This is a tutorial-by-example of using the AirCelNav training software.

Note that the software is work in progress, and has a few rough edges. This tutorial assumes that you know how to do celestial precomputation, and know how to work the Polhemus computer.

For this tutorial, let's do a flight from Dakar to Santa Maria in the Azores, or GOOY – LPAZ. This is a distance of 1392 nm along a great circle route, in a small aircraft cruising at a True Air Speed (TAS) of 120 kts. Flight time is just short of 12 hours, disregarding any winds.

Santa Maria is a small island. So it makes sense to arrive in local daylight, and to be able to make a sun landfall with the Sun in the south behind us. Santa Mario is at UTC time. So, aiming for a 1300 UTC arrival, we should depart around 0100 UTC.

As a date, we'll randomly choose April 6th, 2016.

Dakar is at approx. N15 W17 (N14°44.63' / W17°28.77')

Santa Maria is at approx. N37 W25 (N36°58.43' / W25°10.27')

For our celestial navigation we will use the Polhemus computer, and in this case we need the discs for 15°Latitude, 25°Latitude and 35°Latitude because the distance is too great to fit onto one disc. This means we need some in-between waypoints to be able to plot on the discs. For this we use an equal spacing, so that intermediate waypoints are 20N19W, 26N21W and 32N23W. The route is shown below.
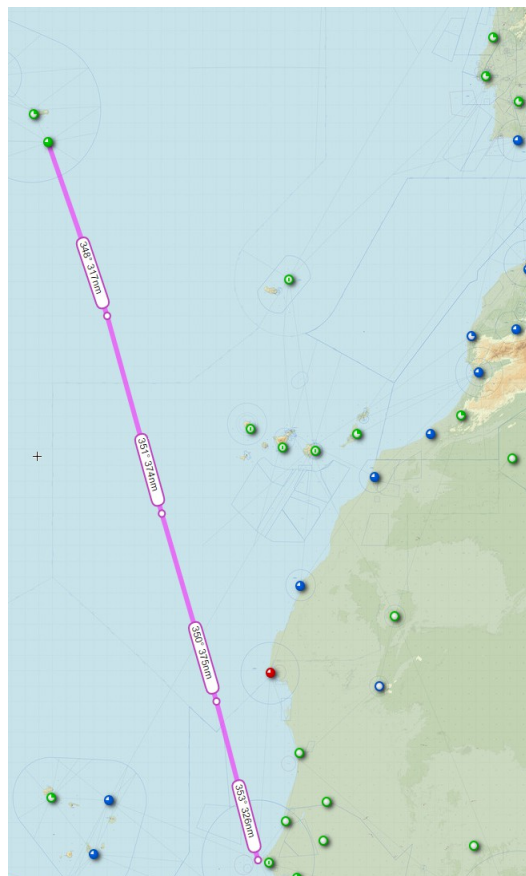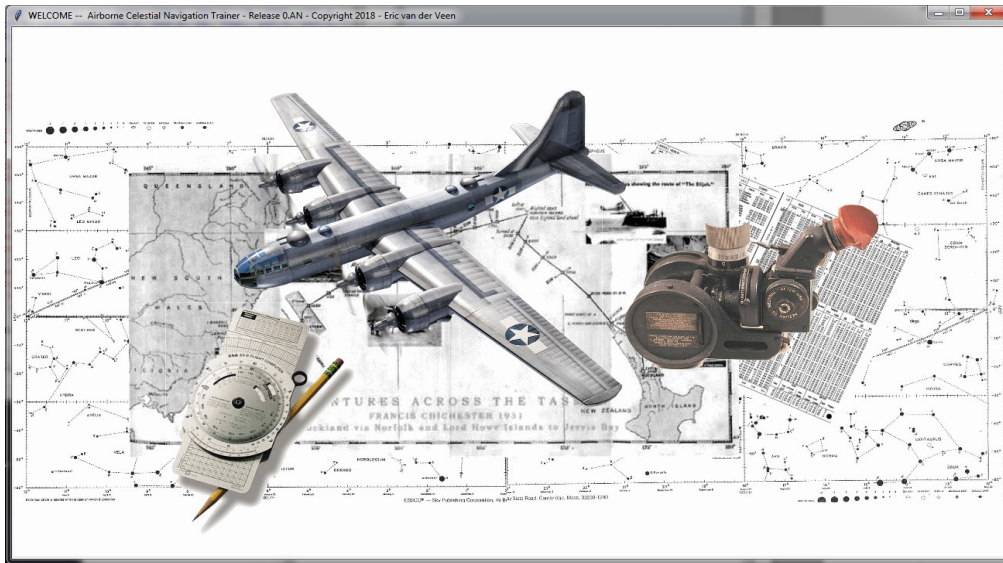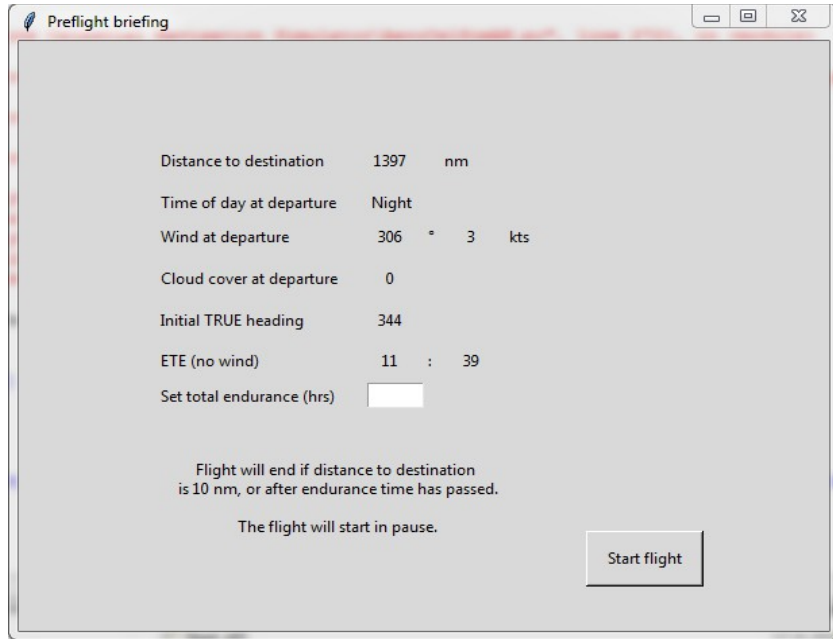
At this point we start the software and enter this data accordingly. The airports are known in the database, and we enter date and time, cruise altitude and speed. The altitude will only be relevant for refraction, not for anything else. We already used TAS instead if IAS, and other effects of altitude are ignored. For cruise, let's choose 9000 ft MSL.

When we press the 'Proceed to briefing' button, we are presented with the following. You may want to write this down or memorize. It will not be repeated.

Preflight briefing

Distance to destination	1397	nm
Time of day at departure	Night	
Wind at departure	306 ° 3	kts
Cloud cover at departure	0	
Initial TRUE heading	344	
ETE (no wind)	11 : 39	
Set total endurance (hrs)		

Flight will end if distance to destination
is 10 nm, or after endurance time has passed.

The flight will start in pause.

Start flight

Let's contemplate this information for a moment.

The window shows the flight distance 1397 nm and estimated flight duration (ETE) 11:39 for a no-wind flight. This nicely matches our earlier data from SkyVector. It also shows cloud cover and wind at the departure airport: 0% cloud, which is promising for an early fix to get the winds. Wind at departure is 306/3, so a very minor headwind . This gives us at least some idea for wind correction and sextant sights, but the weather will change along the flight. In flight, whereas the clouds can be visually checked and will be reported to you, the winds can and will not. The model does not include drift meters, smoke bombs or otherwise.

Further, our outbound TRUE heading is 344 degrees. Using the slide graphic flight computer I we derive a ground speed of 118 knots and a wind correction angle of 1 degrees LEFT. So after departure I'll immediately change heading to 343.

Finally, departure is at night as planned.

This windows now also allows us to set the aircraft's endurance to include safety margin, search time and wind. This is only used to terminate the flight after so many hours if we fail to find our objective. Let's put in a value of 15, to give us 3 hours margin.

At this point we are ready to start. If we now press the start button, the flight will start immediately at the designated time, albeit in pause mode. But first let's plan ahead for the celestial fix for the first leg on the Polhemus…. We will plan a three-star shot for beyond one hour after takeoff to get a first estimate of the wind, and thus plot a DR for 0230Z. Flight time to 0230Z is 1.5 hrs at 120 kts, putting the DR at 180 nm from departure.

Below is the filled Precomputation form for this shot. Without going over every detail, note that we've selected Vega, Antares and Regulus from the HO249 Vol.1, and an AP at 18N, 18 18.9W.

CELESTIAL PRECOMPUTATION

NAVIGATOR EV
DATE 2016-4-6
FIX TIME 0230 Z

STAR SELECTION BY AZIMUTH

Regulus

DEVIATION CHK

BODY				
SRB				
ZN				
T/G HDG				
VAR.	░░░			
MAG HDG	░░░			
		BNS	N-1	STBY
DEV CORR				
COMPASS HDG				

DR

LATITUDE	17°42 N	TR	343	TH		ALT	9 000
LONGTITUDE	18°20 W	GS	—	TAS	120		

BODY	Vega	Antares	Regulus	POLARIS
GHA BODY				░░░
ϒ	224°42.7'			
+ CORR	7°31.2'			
SHA	—			░░░
PLUS 360 IF NECESSARY	—			
GHA ☼	232°18.9			
± E/W LONG	−18°18.9			
LHA ☼	214°	214°	214°	
ASSUMED LAT.	18 N →	18N →	18 N	
DEC.	/	/	/	░░░

BODY	Vega	Antares	Regulus	POLARIS
				360°

AZIMUTH CORR.

	Vega	Antares	Regulus	POLARIS
ZN	55	143	279	
± CONV.				
GRID ZN				
ZN - TR	−72	+20	−69	
MOTION OF BODY	−11.6	−8.6	+14.2	
MOTION OF OBSERVER	−0.6	+1.9	−0.7	
1 MIN ADJ.	−12.2	−6.7	+13.5	
X △ TIME	8	4	0	
TOTAL MOT. COR.	−97.6	−26.8	0	
CORIOLIS	+1	+1	+1	
WANDER	0	0	0	
GS CHGE	—	—	—	
MISCEL	+1'	+1'	+1'	
TOTAL ADJ.	−95.6	−24.8	+2	

ACCELERATION ERROR·CORR TO HC

BODY		HEADING CHGE		BODY	GS CHGE		
	LEFT RIGHT	LEFT ±	RIGHT ∓		AHEAD BEHIND	INCREASE ±	DECREASE ∓
HDG	START						
	END						
	CHG L/R						
	X FOR FAC 1°	—	—	—			
	WANDER CORR						
GS	START						
	END						
	CHG INC/DEC						
	X FOR FAC 1 KT	—	—	—			
GS CHG							

SIGN REVERSED FROM TABLE

	Vega	Antares	Regulus
REFRAC	+1	+1	+1

SIGN REVERSED FROM CORR. CURVE

DOME PERSONAL	—	—	—
TOTAL	+1	+1	+1

	Vega	Antares	Regulus	
Hs TIME	0222	0226	0230	
Q FACTOR	░░░	░░░	░░░	
HA H0249	30°12'	34°55'	30°16'	DR LAT
TOTAL ADJUST	−1°36'	−25'	+2'	░░░
CORR A / DEC				
Hc	28°36	34°30	30°18'	
Ho				
INT TO / AW'Y				PLOT FROM DR LATITUDE 2.0T
ZN	55°	143°	274°	000.4
± CONV				
GRID ZN				
SRB				

CORIOLIS & RHUMB LINE _____ NM   TC + 90°

TABLE IV PRECESSION & NUTATION CORR.

_____ NM _____ DIRECTION

	LATITUDE	LONGTITUDE
FIX		
BNS		
COUNTER ADJ.		

Now, after pressing the button, we are presented with the 'enroute'-screen and we will remain in this screen until the end of the flight. This has four main sections. On top, the time, left the start, pause and time acceleration controls, on the right side the navigation parameters and control, and sextant operation at the bottom.
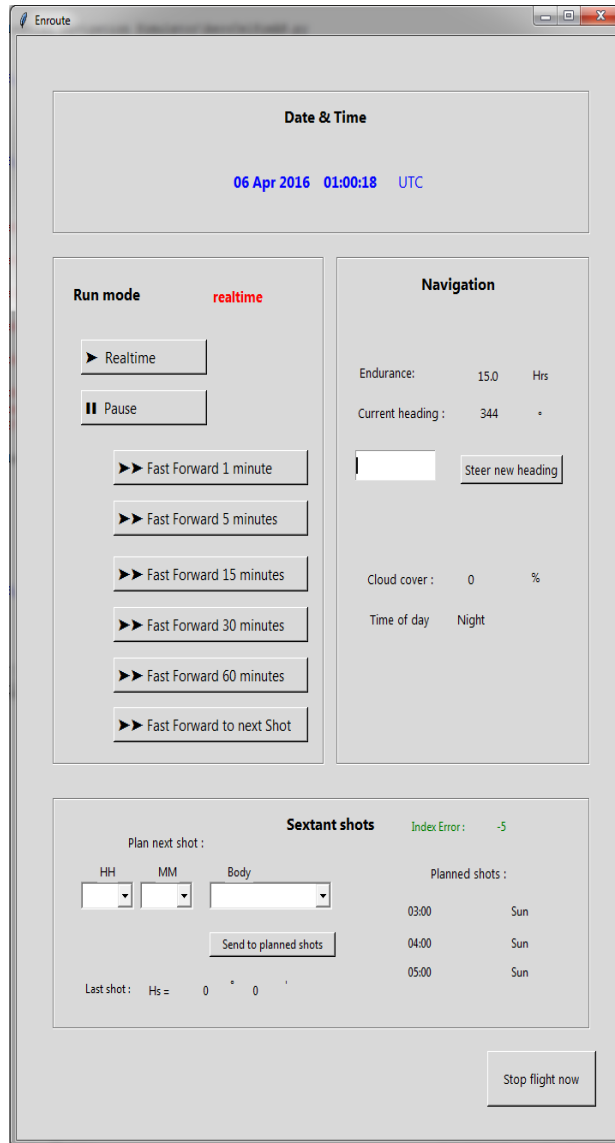
For now, let's just start the flight by pressing the '> realtime' button. This makes the program run in realtime, as is shown in friendly red letters, and as can be seen from the clock near the top of the window. Note that this may not be fully perfect real-time, but it's close enough.

The aircraft is now departing Dakar, immediately at cruise speed and cruise altitude, and on-course. There is no delay for take-off, and there is no climb phase. First we change heading to 343 on the right side window. Any new heading value goes into effect instantly as we press the button.

Now we move to the preparation of celestial navigation. On the right side we can see the current cloudiness, and time of day. Obviously, it is still dark (local time is same as UTC in Dakar, hence just over 01:00). And with clouds obviously still at 0 %.

Note that on the bottom right , three Sun shots have already be pre-set for 3, 4 and 5 hours after takeoff. Near the bottom of the window we enter our first shot, for 8 minutes to the advanced shot time, i.e. at 0222Z . A new sight is automatically sorted for 'soonest first'.

Also note the index error is -5' for this sextant and flight. We will need to apply this error either to the pre-calculation or the observation.

We also enter the 0226Z and 0230Z shots.

Then we sit back and wait.....

Enter the acceleration buttons! On the mid-left are options for a Fast-Forward of 1, 5, 15, 30 and 60 minutes as well as a Fast-Forward until the time of the next planned shot as indicated in the lower right.

Isn't that handy!

But the aviation sextant in virtual use (e.g.Mk IX or A-8A) has a two-minute averager, so the 'FF to next shot' stops just short of the start of the measurement, in this case just before the 0221Z mark.

In this case let's fast forward 60 minutes and stop around the 0215Z mark. You can force the simulation back to realtime at any moment during acceleration.

At 0210Z we observe that there are still no clouds, and we have 13.8 hours endurance remaining.
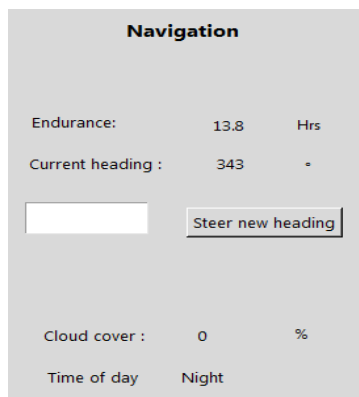
At 0221Z the sextant will start, and in a future version of the software you will hear the familiar sound of the averager ticking. Note that you are NOT supposed to do anything with a sextant throughout the flight.

After the average runs out, the software gives the sextant reading on the bottom as would have been realistic . The reading includes refraction, coriolis, index error, as well as a 'random' error for a non-perfect sextant operator. Note that nutation and precession are not included.

Last shot :   Hs =   28 °   22 '
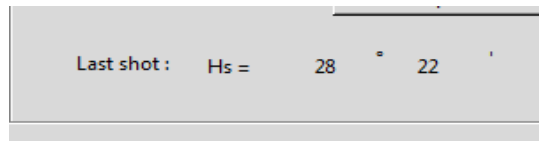
In our case, at the shot time we hear a reassuring beep and read 28°22' for Vega in the bottom left of the screen. With an Index error of -5 this equals to 28°17' which we note on the form quickly, because it will disappear when the next shot result comes up!

We quickly calculate and plot the intercept as 19 nm AWAY.

Then we patiently wait (or Fast-Forward to the next shot). This comes up as 34°52', intercept is 17 nm TOWARDS.

Our final shot yields 30°23' and that means intercept at ZERO.
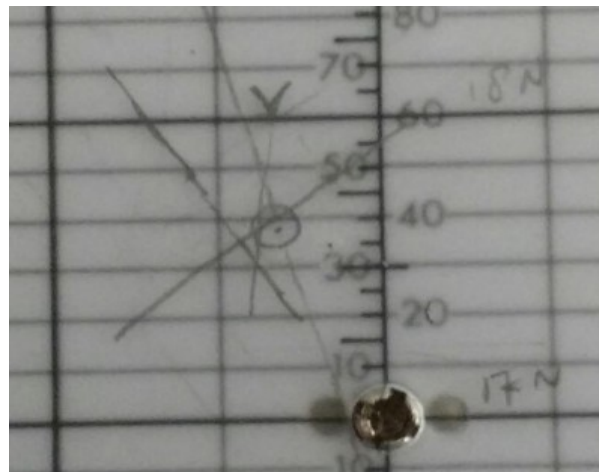
On the Polhemus, this is what it looks like. A very compact cocked hat fix rather close to the DR. It also suggests that the wind has picked up a bit. While the simulation runs, we'll plan forward to the next DR. From the fix to next waypoint, our new TRUE heading is 346, and the actual wind encountered is 036/7. We plan our new heading as 348.

Our next shot should be just on this Polhemus disk, at 20N latitude. This is 150 nm away, let's plan the next shot for one hour later, at 0330Z.

With some experience and routine, this takes no more than 10 minutes.
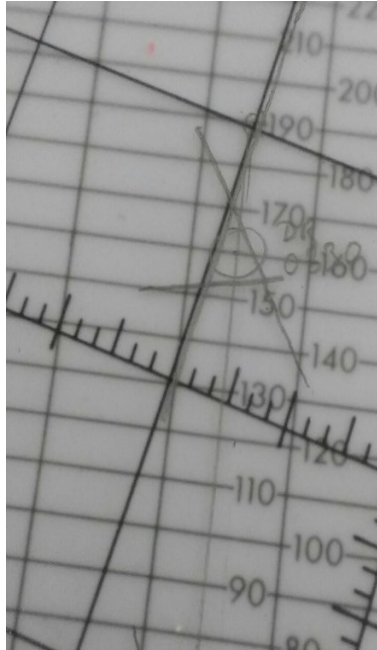
If this is all a bit new and puzzling, try the PAUSE button! To unpause, press either the realtime or any of the fast forward buttons.

Then, same as before:

- Plan the shot

- Plot DR, select stars, fill the form etc.

- Enter the shots in the screen

- Wait or FastForward.

- Plot the fix

And so on.

The new fix turns out as follows: cloud cover is still at 0%. A very clear night! 12.5 hours of fuel remaining. The cocked hat is a bit larger this time, suggesting that 1 or more of the shots have some error to them. But, the fix is perfectly centered on the DR. This implies the winds have not changed much. Below are the form and the Polhemus plot.

CELESTIAL PRECOMPUTATION

NAVIGATOR	DATE	FIX TIME
EV	2016/4/6	0330

DR	LATITUDE 19°30'N	TR 346	TH	ALT 9k
	LONGTITUDE 10°55'W	GS 115	TAS 120	

STAR SELECTION BY AZIMUTH

(Compass rose showing Altair at ~089, Spica at ~223, Alkaid, DoF)

DEVIATION CHK

BODY			
SRB			
ZN			
T/G HDG			
VAR.			
MAG HDG			
	BNS	N-1	STBY
DEV CORR			
COMPASS HDG			

BODY	ALTAIR	Spica	Alkaid	POLARIS
GHA BODY ♈		239°50.1'		
+ CORR		7°31.2'		
SHA		–		
PLUS 360 IF NECESSARY		–		
GHA ☀/♈		247°21.3		
+E/-W LONG		–18°21.3		
LHA ☀/♈		229		
ASSUMED LAT.		20N		
DEC.		–		

BODY	ALTAIR	Spica	Alkaid	POLARIS
				360°

AZIMUTH CORR.

	ALTAIR	Spica	Alkaid	POLARIS
ZN	089	223	334	
± CONV.				
GRID ZN				
ZN-TR	+83	+57	–12	
MOTION OF BODY	–14	+9.5	+6.2	
MOTION OF OBSERVER	+2.4	+1.2	–1.9	
1 MIN ADJ.	–11.6	+10.7	+4.3	
X△ TIME	8	4	0	
TOTAL MOT. COR.	–92.8	+42.8	0	
CORIOLIS	+1	–1	+1	
WANDER	–	–	–	
GS CHGE	–	–	–	
MISCEL	+2	–1	–0	
TOTAL ADJ.	–89.8	+46.8	+1	

ACCELERATION ERROR - CORR TO HC

BODY	LEFT RIGHT	HEADING CHGE		BODY	GS CHGE		
		LEFT ±	RIGHT ∓		AHEAD BEHIND	INCREASE ±	DECREASE ∓
HDG	START						
	END						
	CHG L/R						
X FAC 1°							
WANDER CORR							
GS	START						
	END						
	CHG INC/DEC						
X FAC 1 KT							
GS CHG							

SIGN REVERSED FROM TABLE

REFRAC	+2	+1	+0	

SIGN REVERSED FROM CORR CURVE

DOME PERSONAL	·			
TOTAL	2			

	ALTAIR	Spica	Alkaid	POLARIS
Hs TIME	0322	0326	0330	
Q FACTOR				
HA H0249	22°51	48°38	55°52	DR LAT
TOTAL ADJUST	–1°30'	± 45'	+1'	
CORR A / DEC				
Hc	27°21	49°23	55°53'	
Ho	20°32	50°11	55°43'	
INT TO / AW'Y	49	48	10	PLOT FROM DR LATITUDE 2.0T
ZN	089	223	334	000.4
± CONV				
GRID ZN				
SRB				

TC + 90°

CORIOLIS & RHUMB LINE _____ NM _____

TABLE IV PRECESSION & NUTATION CORR.

_____ NM _____ DIRECTION

	LATITUDE	LONGTITUDE
FIX		
BNS		
COUNTER ADJ.		

Since this seems to go so well, let's undertake a longer leg for the next fix. We transfer the last fix to the next disk on the Polhemus. The fix is at 19 28N and 18 54W.

The next disk goes all the way to 25N, and we'll aim for a DR near that latitude. Let's update our interim waypoint to 25N20W.

From the Polhemus: TRUE heading 351 (and with wind correction unchanged, steer 353.)

Distance to the waypoint: 151+205 = 356 nm. At 120 kts this takes approx. 3 hours. So the next shot will be at 06:30. Now this may be tricky regarding sunrise and stars disappearing against the light sky. So let's aim an hour earlier, at 05:30.

Fast Forward to 05:15.... Note that some clouds are forming, but nothing serious for now.

We get the shots, and plot the fix.

Oh dear...

A very large cocked hat, and we've been blown rather far off course to the East, and short of DR. In fact we're more than 100nm from our DR, so something is wrong.

Ah, I've misplotted the AP at 18 26W instead of 19 26W. Easily fixed, much better now.

We read the the new wind displacement from the Polhemus: 42 nm from 321°. Over a 2 hours period, this means the wind has increased to 321/21 kts. A significant increase, for which we much correct and anticipate a delayed arrival. Also cloud cover has increased to 20%.

Date & Time

06 Apr 2016   05:12:02   UTC

Run mode   realtime

➤ Realtime

❚❚ Pause

➤➤ Fast Forward 1 minute

➤➤ Fast Forward 5 minutes

➤➤ Fast Forward 15 minutes

➤➤ Fast Forward 30 minutes

➤➤ Fast Forward 60 minutes

➤➤ Fast Forward to next Shot

Navigation

Endurance: 10.8   Hrs

Current heading :   353   °

[   ]   Steer new heading

Cloud cover :   10   %

Time of day   Night

Sextant shots   Index Error :   -5

Plan next shot :

HH   MM   Body

[▼]   [▼]   [▼]

Send to planned shots

Last shot :   Hs =   55   °   48   '

Planned shots :

05:22   Deneb

05:26   Nunki

05:30   Arcturus

Stop flight now

I quickly plot a new TRUE TRACK to the 25N20W point of 343°. With wind correction 339° and new groundspeed 100 kts.

We may quickly try to squeeze in another shot before dawn. Let's try a 2 star-fix 0600Z, so I need to hurry. With practice, it can be done in 5 minutes.

I will shoot again Deneb, at 0556Z, and Arctures, at 0600Z.

Here we go, at 0556Z Deneb... Oh oops, Deneb is behind a cloud. No shot this time. This is feature in the software based on the actual cloud cover, to spice things up a bit. I quickly re-plan for 0604Z so I need to change only the sign of the corrections on the form

Arcturus at 0600Z goes well, and so does Deneb this time around and so I have a fix.

Unfortunately, it does not make much sense. In the half hour since the last fix I have travelled 100 nm and I'm back on my original track.

Now the clouds are building, daylight is coming and I'm in for trouble....

Which fix should I trust? Upon review, I do not find any more mistakes. I am tempted to disregard the 0530Z fix. The 0600Z fix actually corresponds well to a DR from 0230Z, and since I made one mistake in the 0530Z fix, there may thus be more.

Hence I decide my actual 0600Z fix is actually the last one I plotted, at 24°10N, 19°50W.

Next waypoint: 28N, 21.5W, TRUE TRACK 338, with wind....let's go back to the 0230 wind. Steer TRUE heading 340.

we'll now go to hourly sunshots, after dawn. Fast forward...

Hm at 0730Z it's still dark, and so this is something I need to calculate before the flight, next time.

I decide to quickly do star shots without pre-computation while I can, and plot afterwards. With some luck, the same stars.

Here goes. At 0730 Deneb, at 0734 Arcturus, and calculate back to 0730. Aargh...too late. It's now too light.
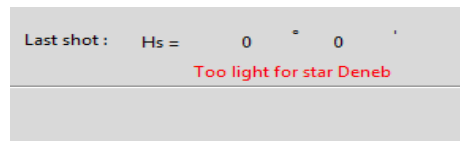
Important lesson. Plan ahead better, also plot the full course on the polhemus disk.

Next then is the Sun at 0800Z, and then every hour after that. Luckily, clouds are not building any further. The sun is very low on the horizon, around 10 degrees, but the screen still says 'Night'. Hmmm..... must be a software bug. I will fix that.

So, I have a 0800Z Sun LOP. I now draw a 10% uncertainty box around my DR, and a 7 nm band uncertainty band on both sides of the Sun LOP. The overlap provides my new fix: It's getting slightly messy....
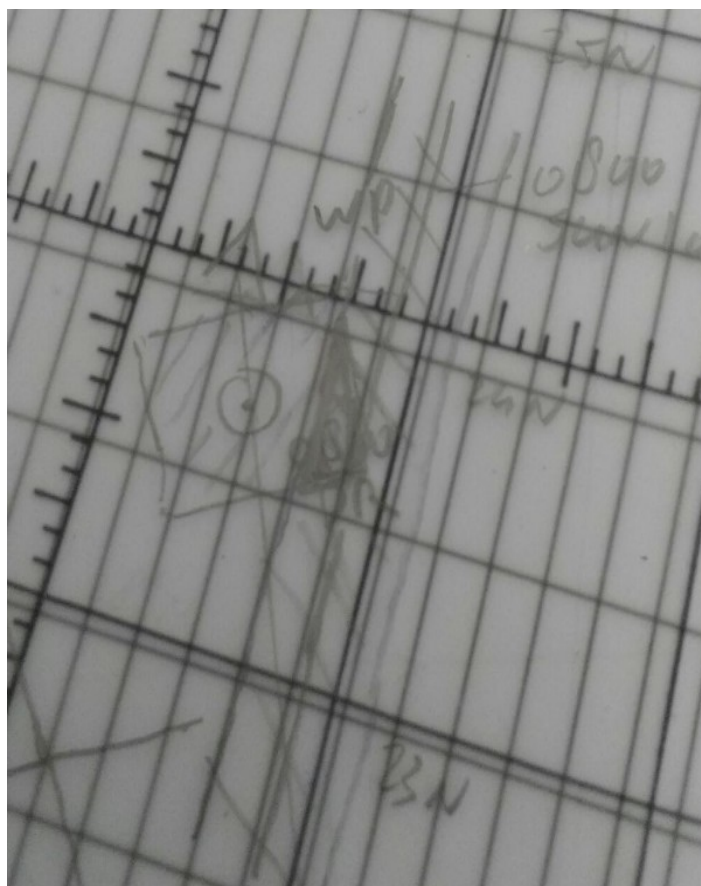
Still, it gives me confidence that I'm still somewhat on track. More importantly, it's all there is.
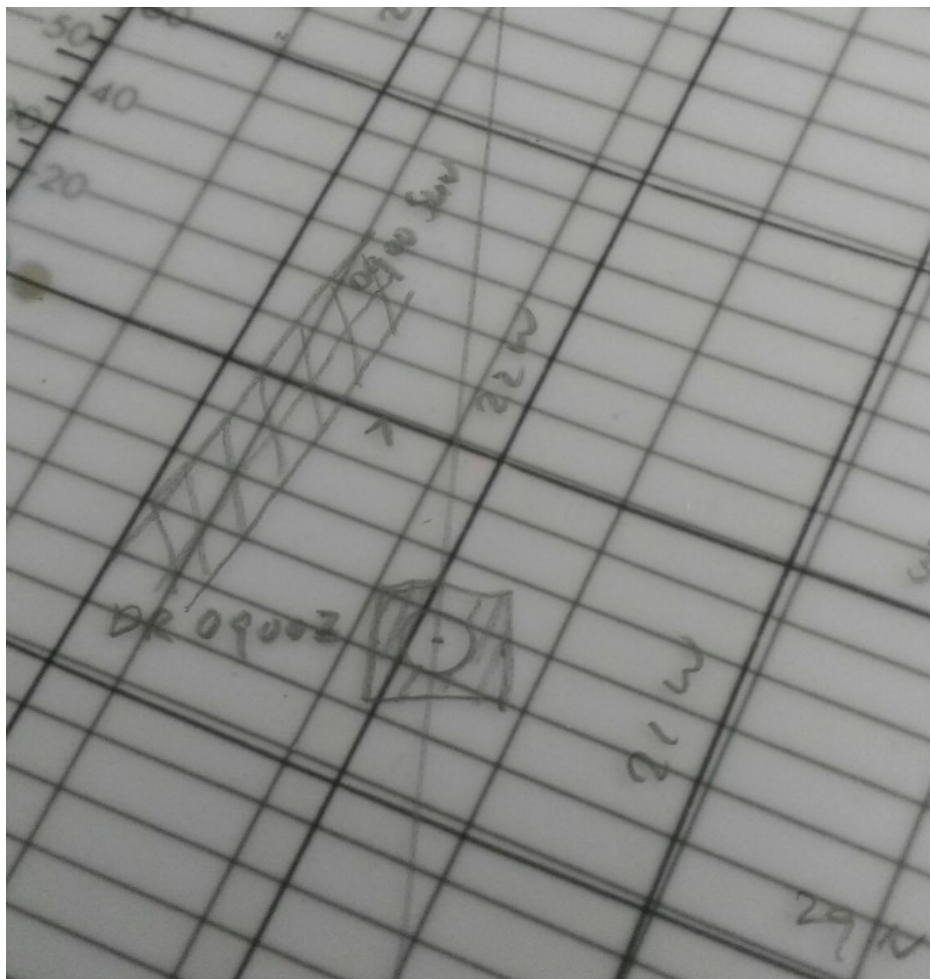
I fix my 0800Z position at 27°39N, 21°11W. And assess the wind as 268/7.

New disk on the Polhemus.....

Next waypoint is 32N23W. TRUE track 340. With wind: 337, groundspeed 118.

DR at 0900Z plotted, do the pre-calc. Here comes the shot now, cloud cover 30%....

And the plot is not good. The Sun LOP does not intersect the 10 % DR box.

We'll need to forward the DR for 1000Z shot. In fact I need to acknowledge that the DR uncertainty box should actually be a lot larger since the last fix was an improvised on. So I'll expand it till it starts to overlap the 0900Z Sun LOP in the NorthWest and proceed from there. New heading 349.

Now towards the 1000Z Sun shot!

And oops, cloud cover is now 90%. Gone is the sun, gone my sole means of navigation.

Cloud cover :   90   %

Last shot :   Hs =   0   °   0   ′
              Sun obscured by Cloud
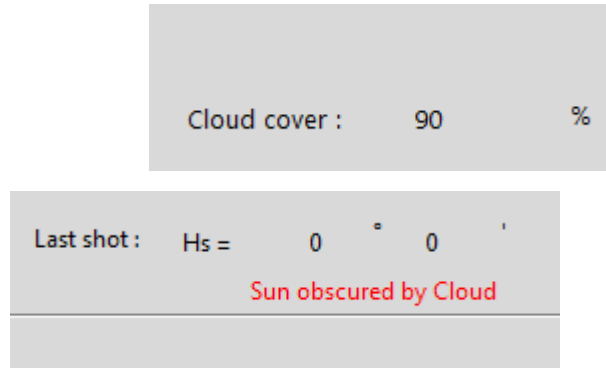
Our only hope is that the clouds will quickly dissipate so we can try a fix later on, and a landfall too. Fingers crossed.

Towards 1100Z, the clouds are slowly disappearing. 50% at 1030Z, 30% at 1045Z so there is hope!

Here comes the shot now. Sun spotted at 45°54. Minus 5' for the index error, yields intercept ….101 nm TOWARDS, which almost puts me over my previous DR. Useless, where will this flight end ?!

One more shot at 1200Z, then we'll start planning for the landfall. At that time I'll aim 10 degrees east, just to be safe.

The last few clouds have now almost disappeared and it's a bright blue day, apparently....

This time I'll forward the 1100Z Sun LOP, and not the DR.

The intersection of the 1200Z Sun LOP and the forwarded 1100Z Sun LOP is a relatively large area, but at least it shows me to the East of my track. I'll now start the landfall by turning 10 degrees right, to 355.

I'll plot a landfall graph for the time 1300Z-1430Z or so, and shoot every 10 minutes. As soon as I intercept the Hc line calculated at any given time, I'll look up the Z at that moment and turn left, perpendicular to that.

1310Z, Ho is 58°59'.

1320Z, Ho is 58°49', Hm that's odd. Should be going up, right?

1330Z, Ho is 58°51', so plenty of error in those shots

1340Z, Ho is 58°34'. Wait, this ain't right. This suggests I've actually overshot my target.

1350Z, Ho is 58°03'.

Let's turn around 180 degrees to 175 degrees, and see if we can intercept the landfall altitude curve. WE have 2.2 hours endurance left.

1400Z, Ho is 57°58'

Ah wait, we've wrongly taken the 35N table in Ho249 instead of 37N. So turn back to 355 and re-plot in a hurry.

And then I'm still already too far. Turn back to 175 again, or 225 for a more smooth approach into the landfall.

Now measuring every 5 minutes, and indeed approaching the landfall line now.

And here comes the turn now!

At 1436Z, Ho is equal Hc for LPAZ, and at Z is 205 degrees, so we turn 295 degrees, straight to LPAZ. Hopefully. Except for the winds that we don't know. Or the distance.

All we can do now is wait till arrival or start a search pattern. We can do a final sun LOP at 1440Z.

But nothing happens, I am not getting a 'success' message.

Let's admit it......I'm lost.

Clearly I need to draw the Landfall plot in greater detail. Another lesson. Also, a landfall near noon is not very sensible, as the Landfall plot then strongly curves.
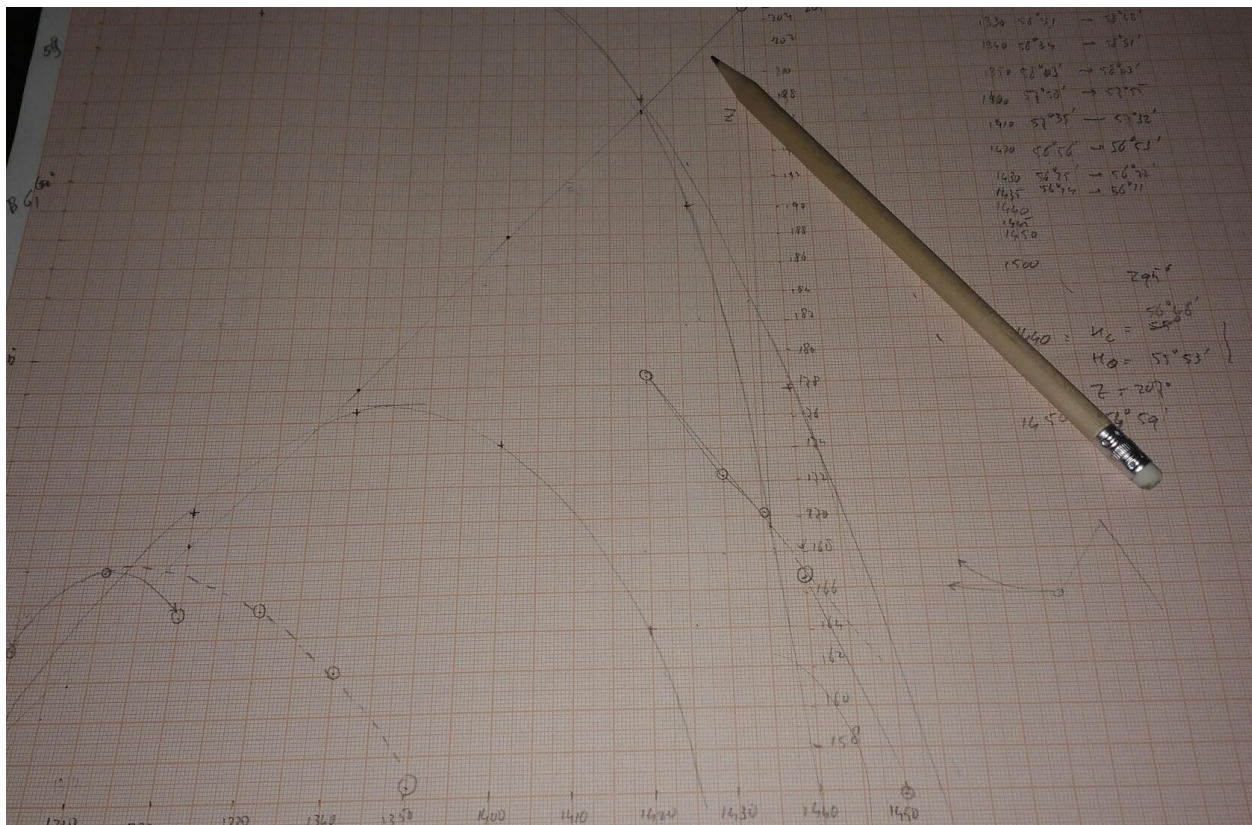
Let's quickly do a new series of shots for 1500Z onwards. Only 1 hour Endurance left now.

Unfortunately, chances are I've past north or south of the island om my westerly course and there's no way to tell.

Turning all ways now.... must go south to bring Hs up towards Hc. Doing another Landfall curve, very rushed.

Less than half an hour fuel left.

Shooting every 5 minutes now and plotting on the new Landfall graph.

Slowly converging to the Landfall curve, but which way to turn when I get there? Less than 10 minutes left...

I must be close. Intercept is 8 nm AWAY.

And then at 15:58:27, it's all over. Time's up. Fuel is out. Down we go.

DEBRIEFING

Now with the flight over, the software produces and saves 3 KML files to view in Google Earth.

First is windfield.kml. This shows windbarbs for a large area around the planned route.

Next is cloudfield.kml. This shows the cloudover in % for the same area.

Final file is tracks.kml. This shows the planned and actual route, and is thus the most interesting one.

Let's have a look.

Apparently, the wind has been from mostly constant NW direction, although gaining strength as I progressed, and peaking at 25 knots at 30N before calming down again towards my destination. Oh and I flew straight through the darkest cloud patch there was....

The discarded fix at 0530Z was actually VERY accurate. The 0800Z fix was good, too.

And boy, I've been all over the place in the end!

I've put in some of my fixes manually (I intend to add this to the software later).

And yes, I've overshot the Landfall. And I've turned the wrong way a few times. And my initial wind assessment was off. And so I have lots to learn.

Exactly what this tool was intended for!

Eric van der Veen

Oct 2018