The **Celestial Navigation** workbook was developed over the past 15 years as a Teaching Aid for United States Power Squadrons® Advanced Grade classes. This Excel Workbook can also be used for checking **JN** and **N** sight folders, homework problems & exams. It can also be used as a tutorial by anyone interested in learning the basic principles of celestial navigation. This workbook won "Best of Show" as a Teaching Aid at the United States Power Squadrons® District 16 Fall Conference in 2009.

This workbook can be downloaded from the USPS District 16 web site https://www.uspsd16.org From the "**Dept. Info**" dropdown menu select "**Educational**" and under "**Quizzes | Workbooks | Software**" select "**Celestial Navigation**".

The **Sight Log** & **Nav Bodies** worksheets are the core of the **Celestial Navigation** workbook and for this workbook to function the following **3 Excel Add-ins** must be available:

Analysis Tool Pak, Analysis Tool Pak VBA & Solver Add-in

See the Procedure for checking **Sight Folders** with the **Celestial Navigation** workbook on page 3.

All cells of the workbook are protected except for the yellow user data entry cells. This prevents the inadvertent modification of cells containing formulas use to calculate the results. Most of the worksheets have an associated macro for clearing the user input cells of previously entered data. These worksheet macros are provided to prevent data from a previous problem being overlooked when entering data for a new problem. Units associated with cells use abbreviations & acronyms from *The American Practical Navigator* "*Bowditch*" **Pub No.9 2002 Bicentennial Edition.**

The **Celestial Navigation** workbook contains the following 36 worksheets:

■ **Sight Log ..** **Provides for the recording of data for up to 255 Celestial Sights** & allows for the saving of data calculated by the **Sight Reduction, SR 96, NASR & HO 229** worksheets needed for plotting Celestial LOPs in the **CLS SAPS** worksheet. The **Export Sight Log** & **Import Sight Log** macros provides the interface with an Excel workbook named **My Sight Log Archive**, which provides for the recording of data from an unlimited number of celestial sights.

■ **Nav Bodies ..** The **Nav Bodies** worksheet calculates data equivalent to what is contained in the ***Nautical Almanac*** for Sun, Moon, Planets & Stars for a given date, time & position using formulas from Jean Meeus "***Astronomical Algorithms***" second edition and the **VSOP87** data for the earth & planets and **ELP-2000/82** data for the moon. Data from the **Nav Bodies** worksheet is used in most of the worksheets listed below.

■ **Sight Planning ..** Based on the DR position and zone time specified in the **Nav Bodies** worksheet this worksheet displays the visible bodies and their associated altitude & azimuth angles. The user selects the first body for a two or three body fix; then this worksheet calculates the ideal azimuth angles for the second body for a two body fix and the second body and third body for a three body fix. This worksheet also provides the geocentric lunar distance to any visible body.

■ **Sight Averaging ..** Given the **Sight Log ID** of a sight string this worksheet displays a plot of sextant altitude vs. time for up to 10 sights and allows bad sights to be removed. This worksheet also calculates the average sextant altitude & the associated time.

■ **Meridian Transit .. 1.** Given the **Sight Log ID** of a sight string taken a short time before & after meridian transit, this worksheet calculates the zone time of meridian transit & the associated sextant altitude at meridian transit.
2. Given the value for the Eqn. of Time & Mer. Pass from the Nautical Almanac this worksheet provides the zone time of Meridian Passage at the DR Position.
3. Given the GHA & declination of the body from the ***Nautical Almanac*** at the zone time of meridian transit & the observed altitude of the body, this worksheet calculates the observer's latitude.

■ **Sight Reduction ..** Sight Checker for the back of **USPS Form SR96** .. Law of Cosines Method +NASR +HO229 Also provides a time diagram and the diagram on the plane of the observer's meridian.

- **SR 96 ..** Sight reduction using the Law of Cosines, this worksheet provides the data needed for checking the front of the **USPS Form SR96.**

- **NASR Table ..** Sight Reduction using the *Nautical Almanac* concise sight reduction tables.

- **HO 229 ..** Sight Reduction using the H. O. Pub. 229 Sight Reduction Tables for Marine Navigation.

- **CLS SAPS ..** This worksheet will plot on a facsimile of a Constant Latitude Scale (**CLS**) Small Area Plotting Sheet (**SAPS**) the **LOPs** of up to 3 Celestial Sights from either a DR or an assumed position. Latitude & Longitude markers can be positioned at the intersection of the LOPs to obtain the coordinates of a fix.

- **SR by DC ..** Sight Reduction by Direct Computation, *Nautical Almanac* pages 277--> 285

- **Sumner LOP ..** From an observation of the Sun this worksheet calculates the Longitudes associated with three specified Latitudes, which define a Line of Position (**LOP**) from which the observed altitude of the Sun would have the same value if taken at the same instant of time from any point along the LOP using the method developed by Capt. Thomas H. Sumner.

- **Fix Sans DR ..** Calculates a Fix using the Intersections of Circles of Equal Altitude from Two or Three Bodies.

- **Fix by DC ...** Position from intercept & azimuth by direct calculation*, Nautical Almanac* pages 282 &283.

- **DR 2 Body Fix ..** Calculates the Latitude & Longitude of a Two Body Fix, from a DR position

- **AP 2 Body Fix ..** Calculates the Latitude & Longitude of a Two Body Fix, from assumed positions.

- **DR 3 Body Fix ..** Calculates the Latitude & Longitude of a Three Body Fix, from a DR position.

- **AP 3 Body Fix ..** Calculates the Latitude & Longitude of a Three Body Fix, from assumed positions.

- **Lunar Distance ..** 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 obtain GMT prior to the common availability of precise 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.

- **NA I & C ..** Increments & Corrections formatted as shown in the *Nautical Almanac.*

- **Dip ..** Calculates tables of dip corrections for a natural sea horizon in minutes of arc for height of eye in feet or meters + tables for dip corrections short of a natural sea horizon in minutes of arc for height of eye in feet or meters & dip short distance in yards, meters or nautical miles.

- **Hs to Ho ..** Calculates Observed Altitude for the Sun, Moon, planets & stars from Sextant altitude, using equations from pages 280 & 281 of the *Nautical Almanac*

- **Moon hs to Ho ..** Moon Altitude Corrections, *Nautical Almanac* pages xxxiv &xxxv

- **Polaris ..** Latitude by Sight on Polaris, *Nautical Almanac* pages 274 & 275

- **24 Hc & Zn ..** A graph of the Sun's Altitude and Azimuth vs Zone Time for a given date & position

- **Analemma ..** A graph of the Sun's Declination vs the Equation-of-Time for an entire year.

- **Set & Drift ..** Calculates set & drift + track & speed made good + course to steer & speed of advance.

- **Course & Distance ..** Calculated using rhumb line or Mid-Latitude equations.

- **Arrival Coordinates ..** Calculated using rhumb line or Mid-Latitude equations also provides for the calculation of DR positions along a given course.

- **Great Circle Route ..** Calculates Great Circle Distance and initial course heading.

- **60 D ST ..** Speed, Time & Distance calculations.

- **Interpolation ..** Interpolation & Data Conversions.

- **NAV Coordinates ..** Diagram of the celestial sphere & definition of the celestial navigation coordinates.

- **Yellow Pages ..** Nautical Almanac Increments & Corrections accurate to 0.01'

- **Rhumb Line ..** This worksheet calculates Rhumb Distance vs. Great Circle Distance between any two locations.

- **Tides ..** Rule of 1/12 for Tide Prediction.

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Procedure for checking Sight Folders with the Celestial Navigation workbook

Step 1 ... Time required about 4 minutes per sight.
For each sight that was reduced, enter the data from the Sight Log in the Sight Folder into columns **C** through **AC** of the Sight Log worksheet in the Celestial Navigation workbook. Double check that data in the student's Sight Folder Sight Log & the entries you made in the Sight Log worksheet are identical.

Step 2 ... Time required about 2 minutes per sight.
For each sight that was reduced, enter the required data from the Nautical Almanac into columns **BB** through **BL** of the Sight Log worksheet in the Celestial Navigation workbook at the whole hour (GMT) for the Greenwich date of the sight.
Double check that the entries you made in the Sight Log worksheet & data in Nautical Almanac are identical.

Step 3 ... Time required about 4 minutes per sight.
For each sight that were reduced perform the following :
1. Enter the Sight Log ID into the Nav Bodies worksheet & click Get Data from Sight Log bar.
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.
[‡]2002 Edition, 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. ...."
2. Using the SR 96 worksheet click Get Sight Log Data bar.

3. Verify that Law of Cosines (LOC) intercept & Zn values from the SR 96 Form agree with values in the SR 96 worksheet & if not why not.   Also verify that the Time Diagram on the SR 96 Form agrees with the Time Diagram displayed in the SR 96 worksheet.
4. Click Store Sight Log Data bar.
5. Using the Sight Reduction worksheet click Get Sight Log Data bar.
6. Verify that the NASR option is selected & verify that NASR intercept & Zn values from the SR 96 Form agree & if not why not.   As an option the NASR & HO 229 worksheets can also be used to check the values on the back of the SR 96 Form.
7. Click Store Sight Log Data bar to store the data needed to plot the LOP from the assumed position.
8. Using the CLS SAPS worksheet enter the required Sight Log IDs & click Get Data from Sight Log bar.
9. 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 plot with the CLS 98 Form.
10. Position the red cross hairs at the Fix or EP shown on the CLS SAPS plot. Verify the values listed on the CLS 98 Form agree with the values derived from the CLS SAPS plot. The values should agree within ±0.5 arc minutes.

To minimize the Sight Log data entry time, the following are the default assumptions for each Sight Log ID:
1. If columns F & G are blank, Watch Error is assumed to be 00:00:00
2. If column J is blank, Standard Time is assumed.
3. If columns O, P & Q are blank, a Natural Horizon is assumed.
4. If column P is not blank, then the value in column P is the Distance to the Dip Short Horizon.
5. If column Q is blank, then Yards is assumed as the Units for the Distance to the Dip Short Horizon.
6. If columns Y & Z are blank, a standard air temperature of 10° C is assumed.
7. If columns AA & AB are blank, a standard atmospheric pressure of 1010 mb is assumed.