NAVIGATION AND FLIGHT PLANNING

FULFILLS PA.I.D, CA.I.D, AI.II.I

Objective	
The student shall understand the process of planning a cross country flight, including route and altitude selection, performance calculations, applicable regulations, and risk management tools. The student shall become familiar with applying weather information to trip planning.	
Instructor Actions	**Student Actions**
- Define terms - Explain route and altitude selection - Demonstrate obtaining NOTAMs and weather - Demonstrate reading performance charts - Demonstrate using E-6B flight computer to calculate performance figures - Demonstrate filing, activating, and closing VFR flight plans with ForeFlight and FSS - Explain applicable regulations - Discuss with the student the PAVE checklist	- Take notes and participate in instructor's discussion - Work with instructor in flight planning for subsequent cross country - Perform calculations on E-6B flight computer - Speak to weather briefer - Practice identifying hazards using PAVE checklist - Practice identifying alternatives as part of NWKRAFT checklist with instructor
Case Studies	**Equipment**
- AOPA Accident Case Study: Into Thin Air	- Chart Supplement - Computer - E-6B Flight Computer - Pilots Operating Handbook - VFR Sectional
Completion Standards	
The student shall explain methods to minimize hazards relating to fuel planning, unforcasted weather, and aircraft performance. The student shall demonstrate proficiency in planning a simulated cross country, including all aspects of NWKRAFT.	

ELEMENTS

RESOURCES

FAA-S-ACS-6C Private Pilot ACS - Area I Task D
FAA-S-ACS-7B Commercial Pilot ACS - Area I Task D
FAA-S-ACS-25 CFI ACS - Area II Task I

14 CFR 91.103 Preflight Action
14 CFR 91.123 ATC Clearances
14 CFR 91.155 Weather Minimums
14 CFR 91.151 Fuel Requirements
14 CFR 91.159 VFR Cruising Altitude

FAA-H-8083-2 Risk Management Handbook
FAA-H-8083-3C Airplane Flying Handbook
FAA-H-8083-9 Aviation Instructors Handbook
FAA-H-8083-25C PHAK Chapter 16: Navigation

AC 91-92 Pilot's Guide to a Preflight Briefing

Piper Tomahawk POH

1. DEFINITIONS

Wind Correction Angle. Increase or decrease in aircraft heading to account for a crosswind component.

Magnetic Variation. Local angular difference between magnetic north and true north due to Earth's magnetic field. See isogonic line on Sectional Chart.

Magnetic Deviation. Angular correction, dependent on aircraft heading, due to aircraft's own magnetic field.

True Course. Course relative to true north, or course read off the Sectional and plotter.

True Heading. True course corrected with wind correction angle.

Magnetic Heading. True heading corrected with magnetic variation.

Compass Heading. Magnetic heading corrected with magnetic deviation. This is the heading we will fly.

Cross Country Is not limited to flights greater than 50 miles. Depends on what you plan to apply cross country time for.

2. CROSS COUNTRY FLIGHT TRAINING

2.1. Private Pilots

See 61.109(a)

3 hours of cross country training including:

- One night cross-country more than 100 nautical miles total distance

5 hours of cross country solo including:

- One solo cross country of 150 nautical miles total distance, with full-stop landings at three points, and one segment of more than 50 nautical miles between the takeoff and landing locations

2.2. Commercial Pilots

See 61.129(a)

- 50 PIC cross country with at least 10 in airplanes
- One solo cross-country flight of not less than 300 nautical miles total distance, with landings at a minimum of three points, one of which is a straight-line distance of at least 250 nautical miles from the original departure point.
- Two training cross country flights, 2 hours minimum each more than 100 miles away, one day one night.

Any previous cross country would need to say "toward 61.127(b)" to fulfill the commercial requirements.

3. INTRODUCTION

While your early flying career may involve many trips to the practice area and within the traffic pattern, our ultimate goal is to escape our neighborhood and explore new places. This lesson introduces the skills of pilotage and the fundamentals of Dead Reckoning, methods for planning a VFR cross country, aviation weather services, risk management, and aeronautical decision making.

We often use the phrase "staying ahead of the airplane" to indicate that the pilot is acting proactively, rather than reactively, to necessary actions. Monitoring the weather at the destination, continously identifying diversions and landing points, and considering fuel burn/aircraft status are examples of stying ahead of the airplane.

3.1. Pilotage

Pilotage is the simplest and most primitive form of navigation. Just was we often navigate our cars by making turns at particular buildings and intersections, we can navigate our airplanes by following landmarks on the surface. The VFR Sectional depicts various kinds of ground features that may be used to assist pilots in navigating. During flight planning, the pilot should compare the expected features around their route of flight. A lost pilot can even deduce their position by comparing whats outside their window to whats on the sectional. However, pilotage works best when used in conjunction with other forms of navigation such as dead reckoning.

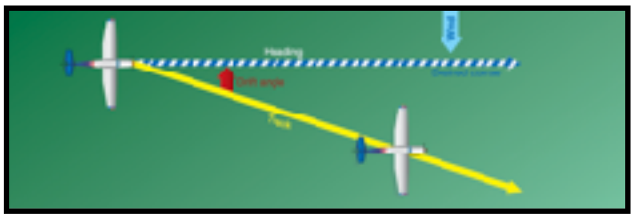
3.2. Dead Reckoning (d=rt)

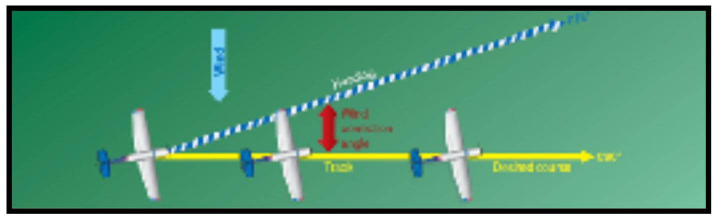
Pilotage is great at determining “big picture” situational awareness. Knowing that you’re east of Lake Okeechobee or south of Palos Verdes can help you maintain or regain your sense of direction. However, pilots need to be slightly more scientific in calculating important performance figures, such as magnetic heading and time enroute. Dead reckoning is navigation solely by means of computations based on time, airspeed, distance, and direction, so it should be used concurrently with pilotage. Additionally, learning how to flight plan without the use of EFBs or modern GPS is a valuable skill to build self-reliance.

3.2.1. Mathematical Concepts

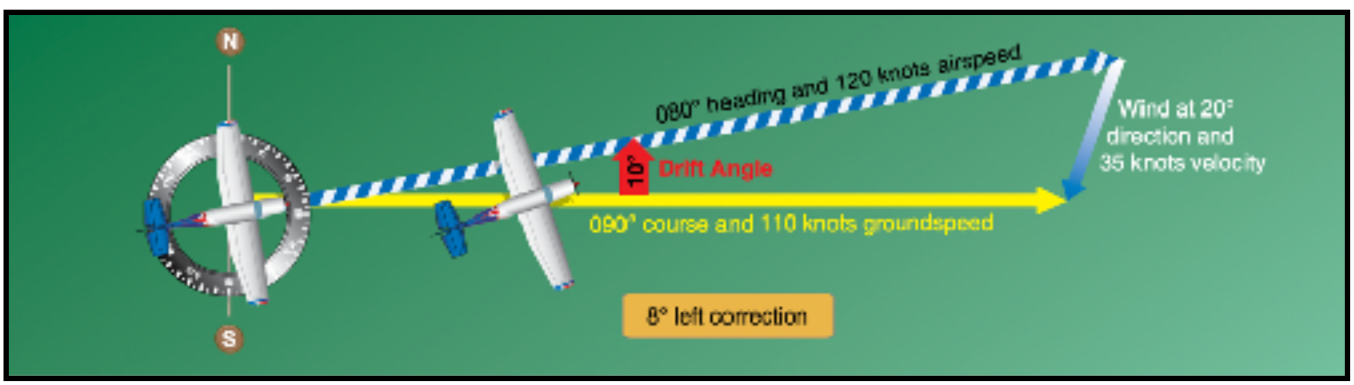
Vectors and the Wind Triangle

On a windy day, if we point the nose where we want to fly, most likely we will get blown off course. However, if we align some of our velocity vector into the wind, we can essentially cancel out the crosswind effect. In the 2nd image, notice how there is a small component of the aircraft’s heading pointed into the wind.





It’s best to think of our aircraft heading and altitude as a vector, which is simply a line drawn with a certain direction (heading/track/course) and magnitude (airspeed or distance). Solving for the wind correction angle and corresponding groundspeed then become easy with an E-6B calculator.



Rates over Time

We are concerned with two rates: fuel burn (gallons per hour) and speeds (NM/hr, i.e. knots). Using the formula **quantity = rate · time** and knowing two of the three parameters, it is simple to find the third.

$$\text{quantity} = \text{rate} \cdot \text{time} \longrightarrow \text{Fuel} = \frac{4.9 \text{ gallons}}{\text{hr}} \cdot 2 \text{ hr} = 9.8 \text{ gallons}$$

$$\text{quantity} = \text{rate} \cdot \text{time} \longrightarrow \text{time} = \frac{\text{quantity}}{\text{rate}} \longrightarrow \text{ETE} = \frac{150 \text{ NM}}{100 \text{ Knots GS}} = 1.5 \text{ hr}$$

4. FLIGHT PLANNING

4.1. Identifying the Destination

Often during flight training, your instructor tells you the destination airport. However, if our goal is to teach real-world flying as a private pilot, often the PIC chooses the destination. Maybe there is a fantastic restaurant in Santa Monico (KSMO)**,** or a scenic campground runway adjacent (L05). Whatever the case, it is the PICs responsibility to ensure the airport is sufficient for your mission.

Before we even draw our course on the sectional, we should ask a few questions about our chosen destination:

- Are the **runways long enough** for takeoff and landing considering density altitude?
- Will we require **fuel**?
- Are the **FBOs open**, should we need them?
- Is the airport open and for **public use**?
- Are there any **services available** if we have a maintenance issue?
- Is there **challenging terrain** surrounding the airport?

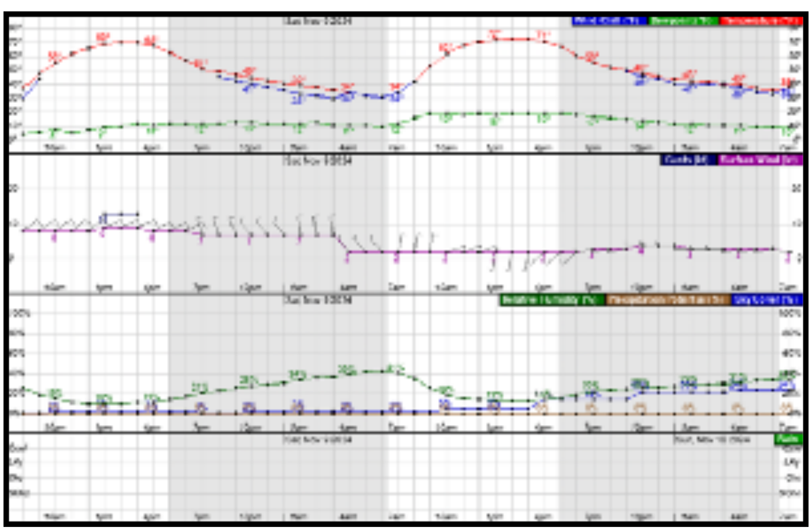
4.2. Getting the Weather

Every pilot has their preferred weather sources, both for long- and short-term weather outlooks. We must be aware of biases we have, such as seeing one source predict VFR weather while many others predict low IFR, but since we want to fly, we trust the VFR source as more true. There will always be another day we can fly.

My first go to short term (now to three days in the future) weather source is the ForeFlight daily weather page. I find the wind forecast to be quite accurate and the ceiling predictions to align with VFR or IFR when indicated. This tool is available as a point forecast anywhere. However, a significant limitation is the lack of cloud layers, only indicating the altitude of the ceiling. We can however apply a rudimentary approximation to determine the lowest cloud layer, as discussed in Weather Theory. A similar tool is available on NWS here.

These factors will influence our cruise altitude decision.

I supplement this tool with the TAFs and forecast discussion. In the forecast discussion, we get a narrative-based forecast with an aviation focus. They often discuss fronts, convection, and clouds that impact the region. Both these products are available on the Aviation Weather Center website.



I also review the prog charts to determine any frontal activity, and compare that with the GOES satellite imagery for my area.

These are just what work best for me. Students should also try out the GFA tool and should definitely make an account with 1800wxbrief.com and explore their weather products. One can even call 800wxbrief (800-992-7433) for a verbal briefing.

As quasi-meteorologists, its our job to review these weather sources to plan our flight accordingly. After review of the weather, we should write it down on the back of our NavLog.

WEATHER LOG						
	Ceiling, Visibility and Precipitation		Winds Aloft	Icing and Freezing Level	Turbulence and Cloud Tops	Position of Fronts, Lows and Highs
	Reported	Forecast				
Departure		27019G24 10SM, CLR, 16/04, A2999 PA: 2281ft	At 4500: 3424+08			
Enroute			At 6500 (avg): 3426+06			
Destination			At 4000 (avg): 3815+10			
Alternate						

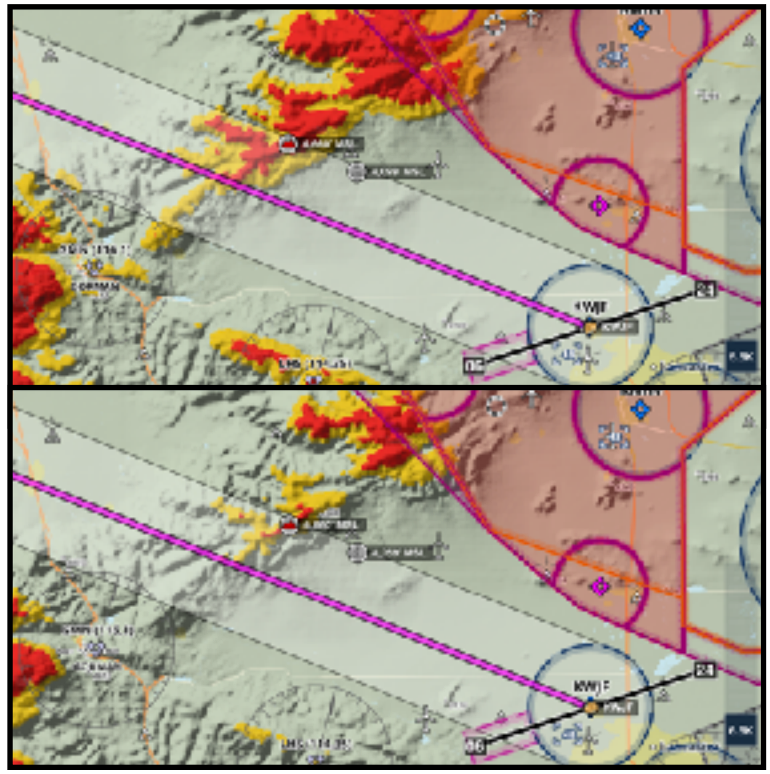
4.3. Route Planning and Altitude Selection

Now we can break out our sectional and plan our course. Take your plotted and draw a line between your departure and arrival airports. For this example, let's say we are flying from KWJF to L17 on a perfectly clear day.

Our next step is to evaluate the route. What airspace do we cross? What kind of terrain are we facing? Are there other airports along our route should bathroom stops be necessary?

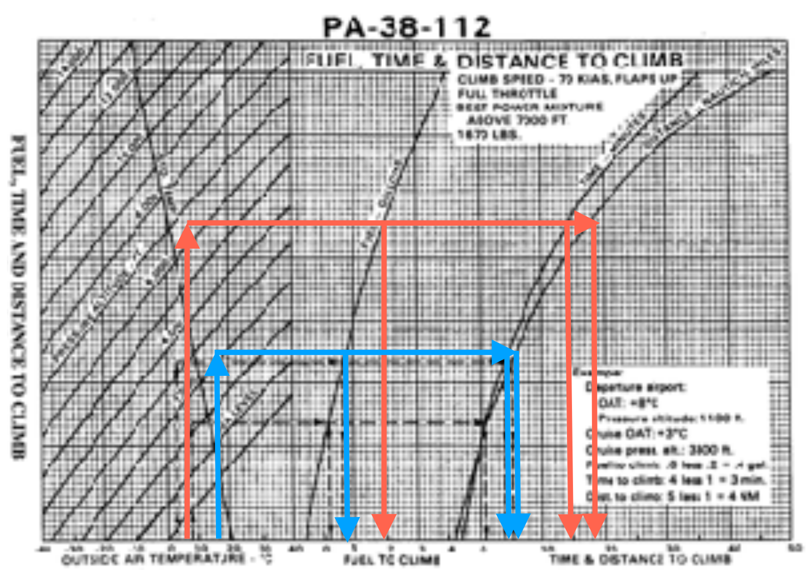
91.159 is the simplest altitude dictator. On eastbound magnetic courses (0°-179°), odd thousand + 500 ft. On westbound magnetic courses (180°-359°), even thousand + 500 ft.

Our flight passes through a special military activity area, which a nearby note indicates may be for unmanned aircraft. However, there are no flight restrictions in special military areas so we can continue planning. Beside the departure Class D airspace, there is no further airspace of special concern.



About 25 miles after departure, the sectional indicates a small mountain range we need to overfly. The ForeFlight hazard advisor does a better job in depicting where high terrain exists, as seen to the right. At 5500 feet MSL, although an eastward VFR cruise altitude, there is less than 1000 feet of clearance. The FAA recommends at least 1000 feet of clearance, **increasing to 2000 feet when winds aloft at peak height are greater than 20 knots.** At 6500 feet MSL, there is over 1000 feet of clearance above the mountains along our route. We will plan for 6500 feet MSL for the outgoing leg. Returning, we will plan for 7500 feet MSL.

The first thing we must find is our top of climb and top of descent. This will tell us how long, how far, and how much fuel is required to climb from our departure airport to our cruise altitude. On the left side of the chart, we draw a vertical line from the ground temperature to the ground pressure altitude. This serves as our baseline, as if we were climbing from sea level to the airport elevation on a standard day. From the top of this line, we draw a line to the rightmost curve (distance). We then draw lines from each curve downward to indicate each value's initial condition (blue lines). We repeat this process for the conditions at cruise altitude. This indicates the fuel, time, and distance needed to climb to cruise altitude from sea level (red lines). By subtracting the fuel time and distance to climb from sea level to cruise with those to climb from sea level to the surface, we can obtain the fuel, time, and distance to climb from the surface to our cruise altitude.



To find the time, fuel, and distance to climb, we simply subtract each red value with its corresponding blue value. So, for this climb to 6500 feet MSL from the surface, we can expect to burn 1.3 gallons in 11 minutes over 12 miles. However, 12 miles is too far for our first checkpoint. It's generally a good idea to select a point nearby to ensure you are flying the right direction before you could stray too far off course. So, our first visual waypoint will be during the climb and closer to the airport than our TOC.

Calculating Top of Descent is much simpler. Simply take the altitude change needed to reach traffic pattern altitude (1658 MSL or 800 ft AGL at L17), divide by 500 feet per minute to find the time to descent, then multiply by the groundspeed during descent to find the distance. Since we havent completed any groundspeed calculations yet, we can use estimates.

When choosing waypoints, the goal is not to fly over them, but rather to see them out the windows. The Sectional and aerial imagery are best suited for this step.

The first point we'll pick is the Little Buttes Antique Airfield just 4 nm from KWJF. Airports are usually a reliable and highly visible landmark. We will mark the sectional where that point is abeam our location and add it to our NavLog. I added a note that we should expect it to the right of course. We will also measure the distance and record it under the distance (leg) column.

Check Points (Fixes)	VOR Ident / Freq.	Cours (Route	H	Dist. Leg / Rem.	GS Es / Ac
WJF Airport					
Little Buttes Airport (dirt) -right-				4	

After passing the Little Buttes Airfield, we know we'll need to climb for another 8 miles. Looking ahead on the sectional there isn't much many landmarks to choose from. However, the aerial map shows a unique terrain feature just a couple miles north of our route. This is another ideal landmark that perfectly coincides with our TOC, increasing the accuracy of our NavLog. However, it may not always be possible to find a waypoint that coincides with a TOC, and often we don't climb in a straight shot along our route, so do not worry too much if your points don't line up perfectly. We'll mark this checkpoint's position on the Sectional and add it to our NavLog. This point also coincides with the 360 radial of the Lake Hughes (LHS) VOR. We will mark that on the NavLog as well in the VOR column.

Check Points (Fixes)	VOR Ident / Freq.	Cours (Route	H	Dist. Leg / Rem.	G Es / Ac
WJF Airport					
Little Buttes Airport (dirt) -right-				4	
TOC / Terrain Ripples -right-				8	

It's best practice to select points 10-15 miles apart. Too close and the NavLog becomes a distraction, and too far the chances for getting lost increase. Looking ahead on our route, the Sectional depicts a plant 10 miles ahead, 5 miles off to the left. Let's verify it will be visible by comparing it to the aerial view. Once confirmed, we will add this to the NavLog as well.

Check Points (Fixes)	VOR Ident / Freq.	Cours (Route	Dist. Leg / Rem.	G Es / Ac
WJF Airport			4	
Little Buttes Airport (dirt) -right-			8	
TOC / Terrain Ripples -right-			14	
Plant -left-				

Up ahead, I-5 passes under our route. Major highways are almost always highly visible. We will add that point to our NavLog.

Check Points (Fixes)	VOR Ident / Freq.	Dist. Leg / Rem.	G Es / Ac
WJF Airport		4	
Little Buttes Airport (dirt) -right-		8	
TOC / Terrain Ripples -right-		10	
Plant -left-		14	
I-5 / Buildings -below-			

We are nearing our destination. We can perform a quick approximation to determine when it is appropriate to begin descending, assuming a vertical speed of 500 feet per minute at ~90 knots ground speed. While we will do our best to maintain that vertical speed, our groundspeed is very likely to change, however, it is sufficient for this portion of flight planning. We must descend from 6500 feet MSL to 1628 feet MSL, or roughly 5000 feet. At 500 FPM, this will take 10 minutes. At 105 knots, or this descent will cover ~18 miles. We will try to find a point 18 miles out to coincide with our TOD.

The sectional depicts a oil tanks just south of the San Joaquin Valley private airport. As these are 19 miles from out destination airport, they are a suitable landmark. Similarly, we will add this to our NavLog.

Check Points (Fixes)	VOR Ident / Freq.	Dist. Leg / Rem.
WJF Airport		4
Little Buttes Airport (dirt) -right-		8
TOC / Terrain Ripples -right-		14
Plant -left-		12
I-5 / Buildings -below-		8
TOD / Oil Tanks -right-		

On a clear California day, our destination airport should begin to come in sight. As we make our descent, we will tune to appropriate weather frequency and start monitoring the tower or CTAF. We will add one more point before our destination to ensure we remain on course throughout the descent. Below our route, there are several oil pumpjacks. Lets add this and our destination to our NavLog.

Check Points (Fixes)	VOR Ident / Freq.	Dist. Leg / Rem.
WJF Airport		4
Little Buttes Airport (dirt) -right-		8
TOC / Terrain Ripples -right-		14
Plant -left-		12
I-5 / Buildings -below-		8
TOD / Oil Tanks -right-		8
Oil Pumpjacks -below-		11
L17 Taft-Kern County Airport		

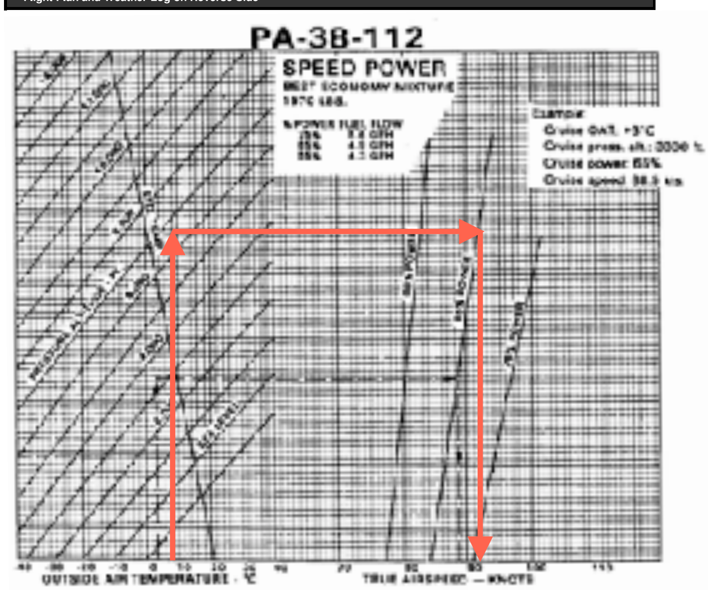
4.4. Performance Calculations

Check Points (Fixes)	VOR Ident / Freq.	Course (Route)	Altitude	Wind Dir.	Wind Vel.	Temp	CAS / TAS	TC	TH (-E / +W Var.)	MH (± Dev.)	CH	Dist. Leg	Dist. Rem.	GS Est. / Act.	ETE / ATE	ETA / ATA	GPH Fuel / Rem.
WJF													65				
Little Buttes			CLIMB	34	24	8		281				4	61				
TOC / Terrain			CLIMB	34	24	8		281				8	53				
Plant			6500	36	26	5		281				14	39				
I-5 / Buildings			6500	36	26	5		281				12	27				
TOD / Oil Tanks			6500	36	26	5		281				8	19				
Oil Pumpjacks			DES	35	15	9		281				8	11				
L17			DES	35	15	9		281				11	11				
Totals »												65					

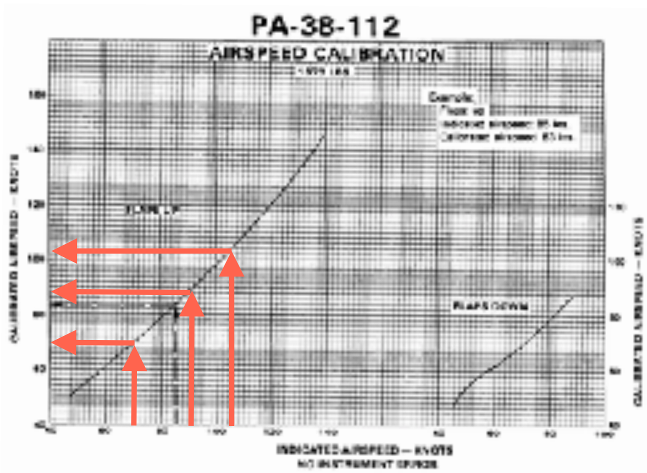
Flight Plan and Weather Log on Reverse Side

Now it is time to calculate all of our performance figures. We can first fill out the rest of the NavLog with all attained during our incipient planning, such as course, altitude, winds aloft, and distances. Some check point names have been shortened to fit.Arguably most important to the flight planning is the performance characteristics we desire: do we want to get to our destination the fastest or with the lowest fuel burn? Said another way, do we wish to increase our airspeed at the expense of added fuel, or decrease the full required at the expense of a slower airspeed? Piper publishes performance charts for pilot's discretion.

For this flight, time is a non-concern, so the economic benefits of a decreased fuel burn outweigh the time savings of a fuel-intensive trip. Entering the Speed Power graph for the PA-38 at our cruise altitude, 6500 feet MSL. A sufficient compromise between speed and fuel burn is at 65% power, so that is what we will select. This chart outputs a true airspeed, which can right into the TAS column in out NavLog.



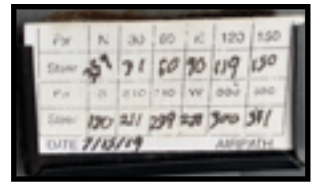
All climbs, especially in high DA days, are performed at Vy. Power available just suffices the climb, and any decrease in pitch yields a wholly inadequate vertical speed. Descents are equally simple, at ~2000 RPM and ~105 knots indicated. Before we add these speeds to our NavLog, we need to convert the 70 KIAS climb and 105 KIAS descent speeds to KTAS. First entering the Airspeed Calibration plot to obtain KCAS, and then calculating KTAS using an E6B, as it of course is dependent on nonstandard temperature and pressure. Pictured below is both an analog and electronic E6B for the 70 KIAS case. The process follows for the 105 KIAS case as well. Lets add this to our NavLog.



E6-B Airspeed	
TAS	77.21
OAT	8 °C
MACH	0.118
TAT	9 °C
CAS	70.00 KTS
PAlt	4500 FT

Check Points (Fixes)	VOR Ident / Freq.	Course (Route)	Altitude	Wind Dir. / Temp	Wind Vel.	CAS / TAS	TC	TH	MH	CH	Dist. Leg / Rem.	GS Est. / Act.	Time Off ETE / ATE	ETA / ATA	GPH Fuel / Rem.
							-L / +R WCA	-E / +W Var.	± Dev.		65				
WJF															
			CLIMB	34 / 8	24	77	281				4 / 61				
Little Buttes															
			CLIMB	34 / 8	24	77	281				8 / 53				
TOC / Terrain															
			6500	36 / 5	26	91	281				14 / 39				
Plant															
			6500	36 / 5	26	91	281				12 / 27				
I-5 / Buildings															
			6500	36 / 5	26	91	281				8 / 19				
TOD / Oil Tanks															
			DES	35 / 9	15	103	281				8 / 11				
Oil Pumpjacks															
			DES	35 / 9	15	103	281				11 / 11				
L17															
Totals »											65				

Flight Plan and Weather Log on Reverse Side



The rest of the NavLog is straightforward. We can calculate wind correction angles for the final course, and groundspeed using those wind correction angles. Lets add these values, along with the variation and deviation, to our NavLog.

Once we have groundspeed, we can continue by adding ETE and fuel burn. Once complete, our navlog will look something like this:

Check Points (Fixes)	VOR Ident / Freq.	Course (Route)	Altitude	Wind Dir.	Wind Vel.	CAS	TC	TH	MH	CH	Dist. Leg	GS Est.	Time Off / ETE	ETA	GPH / Fuel
				Temp		TAS	-L / +R WCA	-E / +W Var.	± Dev.		Rem.	Act.	ATE	ATA	Rem.
											65				4.9
WJF															
		282	CLIMB	34	24	77	281	296	284	282	4	62			
				8			+15	−12	−2		61				
Little Buttes															
		282	CLIMB	34	24	77	281	296	284	282	8	62	11		1.3
				8			+15	−12	−2		53				28.7
TOC / Terrain															
		283	6500	36	26	91	281	297	285	283	14	82	10		0.8
				5			+16	−12	−2		39				27.9
Plant															
		283	6500	36	26	91	281	297	285	283	12	82	9		0.7
				5			+16	−12	−2		27				27.2
I-5 / Buildings															
		283	6500	36	26	91	281	297	285	283	8	82	6		0.5
				5			+16	−12	−2		19				26.7
TOD / Oil Tanks															
		274	DES	35	15	110	281	288	276	274	8	104			
				9			+07	−12	−2		11				
Oil Pumpjacks															
		274	DES	35	15	110	281	288	276	274	11	104	9		0.5
				9			+07	−12	−2		11				26.2
L17															
										Totals »	65		45		3.8

Flight Plan and Weather Log on Reverse Side

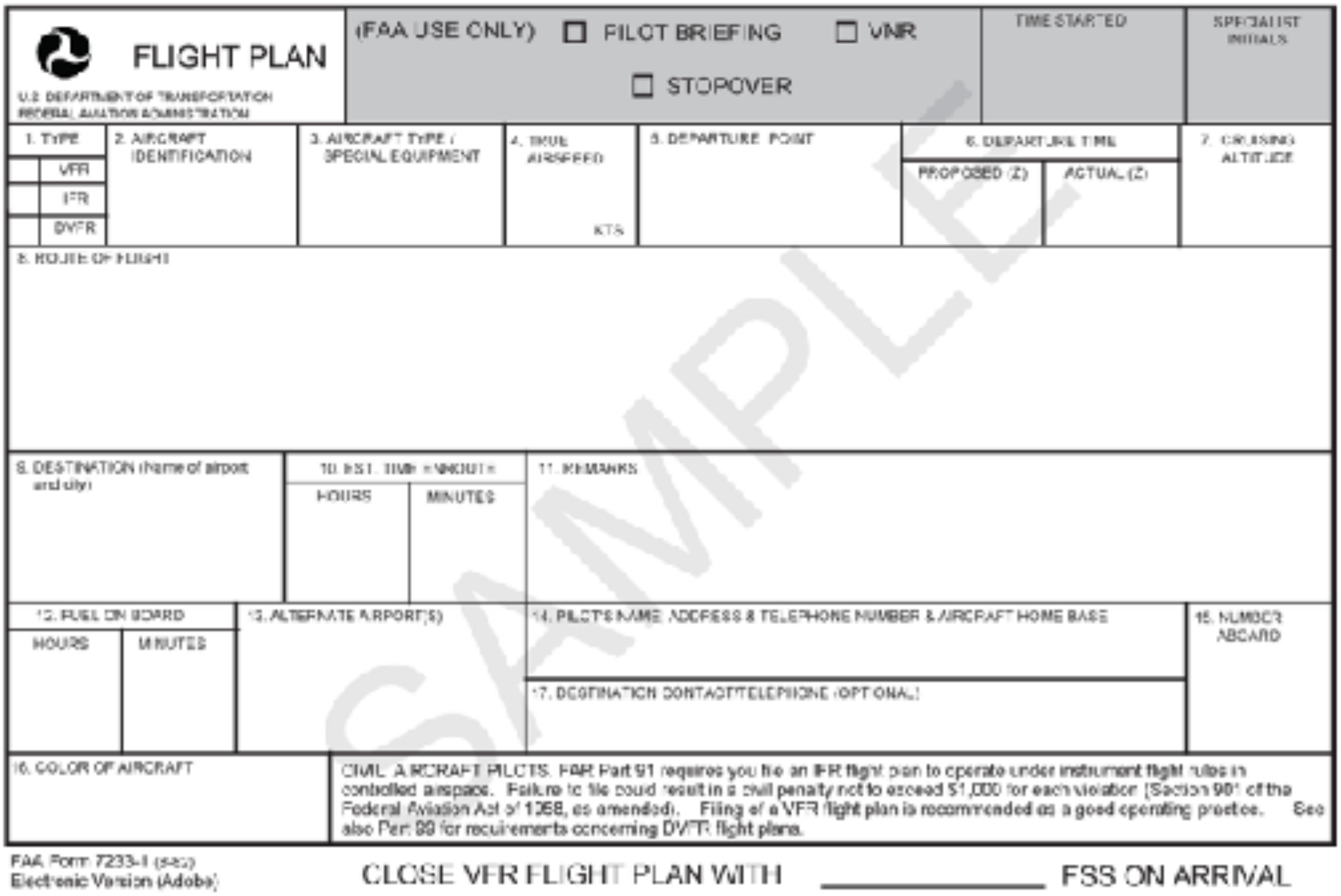
5. VFR FLIGHT PLAN

5.1. Procedures for Filing, Activating, and Closing a VFR Flight Plan

In times where radar coverage was scattered and airspace volume was minimal, flight plans were an effective way of tracking pilot whereabouts. Nowadays, with more reliable communication coverage and the advent of more advanced ELTs, VFR flight following and ELTs/PLBs afford the same level of search and rescue assurance.

- ForeFlight (can activate and close in app)
- 1800wxbrief (can activate and close via phone)
- FSS in air (can activate and close with FSS)

5.2. Elements of the Flight Plan


FLIGHT PLAN
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
(FAA USE ONLY) ☐ PILOT BRIEFING ☐ VNR ☐ STOPOVER
TIME STARTED
SPECIALIST INITIALS
1. TYPE: VFR, IFR, DVFR
2. AIRCRAFT IDENTIFICATION
3. AIRCRAFT TYPE / SPECIAL EQUIPMENT
4. TRUE AIRSPEED KTS
5. DEPARTURE POINT
6. DEPARTURE TIME: PROPOSED (Z), ACTUAL (Z)
7. CRUISING ALTITUDE
8. ROUTE OF FLIGHT
9. DESTINATION (Name of airport and city)
10. EST. TIME ENROUTE: HOURS, MINUTES
11. REMARKS
12. FUEL ON BOARD: HOURS, MINUTES
13. ALTERNATE AIRPORT(S)
14. PILOT'S NAME, ADDRESS & TELEPHONE NUMBER & AIRCRAFT HOME BASE
15. NUMBER ABOARD
17. DESTINATION CONTACT/TELEPHONE (OPTIONAL)
16. COLOR OF AIRCRAFT
CIVIL AIRCRAFT PILOTS. FAR Part 91 requires you file an IFR flight plan to operate under instrument flight rules in controlled airspace. Failure to file could result in a civil penalty not to exceed $1,000 for each violation (Section 901 of the Federal Aviation Act of 1958, as amended). Filing of a VFR flight plan is recommended as a good operating practice. See also Part 99 for requirements concerning DVFR flight plans.
FAA Form 7233-1 (8-82)
Electronic Version (Adobe)
CLOSE VFR FLIGHT PLAN WITH ______________ FSS ON ARRIVAL
SAMPLE

6. RISK MITIGATION TOOLS

See Lesson Plan II.A Human Factors for the following topics:

- ADM
- PAVE
- FRAT

7. REQUIRED PREFLIGHT ACTION AND APPLICABLE REGULATIONS

Certain pilot actions during preflight planning are mandated in 91.103.

Fuel reserves are "enough fuel to fly to the first point of intended landing and, assuming normal cruising speed—during the day, to fly after that for at least 30 minutes; or at night, to fly after that for at least 45 minutes" per 91.151.

NWKRAFT

N	NOTAMs	Departure, enroute, and arrival NOTAMs, found here
W	Weather	Departure, enroute, and arrival weather.
K	Known ATC Delays	Found on FAA website here
R	Runway Lengths	Found on Chart Supplement or ForeFlight
A	Alternatives	Other options for completing flight
F	Fuel	Fuel requirements and reserves considering 91.151
T	Takeoff and landing distances	From POH performance charts

7.1. Fuel Planning

The requirements specified in 91.151 should be considered a bare minimum. We can mitigate fuel exhaustion risks with the following techniques:

- Do not run a tank dry, as it may be possible for the other tank/lines to malfunction. Also asymmetric balance concerns
- Monitor fuel burn during flight and compare to planned fuel burn
- When operating at less than half tanks, begin strongly keeping track of landing points that have fuel available
- Always think about unexpected headwinds, destination airport closures, and possible diversions when considering fuel requirements