Aviation Investigation Preliminary Report

Location:	Oakland, CA	**Incident Number:**	DCA24LA206
Date & Time:	May 25, 2024, 07:44 Local	**Registration:**	N8825Q
Aircraft:	Boeing 737-8	**Injuries:**	181 None
Flight Conducted Under:	Part 121: Air carrier - Scheduled		

On May 25, 2024, about 0744 Pacific daylight time, Southwest Airlines (SWA) flight 746, a Boeing 737-8, N8825Q, experienced a rudder control system anomaly while operating as a Title 14 *Code of Federal Regulations* Part 121 scheduled domestic passenger flight from Phoenix Sky Harbor International Airport (PHX), Phoenix, Arizona to the Metro Oakland International Airport (OAK), Oakland, California. The airplane continued to its destination and landed. The 181 passengers and crew aboard the airplane were not injured.

History of Flight

According to the flight crew, the captain was the pilot flying and the first officer (FO) was the pilot monitoring. The captain said that while reviewing the logbook before the flight, he noted a previously recorded yaw damper discrepancy described as “the yaw damper over-correcting in flight”. He recalled that the corrective action consisted of resetting a few stall management yaw damper computer codes.

The preflight, pushback, and initial taxi segments of the flight were uneventful. However, when cleared for takeoff and while turning onto the runway, after transitioning to rudder pedal steering, the captain noticed momentary stiffness in the rudder pedals.

Following departure, occasional light turbulence was encountered during an uneventful climb to the cruise altitude of 34,000 feet. The captain said that shortly after reaching their cruise altitude, and while flying through some light chop, the aircraft began to experience “a small amount of Dutch roll”. He stated that “the roll was stable, more noticeable in frequency, with only a slight amount of yaw.” The oscillations lasted a few seconds and the autopilot remained engaged throughout the event. The FO characterized the event as a “strange movement of the tail of the airplane back and forth, coupled with very slight rudder movement left and right. The tail movement was noticeable, but not excessive, and I remember my first thought being this is some odd light chop”.

The flight crew discussed the event and noted that they felt the rudder pedals move during the oscillations. They deduced that the oscillations were not caused by the turbulence, as the rudder pedals should not move with the yaw damper system, but rather by the airplane.

After coordinating with Air Traffic Control (ATC), they descended to 32,000 where they encountered similar flight conditions. The same type of aircraft movements was experienced a few more times during the cruise portion of the flight and the captain felt faint rudder pedal movement in phase with the oscillations. The yaw damper light did not illuminate and there were no master caution warnings for the duration of the flight.

SWA maintenance control was notified by the flight crew of a yaw damper issue via the aircraft communication addressing and reporting system (ACARS) and the flight continued to OAK and landed without incident. However, after clearing the runway, the captain felt the same oscillations and rudder pedal stiffness observed earlier in the flight.

After arriving at the gate, the aircraft was met by SWA maintenance, and the airpoance was removed from service. Post-incident troubleshooting and inspection of the airplane was accomplished by SWA maintenance. The examination revealed damage to the vertical stabilizer trailing edge ribs above and below the standby rudder power control unit (PCU). The damage to the stabilizer ribs adversely affects the structural strength of the fitting and is considered substantial damage. As part of the investigation, a timeline of events was created.

Timeline of events

On May 16, 2024, about 1715 CDT, the event airplane, operating as SWA flight 621, landed and parked at gate B5 at the Louis Armstrong New Orleans International Airport (MSY), New Orleans, Louisiana. About half an hour later, the aircraft was moved to a remote spot, R3W, where it remained for the night. In the morning, the airplane was moved back to gate B5 for departure on the 17th (SWA flight 450).

During the evening of May 16, 2024, the KMSY area was impacted with a squall line of thunderstorms which resulted in strong gusting winds up to 73 knots, heavy rain, and a wind shift. The peak gust of 73 knots was recorded at 2336 CDT (0436Z May 17, 2024). A National Weather Service (NWS) Composite Radar Mosaic depicted a bowing segment associated with the squall line around that time (figure 1). The NWS had a Convective Significant Meteorological (SIGMET) current for an area of severe thunderstorms moving from 250 degrees at 35 knots, with tops above 45,000 ft, the NWS also had a tornado watch current for the area at the time. Thunderstorms began at 2212 CDT on May 16th and continued through 0234 CDT on May 17th with a total of 1.37 inches of rainfall.

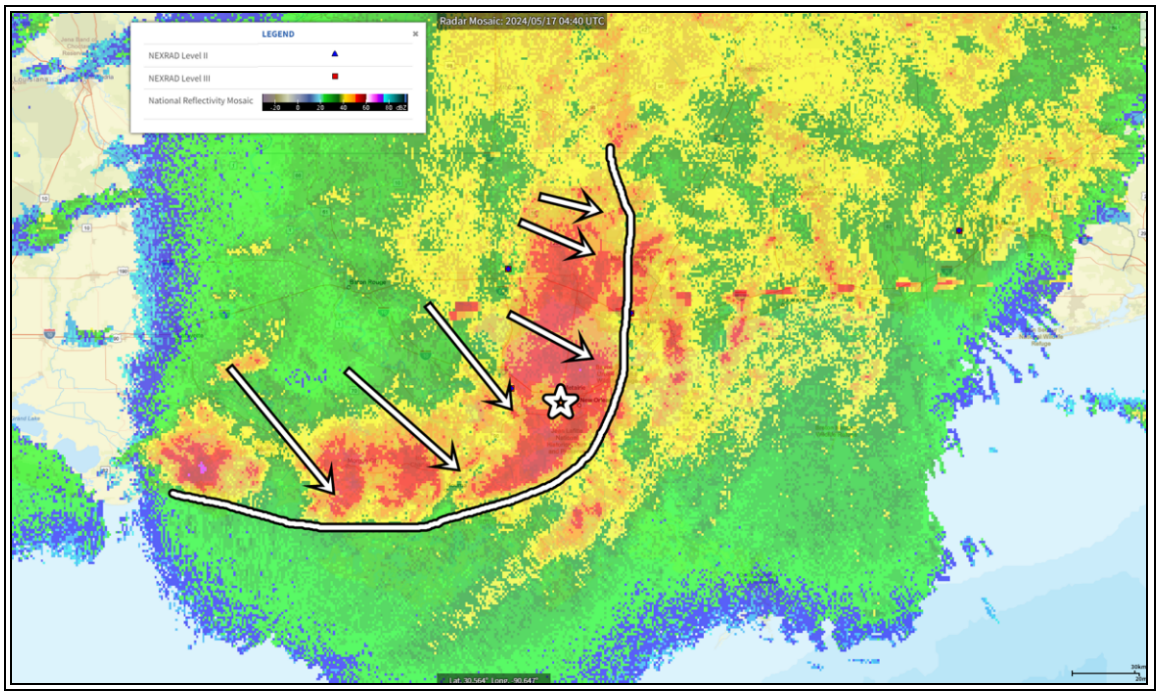

Figure 1. NWS Composite Radar Mosaic depicted a bowing segment associated with the squall line at 2340 CDT.

A Special (SPECI) Meteorological Aerodrome Report (METAR) at MSY was reported at 2342 CDT, wind from 330° at 38 knots, gusting 73 knots, visibility ¼ statute mile, thunderstorm with heavy rain, fog, squall, ceiling broken at 1,100 ft agl [above ground level] cumulonimbus, overcast at 2,500 ft agl, temperature 22°C, dew point 22°C, altimeter 29.75 inches of mercury. The remarks for the SPECI METAR included: automated observation system with a precipitation discriminator, peak wind 280° at 73 knots at time 0436, wind shift at time 0428, lightening distant all quadrants, frequent lightning cloud to ground, in cloud, cloud to air and overhead, thunderstorms overhead moving east, hourly precipitation .75 inches, temperature 21.7°C, dew point 21.7°C, runway visual range (RVR) equipped but no RVR report.

A review of maintenance records shows that on May 23, 2024, the event airplane, operating as SWA flight 2210, landed at William P Hobby Airport (HOU), Houston, Texas where it remained overnight for a normally scheduled “A Core Check”. The check was performed in a maintenance hangar. One of the tasks conducted during this maintenance check was an operational test of the standby hydraulic actuation system, which included a test of the standby rudder PCU. This task involved turning on the standby hydraulic system and having a maintenance technician move the rudder pedals to their left forward and right forward stops at a high rate for 5 cycles and visually checking that the rudder surface moves. According to the maintenance records, the test passed, and no issues were noted. A review of flight data recorder (FDR) data found that this is the last time the standby rudder PCU was powered on.

Rudder system description

Pilot control of the 737-8 rudder is transmitted in a closed-loop system from the pilots' rudder pedals in the cockpit through a single cable system, aft rudder quadrant, pedal force transducer to the aft rudder input torque tube in the vertical fin. Rotation of the torque tube provides the command inputs to the main and standby rudder power control units (PCU's) to move the rudder surface. Two independent input rods (an upper and a lower) from the torque tube provide inputs to the main rudder PCU and one input rod from the torque tube provides an input to the standby rudder PCU. Both PCUs are located in the rear of the vertical stabilizer and are connected to the rudder. The PCUs are mounted inside the stabilizer using vertical support brackets which are attached by fasteners onto the flanges that are part of the stabilizer's internal rib assemblies.

The rudder system does not incorporate a gust-lock function. A gust damping function is provided by the bypass valves of the main rudder PCU. The main PCU contains two independent bypass valves, one in each control valve manifold and operates in one of two modes depending on hydraulic configuration, bypass or normal. When hydraulic pressure is configured to OFF or below 250 psi, the valves are spring-biased to the bypass position. In the bypass mode, an orifice in the valve spool allows the actuator to be moved by external loads with reduced hydraulic resistance. The orifice is sized to meet gust-damping requirements in Title 14 *Code of Federal Regulations* 25.415 when the airplane is on the ground and all hydraulic systems are depressurized. The gust damping prevents wind gusts from driving the rudder into the stops (PCU bottomed) at a rate that could damage the control system or structure. Gust damping is handled by the main rudder PCU, and that function is not present in the standby rudder PCU.

After the May 25, 2024, rudder system anomaly event, SWA maintenance replaced the main rudder PCU as part of their troubleshooting procedures. During the replacement and functional testing of the PCU, maintenance found a damaged bearing in the forward end of the upper input control rod. A new control rod was installed and during the rigging/adjustment of the main rudder PCU, maintenance identified additional structural damage to the rudder system in the area surrounding the standby rudder PCU. The standby rudder PCU was removed and was retained, along with the main rudder PCU, for further examination and testing by the NTSB systems group. Damage was observed on the standby rudder PCU forward support bracket and anti-rotation bushing. The vertical stabilizer trailing edge rib above the standby PCU was also fractured through and adjacent to two of the three holes where the left standby PCU support bracket was attached (figure 2). The vertical stabilizer trailing edge rib below the standby PCU was dented/deformed up to about 0.065" forward of the location where the standby PCU forward support brackets are attached. The damaged structural components were removed for further examination by the NTSB structures group.

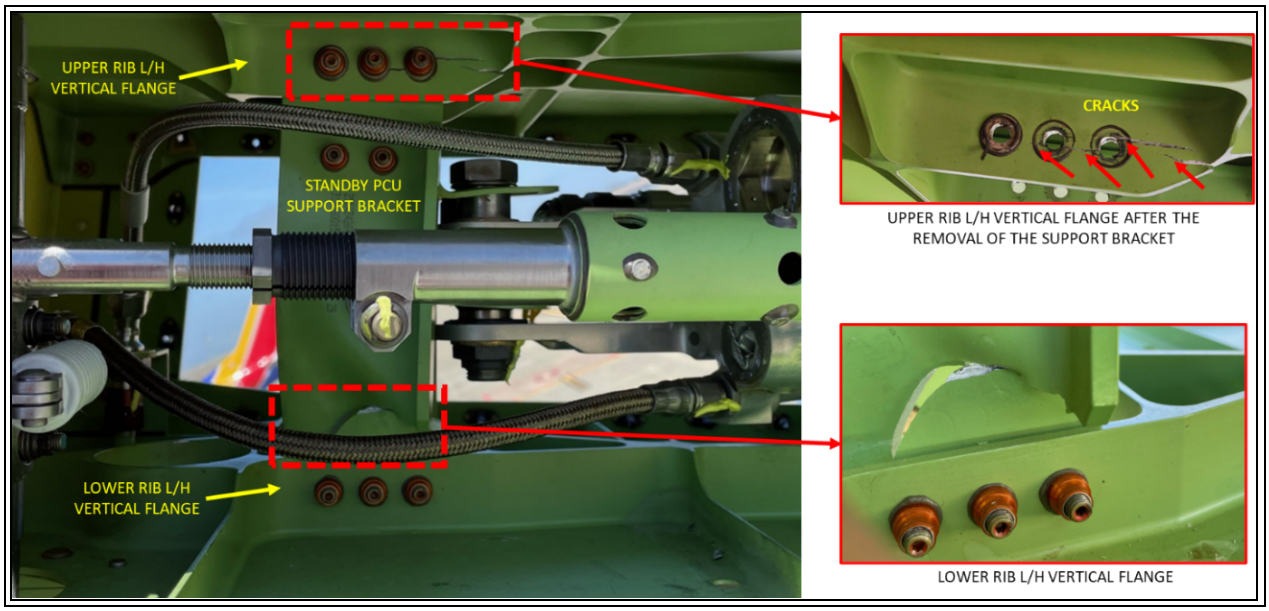

Figure 2. View of damage to the standby rudder PCU support bracket and ribs. (Source: Southwest Airlines)

Investigation

On June 7, 2024, the National Transportation Safety Board (NTSB) was notified by SWA about the event and, in response, began an incident investigation. As part of the investigation, the following parties are participating: the Federal Aviation Administration (FAA), SWA, Southwest Airlines Pilots Association (SWAPA), The Boeing Company, and Parker Hannifin Corporation. The parties were formed into specialized investigative groups led by NTSB group chairs in the areas of operations, aircraft performance, structures, systems, and flight data recorder.

On June 26-27, 2024, the systems group met at the Parker Hannifin facility in Ogden, Utah to examine and test the main and standby rudder PCUs removed from the incident airplane. No anomalies were found with either PCU and both passed their acceptance test procedure.

The damaged structural components were examined by the NTSB structures group during the week of July 1, 2024.

Data

Data from the digital flight data recorder (DFDR) was sent to the NTSB's Vehicle Recorder Laboratory in Washington, DC, for analysis. A preliminary review of the data has been completed and a plot showing the rudder system parameters for the event flight is shown in figure 3. A review of the data corroborated the flight crew's statements regarding the anomalous behaviorof the rudder system during cruise at 34,000 feet. Data showed periodic oscillations, lasting about 20 seconds, in rudder deflection, rudder pedal position, and yaw damper command. These oscillations had a frequency of approximately 0.9 Hz, and an amplitude of about ±0.75 degrees of rudder surface movement. This motion resulted in ±0.03

G oscillations in lateral acceleration at the same frequency, but no significant changes or oscillations in airplane heading or bank angle.

A review of the data also showed that the anomalous behavior of the rudder system began on the first flight after a scheduled maintenance on May 23, 2024. Before the maintenance, yaw damper commands did not correspond to rudder pedal movements. However, after scheduled maintenance was performed on the airplane, rudder pedal movements were noted when the yaw damper was engaged. All occurrences of these oscillations occurred with the yaw damper engaged; when the yaw damper was disengaged in-flight, or when the airplane was dispatched with the yaw damper on the minimum equipment list (MEL), the anomalous behavior was not observed.

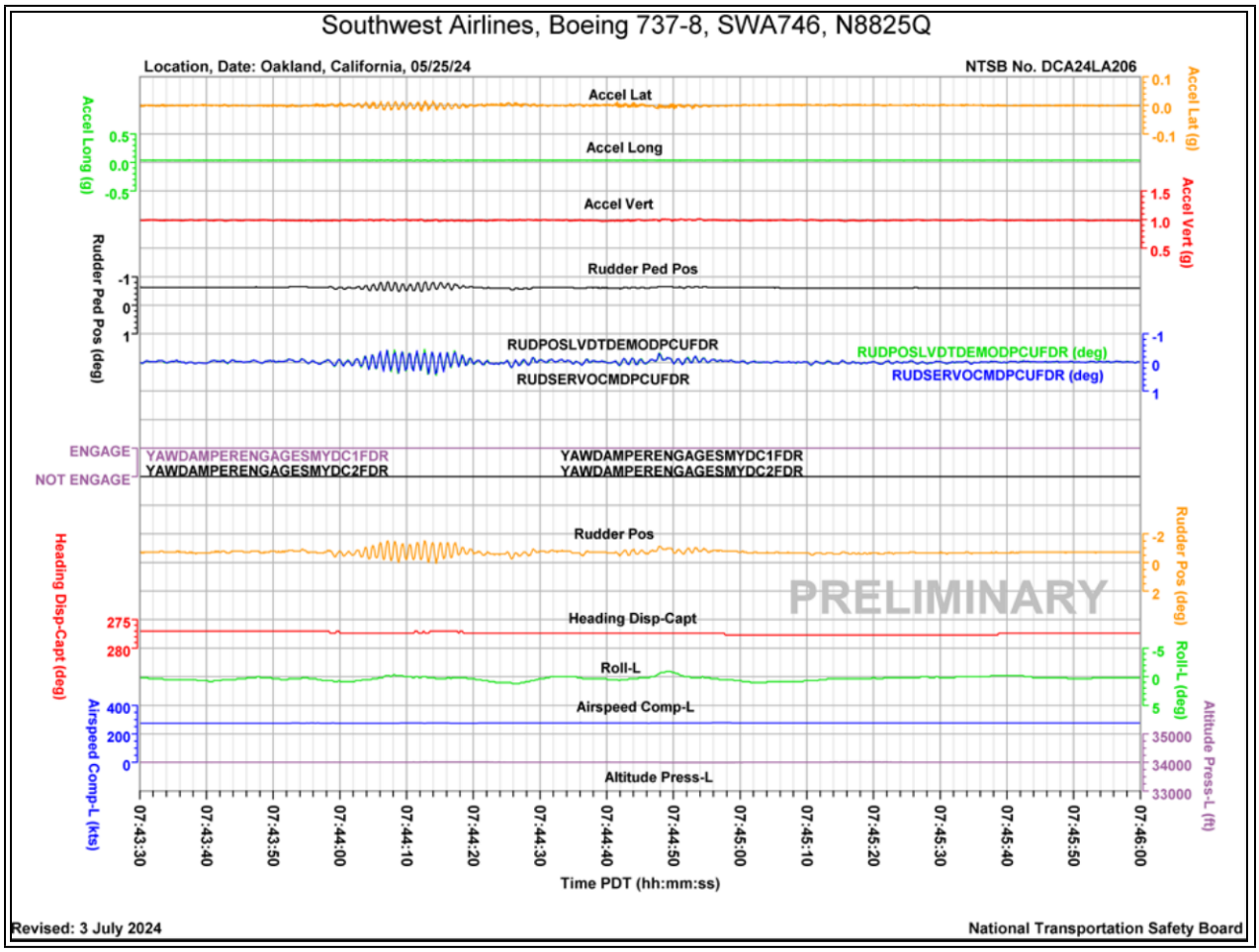

Figure 3. Plot of the FDR data from the event flight.

Safety Actions

Southwest Airlines conducted an inspection campaign on the entire MAX fleet (231 aircraft) between June 17th and June 20th. The aircraft underwent a detailed visual inspection for any damage to the main rudder PCU and standby PCU hardware and structural attach points. No

damage or anomalies were found. New deliveries from Boeing are inspected at make ready, with no findings to date.

As part of Southwest's ongoing fleet monitoring, an algorithm was developed to search MAX Quick Access Recorder (QAR) data, which is the same data set available to the DFDR for rudder oscillations. No aircraft were observed to exhibit the same behavior as N8825. Three aircraft were observed to have small rudder oscillations without associated rudder control surface movement and were inspected out of abundance of caution with no findings. The monitoring of QAR data via this algorithm is ongoing.

Part of the investigation will be determining when the structural damage to the rudder system occurred.

The investigation continues.

Aircraft and Owner/Operator Information

Aircraft Make:	Boeing	**Registration:**	N8825Q
Model/Series:	737-8	**Aircraft Category:**	Airplane
Amateur Built:			
Operator:	SOUTHWEST AIRLINES CO	**Operating Certificate(s) Held:**	Flag carrier (121)
Operator Designator Code:			

Meteorological Information and Flight Plan

Conditions at Accident Site:	Unknown	**Condition of Light:**	Day
Observation Facility, Elevation:	En-route	**Observation Time:**	
Distance from Accident Site:		**Temperature/Dew Point:**	
Lowest Cloud Condition:	Unknown	**Wind Speed/Gusts, Direction:**	/ ,
Lowest Ceiling:		**Visibility:**	
Altimeter Setting:		**Type of Flight Plan Filed:**	IFR
Departure Point:	Phoenix, AZ (KPHX)	**Destination:**	San Francisco , CA (KOAK)

Wreckage and Impact Information

Crew Injuries:	6 None	**Aircraft Damage:**	None
Passenger Injuries:	175 None	**Aircraft Fire:**	None
Ground Injuries:		**Aircraft Explosion:**	None
Total Injuries:	181 None	**Latitude, Longitude:**	37.721298,-122.221

Administrative Information

Investigator In Charge (IIC):	Hauf, Michael
Additional Participating Persons:	Patrick Petrilla; Southwest - Flight Safety Nathan Williams; Boeing Commercial Airplanes Eddie Miller; FAA Craig Jakubowski ; SWAPA Jeremy Katt; Parker Hannifin Corporation
Investigation Class:	Class 3
Note:	The NTSB did not travel to the scene of this incident.