

CFI Notebook

Reference notes for the private, instrument, and commercial pilot candidate and instructor

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*For Zoë, Sebastian, and Malcolm, who hopefully find as much inspiration from me as I
do from them. I hope that they can learn to fly one day too.*

Introduction

DISCLAIMER: As of this writing, the author is NOT an FAA-certified ground or flight instructor. This book must be used for reference purposes, only. For the purpose of ground or flight instruction, the reader is directed to consult a ground instructor, certificated flight instructor (CFI) or certificated flight instrument instructor (CFII).

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Chapter 1

High Altitude Operations

In this chapter, we introduce high altitude operations.

Before we dive in, we must answer a couple of questions.

What are high altitude operations? Simply put, these are operations far outside the “normal” environment you might expect to find on a Standard Day at sea level. We’re talking about altitudes that are not terribly comfortable for humans, and possibly altitudes that are so high above MSL that we won’t find any terrain there at all. There are enough aeromedical factors and enough changes to aircraft performance that we need to consider these operations carefully.

Why do we care about high altitude operations? We might need to get high enough to cross some mountains and stay above terrain. But there is also the desire for speed. I’m not just talking about the speed limit of 250 knots below 10,000 feet - if we wish to go faster, we need to go higher. I’m talking about the fact that *thinner air provides less drag*, which permits us to fly through the air more efficiently.

Mother Nature, of course, exists outside the realm of aviation. The challenges of high altitudes were present well before the first powered flights - just ask anyone who tried to climb Mount Everest in the 1800s. So, first, we must have a look at the atmosphere itself.

1.1 The Atmosphere and Its Layers

Recalling the basics from aviation weather, we know that the atmosphere is divided into several layers. Starting from the ground and going on up, we have the troposphere, the

stratosphere, the mesosphere, the thermosphere, and the exosphere. All weather - and most of the earth's air! - reside in the troposphere. Flight operations rarely venture into the stratosphere (even more rarely now that Concorde is no longer flying).

So, when we say "high altitude", we mean "higher than a short cross country flight but lower than Concorde". We're talking altitudes below about 45,000 feet. If you ever manage to get above that, please let me know. (I'm looking at you, astronaut friends... you know who you are!)

1.2 Density and Altitude

In order to better talk about the atmosphere, can we all agree on a make believe, consistent, common, daresay, *standard* atmosphere?

Well, apparently, we can. Aviators are all too familiar with the International Standard Atmosphere. This aviator only recently learned that when we say standard, we mean Standard, namely, International Standard (ISO) 2533 from 1975, which is identical to the ICAO Standard Atmosphere from -2 to 32 km, or up to about 100,000 feet.

Assuming you've paid the 198 CHF fee, or can otherwise access the standard, you would see an interesting thing happening. You would see the value of p , the pressure, and ρ , the density of the atmosphere, decrease as altitude increases - and rapidly at that. At sea level (zero elevation), pressure is the all too familiar 1013.25 hectopascals. At 3,000 meters or about 10,000 feet, we're down to 701.21 hectopascals - only 69% of the pressure at sea level! That means 69% as much air, 69% as much oxygen available for breathing or combustion, 69% as much drag.

Up at 10,000 meters or about 33,000 feet - typical airliner altitudes - we're down to 262 hectopascals. That's just over 25% of the pressure at sea level.

This is a huge change! It's enough that we need to pay special attention to how we are powering our airplanes, how we are providing our bodies with oxygen, and how we are constructing our airplanes. It's enough that we need to take into account certain operational considerations.

1.3 Propulsion

One of the problems with high altitude flight is that the air is so thin, there may not be enough oxygen for the (internal combustion) engine to run properly.

Recall that a normally aspirated aircraft with a piston engine has a service ceiling. That ceiling is defined as the altitude at which the airplane's climb rate slows to 100 feet per minute [2]. That exact altitude will vary based on aircraft loading and how the conditions compare to a standard day. Famously, Concorde would continue to climb while underway, going higher as it got lighter. But the fact remains: for a piston airplane, we can only go so high.

Since the limitation is oxygen, and not fuel, there are a few ways that we could gain power at a higher altitude.

What if we had an electric aircraft? That would be great - it doesn't need oxygen at all. Today, in 2022, battery technology isn't quite there, nor are solar cells, outside from a very few research aircraft.

What if we simply had supplemental oxygen on board? Certainly, if we carried oxygen tanks, we could supplement the oxygen in ambient air to gain more power. Operationally, this is not a great idea, since we now have to deal with the added weight, complexity, and risk of an oxygen system, and it will not last very long. But air-breathing rockets do exactly this, so it's not a bad idea per se, simply not the right one.

What if we could grab more air from the atmosphere, possibly by compressing the air before it gets to the engine intake manifold? Now we're on the right track.

The first approach we might take is simply inserting a compressor between the outside air intake and the engine's intake manifold. That compressor could be a piston pump, similar to the vacuum pump in the airplane. But that's not terribly efficient: it generates a fair amount of waste heat. For this application, a turbine is a better idea. We could power this compressor with the aircraft's engine, most likely with a belt or a gear drive off the engine crankshaft. Such a contraption has a name: supercharger. It requires more power from the engine, and there are some losses due to the belt or gear drive mechanism, but it is a new positive up to a point: we can shove more oxygen into the engine, and raise our service ceiling.

Some clever person (who?) looked elsewhere on the engine and found another possible source of energy for driving this compressor. They realized that the exhaust gasses coming out of the engine were quite warm and under a decent amount of pressure. What if this energy could be captured? We can add a *second* turbine in line with the exhaust pipe, and use the torque generated by that turbine to drive our intake compressor! As it turns out, this works better than a supercharger. We call this a "turbocharger". Sometimes we have more than one.

(some diagrams should go here)

Operating a supercharged or turbocharged engine has some key differences from operating a normally aspirated engine. One, we need to re-calibrate our manifold pressures. By this I mean, in normal operation, a piston engine's intake manifold would achieve a pressure no higher than ambient pressure, likely no more than 32 inches of mercury. But, a turbocharged (or supercharged) engine may be able to go above this. I say "may" because some turbos simply give sea-level pressure at higher altitudes (turbonormalized), whereas others can go well above sea level pressure. Regardless, the turbo lets the engine run harder than it could otherwise, which means increased heat and risk of engine damaged. There are often limitations on how long an engine may run on a particular power setting as a result.

The turbocharger (or supercharger) turbines are themselves metal parts that are subject to fatigue and thermal stresses. After flights, we want to give the turbines some time to cool down, lest we shut them off entirely and subject them to thermal shock.

Recall that, when we compress air, it gets quite warm. This is unfortunate, since we recall from the application of carburetor heat that warm air will lean our mixture. What if there were a way to compress the air, and then cool it to get it as dense as possible? There is: it is called an "intercooler". But, as this requires even more heat to be dissipated from the aircraft, the intercooler must be carefully placed so that it can dissipate heat effectively.

With a turbocharged engine in particular, the concept of "exhaust gas temperature" takes on a new meaning. Where are we measuring: before the exhaust turbine, or after? It makes more sense to measure before, and we call this the "turbine inlet temperature" or TIT. We need to manage this temperature carefully: we want the TIT to be as high as possible for efficient leaning of the engine, but if it is too high, it could melt the exhaust turbine.

These turbines need to spin quite fast - think 100,000 RPM - in order to be effective. It is challenging and expensive to create machinery that can operate at this speed.

All of this seems awfully complicated for a little bit of extra power. What if there was a better way?

There is. It's called the jet engine.

The jet engine is, at its simplest, a single turbine. It ingests air and compresses it. We inject fuel into the compressed air and ignite it, causing it to heat and expand. The exhaust heats and expands so much that it exerts a force on a turbine, which serves as thrust for the airplane. Much like the turbocharger, the jet engine grabs some energy

from the exhaust system to power the input compression phase.

More specifically, this single arrangement is called a "turbojet". It is simple, powerful, and reliable. So long as fuel usage and noise are of no concern, this is the best power-plant. The military often doesn't care about fuel or noise so we see turbojets on plenty of military aircraft. If we care more about efficiency and noise than (potentially supersonic) speed, we can also attach a really fast-spinning propeller to this, and capture the propeller's thrust in a duct for maximum efficiency. This combination of a turbojet with a ducted fan is called a "turbofan" and is the most popular way of powering large aircraft.

Of course, the propulsion system allows the aircraft to operate at a higher altitude. But what about the pilot, flight crew, and passengers? Do we need to do anything special for them if we are flying at high altitudes?

1.4 Aeromedical Factors

Much like the airplane's engine, the human body needs a certain amount of oxygen to perform.

1.4.1 Hypoxia

1.4.2 Diving and Flight

1.4.3 Humidity

1.5 Supplemental Oxygen Systems

1.6 Operational Considerations

Chapter 2

The Commercial Pilot

So you want to become a commercial pilot? What are the privileges and limitations for such a pilot? What does that even mean?

One thing is for certain: the private pilot checkride is NOT simply a “glorified commercial pilot checkride”. The expectations - and risks - for a commercial pilot are much higher.

Think of it this way. The private pilot checkride represents your first flight with a passenger (albeit a fairly picky one at that). The commercial pilot checkride is meant to simulate your first *job interview* as a pilot. It’s all about professionalism, polish, and positive control.

The private pilot checkride is your change to demonstrate competence. The commercial pilot checkride demonstrates fluency, professionalism, experience, and finesse. Of course, the ATP checkride takes this to another level, but we’ll talk about that another day.

The PHAK [5] is a great reference. So is the AFH [3]. It’s good for commercial pilots to be familiar with hazardous attitudes [1] as well.

2.1 Maneuvers

The Commercial Pilot is held to a higher standard than the Private Pilot. Many of the maneuvers on the private pilot checkride make an appearance on the commercial pilot checkride as well. Quantitatively, the commercial pilot has less margin: tighter limits for airspeed, altitude, heading, bank, landing distance, etc. Qualitatively, the checkride

examiner wants to see that the commercial pilot candidate is the clear master of the aircraft. They are looking for positive control, smoothness, rudder coordination (and cross-coordination when appropriate!), and appropriate use of trim or checklists.

With the private pilot we ask, would I trust the candidate to take my spouse or child flying? With the commercial pilot we ask, would I trust the candidate to take my entire family flying?

The Commercial Pilot ACS [4] is the bible for the Commercial Pilot checkride. We refer to it frequently in this section.

The author has, as of this writing, spent the most time in the P32T type, a T-tailed Piper Lance II. The detailed procedures here implicitly refer to the Lance, and its airspeeds and quirks. Some details will differ based upon the particular aircraft.

2.1.1 Soft-Field Takeoff and Climb

The soft field takeoff and climb demonstrates that the pilot is able to operate the aircraft safely on a dirt, grass, or other similar off-pavement airstrip. The constant theme is unweighting: keeping weight off of the tires, particularly the nosewheel. A secondary theme is smoothness.

We configure the aircraft with two notches of flaps and one or two turns of nose-up trim past the neutral point. Once we begin moving the aircraft, we continue to move until we are airborne or abort the landing. Back pressure on the yoke will transfer as much weight as possible from the nose wheel to the mains. The Lance has very little elevator authority at low speeds so this effect will be minimized.

Taxi smoothly and continuously onto the runway. Apply takeoff power, at perhaps half the rate as usual (taking 6-8 seconds to advance the throttles instead of 3-4) to help prevent kicking up debris. Holding firm backpressure, accelerate down the runway.

The Lance's V_x speed with gear down is only 68 knots. The Lance usually doesn't climb until 70 knots. So, in this aircraft, it may not be necessary to accelerate in ground effect, as we might with many other aircraft. The pilot must be mindful of this.

Once we are airborne at rotation speed above V_x , we hold that to clear a 50- or 100-foot obstacle. Then, once positive rate is confirmed and the obstacle is clear, we retract the gear, lower the flaps one notch at a time, and continue accelerate to our gear up V_x of 87 knots, which just so happens to be V_y with gear down and flaps up. After that, we continue to accelerate to a clean V_y of 92 knots, and continue to climb from there.

Disqualifications might include: porpoising on the ground due to incorrect transition

to ground effect flight (which we shouldn't need in the Lance), stopping once we begin the ground roll, inappropriate use of controls, incorrect airspeeds.

2.1.2 Soft-Field Approach and Landing

The soft field landing demonstrates that the pilot is able to manage the aircraft on a surface other than a paved runway. Much like the soft field take off, the goal of the maneuver is to keep as much weight off of the tires, particularly the nose tire, for as long as possible. Note that, by default, the soft field approach is NOT also a short field approach. However, the Lance's POH does not differentiate between them.

The landing begins as a typical short landing: wheels down at 75 knots, full flaps. In the Lance, a blip of throttle is needed to allow the main tires to gently set down on the ground as opposed to slamming down and potentially digging in. Then, we continue to hold back pressure and leave the flaps down to gently bring the nose down, doing so as late as able. We can lower the flaps to two notches as soon as able, and have the option of leaving them down as we taxi. We must not stop until we are clear of the active.

In the Lance, we typically do these maneuvers with half a tank of fuel and two front seat occupants pushing the station weight limit of 440 lbs. This leads to a fairly fore CG condition where the aircraft is nose heavy. When the aircraft is aft loaded, the nose becomes MUCH lighter, and it is possible to wheelie all the way down the runway unless we are very careful.

Note that the soft field landing has no aiming point specified. This is good, since a true grass strip won't have markings.

Disqualifications might include: bouncing, slamming the nose wheel, stopping on the runway.

2.1.3 Short-Field Takeoff and Maximum Performance Climb

In the short field takeoff, we are looking to use a minimum of runway, lifting off at the earliest spot possible, and to clear a 50 foot obstacle. To use the minimum runway, we position the aircraft as close to the very end of the runway as possible, using a displaced threshold to our advantage. In the Lance we use two notches of flaps. We hold the brakes, apply full power, lean if appropriate, and release the brakes. Seriously - feet off the brakes!

We recall that V_x in the Lance is a mere 68 knots in the dirty configuration. We're lucky if we are airborne at 70-75. Maintain that airspeed until clear. Then it's gear up and flaps up as we accelerate through V_x of 87 knots to V_y of 92 knots.

Disqualifications might include: forgetting to position the airplane as far as possible on the end of the runway, incorrect flap settings, forgetting to run up with brakes held, incorrect airspeeds.

2.1.4 Short-Field Approach and Landing

The Lance doesn't like to be slow as this maneuver reminds us.

The short field approach is an important practical maneuver. On a checkride, we usually have the examiner give us an aiming point, and it's usually the 1000 foot markers. In real life, that aiming point is the numbers as we're looking to truly use minimal runway.

In the Lance, we set up for a full flaps stabilized approach doing 75 knots over the numbers. The plane will want to sink quickly when we cut power so a small dose of throttle will set us up for success. However, it's important to be within 100 feet of the required spot, so a hard landing is better than a failed checkride. Recalling that the 1000 foot markers are 200 feet long (source?), the goal is to be ON the markers.

Once down, retract flaps (easy in the Lance, lower the lever to the ground), apply full back pressure, and call out "maximum braking". It's not necessary to actually brake hard, we don't need to leave tire marks on the runway.

Disqualifications - and there are many for this one - might include: improper configuration, missing the aiming point, bouncing so hard that we porpoise and have to go around, forget to call out "maximum braking".

2.1.5 Power-Off 180° Accuracy Approach and Landing

This maneuver is probably responsible for more failed commercial pilot and CFI checkrides than all the others combined. It is unforgiving and requires a very high degree of precision, particularly to correct for winds. The candidate gets one shot at this one. If they land short, or land long, or have to go around, that's a disqualification. It still makes sense to continue the checkride, but if this happens to you, expect to lick your wounds, spend an hour with a CFI for an additional signoff, and to take another shot in the coming week.

For this maneuver, we fly a traffic pattern with a closer than usual downwind leg ($\frac{1}{3}$ of the way up the Lance's wing instead of just off the tip) and cut the power abeam our touchdown point, the 1000 foot markers. We immediately pitch for our best glide speed of 92 knots, turn a fairly tight pattern, put the gear down once the field is made, and execute a normal, possibly no flaps landing. This ends up being a fairly aggressive,

tight, rounded approach, with no real base leg, as downwind transitions smoothly to base and final.

DO NOT FORGET TO PUT THE GEAR DOWN. If you're less than 50' AGL and don't see three greens, GO AROUND. This isn't worth a new engine.

With respect to the aiming point, there are three possible outcomes:

- Too short. We've lost too much energy and have no hope of making the aiming point. Perhaps our pattern was too wide, we did not correct for wind, or we otherwise failed to manage energy. Identify and call out the situation, and immediately GO AROUND. Whether or not this is disqualifying, this is the correct course of action.
- On point. This is ideal. But getting it magically right by chance means we're not really in control of the aircraft. So, even though this will pass the test, it's not the best place to be.
- Too far. We have not lost enough energy. As long as we don't have *such* an excess of energy that we cannot manage the airplane and the landing, this is fine. We have some tricks to get lower: cut the airspeed (down to 75 instead of 87-92), lower the flaps, slip with flaps extended (approved in the Lance!).

You've got 200 feet from the aiming point for this one. If the aiming point is the near side of the 1000 foot markers, the limit will be the end of them. You'll know immediately when you've done this one correctly, and so will your examiner.

Assuming you do this correctly, this is arguably the hardest part of the checkride. So spend plenty of time practicing.

Disqualifications include: failing to make the aiming point (obviously), failing to go around when appropriate.

2.1.6 Slow Flight and Stalls

Nothing too special about these except the very tight commercial pilot ACS limits: ± 50 feet for altitude, $\pm 10^\circ$ heading, $+5/-0$ for airspeed (which in the Lance is usually 70), and $\pm 5^\circ$ angle of bank. The examiner may want to see these in the clean configuration, or an approach configuration, which could be one notch of flaps, two notches of flaps and gear down, full flaps and gear down. The may ask you to fly straight and level, to turn (usually 15 degrees is about right), to climb or descend, or to do more than one at the same time. If we're doing these power off, of course we cannot maintain altitude,

so allow plenty of margin for descending just above stall speed. If we're doing these power on, correct rudder application is paramount.

Remember: pitch (and quite a lot of nose up trim in the Lance) for airspeed, power for altitude.

Give plenty of space above the ground for these. KMDD airport sits at 2805.4 feet MSL. We could be entering these maneuvers at 5500-6000 feet MSL.

For the commercial pilot, stalls may be to first indication (BEEEP!) or a full stall (BEEEP!, heavy buffet, and a very tiny nose drop and excessive sink rate in the Lance).

Disqualifications include: getting below 1,500 AGL. Make that 2000 AGL. Stall recovery can be up to 550 feet in the Lance. Call that 3000 AGL. Forgetting to make clearing turns is disqualifying. Forgetting to stay coordinated could be as well.

2.1.7 Accelerated Stalls

Fortunately, these are harder to enter than they are to exit. Also fortunately, we don't have an altitude requirement for this one. Well, except for one: DO NOT get below 3000 feet AGL. If we're especially ham fisted, we'll enter a stall, which - shocker! - is disqualifying.

Set up the airplane for V_A , configure as requested, set power appropriately, and enter a coordinated 45 degree banking turn. Don't worry about altitude as long as we're high enough.

Now: PULL. It will take a HEAVY two handed pull in the Lance to get a stall warning. Hear the BEEEP? Wings level and go around. Done.

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