Episode Book

EPISODE #5730

What 4 Gs Actually Does to a Body at 17,000 Feet

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SYNOPSIS

Seventeen thousand feet in under two minutes. That's roughly 140 feet per second — five times the descent rate any passenger has ever experienced. In this episode we take Daniel's question seriously and reconstruct the physical forces inside that cabin: what a G-force actually is (it's acceleration, not force), why positive and negative Gz fail the human body in opposite directions, and what the tolerance curve really says about an untrained person hitting 2-3 G. We also look at why the cabin held together — sixteen-G seat certification written for a crash that never came — and at the three-link survival chain that made this a story instead of a funeral: an open door, a passenger who'd watched enough air-crash television to reach for the yoke, and two Fly Dubai pilots rostered for the return leg, sitting in the back.

TRANSCRIPT



Corn

The image everybody's carrying around from this one is the door. The cockpit door on a modern airliner is a vault. It's a bank vault with a lock the crew controls, and after Germanwings every regulator on earth agreed it should stay shut. And on this flight the door was open, and that's the only reason anybody in the back could do anything at all.



Herman

Which is the whole story in one image, really. The security feature and the survival feature were the same door, and they pointed in opposite directions.



Corn

Right. So Daniel wrote in about this, and he's less interested in the door than in what happened to the bodies behind it. He wants to reconstruct the physical forces in that cabin. What G-forces are, properly, because he suspects most of us use the word wrong. What the passengers actually felt during a descent that dropped seventeen thousand feet in under two minutes. What level of G would alarm somebody with no training at all. And how, given all that, the cabin and the people in it came through intact.



Herman

He also flags something from a while back, which is that civilian procedures are written to keep passengers comfortable, and military ones are written to keep pilots conscious. Those are not the same document.



Corn

They are not. So let's start with what a G-force actually is, because it isn't a force.



Herman

Correct, and this trips up almost everyone. A G is a unit of acceleration, expressed as a multiple of the acceleration we feel just existing on Earth's surface. One G is nine point eight one meters per second squared. When you're sitting in a chair reading, you're at one G. You're not being pushed by anything. The chair is pushing up on you at exactly the rate needed to stop you falling through the floor, and that push is what your body reads as weight.



Corn

So at two G, you weigh twice as much. Not feel like it. Weigh.



Herman

Weigh. Every tissue, every organ, every drop of blood. And that's where it becomes a physiology problem rather than a physics problem. Because your circulatory system evolved to move blood around against exactly one G, and it's very good at that, and it has no plan for two.



Corn

Where does the direction come in?



Herman

Two axes matter in an aircraft. Positive Gz is head to foot, the classic one, the one that pushes you down into the seat. Negative Gz is the reverse, foot to head, which lifts you against the straps. A pushover into a dive gives you negative Gz. A pull-up out of it gives you positive. And this flight likely served the cabin both courses in sequence.



Corn

Which is a nasty combination, because the body fails in opposite directions depending on which one you're getting.



Herman

Blood is heavy, that's the whole thing. Under positive Gz it pools in your legs and your abdomen, and the heart has to fight gravity to get it to the brain. Above about four G, in someone with no training and no countermeasures, the brain is being starved and you go to sleep. Under negative Gz the blood goes the other way, it crowds into your head. That's the one pilots hate more, incidentally, even though it damages you at lower numbers.



Corn

What does negative G do to a person?



Herman

The face swells. The eyes feel like they're being pressed from behind. You get a red haze across your vision, which is called redout, and it's the capillaries in the eye complaining. Sustained, you're looking at retinal hemorrhage, headache that lasts for days. Fighter pilots will take three or four positive G before they'd willingly take one negative for more than a couple of seconds.



Corn

And the civilian side of this, the standard operating procedures, what envelope do they assume?



Herman

Civilian procedures are built around the assumption that passengers will never exceed about one and a half G in normal operations. One point five. Turbulence, a firm landing, a go-around. That's the design case for a cabin full of people in socks. The whole system, seat geometry, cabin crew briefing, the way the autopilot flies, is tuned to keep you inside that box.



Corn

And this event took them so far outside that box that the box is basically irrelevant.



Herman

By a distance. Let's reconstruct it, because the numbers are startling when you actually run them.



Corn

Run them.



Herman

Seventeen thousand feet, under two minutes. If you call it two minutes, that's eight thousand five hundred feet per minute of descent. Normal airline descent is a thousand five hundred to two thousand feet per minute. So this was four, five times the rate a passenger has ever experienced. Per second, you're looking at roughly a hundred and forty feet. That's a thirteen-story building, every second, for a hundred seconds.



Corn

Say that number again.



Herman

A hundred and forty feet per second. You'd cross Tel Aviv from the beach to the eastern edge in about a minute at that rate, if you were going straight down.



Corn

And the feeling of that, in the cabin, for the first second or two, before the recovery starts, is not heaviness. It's the opposite.



Herman

It's lightness. When the nose drops and the aircraft accelerates downward, the floor is falling away from you and your body is briefly in free fall relative to the aircraft. You float against the belt. Loose objects come off the tray tables. That's negative Gz territory, somewhere in the range of minus one, maybe a touch more if the pushover was sharp. Which is uncomfortable but not dangerous in itself.



Corn

Briefly.



Herman

Briefly. The problem is what comes next, because the aircraft has to stop descending. It went down seventeen thousand feet and it did not go into the ground, so at some point somebody pulled the nose back up, and that transition is where the positive G arrives.



Corn

How much?



Herman

This is where I have to wave my hands a little, because the actual recorded G-load isn't public as far as I can find. But you can bound it. A recovery from a steep dive, flown aggressively, in a heavy twin, will pull two to four G at the aircraft. Call it two to three in the cabin, depending on where you're sitting and how smoothly it was done. The tail damage suggests it wasn't done smoothly.



Corn

What does two to three G feel like to somebody who has never felt it?



Herman

At two G your arms are twice as heavy. Lifting your hand off your lap is a decision. At three, you're pinned, your face feels tight, and your peripheral vision starts to grey out. Greyout is exactly what it sounds like, the edges of the visual field going dim and colourless while the centre holds. That's the retina not getting enough blood, and it's the warning before the real event.



Corn

And the real event is?



Herman

G-LOC. G-induced loss of consciousness. In an untrained person without a G-suit and without the straining manoeuvre, it starts around four G and it can come on in about five seconds. You don't black out like in a film. You go grey, then you go dim, then you're simply not there, and you have no memory of the transition.



Corn

Four G. That's the number for an unprepared person.



Herman

That's the alarming number. And the reason I don't think this cabin hit that, or didn't hit it hard enough or long enough to matter, is that the exposure was seconds. Not minutes. The human body tolerates a brief spike far better than a sustained load. There's a whole tolerance curve, and the difference between four G for three seconds and four G for thirty seconds is the difference between a story and a funeral.



Corn

So the survival is partly a story about duration.



Herman

It's mostly a story about duration, and that's the part that gets missed in the coverage. People hear four G and they think of a fighter pilot's whole career of it. It's not the same exposure at all.



Corn

Let's talk about the person who pulled the yoke, because that's the piece that keeps this from being a pure physics story.



Herman

Everything I can find suggests a passenger who had watched enough aircraft investigation television to recognise the situation and reach for the column. Which is remarkable, and it also means the input wasn't a carefully modulated recovery from a trained hand. It was a person who knew one thing, which is that pulling points the nose up, and did it.



Corn

And that action is the reason the recovery started.



Herman

It started the recovery. It may also have been where the tail load came from. A sudden, full pull on the column at high speed is how you overstress a tailplane. Aircraft are certified for a maximum manoeuvre load and there are margins, but a passenger yanking the yoke with both hands is not flying within the certification envelope. That's a control input the design case doesn't cover.



Corn

The photographs after landing. What are they actually evidence of?



Herman

Significant structural damage to the tailplane. Which tells you the forces at the rear of the aircraft exceeded what the designers expected that surface to see in service. Enough to permanently deform or delaminate something. That's a very serious load case and it's a much better window into the extremity of the event than any estimate of passenger G.



Corn

Because the metal doesn't have a comfort threshold. It just has a limit.



Herman

Metal has a limit, and the tail went past it. That's the strongest available evidence that this was not a gently flown descent.



Corn

Now the structural part of the question. How did the cabin survive, physically? Seats, restraints, all of it.



Herman

Modern airline seats are tested to sixteen G forward and fourteen G up, as crashworthiness standards. Those are there for a survivable crash, not for sustained acceleration comfort. So the seats were enormously overqualified for what they actually had to do here.



Corn

They were built for a much worse day than this one.



Herman

Much worse. The belts kept people in. The seats didn't deform. That part of the design chain worked exactly as intended, and it worked because the certification case is written for the crash, which is the worst thing anyone expects the cabin to see. A G spike fits inside that envelope without any trouble.



Corn

Which is a strange kind of luck. The cabin survived partly because it was designed for an event that didn't happen.



Herman

That's exactly the right way to put it. The aircraft was stiff enough for the crash it never had.



Corn

Let's get to the two Fly Dubai pilots.



Herman

This is the part I find astonishing. There were two Fly Dubai pilots on board, rostered to fly the return leg. So they were passengers, in seats, off duty. And when the situation became clear, they took over and flew the aircraft to a safe landing in Saudi Arabia.



Corn

Off-duty crew are still crew.



Herman

Off-duty crew are still crew, and this is the point that the industry will quietly take from this, because the second pilot in the cockpit is load-bearing. We've said that before on this show and it keeps being true. If there had been no second pilot in that cabin, the recovery run by a passenger with a memory of a television episode would have continued until somebody with a licence took it, or it wouldn't have.



Corn

So the survival chain has three links. The open door. The passenger with the memory. The two off-duty pilots who happened to be sitting in the back.



Herman

Three links, and any one of them missing and this is a different episode. That's not a comfortable thought. That's the opposite of a comfortable thought.



Corn

What about the psychological side? Because Daniel's framing is wonder, and I think wonder is right, but there's a cost that isn't physical.



Herman

There always is. People in that cabin experienced a sudden drop, floating objects, a violent pull-up, and then a period where nobody in the cabin knew who was flying the aircraft. Even short of any injury, that's a terrifying couple of minutes and it leaves marks. Disorientation, panic, a sense of helplessness that lasts long after the seatbelt sign goes off. And there's a specific cruelty in the fact that it was an unanticipated event. Nobody had a briefing for it.



Corn

You spent decades explaining small probabilities to worried people. What's the honest version of what you'd tell a passenger about this?



Herman

I'd tell them the number is tiny, and I'd also tell them the thing that actually helped here wasn't training, it was the fact that a person had absorbed something from a documentary and acted on it. Which means the useful thing to say to a nervous passenger isn't "the odds are fine." It's "if the worst happens, some of the people around you will do something, and so will you." That lands better than a probability.



Corn

That's a much better sentence than the odds.



Herman

The odds are true and useless, as I've said before. The sentence about people doing something is also true, and it's the one people can hold onto.



Corn

Where does this leave the procedures, the civilian SOPs Daniel started from?



Herman

It leaves them exposed in a specific way. The whole civilian envelope assumes the aircraft will be flown inside one and a half G, and every cabin procedure, every seat design assumption, every briefing, is downstream of that. This event blew through the assumption and the cabin survived mostly on duration and on seats built for crashes. That's not a designed defence. That's a lucky one.



Corn

So the honest lesson isn't that we should start G-training passengers.



Herman

No. You cannot inoculate a cabin full of people against four G in a way that doesn't create more fear than it removes. The realistic version is narrower. Make sure the cockpit door policy doesn't create a situation where nobody can help. Make sure there's an off-duty crew protocol. Make sure the cabin crew know how to recognise the aftermath in people, not just the event.



Corn

That's a small list and it's the right size.



Herman

That's the thing about this event. It's so far out on the tail that it doesn't justify rewriting much. It justifies paying attention to the handful of links that held.



Corn

Let's sit in the cabin for a second, at the moment of the drop, before the recovery, and try to actually be in it.



Herman

You'd feel the floor go light under you, and your stomach would do the thing your stomach does, and anything unsecured on a tray would lift. Then a beat of weightlessness, a couple of seconds, in which nothing is making sense, because an airliner does not do this on a good day. Then the pull-up comes and everything you own suddenly weighs double or triple what it weighed before, your arms won't come off the armrests easily, and your vision starts to go grey at the edges.



Corn

While the cabin crew who were standing are on the floor. While people who were in the aisle are now against the overhead lockers or on the ceiling, depending on which phase you're in. Which is the part the seat certification numbers don't cover, because seats hold the seated. The people who are walking around are held by nothing.



Herman

And it may explain why the reported injuries from the event were about the phase of flight rather than the G-load itself. The people who were unsecured got thrown. That's the mechanism of injury for most turbulence events, and turbulence is the same physics at a lower intensity. Same blunt mechanism, milder numbers.



Corn

So the seats did their job for the people in them, and the people not in them were the ones at risk.



Herman

That's the shape of it, as far as I can tell from what's public.



Corn

Where does this sit next to the military comparison Daniel raised? Because he's right that the two procedures are written for completely different purposes.



Herman

Fighter pilots train for nine G. They wear a G-suit that inflates around the legs and abdomen and squeezes blood back toward the heart. They do the anti-G straining manoeuvre, the hook, which is a specific pattern of muscle tensing and breath control that maintains pressure in the chest. And they do it under supervision, repeatedly, until their bodies learn it. That's what inoculation looks like, and it takes months.



Corn

And civilian passengers get none of that.



Herman

None, and they shouldn't. There's no version of a cabin briefing that teaches a hundred and eighty people to hook-strain in their seats without terrifying everyone on every flight. The civilian SOP's job is the opposite of training. Its job is to keep the aircraft inside an envelope where no training is needed. That's the whole design philosophy.



Corn

And that philosophy worked, in the sense that this didn't happen for decades.



Herman

It worked right up to the point where somebody else in the cockpit decided to make it not work. Which is the uncomfortable thing about this whole category of event. You can design for the aircraft being flown well. You cannot design for the aircraft being flown by somebody who has decided otherwise.



Corn

And when it happens anyway, the answer turns out to be a door somebody left open and a passenger who remembered something.



Herman

Which is the least engineered part of the entire story, and it's the part that saved everyone.



Corn

I want to come back to the sensation numbers, because Daniel asked "what would alarm a person who isn't prepared" and we've been circling it.



Herman

Straight answer. Up to about one and a half G, a passenger notices pressure and thinks nothing of it, because a firm turn does that and they've felt it. Around two G, the arms feel heavy and the sensation is specific, it's a "something is not normal" feeling even without pain. Around three, the visual field starts to go and that's where alarm is entirely appropriate, because greyout is the body telling you the brain is next. At four, an untrained person is on the edge of losing consciousness and may cross it in seconds. That's the ladder.



Corn

So the honest range for this event is two to three, with a possible spike above.



Herman

That's my estimate, and I'd flag the uncertainty. It depends on the pitch input, the speed, the weight, and how much of the recovery was flown by the passenger and how much by the two pilots once they got forward. Which is the part I don't know, and I'd like to.



Corn

What would you need to find out?



Herman

The flight data recorder trace. The recorded G at the aircraft. That's a metal answer to a physical question and it would end this conversation in about thirty seconds. It'll be in an investigation report at some point, and when it comes out I want to read it.



Corn

That's the thing about this event. It's got the passenger G and the passenger G's downstream effects taped to the tail, and the tail is a photograph.



Hilbert

I agree with most of that.



Corn

Okay.



Hilbert

The bit I'd correct is the passenger and the television. He's being called a hero, and he is one, but he didn't remember the right thing. The episode he was thinking of was a different aircraft with a different control system. The recovery he'd seen on the screen was flown a completely different way. He remembered the wrong aeroplane and pulled the column anyway, and it worked.



Herman

That's a detail I hadn't seen.



Hilbert

It's the sort of thing you only notice if you've had to memorise procedures for something that isn't the thing you're doing. I had a job once where the whole point was the checklist, and the checklist was for equipment we never had. We drilled it anyway, twice a year, because somebody decided a drill was better than no drill.



Corn

And the drill was wrong.



Hilbert

The drill was close enough to be useful and wrong enough to be dangerous, and we knew that going in. The point of the drill wasn't the steps. The point was that when the alarm went off you had already done something like the right thing once, in your head, and your hands went somewhere instead of nowhere.



Herman

That's the actual mechanism, isn't it. The reflex to act.



Hilbert

It's the reflex to act. The passenger in the back didn't have the procedure. He had the reflex, borrowed from a television show that got the aeroplane wrong. And it still worked because the reflex was pointing the nose up, and pointing the nose up was right.



Corn

Which is a fact about human beings in emergencies that no procedure document captures.



Hilbert

It's a fact about people, and it's messy, and I don't think you can train into it deliberately. You can only notice afterwards that it happened.



Herman

So the event needed the wrong memory to survive.



Hilbert

The event needed a memory, and it got a wrong one, and it survived anyway. That's luck wearing a hero's jacket. It doesn't take anything away from him. It means the margin was thinner than the story makes it sound.



Corn

That's a much more honest version of the story than the one in the papers. We are leaving a fair amount on the table if we think the survival was engineered.



Hilbert

Most survival isn't, in my experience. You find out afterwards which parts held, and it's usually not the parts you spent the money on.



Corn

I want to keep that, actually. The parts that held here were a door, a reflex, and two off-duty pilots in row something or other. None of those is a system. They're all just things that happened to be there.



Hilbert

The tailplane I'm still thinking about. That's the part I can't square with a gentle recovery. You don't damage a tailplane flying smoothly.



Herman

Right, and the damage moves the estimate upward. If the recovery was gentle, we should have seen a clean airframe in the photographs. Instead we saw a deformed one. That tells me the actual load case was at the top of the range we've been discussing and possibly past it.



Corn

Which means the passengers almost certainly got the high end of the two-to-three estimate at minimum, and possibly a spike above it, and the only reason nobody was injured by the G itself is that it lasted seconds.



Herman

Seconds. That's the whole defence. Seconds and a seat built for a crash.



Corn

So the thing I keep coming back to is that the safety chain here isn't a safety chain. It's a set of coincidences that happened to line up, and the only part of it that was actually designed was the seat.



Herman

And the door policy, in the sense that somebody had decided the door should normally be closed, and somebody else had decided to leave it open. The policy existed. It just didn't hold.



Corn

Let's close the loop on the passenger sensation, because I think that's what Daniel actually wanted and we've come at it from six angles.



Herman

The honest reconstruction. Two or three seconds of feeling light, floating against the belt, trays lifting, loose papers and cups off every surface. Then a hard pull-up, everything going heavy, arms pinned, vision narrowing at the edges. Somewhere in there the aircraft rolling or pitching further than the cabin had any expectation of, and the sounds changing, engines and airflow going to a register that passengers never hear on a normal flight. And then the recovery, the two off-duty pilots moving forward, and a long period of not knowing, which for some people is worse than the G.



Corn

What kind of G would be alarming to somebody unprepared. Say it plain.



Herman

Two is alarming because you know it's wrong. Three is alarming because you can feel your vision going. Four is where an untrained person passes out, and anything past that without a suit and training is a medical emergency waiting for the seconds to lengthen. This cabin, most likely, got the bottom of that ladder and a taste of the middle. It didn't get to the top, and if it had, we would be having a very different conversation.



Corn

There is one thing people keep getting wrong about this, and I want to name it.



Herman

Go on.



Corn

The story reads as if the passengers were subject to enormous G for two minutes. They weren't. The descent took under two minutes. The G itself was a few seconds at each end of it. The long part was the fall, and the fall is mostly weightlessness, which is unpleasant but not damaging. So the wrong belief is that two minutes of descent means two minutes of crushing force. It doesn't. It's a short, violent shape with a long empty middle.



Herman

And it's why nobody was hurt by the G. The physics that made the event terrifying and the physiology that made it survivable are the same two transition points, and they were both brief. If either had lasted another twenty seconds, this episode would have a much worse ending.



Corn

So what do we do with an event this far out on the tail? Because the temptation is to write a rule.



Herman

The temptation is wrong. The event is so rare that any rule you write from it is a rule for something that will essentially never happen again. The useful thing is smaller. Keep the door policy from locking out the only people who can help. Keep an off-duty crew protocol alive. Teach cabin crew to watch for the people who are struggling after the event, not just during it.



Corn

And be honest that the rest of it was luck.



Herman

Be honest that the rest of it was luck, and that the part we can actually design is the seat, which we already did, and the part we can actually practice is the reflex to act, which we don't really know how to teach. That's where this ends up. A very good outcome from a set of things that mostly weren't under anyone's control.



Corn

Which is a strange place to leave a story about a hero.



Herman

It's the honest place to leave it.



Corn

If you got something out of this deep dive into the physics and physiology of an extraordinary descent, leave us a review and tell a friend. That helps more than anything.



Herman

Thanks as always to Hilbert Flumingtop for producing. This has been My Weird Prompts.



Corn

The human-AI collaboration podcast. Email us at show at my weird prompts dot com. We'll be back soon.