**LOP sight reduction comparisons, using long hand, replica Fuller2cos, miniFuller2cos, Bygrave replica and an original Otis King. 2/7/14**

**Introduction.**

I’ve been following the fascinating debate on navlist regarding the different non electronic methods of reducing the navigation triangle. Here is a fairly non scientific comparison of my favourite methods. I have not used short tables which I find boring and do not fully understand them .I generally prefer slide rules to logs .Beached in my garden overlooking Mount’s Bay in Cornwall, I can just manage to lift the sextant, compass and Fuller 2 slide rule. A tough life.

For assessment, I use my personal “Chichester Test”. What would be the quickest, most accurate and easiest method, with the least writing down and mental arithmetic of intermediate steps etc in an open biplane in the Tasman sea? (For those interested, Gary LaPook and I recently“ re-enacted” the original Chichester navigation calcs (yes dated appropriately enough, April 1st 1931!) with our homemade Bygraves and copies of the original charts and got perfectly similar results to Chichester.

**Example. (supplied by Greg or Hanno?)**

Lat= 34˚10’N

Dec=22˚57’N

LHA=281˚39’

L-Dec=11˚13’

L+Dec=57˚7’

**Long hand methods**

1. **Daniol as supplied by Greg Rudzinski +/- Hanno?**

**Formula**

**Sin h=n-(n+m)a**

**n=Cos(L-D)**

**a=Hv LHA (which is = [1-cos(LHA)/2] for “no tables” slide rule work.**

**m=Cos(L+D)**

1. **Using Trig tables from Schlereth and Hvs from Norrie 1983. + Fuller2 for multiplying step. Do not need trig or Hav tables with the Fullers. The Otis King does perfect simple multiplication.**

 n=Cos(L-D)=11˚13’ Cos=0.9809 0.9809-

 m=Cos(L+D)= 57˚7’ Cos= 0.5429.+ =1.5429 0.6080

 0.3729. sin-1=**Hc 21˚54’**

 Hv LHA=359˚60’-281˚39’=78˚21’= 0.3990x

 **= 0.6080**

Hv LHA=359˚60’-281˚39’=78˚21’= 0.3990x (I cheated here and used Fuller 2 , moves 1.5238>F, A>1,0.3990>A ) > **0.6080** at F. Mini fuller2 s>1.5238,1>L, L>0.3990, read 0.6080 at S. Both less than a minute. **Surprisingly, my original 1960s Otis King was quickest and gave the same exact result! (£25 on ebay a few years ago, perfect condition small enough to fit in your pocket.). Even more amazing, I just tried this on my 1960’s school boy 10 inch linear Thornton and got the same result! Albeit guessing at the last 2 places.**

Both Fullers can give sines and cosines direct, quicker and just as accurate as sine and cosine tables. The Fullers do not have Hv, but I have used **Hv LHA (which is = [1-cos(LHA)/2], using both Fullers which is just as quick as using the tables. ( A possible future project that may interest Greg and hanno would be to build a Big Fuller 2 with sine/cosine scale at the bottom and replace the top log scale with Haversines? Watch this space, but not for few months!**

**Conclusions.**

Well, I’m a convert I think!?. Hanno and Greg like the Daniol method. Me too. I think, on the basis of only one calculation that this works well with the Otis King( and even , possibly the 10 inch linear) doing the single multiplication. (may not be so accurate elsewhere on the scale?). So this, with a few pages of cosines/sines/Hv but no logs and any old slide rule may well give good quick results. Need Fuller2cos if you do not want to use any trig tables.

1. **My Versine method using only 11pages of log/nat versines and cosines pages from Reeds Astro Nav tables .(any year)**

**Formula** (Vers ZD=Vers LHAxCos Latx Cos Dec+Vers(Lat+/-Dec)s) uses tables of natural and log versines and log cos (total 11 pages).Does not need sines.

1. **Versine method**
2. log vers LHA    9.9019
3. log cos Lat      9.9177
4. log cos Dec     9.9642
5. add              29.7838
6. Nat Vers of 9.7838=        0.6081
7. Lat-Dec=11013' Nat vers=0.0191. Add= 0.6272=6806'. =ZD. 900-6806'**= 21054'**

**Using Fuller2(cos) (no logs or trig tables). Same results but no quicker, since no versines and have to convert Vers=1-cosθ.**

**The Haversine method seems to take about the same time as the Versine method. The Daniol method with slide rule multiplication is the quickest and easiest.**

**3) Fuller2cos using the cosine formula.**

**Formula**

Sin Hc=(cos LHAxcos latxcosDec) +/- (sin Lat xsin Dec).

**Minifuller2cos**

**(cos LHAxcos latxcosDec)**

S>1

Cos 78˚21’ >L,L>red, (0.2019 at S)

Cos 34˚10’ >L, L> red

Cos 22˚57’>L, L>red**, read 0.15382 at S record.**

**(sin Lat xsin Dec).**

S>1

Sin 34˚10’>L, L>red

Sin 22˚57’ >L, L>red, **read 0.2189 at S record**

**0.5382+0.2189=).3728.**

S>0.3728

Red>L

**S>1, read 21˚53’ at L**

The Big Fuller2cos takes a little longer, with slightly more moves, but the large scales are easier to read. I have to use magnifiers to get accurate results from the mini, which is otherwise as accurate and quicker.

e.g **(cos LHAxcos latxcosDec)**

C index>cos 78˚21’ (0.2019 at F)

A>1

C>cos 34˚10’ (0.8274 at F)

0.8274>B

A>1

C>22˚57’ (0.9208 at F)

0.9208>B, read 0.15382 at F

**Bygrave replica.**

The instructions are printed on the curser and cylinders. I always use Gary LaPook’s excellent form.(see attached).

**Formulae (from Riet 2008)**

1. **1/cot dec=cosLHA/cotW**
2. **Cos W/cotLHA=cos w/cotAz**
3. **Cos Az/cotY=1/cot Hc**

Lat= 34˚10’N, co-lat =55˚50’

Dec=22˚57’N

LHA=281˚39’

H=360˚-281˚39’=78˚21’

Bygrave moves (see form).Notice you also get Az.

**Conclusions**

I find the Bygrave faster and easier than the other methods, but have more experience with it. The new minifuller2cos, with cosines is surprisingly easy and quick using the standard cosine formula, with less recording/writing down of intermediate results.The only problem is the small scale numbers requiring magnifiers. With practice, I suspect the minifuller2cos using the cosine formula will be as good and as quick as the Bygrave for LOPs and is much better for lunars.. If I could only have one slide rule, it would have to be a general purpose rule such as the new Fuller2cos or minifuller2cos which can do all my celnav calculations without logs or trig tables. The Bygrave is my favourite, but less versatile. It can do lunars, (just and with additional compass measurements for ΔAz,)but it is really a specialised LOP rule.

The Daniol method, using slide rules (perhaps the Otis King is adequate?) for the multiplication seems to be the easiest and quickest “long hand” method.