NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

December 15, 2017

System's Group Chairman's Factual Report

NTSB ID No.: CEN17FA168

A. ACCIDENT:

Location:	Amarillo, Texas
Date:	April 28, 2017
Time:	2348 Central Daylight Time
Aircraft:	Pilatus PC-12, N933DC

B. GROUP MEMBERS:

Chairman:	Mike Hauf National Transportation Safety Board
Member:	Michael Foster Honeywell Aerospace
Member:	Markus Kohler Pilatus Aircraft Ltd.
Member:	Chris McVay Federal Aviation Administration

C. SUMMARY:

On April 28, 2017, about 2348 central daylight time, a Pilatus PC-12 airplane, N933DC, impacted terrain near Rick Husband Amarillo International Airport (AMA), Amarillo, Texas. The pilot and two medical flight crewmembers were fatally injured. The airplane was destroyed. The airplane was registered to and operated by Rico Aviation LLC, under the provisions of 14 Code of Federal Regulations Part 135 as an air ambulance flight. Instrument meteorological conditions prevailed at the time of the accident and the flight was operated on an instrument flight rules (IFR) flight plan. The flight was originating at the time of the accident and was enroute to Clovis Municipal Airport (CVN), Clovis, New Mexico.

D. DETAILS OF THE INVESTIGATION:

D.1 Airplane System Components Recovered On-Scene:

During the on-scene activities in Amarillo, Texas, the investigation team recovered and identified several aircraft system components from the accident site (Reference Table 1). These components were retained, placed in storage bags and shipped to Air Salvage of Dallas (ASOD) located in Lancaster, Texas for further disposition.

On May 22, 2017, the NTSB and two representatives from Honeywell convened at the ASOD facility to review the condition of the components identified in Table 2 and to determine where they should be sent for examination. The review determined that the Central Advisory Control Unit and the altitude preselector could not be tested due to the damage they sustained resulting from the impact, the Central Advisory Display Unit and the mode controller would be sent to the NTSB Materials Laboratory for light bulb filament analysis, the KMH 820 computer would be sent to the Honeywell facility located in Redmond, Washington for a download of its memory chip and the remaining components would be sent to the Honeywell facility located in Olathe, Kansas for testing and disassembly.

Table 1 System's components recovered from the accident site

COMPONENT	PART NUMBER	SERIAL NUMBER	EXAMINATION LOCATION
Central Advisory Control Unit (CACU) 97-2	N/A	3806	N/A
Central Advisory Display Unit (CADU) 91	972.81.32.006	7060	NTSB Materials Laboratory
Autopilot Mode Controller Bendix King KMC 321	XXX-008617*	1430	NTSB Materials Laboratory
KCP 220 Autopilot Computer	065-0064-X*	1898	Honeywell – Olathe, KS
Autopilot Pitch Servo	065-0056-59	5626	Honeywell – Olathe, KS
Autopilot Roll Servo	065-0015-XX*	7301	Honeywell – Olathe, KS
Autopilot Yaw Servo	065-0056-80	3600	Honeywell – Olathe, KS
Autopilot Pitch Trim Adapter Bendix King KTA 336	065-00164-0100	1794	Honeywell – Olathe, KS
Bendix/King KMH 820 Multi Hazard Awareness System	N/A	N/A	Honeywell – Redmond, WA
Altitude Preselector	065-0089-16	1481	Air Salvage of Dallas
AHRS LCR-92	124210-2011-003	1880	Northrop Grumman LITEF GmbH Freiburg, Germany

* The letter X indicates that the number on the data plate was unreadable.

D.2 Flight Control System - Description:

The airplane's primary flight control system for pitch, roll, and yaw is controlled by push-pull rods and/or cables, while the secondary flight control system for roll and yaw consists of electrically actuated trim tabs installed on the primary flight control surfaces, while the horizontal stabilizer is also trimmed electrically. Trim position for pitch, roll, and yaw is visually depicted on a triple trim indicator on the center console. The horizontal stabilizer, rudder, and aileron trim systems share a "Trim Interrupt Switch" which if pressed due to a trim runaway of any of the respective systems, disconnects power from the pitch trim adapter, and the aileron, rudder and horizontal stabilizer trim actuators. The switch is a rocker type installed on the center pedestal protected by a safety cover. The two-position switch has "INTR" for interrupt and "NORM" for normal positions.

D.3 Digital Flight Control System:

The accident airplane was equipped with a Honeywell (formerly Bendix/King) KFC-325 digital automatic flight control system (AFCS) which provides 3-axis control for pitch, roll and yaw. This system provides flight director (FD) guidance, autopilot (AP) functionality and autopilot system monitoring. This system consists, in part, of a single KCP 220 autopilot computer, a mode controller, an altitude preselector, a pitch trim adapter, pitch, roll, and yaw servo-actuators, a control wheel steering(CWS) switch, a go-around switch, autopilot disconnect switch, electronic attitude director indicator (EADI), and an electronic horizontal situation indicator (EHSI). The autopilot computer processes flight environment and navigation data from a variety of sensors to compute pitch and roll steering commands. The pilot provides input to the AFCS through the KMC 321 mode controller, located on the forward instrument panel.

D.3.1 Flight Director - Description:

When the flight director (FD) is engaged, it computes pitch and roll steering commands which are displayed on the pilot’s Electronic Flight Instrument System (EFIS). The FD mode controller provides a complete selection of flight director modes ranging from basic pitch attitude and wings level hold through advanced lateral navigation and vertical speed functions. Only one lateral and one vertical mode can be engaged at a time. Several methods are available to activate the FD; it is not necessary to press the FD pushbutton prior to selecting a flight director mode. Depressing any one of the following pushbuttons will activate the FD in the respective mode: HDG, NAV, APR, BC, ALT or IAS. Depressing the FD pushbutton or the control wheel steering (CWS) pushbutton on the yoke will activate the FD in a pitch attitude (synchronized to the current pitch) and wings level hold mode and will move the command bars into view. When the FD is operating with no lateral or vertical modes selected, the KFC 325 automatically engages in wings level and pitch attitude hold. When a mode is set on the mode controller the green engage or white armed captions show. The autopilot mode caption is also shown on the EADI.

D.3.2 Autopilot - Description:

The AFCS requires the successful completion of a pilot activated Preflight Test (PFT) as a prerequisite for autopilot mode engagement. The AFCS also requires the successful completion of a the KTA 336 Trim Adapter PFT as a prerequisite for trim engagement. A momentary depression of the self -test button on the mode controller will start a five second check of the functionality of the autopilot system, the auto trim system and their system monitors.

Indications to the pilot of a successful completion of the Pre-flight test is four flashes of the trim fail annunciator as the system is driven twice in each direction with the drive request being interrupted. This operation simulates a trim runaway and checks the ability of both monitors to detect it. After the test sequence, the aural warning tones are driven and the autopilot annunciator will flash twelve times. If the

PFT circuit detects a failure, the red TRIM caption stays on and on the Central Advisory and Warning System (CAWS) display unit the red A/P TRIM warning comes on.

Once the PFT has been completed, the pilot can engage the autopilot by depressing the AP pushbutton on the mode controller. When engaged, all the FD modes of operation are directed to the autopilot[1]. The autopilot will disengage when any of the following occur:

- On the mode controller, the AP pushbutton is pushed to turn off the autopilot.
- On the control wheels, the A/P DISC pushbutton is pushed.
- The trim trigger on either control wheel is depressed (manual trim engaged)
- The INTERRUPT TRIM switch is pushed.
- The ALTERNATE STAB TRIM switch is set to UP or DOWN.
- A loss of power to the autopilot computer or the trim adapter occurs
- The monitors within the autopilot computer detect a failure.
- The following autopilot monitor limit(s) are exceeded:
  - Roll rates more than 10 degrees per second (except when the CWS switch is held depressed)
  - Pitch rates more than 5 degrees per second (except when the CWS switch is held depressed)
  - Accelerations outside of a +1.6g to +0.3 envelope (1.0 g's being normal for straight and level flight) Disengagement will take place regardless of whether the CWS switch is activated

The autopilot computer continuously monitors autopilot operations through sensors that monitor the airplane's pitch attitude and accelerations, as well as autopilot servo motor operation. When the autopilot is disengaged, manually by the pilot or automatically when the monitors detect a problem, the following captions and warnings are displayed:

- On the mode controller, the AP caption flashes four times then goes off.
- On the CADU, the amber A/P DISENG caution message will illuminate 3 seconds after the signal input to the CAWS changes from 28V (A/P engaged) to 0V (A/P disengaged) and the Control Wheel Steer (CWS) button is not pressed. The caption will remain illuminated for about 26 to 27 seconds; it extinguishes at a maximum of 30 seconds from the initial time of the autopilot disconnect.
- On the EADI the red AP caption flashes five times then goes off.
- The autopilot disconnect warning tone is annunciated in the loudspeakers and the headsets.
- The CAWS gong warning-tone is annunciated.

The autopilot system incorporates an automatic electric pitch trim system which provides pitch autotrim during autopilot operation via the stabilizer pitch trim actuator, and automatic rudder trim relief function to provide directional trim during yaw damper and autopilot operation. No aileron autotrim function is available on the installed autopilot system. Annunciation of pitch and rudder autotrim occurs on the triple trim indicator by illumination of each respective pitch or rudder trim light, and annunciation to the CAWS to make the autopilot trim advisory caption illuminate. Reference section D.4.2.2 of this report for the annunciations that occur when an auto trim failure is detected.

According to Honeywell, the maximum bank angle that the autopilot can command is 25 degrees. Additionally, if the aircraft is in a steady state condition above 25 degrees of bank, or above the pitch limit[2], the autopilot will engage. However, upon engagement, the autopilot will bring the aircraft back to wings level maintaining the existing pitch attitude. If the aircraft is in a condition that exceeds the following autopilot monitor limit(s), (excessive "G" levels, excessive roll attitude rate, excessive pitch attitude rate), the autopilot will not engage.

[1] Note that the autopilot cannot be activated if the flight director is not operating properly.
[2] The pitch limits are dictated by the autopilot mode: IAS mode (+15° and -10°), PAH/VS mode (+20° and -10°), APR (+20° and -20°), ALT/ALT Capture (Rate limited).

- Roll rates more than 10 degrees per second (except when the CWS switch is held depressed)
- Pitch rates more than 5 degrees per second (except when the CWS switch is held depressed)
- Accelerations outside of a +1.6g to +0.3 envelope (1.0 g's being normal for straight and level flight)

If a pilot were to override the autopilot while it was engaged and the CWS switch was not depressed, the autopilot would attempt to return the aircraft to the state prior to the override condition. However, if the autopilot monitors are tripped while attempting to return to the previous state, the autopilot will disengage.

D.3.3 KMC 321 Mode Controller:

D.3.3.1 Mode Controller - Description:

As shown in Figure 1, the KMC 321 mode controller is equipped with twelve, push-on, push-off (buttons) that allow the pilot to select various flight director modes of operation (Table 2) and to engage the autopilot. Above each button is its respective mode annunciator, which will be illuminated if the corresponding mode is in the engaged mode.

Figure 1 Location of the mode controller

Photograph of the N933DC's instrument panel prior to the accident

Table 2 Description of mode controller modes

Mode	Description	Caption
HDG (Heading Select)	When this mode is selected, it alternately engages and disengages the heading select mode. Heading information is received from the position of the heading bug on the horizontal situation indicator (HSI) Depressing HDG will activate the flight director.	HDG (Green)
NAV (Lateral Navigation)	NAV captures and tracks selected navigation sensors. When this mode is selected, it alternately engages and disengages the Navigation mode. The flight director will command tracking of the coupled navigation receiver. Depressing NAV will activate the flight director.	NAV (Green) ARM (White)

APR (Guidance for Approach)	APR captures and tracks selected navigation sensors with approach accuracy. When this mode is selected, it alternately engages and disengages the Approach mode.	APR (Green) ARM (White)
AP	Alternately engages and disengages the autopilot. Yaw damper is automatically activated when the autopilot is engaged.	AP YD (Green)
BC (Back Course Localizer)	When this mode is selected, it alternately engages and disengages the Back Course Approach mode.	BC (Green)
ALT (altitude hold)	The altitude hold mode holds the current reference altitude mode. This mode commands the aircraft to maintain the pressure altitude existing at the moment of selection	ALT (Green)
IAS (indicated airspeed)	The indicated airspeed mode holds the current reference airspeed. The aircraft pitch command is varied by the flight director to maintain the selected airspeed during changing air conditions, power changes and/or aircraft configuration changes	IAS (Green)
FD	When this mode is selected, it engages the flight director in pitch attitude hold and wings level mode. The pitch attitude is synchronized to the current aircraft pitch attitude.	FD (Green)
TEST	When momentarily pressed, the pre-flight test button initiates the pre-flight test sequence.	Red TRIM caption

D.3.3.2 Mode Controller – Light Bulb Filament Analysis:

During the May 22, 2017 examination of the wreckage at ASOD, the Bendix King KMC321 Mode Controller, S/N 1430, was removed from its respective storage bag and visually inspected. Visual inspection revealed that the unit's case was crushed, its front plate was missing and many of the light bulbs remained in place. (Reference Figure 2) The unit was retained for lightbulb filament analysis; it was placed into a shipping container and shipped to the NTSB Materials Laboratory located in Washington D.C.

On June 21, 2017, a light bulb filament analysis was conducted on the unit at the NTSB Materials Laboratory by a Materials specialist. Except for the "HB" and "TRIM" annunciators, the analysis revealed that each annunciator light had one bulb. Each bulb was examined using a 5X to 50X zoom stereomicroscope. The status of the filament of each bulb is listed in Table 3 below

Figure 2 Photos of the mode controller

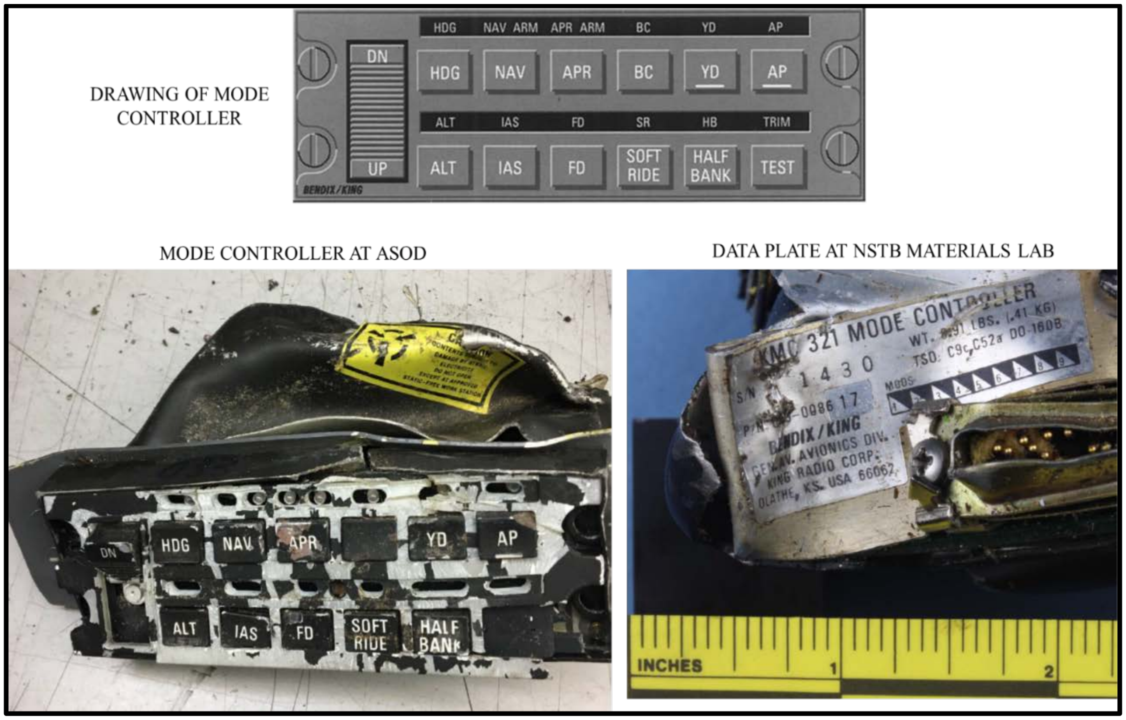


Table 3 Results of mode controller filament examination

Annunciator	Filament Analysis
HDG	Broken, not stretched, possible age-related sag
NAV - NAV	Broken bulb glass, no filament present
NAV - ARM	Broken, not stretched, possible age-related sag
APR - APR	Broken, not stretched
APR - ARM	Broken, not stretched
YD	Broken, not stretched
AP	Broken, not stretched
ALT	Broken, not stretched
IAS	Broken bulb glass, no filament present
FD	Broken bulb glass, no filament present
SOFT RIDE (SR)	Broken, not stretched, possible age-related sag
HALF BANK (HB)	Broken, not stretched
TRIM	Both bulbs-broken bulb glass, no filament present

D.3.4 Autopilot Computer:

The KCP 220 autopilot computer processes flight environment and navigation data to make control signals for the servo-actuators. The computer contains four microprocessors for logic, pitch, roll and yaw calculations and continuously performs a check for failures in the autopilot system. If a failure is detected, the autopilot computer sends signals to the mode control panel, the CAWS display unit and to the audio integrating system which provides a warning tone.

The autopilot computer was recovered from the storage bag on August 31, 2017, during an examination of the wreckage at ASOD. The unit was then sent to the Honeywell Aerospace facilities located in Olathe, Kansas for examination.

On October 5, 2017, an examination was conducted on the autopilot computer by Honeywell in the presence of the FAA and Honeywell. Reference Attachment 1.

D.3.5 Pitch Trim Adapter:

The autopilot Bendix King KTA 336 pitch trim adaptor processes the signals from the autopilot computer to control the horizontal stabilizer position when the autopilot is engaged.

During the May 22, 2017 examination of the wreckage at ASOD, the Bendix King KTA 336, S/N 1794, was removed from its respective storage bag and visually inspected. Visual inspection revealed that it showed only minor external damage. The unit was retained and sent to the Honeywell Aerospace facilities located in Olathe, Kansas for examination.

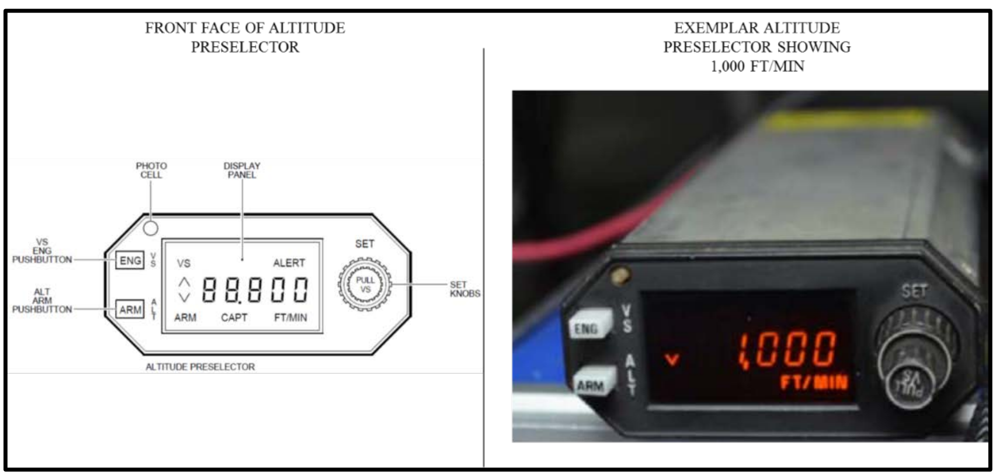
On June 21, 2017, examination and testing was conducted on the unit by Honeywell in the presence of the NTSB, FAA and representatives from Pilatus and Honeywell. Reference Attachment 1.

D.3.6 Altitude Preselector:

D.3.6.1 Description:

According to maintenance records, the airplane was equipped with an KAS 297C Altitude Preselector, having part number (P/N) 065-0089-16 and serial number (S/N) 1481. The altitude preselector controls the altitude alert, altitude select, vertical speed select and vertical speed hold modes. Reference Figure 3 for a photograph of an exemplar unit.

Figure 3 Altitude Selector - Exemplar Unit

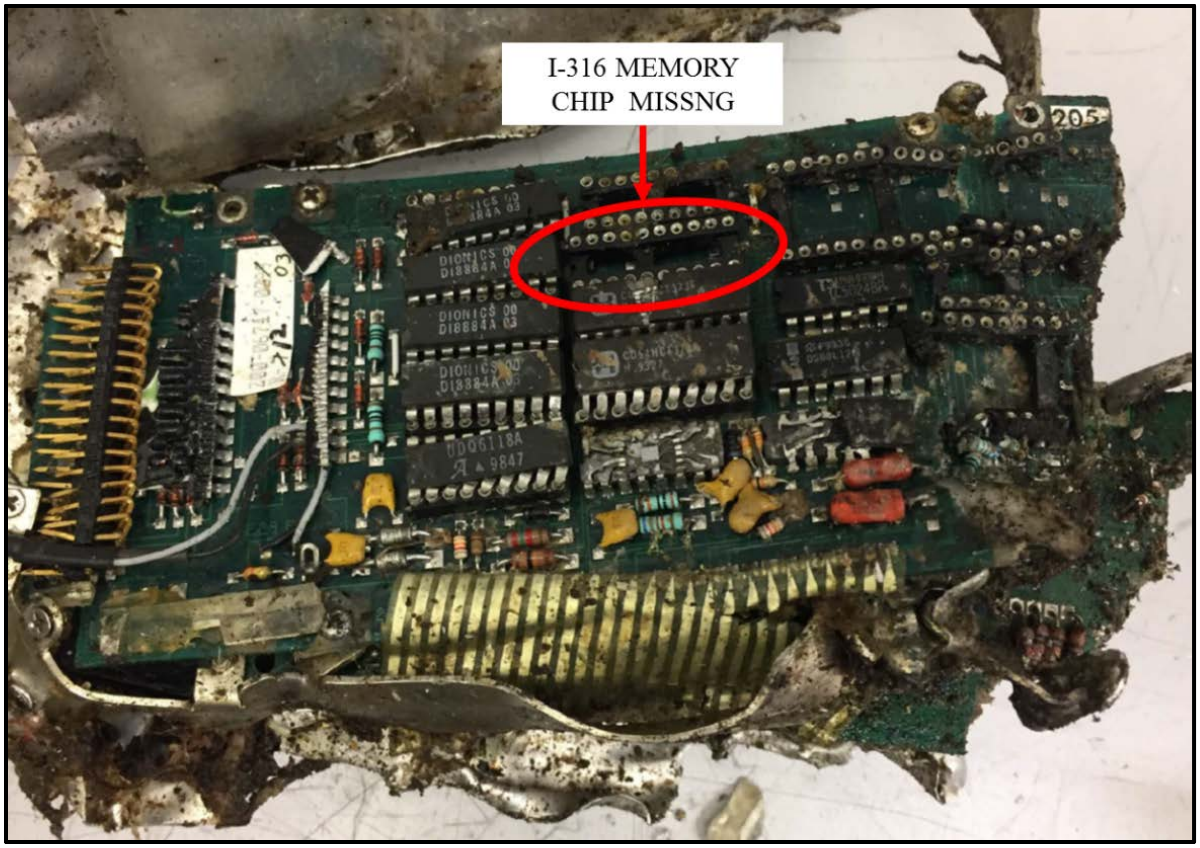


D.3.6.2 Examination:

On May 22, 2017, a visual inspection of the altitude preselector was conducted by Honeywell in the presence of the NTSB during an examination of the wreckage at ASOD. Because the unit had sustained severe impact damage, the purpose of the inspection was to locate its I-316 memory chip which would contain the last pre-selected altitude and vertical speed that were selected.

As shown in Figure 4, the inspection revealed that the I-316 chip was missing; it was not found attached to the circuit board.

Figure 4 Circuit board from the altitude preselector



D.3.7 Autopilot Servos:

During the May 22, 2017 examination of the wreckage at ASOD, the three autopilot servos (elevator, aileron and yaw) were removed from their respective storage bag, retained and sent to the Honeywell Aerospace facilities located in Olathe, Kansas for examination.

On June 21, 2017, examination and testing was conducted on the three autopilot servos by Honeywell in the presence of the NTSB, FAA and a representative from Pilatus. Reference Attachment 1.

D.4 Reported Issue with the Autopilot:

D.4.1 Description:

According to Operational Factors Interview Summaries[3], the Chief Pilot for Rico Aviation indicated that "there was a continuing issue with the accident airplane's autopilot." "It would often disconnect unexpectedly, triggering a master warning tone. It would require the pilot to reset the system by pushing the autopilot test button, then re-engaging the autopilot."

On April 26, 2017 (two days prior to the accident), the Chief Pilot for Rico Aviation captured the accident airplane's autopilot issue on video[4] during a flight. An NTSB summary of the video is described in Table 4.

Table 4 NTSB observations of video

Time (Seconds)	NTSB Observation of the Sequence of Events
0	Video begins with an Amber "A/P DISENG" caption illuminated on the CADU[5].
5	Pilot presses the "AP" button on the KMC321 mode controller.[6] • "A/P DISENG" light on the CADU extinguishes.
6	Pilot presses the "NAV" button on the KMC321 mode controller.
9	Pilot presses the "ALT" button on the KMC321 mode controller. • Indicated altitude is approximately 5,950 feet. • Indicated Vertical Speed is approximately 0.0
11	Indicated Vertical Speed begins to decrease (approximately -100 FPM)
11+	Indicated Altitude begins to decrease.
14+	Messages Displayed: • Red Trim warning displayed on KMC321 mode controller. • Red Master warning. • Red Trim Warning displayed on the CADU. • Blue trim indication displayed on CADU.
15	Blue trim indication displayed on the CADU extinguishes.
20	Pilot presses the "TEST" button on the KMC321 mode controller. • Red Trim warning on KMC321 mode controller extinguishes.
21	• Red Trim warning on KMC321 mode controller flashes • Blue A/P Trim illuminates on CADU Display
23	"A/P DISENG" light on the CADU panel illuminates
24	Red Trim warning on AP mode controller extinguishes
25	The following lights extinguish: • Red Master warning. • Red Trim warning on the CADU. • Blue trim indication displayed on the CADU.
29 (End)	"A/P DISENG" light on the CADU remains illuminated

[3] Reference Operational factors interview summaries located in the NTSB's public docket for accident number CEN17FA168.
[4] Reference Video titled "N933DC AP Disconnect Video - Apr 26, 2017" located in the NTSB's public docket for accident number CEN17FA168.
[5] Reference section D.5 titled "Central Advisory and Warning System (CAWS)" of this report for a description of the CADU.
[6] According to Pilatus, the action of the pilot pressing the autopilot button autopilot (AP) button at time = 5 seconds, is in contradiction to the Aircraft flight manual (AFM). The AFM in several instanced prohibits continued autopilot operation following abnormal operation or malfunctioning. Reference the Operation's Group Chairman's factual report.

D.4.2 Aircraft Testing:

D.4.2.1 Description:

Pilatus developed a comprehensive aircraft test plan[7] consisting of 16 individual system tests (Reference Figure 5) to evaluate the effects (autopilot status, timing of warnings and cautions) that a pitch trim adapter in an untested state would have on the autopilot operation. The tests, highlighted in orange in Figure 5, indicate hypothetical scenarios which would be in contradiction to the Aircraft flight manual (AFM) if the pilot performed them. Testing was performed on an exemplar Pilatus PC-12/45 airplane (MSN 362) in Olathe, Kansas on June 22, 2017.

Each of the 16 tests began with the successful completion of a pilot activated Preflight Test (PFT), which is a prerequisite for autopilot mode engagement. The first eight tests were conducted to determine the effects when the autopilot computer commanded pitch trim for the scenarios in which the autopilot was engaged after the pitch trim adapter had been configured in an untested state by removing power[8] (momentary and sustained) from the unit. Tests nine through sixteen were conducted to determine the effects when the autopilot computer commanded pitch trim for the scenario's in which the autopilot was engaged before the pitch trim adapter had been configured in an untested state by removing power[9] (momentary and sustained) from the unit.

D.4.2.2 Results:

Testing confirmed the expected results as described in the Pilatus test plan (Reference Attachment 2). The following paragraphs provide a brief (high level) summary of the results for test scenarios completed.

For the test scenarios in which the autopilot was engaged after the pitch trim adapter had been configured in an untested state by removing power[10] (momentary < 10 seconds) from the unit, the results indicated that:

- When power to the trim adapter was momentarily removed, no warnings or cautions were displayed on the mode controller or on the CADU.
- Autopilot and altitude (ALT) mode could be engaged with the normal annunciations displayed:
  - AP, YD and ALT illuminated in green on the mode controller.
- When AP pitch trim was commanded the following annunciations occurred:
  - The following three indications illuminated at the same time: 1) the Red Master Warning, 2) the red TRIM annunciator on the mode controller and 3) the red A/P TRIM annunciator on the CADU.
  - Continuous AP trim fail aural warning tone began:
- Pressing the AP disconnect button on the control yoke resulted in the following events:
  - The autopilot immediately disconnected and the green AP annunciator on the mode controller began to flash and the green YD and ALT annunciators extinguished.
  - After three (3) seconds, the AP DISENG caption illuminated on the CADU and the amber Master caution light illuminated.

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7 Reference Pilatus Test Plan located in the NTSB's public docket for accident number CEN17FA168.

8 For tests 1-4, power was removed from the pitch trim adapter by pulling its circuit breaker and for tests 5-8, power was removed by pressing the trim interrupt switch.

9 For tests 9-12, power was removed from the pitch trim adapter by pulling its circuit breaker and for tests 13-16, power was removed by pressing the trim interrupt switch.

10 For tests 1-4, power was removed from the pitch trim adapter by pulling its circuit breaker and for tests 5-8, power was removed by pressing the trim interrupt switch.

- After five (5) seconds, the green AP annunciator on the mode controller stopped flashing.
- After thirty-three (33) seconds, the AP DISENG extinguished on the CADU.
- Continuous AP trim fail aural warning tone remained on:

- Pressing the TEST button on the mode controller resulted in the silencing of the AP fail tone, the initiation and completion of the self-test and, once the self-test had completed, the extinguishing of all warnings.

For the test scenarios in which the autopilot was engaged after the pitch trim adapter had been configured in an untested state by removing power[11] (momentary > 30 seconds) from the unit, the results indicated that:

- Self-test completed.
- Power was momentarily removed from the trim adapter.
- At about 13.5 seconds after power was removed, the following three indications illuminated at the same time: 1) the Red Master Warning, 2) the red TRIM annunciator on the mode controller and 3) the red A/P TRIM annunciator on the CADU. No continuous AP trim fail warning tone occurred.
- Power to the trim adapter was restored and all red warning remained illuminated.
- Autopilot and altitude (ALT) mode could be engaged with the following displays:
  - AP, YD and ALT green annunciations illuminated on the mode controller.
- Because no AP trim could occur, the continuous AP trim fail warning tone never occurred.

For the test scenarios in which the autopilot was engaged before the pitch trim adapter had been configured in an untested state by removing power[12] (momentary < 10 seconds) from the unit, the results indicated that:

- Self-test completed and autopilot and altitude (ALT) mode were engaged.
- When power to the trim adapter was momentarily removed, the following events occurred:
  - The autopilot immediately disconnected upon removal of power and the green AP annunciator on the mode controller began to flash and the green YD annunciator extinguished.
  - Three (3) seconds after power was removed, the AP DISENG caption illuminated on the CADU and the amber Master caution light illuminated.
  - Five (5) seconds after power was removed, the green AP annunciator on the mode controller stopped flashing.
  - Thirty-three (33) seconds after power was removed, the AP DISENG extinguished on the CADU.
- Autopilot and altitude (ALT) mode could be re-engaged with the normal annunciations displayed.
- When AP pitch trim was commanded the following occurred:
  - AP remained engaged.
  - The following three indications illuminated at the same time: 1) the Red Master Warning, 2) the red TRIM annunciator on the mode controller and 3) the red A/P TRIM annunciator on the CADU.
  - Continuous AP trim fail warning tone was annunciated:
- Pressing the AP disconnect button on the control yoke resulted in the autopilot disconnecting and after three (3) seconds, the AP DISENG caption illuminated on the CADU and the amber caution light illuminated. The continuous AP fail tone remained on.
- Pressing the TEST button on the mode controller resulted in the silencing of the AP fail tone, the initiation and completion of the self-test and, once the self-test has completed, the extinguishing of all warnings.

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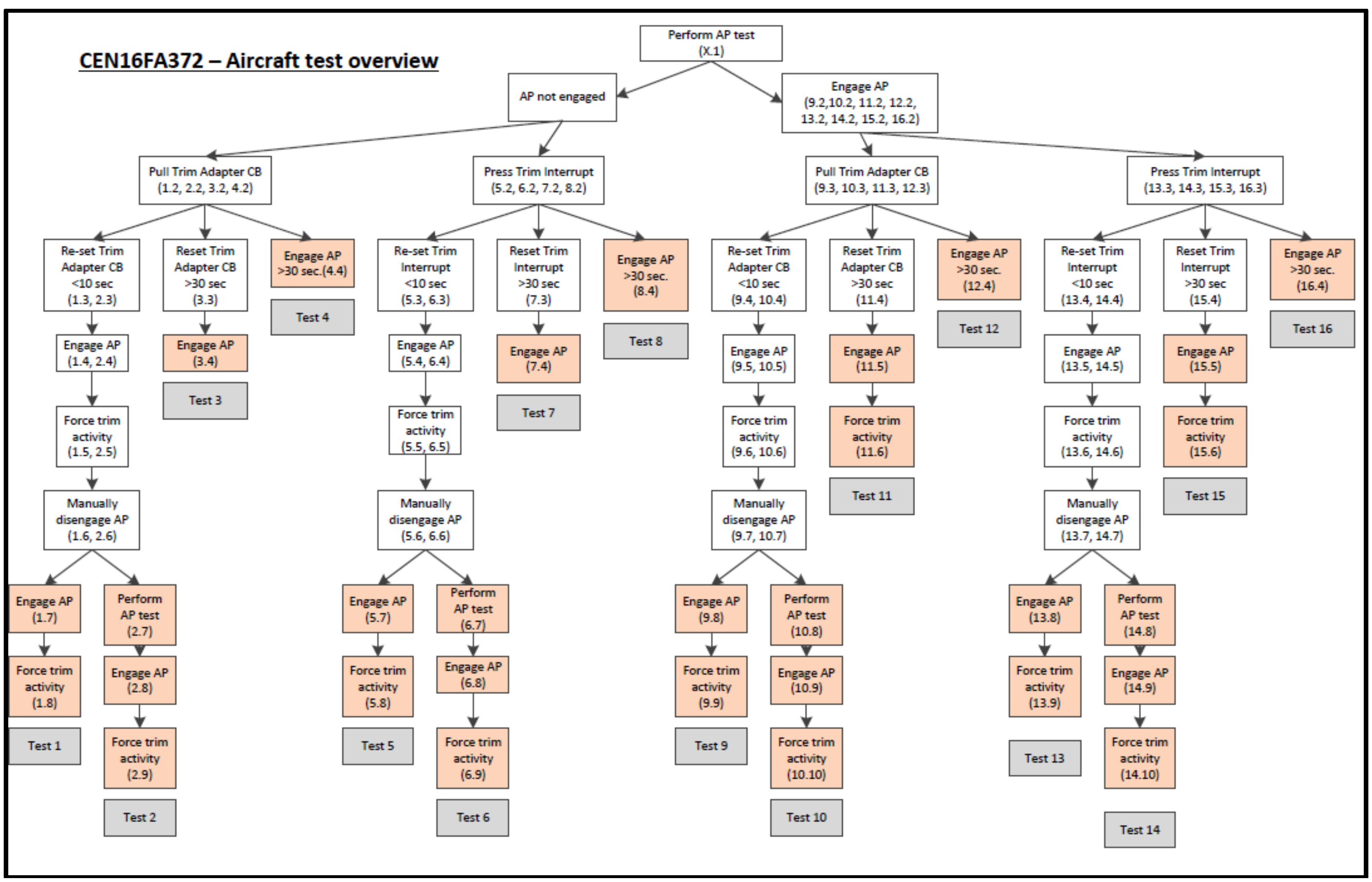
[11] For tests 1-4, power was removed from the pitch trim adapter by pulling its circuit breaker and for tests 5-8, power was removed by pressing the trim interrupt switch.

[12] For tests 1-4, power was removed from the pitch trim adapter by pulling its circuit breaker and for tests 5-8, power was removed by pressing the trim interrupt switch.

For the scenarios in which the autopilot was engaged before the pitch trim adapter had been configured in an untested state by removing power[13] (momentary > 30 seconds) from the unit, the results indicated that:

- Self-test completed and autopilot and altitude (ALT) mode were engaged.
- When power to the trim adapter was momentarily removed, the following events occurred:
  - o The autopilot immediately disconnected upon removal of power and the green AP annunciator on the mode controller began to flash and the green YD and ALT annunciators extinguished.
  - o Three (3) seconds after power was removed, the AP DISENG caption illuminated on the CADU and the amber caution light illuminated.
  - o Five (5) seconds after power was removed, the green AP annunciator on the mode controller stopped flashing.
  - o Thirteen and a half (13.5) seconds after power was removed, the following three indications illuminated at the same time: 1) the Red Master Warning, 2) the red TRIM annunciator on the mode controller and 3) the red A/P TRIM annunciator on the CADU.
  - o The continuous AP trim fail warning tone was not annunciated.
  - o Thirty-three (33) seconds after power was removed, the AP DISENG extinguished on the CADU.
- Autopilot and altitude (ALT) mode could be engaged with the following displays:
  - o AP, YD and ALT illuminated on the mode controller
  - o The red TRIM annunciator on the mode controller remained illuminated.

Figure 5 Test Scenarios



[13] For tests 1-4, power was removed from the pitch trim adapter by pulling its circuit breaker and for tests 5-8, power was removed by pressing the trim interrupt switch.

D.5 Central Advisory and Warning System (CAWS):

D.5.1 System Description:

The Central Advisory and Warning System (CAWS) continuously monitors the aircraft systems and provides an indication to the pilot when an abnormal situation occurs or when the correct operation of those aircraft systems which needs such an indication. The system includes a Central Advisory Control Unit (CACU), a Central Advisory Display Unit (CADU), and WARNING/CAUTION PUSH TO RESET lights.

The CACU, located under the cabin floor at frame 18, contains a microprocessor that receives and processes data from the aircraft systems. The front panel of the CADU, which is installed in the center of the middle instrument panel, can display 42 different messages which are divided into warnings (red), cautions (amber) or advisories (green) and auto systems (blue) conditions[14]. The messages are displayed by using incandescent lamps (two) which are installed behind a color filter and a foil with the legends. Reference Figure 6.

Figure 6 Drawing of CAWS display panel

PASS DOOR	CAR DOOR	CAB PRESS	AIR/GND	PROP LOW P	A/P TRIM
ESNTL BUS	AV BUS	STAB TRIM	OIL QTY	ENG FIRE	A/P DISENG
GEN 1 OFF	GEN 2 OFF	BUS TIE	PUSHER	FIRE DETECT	PUSHER ICE MODE
BAT OFF	INVERTER	BAT HOT	FLAPS	CHIP	N ESNTL BUS
L FUEL LOW	FUEL PRESS	HYDR	ECS	AOA DE ICE	R FUEL LOW
L FUEL PUMP	PASS OXY	DE ICE	INERT SEP	PROBES DE ICE	R FUEL PUMP
IGNITION	DE ICE BOOTS	WSHLD HEAT	PROP DE ICE	COOL	A/P TRIM

After power is supplied to the airplane, the CACU will perform a continuous check of the connections between the CACU and the CADU; it also processes the signals from various aircraft systems. To alert the pilot when a Warning or a Caution message is displayed on the CADU, a Red Master Warning or Amber Master Caution Light (located in the center of the instrument panel) is illuminated and an audio "gong" is annunciated in the flight compartment headsets and on the loudspeakers. The Master lights can be reset (press to reset) by the pilot to be rearmed for the next possible message.

The related caption on the CAWS display unit stays on until the signal from the aircraft system stops or the system is reset. When the CACU detects an advisory condition, it sends a signal to the CADU and the related caption on the CADU comes on. The caption stays on until the signal from the aircraft system stops. When the INSTR LIGHTING ADVISORY switch is set to DIM all the captions on the CAWS DISPLAY UNIT and the WARNING and CAUTION PUSH TO RESET lights become dim.

[14] The blue and green advisory captions show that a system is operating. A blue advisory light indicates an operating system that has high electrical power requirements or an automatic system.

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D.5.2 Background on the Development of the CAWS Control Unit:

The following paragraphs describe the background on the development of the CAWS control unit applicable to pre-10th series aircraft only (i.e. up to MSN 400).

The 10th series aircraft (> MSN 400) are equipped with a different CAWS computer (CACU) and display unit (CADU). Originally, all PC-12's up to S/N 230, (including the accident aircraft S/N 105) were equipped with a CACU91-2 or a CACU91-3 computer. The accident aircraft was equipped with a CACU97-2.

In 2003 Pilatus issued Service Bulletin (SB) 31-005 to replace the CACU 91 computer with a CACU97-2 computer. The functional difference is that in the CACU 91 computer, the engine CHIP light is suppressed in flight and only activates at landing, if triggered by the chip detector. On the CACU97-2 computer, the engine CHIP light will also illuminate in flight if triggered by the chip detector. Otherwise, the CACU 97 computer is a form-fit-function replacement. The CADU was not changed and retained the designation (CADU91).

Pilatus classified the SB as mandatory, but neither the Swiss FOCA or the FAA have issued an airworthiness directive (AD) against it. Therefore, the CACU91-2 and CACU91-3 computer are still acceptable.

At autopilot disengagement, the functionality within the CACU97-2 computer results in the A/P DISENG caption illuminating after a delay of 3 seconds (so that the CAWS gong does not interfere with the A/P mode controller disconnect warn tone) and extinguishing 30 seconds after the occurrence of the disconnect event.

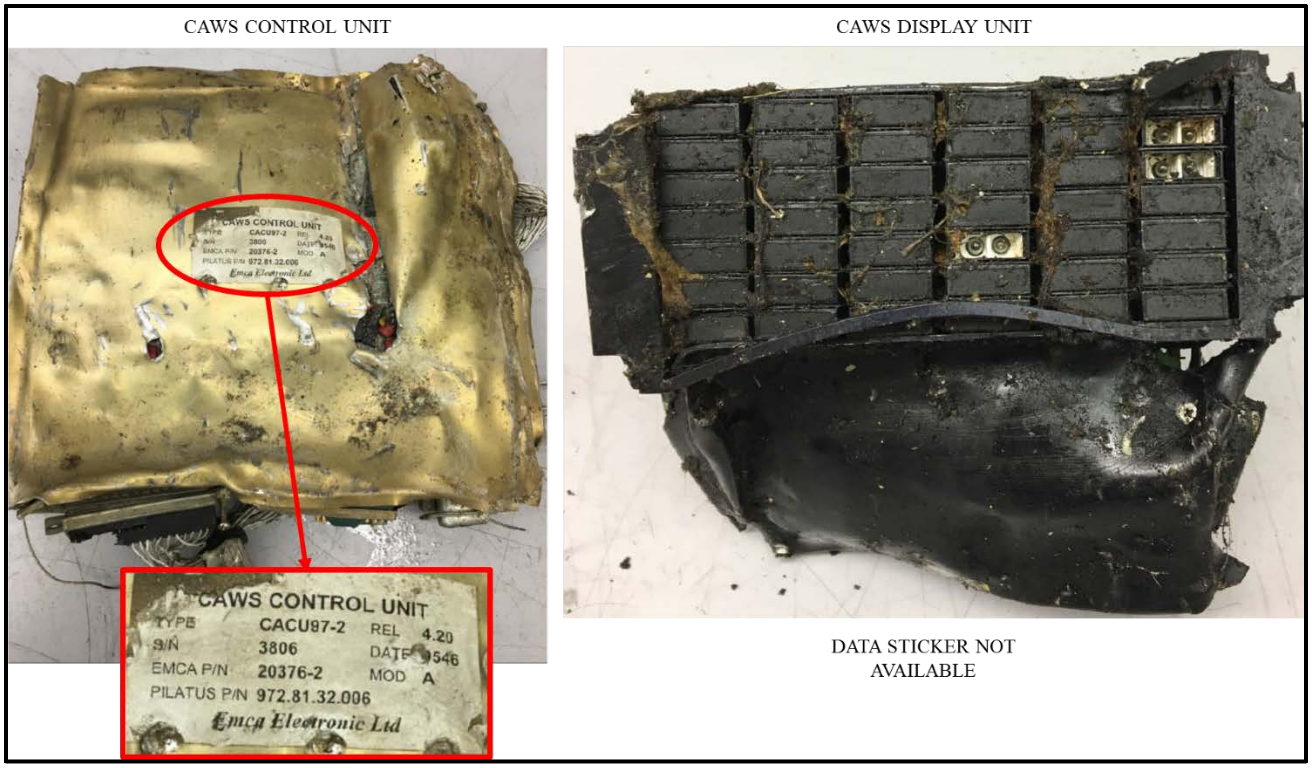
D.5.3 CACU and CADU Examination:

During the May 22, 2017 examination of the wreckage at ASOD, the CADU and the CACU were removed from their respective storage bag and visually inspected.

As shown in Figure 7, the CACU97-2, S/N 3806, was found damaged (crushed) such that it could not be functionally tested.

The casing of the CADU, S/N 7060, was found severely distorted and three annunciation covers were found missing. The unit was submitted to the NTSB Materials Laboratory located in Washington D.C. for filament analysis on each of the annunciator lights.

Figure 7 CAWS Components



On June 21, 2017, a light bulb filament analysis was conducted on the CADU at the NTSB Materials Laboratory by a Materials specialist. The analysis revealed that each annunciator light had two bulbs. Because of the arrangement of the lights (seven rows), radiography of the panel was not possible. Each bulb was therefore examined using a 5X to 50X zoom stereomicroscope and the results of the examination are described in Table 5. For the annunciators in which the filaments were identified as being stretched and possibly stretched, Table 6 provides information on the condition(s) that would have to occur for the filaments to be stretched. Additionally, Figures 8, 9, and 10 show photos of the A/P DISENG, PUSHER, and A/P TRIM (RED) lightbulbs respectively.

NOTE: For the bulb filaments labeled, “BROKEN, POSSIBLY STRETCHED”, the filament was totally fragmented and there were insufficient coil sections to make a firm conclusion as to the state of the filament.

Table 5

Annunciator	Bulb Number 1	Bulb Number 2
PASS DOOR	Broken, not stretched	Broken, not stretched
ESNTL BUS	Intact, not stretched	Broken, not stretched
GEN 1 OFF	Broken, possibly stretched	Broken, possibly stretched
BAT OFF	Broken, not stretched	Broken, not stretched
L FUEL LOW	Broken, not stretched	Intact, not stretched
L FUEL PUMP	Intact, not stretched	Intact, not stretched
IGNITION	Intact, not stretched	Intact, not stretched
CAR DOOR	Broken, not stretched	Broken, not stretched
AV BUS	Broken, not stretched	Broken, not stretched
GEN 2 OFF	Broken, not stretched	Broken, not stretched
INVERTER	Intact, not stretched	Broken, not stretched
FUEL PRESS	Broken, not stretched	Broken, not stretched
PASS OXY	Intact, not stretched	Intact, not stretched
DE ICE BOOTD	Intact, not stretched	Intact, not stretched

CAB PRESS	Intact, not stretched	Intact, not stretched
STAB TRIM	Intact, not stretched	Intact, not stretched
BUS TIE	Broken, not stretched	Intact, not stretched
BAT HOT	Bulbs missing	Bulbs missing
HYDR	Filament fused, burned out	Broken, not stretched
DE ICE	Broken, not stretched	Intact, not stretched
WSHLD HEAT	Intact, stretched	Broken, stretched
AIR/GND	Bulb glass broken, no filament	Broken, not stretched
OIL QTY	Broken, not stretched, possible age related sagging	Intact, not stretched
PUSHER	Intact, stretched	Intact, stretched
FLAPS	Intact, not stretched	Broken, not stretched
ECS	Broken, not stretched	Intact, not stretched
INERT SEP	Broken, possibly stretched	Broken, possibly stretched
PROP DE ICE	Broken, not stretched	Broken, not stretched
PROP LOW P	Intact, possibly stretched (could be sag)	Intact, possibly stretched (could be sag)
ENG FIRE	Broken, not stretched	Intact, not stretched
FIRE DETECT	Intact, not stretched	Intact, not stretched, possibly age related sag
CHIP	Broken, not stretched	Broken, not stretched
AOA DE ICE	Broken, not stretched	Broken, not stretched
PROBES DE ICE	Intact, stretched	Intact, stretched
COOL	Broken, not stretched	Bulb broken, no bulb
A/P TRIM	Broken, not stretched	Broken, not stretched
A/P DISENG	Intact, stretched	Intact, stretched
PUSHER ICE MODE	Broken, not stretched	Broken, not stretched
N ESNTL BUS	Intact, not stretched	Broken, not stretched
R FUEL LOW	Intact, not stretched	Broken, not stretched
R FUEL PUMP	Broken, not stretched, age related sag	Broken, not stretched
A/P TRIM	Broken, not stretched	Broken, not stretched

Table 6

Annunciator	Condition
WSHLD HEAT	The pilot and copilot windshield heaters are controlled by one each controller which can be individually set to OFF, Light or Heavy. Each controller provides a signal to the CAWS indicating its status. The signal conditions are as follows: • Heater OFF Open = caption OFF • Heater set to LIGHT or HEAVY Ground = caption ON The signals are paralleled into the CAWS meaning that one normally working controller is sufficient to illuminate the caption. As part of the TAXI checklist, the AFM instructs to select both windshield heaters to either "LIGHT" and "HEAVY" as required. In both settings, the "WSHLD HEAT" caption illuminates.
PUSHER	An illuminated pusher caption indicates the following: 1) a pusher system malfunction, 2) the system had not been pre-flight tested as required by the AFM, or 3) that the pilot pressed the Pusher interrupt button. It is not indicative of Pusher activation. Pressing the interrupt button on the control yoke (pilot or copilot) illuminates the caption with a delay of three seconds. It remains active as long as the button is pressed and extinguishes as

	soon as the interrupt button is released. Pressing the pusher interrupt switch does not have any effect on an engaged autopilot or its annunciations.
PROBES DE ICE	The green "Probes De Ice" caption indicates that the "De Ice Probes" switch had been set to ON and that the pitot/static heating functioned properly. The same switch also controls the two relays providing power to the AOA vane and plate heaters. Switching the "Probes De Ice" to ON prior take-off is required by the AFM, Sec. 4, 4.18 (14).
A/P DISENG	The amber A/P DISENG caution message will illuminate 3 seconds after the signal input to the CAWS changes from 28V (A/P engaged) to 0V (A/P disengaged) and the Control Wheel Steer (CWS) button is not pressed. The caption will remain illuminated for about 26 to 27 seconds; it extinguishes at a maximum of 30 seconds from the initial time of the autopilot disconnect. The signal input to the CAWS is the pitch/roll clutch command from the KFC 325 flight control computer which changes from 28V to 0V (thereby opening the servo clutches) when the A/P is disengaged or CWS is pressed. Consequently, the status of the YD is not monitored by this signal and disconnection of the YD only will not illuminate the "A/P DISENG" caption. Depending which means are used to manually disengage the AP/YD, a previously active YD may or may not remain engaged. "A/P DISC" button on yoke: AP, YD, FD and any mode indications extinguish "AP" button on mode controller: AP only disconnects, FD and YD remain lit Normal aircraft operating practice is to engage the YD shortly after take-off. Engaging the Autopilot via the AP button on the Mode controller also engages the YD. Pressing the A/P DISC button on the yoke while the Autopilot is not engaged will not illuminate the A/P DISENG caption. Activation of the stall protection system, e.g. an active shaker, will disengage an active Autopilot but not an active YD.
GEN 1 OFF	When Generator 1 goes off-line, the non-essential bus is automatically load-shed (it goes off-line) and would be annunciated with a "N ESNTL BUS" caution. The filaments for this annunciator were both found not stretched.
INERT SEP	An illuminated "INERT SEP" caption indicates that the actuator operating the inertial separator door was in the open position and was providing a ground signal to the CAWS system. An open inertial separator may reduce the take-off performance and is therefore on ground typically only selected open either on a gravel runway or if a flight into known icing conditions is expected. According to the AFM, if icing conditions are expected, set the de-icing switches to the following: • PROP – On • INERT SEP – Open • BOOTS – 3 min or 1 min as required • LH and RH WSHLD switches – Light or heavy as required. According to Pilatus, with the propeller heat ON together with an open inertial separator places the stickpusher system into "Ice Mode" with the associated caption "PUSHER ICE MODE" illuminated. Neither the "PUSHER ICE MODE" filaments nor the green "DE ICE BOOTS" filaments were found stretched.
PROP LOW P	The CAWS annunciator PROP LOW P will illuminate when the propeller pitch is less than 6° (minimum pitch in flight) and the airplane is not on the ground. The signal is provided by a switch installed on the gearbox of the engine which senses the position of the beta-ring. The signal condition is OPEN for no caution and GROUND for caution active. No delay either illuminating or extinguishing the warning is incorporated. The field investigation, by Hartzell, of the propeller determined a blade angle of 28° to 34° e.g. considerably away from the low pitch warning setting.

Figure 8 Photos of A/P DISENG lightbulbs

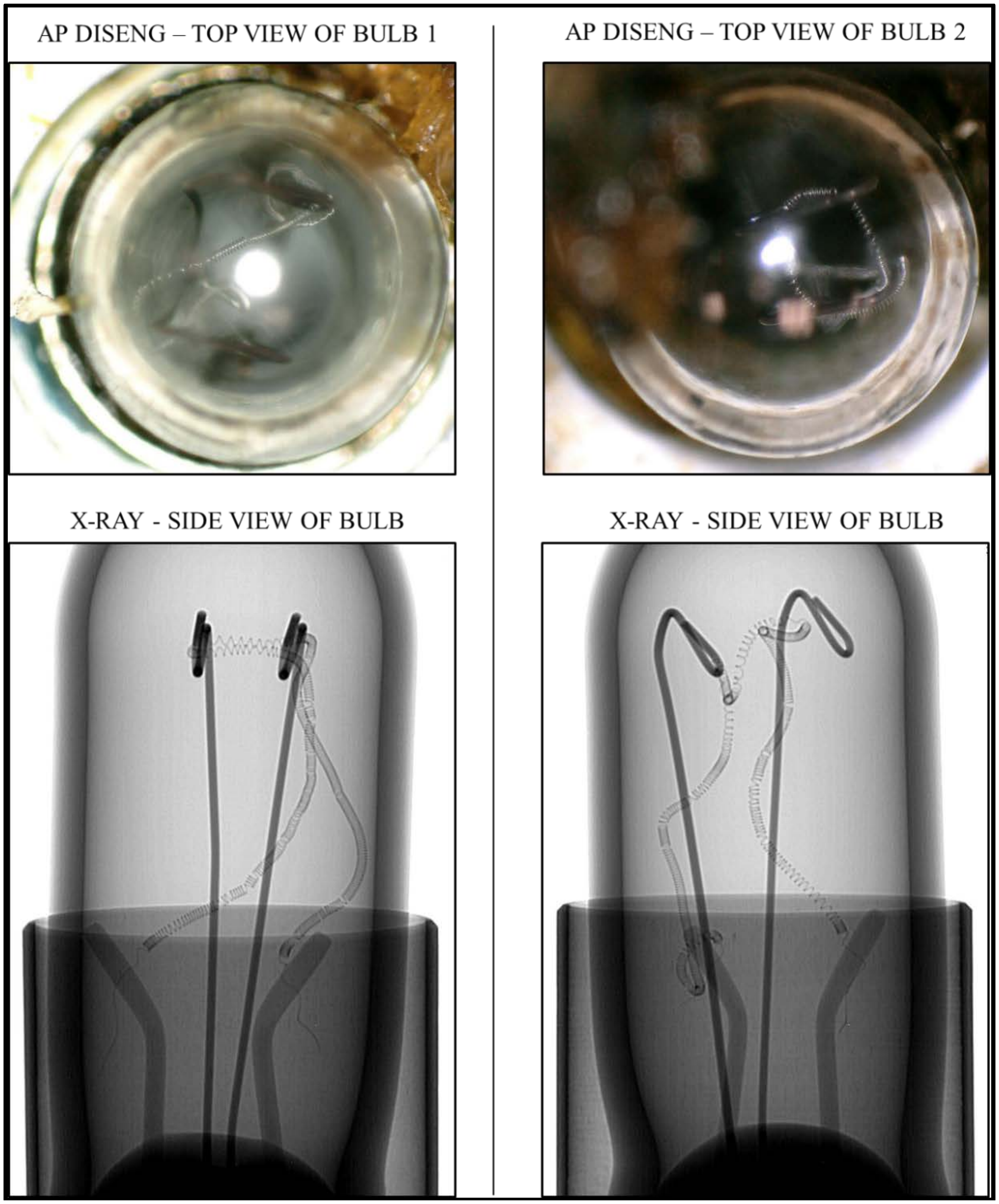


Figure 9 Photos of PUSHER lightbulbs

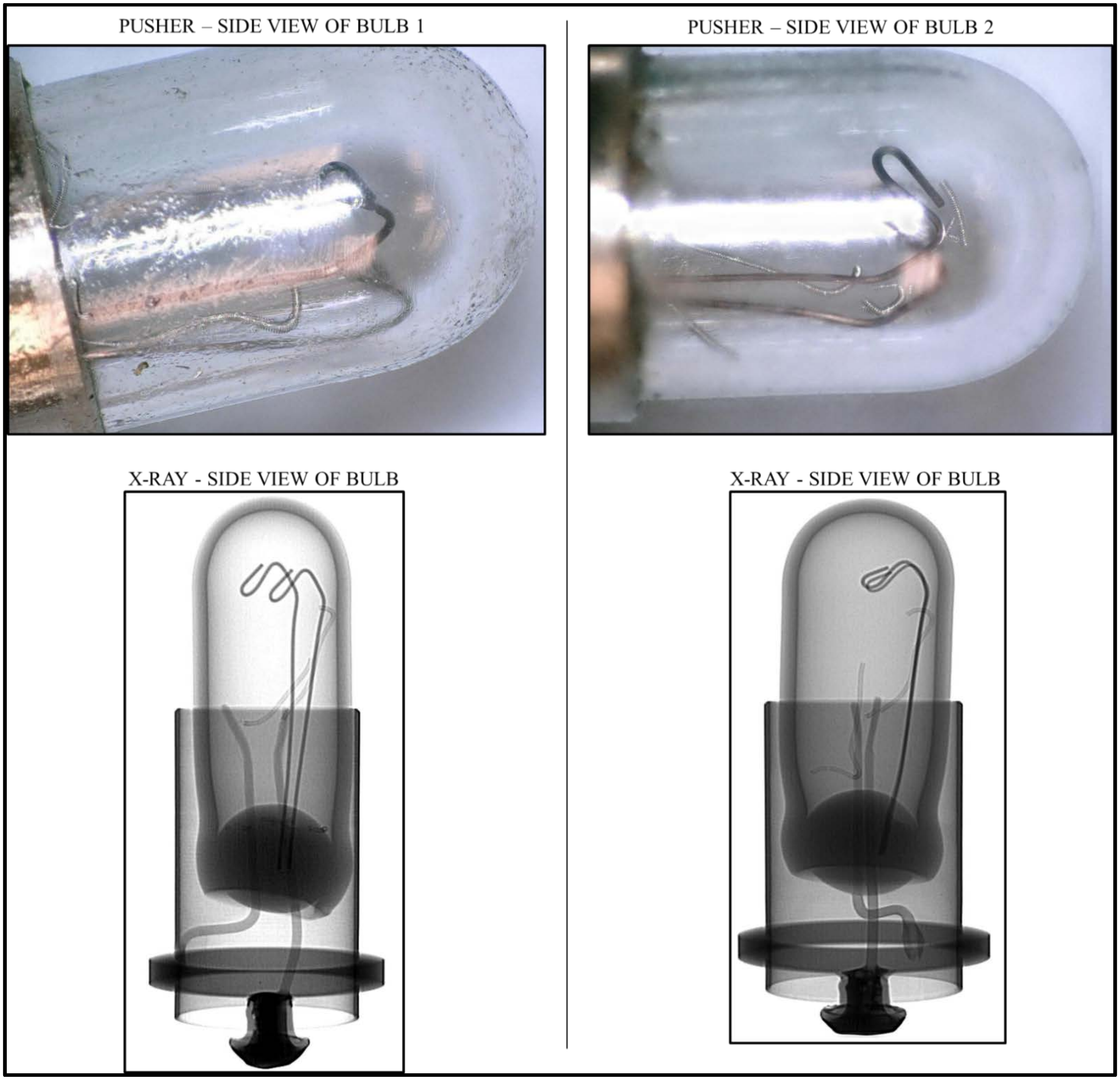
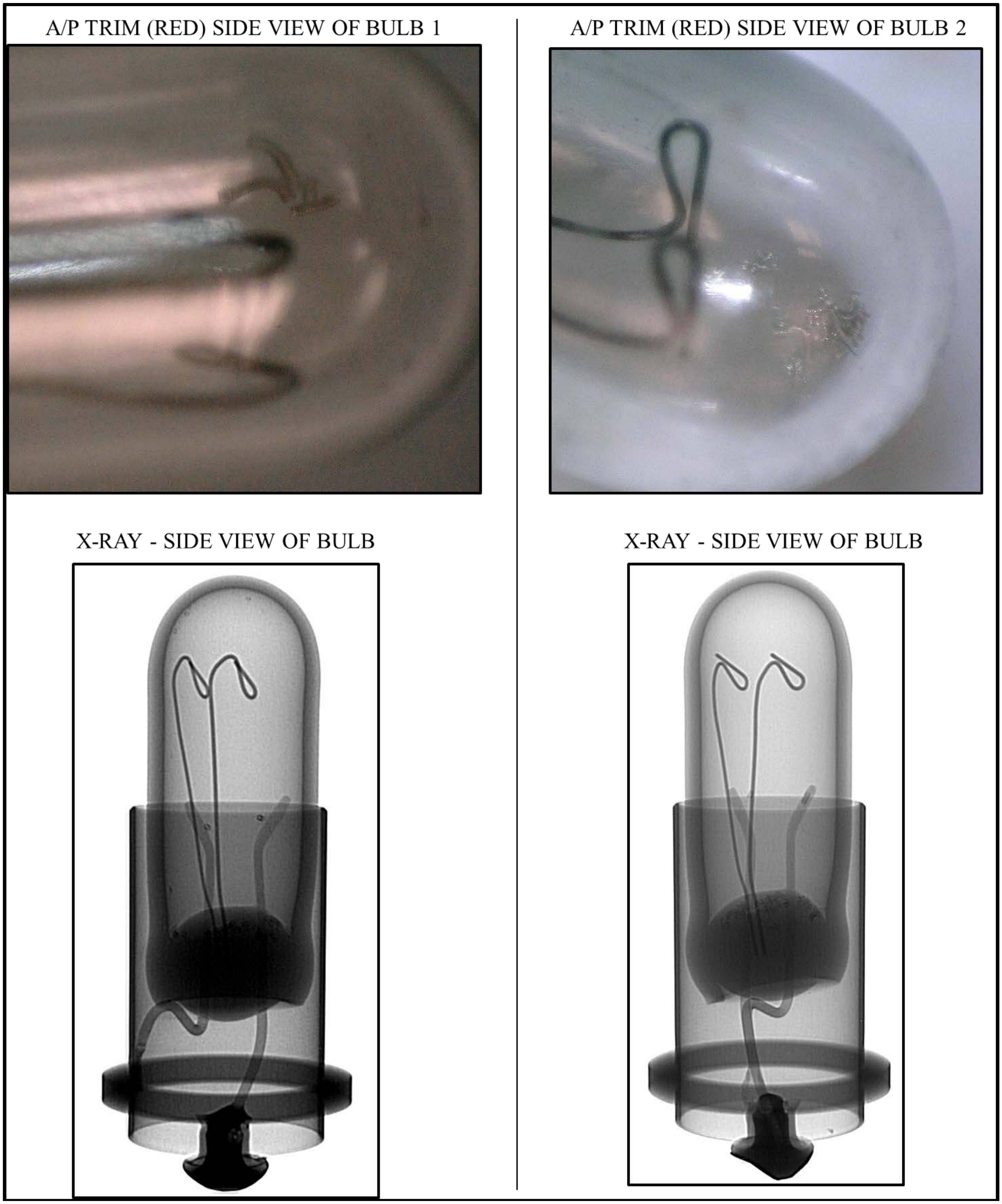


Figure 10 Photos of AP TRIM (RED) lightbulbs



D.6 Attitude and Heading Reference System (AHRS):

D.6.1 System Description:

The Attitude and Heading Reference System (AHRS) senses the magnetic heading of the aircraft and its pitch, roll and yaw attitudes. The AHRS processes the data and gives it to other aircraft systems to use for display and control. An attitude and heading reference unit (AHRU) is one of the components of the AHRS.

The AHRU is a rectangular box that contains fiber-optic gyros and electrolytic tilt sensors; it is installed below the floor, on the centerline, between frame 24 and frame 25. The AHRU processes light axes signals from the fiber optic gyros to calculate the aircraft attitude. It also processes the magnetic heading data from the flux valve to use as a long term magnetic heading reference.

In part, the AHRS sends data to the Electronic Flight Instrument System (EFIS), the autopilot, the Traffic Alert and Collision Avoidance System (TCAS), if installed, and the Enhanced Ground Proximity Warning System (EGPWS).

The AHRU has built-in test equipment (BITE) that continuously monitors the AHRS. The memory of the AHRU keeps a history of the failures that occur. If a power failure occurs the memory of the AHRU keeps the last available satisfactory data.

D.6.2 Examination and Data Extraction:

At the time of the accident, the airplane was equipped with a Northrop Grumman LITEF GmbH AHRU LCR-92, P/N 124210-2011-003, S/N 1880 computer. The computer was located and recovered from the wreckage on May 22, 2017, during an examination of the wreckage at ASOD. The unit was shipped to the Northrop Grumman LITEF GmbH facility located in Freiburg, Germany for examination. The purpose of the examination was to download recorded fault information from memory chips located within the unit. Northrup conducted the examination on August 8, 2017 with oversight by the German BFU (Reference Attachment 3)

The download of the data indicated that the elapsed time of the unit was 2,936.5 hours and the last recorded fault “Roll Synchro Fail” was recorded at elapsed time 2,923.4 hours.

D.7 Multi Hazard Awareness System:

D.7.1 System Description:

The airplane was equipped with a Bendix/King KMH 880 Multi Hazard Awareness System (MHAS) which provides a Traffic Advisory System (TAS) and a Terrain Awareness and Warning System (TAWS). These two functions are controlled through a single TAWS/TAS processor within the KMH 820 Multi-hazard computer. The TAWS and TAS data is displayed on the KMD 850 Multi-Function Display (MFD).

The KMH 880 MHAS was composed of the KMH 820 (TAS/EGPWS Processor), a top mounted directional antenna (KA 815), a bottom mounted antenna (a KA-815 directional antenna which shall provide estimated bearing of target aircraft, or an omni-directional monopole antenna which will not provide bearing information), a top mounted GPS antenna (KA 92), and a configuration module (KCM 805).

The 820 (TAS/EGPWS Processor) captures and internally saves flight parameters over a timeframe from 20 seconds before to 10 seconds after any caution or warning event is triggered. Information for 100 or more 'events' may be retained in the unit's flash memory. During operation, new event data replaces the oldest data once the flight history memory area becomes full. Stored information may later be downloaded by the manufacturer. This capability is intended primarily for systems engineering and quality control purposes.

D.7.2 Examination and Data Extraction:

At the time of the accident, the airplane was equipped with a Honeywell KMH-820 computer. The unit was located and recovered from the wreckage on May 22, 2017, during an examination of the wreckage at ASOD (Figure 11). The unit was shipped to the Honeywell facility located in Redmond, Washington for further examination.

On June 8, 2017, the examination of the KMH-820 computer was conducted by Honeywell in the presence of the NTSB at the Honeywell facility located in Redmond, Washington. Because the KMH-820 computer could not be powered up or functionally tested[15], the examination consisted of disassembling it with the purpose of locating the memory chip (U28) where event codes are stored and then downloading any event codes that may have been recorded during the accident flight. Visual examination revealed that the KMH-820 computer was compromised due to impact damage and heat distress; the outer case was structurally distorted and internal circuit boards were found bent with missing components. The serial number of the unit was not visible due to heat distress. Investigators observed that the U28 chip, the flight history flash memory chip, remained attached to its corresponding pad on the circuit board.

The micro integrated hazard avoidance system (IHAS) circuit card assembly (CCA) was removed via screws. The GPS card, which was damaged during impact, was removed to allow removal of the IHAS assembly. Terrain Database Version installed: 475N, with a release date of 9/15/2015. The U28 Non-Volatile Memory (NVM) chip was found with a crack on its upper surface. Because of this mechanical damage, the investigators determined to not remove from the chip from the circuit board (Figure 12). The unit was repackaged in its shipping container and provided to the NTSB.

On June 13, 2017, the NTSB shipped the KMH-820 computer (including the IHAS circuit card assembly) to Binghamton University - Analytical and Diagnostics Laboratory, located in Binghamton, New York for a non-destructive evaluation of the U28 NVM chip (Reference Attachment 4). The results of the analysis are:

- X-ray inspection revealed that the flash memory package has a wire bonded silicon die. It showed a detailed extent of the cracks in the package and possibly in the memory die. At least 4 wire bonds to the memory die are broken along the line of a crack.
- Acoustic images confirmed that the memory die is severely cracked from the impact damage.
- Since the die is cracked, no digital data can possibly be retrieved from this flash memory package.

[15] The KMH-820 computer could not be functionally tested due to the impact damage it sustained.

Figure 11 KMH-820 computer

KMH 820
OBSERVED DAMAGE

TERRAIN DATABASE
CARD

U28 CHIP LOCATION

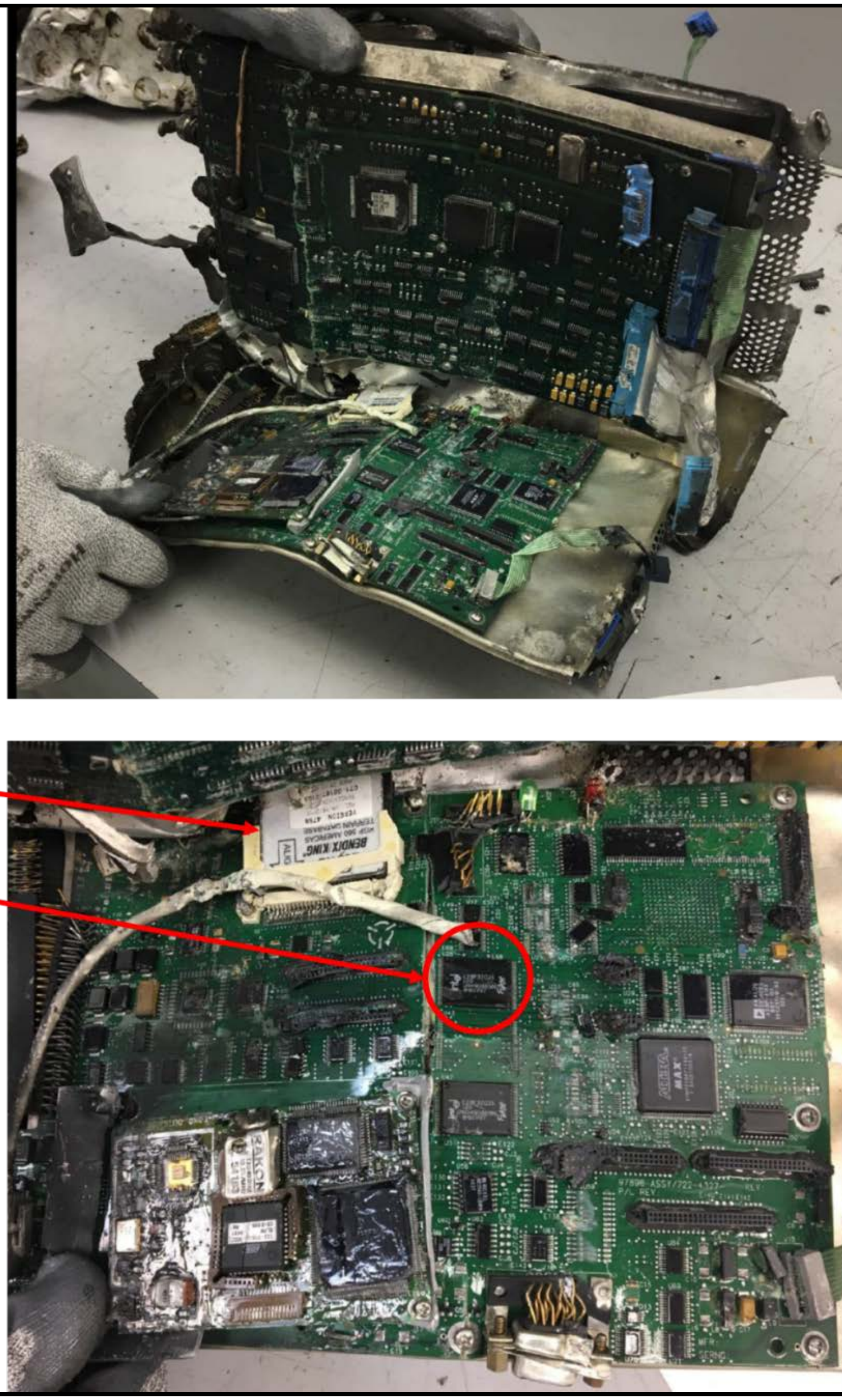
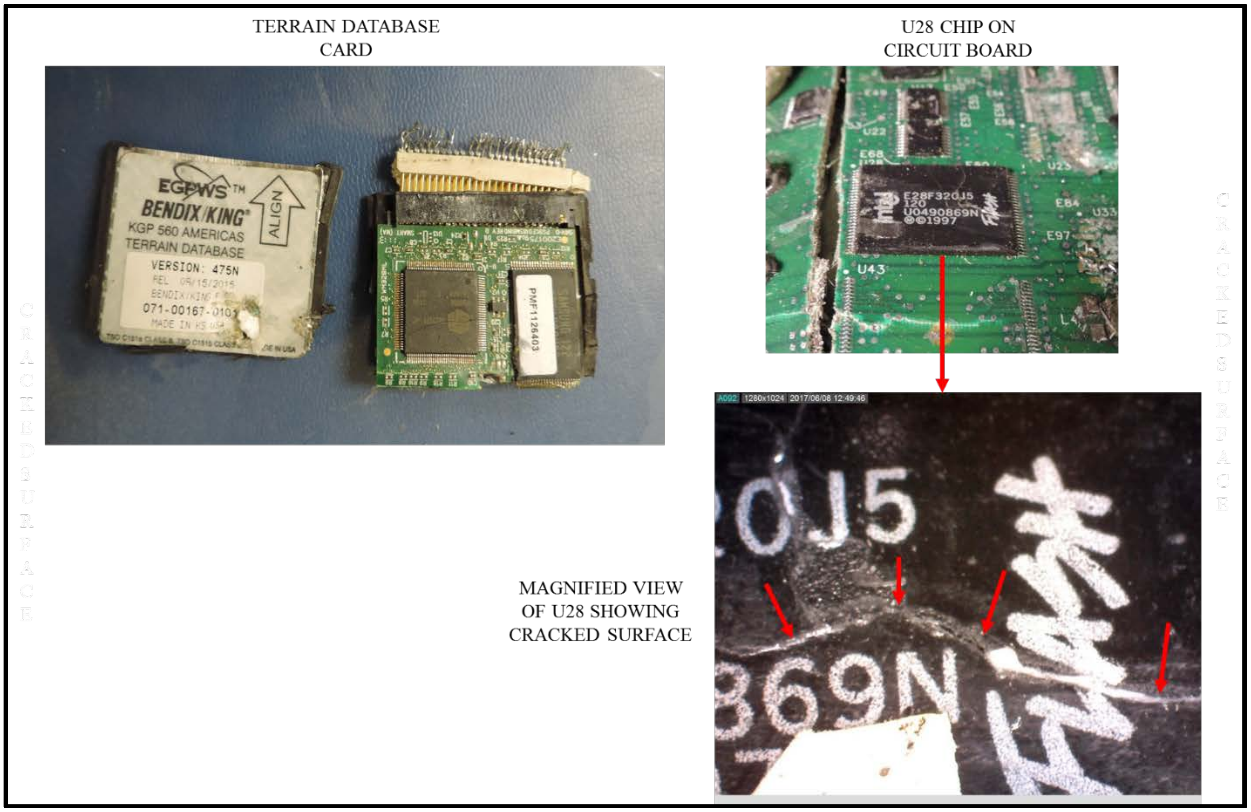


Figure 12 Terrain database card and U28 chip



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