MODERN LUNARS

A WORD ABOUT "LUNARS"

INITIAL WORD: This Document was initially triggered by a request e-mailed from Dave Walden (08 Aug 2016) to study a 1855 Lunar.

The **"Classical" Lunar Methods** – some of them with a number of refinements – use a Moon to Celestial Body observed Sextant Distance and reduce it into its well-known Geocentric Center-to-Center "*Cleared Distance*" image. Such geocentric distance is then compared to Geocentric Center-to-Center Distances predicted by a planetary theory. The requested UT1 time is reckoned *backwards* from such predicted geocentric distances to match the computed geocentric distance derived from the Sextant Distance.

*In **Classical** Lunar Methods the **benchmark** is the **[Geocentric] "Cleared Distance"***.

Various Classical Lunar Methods were implemented and in use for about one century (1770 A.D. – 1870 A.D.) with satisfactory results through the use of tables. They required regular training from Observers and stayed within normal reach of standard – nonetheless extremely careful and meticulous - Navigators at sea. Whatever their refinements, there are still cases which cannot be [sufficiently] accurately solved by any such single Classical Method. In other words, some bits of accuracy are lost here and there during the classical "Lunar clearing" process. **The very best classical *manual computation* methods have a built-in accuracy just reaching the 0.2' level under most cases. Implementation of Classical Methods on modern computers enables to exceed the 0.1' accuracy level. The main shortcoming of the Classical Methods – even when implemented with the Best Planetary Theories on modern computers - is that they fail to accurately represent the "Longitude Error / Sextant Error" ratio. In other words, they remain short of providing Navigators with meaningful "*Immediate Warnings*" about ill conditioned Lunars.**

Although Lunars have definitely become extinct in current day to day life, modern computation power can tackle them with much better efficiency. **The name of the game here is to simply compute the Sextant "*synthetic*" Distance (i.e. the Distance which *should* be observed in a Sextant) and to fine tune successive UT1 values until the computed Sextant "*synthetic*" Distance matches the Sextant Observed Distance [e.g. to +/- 0.5"].** The last UT1 value thus obtained solves the observed Lunar. The computations involved here can incorporate all known effects at [almost] any accuracy level, and – through super accurate Planetary Theories (e.g. JPL ***DE405/LE405*** or "Bureau des Longitudes" ***INPOP13C***) – such Modern Lunar methods have a built-in accuracy [well] below the arc second level. These computations are *huge* compared to the Classical Methods, and they cannot be performed by hand.

*In Modern Lunar Software, there is a **significant change in paradigm** since the **benchmark** has directly become the **Sextant observed distance** itself*. No longer required focusing onto the Geocentric Center to Center Distance which has then become only an [optional] computation by-product. **Modern Lunar Algorithms are excellent at accurately deriving the "Longitude Error / Sextant Error" ratio**. This in turn greatly helps Navigators into getting quite solid information about the reliability of their Longitude determinations through Lunars.

IMPORTANT NOTE: Nonetheless, one should not forget that the results of both the "Classical" and the "Modern" methods can be [extremely] sensitive to the Refraction models used, mainly at low altitudes. Hence with any method, it is *preferable* not to observe Bodies with heights less than 5° or even 10° above the horizon. However, given their high qualities, "Modern" Lunar Methods – i.e. the ones using Sextant Apparent Distances as benchmarks - should nonetheless be considered as [much] more efficient and reliable at tackling low altitude Lunars than their "Classical" counterpart[s].

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Lunar (1): From: ***THE AMERICAN EPHEMERIS AND NAUTICAL ALMANACh 1855*** p 512 and as discussed by William E. Chauvenet:
From position N35°30' W030°00, on Sep 07th, 1855, a Moon to Sun Limbs closest distance is observed at 43°52'10". The Ship Chronometer says: UT1 = 08h08m56,0s (which is the same instant as 20h08m56,0 under their hours reckoning). Height of Eye = 20ft, T = 75°F, P = 29.1" Hg.

I have solved it as follows, with ΔT = +7,7 s :

For UT1 = 08h08m56.0s, I find the Sextant "synthetic" Distance to be at 43°52'30.0" (with a "Cleared" Distance at 45°04'28.5"). For Sextant Distance = 43°52'10.0", UT1 = 08h11m45.6s (with a "Cleared" Distance at 45°03'11.7").

Sextant Distance change: -7.823"/min of UT1

Error on UT1: -46.0s/+0.1' Sextant Distance Error

Error on Longitude: 11.5' towards the East/+0.1' Sextant Distance Error

NOT AN OPTIMUM LUNAR ENVIRONMENT

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Lunars (2), (3) and (4):

I have then investigated 3 simultaneous synthetic Lunars occurring at the same time in different places.

Theory: ***INPOP13C***, Coordinates: Equatorial coordinates (RA, DEC), Apparent coordinates (true equator; equinox of the date), Geocentric.
Target, Date, RA ("h:m:s"), DEC ("d:m:s"), Distance (au, with 1 au = 149 597 870 km)
Sun, 1855-09-07T08:05:00.00, 11 01 26.99883, +06 15 31.9350, 1.007251421 *Geocentric SD = 0.264 647 774 2°(15.87886645') with SD = 695,997 km*
For the Sun Semi-Diameter, no correction for irradiation has been made, as this is an observer dependent effect.
Moon, 1855-09-07T08:05:00.00, 08 10 10.16146, +25 17 31.0209, 0.002701090 *Geocentric SD = 0.246 438 905°(14.78633432') with SD = 1,738 km*
ARIES GHA = 107.057 931 8 ° (107°03'28"555). Here I have used ΔT = +7.68 s. *HP = 0.904 419 770°(54.26518619')*
(23454.79095)

Temperature is on-site Temperature, Pressure is also on-site Pressure, *i.e. QFE* and *not* QNH, (i.e. no QNH Pressure correction required).
"**Height of Eye**" is used for **Refraction and Dip**, while "**Altitude**" [above WGS84 Ellipsoid] is used for **Parallax and augmented SD** space 3D computations. In all the following examples: for ALT = 0 m (WGS84), Height of Eye = 0ft with 75°F (22.8°C) and QFE = 29.1" Hg. And:
for ALT = + 400 m (WGS84), Height of Eye = 0ft with 68°F (20°C) and QFE = 27.6" Hg.

07 SEP. 1855 , ΔT = + 7.68 s UT1 = 08h04m52.32s (TT=08h05m00.00s)	**Lunar (2)** Position: N30°06'39" W030°00'00"		**Lunar (3)** Position: N29°27'12" W005°00'00"		**Lunar (4)** Position: N30°00'00" E055°00'00"	
The RATE OF CHANGE of the Geocentric Center to Center Distance is : - 27.206 "/min of UT1 , to be compared with values below.	Sun Z = 85.42227°, dZ = - 0.02538" Moon Z = 85.42280°, dZ = -14.59022"		Sun Z = 97.99004°, dZ = - 0.02765" Moon Z = 97.98965°, dZ = -28.94652"		Sun Z = 171.88345°, dZ= - 0.00864" Moon Z = 271.11891°, dZ= +16.39620"	
	75°F, 29.1"Hg ALT = 0m (WGS84)	**ALT=+400m (WGS84) 68°F, 27.6"Hg**	**75°F, 29.1"Hg ALT = 0m (WGS84)**	**ALT= +400m (WGS84) 68°F, 27.6"Hg**	**75°F, 29.1"Hg ALT = 0m (WGS84)**	**ALT=+400m (WGS84) 68°F, 27.6"Hg**
***Synthetic* Sextant Distance**	**43°51'45.9"**	**43°52'04.8"**	**44°16'31.0"**	**44°28'02.2"**	**45°00'59.1"**	**45°01'01.0"**
Variation per minute of time	***+ 0.377"***	***+ 0.297"***	**-15.107"**	**-15.128"**	**-19.494"**	**-19.492"**
Δ UT1 / Δ Sextant error	***+ 954.2s / 0.1'***	***+ 1 213.6s / 0.1'***	**-23.83s / 0.1'**	**-23.80s / 0.1'**	**-18.5s**	**-18.5s**
Δ Longitude / Δ sextant error	***238.5'(→ W) /0.1'***	***303.4'(→ W)/0.1'***	***6.0'(→ E)/0.1'***	***5.9'(→ E)/0.1'***	***4.6'(→ E)/0.1'***	***4.6'(→ E)/0.1'***

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