iterate the importance of practice appropriate connector care during any engine connector installation. 2. The Flight Operations Division added Abnormal Engine Parameters in Flight procedure into teh ATR FLEET Training Program.
Aug. 16, 2011	ATR72-500	1. During cruise, No. 1 engine torque dropped to zero causing the pilot shut down No. 1 engine. The No. 1 engine was then restarted and aircrft landed safely. 2. P&WC report confirmed that the defects found on AFU causing the uncommanded autofeathering of engine No. 1.
Mar. 15, 2012	TNA	TNA issued Engineering Circular EC-1203-03 to inform related department for the information in the report with the associated symptom.
Feb. 21, 2015[5]	ATR72-500	After aircraft takeoff, No. 1 engine torque dropped causing No. 1 propeller autofeathering. The aircraft turned back and landed safely.

1.18.2.2 Related Service Information issued by P&WC

On August 15, 2007, P&WC issued SB21742 to do a one-time inspection of AFU. The reason to issue SB21742 was that aging of the AFU electrical connectors and interconnect ribbon solder joints can lead to loss of torque signal. On August 2007, P&WC issued SB21742R1 to recommend sending AFU to an authorized accessory shop that can do the one-time inspection per the latest CMM instructions. On December 2009,

[5] Incident date of this event was after the date of GE235 occurrence (Feb. 04, 2015).

P&WC moved the intend of SB21742R1 in Table 4 of section 05-20-00 of the Engine Maintenance Manual (P/N 3037332, rev. 42) to change this inspection to a repeat inspection. P&WC then cancelled the SB21742 in April 2011 because it is now covered in the Engine Maintenance Manual.

On December 14, 2010, P&WC issued Service Information Letter (SIL) No. PW100-138 (see attachment 9) for AFU inspection / repair at shop visits. The document indicated that some of the AFUs involved in those autofeather events exhibited cracks in the soldering of the U3 voltage converter mounted on the AFU board. Those cracks are believed to have caused momentary electrical disruptions leading to the autofeath events. The manufacturer of the AFU then revised instructions regarding the U3 converter inspection, installation and soldering to its mounting board. In addition, testing requirements for the AFU have been improved via testing at low, high and ambient temperatures.

On September 26, 2011, P&WC issued Service Information Letter No. PW100-147 (see attachment 10) for AFU related autofeather events. The document indicated that several of the reported autofeather events are associated to 28 Volts DC power interruptions at the AFU. On the ATR aircraft, those power interruptions will generate large magnitude torque bug fluctuations. The AFU manufacturer has incorporated related contents to its CMM which include:

- Revised instructions for U3 converter inspection, installation and soldering on the mounting board.
- Inspections related to the J1 and J2 flex conductors and boards interconnect flexible ribbons.
- Functionality testing of the AFU at different temperature (low, high and ambient).

1.18.3 Wreckage and LRU database

Two wreckage databases (structure database and LRUs database, as shown in Attachment 11, 12) were developed using an Excel spread sheet for records keeping and information sharing. The structure database containing 38 pieces of larger wreckage recovered from the aircraft crash site. Data fields of the structure database contain parts nomenclature, location, results of structure examination and related photos. The LRU

database containing 68 line replacement units removed from cockpit and No. 1, 2 engines. Data fields of the LRU database contain item nomenclature, part number, serial number, wet or dry status, shipping information (TSB/BEA/ASC) and related photos.

IV. Appendix

1. ATR-72 Reg. B-22816 Accident Investigation, Engine Inspection Factual Notes
2. Field Notes, Examination of Autofeathering Units at UTAS Rosemount Aerospace, Burnsville, Minnesota, April 8-11, 2015
3. Technical document, Cable TQ sensor – AFU engine 1 & 2, X-Ray and macroscopic examination report, BEA2015-0039-tec08, 20/03/2015
4. Test results of torque and speed sensors

Appendix 1. ATR-72 Reg. B-22816 Accident Investigation, Engine Inspection Factual Notes

Pratt & Whitney Canada
Une société de United Technologies / A United Technologies Company

Service Investigation
Factual Notes

12 February 2015

Aviation Safety Council
Republic of China

Attn:
Director, Occurrence Investigation Division

Subject: ATR-72 Reg. B-22816 Accident Investigation, Engine Inspection Factual Notes.

Please find attached the subject factual notes for your review.

In brief summary of our observations, the nacelle fault isolation for uncommanded autofeather in accordance with the PW127 engine maintenance manual showed the trim plug characterization, the No. 1 torque sensor continuity, and the autofeather unit to torque sensor continuity to be correct. The next action stated in the fault isolation flow is replacement of the autofeather unit.

Boroscope inspection of the turbomachine showed no pre-impact anomalies affecting normal operation.

We will remain in close coordination for the on-going investigation of the engine controls and accessories.

Please regard that these observations are of a preliminary nature and may be altered or corrected on the basis of further information or analysis. A final report will be issued for the investigation.

If you have any questions or require any further information please do not hesitate to contact me at Tel:

Regards,

CC:

PRATT &WHITNEY CANADA

Service Investigation

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	ECCN or USML (ITAR) #	9E991
	P-ECCN or P-USML (Non US Origin)	

FACTUAL NOTES, POWERPLANT INSPECTION IN SUPPORT OF ACCIDENT INVESTIGATION OF ATR-72 REG. B-22816 PERFORMED FOR THE AVIATION SAFETY COUNCIL, REPUBLIC OF CHINA.

P&WC Ref. No.: 15-006

1. INVESTIGATION PARTICIPANTS

The powerplant inspection was conducted on 7-9 February 2015 at the facilities of Songshan Air Force Base, Taipei, Taiwan. The following individuals participated in the investigation as representatives of their respective organizations:

Aviation Safety Investigator
Occurrence Investigation Division
Aviation Safety Council, Republic of China

Investigator
Aviation Safety Division
Aviation Safety Council, Republic of China

Senior Technical Analyst
Operations Service Branch
Transportation Safety Board Canada

Civil Aviation Inspector
Transport Canada

Propulsion & Air Systems Director
Alenia Aeronautica EADS ATR

Field Service Representative
Pratt & Whitney Canada

Service Investigation
Pratt & Whitney Canada

2. LEFT HAND ENGINE HISTORY

PW127M S/N ED0913

Total Hours: 826

Total Cycles: 1236

The engine was installed on the subject aircraft following aircraft delivery due to a low oil pressure event with the original installed engine. Review of the engine logbooks showed no unusual maintenance.

3. LEFT HAND ENGINE EXAMINATION

All positional references in relation to view from aft looking forward. Upstream and downstream references are in relation to gas path flow from compressor inlet to exhaust.

3.1 External Condition

The engine was examined in the airframe nacelle as recovered. All quick engine change items and airframe nacelle to engine connections appeared to be intact, with water immersion damage. The propeller hub remained attached to the hub with the blade outer spans separated.

3.1.1 External Cases

Reduction Gearbox: The housing was intact. The propeller shaft was intact. The reduction gearbox mounted controls and accessories were intact.

Front Inlet Case: Displayed no apparent impact damage. The front inlet case mounted controls and accessories were in place and intact.

Rear Inlet Case/Accessory Gearbox: Displayed no apparent impact damage. The accessory gearbox mounted controls and accessories were in place and intact.

Low Pressure Diffuser Case: Displayed no apparent impact damage.

Intercompressor Case: Displayed no apparent impact damage.

Gas Generator Case: Displayed no apparent impact damage.

Turbine Support Case: Displayed no apparent impact damage. The fuel nozzle manifold was intact.

Please refer to photos No. 1 through 5.

Photo No. 1
Engine left hand view.

Photo No. 2
Engine right hand view.

Photo No. 3
Engine forward view.

Photo No. 4
Engine rear view.

Photo No. 5
Compressor inlet case, autofeather unit and engine electronic control, in-situ.

3.1.2 **Chip Detectors and Filters:**

Due to the flight data recorder information and post impact engine boroscope inspection showing no indications of any mechanical anomalies, the chip detectors and filters were not examined.

3.2 **Disassembly Observations:**

Due to the flight data recorder information showing no indications of any mechanical anomalies, the engine turbo machine was boroscope inspected in accordance with the PW127 engine maintenance manual by a technician from P&WC (S.E.A.) Ltd.

3.2.1 **Turbine Section:**

The turbine section components displayed no indications of any anomalies affecting normal operation, and all components observed showed normal running wear. All components showed water immersion damage. Please refer to photos No. 6 through 11.

Photo No. 6
Second stage power turbine.

Photo No. 7
First stage power turbine.

Photo No. 8
First stage power turbine vane ring.

Photo No. 9
Low pressure turbine.

Photo No. 10
High pressure turbine.

Photo No. 11
High pressure turbine vane ring.

3.2.2 **Combustion Section:**

The combustion section components displayed no indications of any anomalies affecting normal operation, and all components observed showed normal running wear. All components showed water immersion damage. Please refer to photo No. 12.

Photo No. 12
Combustion chamber liner.

3.2.3 **Compressor Section:**

The compressor section components displayed no indications of any anomalies affecting normal operation, and all components observed showed normal running wear. All components showed water immersion damage. Please refer to photos No. 13 and 14.

Photo No. 13
Low pressure impeller and shroud

Photo No. 14
High pressure impeller.

3.2.4 **Reduction Gearbox:**

The reduction gearbox components displayed no indications of any anomalies affecting normal operation, and all components observed showed normal running wear. All components showed water immersion damage. Please refer to photos No. 15 through 17.

Photo No. 15
Reduction gearbox second stage spur gears, detail.

Photo No. 16
Reduction gearbox helical input gearshaft and helical gear.

Photo No. 17
Reduction gearbox helical input gearshaft and helical gear.

3.2.5 **Accessory Gearbox:**

The accessory gearbox was not examined.

3.3 **Controls and Accessories Evaluation:**

The following listed components were removed and forwarded to Transportation Safety Board Canada for routing to their respective vendors for investigation and analysis under the oversight of Transportation Safety Board Canada or the United States National Transportation Safety Board as appropriate.

3.3.1 **Hydromechanical Control System**

Due to the flight data recorder information showing no indications of any anomalies the hydromechanical control system, these components were not removed.

3.3.2 **Electronic Control System**

Propeller Electronic Control: Hamilton Sundstrand Model EPC100-1, P/N 816332-5-401, S/N 13070018. The unit was re-immersed in fresh water and packed sealed in water for shipping. Please refer to photos No. 18 and 19.

Photo No. 18
Propeller Electronic Control.

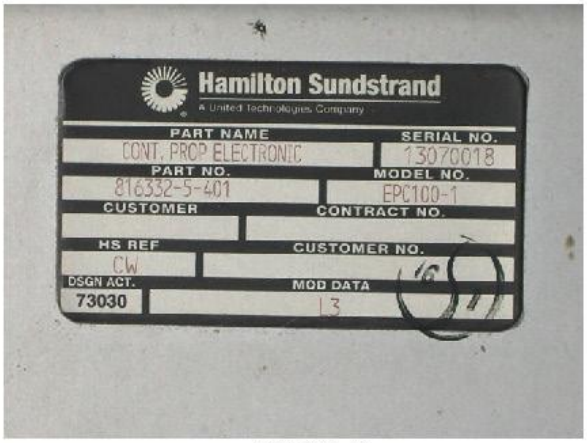

Photo No. 19
Propeller electronic control data plate.

Engine Electronic Control: Hamilton Sundstrand Model EEC132-190, P/N 1012974-002, P&WC P/N 3373309-4, S/N 14040035. Please refer to photos No. 20 and 21.

Photo No. 20
Engine electronic control.

Photo No. 21
Engine electronic control data plate.

Autofeather Unit: Rosemont P/N 30048-0000-28 Rev D, P&WC P/N 30048-0000 Rev. A RE55, S/N RT3077. Please refer to photos No. 22 and 23.

Photo No. 22
Autofeather unit and torque sensor No. 1.

Photo No. 23
Autofeather unit data plate.

Data Collection Unit: Safran P/N 62133, P&WC P/N 3075879-0, S/N 14019276. Please refer to photos No. 24 and 25.

Photo No. 24
Data collection unit.

Photo No. 25
Data collection unit data plate.

3.3.3 **Inlet Temperature and Torque Sensing Systems**

Torque Sensor No. 1: P/N 3073471-02, S/N CH1282. Please refer to photo No. 22.

Torque Sensor No. 2: P/N 3073471-02,S/N CH1734. Please refer to photo No. 23.

Photo No. 26
Torque sensor No. 2.

3.3.4 **Performance Indicating System**

Nh Sensor (upper): P/N 3077761-01,S/N CH2610. Please refer to photo No. 27.

Nh Sensor (lower): P/N 3077761-01,S/N CH2595. Please refer to photo No. 28.

Photo No. 27
Nh sensor upper.

Photo No. 28
Nh sensor lower.

NL Sensor: P/N 3033509, S/N CH21092. Please refer to photo No. 29.

Photo No. 29
Nl sensor.

NP Sensor: P/N3077761-01, S/N CH2615. Please refer to photo No. 30.

Photo No. 30
Np sensor.

3.3.5 **Ignition System**

No ignition system components were removed.

3.3.6 **Air System**

No air system components were removed.

4. RIGHT HAND ENGINE HISTORY

PW127M S/N ED0814

Total Hours: 1624

Total Cycles: 2352

The engine was original installation on the subject aircraft. Review of the engine logbooks showed no unusual maintenance.

5. RIGHT HAND ENGINE EXAMINATION

All positional references in relation to view from aft looking forward. Upstream and downstream references are in relation to gas path flow from compressor inlet to exhaust.

5.1 External Condition

The engine was examined in the airframe nacelle as recovered. All quick engine change items and airframe nacelle to engine connections appeared to be intact, with water immersion damage. The propeller hub remained attached to the hub with the blade outer spans separated. The nacelle aft section and exhaust duct was separated.

5.1.1 External Cases

Reduction Gearbox: The housing was intact. The propeller shaft was intact. The reduction gearbox mounted controls and accessories were intact.

Front Inlet Case: The front inlet case was crushed and the reduction gearbox was forced aft and upward into the engine mount structure. The torque sensor No. 1 probe was deformed due to impact fracture of the inlet housing mounting boss. The autofeather unit lower canon plug boss was deformed by impact. The rest of the front inlet case mounted controls and accessories were in place and intact

Rear Inlet Case/Accessory Gearbox: Displayed no apparent impact damage. The accessory gearbox mounted controls and accessories were in place and intact.

Low Pressure Diffuser Case: Displayed no apparent impact damage.

Intercompressor Case: Displayed no apparent impact damage.

Gas Generator Case: Displayed no apparent impact damage.

Turbine Support Case: Displayed no apparent impact damage. The fuel nozzle manifold was intact.

Please refer to photos No. 31 through 37, 55 and 58.

Photo No. 31
Engine left hand view.

Photo No. 32
Engine right hand view.

Photo No. 33
Engine forward view.

Photo No. 34
Engine rear view.

Photo No. 35
Compressor inlet case. Autofeather unit and engine electronic control, in-situ.

Photo No. 36
Compressor inlet case, right hand side.

Photo No. 37
Exhaust duct and power turbines.

5.1.2 **Chip Detectors and Filters:**

Due to the flight data recorder information and post impact engine boroscope inspection showing no indications of any mechanical anomalies, the chip detectors and filters were not examined.

5.2 **Disassembly Observations:**

Due to the flight data recorder information showing no indications of any mechanical anomalies, the engine turbo machine was boroscope inspected in accordance with the P&WC engine maintenance manual by a technician from P&WC (S.E.A.) Ltd.

5.2.1 **Turbine Section:**

The turbine section components displayed no indications of any anomalies affecting normal operation, and all components observed showed normal running wear. All components showed water immersion damage. Please refer to photos No. 38 through 43.

Photo No. 38
Second stage power turbine.

Photo No. 39
First stage power turbine.

Photo No. 40
First stage power turbine vane ring.

Photo No. 41
Low pressure turbine.

Photo No. 42
High pressure turbine.

Photo No. 43
High pressure turbine vane ring.

5.2.2 **Combustion Section:**

The combustion section components displayed no indications of any anomalies affecting normal operation, and all components observed showed normal running wear. All components showed water immersion damage. Please refer to photo No. 44.

Photo No. 44
Combustion chamber liner.

5.2.3 **Compressor Section:**

The compressor section components displayed no indications of any anomalies affecting normal operation, and all components observed showed normal running wear. All components showed water immersion damage. Please refer to photos No. 45 and 46.

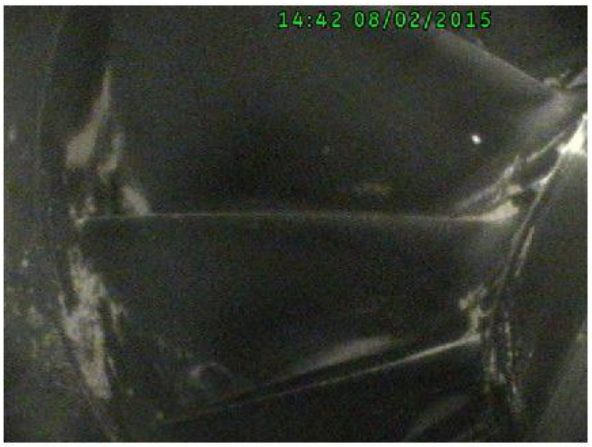

Photo No. 45
Low pressure impeller and shroud.

Photo No. 46
High pressure impeller.

5.2.4 **Reduction Gearbox:**

The reduction gearbox components displayed no indications of any anomalies affecting normal operation, and all components observed showed normal running wear. All components showed water immersion damage. Impact damage to the front inlet case prevented examination of the second stage spur gears. Please refer to photos No. 47 and 48.

Photo No. 47
Reduction gearbox helical input gearshaft and helical gear.

Photo No. 48
Reduction gearbox helical gear, detail.

5.2.5 **Accessory Gearbox:**

The accessory gearbox was not examined.

5.3 **Controls and Accessories Evaluation:**

On nacelle fault isolation for uncommanded autofeather in accordance with the PW127 engine maintenance manual showed the trim plug characterization, the No. 1 torque sensor continuity, and the autofeather unit to torque sensor continuity to be correct. Upon removal of the airframe harness canon plugs for the above checks both the torque probe and autofeather unit canon plugs showed slight water ingress to canon plug retaining collar. The connector pin seats appeared to be dry. The airframe harness was retained for separate investigation.

The following listed components were removed and forwarded to Transportation Safety Board Canada for routing to their respective vendors for investigation and analysis under the oversight of Transportation Safety Board Canada or the United States National Transportation Safety Board as appropriate.

5.3.1 **Hydromechanical Control System**

Due to the flight data recorder information showing no indications of any anomalies the hydromechanical control system, these components were not removed.

5.3.2 **Electronic Control System**

Propeller Electronic Control: Hamilton Sundstrand Model EPC100-1, P/N 816332-5-401, S/N 13080013. The unit was re-immersed in fresh water and packed sealed in water for shipping. Please refer to photos No. 49 and 50.

Photo No. 49
Propeller Electronic Control.

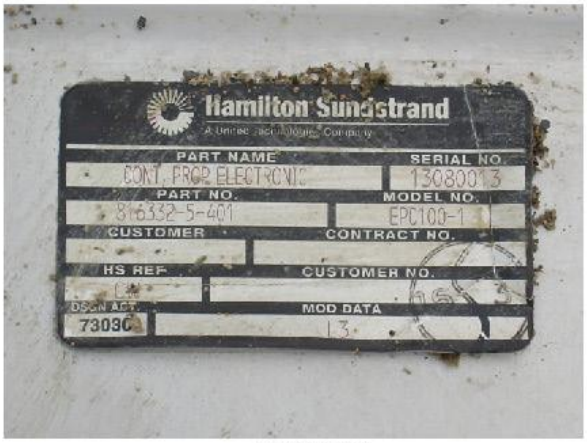

Photo No. 50
Propeller electronic control data plate.

Engine Electronic Control: Hamilton Sundstrand Model EEC132-190, P/N 1012974-002, P&WC P/N 3373309-4, S/N 13100020. The unit was re-immersed in fresh water and packed sealed in water for shipping. Please refer to photos No. 51 and 52.

Photo No. 51
Engine electronic control.

Photo No. 52
Engine electronic control data plate.

Autofeather Unit: Rosemont P/N 30048-0000-28 Rev D, P&WC P/N 3078166-01 S/N RT2362. The lower canon plug boss was deformed by impact. The unit was re-immersed in fresh water and packed sealed in water for shipping. Please refer to photos No. 53 through 55.

Photo No. 53
Autofeather unit.

Photo No. 54
Autofeather unit data plate.

Photo No. 55
Autofeather unit torque sensor canon plug fitting.

Data Collection Unit: Safran P/N 62133, P&WC P/N 3075879-0, S/N 13014743. Please refer to photos No. 24 and 25.

Photo No. 56
Data collection unit.

Photo No. 57
Data collection unit data plate.

5.3.3 **Inlet Temperature and Torque Sensing Systems**

Torque Sensor No. 1: P/N 3073471-01, S/N CH1468. Please refer to photo No. 58 and 59.

Photo No. 58
Torque sensor No. 1, in situ.

Photo No. 58
Torque sensor No. 1.

Torque Sensor No. 2: P/N 3073471-02,S/N CH1457. Please refer to photo No. 59.

Photo No. 59
Torque sensor No. 2.

5.3.4 **Performance Indicating System**

Nh Sensor (upper): P/N 3077761-01,S/N CH2108. Please refer to photo No. 60.

Nh Sensor (lower): P/N 3077761-01,S/N CH2106. Please refer to photo No. 61.

Photo No. 60
Nh sensor upper.

Photo No. 61
Nh sensor lower.

Nl Sensor: P/N 3033509, S/N CH20768. Please refer to photo No. 62.

Photo No. 62
Nl sensor.

NP Sensor: P/N3077761-01, S/N CH2128. Please refer to photo No. 63.

Photo No. 63
Np sensor

5.3.5 **Ignition System**

No ignition system components were removed.

5.3.6 **Air System**

No ignition system components were removed.

6.0 **CLOSING**

These factual notes are based upon observations made on 7-8 February 2015, and may be altered or corrected on the basis of further analysis or information.

PRATT & WHITNEY CANADA CORP.
Thomas A. Berthe
Service Investigation
12 February 2015

Appendix 2. Field Notes, Examination of Autofeathering

A. OCCURENCE

Location: Taipei, Taiwan
Date: February 4, 2015
Time: 1054 (local)
Aircraft: ATR72-212A ver 600 Reg. No. B -22816 TransAsia Airways flight GE235

B. PARTICIPANTS

Name	Representing
XXXXX	ASC, Taiwan
XXXXX	BEA, France
XXXXX	NTSB, USA
XXXXX	Transport Canada
XXXXX	TransAsia Airways
XXXXX	ATR
XXXXX	ATR
XXXXX	PWC
XXXXX	PWC
XXXXX	UTAS
XXXXX	UTAS
XXXXX	UTAS

C. SUMMARY

On February 04, 2015, TransAsia Airways (TNA) passenger flight GE235, an ATR72-212A aircraft, took off from Taipei bound for Kinmen. Just after take-off, the No. 2 engine propeller was feathered automatically. About 40 second later, engine No. 1 was manually shutdown. The aircraft crashed into Keelung River of Nankang section at 1053 Taipei time.

The UTAS Rosemount Aerospace autofeather units (AFUs) removed from the occurrence aircraft, and another AFU removed from an ATR72 aircraft that experienced an uncommanded autofeather event following the GE235 occurrence were tested at UTAS Rosemount Aerospace facilities in Eagan/Burnsville, Minnesota April 8 – 11, 2015.

D. HARDWARE

Removed from B-22816				
S/N	P/N	POS	J2 DOM (lot no.)	TSN / CSN
RT3077	30048-0000-28	1	1301	826 / 1,236
RT2362	30048-0000-28	2	1315	1,624 / 2,352

Removed from B-22806				
S/N	P/N	POS		TSN / CSN
RT2354	30048-0000-28	1	1315	1,180 / NP

E. OBSERVATIONS

CMM testing

Testing was performed in accordance with P/N 30048-0000-* CMM, Testing and Fault Isolation, 73-20-03R11. Detailed test data sheets are provided in a separate document.

AFU	RT3077	RT2362	RT2354
Continuity	NFF	Pin H ; Pin J (See Note 1.)	Pin J (See Note 1.)
Function	NFF	Not possible to	NFF

		complete (See Note 2.)	
Thermal cycle	NFF	-----	NFF
Vibration	NFF	-----	-----

Note 1 : A continuity failure was located at the end of the ribbon inside the 90° connector.
Note 2 : A short occurred approximately 10 minutes into the test.

Special tests

A test to more closely emulate the torque transducer operating voltage levels and temperatures was performed using AFU RT2354. 25V square wave was applied using CONFIG 1 and CONFIG2 (See Table). No leakage was found in either configuration.

	33 (H)	34 (J)	35 (U)
CONFIG 1	I	M	
CONFIG 2	M	I	M

I-input M-monitored

F. FURTHER ACTION

RT3077
No further investigation required. This AFU will be secured at UTAS until further notice.

RT2362
Repair of the 5v rail was discussed and the group decided against it.
The following destructive testing was proposed/recommended:
1. Perform 500v dielectric test
2. Section J2 ribbon/flex circuit 90° (“header strip”)
The work will be performed at UTAS Rosemount Aerospace. UTAS will submit a proposed protocol to the ASC for approval.

RT2354 (incident unit)
This unit is not evidence retained in connection with the GE235 occurrence. The same work recommended for RT2362 is also recommended for RT2354.

Appendix 3. Technical document, Cable TQ sensor – AFU engine 1 & 2, X-Ray and macroscopic examination report

BEA2015-0039_tec08
Date of issue 20/03/2015

Technical document

Cable TQ sensor - AFU engine 1 & 2

X-Ray and macroscopic examination report

Accident on **04/02/2015**
at **Taipei (Taiwan)**
to the **Aeroplane ATR - ATR72 - 200 - 212A (ATR72-600)**
registered **B-22816**
operated by **Transavia**

BEA

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

Ministère de l'Ecologie, du Développement durable et de l'Energie

Foreword

This document and the photographs and technical information contained herein are subject to the laws relating to communication and confidentiality embodied in European Regulation 996 of 20 October 2010.

The conclusions of this document are based on the work undertaken by the BEA (Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile). They should not be used to prejudge the final conclusions of the safety investigation.

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Glossary

AFU	Auto Feather Unit
TQ	Torque

1 - EQUIPEMENT EXAMINED

Following the accident of the ATR 72-212A registered B-22816, the following devices were sent by the ASC to the BEA.

	Cable TQ sensor 1- AFU engine 1	Cable TQ sensor 1- AFU engine 2
		
Manufacturer	ATR	ATR
Part number	44KF1-A	44KF2-A
ASC identification (Exm. Id)	65	66

For the investigation process, it was requested to check the cable in a non-destructive means. An X-Ray examination and a macroscopic examination were performed.

1.1. Connectors references

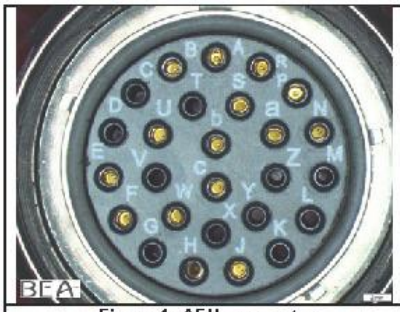

Figure 1: AFU connector

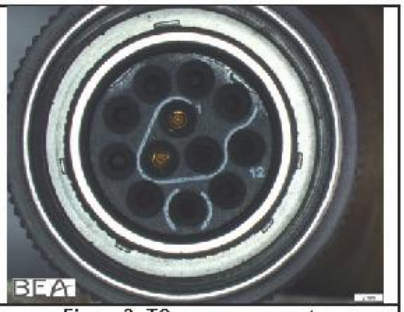

Figure 2: TQ sensor connector

The connection between the TQ sensor and the AFU is made through:

- pin N°1 and pin N°2 on the TQ sensor connector
- pin H and pin J on the AFU connector

2 - RESULTS

2.1. X-Ray examination

No defect was found on the cables:

- No wire damage/disruption
- Connection done between the female pin connectors and the wires on both end of the cable

The X-Ray pictures taken during this examination are provided in Appendix 1.

2.2. Macroscopic examination

The macroscopic examination showed a difference between the pin H of AFU connector on cable 2 and the other pins on this connector.

The following picture was taken with a magnification of 15.

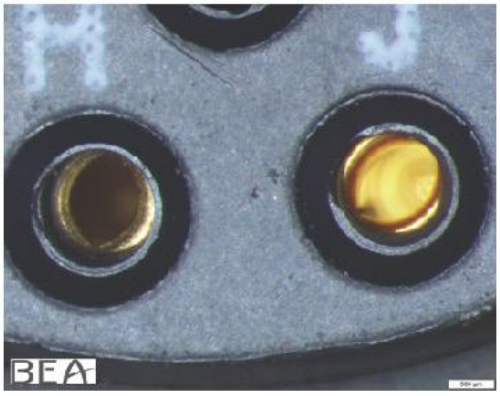

Figure 3: Pin H and J

The following pictures were taken with a magnification of 35.

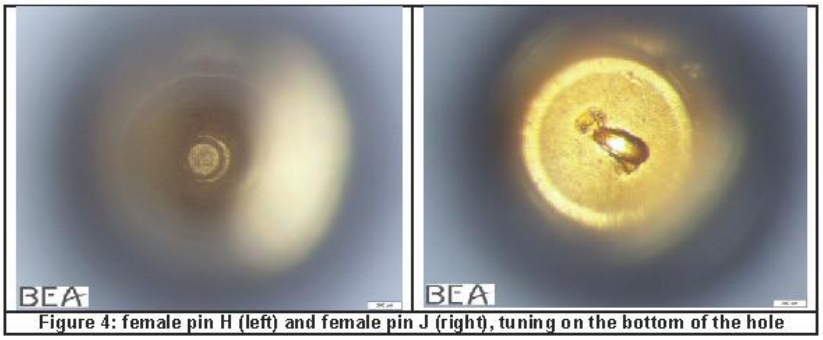

Figure 4: female pin H (left) and female pin J (right), tuning on the bottom of the hole

Pictures of the female pin H of cable 1 and the female pin 1 of TQ sensor (cable 2) were taken.

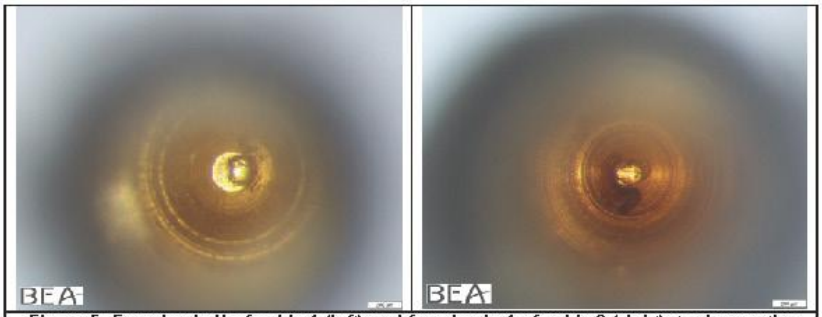

Figure 5: Female pin H of cable 1 (left) and female pin 1 of cable 2 (right), tuning on the bottom of the hole

All these macroscopic views do not allow us to conclude.

2.3. Additional examinations possibilities

All the additional proposed examinations may be considered as destructive examinations.

- Socket disassembly
  - Open the socket
  - Remove of the female pins from the connector
- Microscopic examination
  - Preparation of a longitudinal section of:
    - pin H
    - pin J
    - pin 1
  - Dimensional computation
  - Raw material determination.

Appendix 1. ***X-RAY EXAMINATION PICTURE***

X-Ray examination creates a 2 dimensional picture of the examined object. Depending on the raw material the X-Ray beam goes through, the voltage shall be adapted to spot the desired item. This does not allow taking picture of wire continuity when the surrounding raw material of the wire changes (e.g. when the cable crosses the boundary of a connector).
The continuity is then checked by the X-Ray machine operator, by increasing step by step the voltage.

A1.1. ***Cable picture***

Figure 6: typical RX picture of the cable between the 2 connectors

Both cables RX examination provide the same result. No defect was detected on these cables.

A1.2. ***Cable 1 (ASC identification: exm. Id. 65)***

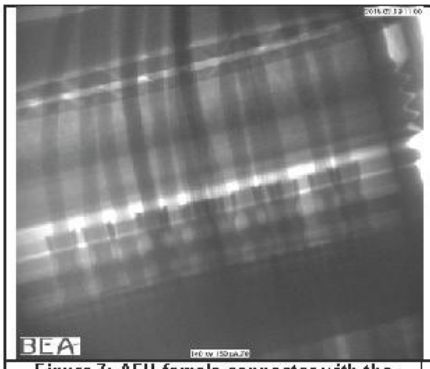

Figure 7: AFU female connector with the connections wire/female pins

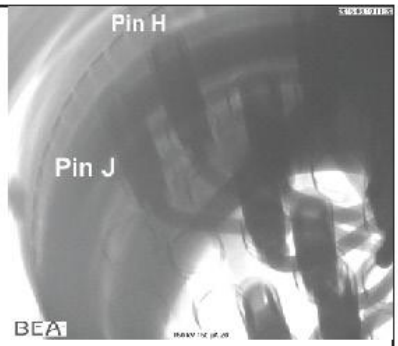

Figure 8: AFU connector: location of the connected pins

A1.3. ***Cable 2 (ASC identification: exm. Id. 66)***

TQ sensor connector

Figure 9: TQ sensor connector

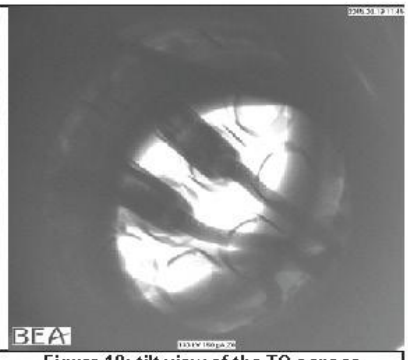

Figure 10: tilt view of the TQ sensor connector

Only 2 female pins are connected to wires (pins 1 and 2). No trouble with these connections was detected by this examination. The other holes of the connector are empty.

AFU connector

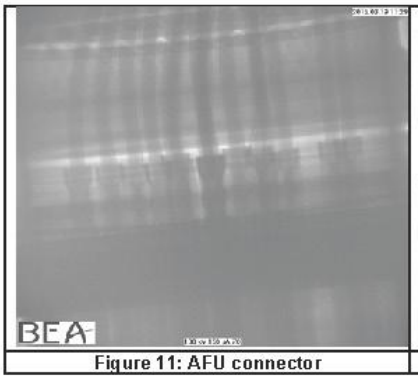

Figure 11: AFU connector

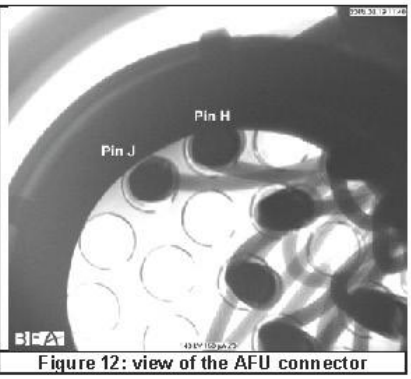

Figure 12: view of the AFU connector

Inside the AFU connector, 15 female pins are connected to wires. Their references are: A-B-E-F-H-J-N-P-R-S-U-W-a-b-c. No trouble with these connections is detected by this examination.
The other holes of the connector are empty (references: C-D-G-K-L-M-T-V-X-Y-Z).

BEA

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

Zone Sud - 200 rue de Paris
Aéroport du Bourget
93352 Le Bourget Cedex - France
T : +33 1 49 92 72 00 - F : +33 1 49 92 72 03
www.bea.aero

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Appendix 4. Test results of torque and speed sensors

No. 1 engine			
Accessary	P/N	S/N	Result
Torque sensor left	3073471-01	CH1282	Satisfactory
Torque sensor right	3073471-02	CH1734	1. Resistance check below minimum limit of 40 mega-ohms (note 1) 2. Test point voltage slightly below minimum limit of 1.5 volts
Np speed sensor	3077761-01	CH2615	1. Three resistance checks below minimum limit of 100 mega-ohms (note 1) 2. Resistance at each coil and between the coils and the housing was within limits but fluctuating (note 2). 3. One of the wires was detached from the pin.
Nh speed sensor (lower)	3077761-01	CH2595	1. Three resistance checks below minimum limit of 100 mega-ohms (note 1)
Nh speed sensor (upper)	3077761-01	CH2610	1. Resistance check below minimum limit of 100 mega-ohms
Nl speed sensor	3033509H	CH21092	Satisfactory
No. 2 engine			
Accessary	P/N	S/N	Result
Torque sensor left	3073471-02	CH1468	1. Open circuit exited in a coil winding resistance check. 2. Three test point voltages at different RPM settings were below minimum limit of 1.5/8.9/8.9 volts. 3. Voltage was erratic

			throughout this series of tests.
Torque sensor right	3073471-02	CH1457	1. Two test point voltages at different RPM settings were slightly below minimum limit of 1.5/8.9 volts.
Np speed sensor	3077761-01	CH2128	Satisfactory
Nh speed sensor (lower)	3077761-01	CH2106	Satisfactory
Nh speed sensor (upper)	3077761-01	CH2108	Satisfactory
Nl speed sensor	3033509H	CH20768	Satisfactory

Note

1. This test point was repeated after heating the sensor at 100° C then allowing it to cool to room temperature resulting in acceptable resistance.
2. Following heating of the sensor to 100° C and allowing it to cool to room temperature there were no open circuit existed.

V. Attachment

1. V-3000/15 - GE235 Answer to Action Log Revision #4 Toulouse, May 19th 2015
2. B-22816 Occurrence-Site Wreckage Field Notes
3. Technical document, AFUs tests, BEA2015-0039_tec10, 12/04/2015
4. AFU INVESTIGATION Document Number D06429311, Non Technical Rev A
5. Technical document, Computer MFC 1 and computer MFC 2 Memories readout, BEA2015-0039_tec11, 16/04/2015
6. Records of EEC, PEC NVM data downloads
7. ACCESSARIES ACCIDENT REPORT, document number RFA No 15ECN00082 SI File No: 15-006
8. Service Bulletin, P&WC SB No. 21742R2, Apr 01, 2011
9. Service Information Letter, P&WC SIL No. PW100-138, December 14, 2010
10. Service Information Letter, P&WC SIL No. PW100-147, September 26, 2011
11. Wreckage structure database
12. Wreckage LRUs database