National Aeronautics and Space Administration

Fire in the Sky:

TWA 800 In-Flight Breakup

Leadership ViTS Meeting

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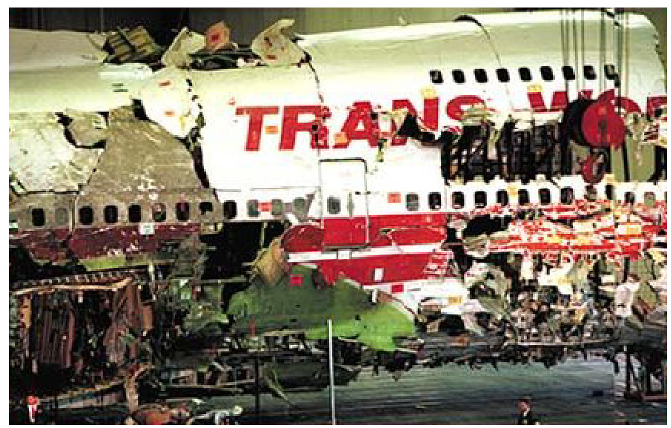

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THE MISHAP

Trans World Airlines (TWA) flight 800 was twelve minutes into a journey from New York to Paris when disaster took the lives of the 230 men, women, and children aboard. The aircraft experienced a normal takeoff roll and reached cruising altitude without major problems, but as the Boeing 747-100 flew over East Moriches, New York, it suffered a sudden and catastrophic in-flight breakup that sent it crashing into the Atlantic Ocean. It took investigators 15 months to recover and sort debris, and the subsequent investigation lasted more than four years. Eventually, the National Transportation Safety Board concluded that an explosion in the center wing fuel tank tore the fuselage apart, causing the plane to crash into the ocean.

Boeing 747-100 Fuel System

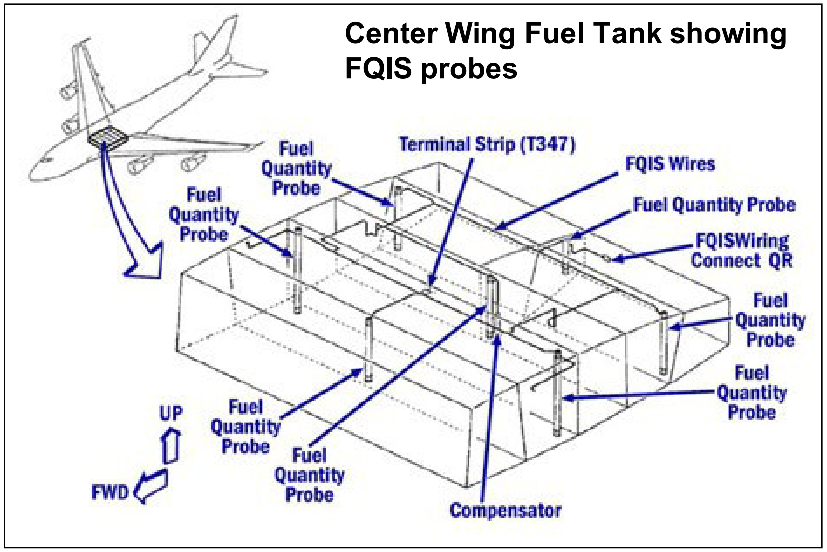
•B-747 uses Jet-A fuel from seven fuel tanks. Each wing contains three tanks, and the lower fuselage holds a seventh tank known as the center wing fuel tank (CWT).

•Whenever the six wing tanks hold sufficient fuel for a flight, the CWT only contains residual fuel from the last flight.

•Inches below the CWT, three air-conditioning packs rest in an un-insulated, unvented area. The CWT absorbs the heat generated by the air-conditioning packs.

•Testing found that a near-empty tank heats quickly, speeding fuel evaporation and increasing flammability of the ullage (the unfilled portion of the tank above the surface of the fuel).

Center Wing Fuel Tank showing FQIS probes

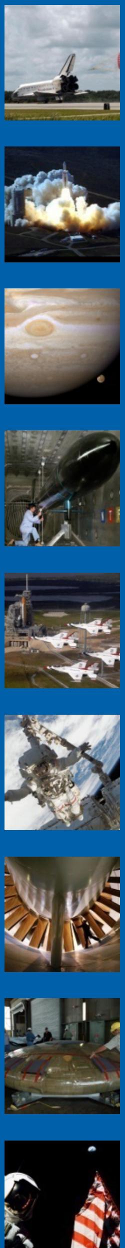


Fuel System Wiring

•The Fuel Quantity Indication System (FQIS) includes probes and compensators connected in series inside each fuel tank.

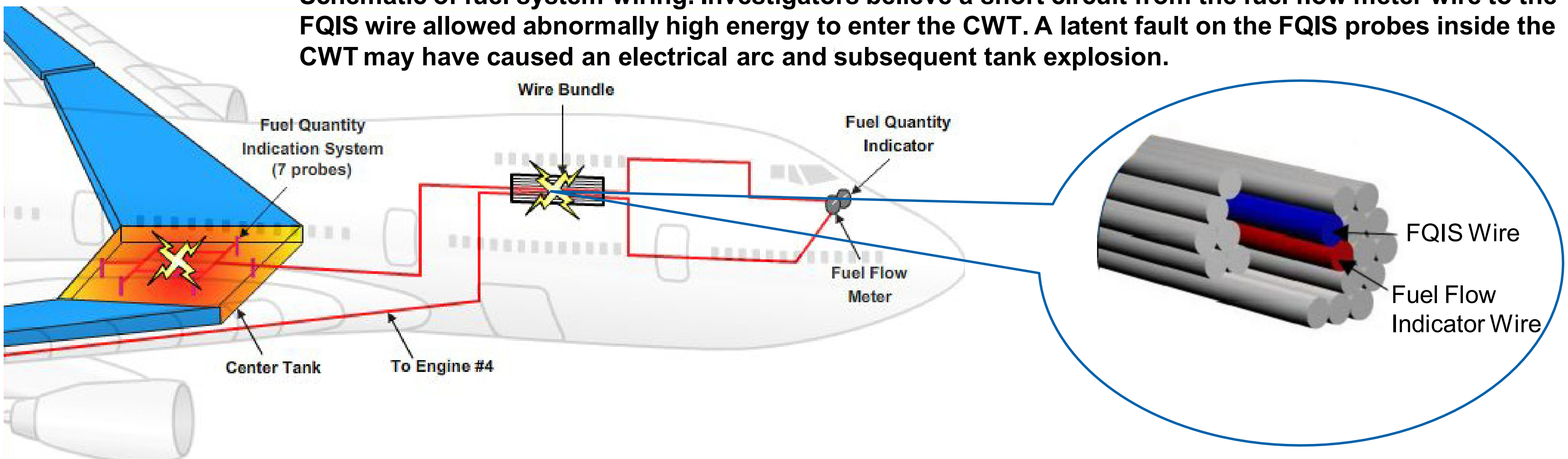
•The minimum ignition energy for hydrocarbon fuels is 0.25 millijoules (mJ). To keep vapor in the fuel tanks from igniting, power supplied to FQIS wiring was intended to have a limit of 0.02 mJ.

•FQIS wiring runs from the fuel tanks to the flight decks along raceways shared with other circuits carrying much higher voltages and energies than those allowed in the FQIS.



WHAT HAPPENED?

Schematic of fuel system wiring. Investigators believe a short circuit from the fuel flow meter wire to the FQIS wire allowed abnormally high energy to enter the CWT. A latent fault on the FQIS probes inside the CWT may have caused an electrical arc and subsequent tank explosion.



CWT Explosion and In-Flight Breakup

•On July 17, 1996, outside temperatures exceeded 80 degrees F, so while the plane rested on the tarmac for 2 ½ hours, aircraft operators left two of three air-conditioning packs running to cool the cabin interior before the next flight. This inadvertently heated the ullage space in the CWT, making the subsequent flight profile overlap flammability limits to a much greater degree.

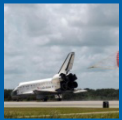
•The next trip from New York to Paris did not require additional fuel in the CWT, so it contained only a small amount that remained from the inbound flight.

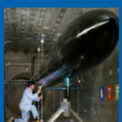
•When the aircraft reached its assigned altitude of 13,000 feet, air traffic controllers instructed the pilots to climb to 15,000 feet.

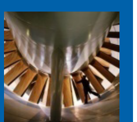
•The pilots began ascending in compliance with the instruction, but at 14,000 feet, the cockpit voice recorder (CVR) recorded interruptions in the background electrical noise, an unintelligible word, and “a very loud sound.” CVR recordings then terminated.

•Witnesses in the area observed a fireball in the sky and saw debris splash into the ocean.

•The widespread distribution of wreckage and eyewitness observations indicated that TWA 800 had experienced a sudden and catastrophic in-flight structural failure. There were no survivors.



PROBABLE CAUSE

NTSB determined the probable cause of the accident was an explosion in the center wing fuel tank resulting from the flammable fuel/air mixture inside the tank. NTSB could not determine the ignition source with certainty, but it concluded the most likely was a short circuit outside the CWT that allowed excessive voltage to enter it through the FQIS. Because FQIS wires are the only wires to enter the CWT and because they are co-routed within wire bundles containing circuitry from higher-voltage systems, investigators theorized that a high-voltage circuit contacted FQIS wires due to chafed, frayed, or otherwise damaged conditions. Then, a latent fault on the probes inside the CWT may have caused an electrical arc and subsequent tank explosion.

UNDERLYING ISSUES

Aging FQIS Components

•When FQIS probes went through qualification testing in the 1960's, examiners found the probes to be free of arcing up to 2,000 volts. The FAA thus deemed the probes "explosion-proof."

•When NTSB investigators tested FQIS components from aircraft that had been operating for more than 30 years (the length of time TWA 800 had been operating), they discovered silver sulfide deposits had accumulated on the probes. The semi-conductive nature of the probes was probably enough to induce an electrical arc in the CWT at minimal voltage.

•Although the FQIS system displayed explosion-proof capability at the time of aircraft certification, designers did not account for the effects of age upon the system, and once certified as explosion-proof, the probes were never retested.

Flawed Assumptions

•When the B-747 was in development, it was generally believed that design practices were capable of completely eliminating in-tank ignition sources. Such a conclusion depended on an explosion-proof FQIS system, appropriate wire configuration, and sufficiently sensitive circuit breakers.

•In addition to discovering latent faults on FQIS components, investigators examined wire configuration on old and new aircraft and discovered that wire layout imposed mechanical wear on insulation that placed the system at risk for failure.

•The thermally activated circuit breakers with which the aircraft was equipped also proved insufficient. Post-accident testing showed currents of 2 to 4 joules could transfer between wires for as long as 25 minutes without heating a wire to the level required to trip such a circuit breaker.

FOR FUTURE NASA MISSIONS

- Wide-body jets can contain up to 240 km of wire, making it difficult to subject the wire harnesses to routine inspection. Thus, problems resulting from age are becoming more and more prevalent.
- NASA faces a similar challenge in its own densely wired systems, therefore designers must install additional layers of safety to protect against wiring malfunctions.
- Products in the concept phase of the project life cycle should account for the effects of age and include a means to later analyze the wire system's integrity.

Wreckage from TWA 800

- Assumptions concerning the FQIS system's explosion-proof capability were never reassessed, even after the aircraft logged millions of hours of operation.
- NASA must continue questioning initial assumptions about operations, equipment, and facilities.
- Sustaining rigorous maintenance and quality checks underscores recognition that failure modes cannot always be identified at the time of a product's inception.