NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF AVIATION SAFETY
WASHINGTON, D.C. 20594

April 12, 2004

AIRWORTHINESS GROUP CHAIRMAN'S FACTUAL REPORT OF INVESTIGATION

NYC03MA183

A. ACCIDENT

Operator: Colgan Air
Aircraft: Raytheon Model 1900D
Location: Yarmouth, MA
Date: August 26, 2003
Time: 15:40 EDT

B. AIRWORTHINESS GROUP

Chairman — Steven Magladry
National Transportation Safety Board
Washington, DC

Member — Willard Crowe
Raytheon Aircraft Company
Wichita, Kansas

Member — Robert Busto
Federal Aviation Administration (FAA)
Wichita, Kansas

Member — Kevin Gonzalez
Colgan Air Inc.
10677 Aviation Lane
Manassas, VA 20110

Member — Robert L. Ramey
Raytheon Aircraft Company
Wichita, Kansas

C. SUMMARY

On August 26, 2003, at 1540 eastern daylight time, a (Raytheon) Beech 1900D, N240CJ, Serial Number UE-40, operated by Colgan Air Inc. as flight 9446 (d.b.a. US Airways

Express), was substantially damaged when it impacted water near Yarmouth, Massachusetts. The certificated airline transport pilot and certificated commercial pilot were fatally injured. Visual meteorological conditions prevailed for the flight that departed Barnstable Municipal Airport (HYA), Hyannis, Massachusetts; destined for Albany International Airport (ALB), Albany, New York. An instrument flight rules flight plan was filed for the repositioning flight conducted under 14 CFR Part 91.

The Airworthiness Group convened in Hyannis, Massachusetts August 27 – 31, 2003 to recover the accident airplane from the water, document the condition of the airplane, and obtain components for additional examination.

The Flight Data Recorder (FDR) and Cockpit Voice Recorder (CVR) were recovered from the accident site on August 27, 2003 and sent to NTSB Headquarters, Washington, DC for processing. Preliminary FDR data indicated an unusual pitch trim tab position for the airplane from shortly after takeoff to the time of the impact of the water[1]. The CVR transcript indicated the pilots were experiencing very high column forces while attempting to keep the airplane nose up. The Airworthiness Group also learned that the pitch trim system forward cable, and the elevator trim actuators had been replaced prior to the flight. The investigation focused on the pitch control of the airplane and in particular the pitch trim control.

The Airworthiness group convened three additional times to perform follow-up examinations:

September 4, 2003 – NTSB Lab, Washington DC – Examination of pitch trim components in the accident airplane throttle quadrant. This showed that though it could not be determined if the forward cable drum was wrapped incorrectly, the Raytheon maintenance documentation was ambiguous and could have led to incorrect routing of the cable on the drum.

October 14 –15, 2003 – Raytheon, Wichita, KS – Examined incorrect pitch trim rigging scenarios on a Beech 1900D airplane. Tested the accident airplane electric elevator trim servo motor and control box. These tests showed that the 1900 can be miss-rigged to produce an airplane nose down command when the trim wheel is moved in the nose up direction. It also showed that rigging checks should have detected the condition. These tests also included a bench test of the accident airplane electric trim motor. The motor operated in the correct direction and performed almost to the specification in terms of rate.

October 22, 2003 – Colgan Air, Manassas, VA – Interviewed mechanics who serviced the pitch trim system prior to the accident flight. Both mechanics interviewed stated that they followed the maintenance instructions for wrapping the trim cable on the drum, and the procedure was not ambiguous. They interpreted the drawing as requiring the cable with the LH threaded turnbuckle to start closest to the

[1] The Elevator Trim Position parameter on the FDR was on the Minimum Equipment List for the flight because the position transmitter had not been calibrated prior to the flight.

slotted side of the drum. The version of the Raytheon Maintenance Manual used (Revision 9) for replacement of the cables, did not specify an operational test be performed. There was a section in the Raytheon Maintenance Manual compact disc (27-30-09) which contained an operational check of the elevator trim system. However, there was an error on the disc, which caused the procedure to not show in the table of contents. A more detail search of the manual would have been required to find the procedure. The mechanics stated that they did not locate or use the maintenance manual elevator trim operational test, but performed numerous tests of their own to ensure the trim system was correctly operating, and they believed it to be operating properly.

This report documents the recovery of the airplane, the condition of the accident airplane, and provides a summary of all follow up testing performed.

D. DETAILS OF THE INVESTIGATION

1.0 Airplane Recovery

The accident airplane crashed in approximately 30 feet of water. The wreckage was recovered from the water on August 28, 2003 using a dive team and platform with a crane. The platform was towed to a boat ramp at the Town of Yarmouth Park, near the mouth of Bass River. The wreckage was transferred to a large flatbed truck and transported to the Cape Air maintenance hanger at Barnstable Municipal Airport. Pictures of the recovery are provided in Appendix A.

2.0 General Flight Control Systems Description

All flight controls, with the exception of the flaps, are cable-operated conventional surfaces, which require no power assistance for normal control by the pilot or copilot. Trim tabs are installed on the left aileron, the rudder, and each elevator. The elevator trim can be manually or electrically operated. The rudder has an independent yaw damp/rudder boost system. The flaps are electrically powered. The accident airplane was not equipped with an autopilot.

3.0 Pitch Control System Description

The Raytheon Model 1900D has a mechanically operated pitch control system, (Figure 1). The control-column pivots forward and aft on bearings that are attached to the control column support arm. The bottom of the "T" control-column is attached to an adjustable-length push-pull rod, which connects to the forward bell crank (Figure 2). The forward bell crank is attached to 3/16-inch diameter cables, which are routed beneath the passenger compartment floor, to the rear cargo compartment, and through the aft pressure bulkhead seals. The cables travel up the vertical stabilizer and terminate at the aft elevator bell crank. The aft elevator bell crank is located within the junction of the vertical and horizontal stabilizers at the top of the vertical stabilizer. Separate pushrods connect the aft bell crank to each elevator through a

control horn (Figure 3). There are adjustable stops on each control horn support, which limit the travel of the elevator. Each elevator is attached to the rear spar of the horizontal stabilizer by three hinges and a control horn. Each elevator has a single partial-span trim tab at the inboard end. The forward outboard corner of each elevator has a balance weight.

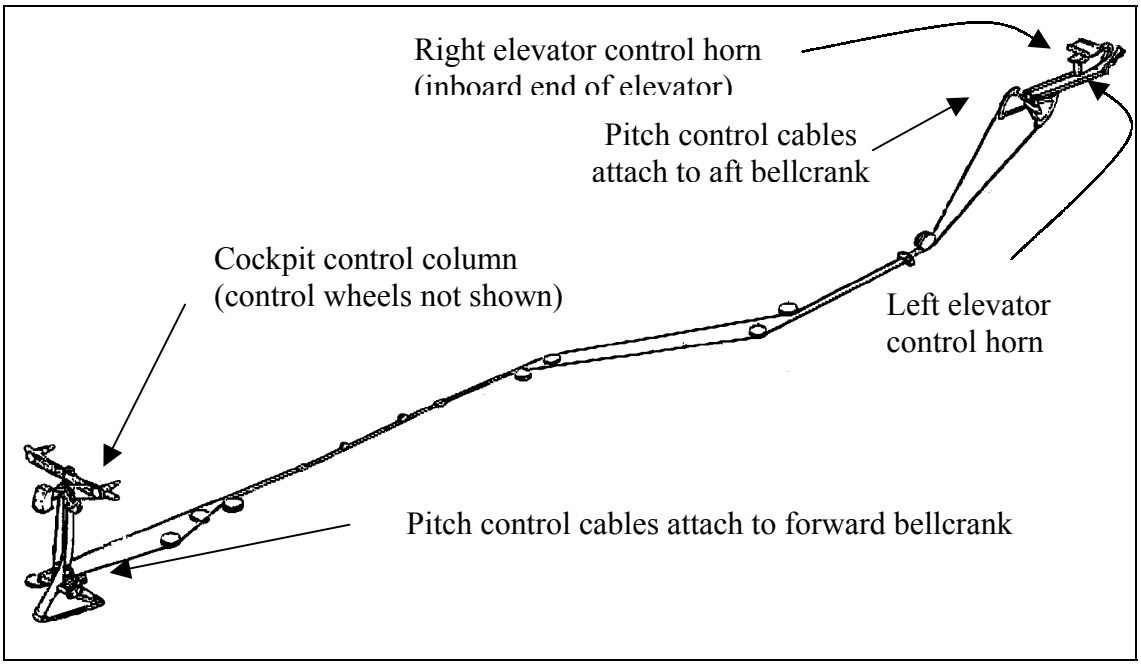

Figure 1. Elevator Control System

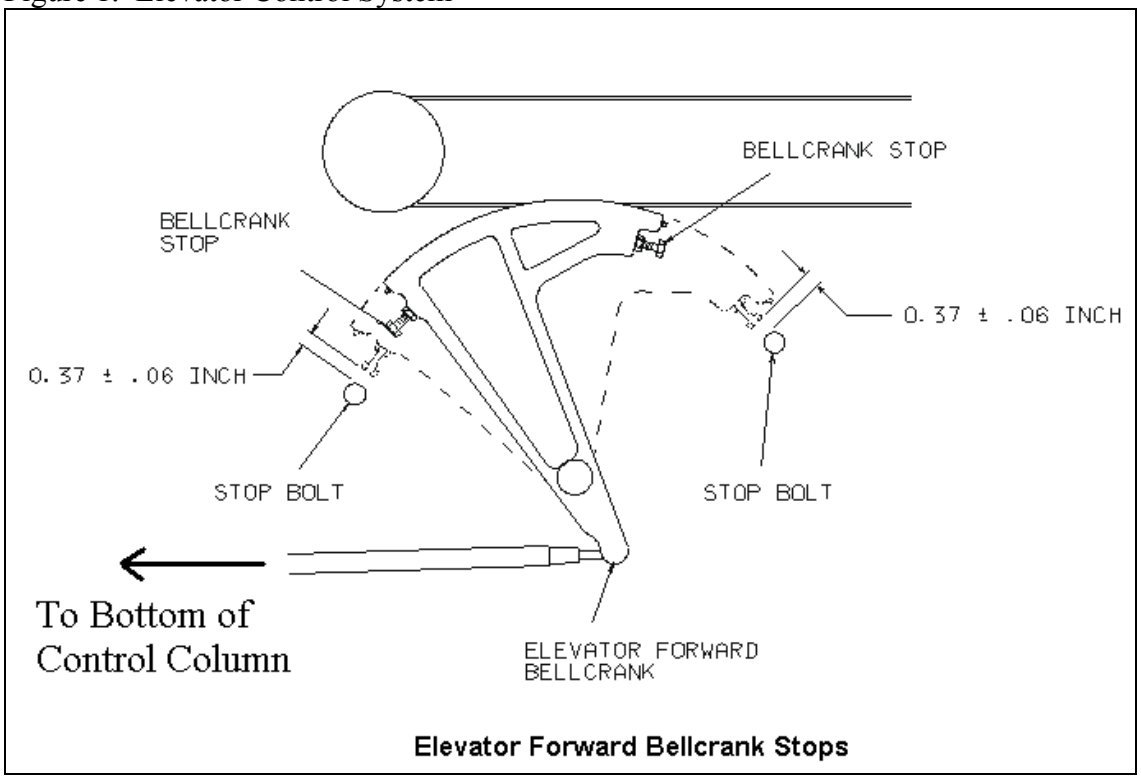

Figure 2. Elevator Forward Bellcrank.

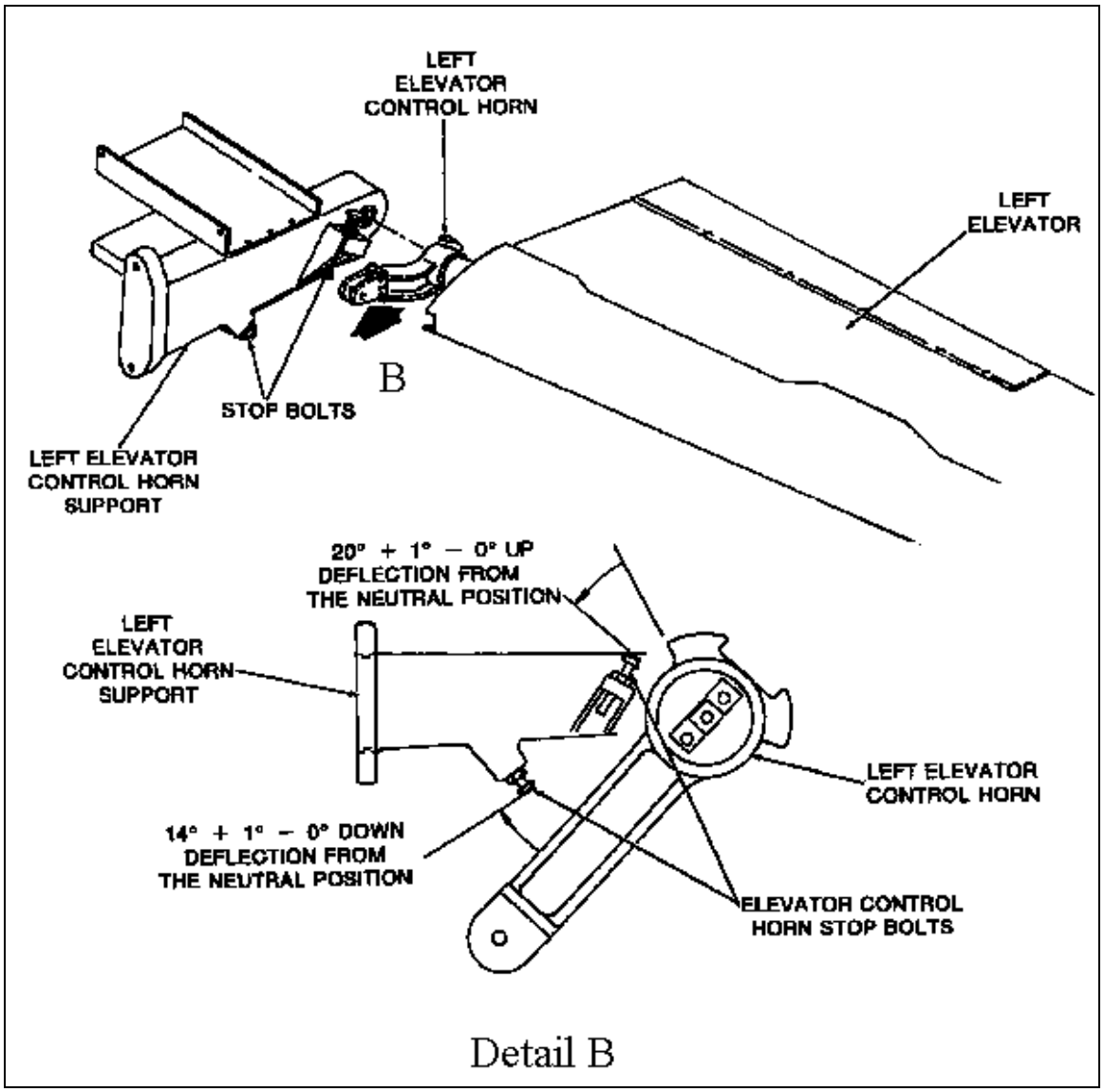

Figure 3. Elevator Control Horn.

4.0 Condition of the Accident Airplane Pitch Control System

The control column was recovered from the wreckage (Figure 4). The pushrod that connects the column to the forward bell crank was fractured, but a short segment remained attached to the column (Figure 5). The Flight Data Recorder (FDR) elevator position sensor rod was fractured. The rod end remained attached to the column. The position sensor and the other segment of the rod was found intact, attached to structure in the pedestal (Figure 6).

Figure 4. Elevator Control Column.

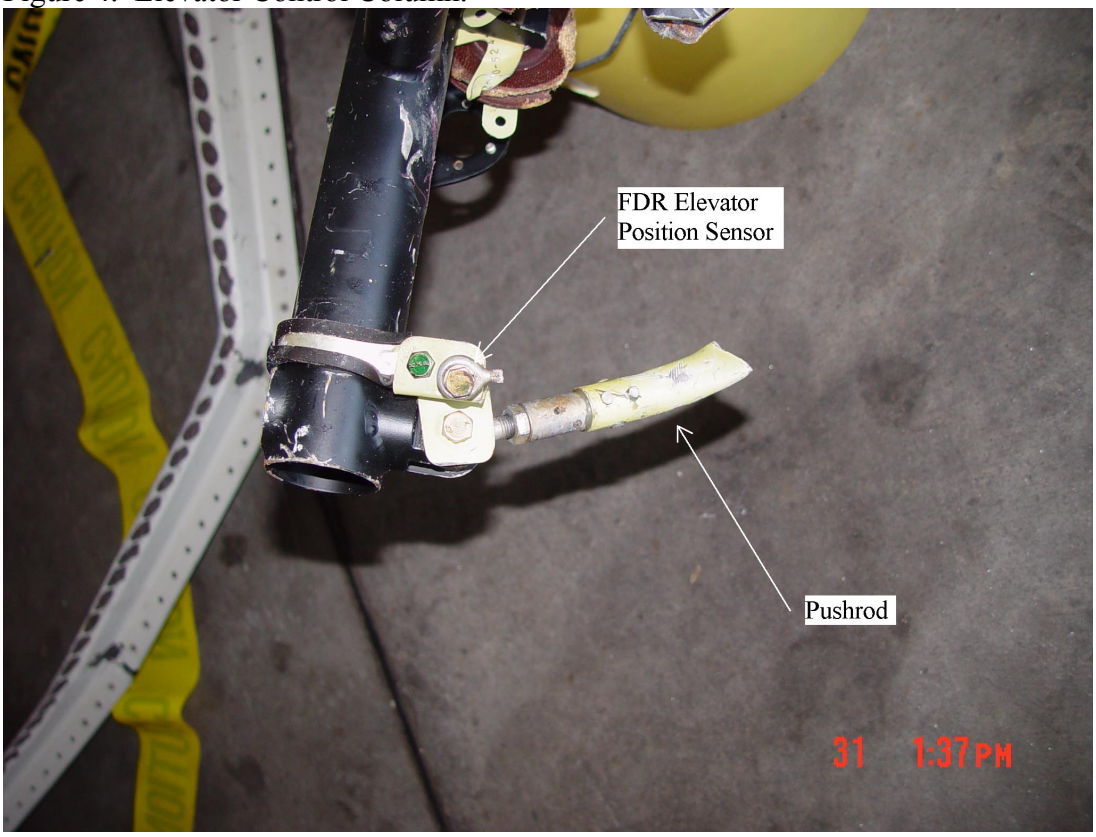

Figure 5. Elevator Pushrod and FDR Sensor.

Figure 6. FDR Elevator Position Transducer.

A portion of the forward bell crank was recovered (Figure 7). The elevator trailing edge Down (TED) control cable (forward cable in tail) was found attached to the forward bell crank. The elevator trailing edge up (TEU) cable was detached from the forward bell crank.

The TED cable was found intact from the forward bell crank to the aft bell crank. The TEU control cable (aft cable in tail) was intact from near the forward bell crank to the aft bell crank.

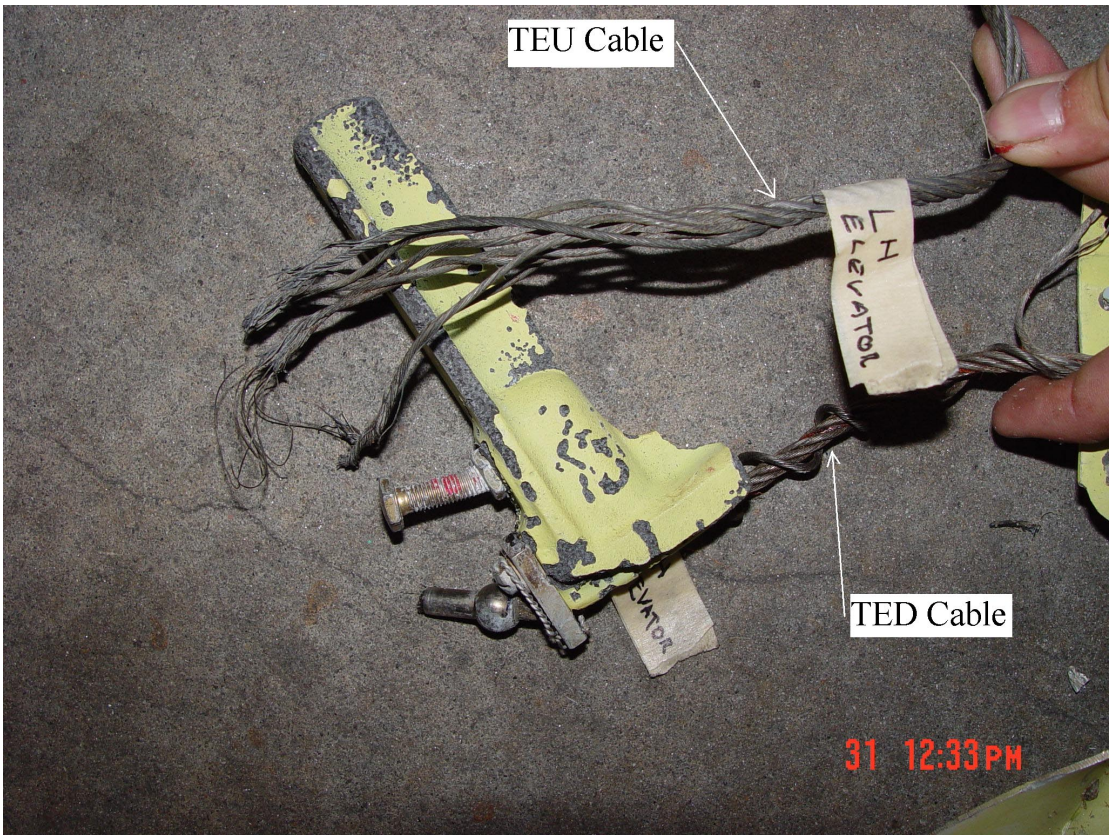

Figure 7. Elevator Control Forward Bell Crank with Cables

The elevator aft bell crank was found in pieces. Two downsprings were found connected to their normal aft bellcrank attachment. The other end of the springs were found not connected to the structure, but the structure was heavily damaged.

The pushrods from the aft bell crank to the elevator horns were intact (Figure 8) and connected to their respective control horns.

The elevator control horn stop bolts were measured. The measurement was from the base of the elevator control horn support to the top of the stop bolt head. The measurements recorded were: left down 0.82, left up 0.69, right down 0.76, and right up 0.68 inches.

There was approximately eight (8) feet of the right elevator found in two (2) parts (Figure 9). Nominal length of the elevator, along the trailing edge, is 8 feet 9 inches. The inboard portion of the right elevator was attached to the elevator horn and two (2) hinge points. The right elevator control horn was riveted to the inboard end of the elevator torque tube. The rivets connecting the right side control horn were found to be tight and the horn was fixed to the right elevator torque tube.

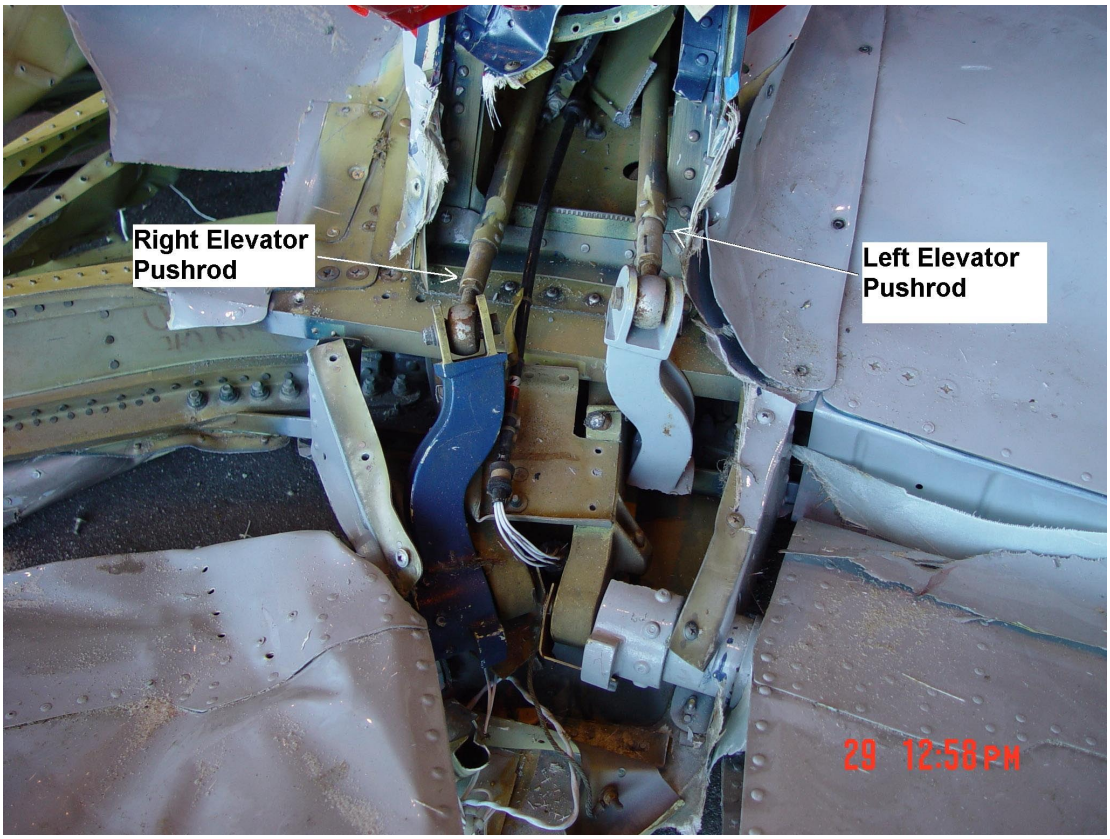

Figure 8. Pushrods Attached to the Elevator Control Horns.

Figure 9. Right Elevator parts after removal from the Horizontal Stabilizer.

There was approximately five (5) feet of the left elevator found (Figure 10). The left elevator was attached to its most inboard hinge. The left side control horn fractured in two pieces. One piece (arm) was attached to the pushrod and the other portion remained riveted to the left elevator torque tube.

Figure 10. Left Elevator and Horizontal Stabilizer.

The elevator balance weights of both elevators were recovered. These weights are normally located at the outboard end of the elevator but were found separated from the rest of the elevator. The balance weights were present and the hexagon shaped bolt heads were safety wired. The weights were not loose and the countersunk screw heads were tight and flush.

There was approximately seven (7) feet of the left horizontal stabilizer found intact. The right side stabilizer was not recovered except for approximately five (5) feet of the rear spar, which was still attached to the tail.

5.0 Pitch Trim Control System Description

The pitch trim can be controlled by manual or electric means. The manual control is made through a pitch trim wheel on the left side of the pedestal in the cockpit (Figure 11).

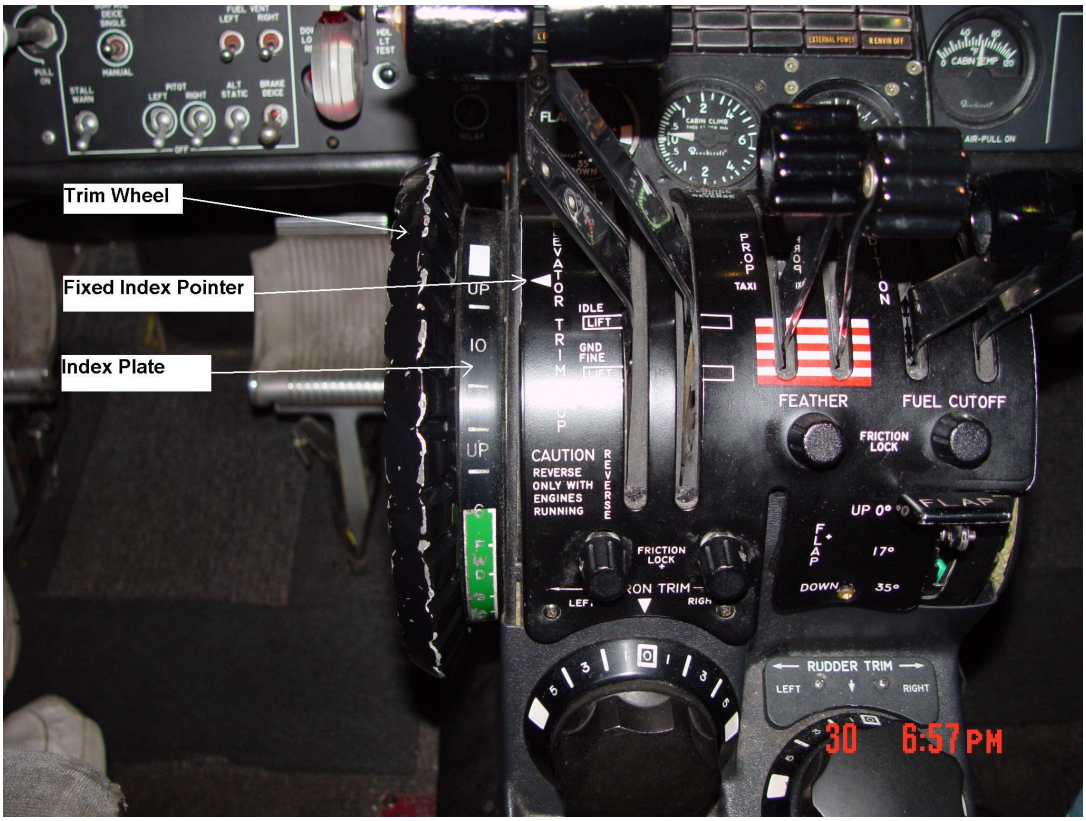

Figure 11. Pitch Trim Wheel in Cockpit (Exemplar Airplane Cockpit)

The trim wheel connects to a sprocket, which drives a chain to another sprocket, which connects to a cable drum (Figure 12). A 1/16 inch cable is wrapped around the cable drum and routed down, outboard, and aft through the fuselage. Figures 13 and 14 show each side of the cable drum. The drum has a slotted side or key way, which connects to the sprocket, so the cable drum cannot be installed backwards. Figure 15 shows the Raytheon Maintenance Manual illustration for wrapping the cable around the cable drum. Figures 16 through 18 show the routing and orientation of the cables from the pedestal, aft to the elevator trim actuators. The forward cable, which was replaced prior to the flight, is a continuous loop from one turnbuckle, shown in Figure 17, to the forward cable drum, and back to the other turnbuckle in Figure 17. The cable is roughly 54 feet long. The location of the elevator trim position sensor for the FDR can be seen in Figure 17.

It was observed that the Figure 15, maintenance illustration did not accurately depict the cable drum part. The illustration appeared to indicate that with the slotted side of the cable drum facing the installer, the cable with the LH threaded turnbuckle should start to the right in the illustration. If installed in this manner, the cable with the LH turnbuckle would come off the aft portion of the cable drum. The cable coming off the aft portion of the cable drum provides a nose down command to the actuator. However, Figure 17 showed that the LH threaded turnbuckle is on the "Nose up" side of the cable. Installing the cable on the drum in this manner would reverse the control to the trim actuator. Note that to reverse the control, the cables would have to

be crossed between the cable drum and the turnbuckles in order to connect to the turn buckles.

Following this observation, Raytheon and the FAA released documentation to address the misleading maintenance procedure. Raytheon released the following Temporary Revisions to the 1900D Maintenance Manual to address the issues:

1. TR 27-9, issued September 12, 2003 to add a Manual Elevator Trim Operational Check.
2. TR 27-10, issued October 22, 2003, which revised the "Elevator Trim Tab Cable Installation" AMM 27-30-04.
3. TR 27-11, issued December 5, 2003, which revised the Elevator Trim Tan Rigging and Elevator trim Tan Actuator Installation procedures.
4. TR 27-12, issued December 18, 2003, which revised the Elevator Trim Tab Cable Installation procedure.
5. TR 27-15, issued March 3, 2004, which revised the Elevator Trim Tab Indicator Adjustment procedure.
6. TR 27-16, issued March 31, 2004, which revised the Elevator Trim Tab Rigging procedure and revised the Elevator Trim Tab Actuator Removal, Cable Replacement and Installation procedure.

The FAA released an immediately adopted Airworthiness Directive (AD2003-20-10), effective October 15, 2003, which instructs operators to incorporate TR 27-9 and provided a change to the maintenance illustration.

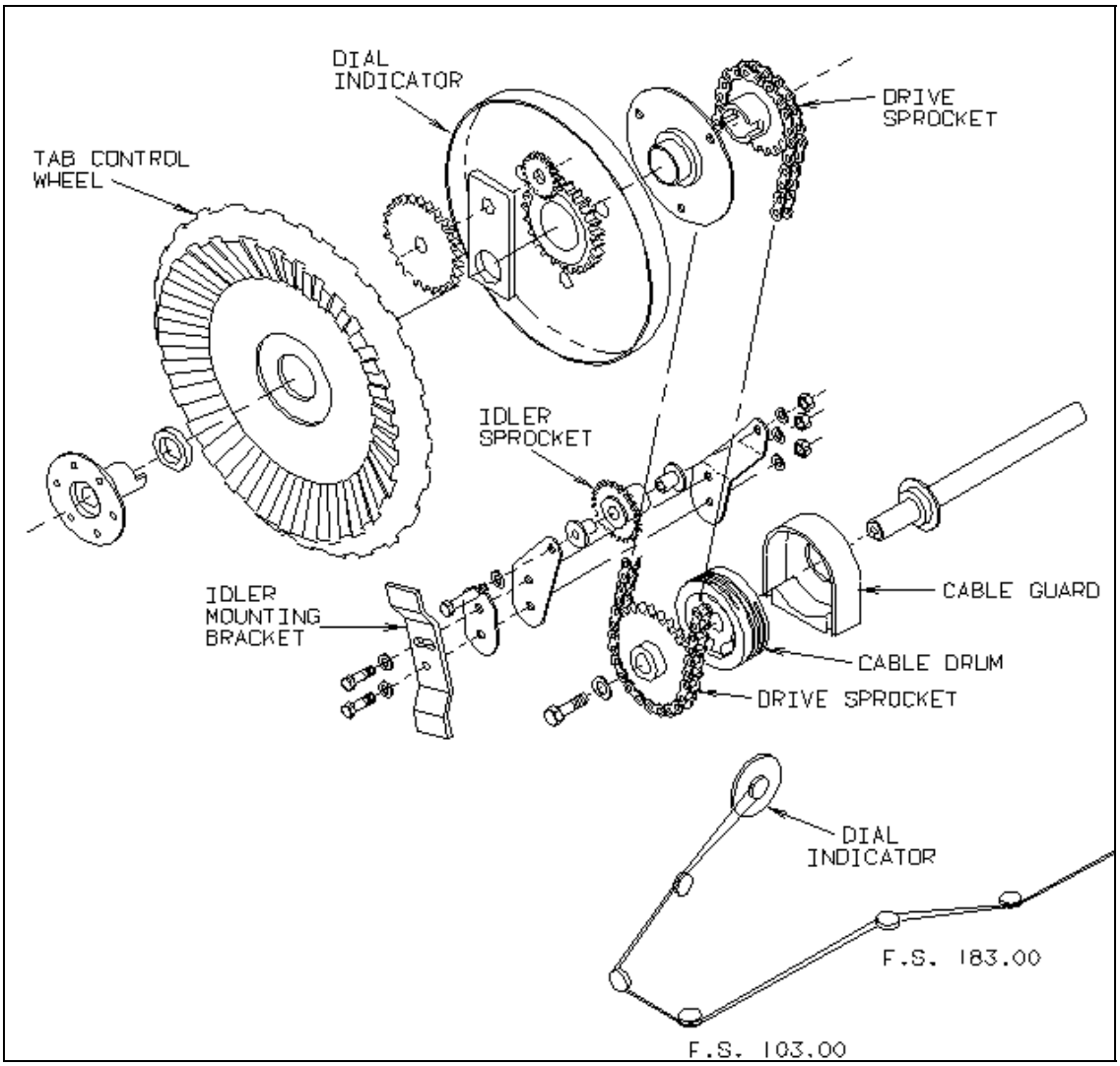

Figure 12. Manual Trim Components

Figure 13. Picture of Slotted Side of a New Cable Drum.

Figure 14. Picture of Non-Slotted Side of New Cable Drum.

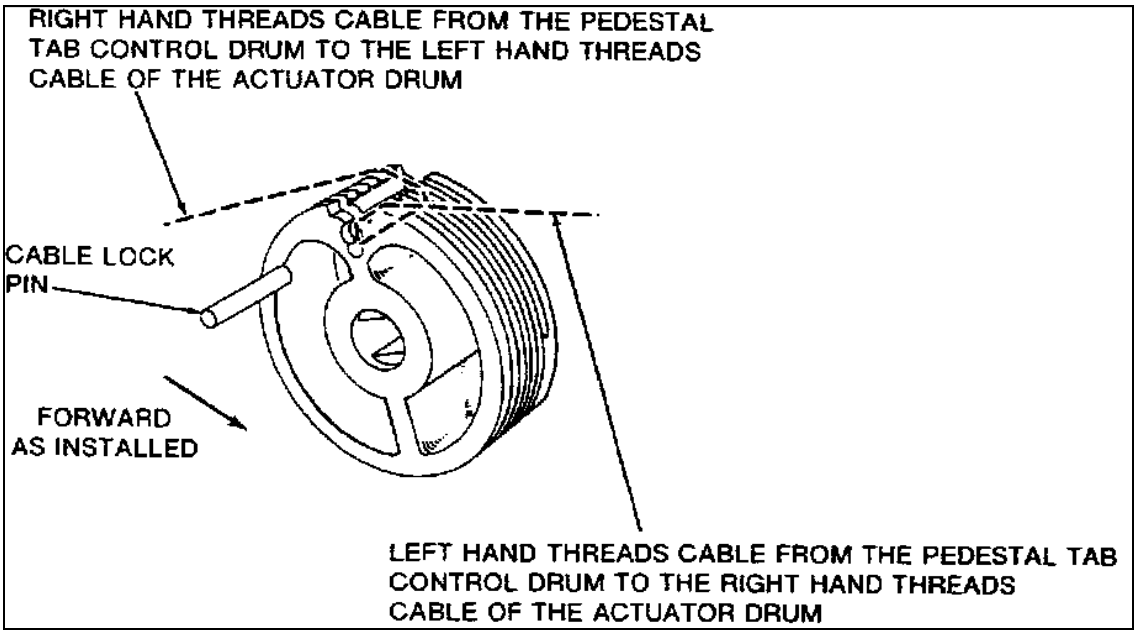

Figure 15. Maintenance Illustration for Wrapping the Cable Drum.

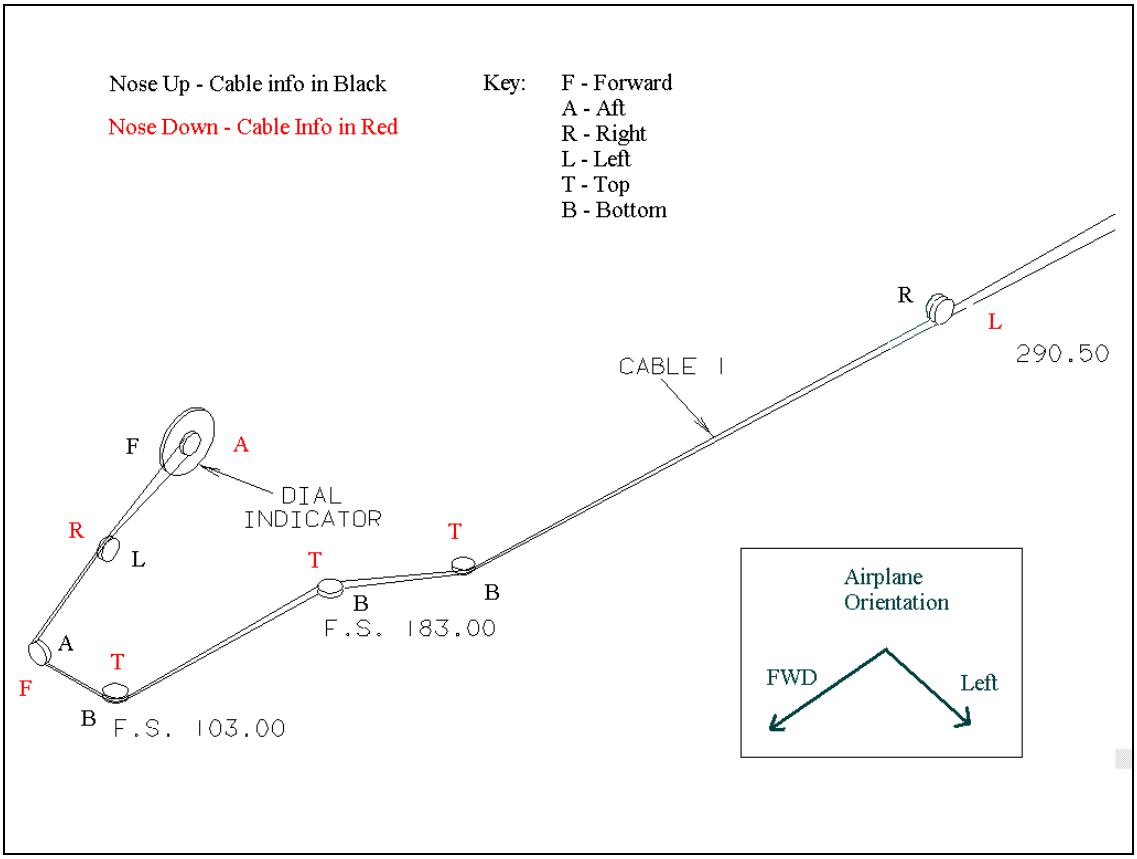

Figure 16. Elevator Trim Cable Routing

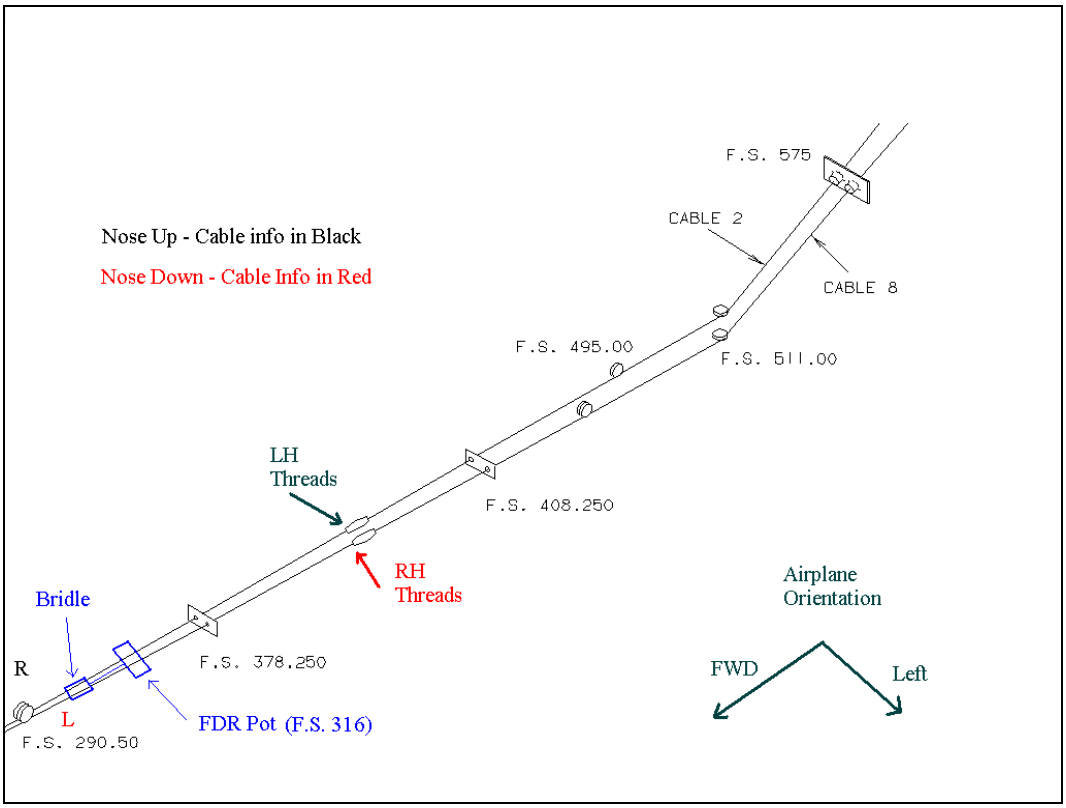

Figure 17. Elevator Trim Cable Routing.

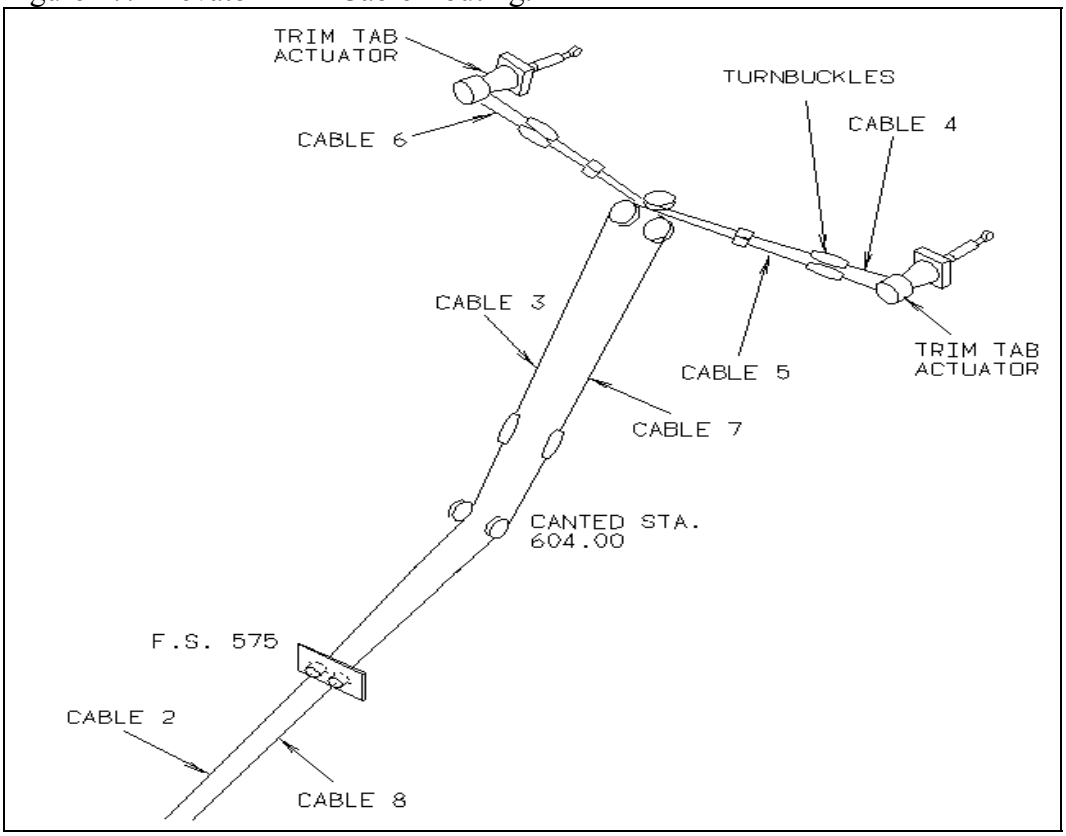

Figure 18. Elevator Trim Cable Routing

6.0 Elevator Electric Trim Control

The electric trim control is made through switches on the control wheel (Figure 19). There are two switches on each control wheel. Both switches must be moved in the same direction to actuate the electric trim motor. Figures 20 through 22 show the electrical diagrams for the electric trim system. The electric trim motor is operated by 28 volts DC. The motor is installed at the base of the vertical stabilizer and is connected to the control cables through drum assemblies. Since the electric trim moves the cables, use of the electric trim also moves the trim wheel in the cockpit.

The electric trim system can be deactivated in four ways:

1. By depressing the trim disconnect switch located on each control wheel.
2. Moving the ELEV TRIM (ON) – OFF switch, located on the pedestal, to OFF.
3. Pulling the ELEV TRIM circuit breaker on the right side panel.
4. Moving the ganged BAT, L GEN, and R GEN sitches to OFF.

In addition any elevator trim servo movement can easily be overcome by manual inputs by the pilots, using the cockpit trim wheel.

The mechanics stated that the tests of the manual and electric trim were performed at the same time. The FDR did not record any tests of the elevator trim system during maintenance. However, the FDR requires 115VAC for operation, but the electric trim requires only 28VDC for operation. Raytheon Aircraft has further advised that it is possible to have the 28 VDC Bus powered without having the 115VAC Bus powered.

Figure 19. Electric Pitch Trim Switches (Exemplar Airplane Cockpit).

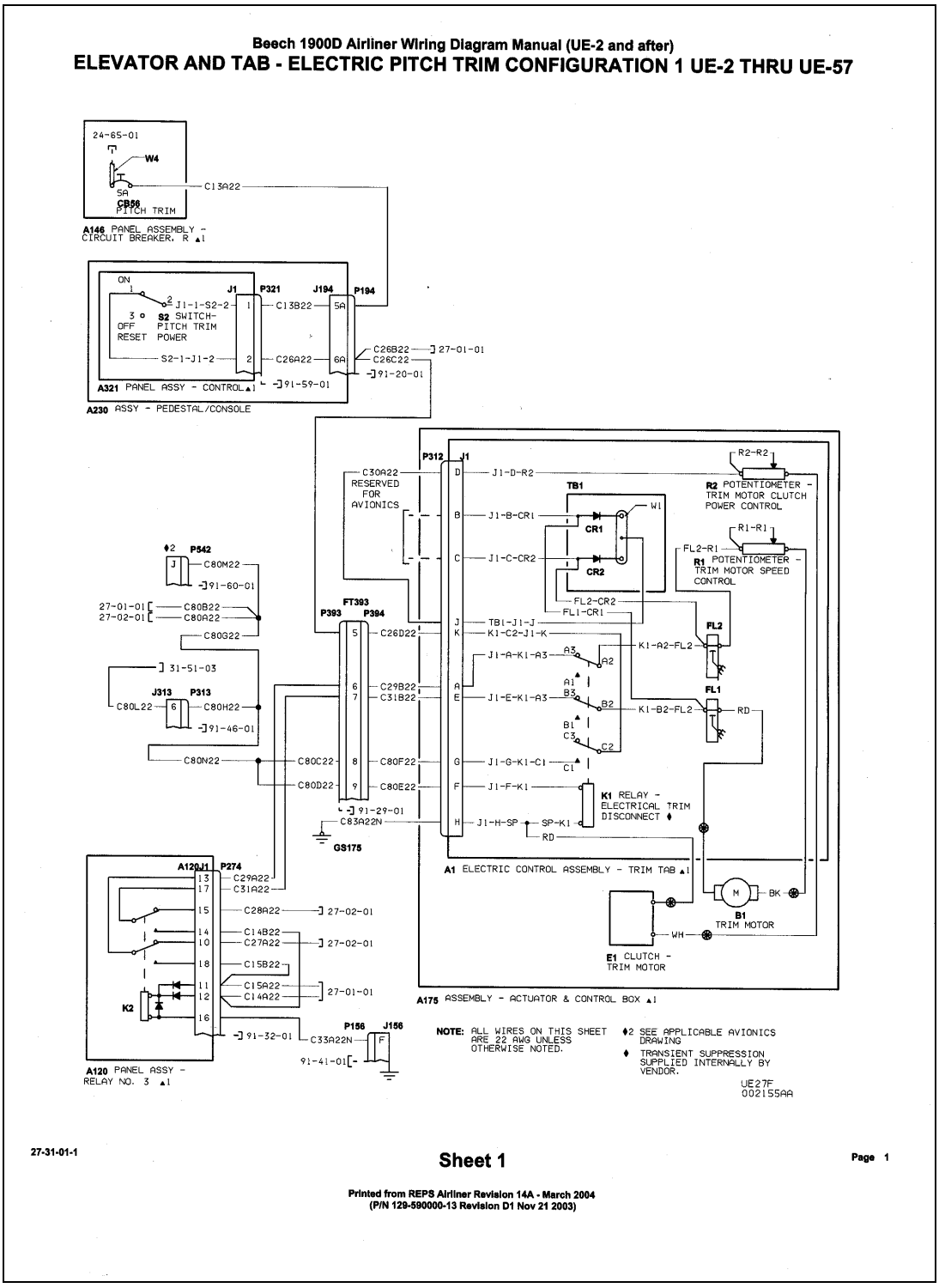

Figure 20. Wire Diagram for Elevator Electric Trim.

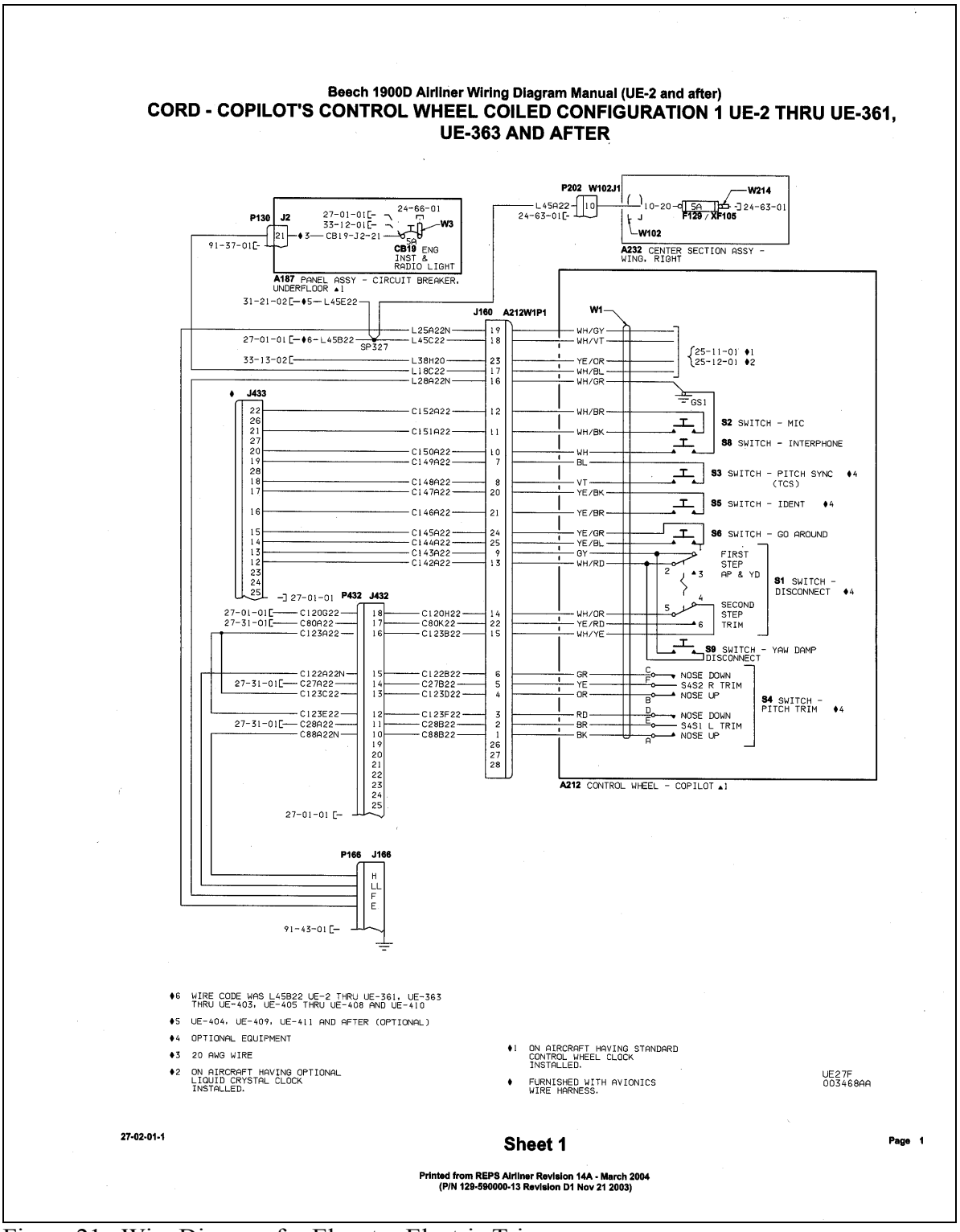

Figure 21. Wire Diagram for Elevator Electric Trim.

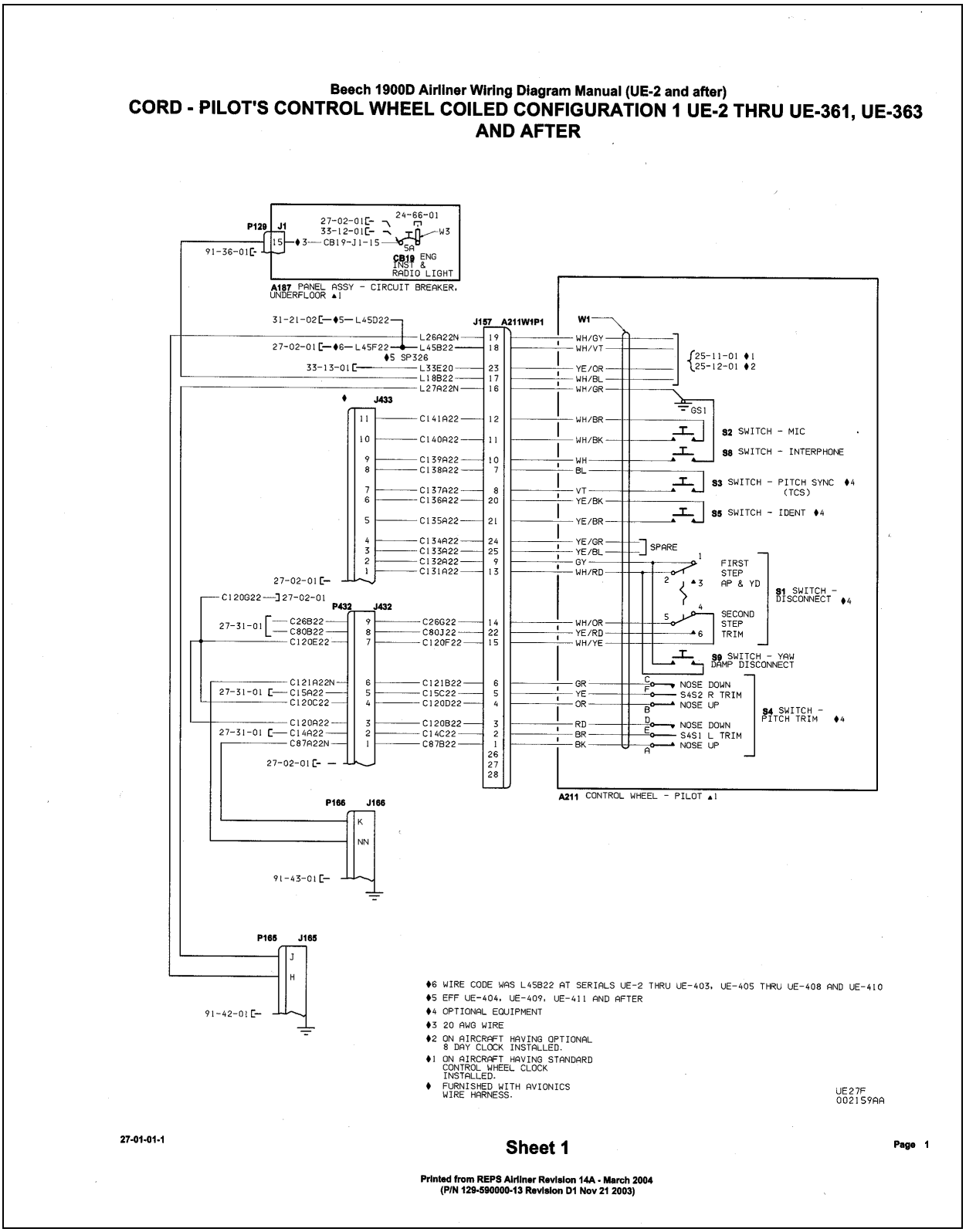

Figure 22. Wire Diagram for Elevator Electric Trim.

7.0 Condition of the Accident Airplane Elevator Trim Components

7.1 Trim Components in the Pedestal and Forward Cable Loop.

All of the manual elevator trim components in the pedestal were recovered from the wreckage, though they were badly damaged (Figures 23 –25).

Figure 23. Pedestal as Recovered from Wreckage

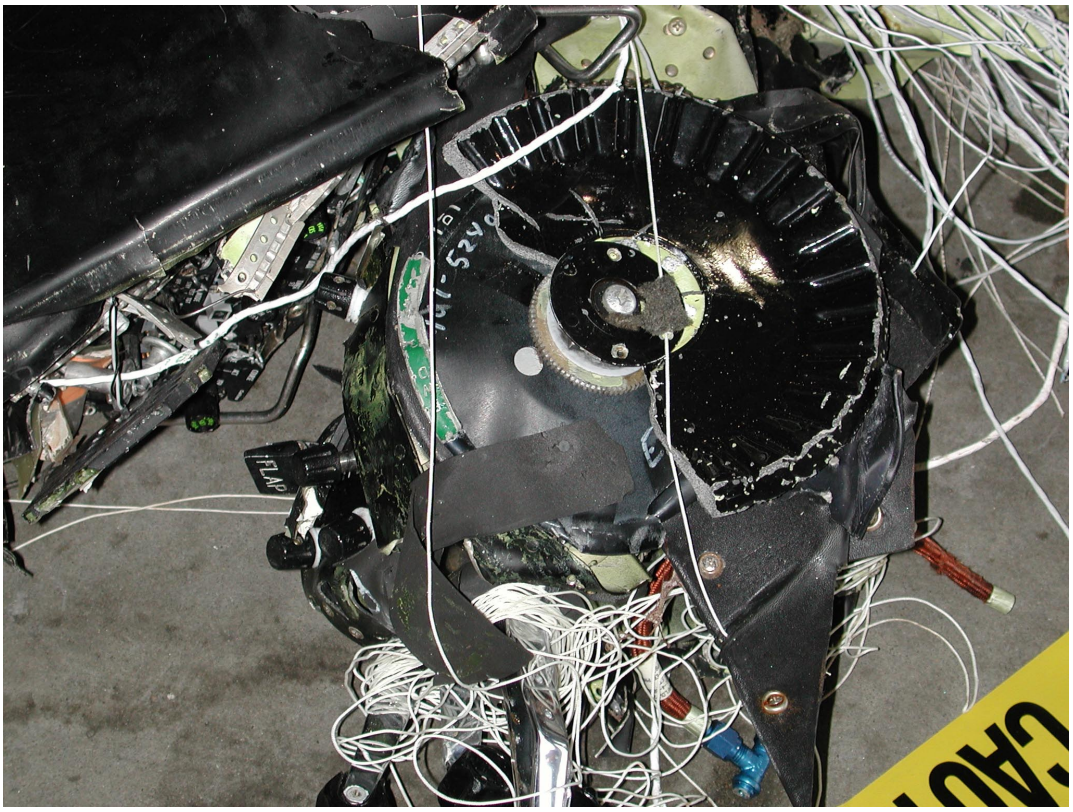

Figure 24. Elevator Trim Wheel as Recovered

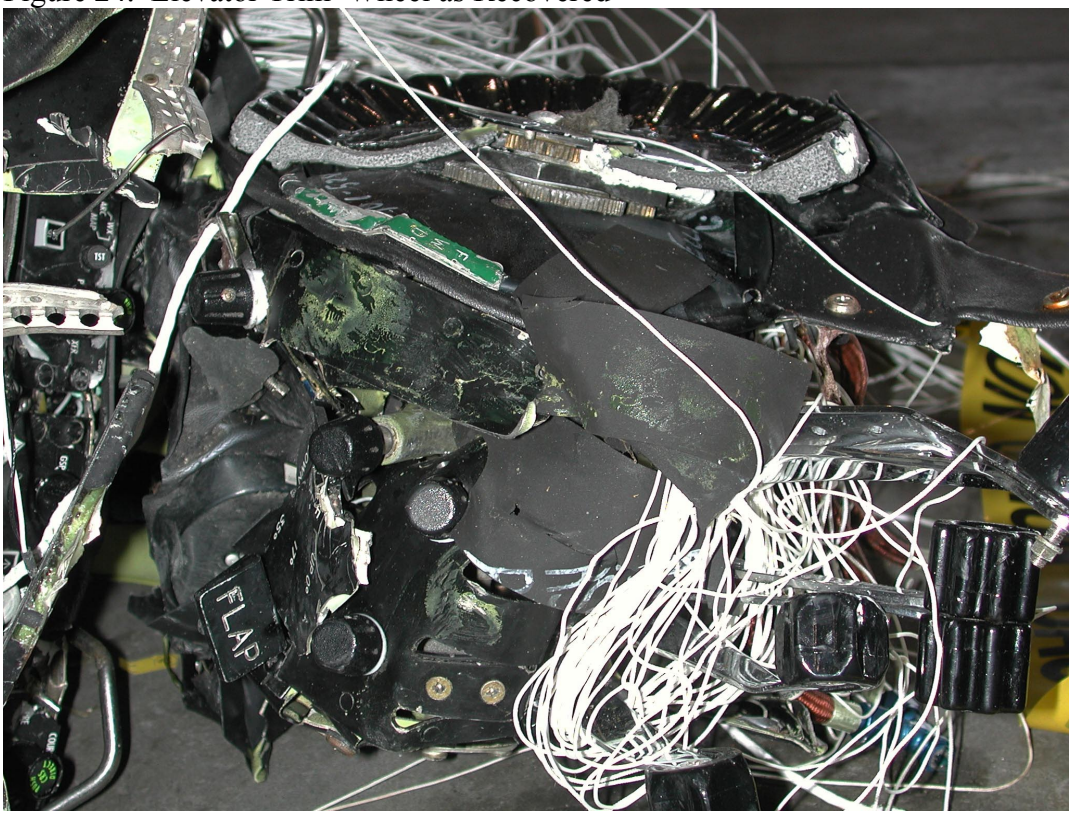

Figure 25. Trim Wheel and Indicator as Recovered

The parts were shipped to NTSB headquarters in Washington DC for examination. Members of the Airworthiness Group convened on September 4th, 2003 to examine the elevator trim controls in the pedestal.

Segments of the elevator trim cables were observed to exit the pedestal and pass through a set of pulleys shown in Figure 26. It was determined that these pulleys were the second set of pulleys from the cable drum shown in Figure 27, location B. The forward cable exiting the cable drum was routed over the aft pulley at location B. The pulleys at location A were not identified in the wreckage.

The panels surrounding the elevator trim drive chain and cable drum were cut away and the routing of these could be observed (Figures 28 and 29).

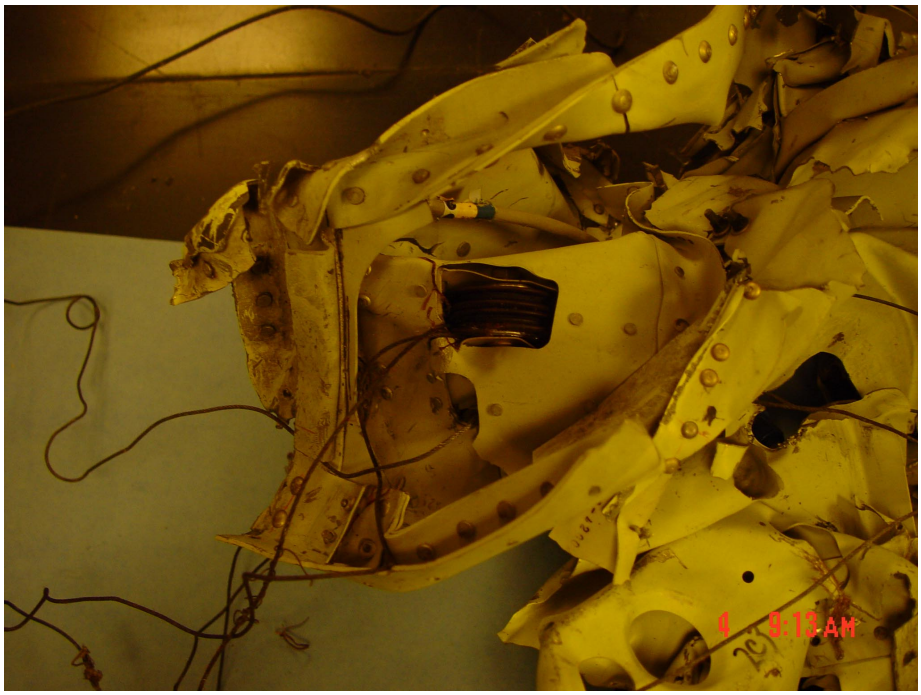

Figure 26. Elevator Trim Cables Passing Through Pulleys

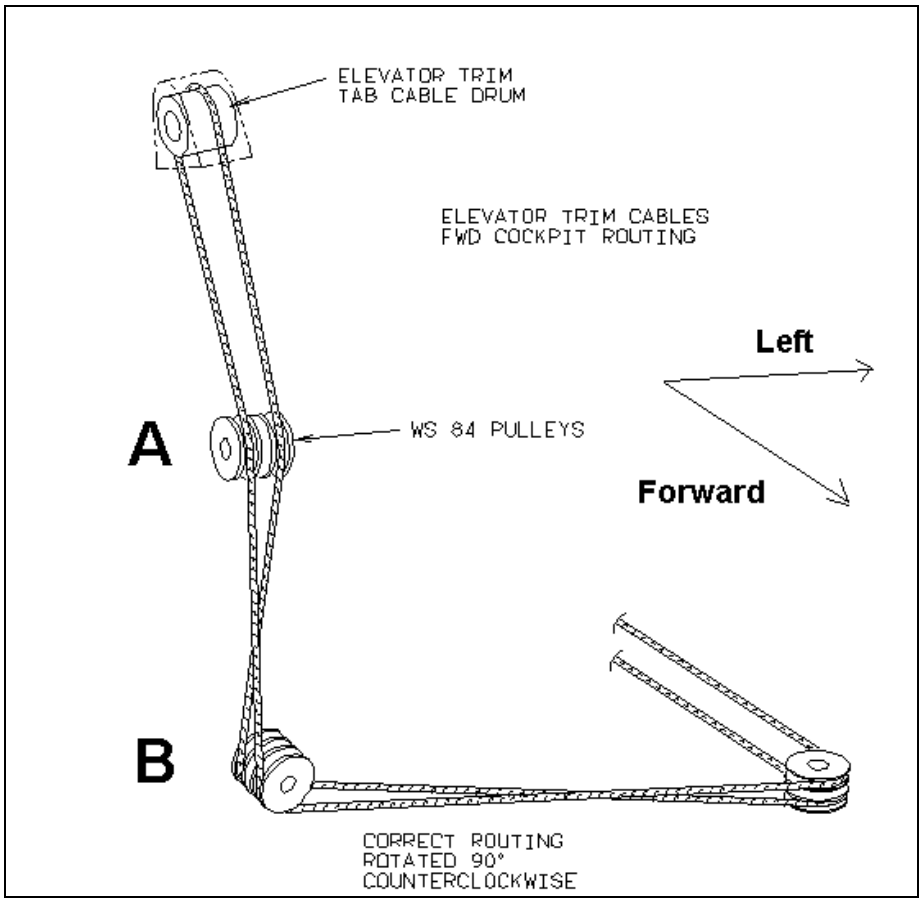

Figure 27. Correct Routing of Cables From the Pedestal.

Figure 28. Elevator trim cable drum support and cover.

Figure 29. Elevator Trim Drive Chain.

The shaft which supports the sprocket and cable drum was removed, and the sprocket was removed from the shaft (Figure 30).

The cable drum and cable was removed from the housing and shaft (Figure 31)

Figure 30. Cable Drum Assembly with Sprocket Removed.

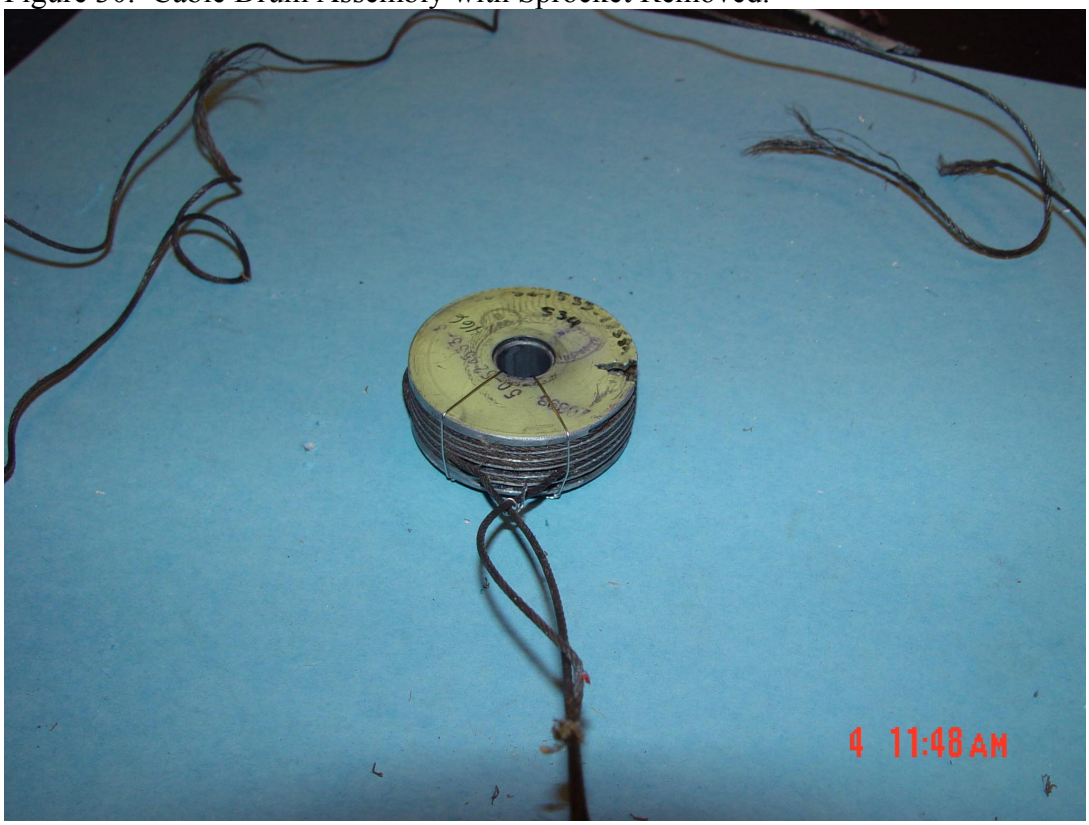

Figure 31. Cable drum with cables.

The cable was removed from the cable drum. A permanent notch was evident where the cable lock pin (Fig. 15) was installed at the "Center" of the cable. The cable segment lengths were measured relative to the "Center"(Figure 32).

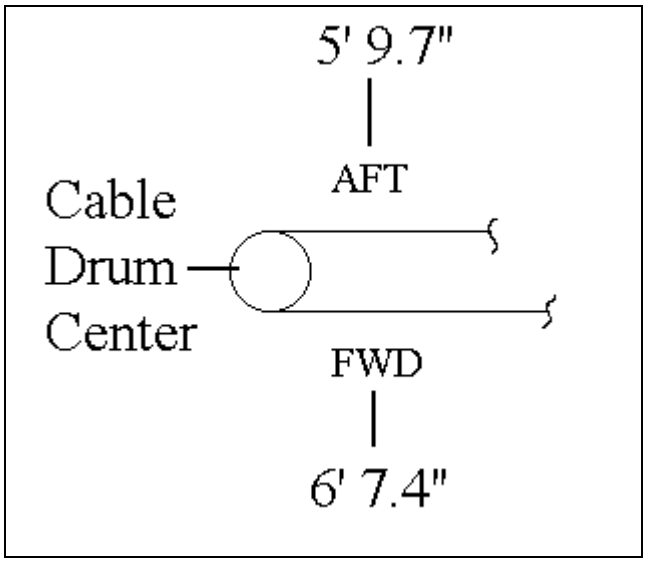

Figure 32. Cable Lengths to "Center" of the Cable

Three additional segments of the forward cable were recovered from the wreckage. In addition, the cable which was removed from the accident airplane during maintenance prior to the accident flight, was obtained from the airline. The dimensions of all of the cables were measured at the NTSB lab, and the results are provided in Figure 33.

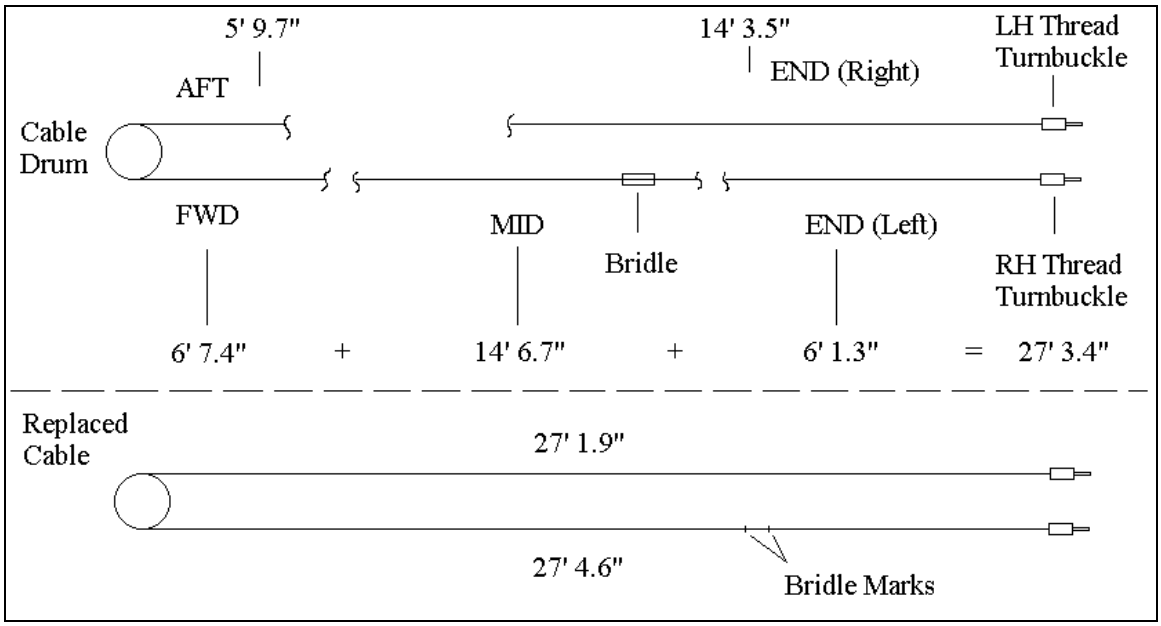

Figure 33. Dimensions of Cable Lengths

The total length of the cable segments labeled FWD, MID, and END(Left) equal 27' 3.4". This dimension is within 1.2 inches of the replaced cable length 27' 4.6".

The remainder of the trim system was recovered relatively intact. A sketch of the recovered components is provided in Figure 34. The group agreed that the rigging of the cables shown in the sketch are all correct. It was observed that the stop on the elevator trim cable on the left side was close to its stop block at the inboard pulley bracket. The cable stop on the right side was located near the right actuator. This position is consistent with a near full airplane nose down trim position.

The left trim actuator, Figure 35,was identified as part number 129-526033-7, serial number PAA 010903. The distance between the actuator housing and the "Dogbone" was 2.28 inches.

The right trim actuator Figure 36, was identified as part number 129-526033-9, serial number 6-22-00-b. The distance between the actuator housing and the "Dogbone" was 2.14 inches.

Raytheon Aircraft Company advised that the above measured extensions were consistent with the actuators being at or near the full nose down trim position.

The group checked the left side trim actuator by pulling on the top cable. The actuator extended, which would produce an airplane nose down effect. The right actuator was fractured and full of sand and could not be checked.

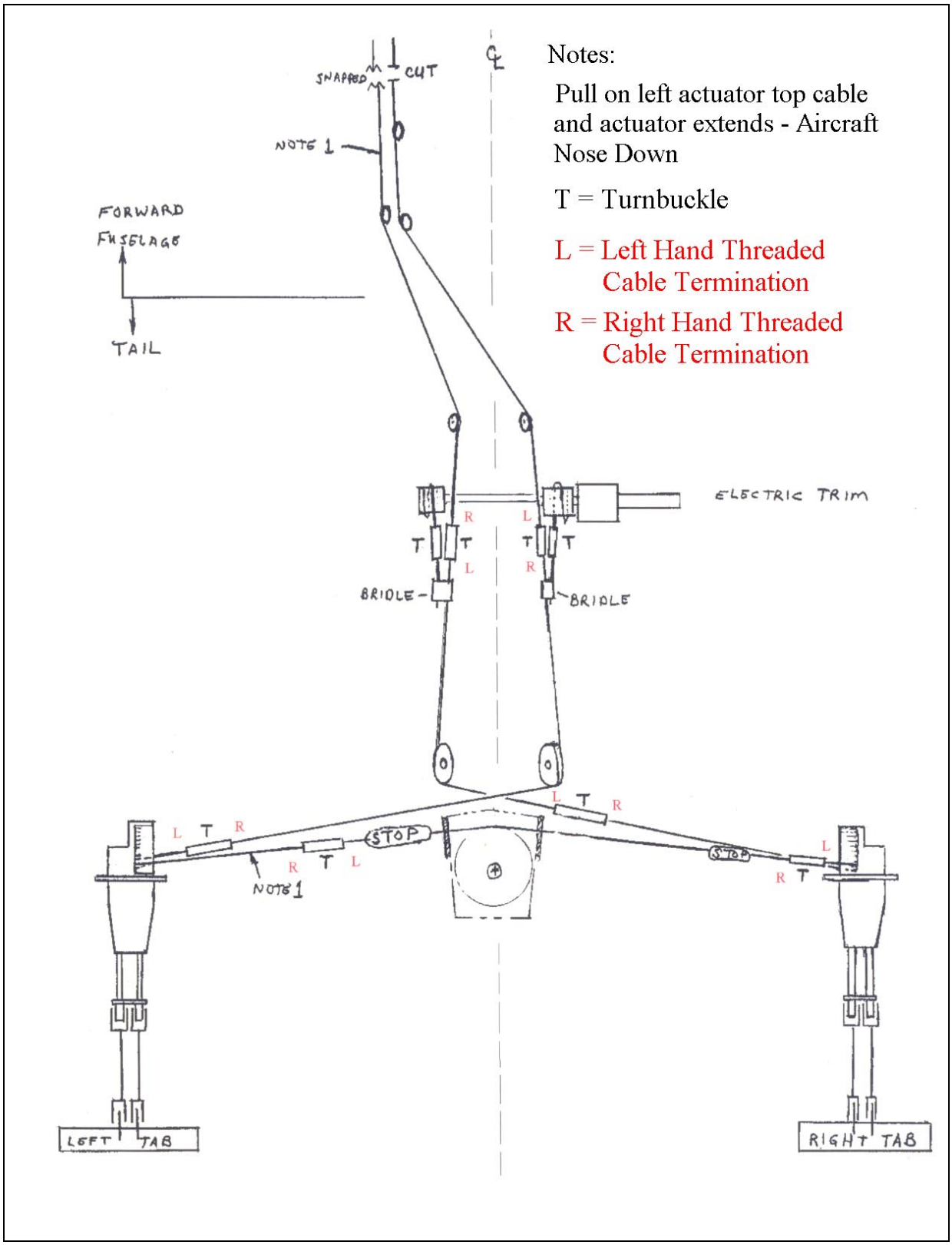

Figure 34. Sketch of Recovered Aft Elevator Trim Components

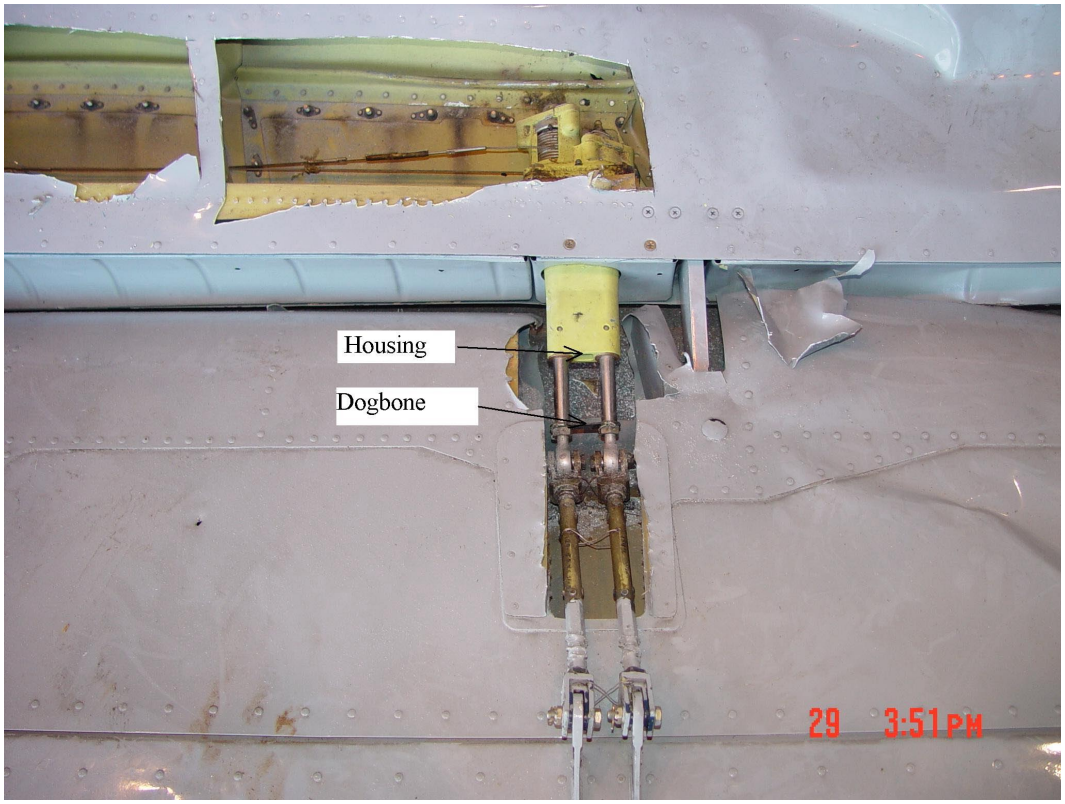

Figure 35. Left Elevator Trim Actuator.

Figure 36. Right Elevator Trim Actuator.

7.2 Electric Elevator Trim

The electric elevator trim servo installation was found still attached to its usual location at the base of the tail, Figure 37. The identification placard showed part number 109-524329-9 and serial number 525-F-92. The servo and drums were removed for examination.

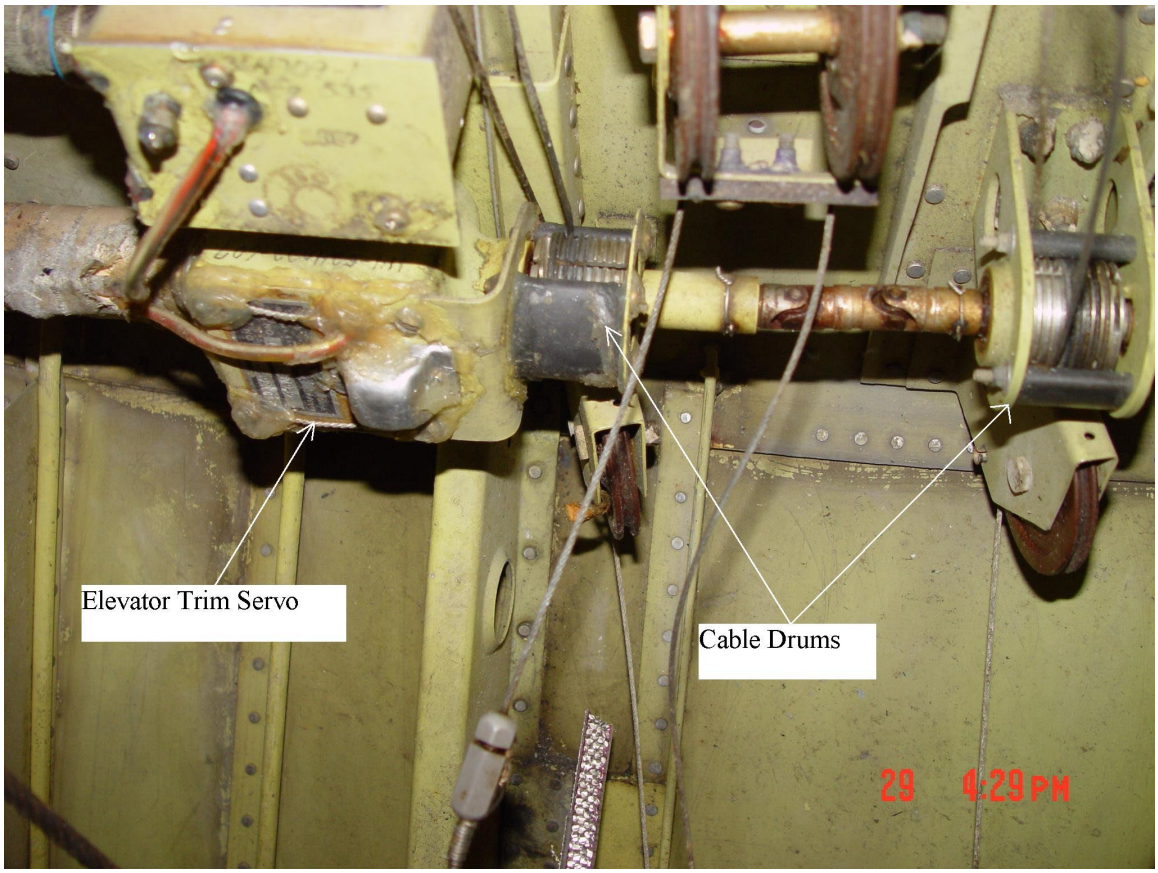

Figure 37. Electric Elevator Trim Servo Motor and Cable Drums

The group convened at Raytheon Aircraft Company on October 15, 2003 to examine and test the accident airplane servo motor.

The trim motor and control box were visually inspected and the following part numbers were recorded:

On the control Box: 101-524887-611, 101-364709-1, 101-524888-5
On the motor: 109-524329-9, 114-524022-607, 50-524497-1

Water was observed seeping out of the clutch housing. A hole was made in the cap over the clutch assembly and the water was drained. The end cap of the motor was removed, rust and a small amount of liquid was observed. The sealant was removed from a portion of the control box and no water was observed.

The wiring diagrams were reviewed and the wires coming out of the control box were identified. Each wire was stamped with the wire numbers indicated on the wire diagram (Figure 20).

It was determined that 28Volts DC applied to Pin A, and Ground applied to Pins E and H would result in the clutch engage and clockwise rotation of the motor as viewed from the output end of the motor (cable to be wound onto the drum). 28 volts DC applied to pin E, and Ground applied to pins A and H would result in the clutch engaged and counter clockwise rotation of the motor.

Pin continuity checks were performed on all combinations of pin to pin and pin to housing (Table 1).

	Pin K	Pin F	Pin E	Pin A	Pin G	Pin H
Pin K		89K	.8 M	.8 M	.4 M	.3M
Pin F			.5 M	.5M	60K	421
Pin E				7.8	65K	.4 M
PinA					60K	36K
Pin G						60K
Pin H						
Housing	2 M	350	2 M	2 M	2M	2M

Table 1. Results of Continuity Checks

28 volts DC was applied to pin E and ground to pins A and H. The motor operated and turned in the counter clockwise direction.

28 volts DC was applied to pin A and ground to pins E and H. The motor operated and turned in the clockwise direction.

The elevator trim servo speed was measured in each direction. The time was recorded for the cable to move 10 inches during motor operation. For clockwise rotation the time required was 30.4 seconds. For the counter clockwise rotation the time required was 31.92 seconds.

Raytheon Maintenance Manual 27-30-07 states that the time required for the cable to travel 10 inches should be between 35.3 and 37.2 seconds. It should be noted that these specified values are for a servo installed on an airplane and connected to the trim cable system. These tests were performed on a bench, absent the trim cable system friction.

8.0 Reverse Orientation of the Elevator Trim

The evidence of misleading maintenance instructions for rigging the forward cable drum, and the FDR data which showed the elevator trim moving in the nose down direction, led the airworthiness group to investigate the possibility of incorrectly rigging the elevator trim system.

The Airworthiness Group convened at the Raytheon Aircraft Services, in Wichita, KS on October 14, 2003 to examine the characteristics of a Beech 1900D with a forward elevator trim cable installed incorrectly, in reverse orientation, about the cable drum. The aircraft used for this evaluation is Model 1900D serial UE-46, N46YV

Raytheon Aircraft Services personnel had prepared the aircraft by removing the pilot's and copilot's seats, the cockpit floorboards, the side panels of the cockpit control pedestal, most of the left side passenger seats, the left side passenger floorboards, the access panel on the belly just aft of the nose gear wheelwell, and access panels in the empennage necessary for this examination of the elevator trim system.

The group began by installing the elevator aft bellcrank rig pin. This placed the elevators in neutral. An elevator travel board was positioned on the elevator and digital inclinometers were installed to both the left and right side trim tabs. The left elevator measured ½ degree trailing edge down and the right elevator measured 0 degrees using the travel board.

The cockpit elevator trim control wheel was set to 0. Both inclinometers were set to zero. The cockpit trim wheel was moved in the aircraft nose up direction.
The inclinometers measured:
17.3 degrees trailing edge down for the left trim tab
17.4 degrees trailing edge down for the right side trim tab.
The mechanic confirmed the cable stop in the tail did contact the fixed stop.

The cockpit trim wheel was moved in the aircraft nose down direction.
The inclinometers measured:
5.8 degrees trailing edge up for the left trim tab
5.9 degrees trailing edge up for the right side trim tab.

It was confirmed the cable stop in the tail did contact the fixed stop.

Inside the fuselage, the total trim system cable travel was measured as $17\ ^{13}/_{16}$ (17.81) inches when moving the trim system from stop-to-stop (aircraft nose up to aircraft nose down). This was used to calculate that there is approximately 1.3 degrees of tab travel per inch of cable travel. (17.3 + 5.8) degrees/17.81 inch=1.3 degrees/inch

The seats and floorboards had already been removed. The plastic conduit tubes in the aft cabin were moved aft to expose the turnbuckles. The aft cable system was 'blocked' to maintain cable tension in the aft system while working on the forward cable. The forward cable ends were disconnected from the turnbuckles.

At the cockpit pedestal, the bolts at each end of the drum shaft were removed. The cable drum was lifted from the pedestal, the shaft removed, the cable guard removed and the cable unwrapped from the drum. The cable drum lock pin was removed and

the cable was lifted from the drum. The cable orientation on the drum was reversed, the lock pin was replaced, and the cable was wrapped again. The cable guard was installed, the drum positioned on the shaft, and the parts installed in the pedestal.

The elevator trim forward cable has a left threaded terminal on one end and a right threaded terminal on the other end. This cable can only be attached to the aft two cables in one way. If the pedestal drum is wrapped backwards, the forward cable must be crossed once in the routing or the cables will not attach to the turnbuckles. The routing has numerous places where the cables change orientation and the paths are very close. The correct routing is not readily apparent.

The cables were now observed to cross and rub in the area between the pedestal drum and the first set of pulleys. This 'cable cross' was worked past the first and second sets of pulleys. The cable cross was located between the second and third sets of pulleys for this evaluation (Figure 27). While attempting to connect the cable ends to the turnbuckles it was noted that the cable length did not allow one terminal end to reconnect. The forward cable system was moved a little and the connection was made. The cables were tensioned and the aft cable system block was removed.

Because the cockpit trim wheel was removed during cable removal, it was necessary to re-index the cockpit trim control wheel indicator. The trim wheel was moved to place the elevator trim tab surface at neutral, and then the trim wheel indicator was slightly adjusted to "re-index" the 0 mark.

The cockpit trim wheel was moved and it was noted that the wheel moves backwards relative to the trim tab movement. When the wheel is moved in the aircraft nose up direction, the trim tabs trailing edge move up. When the wheel is moved in the aircraft nose down direction, the trim tabs move trailing edge down. When the manual trim wheel was rotated in the aircraft nose down direction, the wheel indicator moved well past the markings resulting in none of the indicator markings being visible when the cables reached their stops. When the trim wheel was rotated to the full nose up position the indicator read 3.5 units of trim instead of the normal position ~10 units.

The cables and stops in the tail were examined, measured, and a sketch was made (Figure 38). The measurements in Figure 38 were taken with the tab in the zero degree position. The position of the trim wheel and trim tab were measured (Table 2)

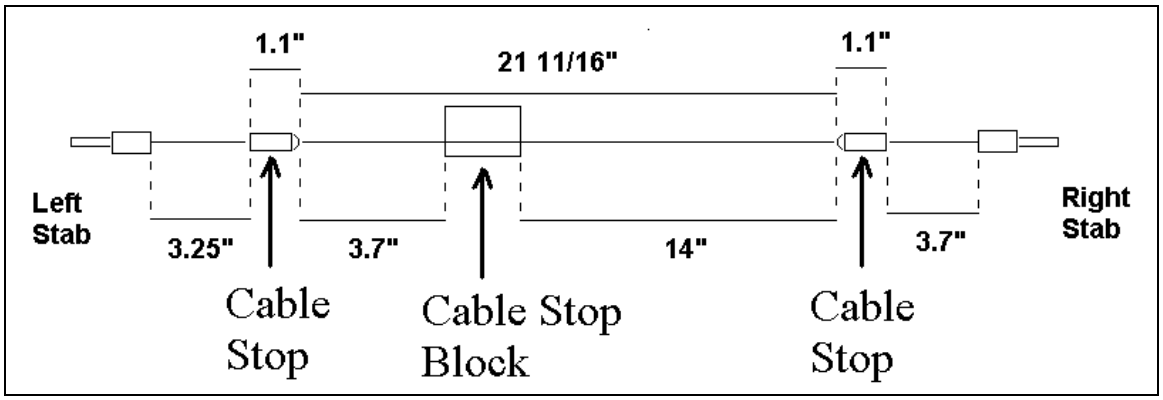

Figure 38. Position of elevator trim stops.

Trim Wheel Position	Right Tab Position (Deg)	Left Tab Position (Deg)
Full Nose Down	17.8 TED	17.4 TED
0	0.6 TEU	0.8 TEU
Full Nose Up	5.6 TEU	5.8 TEU

Table 2. Trim wheel and tab positions

Note: TED – Elevator trim tab trailing edge down
TEU – Elevator trim tab trailing edge up

With the elevator tab at approximately zero degrees the following additional measurements were made (Figure 39)

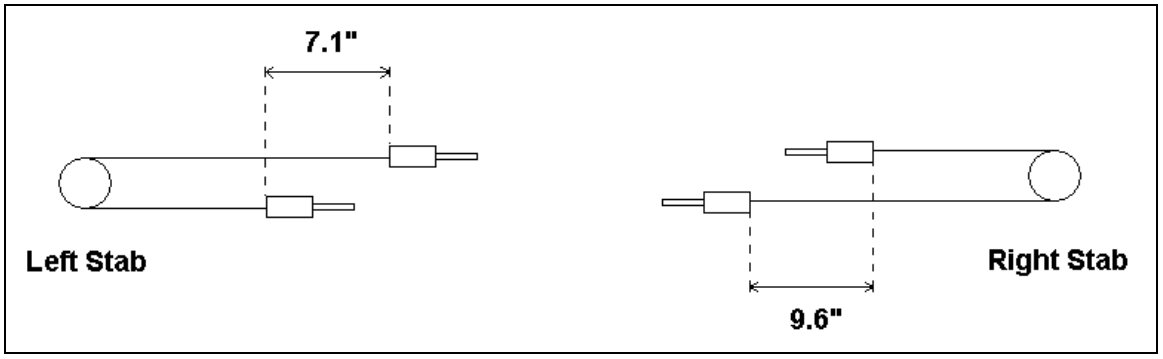

Figure 39. Position of turnbuckles at zero elevator tab deflection.

The next step in the test plan was to attempt to adjust the stops, so full nose up and full nose down travel could be achieved. The idea was to set the trim tab to neutral, set the trim wheel indicator to zero, and then adjust the stops to achieve the normal range of travel of the indicator. The measurements were discussed and the group decided that it was not possible to adjust the stops to meet this goal. One stop (the left side stop) would need to be moved more than was possible; this stop would be located beyond the end of the cable.

Another possibility was evaluated. The trim wheel was rotated to the limit (the stop contacts) in the aircraft nose down direction. Since the system was moving

backwards, the trim tabs were then full down. Then the trim wheel indicator was re-clocked so the indicator showed a normal aircraft nose down limit. The trim wheel was moved in the aircraft nose up direction to the stop. The cockpit trim indicator showed a normal aircraft nose up limit, and since the system was moving backwards, the trim tabs were then full up. The following measurements were made (note that the elevator is in the neutral position with the aft bellcrank pinned):

Trim wheel positioned at zero:

10.8 degrees left tab trailing edge down
11.1 degrees right tab trailing edge down

Trim wheel positioned at aircraft nose up limit:

6.3 degrees left tab trailing edge up
6.3 degrees right tab trailing edge up

Trim wheel positioned at aircraft nose down limit:

16.8 degrees left tab trailing edge down
17.1 degrees right tab trailing edge down

Trim wheel positioned at three (3) units nose up:

6.5 degrees left tab trailing edge down
6.8 degrees right tab trailing edge down

Trim wheel positioned at six (6) units nose up:

2.2 degrees left tab trailing edge down
2.3 degrees right tab trailing edge down

It was noted that with the elevator pinned at neutral, when the trim wheel is at zero, the trim tabs are can be observed to be in the trailing edge down position.

It was observed that if the electric trim is used when the cable is reverse routed, the tab goes in the correct trim direction, but the wheel goes in the opposite direction.

9.0 Maintenance Demonstration

The Airworthiness Group convened at the Colgan Air maintenance facility in Manasas, VA to review the maintenance which was performed on the accident airplane prior to the accident flight. The mechanics which performed the replacement of the forward cable where present for questioning. The results of the questioning is provided in Appendix B.

Both mechanics answered that they interpreted the maintenance illustration (Figure 15) as showing the open or slotted side of the cable drum facing them. Positioning the cable as instructed by the manual would reverse the control from the manual trim wheel. This in conjunction with a crossing of the cables, so that the turnbuckles could be connected, would produce a situation where wheel motion in the trim up direction would cause trim down commands to the trim tab and vice versa.

10.0 Condition of the Accident Airplane Wing, Flaps, and Roll Control components

10.1 Left Wing.

The left side winglet was present in the recovered wreckage. Eight (8) feet of the rear spar outboard of the engine was present. The complete left aileron and aileron tab with the inboard balance weights attached were recovered with the outboard bellcrank still attached to the rear spar and the yoke pin was engaged in the bellcrank arm. The aileron control stop bolts were intact and not damaged. The upper stop bolt (aileron trailing edge down) measures 0.75 inches from the base of the housing to the top of the stop bolt. The lower stop bolt (aileron trailing edge up) measures 0.78 inches from the base of the housing to the top of the stop bolt. The aileron wing cables had separated, approximately 11 feet from the bellcrank. The segment of the aileron wing cables were found with the left wing cable turnbuckles attached. The turnbuckles were located in the wing near the wing root rib, which was the rib nearest the fuselage. The turnbuckles are normally in the wheel well.

There is only one aileron trim actuator and it is installed on the left side. The aileron trim actuator was found attached to the rear spar. The distance from the base of the housing (where the rods exit the body, not the attachment to the spar) to the center of the rod ends (exposed rod length) measured 2.2 inches. The length of both cables from the trim actuator drum to the separated ends was measured. The length of both cables was approximately nine feet two inches (9' 2"). Another section of both aileron trim cables was found with the cable stops attached. The cable stops were located in the wing near the wing root rib, which is the rib nearest the fuselage. The cable stops are normally in the wheel well.

The entire left side outboard flap was recovered. The left side outboard flap actuator is attached to it's structure forward of the rear spar. The flap actuator drive cable was separated from the actuator housing. The left outboard flap actuator measured 2.5 inches from the housing to the center of the bolt hole where the actuator connects to the flap (exposed rod length). The flap actuator was separated from the flap.

There is a flap asymmetric switch mechanism located between the inboard and outboard flaps. The left wing flap asymmetric switch mechanism including the switch is present.

The entire left side inboard flap was recovered and was found attached to its outboard flap track. The left side inboard flap actuator was separated from the structure and was not attached to the flap. The flap actuator drive cable was separated from the actuator housing. The left outboard flap actuator measured 2.75 inches from the housing to the center of the bolt hole where the actuator connected to the flap (exposed rod length).

10.2 Right Wing

The right side winglet was present. Fifteen (15) feet of the right side rear spar was recovered. The spar was broken just outboard of the nacelle. The complete right aileron was recovered with the outboard bellcrank still attached to the rear spar and the yoke pin was engaged in the bellcrank arm. The aileron control stop bolts were intact and not damaged. Both the upper stop bolt (aileron trailing edge down) and the lower stop bolt (aileron trailing edge up) measured 0.85 inches from the base of the housing to the top of the stop bolt. The aileron cables were connected to the wing bellcrank. The aileron cables continued along the rear spar from the outboard bellcrank and were found separated approximately four (4) feet inboard of the right wheelwell. The turnbuckles were located in the wheelwell.

The entire right side outboard flap was recovered. The right side outboard flap actuator is attached to its structure forward of the rear spar. The actuator rod was found separated with the aft portion connected to the flap. The flap actuator drive cable was attached to the actuator housing. The exposed rod length could not be measured due to the separation of the actuator.

There is a flap asymmetric switch mechanism located between the inboard and outboard flaps. The right wing flap asymmetric switch mechanism including the switch is present.

The entire right side inboard flap was recovered and was found attached to its inboard and outboard flap track; the inboard flap track was separated from the spar. The right side inboard flap actuator was not found.

The flap limit switch assembly was found attached to the right inboard rear spar.

The aileron quadrant located in the center fuselage was found. The two left wing and the two right wing cables were attached to the bellcrank and only one of the two cables that route to the control column were attached.

The complete lower main spar cap was recovered thirty six (36) feet. It was cut twenty (20) feet from the left end to facilitate recovery operation.

11.0 Vertical Stabilizer and Yaw Control.

The rudder surface is connected and intact with some impact damage. The rudder control horn located at the bottom of the rudder is intact and attached to the torque tube. The rudder surface stop bolt length was measured. From the structural support to the top of the stop bolt measures 0.81 for the left stop and 0.82 for the right stop. The rudder control horn was found attached to the aft end of the pushrod. The forward end of the pushrod was found connected to the rudder torque shaft arm. The two rudder control cables are intact from the torque shaft sectors to the forward bellcrank normally located under the copilot. The forward bellcrank is in pieces.

The yaw damper top cable is connected to the right upper sector of the rudder torque shaft assembly. The yaw damper bottom cable is disconnected from the bridle that normally connects it to the rudder control cable that connects to the lower sector of the rudder torque shaft.

The rudder trim tab was found intact and installed on the rudder. The rudder trim tab actuator was found intact, connected to the trim tab, and installed on the vertical stabilizer spar. The rudder trim tab actuator cables were examined. The left cable enters the left side of the actuator, and the right cable enters the right side of the actuator. The trim cable routing was followed forward toward the cockpit. From station 511 forward the trim actuator cables measured 11'5" on the left side and 14' on the right side to the place where the cables are broken.

12.0 Landing Gear

The left main landing gear was found attached to the structure. The wheels, tires, brakes, axle, lower torque knee, and socket were recovered as a single assembly but this assembly was not attached to the piston. The left hydraulic actuator was found attached to the structure and to the drag leg assembly and the actuator is extended.

The right main landing gear upper trunion (top brace) was found attached to the wheelwell structure. The piston with the wheels, tires, brakes, axle, lower torque knee, and socket were recovered as a single assembly but this assembly was not attached to the upper trunion. The right landing gear hydraulic actuator was recovered and was found separated from the landing gear.

13.0 Cockpit

The Captain's and First Officer's control wheels were recovered. The electric trim switches were not found.

There are sprockets on the outboard ends of the control column that transfer the rotation motion of the control wheel to a chain that moves the aileron control system. Both sprockets were found and appear intact, although impact damaged.

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