11 September 2019

Celestial Navigation Workbook User's Guide … 15.10

Warning: Not for on the water navigation. Although this workbook provides **fairly accurate** results its only purpose is educational and is not to be used for on the water navigation.

The following 3 Excel Add-ins must be available for this workbook to function:

- **Analysis Tool Pak**
- **Analysis Tool Pak VBA**
- **Solver Add-in**

How to activate Excel Add-Ins

The **Nav Bodies** & **Sight Log** worksheets are the core of this workbook. The Sight Log ID specified in the **Nav Bodies** worksheet determines the , date, time & DR position which is used by many of the other worksheets.

This workbook contains 157 Macros. When opening this workbook you may, depending on the security level you have set for **Excel**, get a Security Warning Message which will allow you to **Enable** or **Disable** Macros. Select **Enable Macros**.

All cells of the workbook are protected except for the user data entry cells. This prevents the inadvertent modification of cells containing formulas use to calculate the results. The user data entry cells for all worksheets except the **sight Log** worksheet have a Yellow background. The user data entry cells of the **Sight Log** worksheet have a white, Lite Green or Pink background. Cells with a **red triangle** in the upper right hand corner have an explanatory note attached. To view the note place the cursor on the cell and the note will be displayed.

Units associated with cells use abbreviations & acronyms from ***The American Practical Navigator*** **"Bowditch" Pub No.9 2002 Bicentennial Edition.**

The worksheets in this workbook were formatted using the **Auto-hide Ribbon** option for viewing on my **HP w2558hc** display screen with a resolution of **1920 x 1200 pixels**. You can resize the worksheet to fit on your computer screen by selecting the range of cells to view, then click on **View** then select **Zoom** from the drop down menu and select the appropriate size for your display screen. Several worksheets use drop down list for selecting the celestial body. If the font is too small to read the celestial body names, select **View** from the menu bar & then **Zoom** to **100%**. The print area has been pre-set, just click on **Print Pre-view** to see what will be on the printed page; also on most worksheets you can select what you want to print.

The initial development of this workbook started in 2004. In 2009 this Workbook won **BEST OF SHOW** as a Teaching Aid at the United States Power Squadrons® District 16 Fall Conference.

For a quick start guide on how to use the **Sight Log** with other worksheets to reduce a series of celestial sights & plot the LOPs to determine a celestial fix click on the Bookmark Link shown below:

The Six Step Process for using the Sight Log worksheet

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Interpolation & Data Conversion Worksheet

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Rhumb Line Distance vs. Great Circle Distance Worksheet

Tides Worksheet

Nav Bodies Worksheet

Sun	Moon	Venus	Mars	Jupiter	Saturn	Stars	Aires
☉	☾	♀	♂	♃	♄	★	♈

Given latitude (L), longitude (Lo), date & zone time, this worksheet calculates the following data:

		☉	☾	♀	♂	♃	♄	★	♈
Greenwich Hour Angle	**GHA**	■	■	■	■	■	■	■	■
Local Hour Angle	**LHA**	■	■	■	■	■	■	■	■
Sidereal Hour Angle	**SHA**	■	■	■	■	■	■	■	
Declination	**Dec**	■	■	■	■	■	■	■	
Azimuth Angle	**Zn**	■	■	■	■	■	■	■	
Altitude	**Hc**	■	■	■	■	■	■	■	
Parallax in Altitude	**PA**	■	■	■	■				
Semi-Diameter	**SD**	■	■						
Refraction	**Ro**	■	■	■	■	■	■		
Visual Magnitude		■	■	■	■	■	■	■	
Local Mean Time	**LMT**	■							
Local Apparent Time	**LAT**	■							
Distance in Astronomical Units	**AU**	■		■	■	■	■		
Zone Time of Start AM Astronomical Twilight		■							
Zone Time of Start AM Nautical Twilight		■							
Zone Time of Start AM Civil Twilight		■							
Zone Time of Rise		■	■	■	■	■	■		
Zone Time of Meridian Transit		■	■	■	■	■	■		
Zone Time of Set		■	■	■	■	■	■		
Zone Time of End PM Civil Twilight		■							
Zone Time of End PM Nautical Twilight		■							
Zone Time of End PM Astronomical Twilight		■							
Altitude on the Prime Vertical Circle		■							
Greenwich Date & Time of Vernal Equinox		■							
Greenwich Date & Time of Summer Solstice		■							
Greenwich Date & Time of Autumnal Equinox		■							
Greenwich Date & Time of Winter Solstice		■							
Equation of Time		■							
Duration of Day		■							
Distance in kilometers			■						
Greenwich Date & Time of New Moon			■						
Greenwich Date & Time of First Quarter			■						
Greenwich Date & Time of Full Moon			■						
Greenwich Date & Time of Last Quarter			■						
Age (Days past New Moon)			■						
Illumination %			■						

Calculations by the **Nav Bodies** worksheet are based on **Astronomical Algorithms** second edition by Jean Meeus (ISBN 0-943396-61-1) and those shown on pages 277 --> 285 of ***The Nautical Almanac***.

The Planet data is based on the most important periodic terms from the French planetary theory VSOP87. For the Earth the full set of 2,425 periodic terms from the French planetary theory VSOP87 are used. For additional information on accuracy see chapter 2 "**About Accuracy**" in the second edition of **Astronomical Algorithms** by Jean Meeus. (ISBN 0-943396-61-1)

The Moon's position is calculated using the most important periodic terms from the ELP-2000/82 theory and has an accuracy of 0.17' for GHA & 0.07' for Dec.

Note: The values for GHA of Aries, GHA & DEC for the Sun, Moon, planets & stars calculated by this workbook agree with the data in the ***Nautical Almanac*** within the accuracy stated in paragraph 24 on Page 261 of the ***Nautical Almanac*** . Cells with a small red triangle in the upper right hand corner have an attached note. To view the note place the cursor on the cell. This worksheet is useful as a quick check on sight reductions when used in conjunction with the **SR96** & **Sight Planning** worksheets.

Excerpts from The ***Nautical Almanac*** provided with the 2008 Edition of The Navigation Course Student Manuals were taken from the 2004 ***Nautical Almanac***. Whereas the 2007 Edition of the Junior Navigation Course Student Manuals provided Excerpts from the 1972 ***Nautical Almanac***, which was used by all previous editions of the JN & N Student Manuals since the 1973 Edition of the JN Student Manual and the 1975 Edition of the N Student Manual. When checking JN Homework & Exams set the year (Cell B4) to 1972 and for N Homework & Exams set the year to 2004.

Data Entry Option 1: Enter the Sight Log ID and click on the yellow bar labeled "Enter Sight Log ID & click this yellow bar to get Body, Zone Time & DR Position from the Sight Log". This will extract the Body, DR Position, Date & Zone Time from the **Sight Log** worksheet.

Data Entry Option 2: Enter all required data manually.

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Sight Log Worksheet

The **Sight Log** worksheet provides for the recording of data associated with up to 255 Celestial Sights. Each row of the **Sight Log** worksheet is identified by a unique Sight Log ID & contains data for a single celestial sight. To start your personal sight Log, click the "Clear Page 1 Data" yellow bar and enter your name into Cell P4. Next for each sight, enter the sextant altitude & other data associated with taking a sextant observation of a celestial body into columns C through AC (See **Step 1** of the six step process for using the **Sight Log** worksheet). Then enter the Greenwich Hour Angle (GHA), Declination (Dec) and other such data needed for reducing a celestial sight from ***The Nautical Almanac*** @ the whole Greenwich hour into columns BB through BL.
(See **Step 2** of the six step process for using the **Sight Log** worksheet).

As a data entry aid for inputting sight strings, a macro is provided at the top of each Sight Log Page via a Yellow bar labeled "Click To Copy". After entering all the data for the first sight in a string of sights (Step 1 & Step 2 of the six step process for using the **Sight Log** worksheet), enter it's Sight Log ID into the yellow cell in column W & the Sight Log ID of the last sight in the string into the yellow cell in column AA, then click on the yellow bar labeled "Click To Copy". Example if the Sight log ID of the first sight in a string of 9 sights is 8 then then the Sight Log ID of the last sight in the string would be 16 (8+9-1 = 16). **Next enter the correct watch time (column I) & sextant altitude (Columns K & L) for the second through the last sight in the sight string.**

The following 14 worksheets can use the **Sight Log** Worksheet to retrieve and/or store data associated with a Celestial Sights via the Sight Log ID:

Nav Bodies
SR 96
Sight Reduction
NASR
HO 229
CLS SAPS
Sight Averaging
Meridian Transit
DR 2 Body Fix
AP 2 Body Fix
DR 3 Body Fix
AP 3 Body Fix
Fix Sans DR
Fix by DC

Click to view the Six Step Process for using the Sight Log worksheet

An unlimited number of celestial sights can be stored when used in conjunction with the **My Sight Log Archive** workbook via the Export Sight Log & Import Sight Log macros. To use either the Export Sight Log or Import Sight Log macros the Excel Workbook **My Sight Log Archive** must be open.

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Using the Export Sight Log macro

Step 1 Open the Excel macro enabled workbook named **MY Sight Log Archive** and select a BLANK worksheet named Sheet1 as the active worksheet. If the **MY Sight Log Archive** workbook does not exist ... create it. If a BLANK worksheet does not exist within the **My Sight Log Archive** workbook ...create a BLANK worksheet named Sheet1. A BLANK worksheet is an unprotected worksheet containing no data or formulas & the name must be Sheet1. The **My Sight Log Archive** workbook can contain as many worksheets as needed, allowing the user to essentially store an unlimited number of sights.

Step 2 Open the **Celestial Navigation** workbook & select the Sight Log worksheet as the active worksheet. Enter the name into Cell E4 that you wish to assign to Sheet1 after exporting the Sight Log data. Then click the Export Sight Log button, this will copy the total contents of the **Sight Log** worksheet to the **MY Sight Log Archive** workbook Sheet1 worksheet and rename the Sheet1 worksheet with the name in Cell E4 of the **Sight Log** worksheet.

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Using the Import Sight Log macro

Step 1 Open the Excel macro enabled workbook named **MY Sight Log Archive** and select as the active worksheet, the worksheet containing the data you wish to import into the **Sight Log** worksheet of the **Celestial Navigation** workbook.
Note: When you open the **MY Sight Log Archive** you may receive the following message: "This workbook contains links to one or more external sources that could be unsafe. If you trust the links, update them to get the latest data; otherwise, you can keep working with the data you have" select "Do not update" The external link is to the list of navigation bodies contained in the **Nav Bodies** worksheet of the **Celestial Navigation** workbook. You do not need to update the list as it does not change. Having the list of navigation bodies in the **MY Sight Log Archive** workbook allows you to enter additional sextant sight data into any worksheet of the **MY Sight Log Archive** workbook.

Step 2 Open the **Celestial Navigation** workbook & select the **Sight Log** worksheet as the active worksheet. Then click the Import Sight Log button, this will copy the content of the active worksheet of the **MY Sight Log Archive** workbook into the Sight Log worksheet of the **Celestial Navigation** workbook, replacing ALL of the data in the **Sight Log** worksheet.

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The Six Step Process for using the **Sight Log** worksheet:

Step 1 Enter the sextant altitude & other data associated with taking a series of celestial sights.
For each Sight Log ID the user must enter the following data:

Parameter	Sight Log Column	♣ Default Value	‡ Select from Drop Down List
Sight Number	C		
Date of Sight	D		
Name of Body being observed	E		Yes
Watch Error … f / s	F		Yes
Watch Error	G	00:00:00	
Zone Description	H		
Watch Time	I		
Standard Time (ST) or Daylight Saving Time (DST)	J	ST	Yes
Sextant Altitude deg.	K		
Sextant Altitude min.	L		
Sextant Index Correction (IC) min.	M		
Height of Eye in units of Feet	N		
Type of Horizon … Natural / Dip Short	O	Natural	Yes
Dip Short Distance (Leave Blank if Natural Horizon)	E		
Dip short Distance Units … Yards / Meters / n. mi.	Q	Yards	Yes
Bearing to Body … N / NE / E / SE / S / SW / W / NW	R		Yes
Observer's Latitude deg.	S		
Observer's Latitude min.	T		
Observer's Latitude … N / S	U		Yes
Observer's Longitude deg.	V		
Observer's Longitude min.	W		
Observer's Longitude … E / W	X		Yes
Temperature	Y	10	
Temperature Units … F / C	Z	C	Yes
Pressure	AA	1010	
Pressure Units … mb / "Hg	AB	mb	Yes
Remarks	AC		

♣ Default Value is used If the associated Sight Log Column is blank (no data value is entered).

‡ Select from Drop Down List (If Yes … Do not manually type in a value).

Sight strings are separated by a blank line. Sight strings can span pages. For example if Sight Log IDs 56, 57, 58, 69 & 70 all contain data, then those 5 sights are considered as one sight string.

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Step 2 For each Sight Log ID enter values for the parameters listed below from ***The Nautical Almanac*** @ the whole Greenwich hour. (the Greenwich Date & GMT are shown in Columns BM to BR). Apply the correct sign (±) to the parameters ***v*** & ***d***

Parameter	Comment	Sight Log Column
SHA deg.	Only for Stars ... For other Bodies leave blank	BB
SHA min.	Only for Stars ... For other Bodies leave blank	BC
GHA deg.		BD
GHA min.		BE
v	For Moon, Venus, Mars, Jupiter & Saturn	BF
HP	For Moon, Venus & Mars	BG
	Not Used Leave Blank	BH
Dec deg.		BI
Dec min.		BJ
Dec N/S	Select frim Drop Down List	BK
d	For Sun, Moon, Venus, Mars, Jupiter & Saturn	BL

Step 3 Use the **Nav Bodies** worksheet to specify the Sight Log ID to use & then click on the yellow bar labeled "Enter Sight Log ID & click this yellow bar to get Body, Zone Time & DR Position from the Sight Log". This will extract the Body, DR Position, Date & Zone Time from the **Sight Log** worksheet.

Step 4 Use the **SR 96** worksheet & click "Get Sight Log Data" to calculate Ho, Hc, intercept & Zn from the DR Position using the Law of Cosines method.

Next click "Store Sight Log Data" to store the calculated values of Ho, Hc, intercept & Zn from the DR Position in the **Sight Log** worksheet.

Step 5 Use the **Sight Reduction** Worksheet & click "Get Sight Log Data" to extract the data needed from the Sight Log to calculate Hc, intercept & Zn from an Assumed Position using the NASR & H. O. 229 methods. Next click "Store Sight Log Data" to store the calculated values back into the **Sight Log** worksheet. The worksheets **NASR** & **HO 229** can also be used to calculate Hc, intercept & Zn from an Assumed Position.

Step 6 Repeat steps 3, 4 & 5 as needed, then use the **CLS SAPS** worksheet & enter up to 3 Sight Log IDs & click on the yellow bar labeled "Enter Sight Log IDs & Click to Get Data from Sight Log" to retrieve intercept & Zn data values from the **Sight Log** Worksheet to plot the LOPs from up to 3 sights on a facsimile of a CLS 98 Plotting sheet to determine the coordinates of a celestial fix.

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Procedure for checking Sight Folders with the Celestial Navigation workbook

Total Time required to check a sight folder is approximately one hour.

Step 1 ... Time required about 4 minutes per sight. (At the present time this is six sights.
For each sight that was reduced, enter the data from student's Sight Folder Sight Log into columns C through AC of the **Sight Log** worksheet. Double check that data in the student's Sight Folder Sight Log & the entries you made in the **Sight Log** worksheet are identical. See Step 1 of the Six Step Process for using the **Sight Log** for additional information**.**

Step 2 ... Time required about 2 minutes per sight. (At the present time this is six sights.)
For each sight that was reduced, enter the required data from ***The Nautical Almanac*** into columns BB through BL of the **Sight Log** worksheet at the whole hour (GMT) for the Greenwich date of the sight. Double check that the data in ***The Nautical Almanac*** and the entries you made in the **Sight Log** worksheet are identical. See Step 2 of the Six Step Process for using the **Sight Log** for additional information**.**

Step 3 ... Time required about 4 minutes per sight. (At the present time this is six sights.)
For each of the six sights that were reduced perform the following :

- Use the **Nav Bodies** worksheet enter the Sight Log ID into cell M3 & click "Get Data from Sight Log bar" (Step 3 of the Six Step Process for using the **Sight Log**).
  If the body is a star or planet, verify that the Hc of the Sun (Nav Bodies Cells E24 & G24) is reasonable for a star or planet sight. See the excerpts from 2002 & 2019 Editions of Bowditch.

  Excerpt from the 2002 Edition of Bowditch, Page 291, Paragraph 1910.
  "Twilight ..... In general, the most effective period for observing stars and planets occurs when the center of the Sun is between about 3° and 9° below the celestial horizon. ...."

  Excerpt from the 2019 Edition of Bowditch, Page 310, Paragraph 1801.
  " … Except for sights of the Sun, Moon, and sometimes Venus and Jupiter, all other bodies used in celestial navigation sights can be measured only during nautical twilight, the period during which the center of the Sun is between 6° and 12° below the celestial horizon. During this period the sky is dark enough to make out the celestial bodies used for sights, but bright enough that the horizon is well enough defined to take an accurate sight. …"

- Next use the **SR 96** worksheet & click "Get Sight Log Data" bar. Verify that Law of Cosines (**LOC**) intercept (a) & Zn values from the SR 96 Form agree with values in the **SR 96** worksheet & if not why not. Click "Store Sight Log Data" bar to store Total GHA, Dec, Hc, Ho, Intercept (a) & Zn in the Sight Log. (Step 4 of the Six Step Process for using the **Sight Log**).

- Then use the **Sight Reduction** worksheet & click "Get Sight Log Data" bar. Note that the Total GHA used by this worksheet was calculated and stored in the **Sight Log** worksheet by the **SR 96** worksheet. Verify that the NASR option is selected & verify that the intercept (a) & Zn values on the back of the SR 96a Form agree & if not why not. Also verify that the Time Diagram on the SR 96 Form agrees with the Time Diagram displayed in the **Sight Reduction** worksheet.
  As an option the **NASR** worksheets can be used to check the values on the back of the SR 96a Form & the **HO 229** worksheet can be used to check the values on the back of the SR 96b Form. Note that the Total GHA used by the **NASR** & **HO 229** worksheets was calculated and stored in the **Sight Log** worksheet by the **SR 96** worksheet. Click "Store Sight Log Data" bar to store the data needed to plot the LOP from the assumed position. (Step 5 of the Six Step Process for using the **Sight Log**).

- Using the **CLS SAPS** worksheet enter the required Sight Log IDs & click "Get Data from Sight Log" bar. Select "Plot LOPs from AP" or "Plot LOPs from DR" and enter the Mid Latitude & Center Longitude used on the CLS 98 Form & compare the **CLS SAPS** worksheet plot with the CLS 98 Form. Position the red cross hairs at the Fix or EP shown on the **CLS SAPS** worksheet plot. Verify the values listed on the CLS 98 Form agree with the values obtained from the **CLS SAPS** worksheet plot. The values should agree within ±0.5 arc minutes. (Step 6 of the Six Step Process for using the **Sight Log**).

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Sight Planning Worksheet

Step 1 Select the **Nav Bodies** worksheet & click on the "Clear User Data" Box.

Step 2 Enter the DR Position, Date & Zone Time of planned sight taking activity. When planning sights of stars & planets consider the following excerpts from Bowditch.

Excerpt from the 2002 Edition of Bowditch, Page 291, Paragraph 1910.
"Twilight ..... In general, the most effective period for observing stars and planets occurs when the center of the Sun is between about 3° and 9° below the celestial horizon. ...."

Excerpt from the 2019 Edition of Bowditch, Page 310, Paragraph 1801.
" … Except for sights of the Sun, Moon, and sometimes Venus and Jupiter, all other bodies used in celestial navigation sights can be measured only during nautical twilight, the period during which the center of the Sun is between 6° and 12° below the celestial horizon. During this period the sky is dark enough to make out the celestial bodies used for sights, but bright enough that the horizon is well enough defined to take an accurate sight. …"

Step 3 Select the **Sight Planning** worksheet to specify the altitude range & magnitude of bodies to flag as "Valid for Sight Taking" (cells O29:O37). Bodies flagged as "Valid for Sight Taking" will then be shown in cells Q1:V38 sorted by Zn values.

The Altitude of the Sun at the position & Time of the planned sight taking activity will be displayed in Cell K36. The value of the Sun's altitude shown in Cell K36 must be less than or equal to the value specified in cell O35 & greater than or equal to the value in cell O37.

For a Two body fix select 1st Body & use a value of Zn near one of the values shown in the Gold Cells (G9 & K9) as a guide for selecting the 2nd Body of a Two Body Fix

For a Three body fix select 1st Body & use values of Zn near the values shown in the Gold cells (I19 & G22) as a guide for selecting the 2nd & 3rd Bodies of a Three Body Fix.

This worksheet also provides data needed to add the Sun, Moon & Planets to the base of the HO 2102D Star Finder & Identifier.

This worksheet also calculates the Greenwich Date & Time of the New Moon First Quarter, Full Moon & Last Quarter.

The Geocentric Lunar Distance to visible bodies is also provided.

For additional information see Chapter 18, Sight Planning, in the 2019 Edition of Bowditch .

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Sight Averaging Worksheet

The **Sight Averaging** worksheet can be used to plot a string of up to 10 sights & calculate the average sextant altitude & calculate a sextant altitude for a specified time.

Given time & sextant altitude (hs) for up to 10 sights taken over a short period of time, this worksheet calculates the average time & average sextant altitude (hs). A plot of sextant altitude (hs) vs. time is provided to help identify any bad sights in the string of sights. To remove a "bad" sight from the list of sights, click on the yellow square associated with the sight to be removed. The time of each sight must be increasing with sight number. Sight number 1 must contain a valid time & sextant altitude (hs). If you consider sight #1 "bad", replace it with the next "good" sight in your sight string.

The trend line will not be valid if the sight string contains sights taken both before and after meridian transit. Use the "**Meridian Transit**" worksheet to Plot sights taken during a meridian transit event.

The parameters Body, Limb, Date, DR L, DR Lo, DST, HE, IC, Atmospheric Pressure, Air Temperature, Horizon, & Dip Short Distance are for sight documentation purposes only.

Data Entry Option 1: Enter the Sight Log ID for the first sight in a string of sights that you want to average & the Blank line separating sight strings defines the last sight to use. Next click on the yellow bar labeled “Get Sight Log Data”. All required data will be extracted from the Sight Log.

Data Entry Option 2: Enter all required data manually.

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Meridian Transit Worksheet

The **Meridian Transit** worksheet is used to plot a string of up to 13 sights taken during a meridian transit event to calculate the maximum sextant altitude & time associated with meridian transit of a body. For best results approximately half of the sights should be before meridian transit & approximately half of the sights after meridian transit. Minimum number of sights is 3, Maximum number of sights is 13. Results are not valid for Sextant Altitudes > 88° ..... Therefore the difference in DR Lat & Declination of the Body should be greater than ± 2°

Given time & sextant altitude (hs) for 3 to 13 sights taken over a short period of time (» 6 minutes) starting before Meridian Transit and continuing for a short time (» 6 minutes) after Meridian Transit, this worksheet calculates a second order polynomial trend line . A plot of sextant altitude (hs) vs. time is provided to help identify any bad sights in the string of sights. To remove a "bad" sight from the list of sights, click on the yellow square associated with the sight to be removed. The time of each sight must be increasing with sight number. Sight number 1 must contain a valid time & sextant altitude (hs). If you consider sight #1 "bad", replace it with the next "good" sight in your sight string.

The method used in this worksheet does not account for the change in declination of the body during the time span (approximately 12 minutes or 0.2 hours) of sights taking. The maximum rate of change in the Sun's declination (1.0 arc minute per hour) occurs around the time of the Vernal Equinox & the Autumnal Equinox. The maximum change in the Sun's declination while taking the string of sights is approximately 0.2 arc minutes (0.2 x 1.0 = 0.2). Also this method assumes a fixed position while taking the sights. The trend line represents a second order polynomial fit of the data.

The parameters DR L, DR Lo, Date, GHA, Dec, HE, IC, Atmospheric Pressure, Air Temperature, Horizon, & Dip Short Distance are for calculating Latitude from MT sight and for sight documentation purposes.

Given declination (Dec) & observed altitude (Ho) & time of sight taken at meridian transit of a body, this worksheet calculates the latitude & longitude of the observer.

The parameters Body, Limb, Date, GHA, Dec, DR L , DR Lo, HE, IC, Atmospheric Pressure, Air Temperature, Horizon, & Dip Short Distance are taken from the Meridian Transit Sight Data Plot section of this worksheet.

Data Entry Option 1: Enter the Sight Log ID for the first sight in a string of sights taken during meridian transit & the Blank line separating sight strings defines the last sight to use. Next click on the yellow bar labeled “Get Sight Log Data”. All required data will be extracted from the Sight Log.

Data Entry Option 2: Enter all required data manually.

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SR 96 Worksheet

This worksheet is used for checking data on the front of USPS SR 96a & SR 96b Forms. Use the **Sight Reduction** worksheet for checking the diagram on the plane of the Observer's Celestial Meridian, the Time Diagram & data on the back of ED SR 96a "Sight Reduction by NASR Method" & ED SR 96b "Sight Reduction Tables for Marine Navigation H.O. PUB. NO. 229".

This worksheet provides the calculations needed to convert sextant altitude (hs) to observed altitude (Ho). This worksheet will automatically inserts the correct GHA Increments & Corrections from ***The Nautical Almanac*** based on the GMT minutes and seconds associated with the sight needed to determine the Total GHA, Declination and then calculate Hc, Zn & intercept (a), by the Law of Cosines method .

Data Entry Option 1: Using the Sight Log ID specified in the **Nav Bodies** worksheet.
Click on the yellow bar labeled "Get Sight Log Data" to extract the date, time, and position, name of the body, Greenwich hour angle (GHA) of the body, declination of the body, sextant altitude (hs), IC, height of eye, & type of horizon from the **Sight Log** worksheet. This worksheet will then calculate Ho, Hc, Zn & intercept (a), by the Law of Cosines method. Next click on the yellow bar labeled "Store Sight Log Data" to save the Total GHA, Declination, Ho, Hc, Zn & intercept (a) values calculated by this worksheet in the **Sight Log** worksheet.

Data Entry Option 2: Enter all required data manually. All cells that require user data input are color coded yellow. Results shown in the turquoise cells for Ho, Hc, EP L & EP Lo are not valid until ***The Nautical Almanac*** values of GHA , *v*, DEC, *d* & SHA of the body are entered for the Date & Mean Time @ Greenwich shown in cells D2 & E2. If a user input cell is blank the numeric value associated with that cell is treated as though a numeric value of zero had been entered. Note: The ***Nautical Almanac*** GHA Increments used to calculate Total GHA by this worksheet depends on the following:

- If the Body Name specified is Moon then the Moon Increments will be used. For Moon sights the Limb (UL or LL) is also required for the worksheet to correctly insert the -30.0' correction for Moon UL sights.
- If the SHA specified is greater than 0° 0.0' then the ARIES Increments will be used.
- If the name of the body is other than Moon & SHA is zero, then the Sun & Planets Increments will be used.

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Sight Reduction Worksheet

Given the referance position, Total GHA, Declination & observed altitude (Ho) of a Body the **Sight Reduction** worksheet calculates Hc, Zn & intercept (a), by the Law of Cosines method, NASR method & H. O. Pub. 229 method. This worksheet is used for checking the diagram on the plane of the Observer's Celestial Meridian, the Time Diagram & data on the back of ED SR 96a "Sight Reduction by NASR Method" & ED SR 96b "Sight Reduction Tables for Marine Navigation H.O. PUB. NO. 229".

A detailed, step by step, procedure for manually constructing the meridian diagram on the plane of the observer's celestial meridian is described in columns F through W rows 63 through 92 of this worksheet.

Data Entry Option 1: Using the Sight Log ID specified in the **Nav Bodies** worksheet, click on the yellow bar labeled "Get Sight Log Data" to extract all required data from the **Sight Log** worksheet (date, time, position, name of the body, Total GHA, observed altitude (Ho) & declination of the body). Note that the observed altitude (Ho), Total GHA & Declination used by this worksheet was calculated and stored in the **Sight Log** worksheet by the **SR 96** worksheet. Verify that the NASR method is selected (cell M11) then click on the yellow bar labeled "Store Sight Log Data" to save the values of Hc, Zn & intercept (a) calculated using the NASR method in the **Sight Log** worksheet.

Data Entry Option 2: Enter all required data manually.

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NASR Tables Worksheet

This worksheet provides for the calculations needed to checking the data on the back page of the **SR 96a** Sight Data Reduction Forms.

This worksheet automatically inserts the correct data vales from ***The Nautical Almanac*** concise sight reduction tables".

Data Entry Option 1: Enter the Sight Log ID for the sight that you want to reduce via ***The Nautical Almanac*** **Concise Sight Reduction Tables** & click on the yellow bar labeled "Get Sight Log Data". Note that the Total GHA used by this worksheet was calculated and stored in the **Sight Log** worksheet by the **SR 96** worksheet. All required data will be extracted from the Sight Log. The LOP data calculated by this worksheet can then be saved in the **Sight Log** worksheet. Click "Store Sight Log Data" bar.

Data Entry Option 2: Enter all required data manually. All cells that require user data input are color coded yellow. If a user input cell is blank the numeric value associated with that cell is treated as though a numeric value of zero had been entered. Clear the yellow user data input cells, this is very important to avoid using data from a previous sight. After clearing the user data input cells, enter the appropriate data from the ***Nautical Almanac*** and other data as required from the front of the **SR 96a** Sight Reduction Form.

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H. O. Pub. 229 Sight Reduction Worksheet

This worksheet provides for the calculations needed to checking the data on the USPS SR 75 Form or the back page of the SR 96b Sight Data Reduction Forms.

This worksheet automatically provides the correct data vales from the H. O. Pub. 229 Sight Reduction Tables for Marine Navigation to construct a facsimile of HO 229 Table Excerpt needed for the sight reduction.

All cells that require user data input have a yellow background. If a user input cell is blank the numeric value associated with that cell is treated as though a numeric value of zero had been entered.

Data Entry Option 1: Enter the Sight Log ID for the sight that you want to reduce via the **H. O. Pub. 229 Sight Reduction Tables** & click on the yellow bar labeled "Get Sight Log Data". Note that the Total GHA used by this worksheet was calculated and stored in the **Sight Log** worksheet by the **SR 96** worksheet. All required data will be extracted from the Sight Log. The LOP data calculated by this worksheet can then be saved in the **Sight Log** worksheet. Click "Store Sight Log Data" bar.

Data Entry Option 2: Enter all required data manually. Clear the yellow user data input cells, this is very important to avoid using data from a previous sight. After clearing the user data input cells, enter the appropriate data from the ***Nautical Almanac*** and other data as required from the front of the USPS SR 75 Form or the SR 96b Sight Reduction Form.

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CLS SAPS Worksheet

This worksheet will plot up to 3 LOPs on a facsimile of a Constant Latitude Scale (**CLS**) Small Area Plotting Sheet (**SAPS**).

Click on the Black Arrows to extend the length of Body 1 LOP

Click on the Brown Arrows to extend the length of Body 2 LOP

Click on the Green Arrows to extend the length of Body 3 LOP

The value of the parameter LOP Increment (Cell B19) specifies how far to extend the LOP on each click.

Click on the Red Arrows to move the Red Latitude & Longitude Markers to the Fix Position. The value of the parameter Marker Increment (Cell H19) specifies how far to move the Marker on each click.

Data Entry Option 1: Enter the Number of Bodies (Cell D11) and the Sight Log IDs (Cells D23, D35 & D47) then click on the yellow bar labeled "Get Data from Sight Log". All required data for plotting the LOPs will be extracted from the Sight Log.

Data Entry Option 2: Enter all required data manually.

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Fix Sans DR Worksheet

This worksheet provides the calculations needed to define a Two or Three Body Fix using Intersections of Circles of Equal Altitude.

Given the Observed Altitudes (Ho) of Two or Three Bodies and the Date and Mean Times at Greenwich when the observations were made along with the Greenwich Hour Angle (GHA) and Declination (Dec) of each of the Bodies obtained from ***The Nautical Almanac***.

When the 3 Body Fix is selected, the 3 circles of equal altitude will have 6 intersections. As the user, it is up to you to select the correct intersections to include in the fix calculation. Three of the intersections should be very close to the same position if the sights used were "accurate".

When the 2 Body Fix is selected, the 2 circles of equal altitude will have 2 intersection as the user it is up to you to select the correct intersection as the fix.

Note: You can use Google Earth to plot a Circle of Equal Altitude (CEA). From the Google Earth Menu Bar click Tools and select Ruler. From the Ruler popup dialog box select the Circle tab & set Radius to Nautical Miles. Position the curser at the GP of the body and click once to start the process of drawing the CEA. Drag the curser until the radius in Nautical Miles matches the radius of the CEA and click again to establish the CEA.

Data Entry Option 1: Enter the Sight Log IDs and then click on the yellow bar labeled "Get Data from Sight Log". All required data will be extracted from the Sight Log.

Data Entry Option 2: Enter all required data manually.

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Sumner Line of Position Worksheet

By the end of the 19th century, lines of position and Sumner's method are in common usage. For additional information see the 1843 edition of ***Finding A Ship's Position At Sea*** by Capt. Thomas H. Sumner & the 1826 edition of ***The New American Practical Navigator*** by Nathaniel Bowditch.

Given an observed altitude of the Sun (Ho) and mean time at Greenwich when the observation of the Sun was made along with the following information:

■ Declination of the Sun, GHA of the Sun, Time of Sun's Meridian Passage at Greenwich and the Equation of Time from ***The Nautical Almanac***.

■ Estimated Longitude @ Time the Sight was taken and the user specified Latitude for point B & Increment for calculating Latitude for Points A & C.

This worksheet provides the calculations needed to define the calculated Longitudes associated with the user specified Latitudes of points A, B & C using the method derived by Capt. Thomas H. Sumner.

Points A, B & C define a Line of Position (LOP) from which the observed altitude of the Sun (Ho) would have the same value if taken at the same instant of time from any point along the LOP.

If a message "**Latitude for point X is Not Valid**" appears see the diagram of the Circle of Equal Altitude in cells A68:K88 for valid limits of Latitude associated with the Sun sight data.

Note: Cells AD3:AE108 contain values for Log Rising vs. Time From Noon. Navigators in the 19th Century would have used tables for "LOG. Rising vs. Time From Noon" contained in the 1826 edition of **The New American Practical Navigator** by Nathaniel Bowditch.

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Set & Drift Worksheet

Given the previous fix Latitude & Longitude, the DR position, the new fix Latitude & Longitude and the elapsed time from the previous fix and speed through water & course, this worksheet calculates:

- Set & Drift + Distance Between DR & Fix.
- Track & speed made good through a current, Course & Speed Through Water.
- Course to steer at a given speed through the water to make good a given course through a current Given Course & Speed Through Water.

Definition of terms:

Set … Calculated value for the direction towards which the current flows based on the DR Position & Present Fix coordinates & elapsed time since Previous Fix.

Drift … Calculated value for the speed of the current based on the DR & Present Fix coordinates & elapsed time since Previous Fix.

Track Made Good (TMG) … aka Course Made Good (CMG) is the single resultant direction from the point of departure to point of arrival at any given time. In this instance it is the direction from the Previous Fix to the Present Fix.

Speed Made Good (SMG) … The expression speed made good (SMG) is used to indicate the speed made good along the track made good. In this instance it is measured from the previous Fix to the present Fix.

Speed of Advance (SOA) … The expression speed of advance is used to indicate the speed made along the intended track.

Course to Steer … The direction in which a vessel is steered or intended to be steered, expressed as angular distance from north, usually from 000° at north, clockwise through 360°. Strictly, the term applies to direction through the water, not the direction intended to be made good over the ground.

Drift Angle … Definition 1. The angular difference & direction measured from previous Fix to DR course to the Track Made Good. **Definition 2.** The angular difference & direction measured from the Course to Steer to given (intended) course through a current.

Data Entry Option 1: Enter the new fix Latitude & Longitude, then click on the yellow bar labeled "Click to get DR Position, Previous Fix, Date & Time from Nav Bodies Worksheet". Then enter Speed Through Water & Course to calculate the "course to steer at a given speed through the water to make good a given course through a current".

Data Entry Option 2: Enter all required data manually.

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DR 2 Body Fix .. Two Body Fix from a DR position Worksheet

This worksheet provides the calculations needed to establish the latitude & longitude of a fix from the intercepts, and Azimuths from two celestial sights.

This worksheet also calculates:

- Set & Drift + Distance Between DR & Fix.
- Track & speed made good through a current, Course & Speed Through Water.
- Course to steer at a given speed through the water to make good a given course through a current Given Course & Speed Through Water.

Enter Previous Fix L, Previous Fix Lo, Δ Time Since Previous Fix, the Sight Log ID's for $Body_1$ & $Body_2$ then click on the "Enter Sight Log IDs to get Data from Sight Log" bar.

Next click on the box containing the text "Click To Solve For Fix". The parameter "ψ" indicates the approximate combined accuracy (latitude + longitude) of convergence to the fix location in minutes of arc.

The parameter "Xing θ" is the crossing angle between LOPs for bodies 1 & 2. The ideal crossing angle of the LOPs for a two body fix is 90°.

Note: You must install the Solver "Add-In" to your copy of Excel in order to use this worksheet and you also must enable macros.

Data Entry Option 1: Enter the Sight Log IDs for the 2 sights that you want to use for determining a fix & click on the yellow bar labeled "Get Sight Log Data". All required data will be extracted from the Sight Log.

Data Entry Option 2: Enter all required data manually.

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AP 2 Body Fix ..Two Body Fix from an assumed position Worksheet

This worksheet provides the calculations needed to establish the latitude & longitude of a fix from the intercepts, and azimuths from two celestial sights when using the ***Nautical Almanac*** Sight Reduction Tables or the HO229 Sight Reduction Tables. Booth of these methods require an assumed position (AP).

Enter Previous Fix L, Previous Fix Lo, Δ Time Since Previous Fix, the Sight Log ID's for $Body_1$ & $Body_2$ then click on the "Enter Sight Log IDs to get Data from Sight Log" bar.

Next click on the box containing the text "Click Here To Solve For Fix". The parameter "ψ" indicates the approximate combined accuracy (latitude + longitude) of convergence to the fix location in minutes of arc.

The parameter "Xing θ" is the crossing angle between LOPs of the two bodies. The ideal crossing angle of the LOPs for a two body fix is 90°.

Note: You must install the Solver "Add-In" to your copy of Excel in order to use this worksheet and you also must enable macros.

This worksheet also calculates:

- Set & Drift + Distance Between DR & Fix.
- Track & speed made good through a current, Course & Speed Through Water.
- Course to steer at a given speed through the water to make good a given course through a current Given Course & Speed Through Water.

Data Entry Option 1: Enter the Sight Log IDs for the 2 sights that you want to use for determining a fix & click on the yellow bar labeled "Get Sight Log Data". All required data will be extracted from the Sight Log.

Data Entry Option 2: Enter all required data manually.

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DR 3 Body Fix .. Three Body Fix from a DR position Worksheet

This worksheet provides the calculations needed to establish the latitude & longitude of a fix from the intercepts (a), and azimuths (Zn) from three celestial sights. . This worksheet also calculates the set & drift when the time from the previous fix is provided.

Enter Previous Fix L, Previous Fix Lo, Δ Time Since Previous Fix, the Sight Log ID's for $Body_1$ $Body_2$ & $Body_3$, then click on the "Enter Sight Log IDs to get Data from Sight Log" bar.

Next click on the box containing the text "Click To Solve For Fix". The parameter "ψ" indicates the approximate accuracy (latitude + longitude) of convergence to the coordinates of the fix location in minutes of arc.

The parameter "Xing θ" is the crossing angle of each set of LOPs (e.g. The crossing angle between LOPs for bodies 1 & 2, bodies 1 & 3 and for bodies 2 & 3). The ideal crossing angle for each set of LOPs for a three body fix is 60°.

The set of parameters "X L" & "X Lo" specify the latitude and longitude of the intersection for each set of LOPs. This set of "X L" & "X Lo" coordinates define the vertices of a triangle. The three body fix latitude & fix longitude calculated by this worksheet approximates the center of an inscribed circle within this triangle.

Clicking in sequence each of the individual boxes contain the text "Intersection between LOPs for Bodies 1 & 2", " Intersection between LOPs for Bodies 2&3", and Intersection between LOPs for Bodies 1 & 3" to solve for the positions where each set of LOPs intersect is equivalent to clicking on the box containing the text "Click To Solve For Fix".

Note: You must install the Solver "Add-In" to your copy of Excel in order to use this worksheet and you also must enable macros.

This worksheet also calculates:

- Set & Drift + Distance Between DR & Fix.
- Track & speed made good through a current, Course & Speed Through Water.
- Course to steer at a given speed through the water to make good a given course through a current Given Course & Speed Through Water.

Data Entry Option 1: Enter the Sight Log IDs for the 3 sights that you want to use for determining a fix & click on the yellow bar labeled "Get Sight Log Data". All required data will be extracted from the Sight Log.

Data Entry Option 2: Enter all required data manually.

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AP 3 Body Fix .. Three Body Fix from an assumed position Worksheet

This worksheet is used to calculate the latitude & longitude of a celestial fix when using ***The Nautical Almanac*** or HO 229 Sight Reduction Tables where an assumed position (AP) is required.

Enter Previous Fix L, Previous Fix Lo, Δ Time Since Previous Fix, the Sight Log ID's for $Body_1$, $Body_2$ & $Body_3$, then click on the "Enter Sight Log IDs to get Data from Sight Log" bar.

Next click on the box containing the text "Click Here To Solve For Fix". The parameter "ψ" indicates the approximate accuracy (latitude + longitude) of convergence to the coordinates of the fix location in minutes of arc.

The parameter "Xing Angle" is the crossing angle of each set of LOPs (e.g. The crossing angle between LOPs for bodies 1 & 2, bodies 1 & 3 and for bodies 2 & 3). The ideal crossing angle for each set of LOPs for a three body fix is 60°.

The three body fix latitude & fix longitude calculated by this worksheet approximates the center of an inscribed circle within the triangle formed by the three LOPs..

Note: You must install the Solver "Add-In" to your copy of Excel in order to use this worksheet and you also must enable macros.

This worksheet also calculates:

- Set & Drift + Distance Between DR & Fix.
- Track & speed made good through a current, Course & Speed Through Water.
- Course to steer at a given speed through the water to make good a given course through a current Given Course & Speed Through Water.

Data Entry Option 1: Enter the Sight Log IDs for the 3 sights that you want to use for determining a fix & click on the yellow bar labeled "Get Sight Log Data". All required data will be extracted from the Sight Log.

Data Entry Option 2: Enter all required data manually.

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Fix By Direct Calculation Worksheet

This worksheet provides the calculations needed to establish the latitude & longitude of a fix using the intercepts, and Azimuths from 2 to 6 celestial sights using the method described in ***The Nautical Almanac*** page 282 paragraph 11.

This worksheet also calculates:

- Set & Drift + Distance Between DR & Fix.
- Track & speed made good through a current, Course & Speed Through Water.
- Course to steer at a given speed through the water to make good a given course through a current Given Course & Speed Through Water.

Data Entry Option 1 Enter the Sight Log IDs for up to 6 sights that you want to use for determining a fix & click on the yellow bar labeled "Get Sight Log Data". All required data will be extracted from the Sight Log.

Data Entry Option 2: Enter all required data manually.

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SR By Direct Calculation Worksheet

Sight Reduction Procedures ... Methods and Formula for Direct Computation... See pages 277, 278, 279, 280 & 281 of ***The Nautical Almanac*** for a detailed explanation of the method used by this worksheet. The altitudes (Ho & Hc) calculated by this worksheet may differ by ±0.1' from what would be obtained from using the increments & corrections tables, "Yellow Pages", in ***The Nautical Almanac***.

Note: This worksheet does not use Increments & Corrections from ***The Nautical Almanac*** "Yellow Pages". The values of GHA & Dec are entered for the UT whole hour preceding and following the time of the sight. The values of GHA & Dec are then calculated for the exact time of the sight by linear interpolation as shown on page 278 of ***The Nautical Almanac***. The GHA & Dec shown here are calculated for the exact UT minutes & seconds and will differ from what would be obtained by using ***The Nautical Almanac*** "Yellow Pages" d & v values to find the corrections for GHA & Dec corresponding to the UT minutes & seconds. The d & v corrections tabulated in ***The Nautical Almanac*** are the values that are valid for the whole minute, the values shown here are correct for the exact second. See page 261 paragraph 24 of ***The Nautical Almanac*** for a discussion on the accuracy of GHA & Dec as tabulated in ***The Nautical Almanac***.

This worksheet was added to illustrate how by using the information contained on pages 277 through 285 of ***The Nautical Almanac*** you can find ha, Ho, Hc, intercept (a) , Zn, and estimated position (EP) by direct computation. The only data you need from a current ***Nautical Almanac*** are the following:

If the Body is a Star enter the Star's SHA.

Enter the Body's GHA from the daily page for the whole UT hour prior to the exact time of the sight "GHA of Body @ UT hr" and the Body's GHA for the whole hour following the time of the sight "GHA of Body @ UT hr +1".

The declination of the body from the daily page for the whole UT hour prior to the exact time of the sight "Dec of Body @ UT hr" and the declination of the body for the whole UT hour following the time of the sight "Dec of Body @ UT hr +1".

For non-standard conditions enter the temperature in degrees Celsius (°C) and the atmospheric pressure in millibars (mb)

Enter height of eye, dip short distance, sextant altitude (hs) and the sextant index correction (IC). Note for a natural horizon enter dip short distance as 0.

The worksheet will then calculate ha, Ho, Hc, intercept (a) and Zn, EP latitude & EP longitude.

The LOP data calculated by this worksheet can be saved in the LOP Data worksheet. Use the "Click on this box to save the data needed for plotting the LOP on a CLS 98 Form"

Note: That the Increments & Corrections table values are not required as the GHA & Dec of the body for the time of the sight are determined from the data supplied at the whole hour prior to and after the time of the sight. This worksheet provides an alternative method for a quick check of a sight.

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Lunar Distance Worksheet

The moon's rapid change of position, (approximately 0.5° per hour), with respect to other celestial bodies near the ecliptic can be used to calculate GMT. The method of using the lunar distance to another body for calculating GMT requires a very accurate & simultaneous‡ measurement of the altitude of the moon, altitude of the body & the lunar distance. Next follows a process to obtain the "cleared" lunar distance . An error of 1 arc minute in the "cleared" lunar distance results in an error of approximately 2 minutes in the calculated GMT, or approximately 0.5° in the calculated longitude. The method of measuring and "clearing" lunar distance to obtain a calculated GMT & Longitude at sea was rendered obsolete with the introduction of John Harrison's H4 chronometer in 1759. However, due to the high cost of precision chronometers, the method of lunar distance to obtain GMT at sea continued to be in use during the remainder of the 18th Century and most of the 19th Century.

In 1766 the first edition of ***The Nautical Almanac*** and **Astronomical Ephemeris**, published by Astronomer Royal of England, contained data for 1767 necessary for the method of lunar distances used to determine longitude. In 1912 the data necessary for the method of Lunar Distance was removed from ***The Nautical Almanac***. ***Nautical Almanacs*** prior to 1912 contained tabulated values, at three hour intervals, of the Geocentric Lunar Distance to the Sun, Venus, Mars, Jupiter, Saturn & selected stars near the ecliptic. Using a present-day **Nautical Almanac** the Geocentric Lunar Distance (GLD) can be calculated using the formula shown below:

GLD = COS-1[SIN(DecMoon)•SIN(DecBody) + COS(DecMoon)•COS(DecBody)•COS(GHABody-GHAMoon)]

The primary purpose of this worksheet is to allow students of Celestial Navigation to test their skill in using a sextant and to provide some understanding as to how celestial observations were used to calculate GMT prior to the common availability of precision chronometers on ships beginning in the early 1800s; and the development of methods of sight reduction by Sumner, St.-Hilaire and others that provided an easier procedure for navigators to determine their position at sea.

‡ This can be simulated by taking a series to measurements of the Moon, body & lunar distance then, using the **Sight Averaging** worksheet, calculate the values for the altitude of the moon, altitude of the body & the lunar distance for a common GMT.

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Nautical Almanac Increments & Corrections Worksheet

This worksheet, ***Nautical Almanac* Increments and Corrections**, is useful for understanding how the increments and corrections data, shown on pages **ii** through **xxxi** of ***The Nautical Almanac*,** were calculated. Also this worksheet can be used to print a reasonable facsimile of the increments and correction pages **ii** through xxxi of ***The Nautical Almanac***. This worksheet will calculate values equivalent to those found in Nautical Almanacs for the year specified in cell A4.

Enter the Year of the Almanac to use in cell A4 and a value for an even number of minutes (0 to 58) into cell B4 to reproduce a given page of the increments & corrections.

To calculate a specific ***v*** or ***d*** correction for the minutes shown in cell B4 enter a value for ***v*** or ***d*** in cell L2 the ***v*** or ***d*** correction value will be shown in cell M2. To calculate a specific ***v*** or ***d*** correction for the minutes shown in cell S4 enter a value of ***v*** or ***d*** in cell AC2 the ***v*** or ***d*** correction value will be shown in cell AD2.

The GHA hourly rates of increase used by this worksheet for calculating the increments & corrections are the following:

Sun & Planets exactly 15°

Aries 15 +(36000/36525)/24 = 15.041067762

Moon 14° 19’ = 14.316666667

GHA increments & corrections calculated by this worksheet use the following formulas:

Sun & Planets ΔGHA °= 15*(UTm +UTs/60)/60

Aries ΔGHA° = (15 +(36000/36525)/24)*(UTm +UTs/60)/60

Moon ΔGHA ° = (14 +19/60)*(UTm +UTs/60)/60

d corr’ = *d**(UTm +0.5)/60

v corr’ = *v**(UTm +0.5)/60

UTm = number of minutes past the whole hour

UTs = number of seconds past the whole minute

Anomalies in the Increments and Corrections tables. In 2001, four of the 10,800 correction values in ***The Nautical Almanac*** were changed.
See below table of anomalies for the four specific values that were changed:

Minute	v or d	corr (pre-2001)	corr (2001 and later)
22	**2.8**	**1.1**	**1.0**
22	**16.4**	**6.2**	**6.1**
52	**9.2**	**8.1**	**8.0**
52	**16.4**	**14.4**	**14.3**

To account for these anomalies a rounding increment was added to the correction values calculated by the above equations. For pre 2001 **Almanacs** a rounding increment of **±0.0** was used and for 2001 and later **Almanacs** a rounding increment of **-0.0000000000001** was used.

Extract from page 255 of *The Nautical Almanac*

6.Increments and corrections The tables printed on yellow tinted paper (pages **ii-xxxi**) at the back of the **Nautical Almanac** provide the increments and corrections for minutes and seconds to be applied to the hourly values of GHA and Dec. They consist of sixty tables, one for each minute, separated into two parts: increments to GHA for Sun and planets, Aries, and Moon for every minute and second; and, for each minute, corrections to be applied to GHA and Dec corresponding to the values of ***v*** and ***d*** given on the daily pages.

The increments are based on the following adopted hourly rates of increase of the GHA: Sun and planets, 15° precisely; Aries, 15° 02.46'; Moon, 14° 19.0'. The values of ***v*** on the daily pages are the excesses of the actual hourly motions over the adopted values; they are generally positive, except for Venus. The tabulated hourly values of the Sun's GHA have been adjusted to reduce to a minimum the error caused by treating ***v*** as negligible. The values of ***d*** on the daily pages are the hourly differences of the Dec. For the Moon, the true values of ***v*** and ***d*** are given for each hour; otherwise mean values are given for the three days on the page.

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Dip Worksheet

The **Dip** worksheet is used for computing the dip for a natural horizon & dip short of a natural horizon using formulas in Bowditch and the alternate method of calculating dip short found on the back of the USPS SR 96 Form.

Dip corrections for a natural sea horizon in minutes of arc using the following formulas.

Dip = 0.97*SQRT(H) or Dip = 1.76*SQRT(H)

Where H is height of eye in feet

& Dip is given in arc minutes.

Where H is height of eye in meters

& Dip is given in arc minutes.

Dip Short corrections using the formula from Bowditch is the following:

Dip Short = 60*Tan-1{H/(6076.1*D) +D/8268}

Where H is height of eye in feet

D is distance in nautical miles

& Dip Short is given in arc minutes.

The Dip Short alternate Method on back of SR 96 Form is the following:

Dip Short in arc minutes ... alternate Method

1. Dip Short = 0.0002052*D +1146*H/D

   Where H is height of eye in feet & D is distance in yards

2. Dip Short = 0.0002244 D + 3438 H/D

   Where H is height of eye in meters & D is distance in meters

3. Dip Short = 0.4156 D + 1.856 H/D

   Where H is height of eye in meters & D is distance in nautical miles

4. Dip Short = 0.4156 D + 0.5658 H/D

   Where H is height of eye in feet & D is distance in nautical miles

Warning: Not valid if value of Dip Short > 200 arc min.

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Hs to Ho Worksheet

Converting Sextant Altitude to Observed Altitude. This worksheet provides an analytic solution for calculating observed altitude (Ho) based on sextant altitude (hs). This worksheet is primarily intended to show the JN/N students how the data on pages A2, A3 & A4 of ***The Nautical Almanac*** were derived. See pages 280 & 281 of ***The Nautical Almanac*** for additional information.

■ Calculate dip (D) for a natural horizon using height of eye (h) in feet

D = 0.97 * sqrt(h)

■ Calculate apparent altitude (Ha) where (IC) is the sextant index error & (Hs) is the altitude measured with the sextant from:

Ha = Hs +IC -Dip

■ Calculate atmospheric refraction (Ro) at a standard temperature of 10° Celsius (C) and a pressure of 1010 millibars (mb) from: Ro° = 0.0167°/tan(Ha +7.32/(Ha+4.32))

If the temperature T° C and pressure P mb are known calculate the atmospheric refraction from: R=λ * Ro Where λ ≈ 0.28P/(T+273) or λ = (283/1010)P/(T+273)

■ Calculate the parallax in altitude (PA) from the horizontal parallax (HP) and the apparent altitude (Ha) for the Sun, Moon, Venus and Mars as follows:

PA = HP * cos(Ha)

For Jupiter, Saturn and the navigational stars HP = 0.0°

For Sun HP = 0.0024°

For Venus & Mars the HP is taken from the critical table at the bottom of page 259 of a current ***Nautical Almanac*** and converted to degrees.

■ Obtain the semi-diameter for the Sun & Moon as follows:

Sun SD taken from bottom of appropriate daily page of Nautical Almanac

Moon SD = 0.2724*HP Where HP is taken for the nearest hour from appropriate daily page of Nautical Almanac

■ Calculate Ho as Ho= Ha -R +PA ± SD (For Upper Limb subtract SD & for Lower Limb add SD)

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Moon Hs to Ho Worksheet

This worksheet calculates altitude correction values based on the Moon's Apparent Altitude (Ha), Horizontal Parallax (HP) & the Limb of the Moon Observed.

The value shown in cell I20 is an approximation of the altitude correction value shown in ***The Nautical Almanac*** upper table. The values shown in cells F28 & I28 are approximations of the additional lower limb and upper limb altitude correction values shown in ***The Nautical Almanac*** Lower table.

Cell I12 shows the additional correction for atmospheric refraction for non-standard conditions.

This worksheet is useful for understanding the Moon altitude correction data shown on pages xxxiv & xxxv of ***The Nautical Almanac***.

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Polaris Worksheet

Latitude by Polaris … The following was extracted from the 1977 Edition of Bowditch article 2027, pages 553 & 554. "Another special case of finding latitude is available in most of the northern hemisphere, it utilizes the fact that Polaris is less than 1° from the north celestial pole. Since Polaris is never far from the north celestial pole, its observed altitude (Ho) , with suitable correction, is the observer's latitude. When Polaris is at upper transit (LHA = 0°) the observer's latitude is equal to the observed altitude (Ho) minus the polar distance (p). When Polaris is at lower transit (LHA = 180°) the observer's latitude is equal to the observed altitude (Ho) plus the polar distance (p). When Polaris is at any other position the correction is approximately defined by the polar distance (p) times the cosine of (h). Thus the correction is a function of the LHA of Polaris (h), and hence also of the LHA of Aries, insofar as the difference between these quantities (the SHA of Polaris) can be considered a constant. Although this method provides sufficient accuracy, a higher degree of accuracy can be obtained by the use of the Polaris correction tables contained in the ***Nautical Almanac***. "

The ***Nautical Almanac*** tables are based on the following formula:

latitude - Ho = p•cos(h) + 0.5•p•sin(p)•sin2(h)•tan(latitude)

where p = polar distance of Polaris = 90° -Declination of Polaris

h = Local Hour Angle of Polaris = LHA of Aries + SHA of Polaris

The value of a0, which is a function of LHA Aries only, is the value of both terms of the above formula calculated for the mean values of SHA and Dec. of Polaris, for a mean latitude of 50° , and adjusted by the addition of a constant (58'.8). The value of a1 which is a function of LHA of Aries and latitude, is the excess of the value of the second term over its mean value for latitude 50°, increased by a constant (0'.6) to make it always positive. The value of a2 , which is a function of LAH Aries and date, is the correction to the first term for the variation of Polaris from its adopted mean position increased by a constant (0'.6) to make it positive. The sum of the added constants is 1° , so that:

Latitude by Polaris = corrected sextant altitude -1° +a0 +a1 +a2

The Nautical Almanac table at the top of each Polaris correction page (274→276) is entered with LHA Aries, and the first correction (a0) is taken out by single interpolation. The second and third corrections (a1 and a2) are taken from the double entry tables without interpolation, using the LAH Aries column with the latitude for the second correction (a1) and with the month for the third correction (a2).

Use the "Nav Bodies" worksheet to specify date, time & DR Position for the Polaris sight you are using to determine Latitude. User inputs required are the Sextant altitude of Polaris (hs), Sextant IC, height of eye & dip short distance if applicable. For non-standard atmospheric pressure & temperature, this spreadsheet also provides for the input of atmospheric pressure in mill-bars temperature in degrees centigrade. This worksheet calculates the observed altitude (Ho), the Polaris Correction and the observers latitude based on the Polaris sight data.

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24 Hc & Zn Worksheet

Use the **Nav Bodies** worksheet to specify the Date & DR Position. The "24Hc &Zn" worksheet will display a graph showing the Altitude (Hc) & Azimuth (Zn) of the Sun vs Zone Time for the Date specified in the **Nav Bodies** worksheet.

The graph of Hc vs Zone Time is useful for visualizing how the maximum altitude of the Sun, the duration of daylight & twilight periods change with latitude and time of year.

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Analemma Worksheet

The **Analemma** worksheet shows a plot of the Sun's Declination vs the Equation of Time for an entire year. The Analemma is useful for showing how the Equation of Time changes through the year and also for explaining the difference in Local Apparent Time & Local Mean Time.

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Course & Distance Worksheet

Given departure latitude (L1), departure longitude (Lo1), arrival latitude (L2), arrival longitude (Lo2), this worksheet calculates true course heading (C), distance (D) in nautical miles. Where rhumb line distance & course heading are calculated as shown below:

$\Delta Lat = L2 - L1$

$\Delta Lo = Lo2 - Lo1$

$\Delta\phi = \ln[\tan(L2/2+\pi/4)/\tan(L1/2+\pi/4)]$

IF $\Delta\phi = 0$ then $\beta = \cos(L1)$

else $\beta = \Delta L/\Delta\phi$

Distance $D = \sqrt{[\Delta L^2 + \beta^2.\Delta Lo^2]}.R$

True Course Heading: $C = atan2(\Delta\phi, \Delta Lo)$

Given variation & deviation this worksheet also calculates compass course. If given speed in knots, then time in route is calculated. If given time in route then speed in knots is calculated.

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Arrival Coordinates Worksheet

Given Departure Latitude, Longitude, Rhumb Line Distance, Course Heading, this worksheet calculates Destination Latitude, Longitude.

$\lambda = D/R$ where R = 3437.74677 n. mi.

$Lat2 = Lat1 + \lambda.\cos(\theta)$

$\Delta Lat = Lat2 - Lat1$

$\Delta\phi = \ln[\tan(Lat2/2+\pi/4)/\tan(Lat1/2+\pi/4)]$

if $\Delta\phi = 0$ then $\beta = \cos(Lat1)$

else $\beta = \Delta Lat/\Delta\phi$

$\Delta Long = \lambda.\sin(\theta)/\beta$

$Long2 = mod[(Long1+\Delta Long+\pi), 2\pi] - \pi$

Given variation & deviation this worksheet also calculates compass course. If given speed in knots, then time in route is calculated. If given time in route then speed in knots is calculated.

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Great Circle Route Worksheet

Given departure latitude (L1), departure longitude (Lo1), arrival latitude (L2) & arrival longitude (Lo2), this worksheet calculates great circle distance & initial true course heading, using Law of Cosines method.

Spherical Law of Cosines For Great Circle Distance & Initial Course Heading:

$D = acos(\sin(Lat_1).\sin(Lat_2)+\cos(Lat_1).\cos(Lat_2).\cos(\Delta Long)).R$

$\theta = atan2(\cos(Lat_1).\sin(Lat_2) - \sin(Lat_1).\cos(Lat_2).\cos(\Delta Long), \sin(\Delta Long).\cos(Lat_2))$

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60 D ST Worksheet

Given Speed & Time .. Calculate Distance

Given Distance & Time ... Calculate Speed

Given Distance & Speed ... Calculate Time

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Interpolation & Data Conversion Worksheet

Local Mean Time to Zone Time Conversion
Zone Time to Local Mean Time Conversion
Decimal Hours to Hours minutes & seconds
Decimal Degrees to degrees minutes & seconds
Lagrange 1st Order Interpolation aka Linear Interpolation
Lagrange 2nd Order Interpolation
Lagrange 3rd Order Interpolation
Double Linear Interpolation
Time to Arc Conversion
Arc to Time Conversion
Temperature Conversion
Pressure Conversion

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Navigation Coordinates Worksheet

Data from chapter 15 "Navigational Astronomy" in Pub. No. 9 THE AMERICAN PRACTICAL NAVIGATOR "BOWDITCH" 2002 Bicentennial Edition.

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Yellow Pages Worksheet

This worksheet is useful for understanding how the increments and corrections data, shown on pages ii through xxxi of ***The Nautical Almanac***, are calculated.

This worksheet calculates Increments and corrections accurate to ±0.01

The GHA hourly rates of increase used by this worksheet are the following:

Sun & Planets exactly 15°

Aries 15 +(36000/36525)/24 = 15.041067762

Moon 14° 19' = 14.316666667

GHA increments & corrections calculated by this worksheet use the following formulas:

Sun & Planets ΔGHA °= 15*(UTm +UTs/60)/60

Aries ΔGHA° = (15 +(36000/36525)/24)*(UTm +UTs/60)/60

Moon ΔGHA ° = (14 +19/60)*(UTm +UTs/60)/60

d corr' = *d**(UTm +0.5)/60

v corr' = *v**(UTm +0.5)/60

UTm = number of minutes past the whole hour

UTs = number of seconds past the whole minute

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Rhumb Line Distance vs. Great Circle Distance Worksheet

Given departure latitude (L1), departure longitude (Lo1), arrival latitude (L2) & arrival longitude (Lo2), and using spherical trigonometry equations this worksheet calculates the rhumb line course & distance and also the great circle distance & initial course heading.

This worksheet also calculates arrival coordinates given departure latitude (L1), departure longitude (Lo1), rhumb line distance, true course heading.

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Tides Worksheet

Given values for high and low tides and the time between high & Low, this worksheet calculates the intermediate tide heights for six time increments between low & high for incoming tides & the intermediate tide heights for six time increments between high & low for outgoing tides using the following methods:

- Rule of 1/12 for Tide Prediction
- Rule of 1/10 for Tide Prediction
- Tide Predicting using COSINE Function
- USPS AP Class Rule for Tide Prediction

In comparing these four methods for tide prediction you will notice that the only difference is the value given for the height of the tide at the first time increment following or preceding the high or low.

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How to activate Excel Add-Ins

To activate an Excel Add-In click the **File Tab**, then click **Options**, next click the **Add-Ins Category**. In the message box, click **Excel Add-Ins**, & then click **Go**. The Add-Ins dialog box will appear. In the Add-Ins available box select the check box next to the Add-In that you want to activate, and then click **OK**.

Check to box next to the following 3 Excel Add-ins:

- **Analysis Tool Pak**
- **Analysis Tool Pak VBA**
- **Solver Add-in**

Then click **OK**

Return

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Nav Bodies worksheet Accuracy

The values of GHA for Aries (♈), the SHA for stars, the GHA and Dec for the Sun, Moon & Planets calculated by the **Nav Bodies** worksheet are in general agreement with the values tabulated in ***The Nautical Almanac*** (with a maximum difference of approximately ±0.10 arc minutes for values @ whole hour & ±0.15 arc minutes where *Nautical Almanac* increments & correction are applied.

Page 166 of Meeus, ***Astronomical Algorithms***, states that a very high accuracy (0.01 arc seconds) is obtained when use is made of the complete VSOP87 theory. The **Nav Bodies** worksheet uses the complete set of 2425 terms of the VSOP87 theory for the Earth & uses the most important periodic terms of the VSOP87 theory for the planets Venus, Mars, Jupiter & Saturn. Data for the Sun from Example 25.a of Meeus are shown below in Sun Data Example in the column labeled VSOP87 and compared with the results obtained by the **Nav Bodies** worksheet. The maximum difference is less than 0.01 arc seconds.

The difference in the values for the Moon's right ascension (α) and declination (δ) calculated by the **Nav Bodies** worksheet and the values shown in example 47.a test case on page 342 of Meeus, which were obtained by using the complete ELP-2000/82 theory are shown below in Moon Data Example. For additional information on accuracy see chapter 2 "About Accuracy" in the second edition of ***Astronomical Algorithms*** by Jean Meeus ISBN 0-943396-61-1

Sun Data Example **UT date 13 October 1992** **UT time 00:00:00** **Meeus Example 25.a page 165**	**VSOP87**	**Nav Bodies**	**Difference**	
geocentric longitude (Θ+ΔΘ)	199.9072722°	199.90727215°	0.00018	arc sec
geocentric latitude (β+Δβ)	0.0002°	0.00020015°	0.00054	arc sec
Apparent longitude (λ)	199.9059889°	199.90598809°	0.002916	arc sec
radius vector (R)	0.99760853 AU	0.99760852 AU	0.00000001	AU
right ascension (α)	198.3781209°	198.37812344°	0.009144	arc sec
declination (δ)	-7.78381667°	-7.78381766°	0.003564	arc sec
Moon Data Example **Meeus Example 47.a page 342**	**ELP-2000/82**	**Nav Bodies**	**Difference**	
right ascension (α)	$8^h\ 58^m\ 45.1^s$	$8^h\ 58^m\ 45.2^s$	$0^h\ 0^m\ 0.1^s$	
declination (δ)	13.7683680°	13.76836666°	0.00504	arc sec

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