From Humble Pi by Matt Parker ISBN 978 0 141 98914 3

[This is an extract, from a fascinating book, which highlights the one thing that Napoleon got right. His worst crime was the invention of margarine.]

Massive problems

Aircraft fuel is calculated in terms of its mass, not its volume. Temperature changes can cause things to expand and contract; the actual volume fuel takes up depends on its temperature, so it's an unreliable measurement of quantity. Mass stays the same. So when Air Canada flight 143 was taking off from Montreal on 23 July 1983 to fly to Edmonton, it had been calculated that it required a minimum of 22,300 kilograms worth of fuel (plus an extra 300 kilograms for taxiing, and so on).

There was still some fuel left from the flight in to Montreal, and this was measured to check how much fuel needed to be added for the next flight. Except that both the ground maintenance personnel and the flight crew performed their calculations using pounds instead of kilograms. The amount of fuel required was in kilograms, but they filled the aircraft using pounds and 1 pound equals only 0.45 kilograms. This resulted in the aircraft taking off with approximately half as much fuel as it required to make it to Edmonton. The Boeing 767 was now going to run out of fuel mid-flight.

In an unbelievably lucky twist of fate, the aircraft, flying with a dangerously low amount of fuel, had to make a stopover in Ottawa, where the fuel levels would be double-checked before the plane took off again. The plane landed safely, with the eight crew members and sixty-one passengers unaware how close they had come to running out of fuel mid-flight, It's a near-miss which reminds us that using the wrong units can put people's lives in danger.

But then, in an unbelievably unlucky twist of fate, the crew doing the fuel check in Ottawa made exactly the same kilogram/pound unit error and the aircraft was allowed to take off again with barely any fuel left. The fuel then ran out mid-flight.

There should be several alarm bells going off as you read this story. It's so unbelievable as to strain credulity. Surely a plane will have fuel gauges to indicate how much fuel is left? Cars have such a gauge and, if an automobile runs out of fuel, it merely rolls to a stop and causes a mild inconvenience: you have to walk to the nearest petrol station. If a plane runs out of fuel, it also rolls to a stop — but only after dropping thousands of metres (three thousands of feet) out of the sky. The pilots should have been able to glance up at the fuel gauge and see that they were running low.

This was not some light aircraft with a dodgy fuel gauge either. It was a brand-new Boeing 767 recently acquired by Air Canada. A brand-new Boeing 767 . . . with a dodgy fuel gauge. The Boeing 767 was one of the first aircraft to be kitted out with all manner of avionics (aviation electronics), so much of the cockpit was electronic displays. And, like most electronics, that is all great. . . until something goes wrong.

Because of the lack of roadside assistance when you're thousands of feet up, in aviation redundancy is the name of the game. Aeroplanes need to bring their own

spares. So the electronic fuel gauge was linked to sensors in the fuel tanks by two separate channels. If the two numbers coming from each tank agreed, then the fuel gauge could confidently show the current fuel level. The signals from the sensors in the tanks (one'in each of the aeroplane's wings) went into a fuel- level processor which then controlled the gauges. Except this processor was on the blink.

One flight before its disastrous trip, the Boeing 767 was sitting in Edmonton and a certified aircraft technician named Yaremko was trying to work out why the fuel gauges were not working. He found that, if he disabled one of the fuel-sensor channels going into the processor, the gauges started working again. He deactivated the circuit breaker for that channel, labelled it with a piece of tape marked 'inoperative' and logged the problem. While waiting for a new processor to replace the faulty one, the aircraft could still be compliant with the Minimum Equipment List (required for the plane to be flown safely), if a manual fuel check was carried out. So now the fuel double-check consisted of the gauge with one sensor channel and someone looking in the tank and physically measuring the amount of fuel before take-off.

This is where everything gets a little bit 'Swiss Cheese' [all the holes in slices accidentally lining up. Americans mostly buy 'cheese' slices.]: the disaster makes it through several checks that could have identified and solved the problem.

The plane was flown from Edmonton to Montreal by Captain Weir, who had misunderstood a conversation with Yaremko and thought the fuel-gauge problem was an ongoing issue and not something that had just happened. So when he handed the aircraft to Captain Pearson in Montreal he explained the fuel gauge had a problem but that a manual fuel check was enough to cover this. Captain Pearson took this to mean that the cockpit fuel gauges were completely inoperative.

While this pilot-to-pilot conversation was happening in Montreal a technician named Ouellet was checking out the aircraft. He did not understand the note Yaremko had logged about the fuel gauge so he tested it himself, which involved reactivating the circuit breaker. This caused all the gauges to go blank and Ouellet went off to order a new processor, forgetting to re-deactivate the circuit breaker. Captain Pearson then got into the cockpit to find all the fuel gauges blank and a label on one channel circuit-breaker saying 'inoperative' which is exactly what he expected from his misunderstood conversation with Captain Weir. Because of this unfortunate series of events, a pilot was now prepared to fly an aircraft with no working fuel gauge.

This would of course have been fine, if the fuel calculations had been performed correctly. But it was the early 1980s and Canada was starting the transition from imperial units to metric units. In fact, the new fleet of Boeing 767s were the first aircraft Air Canada had which used metric units. All other Air Canada aeroplanes still measured their fuel in pounds.

To add to the complication, the conversion from volume to mass used the enigmatically titled factor 'specific gravity'. Had it been called 'pounds per litre' or 'kilograms per litre', the problem would have been avoided. But it wasn't. So after measuring the depth of the fuel in the tank in centimetres and successfully converting that to litres, everyone then used a specific gravity of 1.77 to do the

conversion: this is the number of pounds per litre for the fuel at that temperature. The correct specific gravity of kilograms per litre would have been around 0.8. And a conversion mistake was made both before take-off in Montreal and again during the stopover in Ottawa.

So, sure enough, in mid-flight after leaving Ottawa the plane ran out of fuel and both engines failed within minutes of each other. This resulted in an error-noise *bong!* which no one in the cockpit had ever heard before. I get nervous when my laptop makes a noise I've never heard before; I can't imagine what it's like when you're flying a plane.

The major problem with both engines failing is that – of course - the plane no longer has any power to fly. A smaller but still important issue is that all the new fancy electronic displays in the cockpit needed power to work and, as they ran directly off a generator attached to the engines, all the avionics went dead. The pilots were left only with the analogue displays: a magnetic compass, a horizon indicator, one airspeed indicator and an altimeter. Oh yeah, and the flaps and slats which would normally control the rate and speed of descent also used the same power, so they were dead as well.

In the one stroke of good luck, Captain Pearson was also an experienced glider pilot. This was suddenly super useful. He was able to glide the Boeing 767 over 40 miles to a disused military base airfield in the town of Gimli. It was only a 7,200-foot runway but Captain Pearson was able to hit the ground within 800 feet of the start of it.

In a second stroke of good luck, the front landing gear failed, causing the front of the aircraft to scrape along the ground, providing some much-needed braking friction, and the plane came to a halt before the end of the runway - much to the relief of the people staying in tents and caravans at the far end, which was now used as a drag-racing strip. Here's the thing about turning off all the engines on a 767: they fly much more silently. Some people had the fright of their life when a jet airliner suddenly appeared on the disused runway, seemingly out of nowhere.

Landing the aircraft as a glider was a phenomenal achievement. When other pilots were given the same scenario in a flight simulator, they ended up crashing. After the Boeing 767 was repaired and returned to service in Air Canada's fleet, it became known as the Gimli Glider and achieved a reasonable level of fame.

It was eventually retired in 2008 and now lives in an aeroplane scrapyard in California. An enterprising company bought some sections of its fuselage and now sells luggage tags made from the metal skin of the Gimli Glider. I guess the idea is that the aircraft was lucky to survive a dangerous situation, so having a part of the plane should bring good luck. But then again, the vast majority of aeroplanes don't crash at all so, strictly speaking, this plane was bad luck. I bought a piece of the fuselage and attached it to my laptop, which does not seem to have crashed more, or less, than usual.

https://www.ebay.co.uk/itm/PLANETAGS-AIR-CANADA-B767-GIMLI-GLIDER-KEY-CHAIN/124145837245?hash=item1ce7ab24bd:g:1OkAAOSwIlBejQ~u