PHILLIP GREENSPUN: All right, we're going to talk about aircraft performance, which is figuring out all of this stuff if you're an airplane, basically, how much runway you're going to use on both ends, how long it's going to take you to get there, which is another way of saying how much fuel you're going to use. If it's a helicopter, it's a little bit different. Mostly, you're worried about hover performance. So if you're going to a friend's house, are you going to be able to park the helicopter in midair-- that's called an out of ground effect hover-- and very slowly descend into the backyard, dodging the trees and power lines and anything else?

So these are all things that can be found in the aircraft manuals. And the FAA will test you on them a little bit. This is important partly because you want to be able to complete your flight safely, and also because of FAR 91.103, which is that, before you do a flight, you've got to become a-- it's pretty all-embracing, all-available information concerning weather, and aircraft performance, how the aircraft's going to perform given the altitude of where you're going, and the temperature that's prevailing there at the time. Wind also, you know? If you find out that there's a 40 knot wind scheduled for where you're going and it's a direct crosswind to the only runway, then that might to cause you to choose a different airport.

OK, here's a reminder of the thrust and drag. Whenever you're generating lift, you're also generating some drag. And that's lifting the unwanted direction of backwards, usually. So the aircraft is also producing a parasitic drag by trying to punch its way through this vicious fluid of air. Where these summed up drag curves intersect is pretty much the bottom of the total drag curve, the minimum drag, or L over D max.

The climb performance, the best speeds to go are all kind of tied into this drag curve. And the best angle of climb is what you use. That's a slower airspeed and the best rate of climb. If you're in a small airport, trying to clear the trees at the end of the runway, you're going to fly Vx, the best angle of climb. This is one of those few V speeds that you're actually expected to know the abbreviation for.

And if you're going to just take off out of a big airport, like Hanscom Field, and just want to get up to your cruising altitude reasonably quickly, then you-- hey. Thanks, Richard. Richard's a Mooney pilot. Made it to California many times.

AUDIENCE: [INAUDIBLE]

PHILLIP GREENSPUN: So if you actually look at the Vx, one thing to notice is that it all depends a bit on the wind. Let's say there's 100 knot wind blowing down the runway. You don't need to fly very fast in order to clear the trees at the end of the runway because you're basically already flying. And you can go straight up like a helicopter in terms of your path over the ground, whereas Vy, just to gain altitude, that doesn't depend at all on the prevailing wind.

So if you're trying to clear something on the ground, the wind matters. A tail tailwind would be very destructive. It'll be pushing you towards the obstacle. And a headwind will be very helpful.

Cruise climb, most of the time you don't actually push the airplane to these speeds. They're pretty far nose up, which is a little bit alarming to passengers. And it's harder to see over the nose, and the engine isn't getting as much cooling air at these lower speeds. So typically we'll fly about 10 knots faster in a GA airplane. So for the Cirrus, for example, 96 is the book Vy at sea level, and flying something like 105 knots is more conventional.

The PC-12 climbs-- you know, it might be able to do 3,000 feet a minute at 120 knots. But if you're not in a desperate hurry to get up above the bumpy clouds or something, then 150 knots is more conventional.

OK, so let's remember that you've got thrust and power. So the thrust is a force that lets you climb up over the trees. The power is thrust times the speed. And it's thrust operating over a period of time. So the more excess power you have, the higher the rate at which you can climb. Anyway, we'll see some more of that here.

You've got a best glide ratio. If you want to get to the decent place to land and you've lost your engine, what's a good speed to fly? Well, L over D max is an excellent speed to fly, because that's where the lift over drag is at its highest point and you'll make the best time over the ground. Again, that has to be adjusted a little bit for wind. If you're going into 100 knot wind and the Cirrus best glide speed is 96 knots, that's not going to work out very well. You're not going to go anywhere over the ground.

That's a photo that I took at the Newport Jazz Festival. I don't want to say self portrait. Anyway, weight has a huge factor on all these speeds, because actually a lot of them are related to angle of attack. And it certainly affects your performance. So everything about higher weight is pretty bad.

Wind, you might think that a tailwind is always good. But really, the tailwind is only good for extending your cruise range. Everything else, pretty much, the headwind is better for. So think about the headwind. Again, think of these extreme cases. If you've got 100 knot wind right in your face, then you can fly without moving. That's basically a wind tunnel.

OK, center of gravity. This is also a little bit counterintuitive. If you load the airplane up so that all the way to the back, and it's super nose up, and you're having to push the stick forward to keep the plane level, that actually is where you get your maximum performance. Everything is better about having an aft center of gravity with one exception, which is the stability of the handling of the aircraft.

And obviously, if you load it up so much in the back that you can't push the nose over, that would be outside of the CG range, or well outside of this range, let's hope. Then you wouldn't even be able to control the aircraft because you can't get the nose down enough. So having that forward CG gives you more stability. That's where you're going to be when you're a student pilot.

If you're in a four-seat aircraft and it's just you and the instructor in front and the back seats are empty, then it's pretty obvious that it's going to be a somewhat forward CG, because the aircraft is designed to hold at least some weight in the back seats. One thing you can do is sort of, just as a first approximation, you know, pay attention-- we're going to have a talk on weight and balance later from Tina. But just keep in mind that the aircraft is kind of designed for, you know, two adults in the front and maybe one adult in the back, or two kids in the back. So if you load it up that way, it's almost always going to work.

If, on the other hand, you have a big, heavy friend and, you know, his other big heavy friend or his box of anvils, and the guy says, well, look, I just want to sleep in the back, I don't want to be up front and get distracted, and you're a lightweight person all by yourself from the front, you know, that's the situation where it's important to really do the calculations and think carefully about it. Because that wasn't something that Cessna and Piper were thinking about when they designed the aircraft.

OK, atmospheric pressure. Remember we talked about how the atmosphere is going to be expanded when it's hot and contracted when it's cold? And the altimeter is really telling you how much of the atmosphere you've climbed up through. So you can see here on the right, if you look over here, and you're measuring your altitude, you're basically getting this whole stack of molecules contributing to the pressure, whereas if you're up high in the stratosphere or something, only a handful of molecules are on top of you putting pressure into your altimeter.

OK, here's that standard atmosphere again. So you can see it's two niner niner two and 15 degrees at sea level. So the aircraft performance is hugely affected by changes in air density, which themselves are affected by the prevailing pressure, which is mostly a function of altitude, the temperature, and the humidity. Usually, the conditions are referenced to the ISA, the standard atmosphere.

The summertime, it'll be, you know, ISA plus 15 or ISA plus 20. And if it's the wintertime, it might be ISA or ISA minus 20. When the air density is reduced and there are fewer molecules around, the engine is not taking in as much air for combustion. Remember that the jet engines are normally aspirated. And the piston engines also that are without a turbocharger, they're just trying to burn up a fixed volume of air. And that's going to correspond to a different number of molecules of air and fuel depending on the altitude.

The only good thing about going up high-- the propeller's also not grabbing as much air for thrust. The only thing good about going up high is that drag is reduced, and that's why you see the airliners up high. They go faster and they save a lot of fuel.

OK, some definitions. The pressure altitude is just the-- it's going to be your height above sea level with the altimeter set to two niner niner two. You just have to take the two niner niner two minus the actual altimeter setting that's being published, multiply that by 1,000, so a full inch of altimeter adjustment, from two niner niner two to three zero niner two would correspond to 1,000 foot difference in pressure altitude. And you can calculate that by a chart.

Here's a chart that they give you if you don't like the formula. So this is something, again, you might have to do on a test. I'll say, OK, at two nine niner two, the correction is 0. At 30.0, the correction is minus 73. So up here you can see we've got this formula where we interpolated between the two to try to figure out, what would the pressure altitude be if we start with a field elevation of 3,563 and the altimeter is two niner niner six, which is just a little bit non-standard?

We would expect a 40 foot difference. If we look at the table and we interpolate, we come up with a 36.5 foot difference. And we find out that the airplane feels as though it's only at 3,526 feet above sea level, assuming the temperature matches that ISA standard.

All right, so density altitude is a lot more important. And oftentimes it will be reported on the

ASOS or ATIS. So the airport will actually tell you density altitude is 3,000 feet or 2,000 feet or whatever it is. That you get from correcting what's usually a relatively small correction for pressure altitude compared to the actual altitude, but correcting it for the non-standard temperature. I think, as I said earlier, you know, flying is a lot more popular in New England in the summertime than in the wintertime, so it's usually warmer than standard.

Density altitude has a huge effect on performance. And it's a non-linear relationship, so you have to look it up in a table or calculate it with the E6B. We'll see. Maybe I'll play around with the E6B so people can look at it during breaks. I have the slide rule and the manual right here. And I think we'll try to get the document camera going, so maybe I can show you guys some exciting slide rule activities.

OK, so you can calculate it, though, using the E6B, like I said, using charts. And there's various web and app way of doing it. So the density altitude, here's a chart. So again, this is the kind of stuff that's on the written exam. You guys are all pretty good at working with charts and tables, so I'm sure you won't have any trouble.

They're giving you these initial conditions up here on your left. So you look to find where the pressure altitude is on the chart. And it says to, you know, add 626 feet, which is interpolating between those two. Then you've got this pressure altitude line of going from here down to here at 5,856. And now we've got to correct that for temperature.

So here's our temperature of about 80 degrees, 81 degrees. And then we go over to the left, and we can read that-- I think I told you guys that, in the summertime, usually the density altitude is about 2,000 feet higher than the pressure altitude. And sure enough, here it's 8,250, which is about 2,400 feet higher than the pressure altitude. So the density altitude gave us a little more than a 2,000 foot boost for that non-standard temperature.

The reason it's so much, I guess, is it's not-- 80 degrees at sea level wouldn't be that high above the standard temperature. But 81 degrees Fahrenheit at a mile above sea level is quite a spectacular temperature compared to the standard atmosphere. Let's go back to the standard atmosphere. Yeah, so at 5,000 feet, it's only supposed to be seven degrees Celsius. And here we said it was about 27 degrees Celsius. So that's ISA plus 20. Just like I said, if you look at a lot of jet performance charts, you have ISA minus 20 ISA and ISA plus 20.

Oh, flight computer demo if there's time. Let me just futz with that at the end of all this. I'll give you an E6B intro. When are they the same? I think this is an FAA test question, when the temperature distribution is the same as that of the standard atmosphere.

OK, humidity is also another enemy, a little bit more surprisingly. The water vapor molecules, actually, in the air actually reduce the density of the air. You might think that they would increase it. I don't know. Maybe there's a chemist or a physicist in this crowd who can explain why. I'm not exactly sure myself. But it's just something to remember, that contrary-- if the air feels heavy to you, it feels light to your aircraft engine and to your wings.

It's a smaller effect than temperature, but the engine performance supposedly can be reduced by about 7%. This is not something that we normally correct for. However, there is this nice web calculator that I found for free on pilotfriend.com. And you get to enter the relative humidity of the air.

So where is that? We have the air temperature. Oh, we have the dew point, right? So we said it was a 30 degree temperature and a 28 degree dew point. So that's a pretty narrow spread. And therefore, it's a pretty high humidity day. So they say, well, it's 78% humidity, and we're correcting that up to 8,107.

You can play around with this on your own. If you reduce the dew point to 10 degrees Celsius, which is going to be a really dry-- you know, 30 to 10 split is a nice, dry day out west or, you know, here occasionally a crisp day-- then it's only 7,735. So the change in humidity had about a 300-foot effect on the altitude. But the change in temperature was nearly 3,000 feet.

OK, the maximum convenience way to do this is with apps. So ForeFlight, for example, will just tell you. The density altitude-- this was, I think, Sunday night at Bedford. Let's look at this beautiful-- I don't know how many people will come to [INAUDIBLE] now. So Bedford's approximately at sea level, about 130 feet above sea level. It was minus 4 degrees, and the density altitude was minus 1,400. So we were flying, you know, skimming the surface of the Dead Sea or something in terms of performance. So the airplane will be really happy about flying all wintertime, and it'll climb better than the book, most of the numbers in the book.

OK, the density altitude is often just kind of baked into the performance chart. Pipers normally take off with no flaps. But if you want to get off the ground really quickly, like taking off over grass or mud or something, you can put down the flaps and try to have less time on the ground and not be going so fast over the ground. Your ground rill will be shortened.

Anyway, so here, they don't actually ask you to ever calculate the density altitude. They just say, OK, it's almost 30 degrees outside. And it looks like we're up here at about 1,500 feet. So we'll start here on the performance chart. These people are virtuous. The only weigh 2,175 total, so we come down a little bit. And we can come over here, and we find that it's going to take-- is there a wind here-- 15 knots of headwind. So we come down this graph and we find that it will take us 1,500 feet to take off over a 50 foot obstacle. Fair enough?

So anyway, we never figured out what the density altitude was. It was just something that affected where we started on the chart. I guess, maybe it's implicit in here. I think it is implicit, right? Because we're starting up high. Maybe somebody who is smarter can figure this out. Yeah, so sea level at 0-- Yeah, I think we can pull it out of those graphs. But nobody would, because what you're really interested in is the number of how long you're going to be on the runway.

All right, you'll have to slow down if you're in turbulence. So if you plan for some kind of flight a certain amount of time and it's going to be very bumpy-- I remember we talked about maneuvering speed. Depending on your weight, you'll have to slow down to avoid bending the aircraft. Or, you know, turbulence that's severe enough to bend the aircraft is extremely rare. But turbulence that's sufficient to make you and your passengers unhappy is a lot more common. And in both cases, you know, you pull away back on the speed.

So in the Pilatus, for example, you'll pull back to 150 knots from 200 knots. In the Cirrus, you know, you might pull back from 130 down to 100. And in a helicopter, you know, you'll pull back from 110 knots to maybe 70.

OK, pilot technique. So all the book numbers depend on the pilot doing what the book says. So think about clearing an obstacle at the end of the runway. That's dependent on the pilot rotating within a couple knots of the specified rotation speed, getting the gear and the flaps retracted if they've been deployed, or if the gear are retractable at the recommended airspeed, and just generally having the pitch attitude and the air speeds where the manufacturer tested the aircraft.

And think about it. You might say, well, you know, anybody can do that. You're rolling down the runway at Hanscom Field. It's a mile and a half long. You know, you're fresh, so that performance is-- you're probably going to come pretty close to the book performance.

But think about doing a go-around. You've just done a two hour flight. You were trying to land at the airport. You know, somehow, either there was somebody else on the runway or, you know, you didn't get the approach just right, so you decided you're going to go around and try again. At that point, you know, you've got to reconfigure the airplane, change the flap configuration, change the gear configuration.

There's a couple interesting incidents that have happened. Well, it was, unfortunately, not very interesting for the people involved. But there was an American Airlines flight that got disoriented in Colombia in the clouds. And the terrain warning system said, you know, terrain, terrain, pull up, pull up. And so they advanced the thrust levers.

You can follow that link and read about it. They advanced the thrust levers and had maximum power, but they neglected to-- they had the spoilers deployed for a descent. They didn't retract the spoilers, so the airplane was climbing but not nearly as well as it would have without the spoilers retracted. So that's an example where, you know, in a critical situation or a fatigue situation, you may not--

I wish I could get this-- I don't know if I can move this onto the screen. I want to show a picture of this crazy airplane that I flew. Tada! Look at that Russian seaplane. It's got two Cirrus engines in there. I don't even see the second engine.

Well, there it is. You can see that propeller over there. So sorry. There's one propeller sticking up. There is the other one. So it's got two Cirrus engines, 200 horsepower each mounted on pods. And if you say, how can that airplane climb after an engine failure on one little Cirrus engine when it has-- I don't know. I think it could seat seven people. The answer is it really can't.

So I tested that airplane out because I thought it was cool. And I went flying with an airline captain. And piston twins aren't really required to demonstrate any kind of climb performance. For jets, there are certain minimums. On one engine, it has to be able to still climb 750 feet per minute or something. But for these piston twins, the FAA says, you know, you should know that you're buying a pig anyway. And if you care, go and get yourself a turbine, or don't load everybody in there.

But anyway, this [INAUDIBLE] thing, it could not climb on one engine. We couldn't even maintain altitude on one engine. And it turned out that we'd forgotten to close the cowl flaps. It had these extra openings for cooling to provide extra cooling at high power settings. And if you don't close them, there's extra drag. And that extra drag was enough to turn what should have been, you know, 150 foot climb rate or something into 150 foot sink rate or something. So that's another thing that can affect performance.

OK, runway condition. This really affects your planning, whether you can take off, whether you can land, how much weight you can put in there. So for example, if it's dry grass, you need a longer runway than if it's paved. Alternatively, you can take off at a lower weight. If it's wet grass, you need a lot more room to land and, you know, yet more room to take off.

At the airline, if the runway was grooved, which almost all bigger US airports have these grooved runways, we didn't make any adjustments. Didn't matter how heavy the rain was. It didn't matter how long it had been raining. We just assumed it was going to perform exactly the same as if it were dry. If it's not a grooved runway, though, and water can sit on the runway, it can have a big effect on performance.

So here are some numbers that I pulled. I'm type rated in the Cessna Mustang, which is an interesting little business jet. It lands at about the same speed as the Beechcraft Baron, so it's a great beginner jet. Anyway, so in conditions where you need 3,000 feet of runway, that's up at pretty high altitude, you're going to need 4,240, Cessna says, if it's wet. If water is actually standing on it, I think 0.1 inches of water was even more, you'll need yet more runway.

If it's snow, a little bit more. Wet ice, it was just off the chart. But if you started at 2,200 feet of dry runway, you would need 16,600 feet. So actually, oftentimes, when the surface is contaminated, that's one reason why even fairly small business jets may need a long runway, like at Logan or at Hanscom Field. Even an airport like Nashua, which has 6,000 feet may not be enough if they're reporting that there's snow on the runway.

OK, what about slope? So going downhill is obviously a lot easier than going uphill. And you can see here-- and also stopping going uphill is a lot easier. So here are some numbers from the Cirrus book that every one degree of slope increases your takeoff run by 22% at sea level, for example. And you also get a 9% reduction in the landing distance.

OK, ceiling. The service ceiling of the aircraft is a little bit below the absolute ceiling. That's where the FAA says the plane will climb 100 feet per minute. The manufacturer has demonstrated to the FAA that the airplane could, at least when it was brand new, make 100 feet per minute in climb rate. So that's 13,500 feet for a 172 Cessna. And I think that's pretty typical for these normally aspirated four-seaters. Somewhere around there is where it'll stop climbing.

The Cirrus, there's a limitation in there that says maximum operating altitude is 17,500 feet. I think that's more regulatory, because you can't take the Cirrus up into the flight levels. They need extra equipment to go up above 18,000 feet, maybe. I don't think it's really practical to get up to 17,500 feet at maximum gross weight in the standard atmosphere. I've gotten into about 13,000 feet out west in the summer, so that is more like being at 15,000 feet. But it was barely climbing.

OK, range versus endurance. So we're going to get back into the power and drag curves here. The max range airspeed is going to depend on the wind, like I said earlier. If you have 100 knot headwind, then you have to go faster than 100 knots in order to go anywhere.

If you want to loiter for some reason-- this year at Oshkosh was a nightmare for people who didn't go IFR. They had a lot of marginal VFR weather. So for the first couple of days, when people were arriving, there were these short windows, just an hour or two, when people could really get in legally, the VFR homebuilder types. So they were just holding. People were literally holding for three hours and then finally had to give up and go and refuel somewhere.

But if you're in that situation, you want to set your speed to whatever the minimum fuel consumption speed is. And it can be quite different. The Robinson R44 manual talks about 100 knots for max range. I believe that's assuming a 10 knot headwind, since usually we're suffering with a headwind more often than with a tailwind.

And you might say, how is that possible? How is it possible to have a headwind-- unless God hates you, how is it possible to have a headwind more than half the time? If you think about it-- Richard, you know the answer?

RICHARD: I do.

PHILLIP GREENSPUN: What is it?

RICHARD: Here's the question. You're flying 100 miles to an airport. In zero wind, how long does it take to fly-- you're on an airplane that flies 100 miles an hour. How long does it take to fly round trip?

PHILLIP GREENSPUN: Trick question.

RICHARD: 100 miles apart, 100 miles an hour airplane, no wind. How long is a round trip going to take?

AUDIENCE: 2 hours?

RICHARD: Yeah. Let's say you have a 50 knot headwind. It's exactly on your nose. You can get 50 knots headwind on the way out and 50 knot tailwind on the way back. How long does it take?

AUDIENCE: 2 hours.

RICHARD: Wrong. Work it out.

PHILLIP GREENSPUN: Well, that's one aspect. You're going to spend more of your time, as Richard's saying. It's going to take you two hours to get there in one direction, and then it won't take you zero time to get back, so you're spending more of your time in the headwind than in the tailwind. But there's something even worse. I saw this the other day in the Cirrus.

There was about a 70 knot wind that was actually a little bit-- it should have been a little bit of a tailwind. It was more than 90 degrees off my desired track. But if you think about it, the airplane's constantly having to fight its way back into that wind, so it's effectively taking a longer flight path. So even the wind is directly a beam wind 90 degrees off, there's actually-- the majority of the circle, the 360 degrees circle of wind directions, the majority of that is subtracting from your performance and has at least some headwind component.

Sound crazy? Think about it, yeah. So if you're going 100 miles and there's also this 100 knot side wind, you're having to spend quite a bit of your energy continuing to steer into that side wind.

OK, here is a power and drag curve for an RV-6A. The experimental guys are, in this case, more aggressive about producing charts. So if you actually care about where you're going, you want to be a little bit up the power required curve. You want to find out where it's tangent to one of these lines going back to zero. And if all you care about is maximum endurance, you just want to be at the point where the curve is at its bare minimum, because then you're consuming the least power and, in theory, burning the least amount of fuel. Does that make sense?

All right, The terms. Ground roll, these performance charts in the book that you get with the airplane, they will assume a static start. So that means you're holding the brakes, you slam the power forward, you let off the brakes, and you're going to get the book numbers, because there's no acceleration time for the engine.

And actually, that's how jets are supposed to take off, too. But you probably remember from your commercial flights, that's not really how it happens. The pilots don't hold the brakes, you know, spend-- it takes maybe 10 seconds for a really heavy jet engine to spool up to full power. They don't just sit there holding the brakes, engine's at the max, and everything's screaming in the airplane, shaking, because it's just uncomfortable.

So they usually cheat-- technically, they're not really supposed to do it because, you know, at that point, your test pilots. You don't really have any data for a rolling takeoff. But, you know, again, it would be kind of unnerving for passengers, I think, if they are sitting there with the airplane straining against the brakes.

OK, same deal here. Ground roll and the total distance to clear the 50 foot obstacle, this is what I was telling you about the other day with the Cirrus hero who wanted to go to, I think, about 2,500 feet of runway. Actually, we had to subtract some. I think it was 2,700 minus 400. He had about 2,300 feet of runway. And he wanted to go there in the Cirrus, which takes 2,100 feet.

Another guy actually wanted to go to-- there's a private air park in Falmouth, Massachusetts where you can have a house right next to the runway and keep the airplane in your garage. And that airport's only 2,300 feet long. And another east coast aero club guy-- I was handing the airplane over to him and he had this huge friend with him. This guy was like a NFL linebacker. So it was just the two of them, but big. And he wanted it also at full, topped off on fuel, so they're going to be right at gross weight.

I said, where are you going? He said Falmouth. He'd just gotten his private pilot certificate a few months earlier. This guy was not commercial IFR rated like the other. And I said, look, you know, if you do everything perfect, you're going to use up 92% of that runway because it's hemmed in by these obstacles. So don't do it. So he did end up going to Hyannis, I think.

All right, landing technique can actually affect the performance. So they talk about, an average pilot, the book numbers, they're predicated on extremely aggressive braking, like right to the point where you would flat spot the tires. So don't count on getting those book numbers unless you're willing to be more aggressive than probably you would want to be. And actually, I'll tell you a story about my airline days.

I did a visual approach in the Laguardia. And with jets, it's not conventional to try to do the really greaser landings that you would do in a little airplane, because you need to get the airplane down and the spoilers to pop up. The jets are very efficient gliders. They don't have a big prop in front. And when you pull the power back on a piston aircraft, it really slows down dramatically because the prop has a lot of air resistance. None of that's going for you with the jet which is more efficient to begin with.

So basically, the task of an airline pilot is really to slam it on, and that way the spoilers pop up and then the brakes start really working effectively. And you turn off the runway in Laguardia before you go into the river. So I landed like a Cirrus, because it was my first month on the job, and I chewed up by 1,500 feet of runway before the airplane touched down. And I applied fairly gentle braking and thrust reverse and turned off after about 5,000 feet of runway. And the captain's like, that sucked. I'm going to show you how it's done the next leg.

So we did Laguardia to Charlotte, North Carolina. Who else did that leg?

AUDIENCE: [INAUDIBLE]

PHILLIP GREENSPUN: Captain Sully. So he dumped his passengers into a filthy cold river and they called him a hero. I got my passengers to Charlotte warm and dry, and where was my medal? Where is my fame? Nowhere. All right, so life is unfair. You've learned that.

Anyway, so the captain takes this one. Air traffic control lines us up. Instead of the visual approach where you're doing everything by eye and following another aircraft, and you can't use any of the fancy automation, we were lined up 10 or 15 miles out for a straight in approach to this angled runway at Charlotte. And all the captain had to do was-- on autopilot, all he had to do was tweak the thrust levers for the perfect airspeed.

The autopilot's flying. He disconnects the autopilot a couple feet above the ground. Now he's hand flying. All he has to do-- the CRJ doesn't have, the 50-seater, any leading edge devices, so it has to be pointed down a bit like a lawn dart. It's not that different from landing a Cirrus.

It's unconventional for an airliner. The airliners, you notice they usually-- because of the leading edge devices, even when they're going 120 knots or so, they can be kind of nose up and they still fly pretty well. So the airplane almost can be flown-- and it can auto land, in some cases, onto the runway by itself with just a slight additional flare at the end.

The CRJ has to be kept nose down 145 knots faster than all but the very biggest jets, and then it has to be, you know, flared from minus five to maybe plus five or plus seven at the end. So the captain, after telling me what a bad job I had done, he flared about five feet too high, and the airplane just sailed over 4,500 feet of runway, I think, before it finally touched down. And he slammed on the brakes, maximum thrust reverse. We barely made it off. I think we made it off after 7,200 feet of runway, so we would have been, I think, in the water in Laguardia.

So that's the kind of thing where, you know, you can't-- that's why these safety margins are good to build into your own flying, because, you know, the book number said the airplane would land a lot shorter than that. Also, in a jet, there's really not a good go-around technique. Once you're below 50 feet, you're not supposed to try to add power and go around because it takes a while to spool the engines up.

All right, in turbulence, you usually will increase your approach speed, which means you're going to chew up more runway. You're supposed to add half the gust factor as a rule of thumb. So if the wind is 15 gusting 25, you're going to speed up your approach by five knots. And I got the numbers here for the Cirrus. 75 is kind of a good overall number, and then you'll beef it up to 80. But that means, unless it really is a headwind when you're landing, you're going to chew up a little more runway than expected.

OK, flaps, as Tina mentioned, they enable you to keep your approach speed low while having a nice steep approach angle. So that's good for getting over trees and stuff. If you're in an aerobatic airplane or something else that doesn't have flaps, you can actually slip and go sideways down towards the runway and get over the obstacles, but it's a lot easier just to put the flaps down.

OK, the charts come in all kinds of variations in the POH, especially for the bigger airplanes. You'll have, you know, 10 charts that look identical except for a couple of numbers, like the exact flap position, whether the anti-icing is on or off. The Piper Warrior POH is a lot simpler, and that's some of the charts we're going to cover in addition to some of the anonymous airplane charts that the FAA gives you with the test. So one thing to remember if you're a renter, in addition to the fact that you want to build in maybe some charter and airline minimums into your flying, is that all those numbers were with the brand new airplane that was perfectly straight and had a perfect engine.

OK, so wind components. You're going to get a shorter takeoff and landing distances with a headwind. A tailwind, actually, it may not be legal to operate a high performance aircraft on a runway with a tailwind of more than a certain amount. I think for the c.r. It was 10 knots. We just simply could not land with a 10 knot tailwind or more than a 10 knot tailwind.

Crosswind is a little bit different. You'll get a max demonstrated crosswind component in the manual. So it'll tell you a test pilot managed to hold this airplane straight on the runway with full flaps, or whatever the normal landing configuration is, and there was enough rudder to land with a 15 knot crosswind. So that's max demonstrated. It's not a limitation. So if it is, it'll say, this is a limitation.

But max demonstrated just means a test pilot did it. It'll probably work for you too if you manipulate the controls in the same way. And beyond that, you can't be sure. So one thing that people will do is they will adjust the flap amount to have-- a reduced use of flaps in a heavy crosswind, that keeps the airspeed up. You will chew up more runway. But when the wheels actually touch the ground, the wheels provide a little bit of stabilization and help keep you from getting blown off the runway.

You're going to see tomorrow Dojo from the Brazilian Air Force is going to tell you about testing the various airplanes, but especially the Super Tucano, in very heavy crosswinds down there in South America. They have some pretty heavy winds. I think they went to Chile to do that. I could be wrong. Or maybe it was just right next to the Andes in Brazil.

OK, crosswind chart. So this here shows you that, if you have a 40 knot wind at a 30 degree angle, you go over here on the chart to the 30 degree line, you use this 40 knot ring, and then you can find that it's a 35 knot headwind and a 20 knot crosswind. Does that make sense?

I will tell you when I was getting a type rating for this Cessna Mustang flight safety, there were a couple of Boeing 737 pilots there, and they had no idea how to use this chart. And they couldn't even give the right answers. If you said, you know, you're landing on runway 27 and the wind's coming from 315, is that a tailwind or a headwind? And they couldn't answer that question either.

Basically, all they do is go from towered airport to towered airport. The tower tells them what runway to use. They are from the Philippines, so I guess it's not insanely windy there like it would be in Argentina. I once landed in Argentina in Ushuaia on a commercial airline flight, and it was 50 knot-- the wind was, I think, 35 gusting 50. And the pilots, you know, I talked to them afterwards. They said it was just a normal day. They wouldn't even bother talking about that.

So anyway, these skills apparently rest. I'm sure those guys, you know, had used a chart like that at one point in their training. They did get their type rating, so the good news is you can get your type rating without knowing how to use that.

OK, here's one of the FAA charts. This is what they give you on the test. It's a lot easier to use than the POH. Here's a problem. They're giving you an example problem. Let's see.

We're at somewhere in Colorado, apparently 5,650 feet. We weigh 2,950 pounds in this airplane that they won't tell us what it is. It's nine knots of headwind. Notice these associated conditions. These are really critical. And again, if they give you a choice of multiple charts, that's where the trick is. You know, they're trying to get you to use the wrong chart. That's more on the AP exam than on the private one.

But yeah, see here, powerful throttle, cowl flaps are open. This is some kind of more complicated plane, that you got the right mixture set even before you take off for high altitude. All right, so what do we got here? We got temperature of 15. We go up to the air pressure altitude, pretty close to 6,000.

We come over here, we're apparently right at gross weight, so at least that's realistic. Most aircraft take off right at gross weight for most flights. There's nine knots of wind, so that's going to subtract a little bit from our runway requirements. And here we can see it's 1,500 feet of ground roll and a little over-- what is that, 2,300? Yeah, 2,300 to clear the 50 foot obstacle.

So these charts are not hard to use. And in the real world, maybe in the FAA figure, they actually give you this example. So you can see how it's done and then, you know, you just draw the lines in a different place. So they're not trying to trick you.

Here's a chart for the Pilatus PC-12. There's also apps to do it, which I'll show you a little bit later, similar to that Piper chart we saw earlier where you calculate the density altitude without realizing that you've calculated it. Yeah, so here you've got pressure altitude and temperature, and you're implicitly calculating density altitude. Then you go over to weight.

Look at this one. The Pilatus guys, I think they are having some fun here. They're saying you're taking off at 7,000 pounds. So you're missing almost 3,000 pounds of people and bags. You paid all this money for this airplane and you're barely using it. So I don't think that happens too often unless you've just dropped everybody off at an airport with no fuel and you're repositioning.

Anyway, so you've got the headwind. They've got uphill and downhill all baked into this nice chart. You can get all these good numbers. This is why Cirrus is better, why they're the best seller. They just say, look, here is this table. There's a few corrections that you can use if you want to up there in the upper right for headwind, tailwind, grass. But basically, they make the usual case very simple of a level runway, a paved runway.

It's always more conservative to go more. You know, you don't have to interpolate. You can just say, well, it's 25 degrees, so I'll use the 30 degree number.

OK, what is the rate of climb here? We're in a gross weight of 1,670 pounds. It's 2,000 feet. How do we figure that out? This is one of the FAA example tables, and it's as simple as finding the right row in the table, row and column in the table.

Or actually, have a look here. So they're saying the mixture has to be lean to get these numbers. The flaps have to be up. You've got to be at full throttle. OK, same deal, max rate of climb. I forget if this a-- this might be a paper chart, but you can see that associated conditions up there in the top left. That's absolutely critical.

You know, The gross weight-- Cirrus, actually, a lot of the performance numbers in the Cirrus for cruise speed are at 2,600 pounds and you're flying along at 2,950 because you took off at 3,000. You're wondering, how come I'm not getting these numbers? But of course, you know, they're being optimistic about-- they're putting their airplane in the best light by positing some weight that probably doesn't exist in real life.

All right, here they give us an example of 5,000 feet pressure altitude, OAT of 16 degrees, so ISA plus 11, max rate of climb, 374. So I guess, yeah, 5,000 feet. Here's ISA plus 11. It says 376 with some kind of elaborate interpolation. I guess you find that last couple feet per minute that you subtract.

Here's cruise charts. I think, again, this is from the FAA test supplement. They're just giving you-- remember I told you it would be ISA minus 20? That's the chart on the left. The one in the middle is the standard day. And on the right is a summer day, ISA plus 20. Notice that they'll give you fuel flow and the true airspeed given various engine speed and manifold pressure settings. This looks like it's for a piston twin.

OK, landing performance is a pretty similar kind of chart. Not going to go through this exactly, but you can see they're giving you the worked example. And you come up with-- let's see. It's going to be about a little over 1,000 feet of ground roll and 1,700 feet, they claim, to clear a 50 foot obstacle.

Here's an FAA question, actually. So let's see. Determine the total distance required for takeoff to clear a 50 foot obstacle. Standard temperature, sea level. So actually, this is testing you. This is pretty advanced, right? They're saying it's the standard temperature at sea level, so you have to know that it's 15 degrees.

We only weigh 2,700 pounds, so we're going to have to ride down this curve a little bit. And the wind's calm, so we're not going to get any boost from the wind. So what do you guys think? Have any of you been able to kind of see what the most likely number is by following these? Somebody says A? Let's see.

It's a little bit lighter. That kind of makes sense. But on the other hand, the wind's calm, so we didn't get that reduction from the wind. Let's see. So if we came down here, it's going to start from sea level, 15 degrees. Come over here. Come down here over a 50 foot obstacle, then we have to go up.

Anybody want to revise their estimate? A, we heard A last time. It seems a little short to clear the 50 foot obstacle. I agree with you that you'd be well off the ground by 1,000 feet. Tada! All right, obviously, you know, if you have a pencil and a little more time to do that, it's easier. That's kind of the hard way.

Let's look at the easy way. Getting the runway numbers for low performance aircraft, it actually remains pretty common to just use the POH. People aren't usually in a situation where they have to worry about it. If you're going from Hanscom Field or Martha's Vineyard and back, you know, both airports are big enough for a Boeing, and you're not going to be carefully calculating these numbers unless you really don't have much else to do.

Apps, though, are available even for low performance aircraft, and they're very useful if you're going, you know, into tighter airports And you might have to worry about that. The time and fuel stuff is everywhere on the web and the apps. But the actual runway numbers are a little bit less common. Let me show you a couple of things.

Here's Gyronimo. So they sell these for different aircraft. This is just off their website. And for an SR22, you can see you put in-- they must be European. They say aircraft mass 3,359. And you've got your temperature, your takeoff elevation, your altimeter, runway conditions. I don't know what that plus 5% is. Maybe they're saying-- oh, I don't know if that's between-- is it half grass and half paved? Anyway, you can put in everything relevant and it's going to tell you how much ground roll and how much takeoff distance. So that's pretty slick. It's a lot easier than relying on the POH.

The calculator for the Pilatus is free. That's the good news. And here, same deal. You put in your weight, the temperature, if there's any headwind, the airport elevation, and you get the numbers.

All right, we can try to get the doc camera working for a demo in a minute here. But in the meantime, first of all, are there questions? And secondly, what is this aircraft? And what's it designed for?

AUDIENCE: Question about the test. Will it be on the [INAUDIBLE] for this class? Because it's online, right?

PHILLIP GREENSPUN: Yeah. Well, you can print out the test supplement. That's public. It's in our Dropbox. And also, the FAA makes this chart supplement public, so you can see all the figures that you're going to see before the test. I think, actually, when you're done with your test, I think you can print out all the questions and it'll show you what you got right.

AUDIENCE: OK. Because for the grass, this is going to be harder for me to [INAUDIBLE].

PHILLIP GREENSPUN: Oh, yeah. Yeah, just print out the chart. Yeah, sure, another chart supplement. Anybody have any brilliant ideas about this aircraft? It says Grizz on it.

AUDIENCE: [INAUDIBLE]

PHILLIP GREENSPUN: That's a Burt Rutan design, the climate change denier. And this is a super short field airplane. It actually doesn't land as short as you might think. I think it might be a four-seater, though, so I guess it is pretty darn short for a four-seater. But it has huge flaps and a lot of wing area, and it's got that-- I think it has ordinary-- Yeah, see, it has essentially three surfaces right? It's got kind of a helper wing or a canard out in front, the regular wing, and then an ordinary conventional tail plane.

Let me see if I can get this doc camera working. All right, so let's say we want to know how much fuel we're going to use. See that fuel pounds there? Where is that? Somewhere along here-- well, actually, I happen to know it's got to be somewhere-- we're 10 pounds.

Yeah, see, there's US gallons right there. So we line this up. And you can tell this was designed for piston folks, because their idea of fuel weight is six pounds per gallon, and jet fuel weighs 6.7. But at this point, now we've got our handy slide rule. So we know, if we load on, for example, 10 gallons of fuel, it's going to be 60 pounds. And the Cirrus holds 56 gallons, so that's going to weigh 300 and-- looks like 345. Oh, sorry, 335 gallons. 335 pounds.

More to the point, you can calculate density altitude. So over here, for example, you can say the pressure altitude is-- let's call it sea level. And it's very hot, though. It's plus 40 degrees. So now you see the density altitude up there is about 2,000 feet. Does that make sense?

So you've set the pressure altitude at the bottom or inside this little window at zero, and then the density altitude gets read out here after you line it up with a temperature. There's also something that you can do, well, just with the basic rate.

So let's say you decide that you're going to be going-- this is more for performance planning. But let's say you're a Cirrus and you're going 150 knots. If you end up needing to go, let's say, 300 nautical miles, it tells you that'll take you two hours. Not too exciting, but the wind side is a little more exciting. I'll bring a pencil tomorrow for the flight planning talk and we can play around with wind vectors on there.

But anyway, fortunately, a lot of this stuff is explained in the book. You guys are free to come up and play around with it anytime. There's a temperature conversion scale here on the bottom. And it's a fun toy.

Tina, anything else that we should cover here? Or should be segue? What's the next--

TINA SRIVASTAVA: So we're going to take questions, and then there's a short break, and then weather data.

PHILLIP GREENSPUN: OK, the next one's weather data. You'll need a break for that one. That's how you find out all this stuff. Let me go back to the PC. Who else has questions?

AUDIENCE: Can you go [INAUDIBLE]?

PHILLIP GREENSPUN: Go back over and look at a POH graph?

AUDIENCE: Yeah.

PHILLIP GREENSPUN: Which one? You want to do with the FAA exam ones?

AUDIENCE: Yeah, the last one.

PHILLIP GREENSPUN: Lane landing performance, or this one from the actual test?

AUDIENCE: Yeah, [INAUDIBLE].

PHILLIP GREENSPUN: This one?

AUDIENCE: Yeah.

PHILLIP GREENSPUN: OK, so I don't think they ever give it worked out for you. Let me switch to the laser pointer mode. OK, so what do they tell us? They told us it was standard and sea level. That's the one part of the standard atmosphere that people, I think, are expected to remember, that at sea level it should be 15 degrees Celsius.

So we come down here. We say it's 15 degrees out. We're going to hit the sea level pressure altitude. We're going to slide over this way, just like in the example. And then we're going to slide down, following this curve, to 2,700 pounds.

And we're going to go over here, and we're going to say, look, there's no wind. The wind's calm, so we'll keep going over here, and we find that we need about a little less than 1,000 feet, maybe 800 feet, for a ground roll. But to clear the 50 foot obstacle, look at the bottom there. We need to go up, following one of these lines, and that's how we get to the 1,400 number. Did that help? You still look a little bit skeptical.

AUDIENCE: Yeah, it just doesn't look like that line [INAUDIBLE]

PHILLIP GREENSPUN: Well, remember, we would be doing this with a virtual pencil. These lines are just for reference, telling you kind of what slope to follow with your pencil. So it's not like these are the only available points. So it's not like it's going to be either this for the answer, or this for the answer, or this for your answer.

Even in their worked example, you can see their red line for the answer is just parallel to that gray line. They're not picking one of the gray lines. So they're guidelines for how you should move your pencil in each phase. I hope this motivates you to buy that Gyronimo app. It certainly would motivate me to do it.

TINA SRIVASTAVA: If you want to look at it on a real book, I'll pass around-- again, this is my POH for Cessna 172. So this might be the type of plane that you're using as your training aircraft. And I have a couple of pages that are marked with a piece of paper. So one talks about how you calculate the takeoff distance. And one is weight and balance.

We'll actually have a whole section dedicated to weight and balance. But just to give you a sense of how you can follow with your pencil, and you'll actually see some pencil markings of my own fairly close to the limits here of our center of gravity moment envelope here, but still within the box, so just to give you an idea of how you can do that with a real paper and pencil.

AUDIENCE: Yeah. [INAUDIBLE] So within that [INAUDIBLE] Is that the reason?

PHILLIP GREENSPUN: Yeah. So the question is, you know, we don't have any kind of readout in the aircraft for density altitude. So is that why we're always calculating with our handy E6B or listening to the ASOS or whatever? So, yeah. Yeah, basically your instruments in the aircraft can tell you the temperature, outside air temperature, maybe not quite as accurate as the one from the airport if you're on the ground.

And they can also show you, if you set your altimeter to two niner niner two, you can see the pressure altitude. But the relationship between the two is not simple. And there's nothing onboard the aircraft conventionally that will calculate it for you.

And I don't think that's quite true. I think a lot of modern GPS boxes will do that calculation for you. But you have to type in all the numbers. They don't usually just grab it. They will give you things like true air speed. They'll definitely calculate that. So if you're indicating 150 but you're up really high, they'll tell you, well, now you're going 200 knots in true air speed, and then they'll give you your ground speed, too. And they'll even show you with a wind vector.

TINA SRIVASTAVA: Any other questions? OK, great. So we'll just take a 10 minute break and start up again at 2:15 with weather data. And that's the one you guys seem to keep asking about, so we'll talk about also, towards the end of that talk, how you build your own ADS-B receiver.