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CELESTIAL FIX BY CALCULATOR
FOR ALL BODIES AND ALL POSITIONING PROBLEMS WITHOUT OR WITH INTERCEPTS AND AZIMUTHS

K-12 METHOD

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The method described is a single program method developed for a Texas Instruments SR-52 programmable hand-held calculator, but it can also be easily used on any other programmable calculator of the same or higher capacity. It provides a direct solution for latitude and longitude of the observer's position from simultaneous or non-simultaneous observations of two celestial bodies (either the sun, moon, planets or stars) as well as from a double observation of one body (usually the sun, which until now has been practiced by advancing the earlier position line to the time of the last observation) even for cases where the second observation is close to or exactly on the observer's meridian. The coordinates of the fix are obtained directly on the sphere as the intersection of circles of position, thus obviating the need to determine position lines (intercepts and azimuths) by the Marcq St. Hilaire method or to draw a diagram of the situation in the sky in order to decide what to do with calculated parameters.

The method — named the K-12 method — has been devised by the author and is a modified version of his K-11 method published in five volumes of Tables K-11 for selected stars only. [1]; [2]; [3]. It takes the form of a single program of 666 steps with 19 addressable memory registers, requiring three magnetic cards for Texas Instruments calculator SR-52 or a single one for a TI-59, and it may be used for any latitudes or with any celestial body. Normally it provides a direct solution for latitude and longitude from non-simultaneous observations of two celestial bodies at the time of the second sight (which is common in actual navigational practice) solving parameters of the second body's navigational triangle. Thus in order to obtain more accurate longitude the second celestial body should not be chosen in the vicinity of the observer's meridian. However, the program also provides the possibility of computing the parameters of the first body's navigational triangle, but the first version is a simpler one. The same program also applies to simultaneous observations of two bodies.

Furthermore, it enables solution of a double observation of one celestial body, even for the case of the sun when the second sight is at local noon, since here longitude is obtained as the difference between the local hour angle (LHA) computed from the corrected first body's navigational triangle and the first sight Greenwich hour angle (GHA). In addition, two cards of the same program enable the computation of intercepts and azimuths for navigators preferring to determine position lines rather than directly the latitude and longitude of the observer's position, or wishing to check the K-12 method by means of the Marcq St. Hilaire method (see Example 3, Third Solution).

Because of the above characteristics this is truly a unique method for the direct computation of a celestial fix by calculator, requiring only a single program for the solution of all positioning problems encountered in celestial navigation.

The basic principle for direct solution of latitude and longitude in the K-12 method for the case of simultaneous observations of two celestial bodies is the determination of an accurate value for the second body's parallactic angle X2 (figure 1). This is made possible by computing auxiliary angles A and B and by using the precomputed approximate value for the second body's parallactic angle AX2 (figure 2) which determines how to combine angles A and B to find X2 without the need to draw a diagram showing the situation in the sky, which would prolong the solution procedure. The use of this approximate parallactic angle was envisaged by the author as long as 25 years ago [4]. With the computed X2, observed altitude Ho2 and declination Dec 2 we compute the latitude L and the meridian angle MA2. Then MA2 is converted into LHA2, from which the second body's GHA2 has to be subtracted in order to obtain the longitude, λ, of the observed position, i.e. the coordinates of the observer's zenith Z.

The other variations of the navigational problem, i.e., non-simultaneous observations, the case where the second body is close to or directly on the observer's meridian, or double observation of the same body, are solved by the same program employing the corrected altitude of the first sight, Ho1 ctd, for the time elapsed and the distance made good, or by computing the parameters for the first body's navigational triangle (see Example 2, First Solution). In addition, when the azimuth of the first body is not taken or it is preferred to have it computed, the same program computes also the true azimuth very simply at the beginning of the procedure for direct solution of the fix (see Example 1, First Solution). This computation of the azimuth may also be used for determining the compass deviation.

In this program, provisionally named NG1-40-1, 2, 3, **the formulae given below refer to non-simultaneous observations of two celestial bodies,** and the solutions of the three examples which follow after the formulae are worked with the SR-52 calculator in conjunction with the PC-100 printer. The print-out shows the entering arguments, some intermediate calculations and the final result, i.e. the latitude and longitude of the observer's position (fix). The three examples are for cases of non-simultaneous observations of two stars, a double observation of the sun and simultaneous observations of the sun and moon respectively. They are taken from the author's pub-

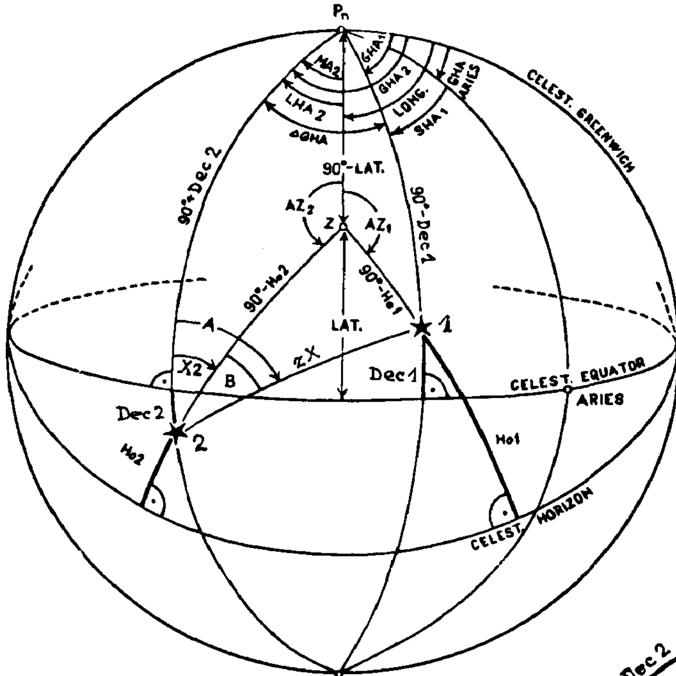

FIGURE 1

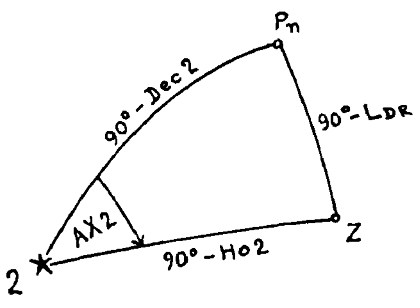

FIGURE 2

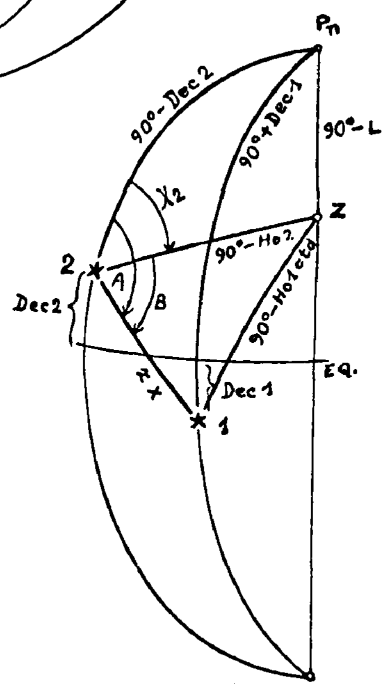

FIGURE 3

lished Tables K-11, the book "New methods of ship's position finding from celestial observations" and Tables K-1, presenting a further test of these manuals already used in practice.

Ho1 correction = knots × Δ GMT × cos Rel Az1 (1)
where Δ GMT is the absolute difference of Greenwich Mean Times (GMT)

FIG. 4. — Texas Instruments SR-52 calculator and PC-100 printer.

and Rel Az1 is the first body's true azimuth relative to the ship's true course (Rel Az1 = T Az1 ~ T Course).

Ho1 corrected = Ho1 + Ho1 correction (2)

Δ GHA = GHA2 ~ GHA1; absolute difference of Greenwich hour angles (3)

$$AX2 = 2\left[\sin^{-1}\sqrt{\frac{1}{\sin(90^\circ - Ho2)}\,\frac{1}{\cos Dec2}\cos R\sin(R - L_{DR})}\right]$$

$$R = \frac{(90^\circ - Ho2) + Dec2 + L_{DR}}{2} \qquad (4)$$

$$zx = 2\left[\sin^{-1}\sqrt{\sin^2\frac{Dec2 - Dec1}{2} + \sin^2\frac{\Delta GHA}{2}\cos Dec2\cos Dec1}\right] \qquad (5)$$

$$A = 2\left[\sin^{-1}\sqrt{\frac{1}{\sin zx}\,\frac{1}{\cos Dec2}\cos F\sin(F - Dec1)}\right]$$

$$F = \frac{zx + Dec2 + Dec1}{2} \qquad (6)$$

$$B = 2\left[\sin^{-1}\sqrt{\frac{1}{\sin zx}\,\frac{1}{\cos Ho2}\cos G\sin(G - Ho1\ ctd)}\right]$$

$$G = \frac{zx + Ho2 + Ho1\ ctd}{2} \qquad (7)$$

$$X_2 = A \sim B \tag{8a}$$

$$X_2 = A + B \text{ ; si} > 180^\circ\text{, on a } 360^\circ - (A + B) \tag{8b}$$

$$L = 90^\circ - 2\left[\sin^{-1}\sqrt{\sin^2\frac{Ho2 - Dec2}{2} + \sin^2\frac{X2}{2}\cos Ho2 \cos Dec2}\right] \tag{9}$$

L is obtained in the correct value with its sign, + if North, and − if South.

$$MA2 = 2\left[\sin^{-1}\sqrt{\frac{1}{\sin(90^\circ - Dec2)}\frac{1}{\cos L}\cos U \sin(U - Ho2)}\right]$$

$$U = \frac{Ho2 + (90^\circ - Dec2) + L}{2} \tag{10}$$

$$LHA2 = MA2 \text{ Ouest} \tag{11a}$$

$$LHA2 = 360^\circ - (MA2 \text{ Est}) \tag{11b}$$

$$\lambda = LHA2 - GHA2 \tag{12}$$

λ is obtained in the correct value with its sign, + if East, and − if West.

Computation of intercepts and azimuths. If for any reason (either from habit, or as a check of K-12 method by Marcq St. Hilaire method using the calculator) the navigator wishes to compute the intercepts and azimuths of the observed bodies he can use the same programmed cards, NG1-40-1 and NG1-40-3, to compute altitude Hc, intercept a, and azimuth Zn (see Example 3, Third Solution).

The NG1-40-1 card converts the entering arguments from degrees-minutes-decimal minutes to degrees and decimals and retains them in the proper addressable memory registers.

The NG1-40-3 card solves equations (9) and (10) and, when Dec is substituted for Ho2, MA for X2, and L_{DR} for Dec 2, will give the altitude Hc and azimuth Zn. This card also solves equation (12), and gives the intercept if Ho is substituted for LHA2 and Hc for GHA2.

The latitude and longitude of the fix may be obtained directly by using the existing Texas Instruments NG1-26 card (see Example 3, Third Solution), or else the azimuths and intercepts can be plotted graphically to obtain the point of intersection of the lines of position and thus derive the latitude and longitude.

Computation of the azimuth needed for determining compass deviation. The NG1-40-1 card solves equation (4), and when L_{DR} is substituted for Dec, and Dec for L_{DR} will give the true azimuth of the observed celestial body, measured from 0° at the North pole through 180°, therefore it should be labeled with prefix N and suffix E or W to agree with the body's position Eastward or Westward of the observer's celestial meridan (see Example 1, First Solution).

EXAMPLE 1 : 7 October 1968, L_{DR} 9° 01.5′ N, λ_{DR} 130° 30.0′ W;

True course 303°, Speed 16 knots, Height of observer's eye 39 ft, IC 0′.

With the sights listed below, find the observer's position at the time of the 2nd sight, using a Texas Instruments SR-52 calculator.

No.	Name	GMT	Hs	T Az T C	Rel Az	GHA	Dec	MA
1	ANTARES	$3^h19^m10.0^s$	31°26.7′	231.8° 303.0	71.2°	178°45.8′	– 26°22.0′	W
2	FOMALHAUT	3 22 05.0	29 41.7	–		82 22.4	– 29 47.3	E

FIRST SOLUTION, by the K-12 method, using newly programmed cards and the PC-100 printer

NG-40-1, 2, 3 preceded by existing sextant correction card NG1-21

```
Hs1      3126.7
Eye        39.
  31.1903229 Ho1
             1. Sight No

Hs2      2941.7
Eye        39.
 29.33566384 Ho2
             2. Sight No

GMT2     3.2205
GMT1      3.191
         0.0255 ΔGMT
knots       16.
 .7777777778 DMG
Rel.Az1    71.2
 .0041731775 Ho1 cor.
 31.32173679 Ho1 ctd
Dec 2   -2947.3
LDR       901.5
 57.82260148 AX2
GHA 2    8222.4
GHA 1   17845.8
          96.39 ΔGHA
Dec 1    -2622.
 57.79508014 X2
 902.5690928 L
-13033.15656 λ
9°02.6′N, 130°33.2′W
```

NG-40-1, 2, 3 with manually corrected sextant readings

Hs1	31°26.7′
cor. –	7.7
Ho1	31°19.0′
Hs2	29 41.7
cor. –	7.8
Ho2	29°33.9′

```
GMT2     3.2205
GMT1      3.191
         0.0255 ΔGMT
knots       16.
 .7777777778 DMG
Rel.Az1    71.2
 .0041731775 Ho1 cor.
Ho1       3119.
 31.32083984 Ho1 ctd
Ho2      2933.9
Dec 2   -2947.3
LDR       901.5
 57.82335873 AX2
GHA2     8222.4
GHA1    17845.8
          96.39 ΔGHA
Dec 1    -2622.
 57.79389391 X2
 902.6503733 L
-13033.14189 λ
9°02.7′N, 130°33.1′W
```

NG1-40-1, 2, 3, with sextant readings corrected manually and precomputed True Azimuth

```
Ho1       3119.
LDR       901.5
Dec1     -2622.
N128.5357984W
 231.5°          T.Az1

GMT2     3.2205
GMT1      3.191
         0.0255 ΔGMT
knots       16.
 .7777777778 DMG
Rel.Az1    71.5
 .0040234806 Ho1 cor.
Ho1       3119.
 31.32069015 Ho1 ctd
Ho2      2933.9
Dec 2   -2947.3
LDR       901.5
 57.82335873 AX2
GHA2     8222.4
GHA1    17845.8
          96.39 ΔGHA
Dec 1    -2622.
 57.79371942 X2
 902.6505472 L
-13033.14272 λ
9°02.7′N, 130°33.1′W
```

SECOND SOLUTION, by the Marcq St. Hilaire method, using existing cards :

NG1-21 for sextant correction, NG1-25 for star sight reduction, NG1-26 for fix by two observations – and the PC-100 printer.

Additional entering data :

No.	Name	SHA	GHA Aries for 3^h GMT
1	ANTARES	113°08.0′	60°49.5′
2	FOMALHAUT	16 00.7	60 49.5

```
Hs1        3126.7
Eye          39.
  31.1903229 Ho1
         1.Sight No

Hs2        2941.7
Eye          39.
 29.33566384 Ho2
         2.Sight No

LDR        901.5
λDR       13030.
mGMT1      0.191
SHA1      11308.
hGHA♈     6049.5
Dec1      -2622.
 31.17323392 Hc1
 1.514829932 a1
 231.4809356 Zn1
         1.Sight No

mGMT2     0.2205
SHA2      1600.7
hGHA♈     6049.5
Dec2     -2947.3
  29.3656867 Hc2
-3.003809567 a2
 131.9824342 Zn2
         2.Sight No

Sight No       1.
Sight No       2.
 13032.96072 λ
 902.7411511 L

9°02.7′N, 130°33.0′W
```

EXAMPLE 2 : 31 January 1954, L_{DR} 33° 16.6′ N, λ_{DR} 27° 40.5′ E;

True course 141°, Speed 15 knots, Height of Observer's eye 36 ft, IC 0′. With a double observation of the sun's lower limb as listed below, find the position at the time of the second sight, using a Texas Instruments SR-52 calculator.

No.	NAME	GMT	Hs	T Az T C	Rel Az	GHA	Dec	MA
1	SUN	$6^h31^m16^s$	14°55.0′	123.3° 141.0	17.7°	274°27.2′	– 17°30.8′	
2	SUN	10 02 04	39 34.8	–		327 08.9	– 17 28.5	E

FIRST SOLUTION, by K-12 method, using newly programmed cards and the PC-100 printer.

NG1-40-1, 2, 3 preceded by existing sextant correction card NG1-21

```
Hs1        1455.
SD          16.3
Eye          36.
  15.01589223 Ho1
          1. Sight No

Hs2       3934.8
SD          16.3
Eye          36.
  39.44058676 Ho2
          2. Sight No

GMT2   10.0204
GMT1    6.3116
        3.3048 ΔGMT
knots      15.
          52.7 DMG
Rel.Az1   17.7
 .8367192672 Ho1 cor.
 15.86975324 Ho1 ctd
Dec 2   -1728.5
L DR     3316.6
 7.989784498 AX2
GHA2   32708.9
GHA1   27427.2
        52.695 ΔGHA
Dec 1   -1730.8
 4.894271148 X2
 3236.482736 L
 2823.079886 λ

32°36.5'N, 28°23.1'E
```

NG1-40-1, 2, 3 with manually corrected sextant readings

Hs1	14°55.0′
cor. +	6.9
Ho1	15°01.9

```
GMT2   10.0204
GMT1    6.3116
        3.3048 ΔGMT
knots      15.
          52.7 DMG
Rel.Az1   17.7
 .8367192672 Ho1 cor.
Ho1     1501.9
 15.86838593 Ho1 ctd
Ho2     3944.1
Dec 2   -1728.5
L DR     3316.6
  7.99008987 AX2
GHA2   32708.9
GHA1   27427.2
        52.695 ΔGHA
Dec 1   -1730.8
 4.896602316 X2
 3236.472864 L
 2822.957381 λ

32°36.5' N, 28° 23.0' E
```

NG1-40-1, 2, 3 with manually corrected sextant readings and LHA at the time of the first observation

Hs2	39°34.8′
cor. +	9.3
Ho2	39°44.1

```
GMT2   10.0204
GMT1    6.3116
        3.3048 ΔGMT
knots      15.
          52.7 DMG
Rel.Az1   17.7
 .8367192672 Ho1 cor.
H01     1501.9
 15.86838593 Ho1 otd
Ho2     3944.1
EXC     39.735 Ho1 otd
 15.86838593 Ho2
Dec 1   -1730.8
LDR      3316.6
 46.54019444 AX1
GHA1   27427.2
GHA2   32708.9
        52.695 ΔGHA
Dec 2   -1728.5
 47.37755451 X1
 3236.472864 L
 2822.957381 λ

32°36.5'N, 28°23.0'E
```

SECOND SOLUTION, by the Marcq St. Hilaire method, using existing cards.

To my knowledge, the Texas Instruments Navigation Library for the SR-52 calculator does not yet include cards for a running fix in celestial navigation. Consequently there is no program to determine the position by a double observation of the sun by advancing the earlier line of position to the time of the second observation, as described in the *American Practical Navigator* [5], although this method would be of great use in navigation.

The K-12 method, however, provides the solution to this problem, utilizing the same single program. This means that different programs are not needed for different celestial bodies as is the case at present in the existing Texas Instruments Navigation Library for SR-52 calculators.

EXAMPLE 3 : 21 February 1950, L_{DR} 34° 51.5′ N, λ_{DR} 38° 06.4′ W;

For nearly simultaneous sights of the sun and moon, and with the lower limbs as listed below, find the position at the time of the second sight, using the Texas Instruments SR-52 programmable calculator.

No.	NAME	GMT	Hs	GHA	Dec	MA	IC	SD	HP	EYE
1	SUN	17ʰ26ᵐ40.8ˢ	30°40.5′	78°13.9′	– 10°34.7′		+ 0.9′	16.2′	–	21 ft
2	MOON	17 27 01.8	64 53.5	29 08.8	+ 11 38.7	E	+ 0.9	14.8	54.4	21 ft

FIRST SOLUTION, by the K-12 method, using newly programmed cards and the PC-100 printer

NG1-40-1, 2, 3 preceded by existing sextant correction card NG1-21

```
Hs1        3040. 5
IC            0. 9
SD           16. 2
Eye          21.
  30. 51323419 Ho1
            1. Sight No

Hs2        6453. 5
IC            0. 9
SD           14. 8
Eye          21.
HP           54. 4
  65. 27110322 Ho2
            2. Sight No

GMT2  17. 27018
GMT1  17. 26408
         0. 0021 ΔGMT
knots        0.
             0. DMG
Rel.Az1      0.
             0. Ho1 cor.
  30. 85898386 Ho1 ctd
Dec 2     1138. 7
LDR       3451. 5
  17. 55180768 AX2
GHA2      2908. 8
GHA1      7813. 9
       49. 085 ΔGHA
Dec 1    -1034. 7
  18. 01481852 X2
  3447. 302053 L
 -3808. 826975 λ

34°47.3′N, 38°08.8′W
```

NG1-40-1, 2, 3 with manually corrected sextant readings

Hs1	30°40.5′
IC +	0.9
cor. +	10.2
Ho1	30°51.6′
Hs2	64 53.5
IC +	0.9
cor. +	32.9
Ho2	65°27.3′

```
GMT2  17. 27018
GMT1  17. 26408
         0. 0021 ΔGMT
knots        0.
             0. DMG
Rel.Az1      0.
             0. Ho1 cor.
Ho1       3051. 6
          30. 86 Ho1 ctd
Ho2       6527. 3
Dec 2     1138. 7
L DR      3451. 5
  17. 53972679 AX2
GHA2      2908. 8
GHA1      7813. 9
       49. 085 ΔGHA
Dec 1    -1034. 7
  18. 01566153 X2
  3447. 187008 L
 -3808. 801911 λ

34°47.2′N, 38°08.8′W
```

For simultaneous or nearly simultaneous observations this is enough

Note :

1. Manual corrections of sextant readings can easily be taken from Altitude Correction Tables in the *American Nautical Almanac.*
2. For simultaneous or nearly simultaneous observations it is not necessary to take the compass azimuth or compute T.Az1 of the 1st body because Ho1 cor. is zero or nearly zero, therefore the procedure can start at the half way with Ho1.

SECOND SOLUTION, by the Marcq St. Hilaire method, using existing cards :

NG1-21 sextant correction, NG1-22 for sight reduction – sun, NG1-23 for sight reduction – moon, NG1-26 for fix by two observations – and the PC-100 Printer.

Additional entering data :

No.	NAME	GHA for 17^h GMT	ν	Dec for 17^h GMT	d
1	SUN	71°33.7′	–	– 10°35.1′	+ 1.8′
2	MOON	22 34.5	+ 16.3′	+ 11 32.8	+ 13.2

Note :

1. When executing the program NG1-21, if any entering data or labels are erroneously entered then the instructions given in the Program Manual should be strictly followed. Otherwise improper storage of observed altitudes will result, and the intercept and fix will be erroneous. The same holds true for the Sight Reduction programs since these programs do not permit an error made under any label to be obliterated by pressing the CLR key and reentering at the step corresponding to the label like the NG1-40-1, 2, 3 program. Furthermore, the NG1-40-1, 2, 3 procedure has the advantage of being shorter.
2. In this example the computed altitudes for the sun and moon obtained by the Sight Reduction Programs differ from those calculated with the aid of Nautical Tables. Accordingly, the fix coordinates obtained with cards NG1-21, NG1-22, NG1-23 and NG1-26 show a difference in latitude of 0.4′, and of 0.3′ in longitude. The fix calculated by the newly programmed cards NG1-40-1, 2, 3 is very accurate and differs only by 0.1′ in latitude from the position 34°47.1′N, 38°08.8′W which was calculated with the aid of conventional tables and plotting of position lines.

```
Hs1        3040.5
IC            0.9
SD           16.2
Eye          21.
  30.51323419 Ho1
         1.Sight No

Hs2        6453.5
IC            0.9
SD           14.8
Eye          21.
HP           54.4
  65.27110322 Ho2
         2.Sight No

L DR       3451.5
λ DR       3806.4
msGMT   0.26408
GHR h GMT  7133.7
d             1.8
Dec     -1035.1
  30.47328387 Hc1
  3.991719772 a1
  227.5174851 Zn1
         1.Sight No

msGMT   0.27018
ν            16.3
GHA h GMT  2234.5
d            13.2
Dec        1132.8
  65.24034793 Hc2
  3.125882377 a2
  158.5047249 Zn2
         2.Sight No

Sight No       1.
Sight No       2.
  3808.492297 λ
  3447.475433 L
34°47.5'N, 38°08.5'W
```

THIRD SOLUTION, by the Marcq St. Hilaire method using from the K-12 program two of the newly programmed cards (NG1-40-1,3) and Printer PC-100 to obtain intercepts and azimuths. The intersection of position lines (fix) is obtained either by using existing card NGl-26 or graphically.

Additional entering data

No.	NAME	MA
1	SUN	40°07.5′W
2	MOON	8 57.6 E

NG1-40-1, 3 with sextant readings corrected manually and fix coordinates obtained graphically

```
          SUN
Dec     -1034.7
LDR      3451.5
MA       4007.5
         STO 14
Ho       3051.6
  3047.241836 Hc
  4.369273489 a1
   227.512703 Zn1
          MOON
Dec      1138.7
LDR      3451.5
MA        857.6
         STO 14
Ho       6527.3
  6524.006864 Hc
  3.304247011 a2
  158.5041161 Zn2
```

Fix

Coordinates at intersection of position lines plotted graphically :
L34°47.1′N, λ 38°08.8′W

NG1-40-1, 3 with sextant readings corrected manually and fix coordinates obtained with NGl-26

```
          SUN
Dec     -1034.7
LDR      3451.5
MA       4007.5
         STO 14
Ho       3051.6
  3047.241836 Hc
  4.369273489 a1
   227.512703 Zn1
          MOON
Dec      1138.7
LDR      3451.5
MA        857.6
         STO 14
Ho       6527.3
  6524.006864 Hc
  3.304247011 a2
  158.5041161 Zn2
           Fix
a1            4.4 STO 08
Zn1         227.5 STO 09
a2            3.3 STO 10
Zn2         158.5 STO 11
LDR      3451.5
λDR      3806.4
Sight No.     1.
Sight No.     2.
  3808.833719 λ
  3447.177664 L
34°47.2′N, 38°08.8′W
```

NG1-40-1, 3 preceded by existing sextant correction card NG1-21 and followed by NG1-26 to obtain the fix coordinates

```
  30.51323419
  3051.5      1. Ho1

  65.27110322
  6527.2      2. Ho2
          SUN
Dec     -1034.7
LDR      3451.5
MA       4007.5
         STO 14
Ho1      3051.5
  3047.241836 Hc
  4.269273486 a1
   227.512703 Zn1
          MOON
Dec      1138.7
LDR      3451.5
MA        857.6
         STO 14
Ho2      6527.2
  6524.006864 Hc
  3.204247008 a2
  158.5041161 Zn2
           Fix
a1            4.3 STO 08
Zn1         227.5 STO 09
a2            3.2 STO 10
Zn2         158.5 STO 11
LDR      3451.5
λDR      3806.4
Sight No.     1.
Sight No.     2.
  3808.800456 λ
  3447.295894 L
34°47.3′N, 38°08.8′W
```

DISCUSSION AND CONCLUSION

The possibilities realized by the K-12 method using the SR-52 programmable hand-held calculator differ considerably from the results given by the mini-computers Galaxy 1 and Interceptor which were described by the author in an earlier paper [6]. The K-12 method is primarily a direct method giving the latitude and longitude of the position, whilst Galaxy 1 and Interceptor give only the intercept and azimuth, like the second version of the K-12 method. However, modern inspection tables such as my Tables K-21 (described in reference [6]) provide the computed altitudes and azimuths in a very simple way, like the calendar which gives the name of the holiday when entering with the year, month and date. Such tables give the navigator less chance of making an error than when using a calculator, because in the use of the calculator buttons must be pressed repeatedly in a strictly scheduled sequence, and the calculator procedures also involve the entering of different units and the need for careful tracking of the decimal point. Nevertheless, with Tables K-21 it is further necessary to find the altitude differences (intercepts) and plot the position lines in order to obtain the latitude and longitude of the position.

It should also be noted that the price of the tables is considerably less than that of a programmable calculator and its magnetic cards, and that caution notes printed in users' instructions for these calculators recommend that navigators should take, along with the calculator, the adequate navigation tables as insurance against a failure of the calculator or programmed material.

Bearing all this in mind, I would like to conclude with the same words as I did in my former paper: "Let us leave navigators the major responsibility of deciding which of the accessories available — tables or electronic gadgets — they will use for their onboard calculations."

Meanwhile, it is evident that the capacity of hand-held programmable calculators is constantly expanding, with larger numbers of program steps and addressable memory registers. The application of microprocessors integrated with a precision quartz chronometer has advanced them into the miniature-computer state, bringing them closer to their bigger electronic brothers (computers), which enables simplification of the K-12 method program.

Consequently, we can expect in the future a preference for the programmable calculator or mini-computer, with their capability to compute not only the intercept and azimuth but also directly the latitude and longitude of the fix. Accordingly, the K-12 method, with a single program for the solution of all positioning problems in celestial navigation, might be of interest to producers of hand-held programmable calculators or, with certain modification, also to producers of mini-computers. In this connection, any interested manufacturers of hand-held programmable calculators may refer directly to the author to obtain the step-by-step procedure and other documents and also his permission to insert the K-12 method and the cards in their navigation pac.

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