Episode Book

EPISODE #5546

How Fast Before an Engine Can Swallow a Person?

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SYNOPSIS

Daniel wrote in asking a grisly question: how fast does a jet engine have to be spinning before a person on the ramp becomes something it can swallow? The answer turns out to be barely above idle — and the reason why reframes the whole hazard. It isn't engine RPM that kills, it's mass flow, and a large turbofan at ground idle is already pulling hundreds of kilograms of air per second through a ring you could stand in. We unpack the physics behind the little stick-figure diagram on the cowling: the capture streamtube, why "sucked in" is the wrong mental model, why the slow regime produces survivors while the high-power regime doesn't, and why the placard is a conservative worst-case envelope that crews learn to stop reading. Plus: why nobody actually knows how often this happens.

TRANSCRIPT



Corn

Here's the thing I keep circling back to. You're walking up the jet bridge, you glance down at the cowling, and there's this little diagram. A stick figure, a red arc, a number nobody reads. And the question is whether that little cartoon is the whole safety system.



Herman

It's a big part of it.



Corn

That's what Daniel wants to know about. He wrote in with a whole thing about the grisly cases you occasionally read about, a mechanic going into a running engine, and he's seen that placard on the cowling and always wondered how fast an engine actually has to be turning before a human being becomes something it can swallow. He's not asking about bird strikes. He wants the ground case.



Herman

Good. Because the ground case is the strange one.



Corn

And he's got the context right. The ramp is chaos. Tugs, baggage carts, people walking under wings during the walkaround, engines running the whole time. So what's the physics that makes that environment lethal? What does the placard actually encode? Are there documented cases of people who went into an intake and lived? And has anyone actually counted how often this happens a year?



Herman

Four questions and a body count.



Corn

So let's start with the number Daniel actually asked for. How fast is fast enough.



Herman

The answer is barely above idle, which is the alarming part. But the reason why takes some unpacking, because the question as asked, how fast does it need to be running, is pointing at the wrong variable.



Corn

Meaning what.



Herman

Meaning RPM isn't the thing that hurts you. A large turbofan at ground idle on the ramp is already moving hundreds of kilograms of air per second. The air velocity at the intake lip is on the order of tens of metres per second. That's a stiff wind concentrated into a ring about the diameter of a person. It's not the engine turning fast. It's the mass flow, and mass flow at idle is already enormous.



Corn

So the relevant threshold isn't engine speed, it's the velocity of the air at the lip and the mass behind it.



Herman

Right. And that gives you two regimes that structure the whole episode. The slow regime, where the hazard is a strong steady pull that drags a person off balance. And the high-power regime, where the hazard is instantaneous and unsurvivable. Almost every ground ingestion event happens in the first regime. That's why survival cases exist at all.



Corn

Which is the strange comfort in the whole topic. If it always happened at takeoff thrust, there'd be no survivors to talk about.



Herman

There'd be no episode. There'd just be a statistic.



Corn

Let's set the vocabulary, because we're going to use it for the next twenty minutes. Inlet danger zone. Ingestion. FOD, foreign object debris. And the distinction that matters most, sucked in versus pulled in.



Herman

That distinction is the whole thing. People imagine a vacuum cleaner. A person walking past a running engine gets yanked off their feet from ten feet away and vanishes. That's not what happens.



Corn

What happens.



Herman

The engine generates an airflow field that extends forward of the intake lip. It's roughly a hemispherical capture streamtube. Think of it as a bubble of moving air sitting in front of the cowl. Walk into that bubble and you're standing in a current. The current pushes on your frontal area. If you're within a metre or two of the lip and the engine is at idle, that current is strong enough to take your feet out from under you. Once you're off balance and sliding, the airflow does the rest.



Corn

So the engine doesn't reach out and grab you. You walk into it.



Herman

You walk into it and then you can't walk out of it.



Corn

I want to make sure I've got the geometry right, because I think people picture this as a cone that shoots out of the front of the engine. But you're describing something that sits in front of the cowl like a bubble.



Herman

A bubble is the right image. At idle, the capture streamtube extends maybe a metre or two forward of the lip and then curves back toward the cowl. It's not a long invisible funnel reaching out across the apron. It's a compact region of moving air right at the mouth of the engine. The reason that matters is that it means the hazard is entirely about proximity. You don't get grabbed from across the ramp. You get grabbed when you're already close enough to touch the cowl.



Corn

So how does that compare to, say, the airflow around a helicopter rotor, which people also imagine as this wide invisible death zone?



Herman

Different physics entirely. A rotor generates a downwash that spreads out and affects a large area. An intake at idle generates a local field that falls off very quickly with distance. The reason the danger zone placard looks so small is that the hazard really is that local. The placard isn't being stingy. It's being accurate.



Corn

And the scale of the environment. A busy ramp at a large airport at pushback time has dozens of moving vehicles and people within tens of metres of running engines. And the engines are running precisely when the walkaround and the disconnect work are happening.



Herman

That's not a design flaw. That's the job. You can't do a walkaround on an engine that isn't running if you're checking for leaks. You can't disconnect a tug from a running aircraft without standing near a running engine.



Corn

Let's do the physics properly, because the number is smaller than you'd think.



Herman

Start with the mechanism. A turbofan is a mass-flow device. It doesn't care about thrust rating when it's sitting on the ramp. It cares about how much air it's pulling and how fast. At ground idle, a big high-bypass engine, the kind hanging under a widebody, is moving on the order of several hundred kilograms of air per second. Some of the bigger ones push past a thousand.



Corn

Per second. That's the mass of a small car, every second, through a hole you could stand in.



Herman

And the velocity at the lip is what does the work on a body. Tens of metres per second. Think forty, fifty kilometres an hour of moving air, concentrated into a ring. Stand in that and you're standing in a gale that's trying to move you toward the engine.



Corn

So the suction force on a person scales with the local air velocity and the person's frontal area, not with the engine's rated thrust.



Herman

That's the key insight. A person is a bluff body. The force on a bluff body in a flow is proportional to velocity squared times area times a drag coefficient. You don't need a fast flow if the area is large. A human being standing sideways presents maybe half a square metre of frontal area. Put that in a forty kilometre an hour flow and you're feeling real force.



Corn

How real.



Herman

Enough to pull a standing adult off balance within a metre or two of the lip. Not enough to yank you across the apron. Enough to take your feet.



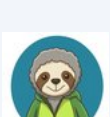
Corn

And once your feet are gone.



Herman

Once your feet are gone, you're on the ground, and the flow is dragging you. And the closer you get to the lip, the faster the flow, and the faster the flow, the more force, and it's a positive feedback loop that ends at the fan face.



Corn

That's the part that's grim. It's not a sudden event. It's a slide.



Herman

It's a slide you can't stop. Which is why the danger zone placard exists. The diagram on the cowling is not decorative. It encodes a calculated envelope. Typically a forward distance and a lateral arc. Inside that envelope, the airflow field is strong enough to be hazardous to a person, or to lift loose objects off the ground.



Corn

How is the envelope derived.



Herman

From the engine's mass flow at ground operating conditions. The manufacturer calculates where the capture streamtube is strong enough to matter, and then they build in margin, because the envelope has to cover a range of wind conditions and body orientations. A person walking forward into the flow is in more danger than a person walking sideways. A person crouched is in less danger than a person standing. The placard has to cover all of them.



Corn

So it's conservative by design.



Herman

It has to be. It's a single diagram that has to keep a distracted person alive in a crosswind at night.



Corn

Which raises the obvious problem. The danger zone changes with engine power setting. At idle the envelope is small. At breakaway thrust, the power setting you need to get a heavy aircraft rolling from a standstill, it grows. At takeoff thrust it's enormous.



Herman

And the placard doesn't change.



Corn

The placard is a single worst-case diagram.



Herman

Right. It's static. It doesn't know what the engine is doing. That's why ground crews are trained to treat the whole area as hot whenever the engine is running. The diagram is the floor of the safety case, not the ceiling.



Corn

So the diagram is conservative for the worst case, and the worst case is takeoff thrust, and the engine spends most of its ground life at idle, which means the diagram is over-conservative most of the time.



Herman

Which is exactly why people stop reading it.



Corn

There it is.



Herman

That's the human factors problem, and we'll come back to it. But first, let me address the sucked-in-versus-pulled-in thing head on, because it's the misconception that makes the whole topic feel like science fiction when it's actually just fluid dynamics.



Corn

Go.



Herman

Nobody is vacuumed off the tarmac from ten metres away. The airflow field doesn't have that kind of reach at idle. What happens is you enter the capture streamtube, which at idle extends a metre or two forward of the lip. You feel a pull. You take a step. You're off balance. You're sliding. The flow accelerates as you approach the lip because the streamtube narrows. By the time you're at the lip you're moving fast enough that you're not getting up.



Corn

So the danger is proximity plus a stumble.



Herman

Proximity plus a stumble plus a moment of inattention. Which is why the walkaround is the highest-risk activity. You're walking within metres of a running engine, often in poor lighting, often with wind, often with the engine at idle but sometimes at breakaway thrust. The geometry of a person walking around a cowl puts them inside the envelope for a few seconds at a time.



Corn

Every walkaround.



Herman

And the same physics that endangers people lifts loose objects. Tools, baggage tags, gravel, a dropped pen. The ingestion of those objects is the same fluid dynamics at smaller scale, which is why FOD walks and tool control are treated as safety-critical. If a wrench can get in, a person can get in.



Corn

Same streamtube, different frontal area.



Herman

Same streamtube. The wrench just has less drag area, so it needs to be closer, or the engine needs to be running harder.



Corn

Is there a rule of thumb people use for how far a loose object can travel?



Herman

There's a rough intuition rather than a rule. A flat, light object with a lot of surface area, like a bag tag or a sheet of paper, can be lifted from further out than a dense compact object like a bolt. But the honest answer is that the placard doesn't distinguish. The envelope is drawn for the worst case object, which is a person. Anything smaller is covered by default.



Corn

So the physics says the threshold is low. The obvious next question is how often this actually happens, and has anyone survived it.



Herman

The honest answer to how often is that nobody knows, comprehensively. And that's not me being coy. There is no single global registry that separates human ground ingestion from bird strikes, from FOD ingestion, from maintenance-related engine damage.



Corn

So the data is scattered.



Herman

Scattered across national accident investigation bodies, airport operators, insurer loss records, and the reporting categories don't line up. Some events get classified as ground-crew injuries. Some get classified as engine events. Some are near-misses that never get reported at all.



Corn

Which is itself a finding.



Herman

It's the finding. Daniel asked whether anybody tracks this on an annual basis, and the answer is no, not in a way that lets you say whether the number is going up or down.



Corn

Let me put the documented case on the table, because there's one that drove a lot of the recent attention. January 2023, Montgomery, Alabama. A ground worker was killed after being ingested into the engine of an aircraft that had just arrived at the gate.



Herman

That case was widely reported, and what made it more than a tragedy was that it surfaced prior safety warnings about ground operations around running engines. Warnings that existed and didn't prevent it.



Corn

Which is the systemic point. The physics is well understood. The human factors are not.



Herman

The physics is textbook. The human factors are the hard part. And this is where the survival question gets interesting, because there are documented cases of people surviving ingestion into a jet engine, and they share a common structure.



Corn

Structure how.



Herman

Low engine power. The person was pulled in but not through the fan. And the outcome depended on where in the intake geometry they ended up, and how quickly the engine was shut down.



Corn

I want to be careful here, because the record is thin and the cases are rare. We're not going to overstate the number.



Herman

We're not. The cases exist, and they're rare, and the specifics are sparse in the public record. But the pattern is real.



Corn

Explain the pattern, because it's counterintuitive. You'd think going into a jet engine is a binary. You're either fine or you're gone.



Herman

A high-bypass turbofan's fan is at the front, and the airflow path through the fan and into the bypass duct is not a straight line into a blender. The fan is a set of blades, and the bypass duct is an annulus around the core. A person pulled against the fan face at low power may be held there rather than drawn through.



Corn

Held there.



Herman

Pinned against the fan face by the airflow, with the engine at idle, and the blades turning slowly enough that they're not cutting through a body the way they would at high power. The decisive variable then becomes how fast somebody hits the fuel cutoff.



Corn

So shutdown speed matters more than anything else.



Herman

More than anything else. The difference between a survivable event and a fatal one, in the low-power regime, is measured in seconds of human reaction time.



Corn

That's a brutal thing to think about. Somebody's alive because a colleague's hand moved fast.



Herman

That's the whole story of the low-power regime.



Corn

Let's talk about the ground environment risk factors, because this is where the research gets specific. Pushback and arrival are the highest-risk phases.



Herman

Because engines are running and ground crews are in close proximity. Pushback is the moment when a tug is attached, a headset is on, a person is standing at the edge of the apron watching the intakes while the aircraft moves. Arrival is the moment when the aircraft comes to the gate with engines still spooling down and ground crews are already moving in.



Corn

And walkarounds put people inside the danger envelope for brief periods.



Herman

Brief periods, repeatedly, in a noisy, dark, time-pressured environment where a person's situational awareness of which engines are running is imperfect. That's the environment. It's not a laboratory.



Corn

So the placard and the training exist, and the environment is chaotic enough that compliance is not automatic.



Herman

Compliance is a behaviour, and behaviour degrades under time pressure. That's the systemic point. The physics is solved. The human factors are not.



Corn

And we can't tell whether it's getting better or worse, because we don't count consistently.



Herman

If we don't count these events consistently, we cannot tell whether they're getting more or less common. And that's a uncomfortable place for an industry that otherwise measures everything. Aviation measures everything. Fuel burn, on-time performance, tire wear, cabin humidity. And this one thing, the thing that kills ground workers, is scattered across a dozen reporting categories that don't talk to each other.



Corn

The answer to Daniel's last question is: no, not in a way that would let you draw a trend line.



Herman

Which means the Alabama case could be a rare outlier, or it could be the visible tip of a pattern that simply isn't being tracked. And we don't know which.



Corn

That's the uncomfortable part.



Hilbert

It's the diagram that's the problem, not the physics.



Corn

Say more.



Hilbert

I spent a stretch of my working life as a ramp rat for a regional carrier. One of my jobs was to stand at the edge of the apron during pushback with a headset on, watching the engine intakes while the tug did its work. First day, the guy training me walked me out to the cowling and pointed at the placard and told me exactly how far back from a running engine I was allowed to stand. The number was smaller than I expected. A lot smaller. I remember thinking, that's it? That's the whole margin?



Corn

Did you use the diagram after that.



Hilbert

Nobody used the diagram. The training wasn't about the diagram. It was about the sound. You learn to hear which engines are running and at what power setting before you ever look at anything. A CF34 at idle has a sound. A CF34 at breakaway thrust has a different sound. You learn the difference in your first month, and after that you navigate by ear. The diagram is what you consult when you're new, or when you're unsure, or when you're standing in front of an engine type you haven't worked before.



Corn

The experienced crew don't need it.



Hilbert

The experienced crew have internalized it. Which is fine, until the day it isn't. The most dangerous moment I remember wasn't a running engine at all. It was a crew member who walked behind a running engine to get to the other side of the aircraft, because it was the shortest path. The engine was at idle. Everyone had stopped thinking of it as dangerous. That's the failure. Not ignorance of the diagram. Habituation to the engine.



Corn

The placard doesn't help you when you've stopped noticing the engine.



Hilbert

The placard is a static diagram applied to a dynamic environment. The engine at idle on a warm afternoon with a light crosswind is not the same hazard as the engine at idle on a cold morning with a gust. But the placard is the same placard. And after a few hundred shifts, the engine at idle stops registering as a hazard at all. It's just the thing making noise at the gate.



Herman

That's the piece the research can't give us. The habituation.



Corn

Let's pull this together. If the physics threshold is barely above idle, and the danger zone is a static placard in a dynamic environment, what does that say about how we train people for a hazard that's always present and almost never fires?



Herman

It says the training has to fight habituation, and habituation is the hardest thing to train against. You can teach a person the physics in an afternoon. You can't teach them to stay scared of an idle engine for ten years.



Corn

The measurement gap is still unresolved. We don't have a reliable annual count of ground ingestion events involving people, which means we can't say whether the Alabama case was a rare outlier or part of a pattern that simply isn't being tracked.



Herman

That's the honest place to land. The physics is solved. The counting isn't. And the human factors are the part nobody's cracked.



Corn

The little stick figure in the red arc. The diagram almost nobody reads. It's not a boundary. It's a bet. A bet that a distracted person in the dark will read a static number and behave as if the engine is always at its worst.



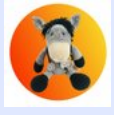
Herman

Most of the time, the bet pays off. Which is exactly why nobody updates it.



Corn

If you take one thing from this, it's that the danger zone on the cowling isn't a measurement. It's a conservative guess about the worst case, printed once, and then trusted for the life of the airframe.



Herman

The gap between that printed guess and what the engine is actually doing at any given moment is where people get hurt.



Corn

Thanks to Hilbert Flumingtop, our producer. This has been My Weird Prompts. If you want to send us a prompt, email us at show at my weird prompts dot com. We'll be back soon.