Root Cause Analysis Report

AA Flight 191

Problem Statement

Report Number	RCA-28-07-17-114	**RCA Owner**	Chris Eckert
Report Date	7/28/2017	**RCA Facilitator**	Brian Hughes

Focal Point: AA Flight 191 Crashed - 273 Fatalities

When

Start Date: 5/25/1979	End Date: 5/25/1979
Start Time: 3:02 PM	End Time: 3:02 PM
Unique Timing	After losing hydraulic systems when engine #1 detached during takeoff.

Where

	Hydraulic Systems 1 & 3, #1 Electrical Bus (damaged by engine detachment)
	Engine #1 (detached from airplane)
Other	DC 10 - N110AA
Other	American Airlines

Actual Impact

Safety	273 Fatalities (258 passengers, 13 crew, 2 on ground)	$0.00
Cost	Loss of aircraft, damage to buildings on ground	$0.00
Reputation (External)	Extensive coverage and previous DC 10 incidents caused loss of confidence in this class of aircraft	$0.00
Frequency	1 times Overall	
Frequency Note	This is the only crash of a DC 10 from this type of failure.	

Report Summaries

Executive Summary

READ THIS FIRST!

We need to disclose that this EXAMPLE RCA is based upon publicly available information from the NTSB report on the matter and not from any independent investigation conducted by Sologic. Sologic has not investigated this incident in any official capacity, and we do not want to imply that we were in any way associated with this event. The only purpose of this root cause analysis report is for it to be used as an example for our students and other interested parties.

Problem Setup:

With fatality investigations, or any safety investigation for that matter, we think it is important to include the number and severity of injuries sustained in the focal point. This ensures that we prioritize the RCA to focus on the impact to the people involved.

You will see that we have three immediate causes leading up to the focal point: 1) “Plane struck the ground” – the physical mechanism for the break-up of the plane, 2) “271 on board (258 passengers, 13 crew members, 0 survivors)” – an accounting of those on board the plane, and 3) “2 fatalities on the ground in path of falling debris” – an accounting of the fatalities on the ground.

Cause and Effect Summary

On May 25, 1979 at approximately 3:02 PM, American Airlines flight 191 crashed, killing all 271 people on board and 2 on the ground. The aircraft was a DC 10, tail number N110AA. This was a regularly scheduled flight.

As the plane accelerated during its take-off roll, the left engine (engine #1) ripped free of its mount under the wing. The engine was at full thrust at the time. This pushed the engine forward of the wing where the wind velocity then caught the engine and flipped it back up and over the left wing, where it landed in the runway. The pilots were aware that engine #1 was no longer available, but not that it was no longer attached to the aircraft. Since they had achieved take-off speed, they could no longer safely abort. Procedure called for them to continue to take-off, and then circle back to the airport to land. The plane rotated back, and then took flight.

However, when the engine ripped free from the wing, it damaged two of the three hydraulic systems as well as the #1 electric bus. These hydraulic systems controlled the leading edge slats on the left wing. Leading edge slats extend the leading edge (front) of the wing forward during times when the aircraft is flying slower, such as during take-off and landing. By extending forward, they (along with the rear flaps) effectively increase the size of the wing. This reduces what is known as the “stall speed” – the speed at which lift is no longer provided.

During take-off, the leading edge slats of both wings were fully extended to provide maximum lift. However, with the loss of hydraulic pressure, there was nothing holding the left slats in place. The wind generated by forward motion pushed the slats back up into the wing. This increased the stall speed of the left wing. However, the right wing operated normally with slats fully extended. This caused an imbalance in lift between the wings, which then caused the left side to dip.

The pilots were unaware of the flap position or that the aircraft was traveling below stall speed. This was in part because the pilot's stick-shaker stall indicator and flap position indicators were unavailable. These components were powered by the #1 bus, which went out with the loss of the #1 engine. The co-pilot was in control of the aircraft, but his controls did not include the stick-shaker stall warning – an add-on feature that American Airlines chose to forgo.

The imbalance in lift ultimately caused the plane to achieve a 112-degree angle. This was simply unsustainable, and the plane crashed 50 seconds after takeoff.

The engine ripped free when the mounting hardware failed. This hardware had been damaged 8 weeks prior during engine maintenance and subsequent forces of multiple take-offs and landings degraded it to the point of failure. The damage occurred when the engine was being removed for maintenance. The engine is attached to a pylon, which is attached to the wing structure. McDonnell Douglas service manuals state that the engine and pylon need to be removed in separate steps. However, airlines operating DC10s had discovered that they could be removed together. This saved many steps and work hours. However, doing so meant that both engine and pylon required stabilization during the process.

American Airlines chose to use a large forklift to stabilize the engine and pylon during removal. However, this method was imprecise. The forklift driver could not actually see the mounting area and had to rely on hand signals from a spotter. During this particular maintenance operation, the pylon had become jammed which led the maintenance crew to move the engine back and forth. This caused damage to the rear mounting hardware. However, this damage was not noticed at the time. The work was completed, the engine and pylon were reinstalled, and the airplane was returned to service. The subsequent forces of multiple take-offs, flights, and landings ultimately led to the catastrophic failure of the mounting hardware.

--END OF SUMMARY--

Solutions

SO-0001	**Solution**	Immediately discontinue the practice of raising/lowering engines with the pylon still attached.		
	Cause(s)	American Airlines procedure to remove both engine/ pylon		
	Note	It was much safer to the equipment to remove the engine, and then the pylon.		
	Assigned		**Criteria**	Passed
	Due		**Status**	Validated
	Term	short	**Cost**	
SO-0002	**Solution**	Modifications were made to the slat actuation and position systems, along with stall warning and power supply changes.		
	Cause(s)	Pilots did not increase speed - unaware flaps had retracted		
	Note	These changes help provide the pilots with more accurate information regarding slat position.		
	Assigned		**Criteria**	Passed
	Due		**Status**	Validated
	Term	short	**Cost**	
SO-0003	**Solution**	Make adjustments to recommended take-off/climb airspeed schedules with respect to stall speeds.		
	Cause(s)	Pilots did not increase speed - unaware flaps had retracted		
	Note	No additional notes.		
	Assigned		**Criteria**	Passed
	Due		**Status**	Validated
	Term		**Cost**	
SO-0004	**Solution**	Slat relief valves were mandated to prevent slat retraction in case of hydraulic line damage.		
	Cause(s)	Left flaps retracted - smaller surface area = higher stall speed		
	Note	These valves ensure that in case of loss of hydraulic fluid that the flaps fail to deployed position, thereby minimizing stall speed.		
	Assigned		**Criteria**	Passed
	Due		**Status**	Validated
	Term		**Cost**	

SO-0005	**Solution**	Inspect all other DC10s for similar fatigue/damage		
	Cause(s)	#1 rear pylon mount damaged		
	Note	Inspections were conducted for all other DC10s - several were found to be damaged.		
	Assigned		**Criteria**	Passed
	Due		**Status**	Validated
	Term	medium	**Cost**	
SO-0006	**Solution**	Stick shakers for both pilots became mandatory in response to this accident.		
	Cause(s)	Co-pilot's stick not equipped with stall warning/stick shaker		
	Note	As a result of this accident, stick shaker stall warnings became required for both the pilot and co-pilot.		
	Assigned		**Criteria**	Passed
	Due		**Status**	Validated
	Term	short	**Cost**	

Team

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Chart Key
Transitory
Non Transitory
Transitory Omission
Non Transitory Omission
Undefined
Chart Quality Alert
Focal Point
Evidence
Notes
Solutions
Tasks
AA Flight 191 Crashed - 273 Fatalities
AA 191 struck the ground
Flight became unsustainable/ unrecoverable
Airplane rolled to 112 degrees
Positive lift on right wing
Right wing was undamaged, flaps deployed
END
Terminated Because:
Desired State
Airplane velocity less than stall speed for left wing
Left flaps retracted - smaller surface area = higher stall speed
Solutions
Slat relief valves were mandated to prevent slat retraction in case of hydraulic line damage.
Criteria Pass Status Validated
These valves ensure that in case of loss of hydraulic fluid that the flaps fail to deployed position, thereby minimizing stall speed.
Hydraulic systems 1 & 3 catastrophically damaged
Connects To:
#1 Engine fell off
Flaps fail to retracted position
System design
Terminated Because:
Other causual paths more productive
Pilots thought engine was out, not that it had fallen off
Could not visually see the wing
Terminated Because:
Other causual paths more productive
Pilots did not increase speed - unaware flaps had retracted
Solutions
Modifications were made to the slat actuation and position systems, along with stall warning and power supply changes.
Criteria Pass Status Validated
These changes help provide the pilots with more accurate information regarding slat position.
Make adjustments to recommended take-off/climb airspeed schedules with respect to stall speeds.
Criteria Pass Status Validated
No additional notes.
Other stall/ flap position indicators unavailable to Captain
Captain's instruments went offline -lost power
Damage to #1 Electrical bus
#1 Engine fell off
Damaged rear pylon mount failed
Stresses from multiple take-offs/ landings finally reached failure
Airplane returned to service with damage to #1 rear pylon
Unaware of damage to #1 rear pylon
#1 rear pylon mount damaged
Solutions
Inspect all other DC10s for similar fatigue/damage
Criteria Pass Status Validated
Inspections were conducted for all other DC10s - several were found to be damaged.
#1 engine/pylon removed 8 weeks prior
Scheduled maintenance
Terminated Because:
Desired State
American Airlines procedure to remove both engine/ pylon
Solutions
Immediately discontinue the practice of raising/lowering engines with the pylon still attached.
Criteria Pass Status Validated
It was much safer to the equipment to remove the engine, and then the pylon.
McDonnell Douglas procedure removed each separately
Terminated Because:
Other causual paths more productive
New procedure saved 200 hours, less complex
Terminated Because:
New investigation?
Engine/pylon jostled around during removal
Forklift used to support engine did not provide consistent support
Pylon had become jammed during removal
Forklift needed to be repositioned to get engine to drop
Sufficient force to damage mounting hardware
Terminated Because:
Other causual paths more productive
Engine forces - occurred during full power for takeoff
Terminated Because:
Other causual paths more productive
Location of #1 Electrical bus system proximal to #1 Engine
Terminated Because:
Other causual paths more productive
Secondary power not routed to Captain's instruments
Secondary power option was available
Terminated Because:
Desired State
Navigator &/or Captain could have, but did not re-route
Co-pilot's stick not equipped with stall warning/stick shaker
Solutions
Stick shakers for both pilots became mandatory in response to this accident.
Criteria Pass Status Validated
As a result of this accident, stick shaker stall warnings became required for both the pilot and co-pilot.
Deemed too expensive by American Airlines
Terminated Because:
Other causual paths more productive
Offered as an option by McDonnell Douglas
Terminated Because:
Other causual paths more productive
Airplane flying at 350 feet
Pilots followed procedure for lost engine continued to takeoff
Terminated Because:
Desired State
Procedure directs to continue with takeoff, then circle back
Unable to abort after achieving take-off speed
Terminated Because:
Other causual paths more productive
Pilots could/ did not recover
Terminated Because:
Other causual paths more productive
271 on board (258 passengers, 13 crew members, 0 survivors)
Normally scheduled flight
Terminated Because:
Desired State
Believed aircraft was fully functional
Terminated Because:
Other causual paths more productive
2 fatalities on the ground in path of falling debris
Terminated Because:
Other causual paths more productive