Essential Question: 10 May 2021

What was wrong with the DC-10? How did it regain public trust?

Questions/Key Points	Notes
Engine failures are common relative to other things that can go wrong, and pilots are typically well prepared for them. This should not have been a problem in this case, especially since it was a trijet, but the design flaw of the hydraulic system made it bad.	(for ref.: a DC-10) ID notes: no winglets, trijet, engine no. 2 has no S-duct  • UA232 ◦ https://sma.nasa.gov/docs/default-source/safety-messages/safetymessage-2008-08-01-unitedairlinesflight232crash-vits.pdf?sfvrsn=f4a91ef8_4 ◦ https://aviation-safety.net/database/record.php?id=19890719-1 ◦ https://libraryonline.erau.edu/online-full-text/ntsb/aircraft-accident-reports/AAR90-06.pdf NTSB final report ◦ https://www.skybrary.aero/index.php/DC10,_Sioux_City_USA,_1989 ◦ Basics: ▪ Flight: United Airlines 232 ▪ Routing: KDEN/stapleton-KORD ▪ Aircraft: DC-10 N1819U ▪ Date: July 19, 1989 ▪ Time of departure: 14:09 lt (CST) ▪ Time of impact: 16:00 lt (CST) at KSUX (Sioux City, Iowa) ◦ UA232 departs KDEN at 14:09 and climbs normally to FL370, their assigned cruising altitude. ◦ At 15:16, the #2 engine fails and explodes, resulting in a large bang. (Engine no. 2 is the one on the tail) ◦ When running the engine shutdown checklist, aircraft instruments show that all hydraulic pressure is gone ◦ Pilots lose normal control of the aircraft; it enters a descending right turn ◦ Ca. corrects the turning by using differential thrust ◦ Hydraulic pressure wasn't restored despite using backup pumps ▪ Flight controls were ineffective b/c they were controlled by hydraulic systems ◦ (What happened, unbeknownst to the pilots, was that the shrapnel from the engine explosion punctured hydraulic fluid pipes that was near the horizontal stabilizer, which resulted in all the hydraulic fluid leaking out into the air) ◦ ATC comms: Minneapolis ARTCC ▪ They suggest going to Des Moines but later switch to Sioux City after pilots and ATC decide it is a better option based on their course

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The pilots of this flight really did an exceptional job at handling the situation despite the number of injuries and fatalities. The captain's quick thinking to use thrust as a flight control probably saved the situation (to any extent)	○ CRM: There was a DC-10 check airman onboard, whom the captain employed the assistance of. He had him do a visual observation of the flight control surfaces, and then handle the differential thrust, which was their only method of control ■ https://www.faa.gov/tv/?mediaId=447 ■ This was one of the earlier examples of what we now know as Crew Resource Management, in which the flight deck becomes a more democratic environment, rather than militant (wherein the captain is generally not questioned). The crew uses any personnel or resources they can to ensure safety in nonemergency and emergency situations ○ The inboard ailerons were deflected, which was probably causing the right turning tendency. There was significant damage to both horiz. stabilizers ○ As the flight crew wrestles the aircraft to the ground, it experiences phugoid oscillations, in which the nose drops, resulting in an increase in airspeed, which then results in an increase of lift, which causes the nose to pitch up again until it loses airspeed, causing the nose to drop again and start the cycle over again. ■ This usually doesn't happen in normal flight because the stabilizers can adjust their angle of incidence, balancing pitch changes due to thrust changes ■ However, since the horiz. Stabilizers weren't working in this case, it cause the phugoid oscillations ○ The aircraft approaches RWY22 at KSUX, rather than RWY31 which was originally suggested by ATC. For a moment, it seems that the aircraft is in a somewhat stable approach towards the runway and on a normal glidepath. ○ However, a few hundred feet above the ground, the aircraft enters a final phugoid oscillation. The nose pitches down and the right wing drops; GPWS issues a sink rate warning ○ The check airman knows that the power must be used for the approach, which is what he does ○ The aircraft impacts the ground, right wing first, then by the right main landing gears ○ The aircraft skids to the right, then cartwheels and bursts into flames ○ Injuries: 111 fatalities, 47 serious, 125 minor, 13 uninjured ○ Probable cause: Inspectors and mechanics at United Airlines failed to notice fatigue cracks in an engine fan blade, which caused the engine to explode
Engine explosions due to stress fractures are the manufacturer's fault as well as maintenance, but keep in mind here that GE is the engine manufacturer, not MD. MD made the mistake with the hydraulic lines.	○ There was a design flaw in the DC-10, which was that all three hydraulic systems (they were separate) had pipes near the horizontal stabilizers, which meant that the shrapnel from the engine explosion took out all three lines at once ○ Airman training manuals produced by McDonnell Douglas didn't even consider the scenario that all three hydraulic lines were failed, as they considered it an impossibility ○ Proposed actions ■ Improve aircraft seatbelts ■ Inspect GE CF6-6 Engines ■ Inspect the fire fighting vehicles used on the day of the accident ■ Improve aircraft inspection technologies

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The other issue, as suggested in the NTSB's safety recommendations, was that the cabin was not prepared quickly enough for landing, which may have saved more lives.	■ Encourage the development of backup systems for flight control systems powered separately from main power sources ■ Conduct safety reviews of currently certified aircraft to ensure redundancy of safety systems regarding power and control ■ Evaluate company records of engine and aircraft manufacturers and consider creating an FAA database in order to track down faulty parts ■ Airworthiness Directive for CF6-6 Engines regarding maximum service life and/or inspections ■ Improve air crew training to stress the importance of quickly readying the cabin for an emergency landing ● Other Notable DC-10 accidents ○ AA96 ■ https://aviation-safety.net/database/record.php?id=19720612-0 ■ https://libraryonline.erau.edu/online-full-text/ntsb/aircraft-accident-reports/AAR73-02.pdf NTSB final report ■ Design flaw in the aft cargo doors made the compartments appear closed on walkaround when they really weren't. Door opened mid flight and damaged vert and horiz stabilizers ● There was a viewport to visualize the locking pins on the door, which was not properly inspected during preflight ■ 0 fatalities
Both AA96 and TK981 were caused by the same design flaw in the cargo door. Only difference is that the depressurization was much more severe in the case of TK981, which resulted in many deaths.	○ TK981 ■ https://aviation-safety.net/database/record.php?id=19740303-1 ■ https://reports.aviation-safety.net/1974/19740303-1_DC10_TC-JAV.pdf French investigating agency final report ■ https://assets.publishing.service.gov.uk/media/5422eedde5274a1317000247/8-1976_TC-JAV.pdf translation ■ Same problem as AA96 with aft cargo door mechanism, except the situation was much worse here. Again, view port wasn't inspected properly ■ Rapid decompression caused a large portion of the rear of the aircraft to be blown out completely. 6 pax fall out of the plane immediately ■ Because of the structural damage, flight controls are useless and engine no. 2 is inop; pilots lose control and the aircraft crashes ■ 346 fatalities, all people onboard died.
Although AA191 was caused by human error, it was the final straw that grounded all DC-10s by the FAA.	○ AA191 ■ https://aviation-safety.net/database/record.php?id=19790525-2 ■ http://libraryonline.erau.edu/online-full-text/ntsb/aircraft-accident-reports/AAR79-17.pdf NTSB final report ■ Improper maintenance led to the no. 1 engine being reinstalled incorrectly on the aircraft; it fell off completely during the takeoff roll at rotation ■ Pilots continue with the takeoff (can't abort after V1 and Vr) ■ In the air, asymmetrical stall; rolls increasingly until it impacts the ground ■ 271 onboard all die; +2 people on the ground die as well

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While people may be hesitant to fly on a recertified aircraft after a series of deadly accidents, it's usually not enough to make people actively avoid the aircraft or flying as a whole in substantial numbers. Additionally, passengers who are booking with price as the priority probably won't pay more for a ticket just because of the equipment being used.	○ And many more, for a variety of reasons ● Public reactions, and the solutions ○ https://www.jstor.org/stable/2630903 ○ https://www.nytimes.com/1989/07/20/us/troubled-history-of-the-dc-10-includes-four-major-crashes.html ○ There were many accidents, many of which were highly publicized ○ Was grounded in 1979 after AA191 ○ People thought that if it was recertified, people wouldn't want to fly on it ever again ■ This situation is actually quite similar to the 737 MAX ○ Turns out that after it was recertified, people went back to flying on it as they did beforehand ○ Airlines ended up abandoning the aircraft eventually though, as tri-jets became less and less popular for their fuel burn ○ MAX: not sure what the passenger numbers are right now, and it would probably be off bc of COVID, but the average passenger is unaware/doesn't really care what aircraft they're flying on even though the information is displayed at booking ○ If they are concerned about flying on a MAX, the passenger always has the right to reschedule and cancel, and change fees are gone for most major US airlines now. Even then, it's usually more of an "oh shit I'm flying on a MAX I hope nothing goes wrong" rather than "I want to get off because I'm on a MAX" ■ Hassle of cancellation/rebooking is usually greater than the fear of being on the aircraft ■ MAXs are probably some of the safest aircraft in the air right now because the pilots are especially wary of the issue

Summary

The DC-10 was one of the more infamous aircraft of history, with its poor PR and safety record. Still, it carried millions of passengers millions of miles around the world, and recovered after being recertified. Although it was rejected by airlines in favor of more fuel efficient twin-jets, it is still being used today in cargo operations.