John Bell's VNAV Whiz Wheel

Disclaimer and Introduction

I am just an ordinary line captain. The VNAV Whiz Wheel was developed for my own use to make descent planning easier on non-VNAV aircraft such as the 737-200 or 727. Part of the reason for the development was that my airline adopted the concept of making non-precision approaches using a procedure called CANPA, for Constant Angle Non-precision Approach. This document is basically a de-identified version of the document that I developed for my airline. Since this was developed on my own time, the copyright is mine. It works well in a jet environment. I am not sure how applicable it is to a general aviation environment. Use at your own risk.

Overview

Mental arithmetic has never been one of my better skills. Perhaps this is part of the reason that I have a propensity to carry computational gadgets such as Palm Pilots, or perhaps my gadgets are part of the cause. At any rate, I figured that there must be a better way of calculating descents and CANPA approaches.

What I have come up with is a small circular calculator for calculating 3 nautical miles per 1000 feet of altitude, 3 to 1, descents. A restriction point consisting of an altitude at a DME is set and corresponding DME's and altitudes can be read that are along a 3 to 1 profile passing through this restriction point. This 3 to 1 profile is a 3.14 degree slope.

You might first cringe to think something that appears to be like an E6-B could make life easier. I think that after you work a couple of examples that you will find calculating descents with the Whiz Wheel is simpler and more accurate than 3 to 1 in your head. After flying a rotation or two with it, I think that you might even find it quick and easy.

I honestly can't remember the last time that I actually had to shoot a real non-precision approach on the line. However, crossing restrictions on a normal descent is routine. I have found that the Whiz Wheel works very well and very easily for normal every day descents. I devote most of the explanations to CANPA examples, which makes the functioning of the Whiz Wheel appear to be more complicated and less useful than it actually is in day-to-day use.

Making the Whiz Wheel

You will find the Whiz Wheel printed on the last page of this document. Ideally, print the calculator on card stock and add a pivot at the center. For the pivot, I used a small eyelet from a local fabric store. The price for a package, which included the tool to flatten the end was about $3.00.

As you will see from the examples, the two disks need to be adjusted once per descent restriction. Thus, the ability for the inner disk to spin freely is not important. Before you read the rest of this, cut out the two disks and use paper clips to hold them together to follow the examples.

Basic Operation

The operation is very basic. One restriction consisting of an altitude and DME can be set and then corresponding altitudes and DME of a 3 to 1 line through this point can be read. For cruise descents, the altitude in thousands of feet is set over the DME. For approaches, the altitude in hundreds of feet is set over the DME in tenths.

Just like an FMS, distances before you reach the station are negative and distances beyond are positive.

Limitations

- The Whiz Wheel only calculates one angle -- 3.14 degrees or 3 nm. to 1000 feet of descent.
- A corollary of the above is that there can only be one restriction point unless the other point is on the 3 to 1 profile.
- There is no compensation for DME slant range.

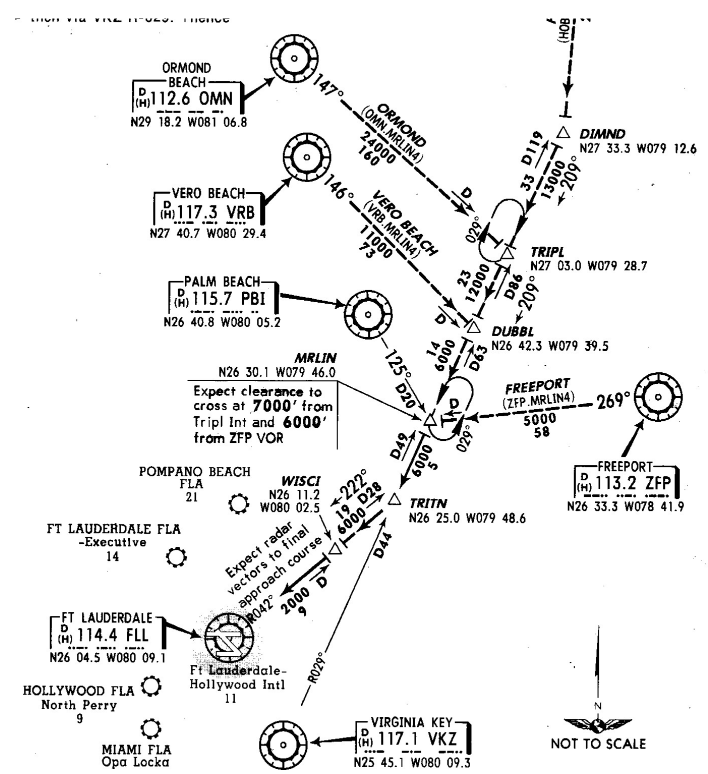
Cruise Descents

Before I start on the examples, let me say that you will probably want to add a "comfort" factor for cruise descents – choose your own. You will also want to add the distance to slow at the restriction. In these examples I do not do either of these. I want to show you how the Whiz Wheel calculates the 3 to 1 without confusing the examples with these factors.

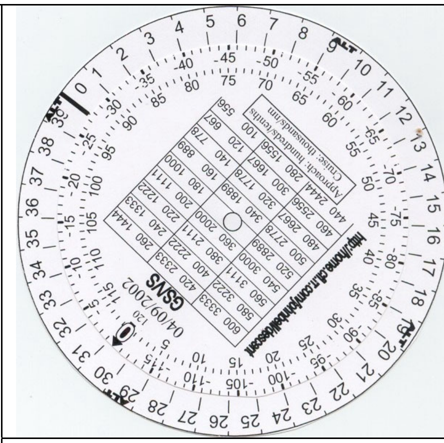
The standard descent profile is to start a 1000 fpm descent 15 miles early until intercepting the 3 to 1 profile. The Whiz Wheel will let you know where this 3 to 1 profile is.

I also have the descent rates for a given ground speed for a 3 to 1 descent in the middle of the Whiz Wheel. You will have to adjust the rates of descent as the TAS and winds change during a cruise descent. During the constant mach phase, the TAS will increase. During the constant indicated airspeed phase, the TAS will decrease. One thing we do have on the 737-200 is the ability to get a ground speed out of the PDC.

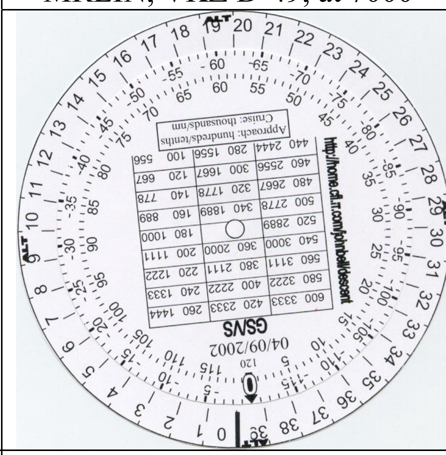
Example: FLL MRLIN FOUR Arrival, 10-2B, 24 Jan 97



FLL MRLIN 4, 10-2B, 24 Jan 97



MRLIN, VKZ D-49, at 7000'

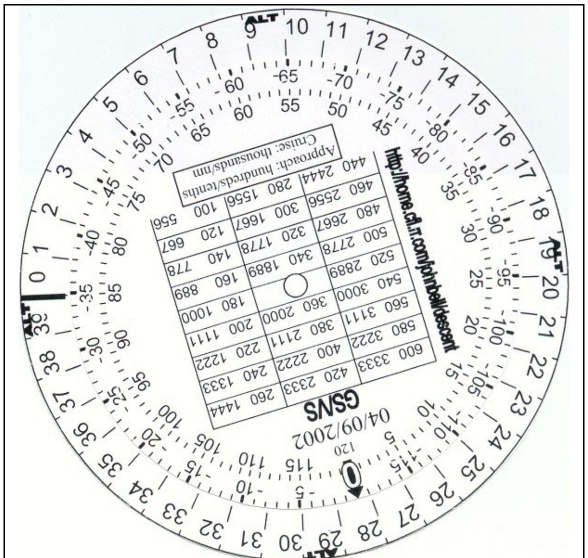


TRIPL, OMN D160, at 19,300'

This is an example of a cruise descent as opposed to an approach. The altitude in thousands is set over the DME. In this case, the restriction is MRLIN at 7000'. Thus, 7 is set above –49. All of the altitudes should now line up on a 3 to 1 line.

To add a little twist, let's use the OMN transition. Using the MRLIN restriction, this would mean that TRIPLE should be a little over 19,000' – we'll say 19,300,' which is probably more precision than is justified. For the OMN leg, D160 at 19,300' becomes the restriction. The catch is that the Whiz Wheel only goes to 120 nm. Since the relationship between the mileage and altitude is linear, we can simply subtract 100 from the DME and all other DME's for this restriction. Thus, 19.3 is set over positive 60. Even thought +60 is the same as –60, the point is that this distance is beyond the VOR so it is positive. Now all of the distances (minus 100 nm.) and altitudes for the OMN transition line up. The 3 to 1 line would intersect 33,000 feet at 119 nm., 30,000' at 128 nm., etc. Once you are on the VKZ leg, just reset the restriction to MRLIN.

DME more than 120



D –65 at 10,000’

In the OMN transition of the MRLIN example, since all of the distances involved where over the Whiz Wheel’s maximum of 120 nm, it is simpler to just subtract 100 and use all of the distances as the distance minus 100. The above picture is a little different scenario. The restriction is cross 65 before at 10,000.’ If you are at 30,000’ this is just 5 nm. beyond the 120 maximum, -125. Likewise, 33,000’ is –134 and 35,000 is -140.

Approaches

CANPA

I have to admit that I was an early skeptic and late convert to CANPA approaches. I like the concept when the aircraft has a FMS with VNAV. However, without some way of correlating the aircraft’s position with the desired altitude, CANPA is nothing more than VPDR, vertical profile dead reckoning. The Whiz Wheel is very good at correlating a DME with the desired altitude. If there is no usable DME, the non-precision approach is vertical profile dead reckoning with either dive and drive or CANPA.

My preliminary objection to CANPA was that the VDP at an MDA provides a gate that the aircraft passes through to set up the final glide. In a CANPA approach, this gate becomes just a reference point. If the runway has a VASI, losing this gate is no big deal. If the approach is a timed approach, this VDP is just a dead reckoning point and using CANPA has lost nothing. My objection to CANPA was that this gate might be your best tool for setting up a good final glide under circumstances of flying a non-precision approach with DME to a runway without a VASI with poor visual cues.

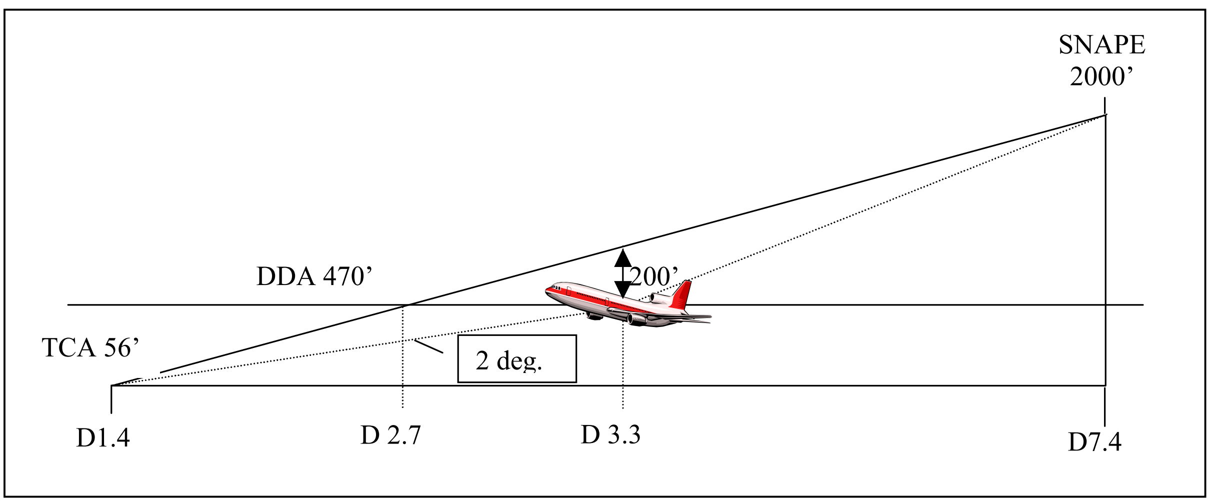
As an example, I will use the FLL ILS 27R (11-4 15 Feb 02) with the glide slope out to illustrate how easy it would be to get low on the CANPA approach.

From SNAPE to the cross the threshold at the TCA is a 3.05 degree descent. If the aircraft is on the glide slope it should reach the DDA at D2.7[1].

It is very conceivable that with approximately two minutes of descent time from the altitude at SNAPE to the DDH that the aircraft could end up 200 feet low on the profile. If the plane were 200 ft. below profile, it would intercept the DDH at a D3.3[2]. From this point to the runway would be a descent angle of 2 degrees[3]. Considering that 1 dot low on the glide slope is ¼ degree, 1 full degree low would be 4 dots low. Considering that the ILS only indicates 2 dots low, this is really dragging it in.

I think that it would be very easy for the pilot to see the runway at this point below the profile and continue the approach to the runway. The old dive and drive method would have the pilot level off until reaching the VDP before starting down below the MDA.

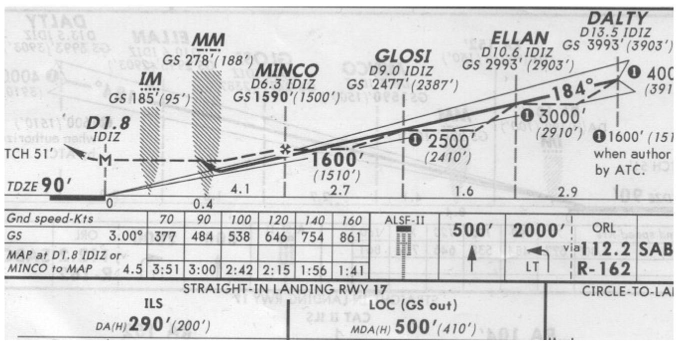
In this case, FLL 27R has a PAPI. The PAPI is a better reference than a VDP anyway, so nothing is loss by shooting the CANPA. However, if the runway did not have a PAPI, the ability to accurately fix this final glide would be a loss.



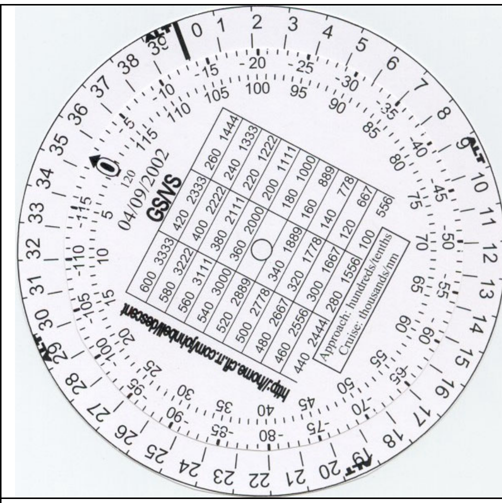
Where the Whiz Wheel is useful on this approach is that it allows you to quickly check the DME against the 3 to 1 profile at several points in the descent and make small adjustments to the vertical speed to stay on the profile

[1] 1.4 nm. + (470 ft.-56 ft.)/tan(3.05)/(6080 ft./nm.)
[2] 2.7 n.m. + 200 ft. / tan(3)/(6080 ft./nm/)
[3] atan((470 ft. – 56 ft.)/((3.3 nm. – 1.4 nm.) *6060 ft./nm.))

Example: MCO, ILS 17, 21-1, 15 Mar 02



MCO ILS 17, 21-1, 15 Mar 02



TCA 141' over D-1.8

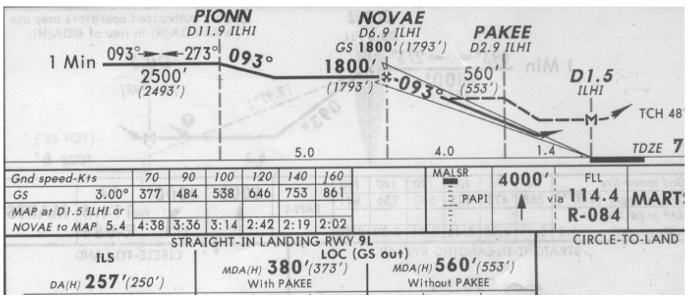
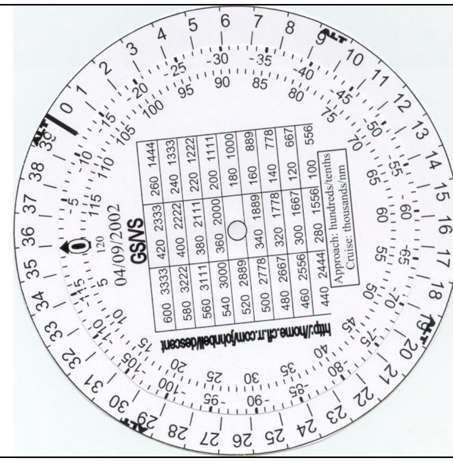
Figure 1

Figure 1 shows the MCO ILS 17 with the glide slope inoperative. The threshold crossing altitude of 141' (TCH of 51' + TCZE of 90') is set on top of the corresponding DME of 1.8. For approaches, the altitudes on the Whiz Wheel are in hundreds and the DME is in tenths. Thus, about 1.4 is placed over –18. The negative value was used because this point is before the DME facility.

You can now look at any altitude and find the corresponding DME for a 3 to 1 glide slope passing through the threshold restriction. Conversely, you can also look at any DME and find the corresponding altitude. For example, the DDA of 550 should be at about 3.0 or 3.1 DME. The Whiz Wheel has MINCO, D6.3, at a little over 1600 feet. The plate has MINCO at 1600 for the glide slope inoperative and 1590 when on the glide slope. This is about right, because 3 to 1 is actually 3.14 degrees – just a bit steeper than a standard 3 degree slope. I always like to check a charted value at the FAF to make sure that I have set the restriction correctly.

What I really like about the Whiz Wheel is that you can easily pick several points along the approach to check the descent. For example, 1000' should be at 4.4 DME.

Example: FLL, ILS 9L, 11-1, 15 Feb 02

	
FLL ILS 9L, 11-1, 15 Feb 02	PAKEE 560’ over D-2.9

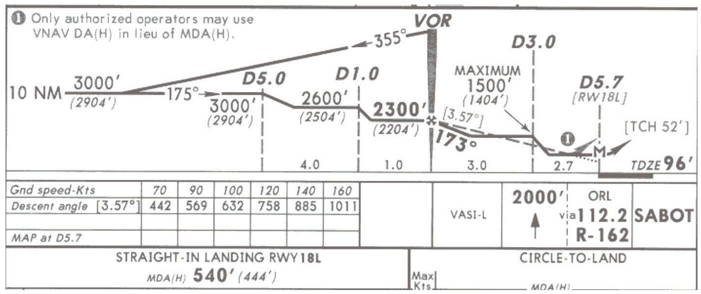
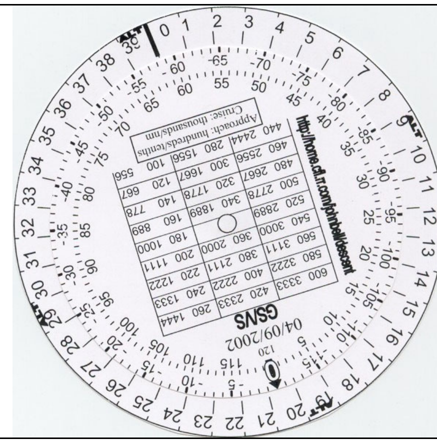
This approach has step down fix. However, this is really not a big deal. You have to cross PAKEE, D2.9, at 560’. Hopefully no approaches with similar restrictions are designed to keep you high with a final steep dive to the runway. Usually these restrictions are designed to be close to being on the glide slope. In fact, in this case, the altitude on the glide slope if it were being used would be 553’.

My solution is just to make this point, PAKEE, the restriction instead of using the threshold. The altitude difference over the threshold from moving the restriction to a relatively close point like this is minimal. Looking above the –15 on the DME scale, which is D1.5, the Whiz Wheel TCA is 100’ instead of the published 55’. As a cross check to make sure that I have set the restriction correctly: NOVAE, D6.9, is a little below 1900.’ You could also check that the altitude at NOVAE of 1800’ feet is at D6.7 on the Whiz Wheel. This is not exact, but corresponds reasonably closely with the chart.

If you were to set the threshold at 55’ TCA and D1.5, the altitude at PAKEE would be 500. This would technically be incorrect, but not dangerously inaccurate.

Lastly, the DDA is 430’ and the DME at this point should be –2.5 calculated with the Whiz Wheel.

Example: MCO VOR 18L, 23-1, 15 Mar 02

	
MCO VOR 18L, 23-1, 15 Mar 02	TCA 148' over D5.7

There are two things that are a little different about this approach: The DME values are beyond the VOR and the angle is steeper than the standard 3 degrees. In fact, at 3.57, the angle is steeper than the Whiz Wheel's 3.14-degree slope.

Note that since the DME values are beyond the VOR, they are positive. Thus, 1.5 on the outer wheel is placed over the positive 57 on the inner wheel for the threshold restriction.

My personal and unofficial advice for an approach with a steeper than standard angle is to consider it to be a WAG with a floor. The Whiz Wheel calculates that the VOR should be crossed at 2075' as opposed to the charted 2300'. You still have to cross the VOR at 2300'. However, you will have to descend just a little steeper. With about 3 minutes to fly from the FAF inbound, this works out to be about 75 fpm greater than normal. In this particular case, the DME will be unusable for at least a mile or two because of the slant range. By the time you get to D3.0, the DME should be reasonable and you can double check the profile. The Whiz Wheel has D3.0 being at 1050', well below the 1500' maximum at this point. The DDA of 590 should be about D4.4.

Approach notes

As you can see, a DME is necessary for using the Whiz Wheel to get profile information. An approach without DME based on timing is a vertical profile dead reckoning maneuver no matter whether you are using dive and drive or CANPA. For some approaches without a published DME, you might still be able to find a useful DME reference with a little ingenuity. To use a non-published DME you must have the following conditions:

1. You must be able to calculate a DME for the runway threshold
2. The DME must be reasonably in line with the approach.

Realistically, if you have a VASI for vertical guidance after you break out, the effort to find a threshold DME may not be worth the effort.

I am not recommending that you get so creative that you make up your own approach. I am recommending that you consider non-obvious sources to cross check your descent with common sense and caution. Remember that this is just a cross check. Reaching the DDA is now the point to miss or continue. If you totally mess up your calculations for using a non-published DME, you should use your sense of reasonableness for a low limit and the procedural 1,000 fpm for the high limit of your descent rate. Your DDA will provide a low limit to the actual profile.

I can't find any restriction that requires both radios be tuned to the same facility for a non-precision approach. In fact, NDB approaches are approved with only one ADF and some approaches require that the second radio be cross-tuned to identify intersections by cross radials. Thus, I can see no problem with having the second radio tuned to a different facility for the DME. However, this is personal opinion rather than Delta policy or procedure.

If you are flying a 3 to 1 profile based on a DME that is not aligned with the runway, the descent will be shallower than 3 to 1. Taking this problem to the absurd limit for illustration: Think of a DME that is directly 90 degrees to the side of the approach. As you progress along the approach, the DME will not change at this 90 degree point because you are traveling tangent to the DME arc. Thus, descending 333 feet for every mile of DME change will result in level flight because the DME is not changing.

There is no hard limit to what constitutes sufficiently aligned with the runway, but I would consider a 25-degree offset to be a good limit. This 25-degree offset results in a 2.84-degree approach. If you want to run the numbers: actual descent angle for flying a 3 to 1 profile in reference to the DME = asin (.05482 * cos(DME offset angle)).

A little resourcefulness is required to find the DME of the threshold if it is not published. You might look for a VOR approach to the same runway. For example, the EWR VOR 22L will give the TEB DME for 22L. This would be useful for shooting the ILS 22L if both the glide slope and DME are inop. You might also be able to find the DME of a FIX published. ISP ILS 6 is such a case. The distance from CCC to the final approach fix, LOKKS, is published and the DME at the runway threshold can be back calculated.

IND is an example where the VHP DME would be worthless for all but the approaches to 32.

Conclusion

I think that if you play with the Whiz Wheel enough, you will find it easier and more accurate than mental arithmetic in your head. Find some paper clips and cut out the Whiz Wheel on the next page and work a couple of descents.

John Bell's Whiz Wheel VNAV calculator

Cut out both wheels and pivot at the center. I found an eyelet kit at a fabric store for the pivot for about $2. This will calculate a 3 to 1 descent. Place the altitude restriction on the outer wheel over the distance on the inner wheel. For cruise descents use thousands over DME, for approaches use hundreds over tenths. Negative values are before the station and positive values are beyond the station.
Your feedback is appreciated.

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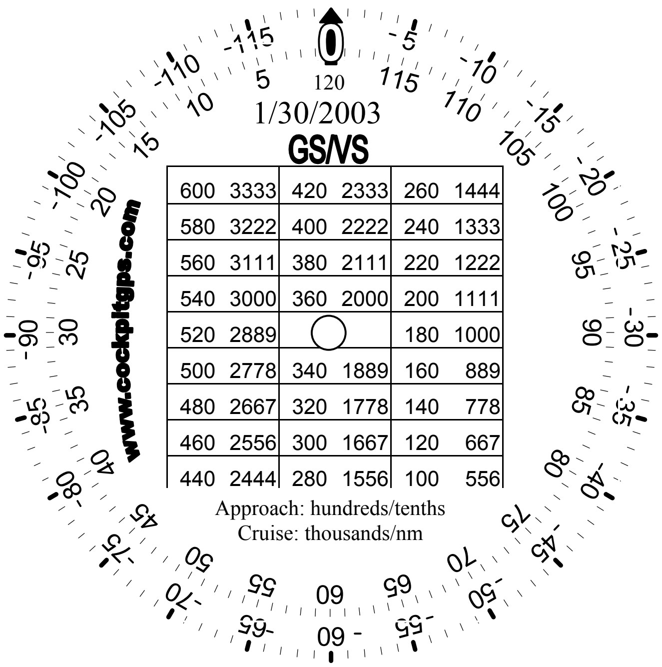

600	3333	420	2333	260	1444
580	3222	400	2222	240	1333
560	3111	380	2111	220	1222
540	3000	360	2000	200	1111
520	2889			180	1000
500	2778	340	1889	160	889
480	2667	320	1778	140	778
460	2556	300	1667	120	667
440	2444	280	1556	100	556