Approach Impossible

“Chair Flying” to **minimums** or **not at all**

Pilot Jon Cain “chair flies” an arrival before leaving the ground.

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Much of flying is an “act of faith.” You are placing your trust in those who designed and built the aircraft, in those who maintain it, and in those who trained you to defy gravity for a living. Your act of faith goes even further than you may realize, however.

Who, for example, ensures the instrument approach you are about to fly can be safely flown down to minimums without breaking anything? We assume the approach was designed correctly, tested in real world conditions, and has the seal of approval from the aviation authority of the host nation. In most cases, all of that is true.

A Jeppesen approach plate will often have the term “TERPS” or “PANS-OPS” printed on one side. In the first case, the approach was designed in accordance with the U.S. Standard for Terminal Instrument Procedures (TERPS), an FAA Order (currently numbered 8260.3C) in a constant state of revision. In the second case, the guidance came from the International Civil Aviation Organization (ICAO) Procedures for Air Navigation Services, Aircraft Operations (PANS-OPS), also known as ICAO Document 8168. With the TERPS or PANS-OPS “seal of approval,” you know the approach plate has been vetted. But in either case, can you assume the instrument approach is flyable down to minimums exactly as published?

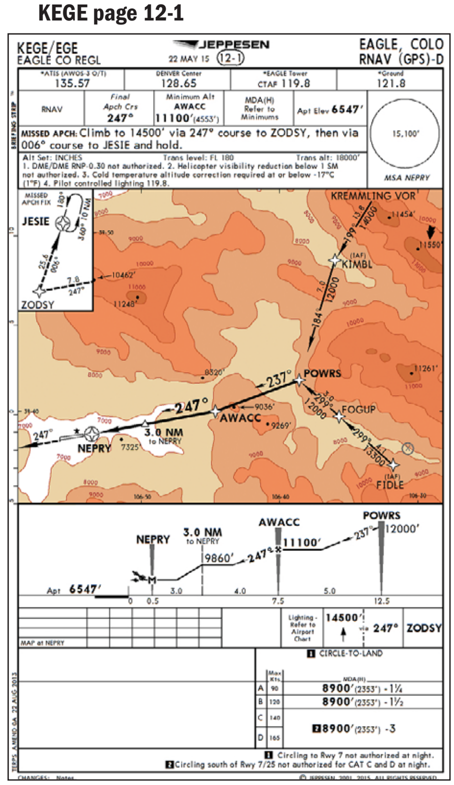
Unfortunately, the answer is no. There are cases when the approach, while legal, is improbable because the terrain makes the required descent angles unsafe. Other approaches, while perfectly safe, are impractical due to airspace design or airport congestion. Finally, some approaches are impossible to fly because of poor design and will guarantee the need to execute a missed approach if attempted down to minimums. You can, however, discover these improbable, impractical and impossible approaches before leaving the ground. And that knowledge can help you come up with a “Plan B.”

The key is to “chair-fly” the approach by visualizing each step of the procedure while considering terrain, country-specific and other local restrictions, and aircraft descent and turning performance. In many cases advanced trigonometry is helpful but not required; a few basic math rules of thumb and a pocket calculator will suffice.

Mountainous Terrain — The Improbable Approach

If you’ve never flown into Eagle County, Colorado, Regional Airport (KEGE) and had only the publicly available instrument approaches available, you might think the published RNAV (GPS)-D

Eagle, Colorado RNAV(GPS)-D, Jeppesen KEGE page 12-1



weather minimums of 2,353 ft. and 3 sm would allow a comfortable and safe arrival with weather just above those figures. But that would be wrong thinking. There are special approach procedures requiring operator approval and specific training for EGE, but the RNAV (GPS)-D can be flown by any RNAV-capable aircraft and instrument rated pilot. Easy, right?

Pilots with at least one approach into this airport know that flying north of the procedure course down a valley in visual conditions is the better choice. They only begin the approach if they can spot the airport from waypoint POWRS at 12,000 ft. MSL, nearly 6,000 ft. above the runway. They have basically doubled the weather minimums. But what if you've never flown into Eagle and don't know anyone who has?

Imagine yourself flying the approach in Instrument Meteorological Conditions (IMC) after successfully making the descent to 9,860 ft., your last step-down altitude prior to the missed approach point. While you began the day with a bit of concern, you breathed a sigh of relief when the ATIS reported the weather was 3,000 ft. and 4 sm. You still have a mile before you can leave the step-down altitude but start to make out what has to be the runway. You spot it! But then it hits you that even though the runway is 4 mi. away, you are still over 3,000 ft. above the landing surface. Too high! Now what? Can you circle? The surrounding Rocky Mountain terrain discourages that thought immediately. You have no choice but to go missed approach and think of a new way to get your passengers to their Vail ski chalet.

Thankfully, Garfield County Regional Airport in Rifle, Colorado (RIL) is just over 30 nm to the west and can fit you in on their crowded ramp. The FBO was out of rental cars and any available hangar space was already taken. As your passengers wait for their ground transportation to catch up, you are forced to revisit the decision-making that brought you to this point.

The Eagle County weather was well above minimums, but landing from the approach in that weather would have required a wildly unstable approach and been unsafe. It appears the Garfield ramp had already been consumed by other crews who knew better than to attempt an approach to Eagle with a 3,000-ft. ceiling and "only" 4 sm visibility. The more seasoned pilots unveil the Eagle County secret. "If I don't see the runway before POWRS," one pilot tells you, "I'm not descending any farther." He goes on to tell you that even on a clear day, flying with the needles centered leaves you too high to land. "You have to fly down the valley to the north, otherwise you aren't landing." Well, now you know better! But how could you have known this without previous experience?

The key to flying an unfamiliar instrument approach correctly the first time is to mentally put yourself on the approach before you have to do it for real. You can do this from your dining room table, hence the seasoned veteran's technique of "chair-flying," but you need to be methodical about it. You

Descent Angle

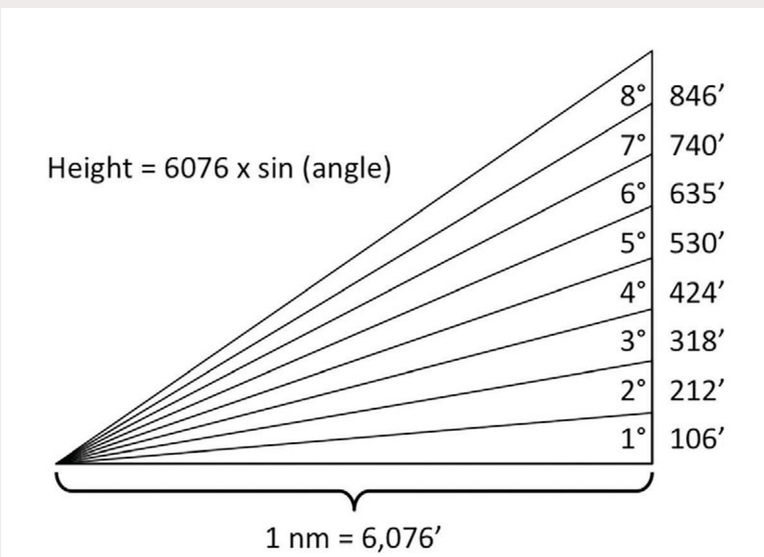
As a rule of thumb, most jets descend easily at a 3-deg. angle but require extraordinary measures at higher angles. You can use a calculator to solve the trigonometry: The height of an airplane 1 nm away from a point is equal to 6,076 ft. times the sine of the angle. For example, a 3-deg. angle leaves an airplane at 318 ft. when 1 nm away. But you don't really want to add a scientific calculator to your flight bag, do you? If you figure the descent angles from 1 to 8 deg. you will notice a strange coincidence: The angle approximates the height loss in hundreds of feet. You can use that coincidence to coin a rule of thumb:

$$\text{Descent Angle} = \frac{\text{Altitude to Lose (Hundreds of Feet)}}{\text{Distance to go (nm)}}$$

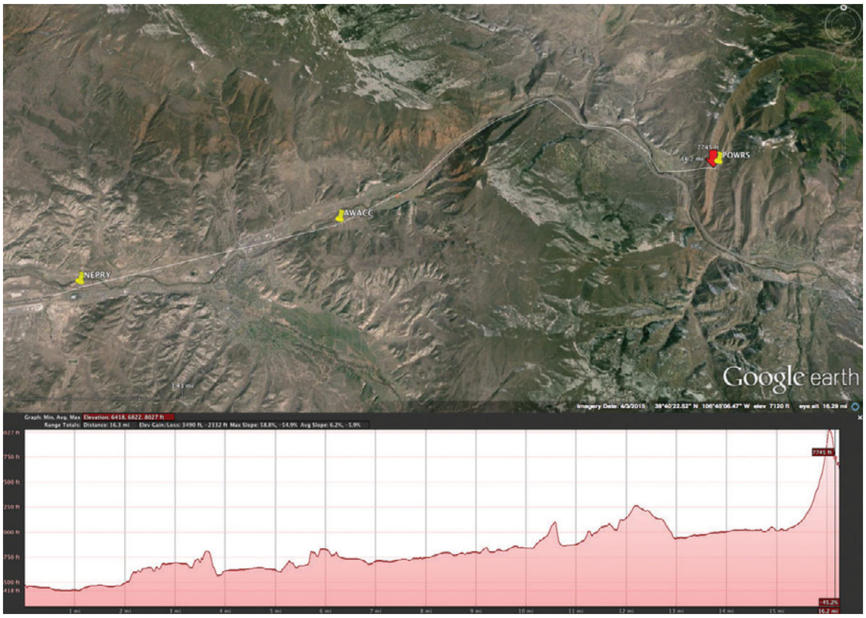
And:

A normal 3-deg. descent requires 318 ft. of altitude for every 1 nm traveled.

So, let's say you are at 10,000 ft. and need to descend to an airport with a 1,000-ft. elevation, which means you are losing 90 hundreds of feet. If you had 30 mi. to do that you are in great shape, with a textbook perfect 90 ÷ 30 = 3-deg. descent. But what if ATC delayed you until 15 mi.? Now you are looking at a 90 ÷ 15 = 6-deg. descent. You are in "slam dunk" territory!



Typical heights versus vertical path angles



Terrain elevation along the valley north of the KEGE RNAV(GPS)-D approach, from Google-earth

need to think about the airplane's ability to descend and turn along each segment of the approach.

Looking back at our RNAV (GPS)-D approach into Eagle County we understand immediately that the terrain imposes descent restrictions until at least the 9,860-ft. step-down altitude located 3.5 mi. from the runway. If the weather was good enough to spot the runway from this distance, what kind of descent rate is needed? We need to descend 9,860 – 6,547 = 3,313 feet, or 33 hundreds of feet. Using our descent rule of thumb, we find that our required descent rate will be 33 ÷ 3.5 = 9 deg. Under TERPS, the maximum glidepath angle for a precision approach is 3.1 deg. for Category D and E aircraft, 3.6 deg. for a Category C aircraft and 4.2 deg. for a Category B aircraft. While those numbers don't restrict how you fly this non-precision approach, they offer you a good idea of what can be done safely. The 9-deg. descent angle is simply too steep.

Our chair-flying exercise reveals that flying this approach with the needles centered leaves you too high to make a stable approach to landing from instrument minimums. The terrain depiction on the instrument chart reveals a valley to the north of the approach course that would allow you to descend earlier and provides the added benefit of lengthening your flight path to give you more distance to descend. But will it be enough?

The first time I flew into Eagle, I took a paper terrain map and plotted a hypothetical ground track to determine the distance flown. These days there are free internet applications that can automate the process. Using a terrain mapping application such as Google Earth shows the valley route from waypoint POWRS to the runway is 16 nm long. Beginning our descent from POWRS means we have to lose 12,000 – 6,547 = 5,453 ft., just over 54 hundreds of feet. That reduces the required descent gradient to 54 ÷ 16 = 3.4 deg.

The terrain at many airports in mountainous areas makes landing from instrument approaches improbable because the required descent rates are too high while remaining precisely on course. Other approaches can be impractical because of national rules, air traffic density or other unusual circumstances.

Unusual Circumstances — The Impractical Approach

ICAO course reversal entry procedures are different than U.S. procedure turn entry rules and the difference can get you in trouble. The international procedures do a better job of ensuring you begin the approach on course but often require extra maneuvering prior to starting the approach.

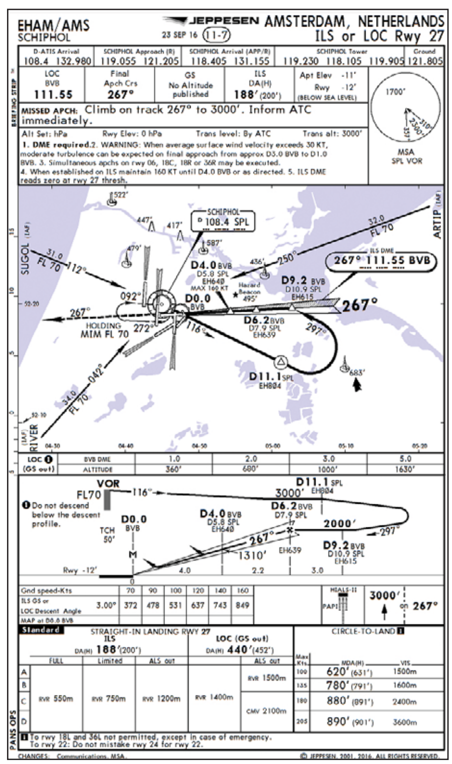
Some airports can compound this confusion with local procedures needed to deal with high-density traffic. These local procedures are rarely published where a visiting international pilot can be forewarned.

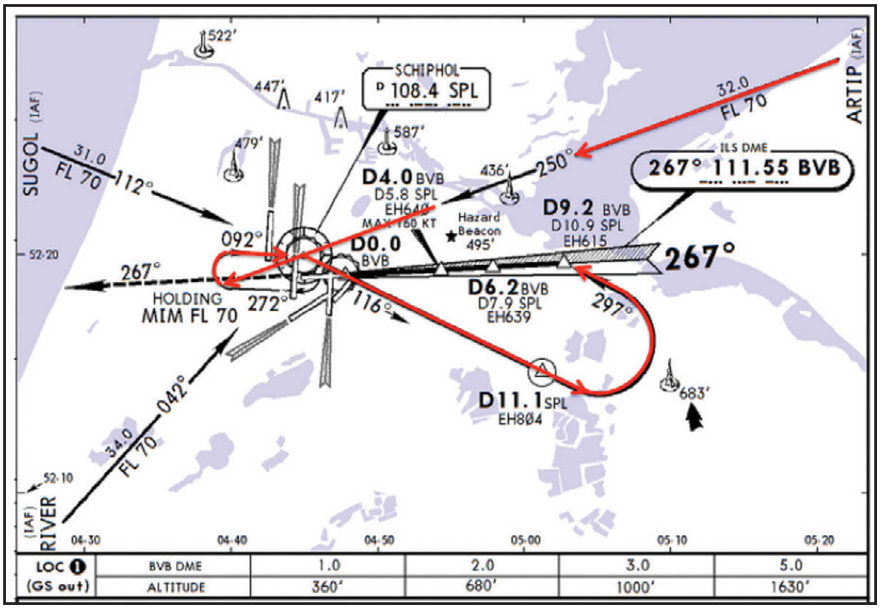
The ILS or LOC Rwy 27 to Schiphol Airport (EHAM) in Amsterdam provides a classic example. Under PANS-OPS this type of course reversal is known as a base turn and must be begun from a specific entry sector. The entry sector is generally within 30 deg. of the outbound course. If outside the entry sector, the holding pattern must be used to get within that sector before starting the approach.

Our Schiphol example approach has two initial approach fixes for aircraft arriving from the west and one from the east. Only pilots entering from SUGOL are permitted to immediately begin the outbound segment of the approach. Pilots arriving from ARTIP and RIVER are expected to execute a turn in holding at the Schiphol VOR.

About a year ago I was arriving from the west and got the clearance, "cleared ARTIP ILS Runway 27." Under U.S. procedures I could fly from ARTIP to SPL and then turn left to intercept the 116-deg. outbound radial. This would have earned me a violation

Schiphol ILS or Loc Rwy 27, Jeppesen EHAM page 11-7





LOC (GS out)	BVB DME	1.0	2.0	3.0	5.0
	ALTITUDE	360'	680'	1000'	1630'

Schiphol ILS or Loc Rwy 27 "Double" course reversal

under ICAO rules.

Because we chair-flew the arrivals into Schiphol as a crew, we were fully prepared to deal with having to reverse course twice. This "double" course reversal hardly makes sense for one of the world's busiest airports, but these are the rules as published under ICAO PANS-OPS. If we had lost communications or air traffic control had lost radar, we would expect to fly the arrival precisely this way. But we knew it couldn't end up this way since Schiphol is far too busy. Our chair-flying exercise included other options to arrive at each runway. There was also a VOR approach to Runway 27, though it is hardly anyone's first choice of a procedure to use in actual instrument conditions.

The Jeppesen airport arrival briefing pages spelled out the lost communications scenario that included the double course reversal. But those pages also noted, "navigation in the initial and intermediate approach segment is primarily based on radar vectors by ATC."

As we neared the airport our first clearance was "cleared ARTIP, ILS Runway 27." We realized our hypothetical double course reversal was really possible but suspected a vector might shorten things considerably, so we began configuring early. Shortly after passing ARTIP we got a new clearance, "Direct Papa Alpha Mike, cleared the ILS Runway 27."

Now we could have had a new problem: Where is Papa Alpha Mike? Fortunately, we had also reviewed the VOR Runway 27 approach, which is flown off of the PAM VOR.

There is no doubt the ICAO double course reversal can be impractical at times, but it also serves to remind us that many U.S. procedures are exceptions to ICAO PANS-OPS. We need to know the rules of the host country and keep a level of situational awareness to make an impractical approach usable.

Sometimes an approach can seem straightforward and quite practical, but a simple design error will make landing at the published minimums impossible.

Poor Design — The Impossible Approach

Approaches with specific tracks to fly can seem deceptively easy: You just need to follow the heavy black line. But these approaches can be built for the approach designer's convenience, not the pilot's. Chair-flying these approaches ahead of time can reveal minimums that are set too low.

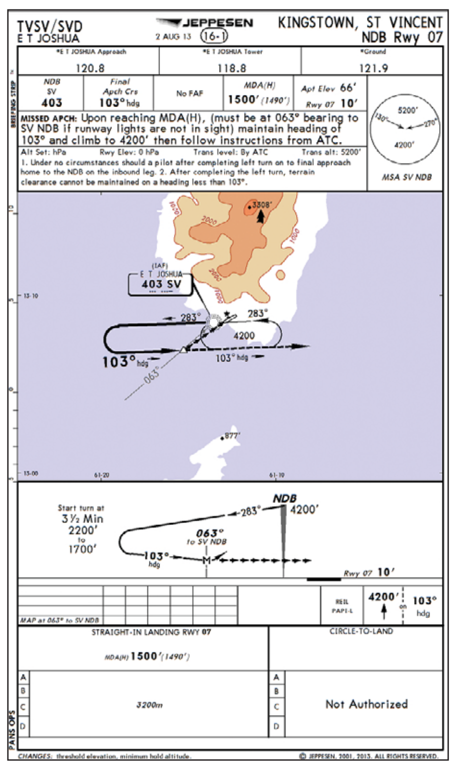
The NDB Runway 07 into E. T. Joshua Airport, Kingstown, St. Vincent (TVSV) looks straightforward at first glance. You pick up a 283 deg. course for 3.5 min., turn left, and then turn left again when on runway centerline. The MDA is at 1,500 ft. and the minimums are 3,200 meters, about 2 sm (1.73 nm).

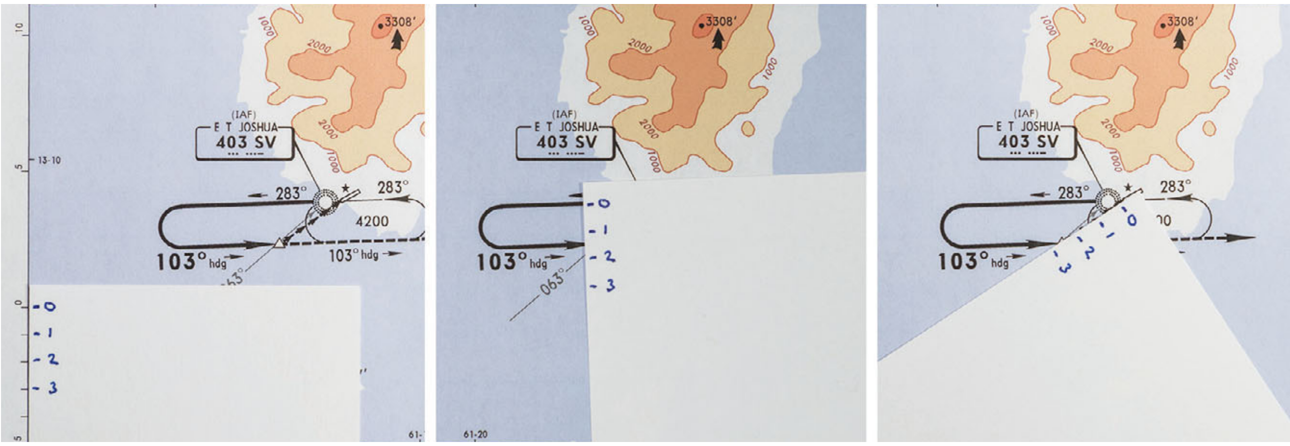
I first flew this approach in a Gulfstream V with a ragged ceiling between 1,500 and 2,000 ft. but good visibility outside the clouds. Our approach speed was just under 120 kt. and we planned on flying the entire procedure fully configured at that speed. We didn't spot the runway until right on an extended centerline and by then we were too high to land. Fortunately, on the second try, the ragged ceiling allowed us to spot the runway earlier and descend comfortably to land. Our postflight critique began with one thought: "Why were we too high on the first try?"

Had we chair-flown the approach ahead of time, we would have realized landing at minimums would have been impossible. The distance needed to descend from the 1,500-ft. MDA to the near sea level runway exceeded the distance available along the 063-deg. extended runway centerline or within the distance of the visibility minimum. But you cannot predict your distance from the runway on that extended centerline without knowing your aircraft's turn radius.

Since we flew the entire procedure

E.T. Joshua NDB Rwy 07, Jeppesen TVSV page 16-1





Measuring course distances with a hand drawn ruler

at 120 kt., we were doing 2 nm per minute. (120 nm per hour divided by 60 min. in an hour.) That gave us a turn radius of 0.6 nm. Doubling that gives us our turn diameter and the answer to the question, how far south of the runway is the 103-deg. course? Answer: 1.3 nm.

But we will be flying the diagonal 063-deg. line, which gives us more distance to descend. But how much more distance? At this point, we have two options on determining the distance: Armed with our turn radius, we can plot our ground track on the approach chart or we can do the same mathematically.

The heavy black line on the approach plate may or may not be an accurate representation of the aircraft's actual ground track, depending on the aircraft's speed and environmental conditions. We can construct our own hand-drawn ruler by transferring the scale on the left of the Jeppesen chart onto the edge of an index card or other straight-edged paper. Using this makeshift ruler, we discover that the heavy black line traces an eastbound course that is about 1.5 nm south of the westbound course. Because we know our turn diameter will be 1.3 nm, we know our aircraft will actually fly inside the depicted track but will be close.

We then measure the distance from the eastbound track to the runway and see we will have less than 2.5 nm, because we will be inside the depicted course.

With a little knowledge about right triangles and a scientific calculator, we can find the distance between our turn to final and the runway more precisely. Instrument approaches are often made up of straight lines and semicircles that can be further broken down to a series of triangles. In the case of our Joshua NDB approach, the distance to descend along the 063-deg. course line is the hypotenuse of a right triangle for which we know the smallest angle because we turn left from 103 to 063 deg., a difference of 40 deg.

Our right triangle lengths decoder tells us the length of the (c) leg is equal to the length of the (a) leg divided by the sine of the angle (A). A calculator makes quick work of this: c = 1.33 ÷ sine (35) = 2.1 nm.

Whether you use the hand-drawn ruler or a scientific calculator, the chair-flying exercise reveals that we have less than 2.5 nm to descend 1,500 ft. Our earlier rule of thumb tells us that this will require a 15 ÷ 2.5 = 6-deg. descent rate. No wonder we were too high to land!

So the next question would be how much distance do you need to make that descent? Remembering that a 3-deg. glidepath takes 318 ft. per nm, our answer is 1,500 ÷ 318 = 4.7 nm. In terms of visibility, that equates to 5.4 sm.

Now we know the approach minimum of 3,200 meters (2 sm) does not provide enough distance to descend in a safe, stabilized manner. We had future trips to St. Vincent and realized we would need Visual Meteorological Conditions (VMC) to safely land.

Low Altitude Turn Radius

An airplane's turn performance at a constant altitude can be derived by combining formulas for centrifugal force, load factor and the trigonometry of a circle. The resulting math is precise, but not cockpit friendly:

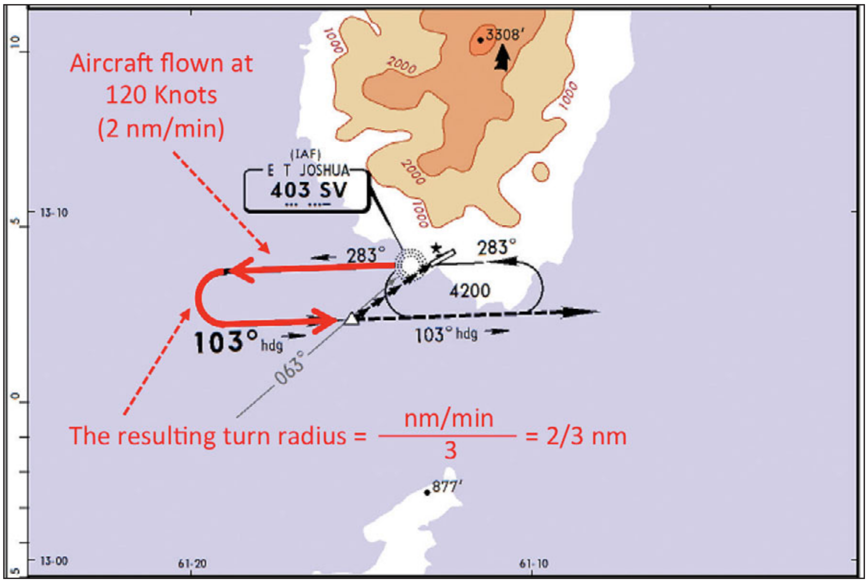
$$\text{Radius of Turn (ft)} = \frac{V^2}{11.26 \tan \Theta}$$

V is the true airspeed (in knots), tan is the trigonometric tangent function, and (the Greek symbol "theta") is the bank angle (in degrees).

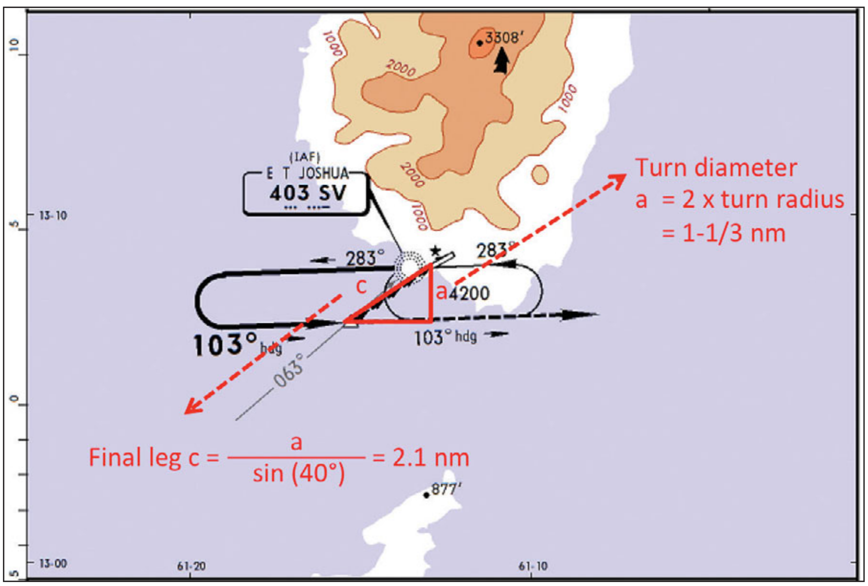
By converting knots to nautical miles per minute and assuming a 25-deg. angle of bank turn, we can greatly simplify the formula:

$$\text{Radius of Turn (nm)} = \frac{\text{(nm/min)}}{3}$$

This has an acceptable accuracy up to 170 kt.



Determining turn radius

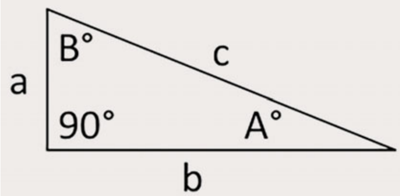


Approach geometry

An Instrument Approach Chair-Flown at 0 Kt.

If an instrument approach looks unusual at first glance, it will be worth a second or third examination. But analyzing an unusual instrument approach just minutes prior to beginning your descent doesn't leave you a lot of time to consider if the approach is improbable, impractical or perhaps impossible. Chair-flying the approach before you leave the ground gives you the time to come up with other options, including not going in the first place.

The only real math skill needed is knowing how much airspace your airplane needs to turn. With a few rules of thumb, an approach plate drawn to scale and a sharp pencil, you can accurately predict your flight path and find out if you are looking at an impossible approach before you are committed to flying it. **BCA**



Typical right triangle

Right Triangle Length Decoder

When dealing with right triangles, you only need to know the length of two sides or the length of one side and one of the smaller angles to determine the length of the remaining side or sides. The sides are typically labeled with lower case letters: a, b and c. The opposite angles are given the same letters in upper case: A, B and C.

For example, if you know the length (c) and the angle (A), you can find the length (a) with a scientific calculator by entering (A), pressing the sine key (typically labeled "sin") and multiplying that by the lengh (c).

a = (c) sin(A)
a = (c) cos(B)
a = (b) tan(A)
a = b / tan(B)
a = c / sec(B)
a = c / csc(A)
b = (c) sin(B)
b = (c) cos(A)
b = a / tan(A)
b = (a) tan(B)
b = c / sec(A)
b = c / csc(B)
c = a / sin(A)
c = b / sin(B)
c = b / cos(A)
c = a / cos(B)
c = (b) sec(A)
c = (a) sec(B)
c = (a) csc(A)
c = (b) csc(B)