CAPCA

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Celestial Navigation at Sea

Agenda

- Moments in History
- **LOP (**Bearing “Line of Position”) **-- in piloting and celestial navigation**
- **DR Navigation**: Cornerstone of Navigation at Sea
- **Ocean Navigation**: Combining DR Navigation with a fix of celestial body
- **Tools of the Celestial Navigator** (a Selection, including **Sextan**t)
- **Sextant Basics**
- **Celestial Geometry**
- **Time Categories** and Time Zones (West and East)
- **From Measured Altitude Angles (the Sun) to LOP**
- **Plotting a Sun Fix**
- **Landfall Strategies**: From NGA-Ocean Plotting Sheet to Coastal Chart

Disclaimer!

M0MENTS IN HISTORY

1731 John Hadley (English) and Thomas Godfrey (Am. Colonies) invent the Sextant

1736 John Harrison (English) invents the Marine Chronometer.

Longitude can now be calculated (Time/Speed/Distance)

1766 First Nautical Almanac by Nevil Maskelyne (English)

1830 U.S. Naval Observatory founded (*Nautical Almanac*)

An Ancient Practice, again Alive Today!

Celestial Navigation Today

- To no-one's surprise, for most boaters today, navigation = electronics to navigate.
- The Navy has long relied on it's GPS-based Voyage Management System. (GPS had first been developed as a U.S. military "tool".)
- If celestial navigation comes to mind, it may bring up romantic notions or longing: Sailing or navigating "by the stars"
- Yet, some study, teach and practice Celestial Navigation to keep the skill alive— and, once again, to keep our nation safe

Celestial Navigation comes up in literature and film to this day:

- *Master and Commander* with Russell Crowe and Paul Bettany. Film based on:
- The "Aubrey and Maturin" novels by Patrick O'Brian
- *Horatio Hornblower* novels by C. S. Forester
- The Horatio Hornblower TV series, etc.
- *Airborne* by William F. Buckley

In 2000, U. S. Navy Stopped Teaching Celestial Navigation

Why? Reliance on GPS-Based Systems

In 2015 the U.S. Naval Academy started teaching and using Celestial Navigation again.

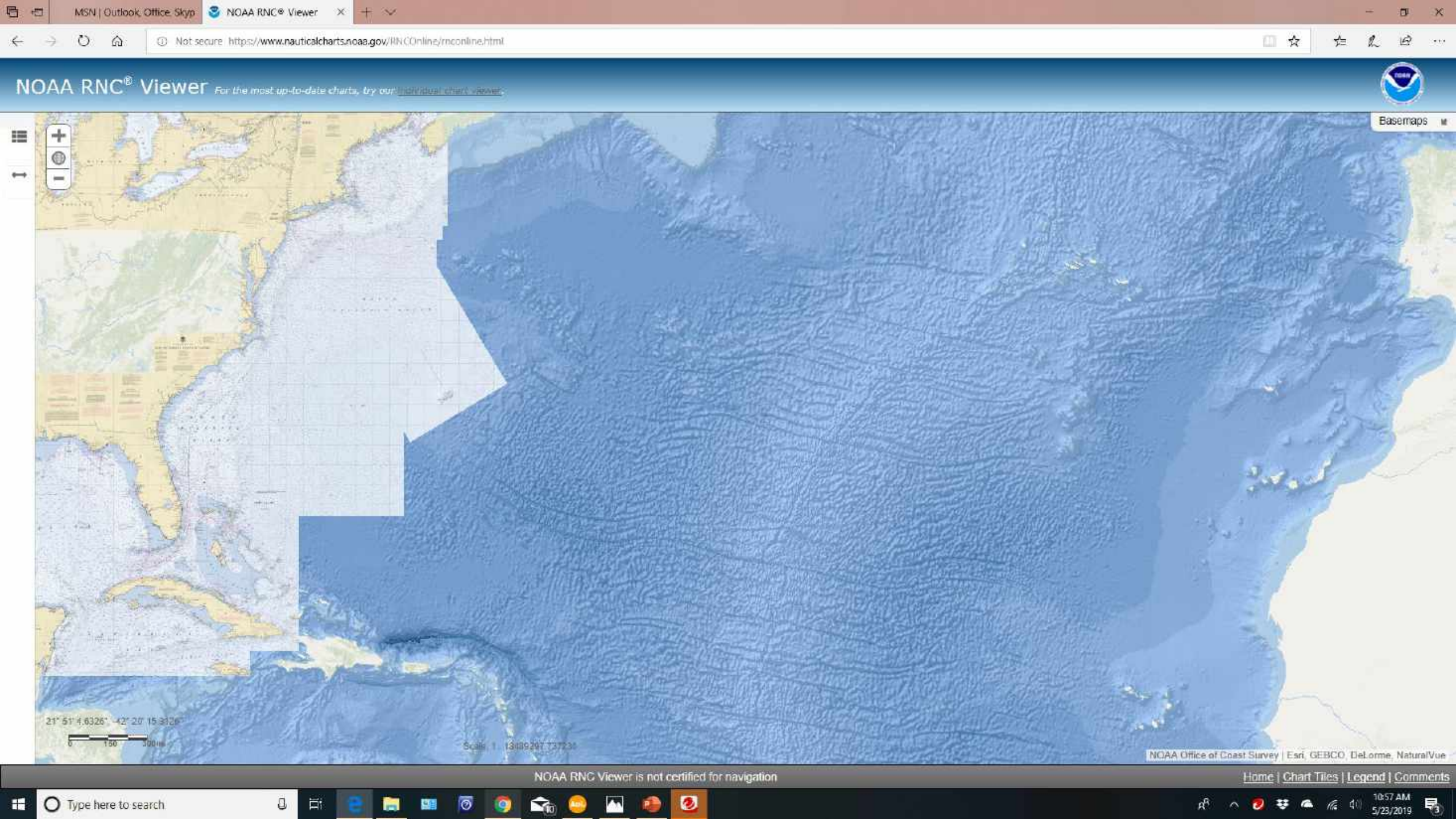
Why?

In June 2019, the U.S. Navy graduates it's first class of 19 sailors who had mastered the expanded Quarter Masters Class "A" Curriculum

Why?

Answer: GPS Signals can Experience Interference

- Space Weather--Example: Sunspots (WP of May 21, 2019)
- Jamming by “Bad Actors”
- Shooting down of satellites assumed possible
- Galileo outage July 2019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Tools and Resources of the Celestial Navigator –A Selection

- NGA Position Plotting Sheet
- Plotting Tools (Knowledge of Piloting Procedures)
- Log Book
- Sextant
- Time Piece
- Resources: Nautical Almanac, Sight Reduction Table, Computer (

Need good sense of balance, a sturdy harness and sturdy tether


CELESTIAL

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191021-N-SL179-1039 ATLANTIC OCEAN (Oct. 21, 2019) The amphibious dock landing ship USS Oak Hill (LSD 51) pulls alongside the amphibious assault ship USS Bataan (LHD 5) for a fueling-at-sea

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10/22/2019

Need good Data (**Total of 13 data points. Some are:**)

- **Celestial Body**
- **Sextant reading**
- **Date**
- **Time (Time Zone)**
- **Data from Resources (Nautical Almanac)**

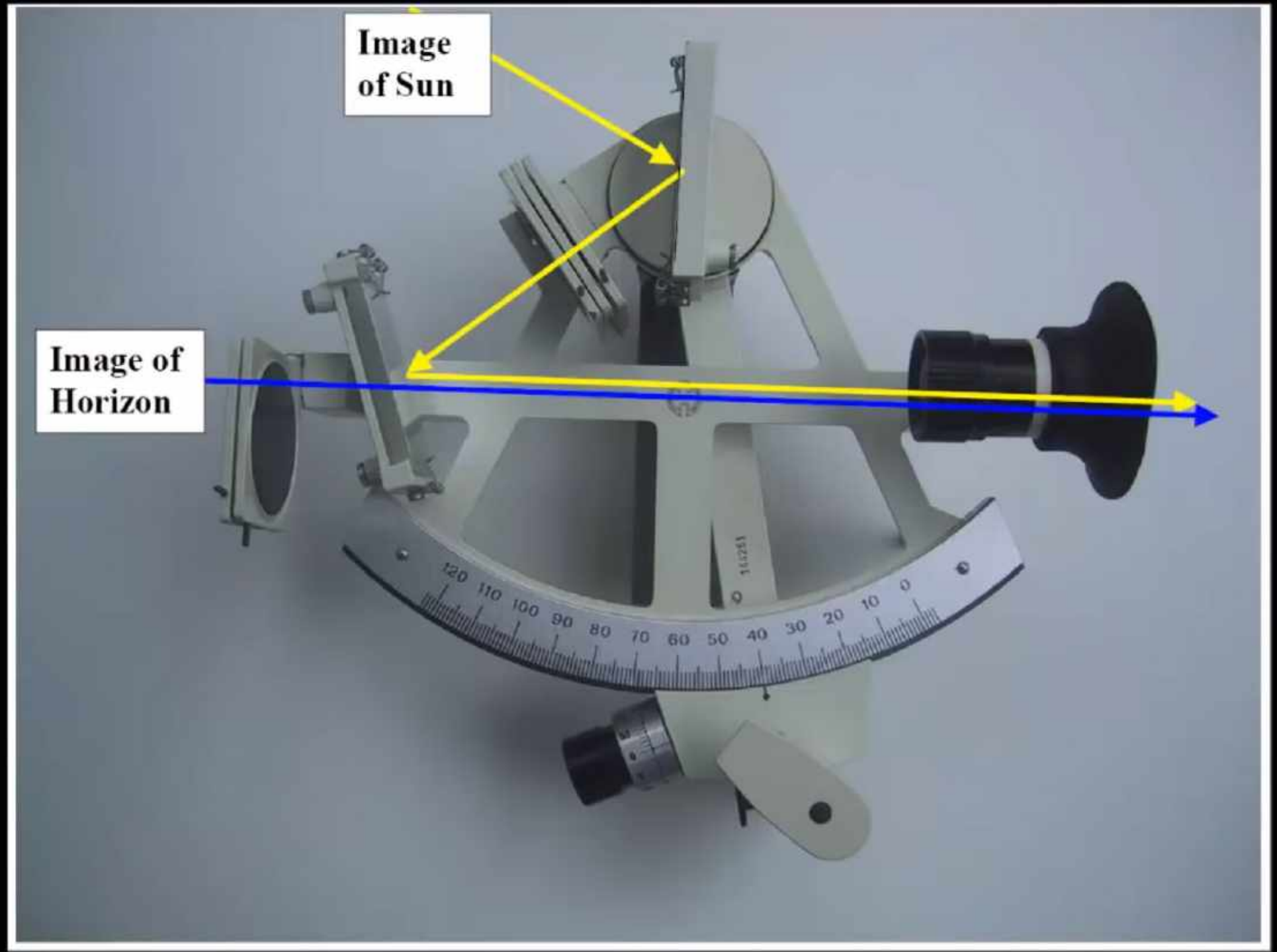


Image of Sun
Image of Horizon
120 110 100 90 80 70 60 50 40 30 20 10 0

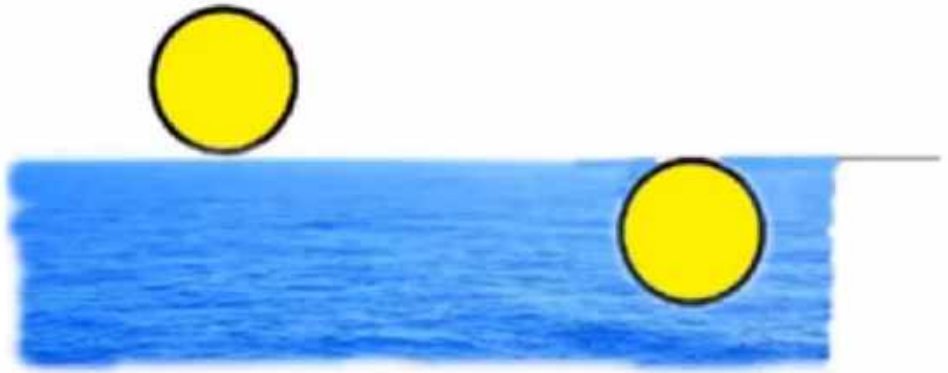
View Through Sextant

- *Altitude of Sun (Hs) above your visual horizon is measured with the sextant*
- *This is what you'll see through the scope of a sextant with a split horizon mirror:*

- *Sun is on right in the sun shade area*
- *Sea, sky and horizon are on left*

Limb of Sun or Moon

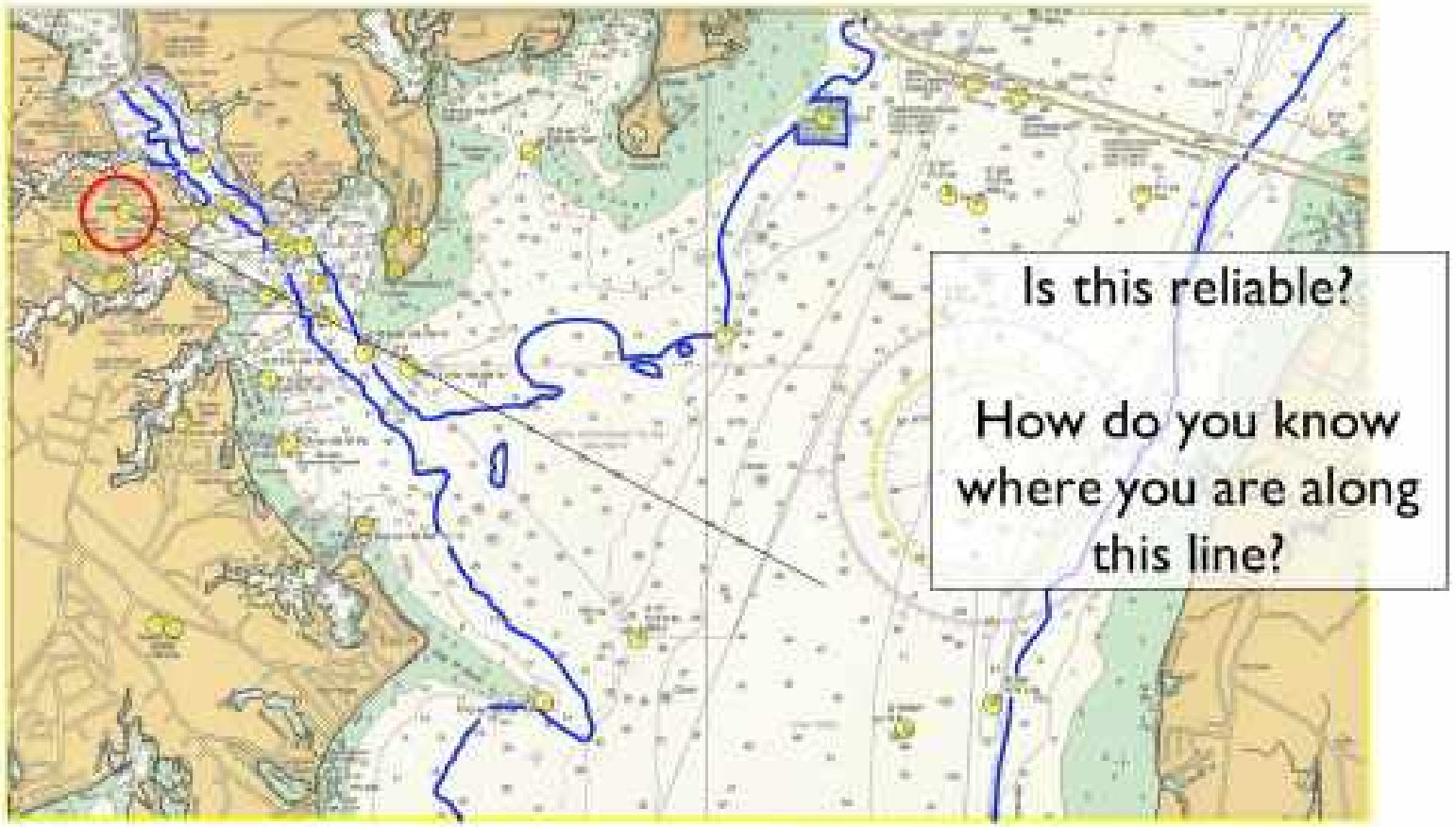
Lower Limb shot



Upper Limb shot

TRIANGULATION

- Each of these bearings are considered a "Line of Position"



TRIANGULATION

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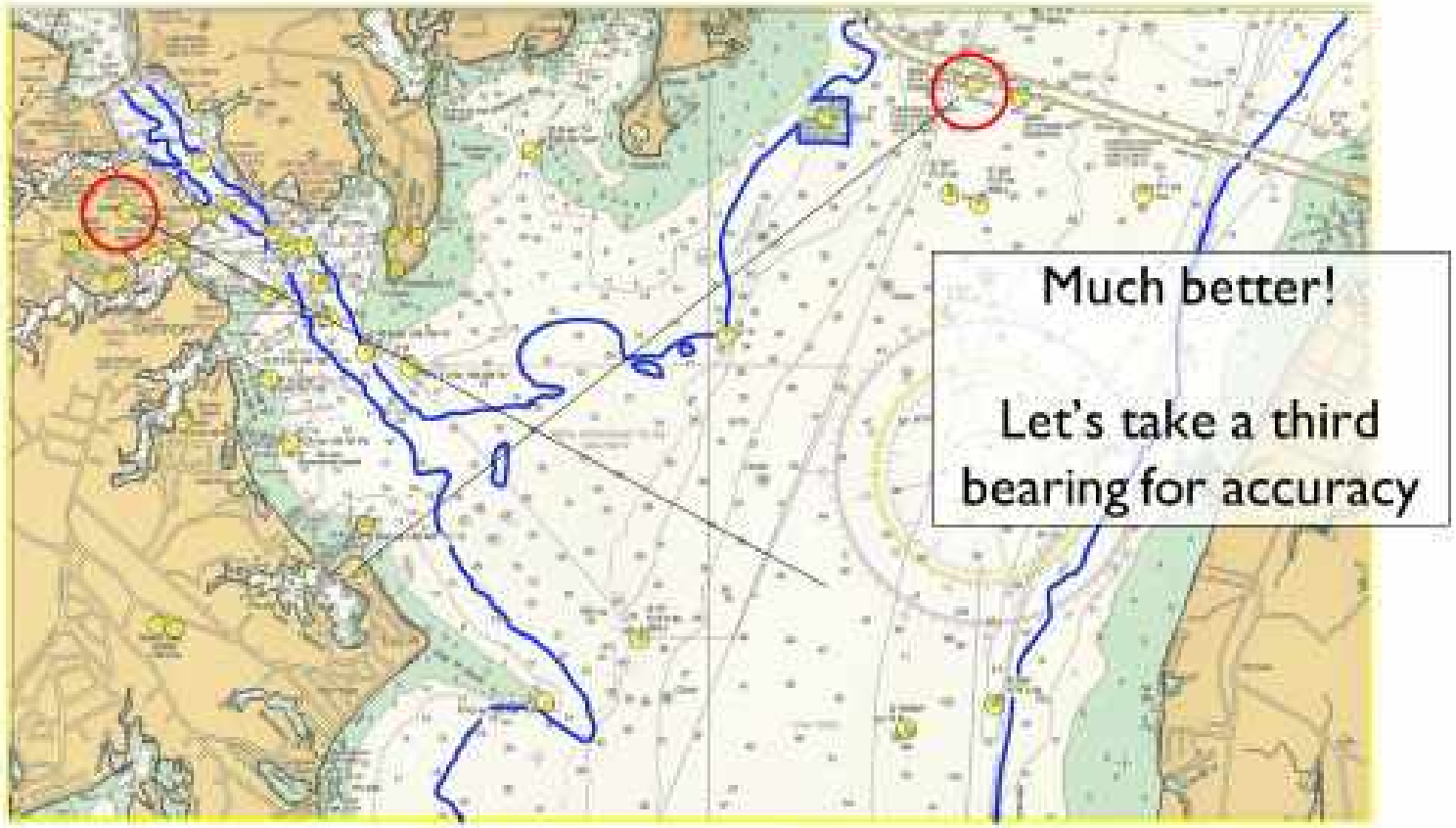

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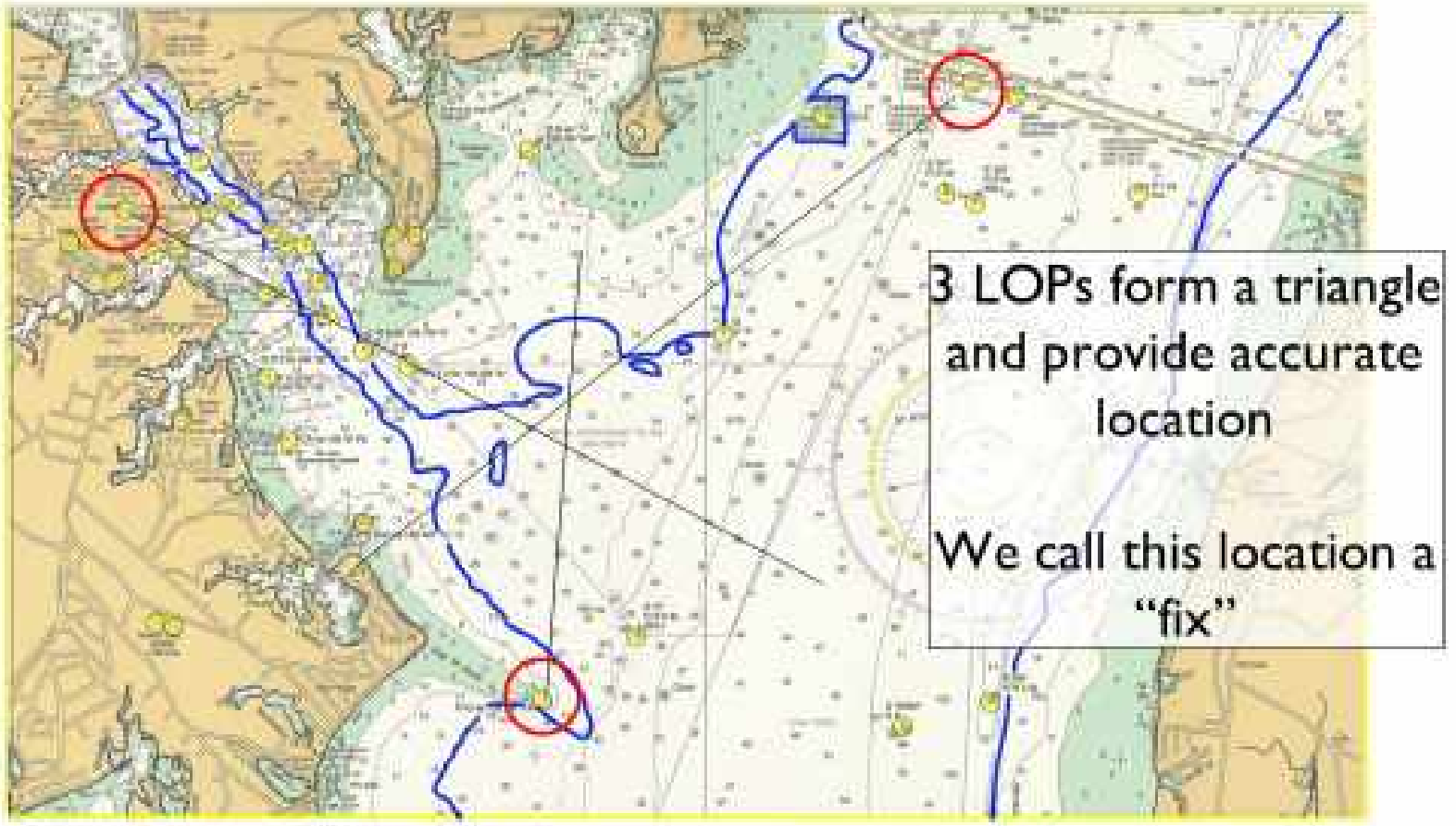


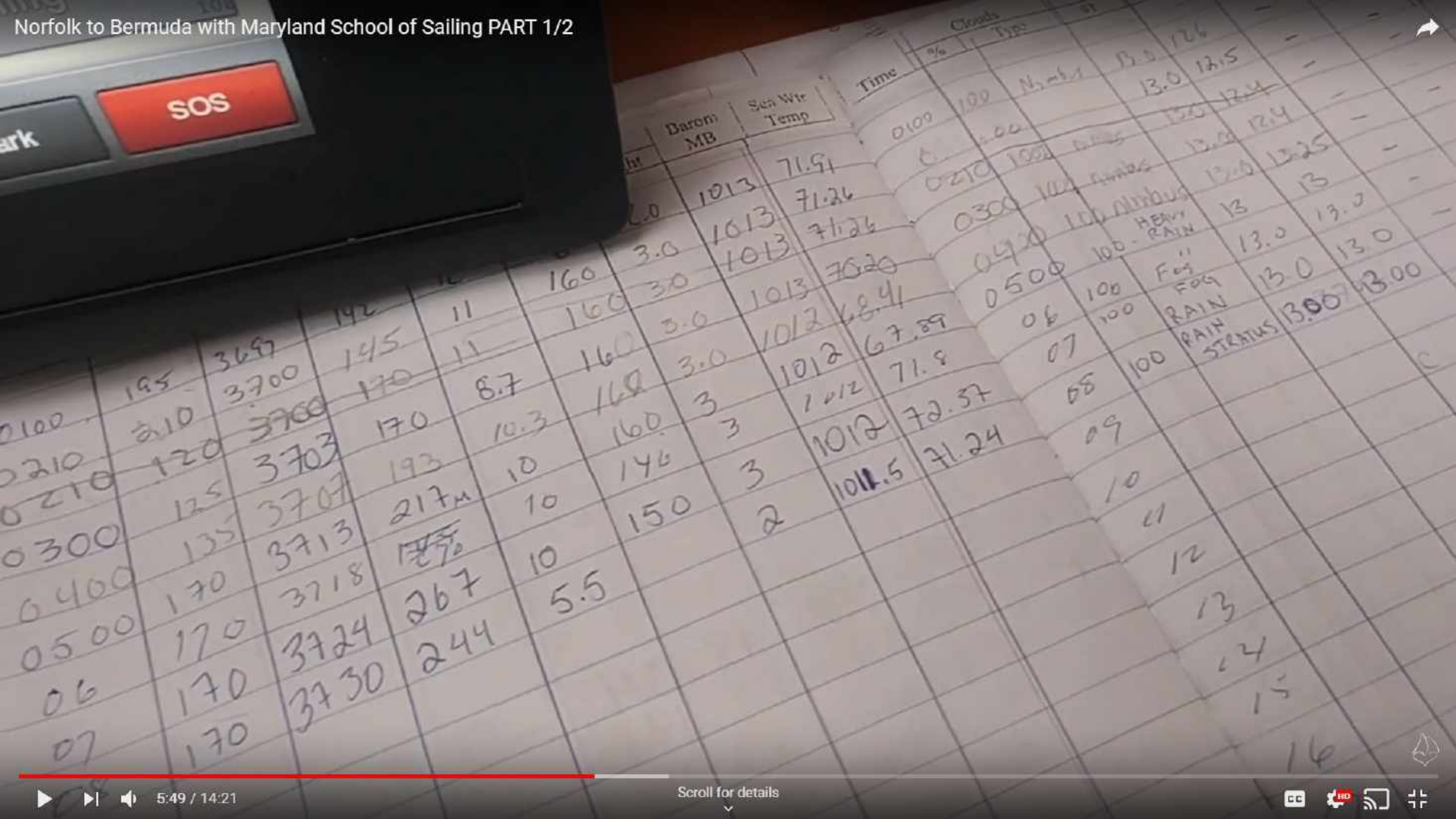
Ocean Navigation

- ***Our objective is to combine DR navigation with measurements of the Sun's Altitude Angle (Hs) into a meaningful ocean navigation process***

- ***Also applies to Moon, Planets and selected Stars***

DR Navigation

- *Dead Reckoning (DR) Navigation is the cornerstone of navigation at sea*
- *DR consists of two factors:*
  - *Course steered based on ship's compass*
  - *Distance traveled based on ship's distance log relative to the seawater*
- *Essential tools:*
  - *DR logbook*
  - *Position Plotting Sheets*


Norfolk to Bermuda with Maryland School of Sailing PART 1/2
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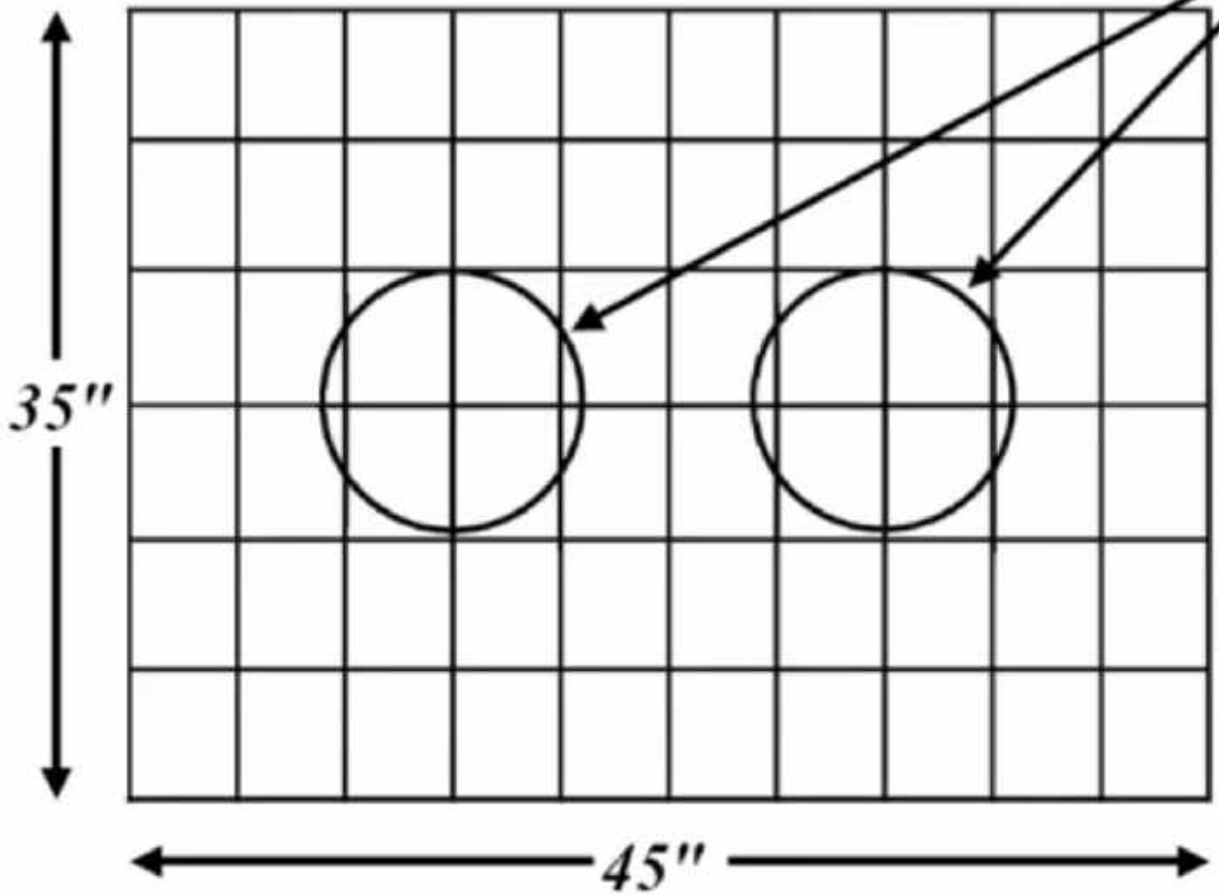
Navigation Logbook

- ***Hourly entries:***
  - ***Course steered per Compass during past hour***
  - ***Distance Log reading on the hour***
- ***Every four hours:***
  - ***Average the courses steered***
  - ***Convert average courses from °Compass to °True using TVMDC***
  - ***Compute distance for the four hours***
  - ***Plot Course & Distance***

Typical Plotting Sheet



True Compass Rose

- Minutes of angle are printed in both directions
- Latitude degrees are pre-printed
- Longitude degrees are not printed

Sample Problem #1- Setup of Position Plotting Sheets:

Setup Position Plotting Sheets for a cruise from Norfolk, VA to Bermuda.
Departure: Buoy "CBJ" east of Cape Henry; Lat = 36°56.1N, Long 75°57.5W
Destination; NE corner of DMA#26341 Chart of Bermuda; Lat = 32°32.1N, Long 64°31.0
Rhumb Line Course: 115° True
Position Plotting Sheets required: DMA#925 & #926

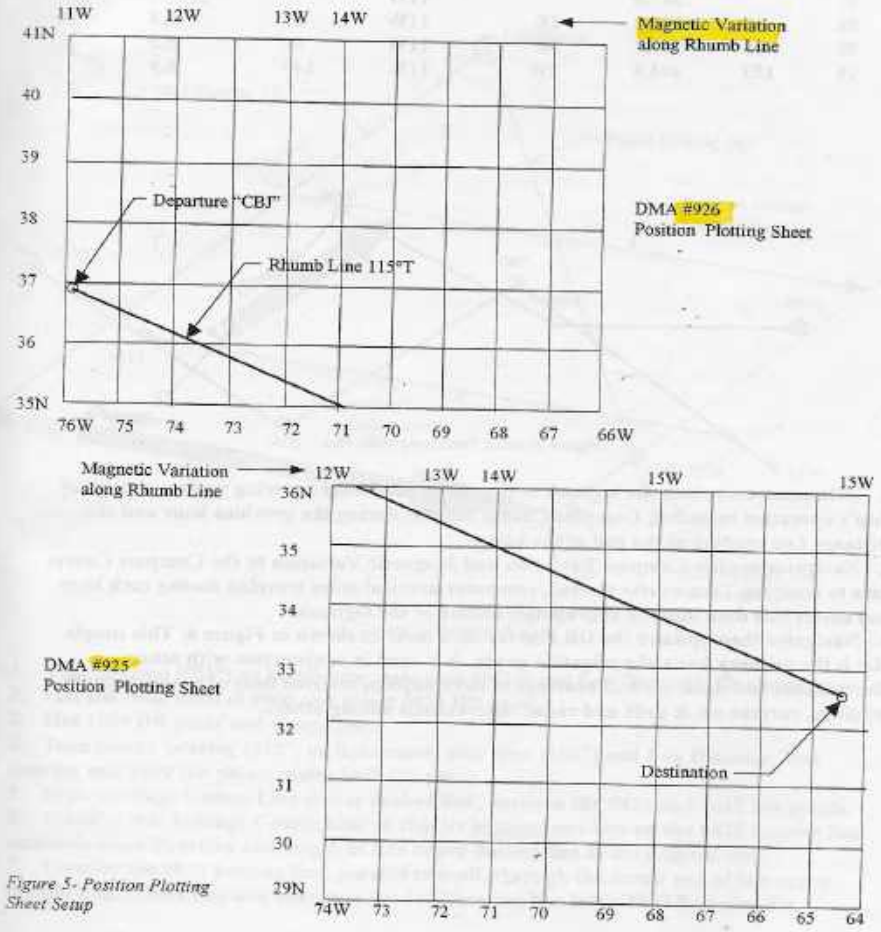
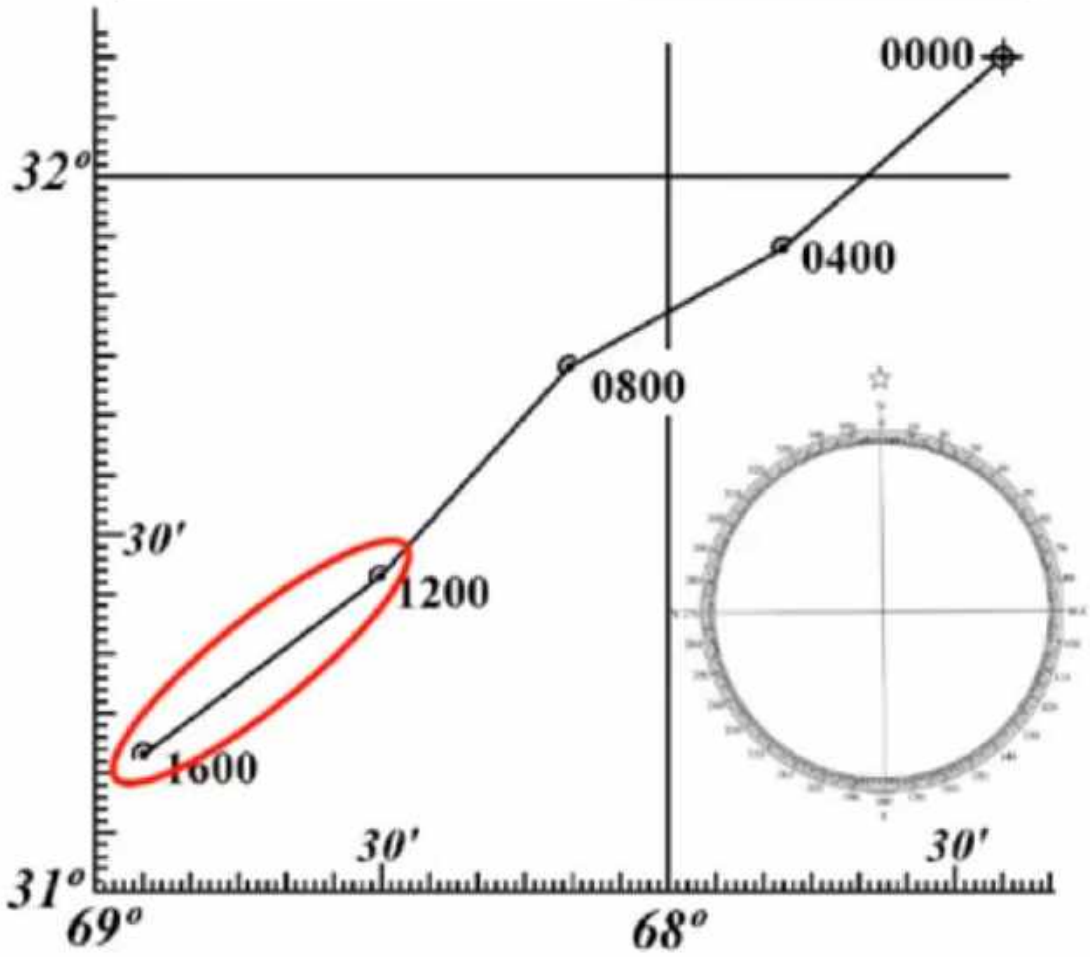


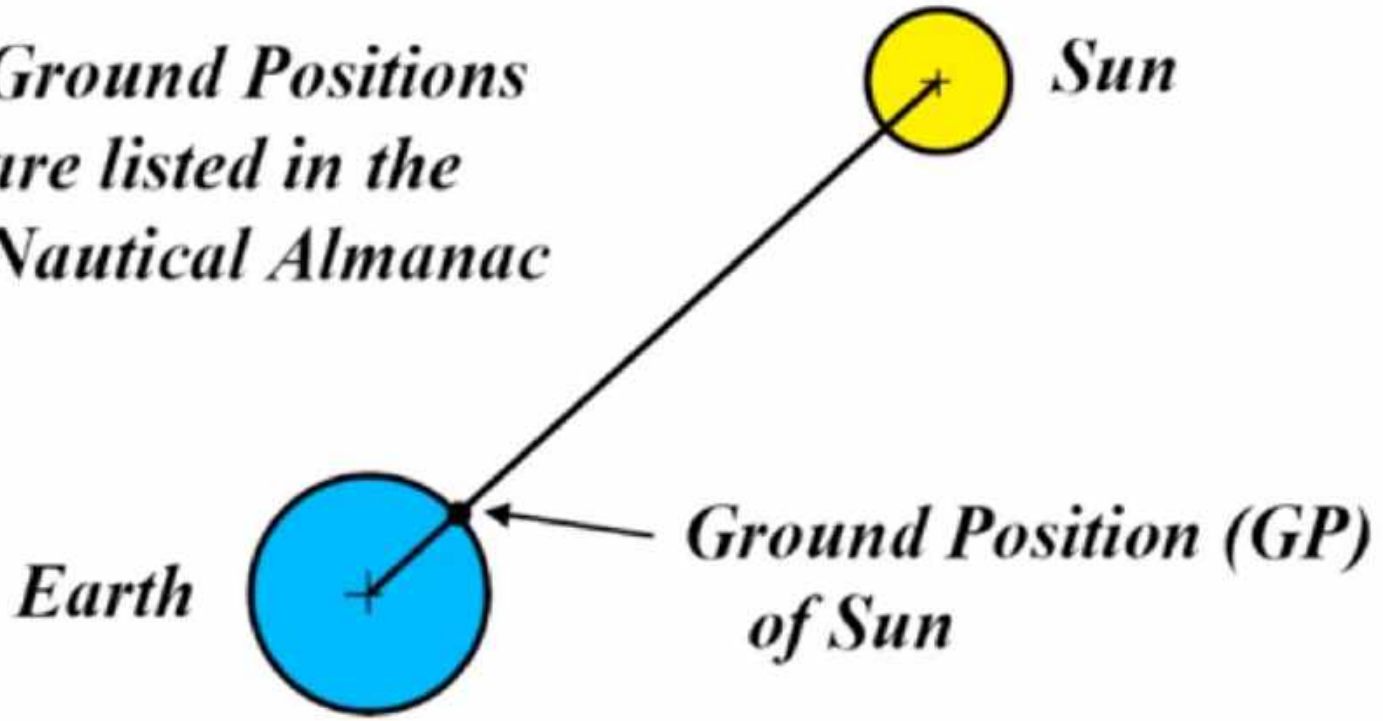
Figure 5- Position Plotting Sheet Setup

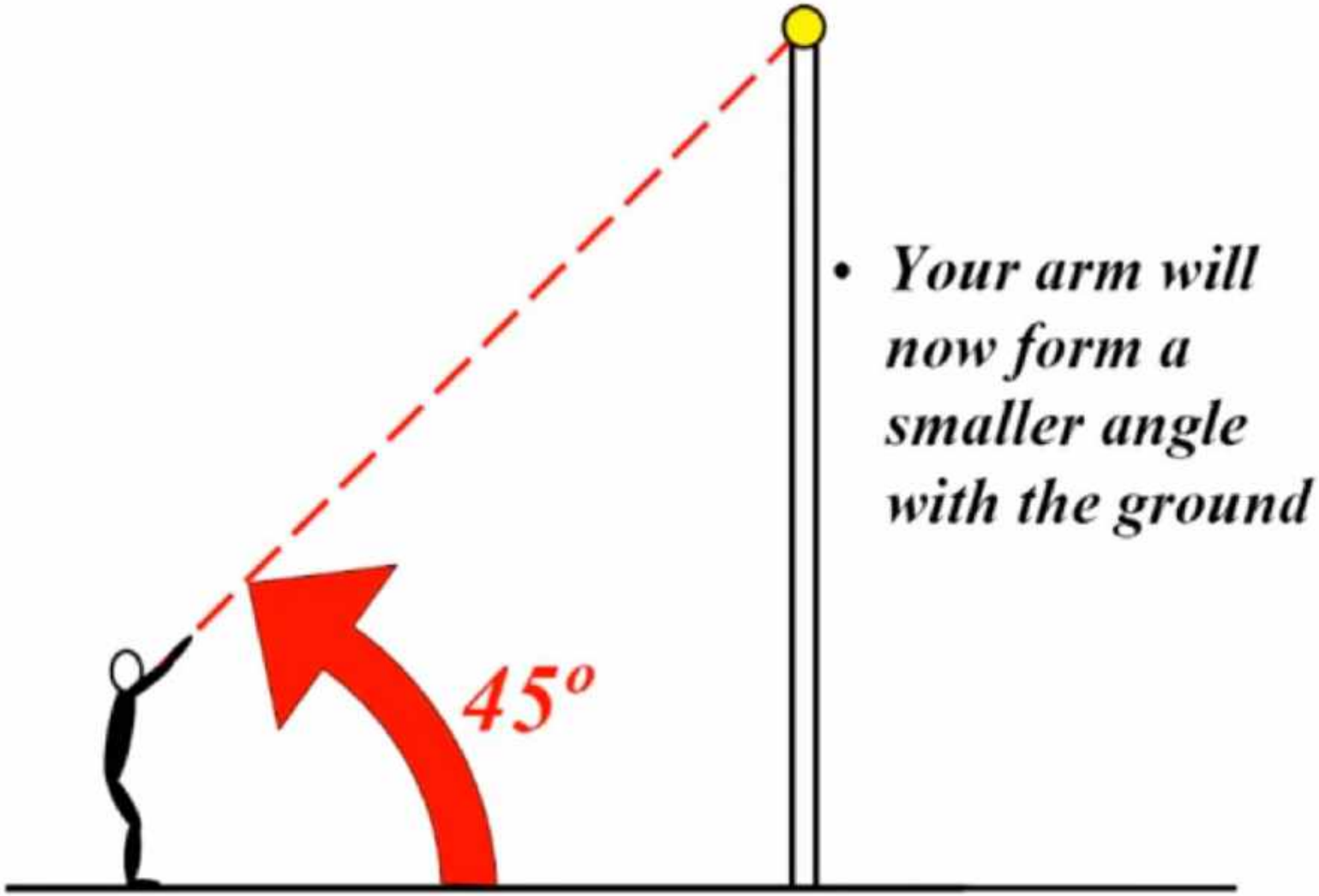
Dead Reckoning Plot



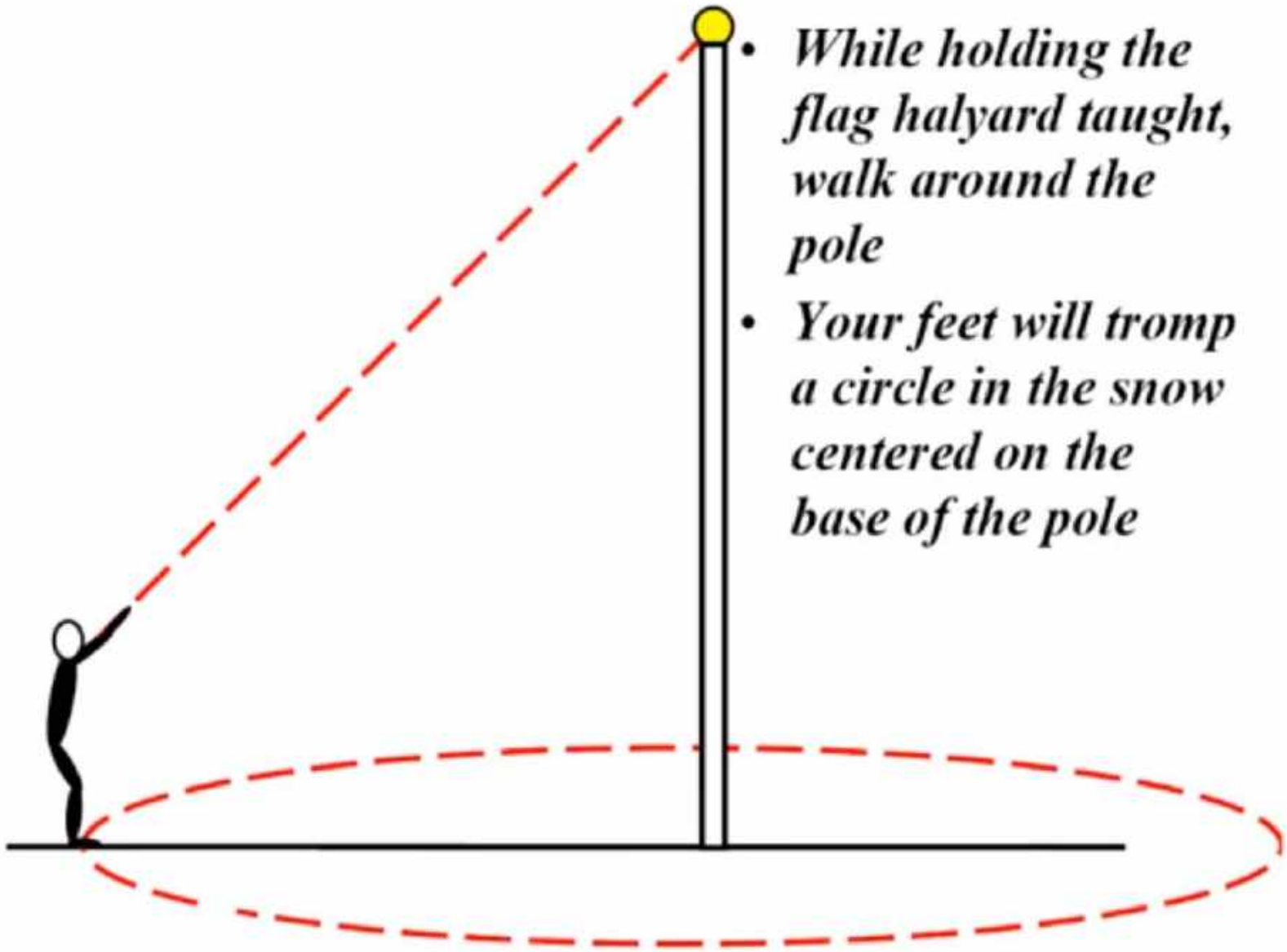
Celestial Geometry

- Ground Positions are listed in the Nautical Almanac

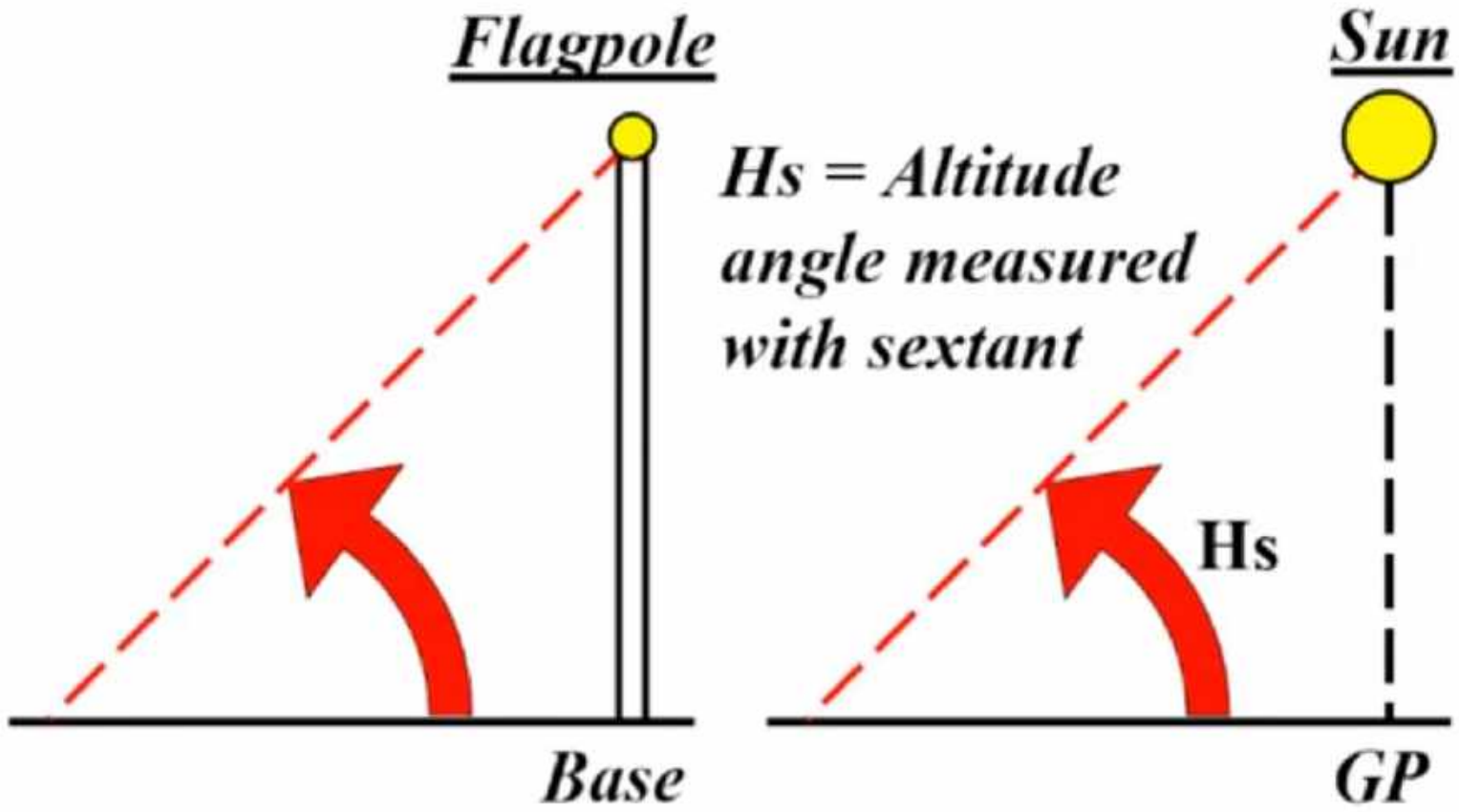


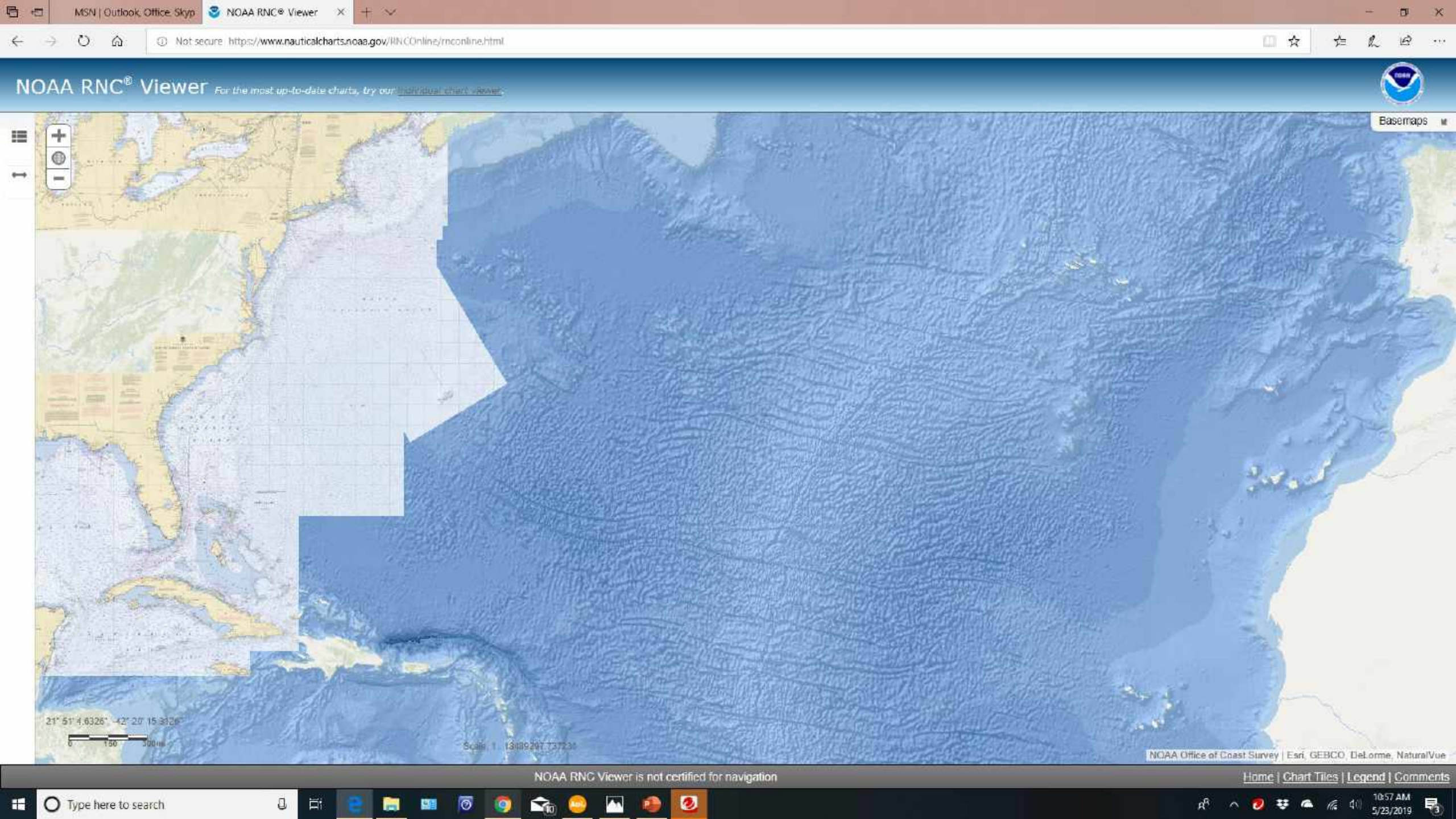


- *Your arm will now form a smaller angle with the ground*



- *While holding the flag halyard taught, walk around the pole*
- *Your feet will tromp a circle in the snow centered on the base of the pole*


Flagpole
Hs = Altitude angle measured with sextant
Base
Sun
Hs
GP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Date

- *Date needs to be the date at Greenwich, England to correlate with GMT that you use*
- *It is not uncommon to have a date change when you convert your ship's time to GMT*

Time Categories

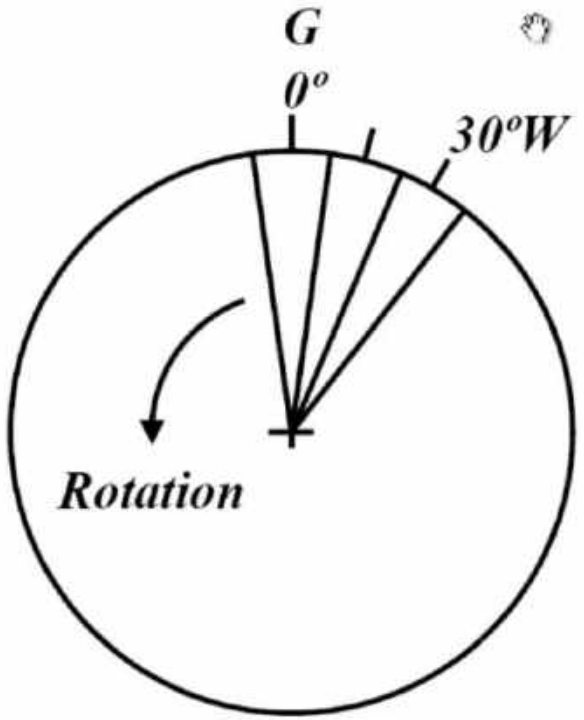
- *Greenwich Mean Time*
- *Zone Standard Time (15° wide)*
- *Local time*
  - *State Times*
  - *Daylight Time*
  - *Ship's Time*

Time Zones

- *Earth rotates 360° in 24 hours*
  - *That's 15° per hour*
- *Each Time Zone*
  - *Is 15° of longitude wide*
  - *And equal to one hour*

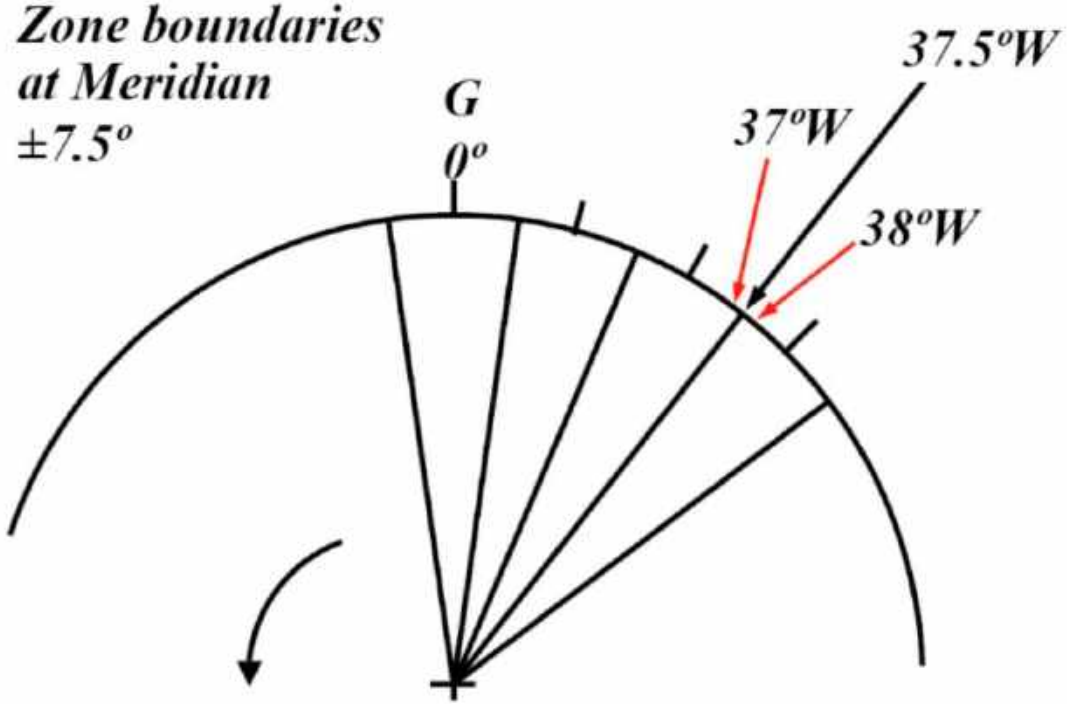
Earth Rotation

- *Earth as viewed from above North Pole*
- *Greenwich is Time Zone 0*
- *30°W is Time Zone 2W*
- *Each zone is 15° of longitude wide and equal to one hour*



Time Zone Change

- Zone boundaries at Meridian ±7.5°



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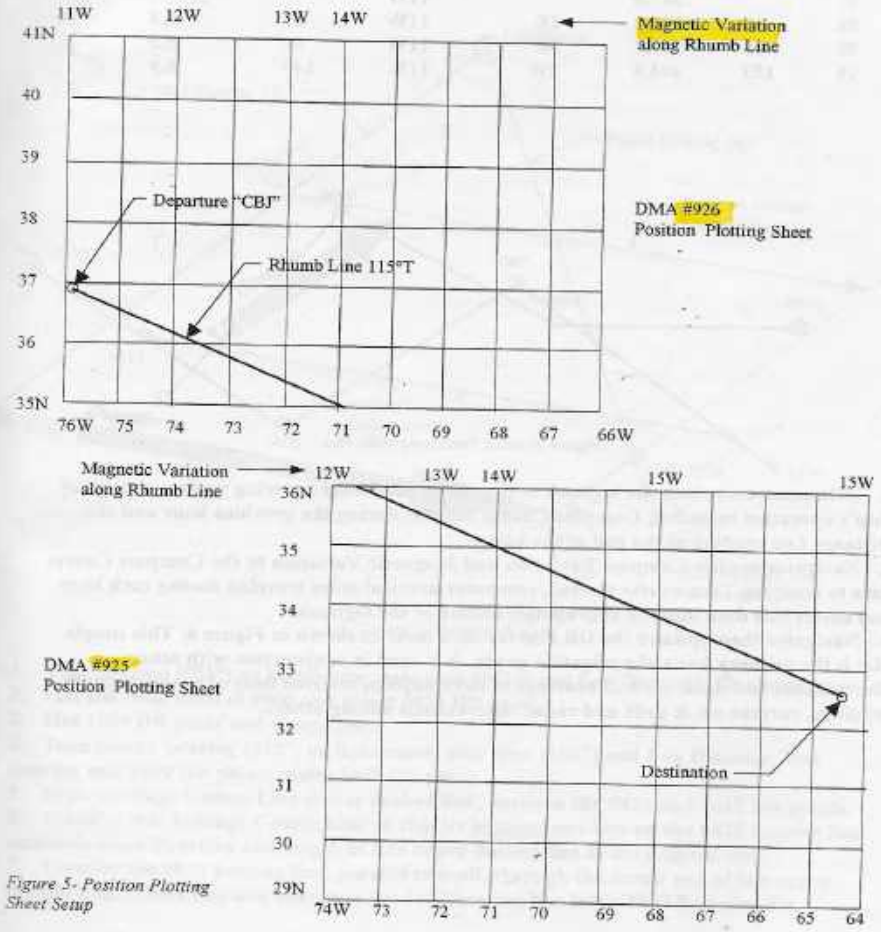


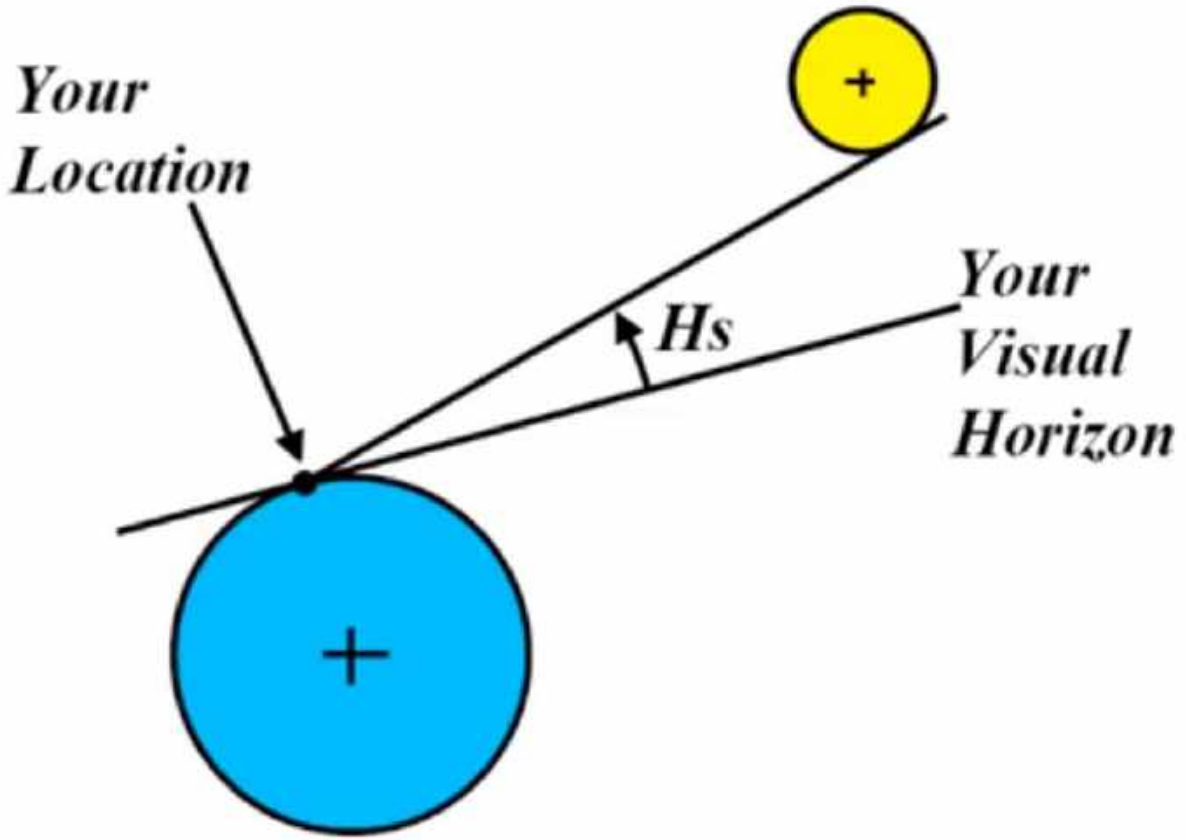
Figure 5- Position Plotting Sheet Setup

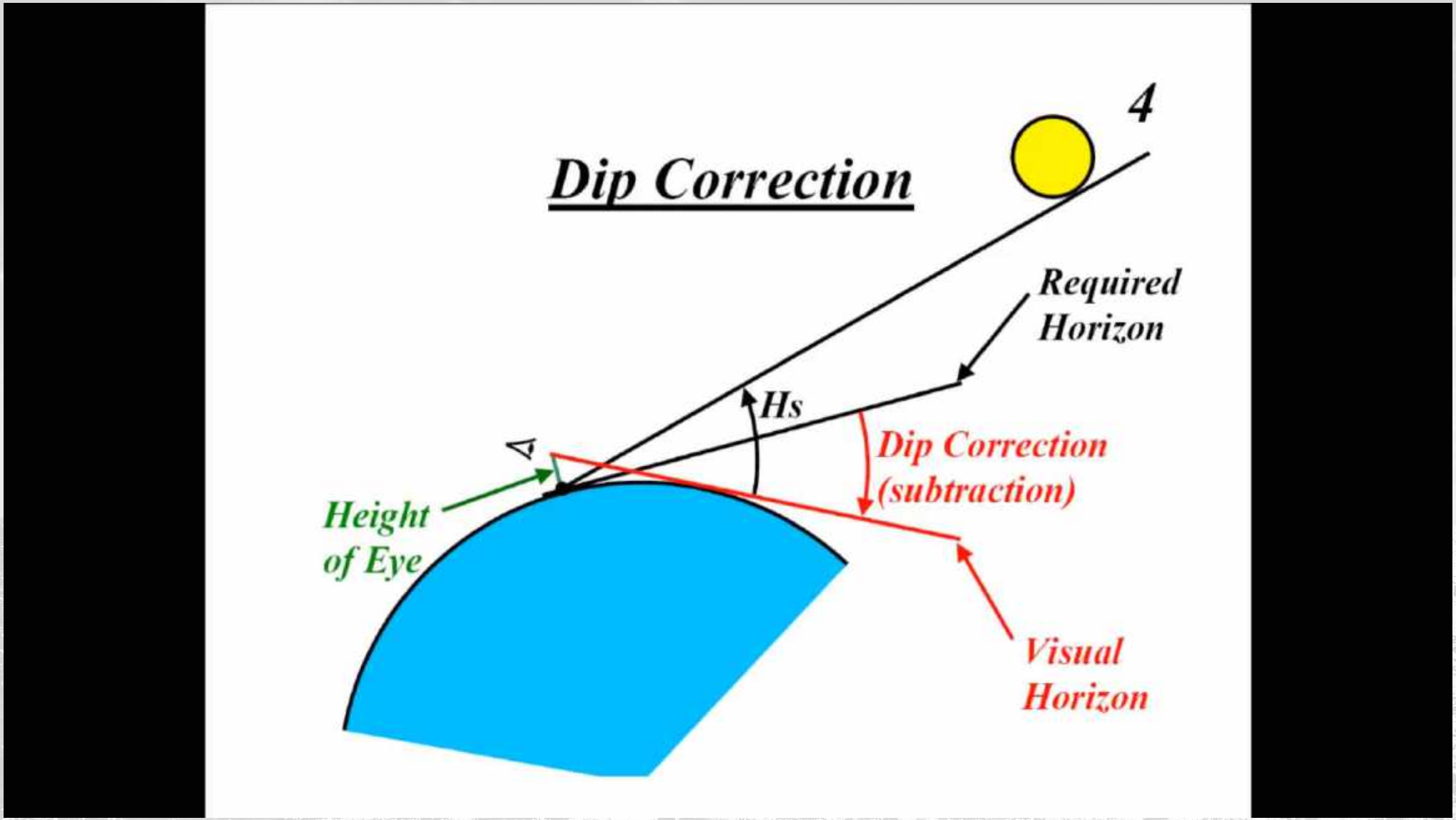
View Through Sextant

- *Altitude of Sun (Hs) above your visual horizon is measured with the sextant*
- *This is what you'll see through the scope of a sextant with a split horizon mirror:*

- *Sun is on right in the sun shade area*
- *Sea, sky and horizon are on left*

Sextant Altitude of Sun (Hs)

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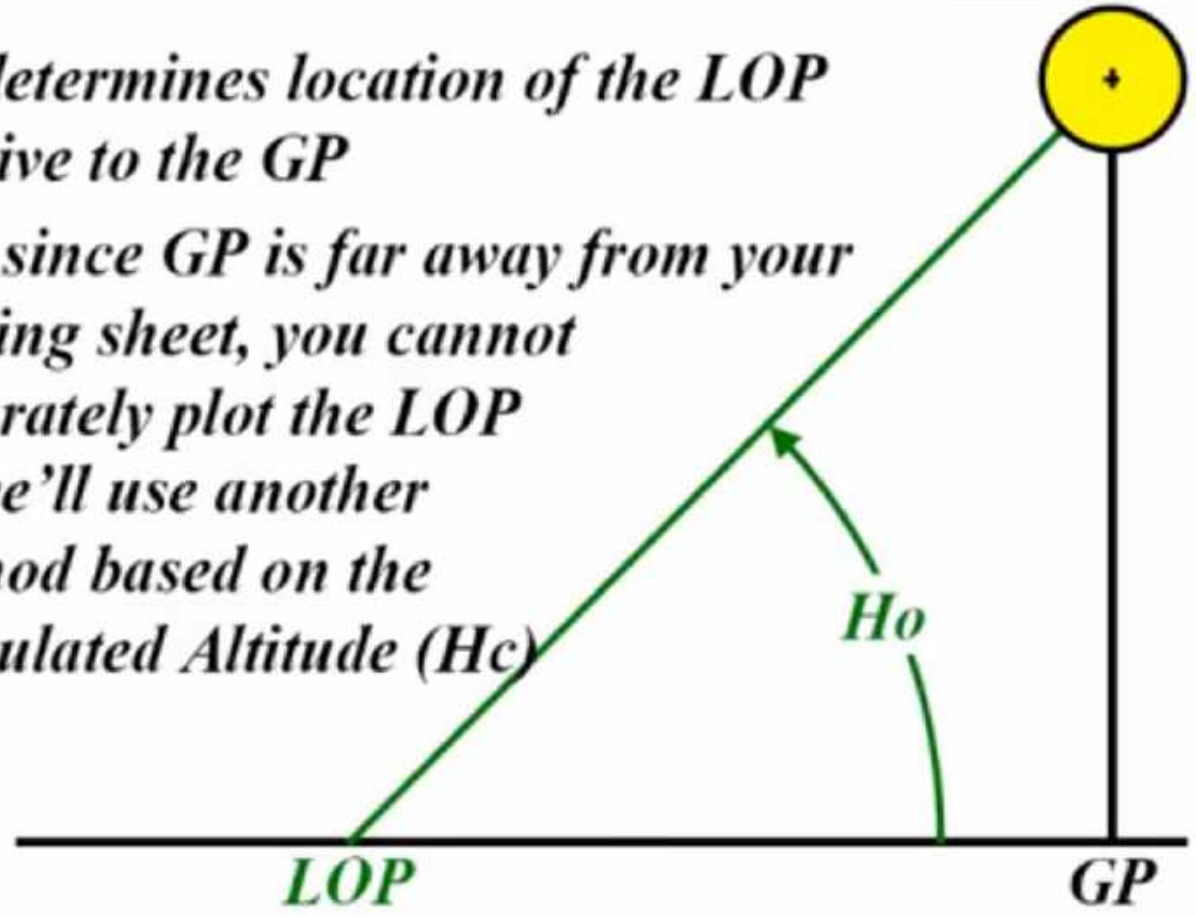
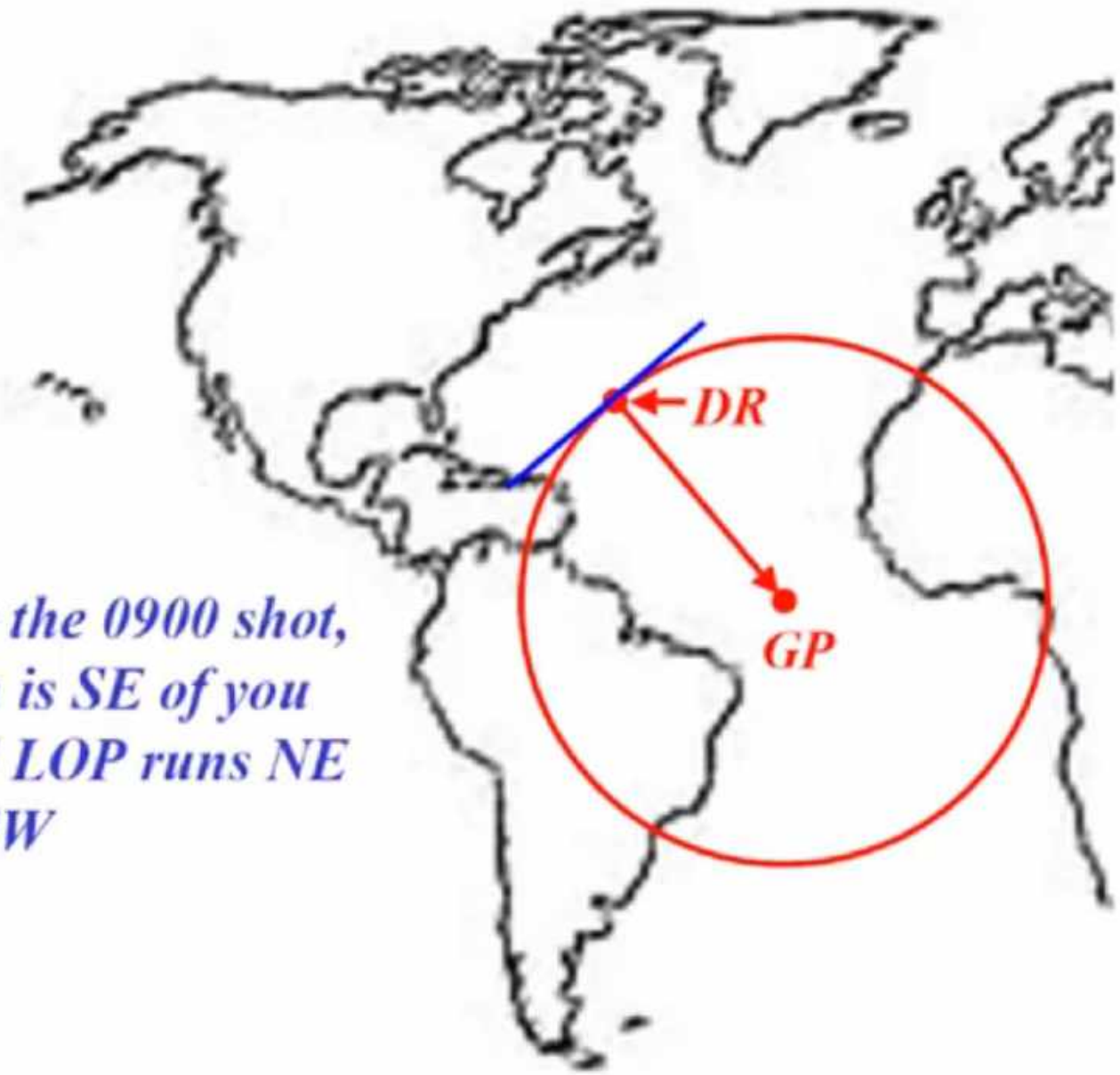
Dip Correction
Required
Horizon
Hs
Dip Correction
(subtraction)
Height
of Eye
Visual
Horizon

Observed Altitude (Ho)

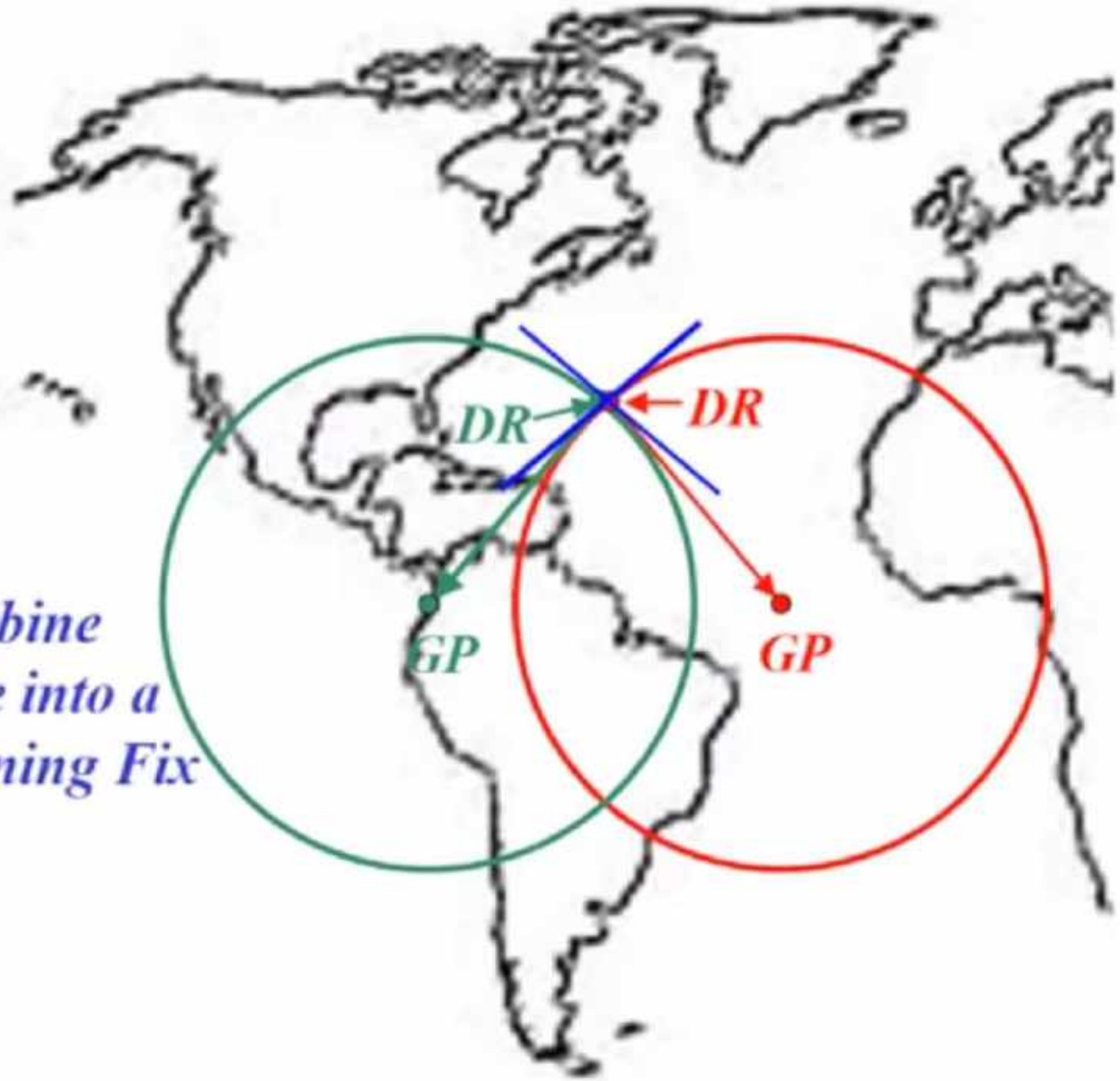
- *Ho determines location of the LOP relative to the GP*
- *But, since GP is far away from your plotting sheet, you cannot accurately plot the LOP*
- *So we'll use another method based on the Calculated Altitude (Hc)*



- *For the 0900 shot, Sun is SE of you and LOP runs NE to SW*



- *For the 1300 shot, Sun is SW of you and LOP runs NW to SE*



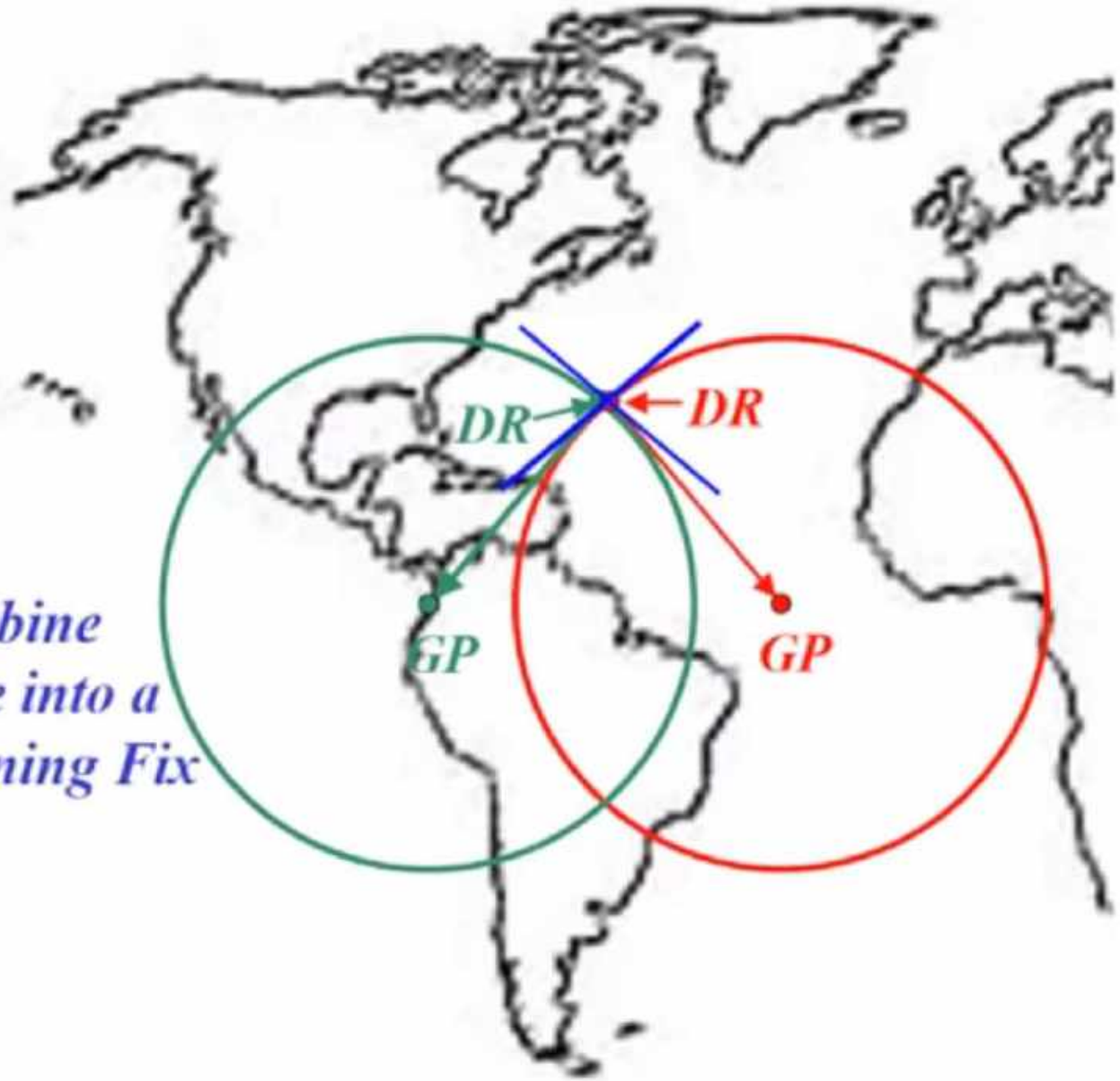
- *Combine these into a Running Fix*

Running Fix

- ***Example: Shoot Sun at 0900 and 1300***
- ***If you are in Northern Hemisphere, and Sun is south of you:***
  - ***0900 shot will give a roughly NE to SW LOP***
  - ***1300 shot will give a roughly SE to NW LOP***
  - ***Times will vary with latitude and season***
- ***Running Fix procedure allows combining these two LOPs***

Navigation Logbook

- ***Hourly entries:***
  - ***Course steered per Compass during past hour***
  - ***Distance Log reading on the hour***
- ***Every four hours:***
  - ***Average the courses steered***
  - ***Convert average courses from °Compass to °True using TVMDC***
  - ***Compute distance for the four hours***
  - ***Plot Course & Distance***



- *Combine these into a Running Fix*

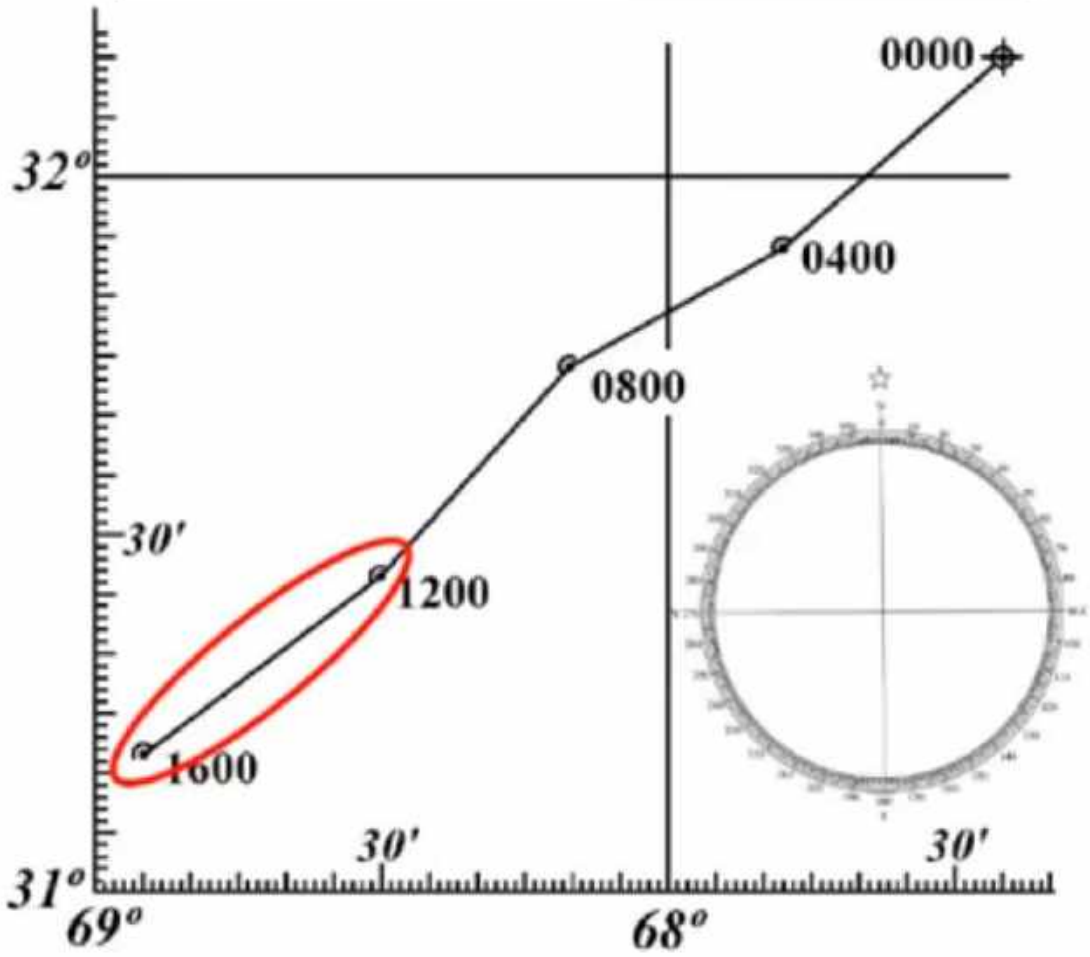
Dead Reckoning

- ***Dead Reckoning is where you think you are based on course steered and distance traveled, but:***
- ***Dead Reckoning (DR) is always in error due to:***
  - ***Compass errors***
  - ***Distance measurement errors***
  - ***Steering errors***
  - ***Crewmember reading & recording errors***
  - ***Seawater currents such as Gulf Stream***
  - ***Wind leeway (side slip)***

Dead Reckoning

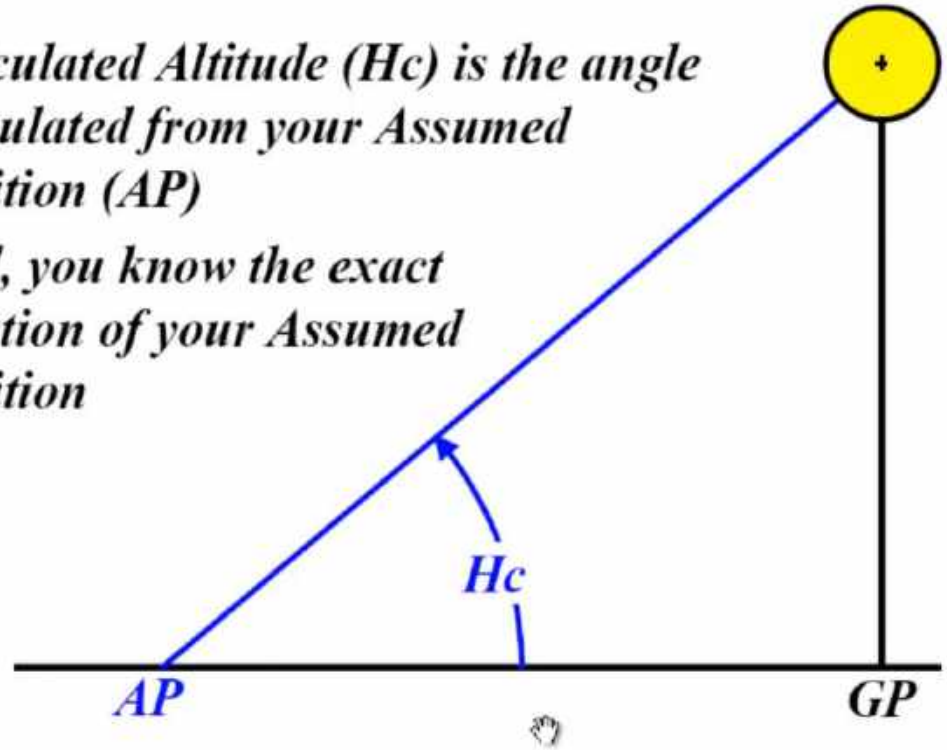
- ***In spite of these errors, DR is an essential component of navigation at sea because it is the structure that enables meaningful use of other information***

Dead Reckoning Plot



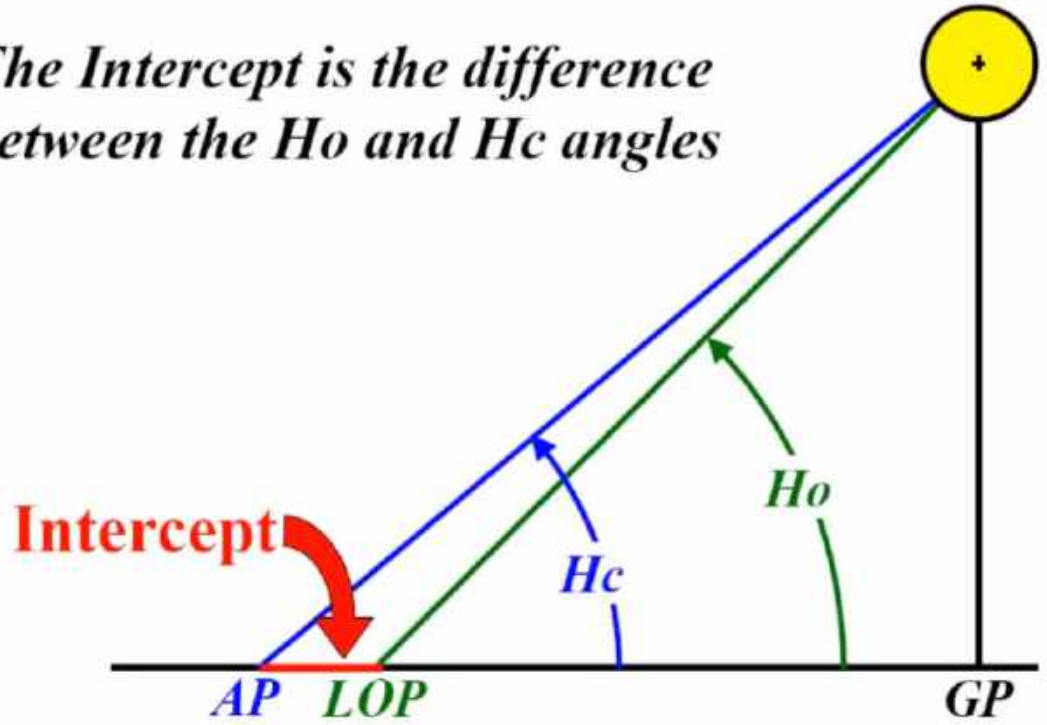
Calculated Altitude (Hc)

- *Calculated Altitude (Hc) is the angle calculated from your Assumed Position (AP)*
- *And, you know the exact location of your Assumed Position*

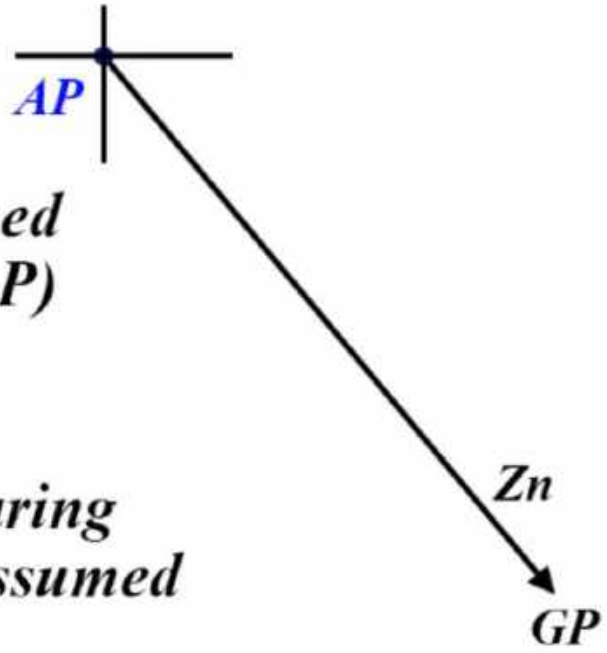


Intercept

- *The Intercept is the difference between the Ho and Hc angles*

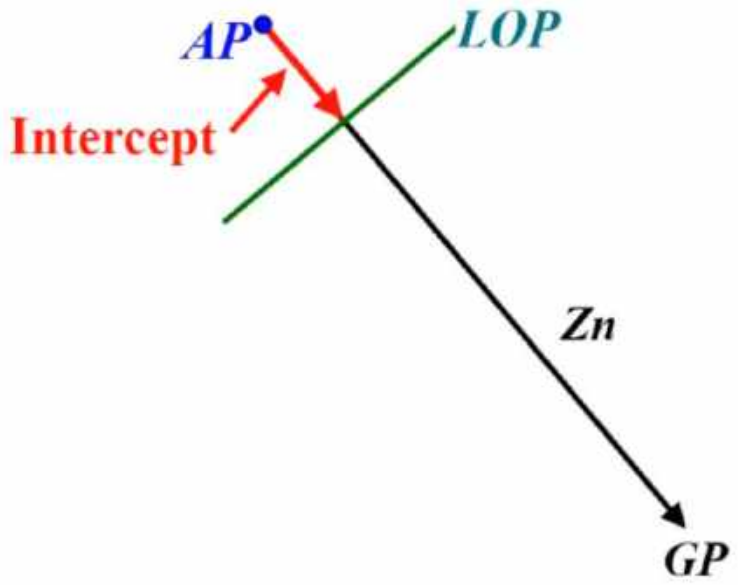


Azimuth (Zn)



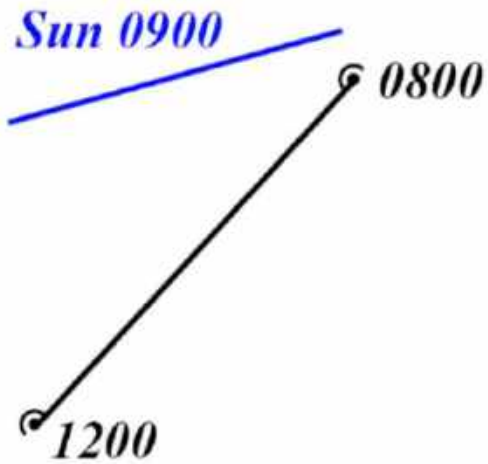
- Plot Assumed Position (AP) Latitude & Longitude
- Plot Zn bearing from the Assumed Position

Plot LOP

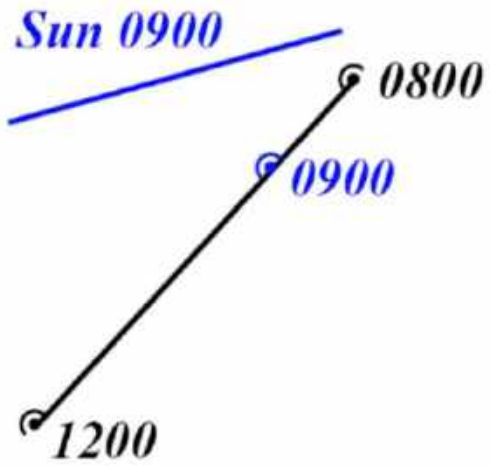


- *Draw the LOP line through the Intercept arrow point at right angles to the Zn*

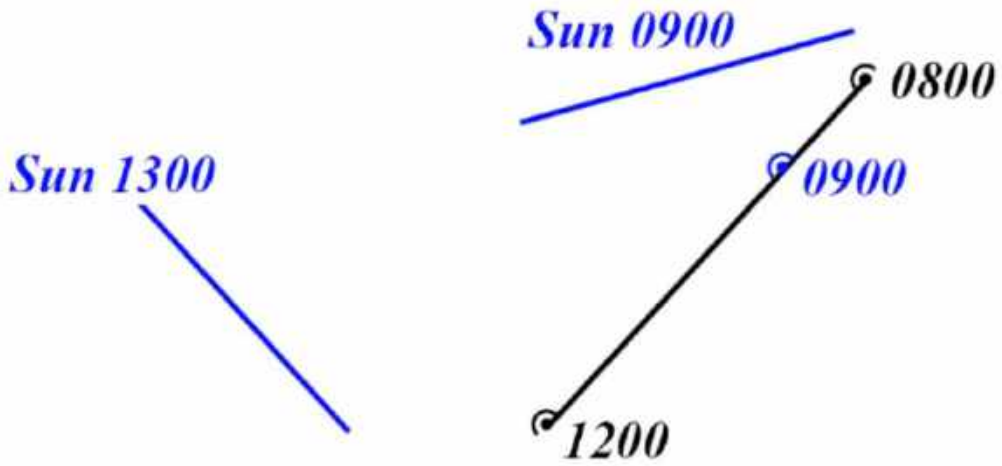
Plot 0800-1200 DR



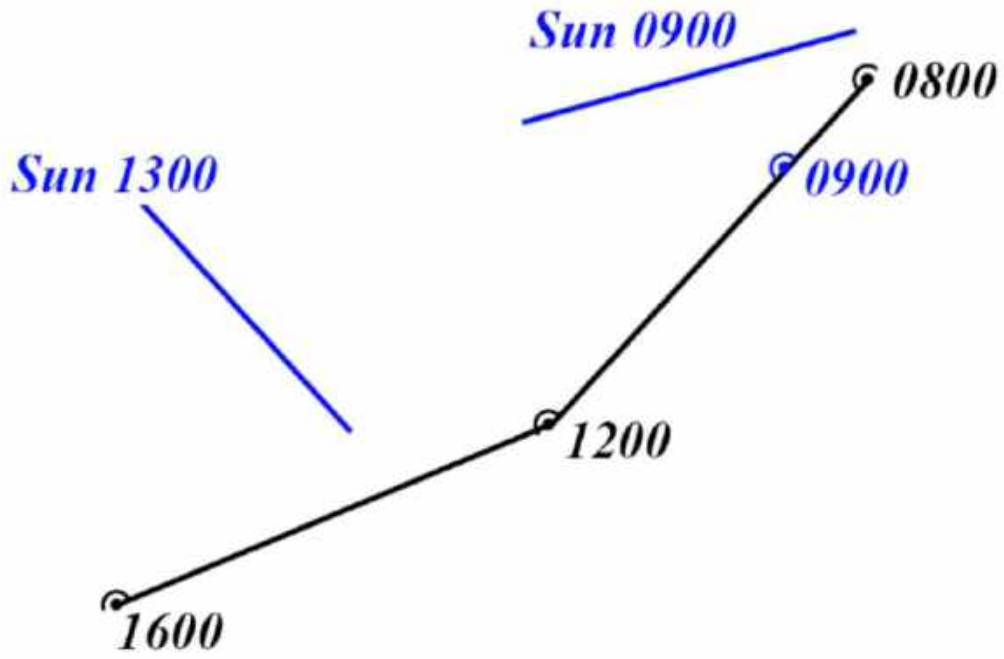
Mark 0900 DR Point



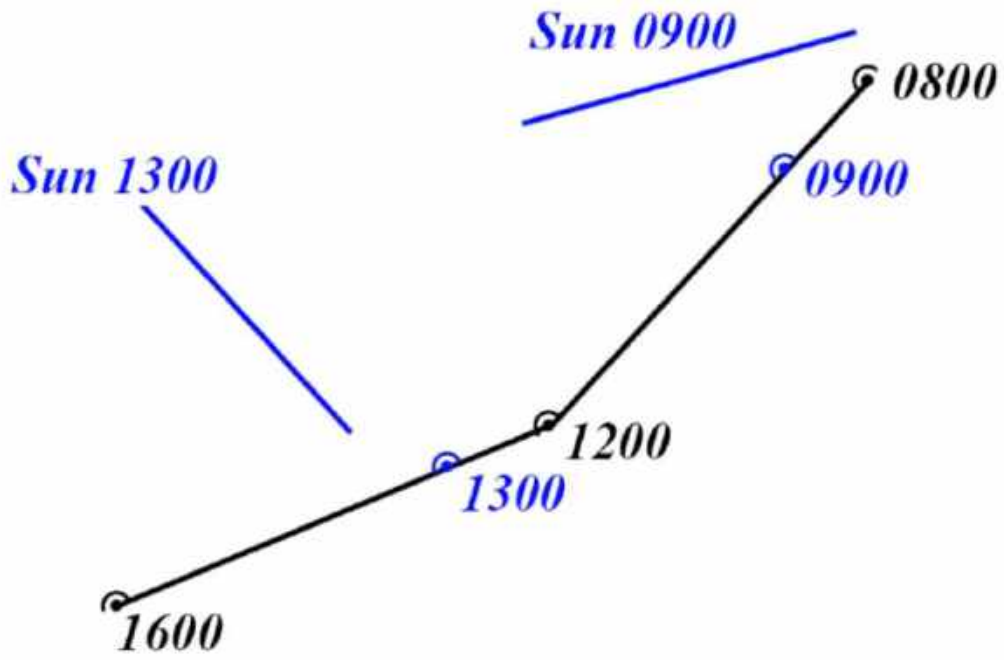
Plot 1300 Shot



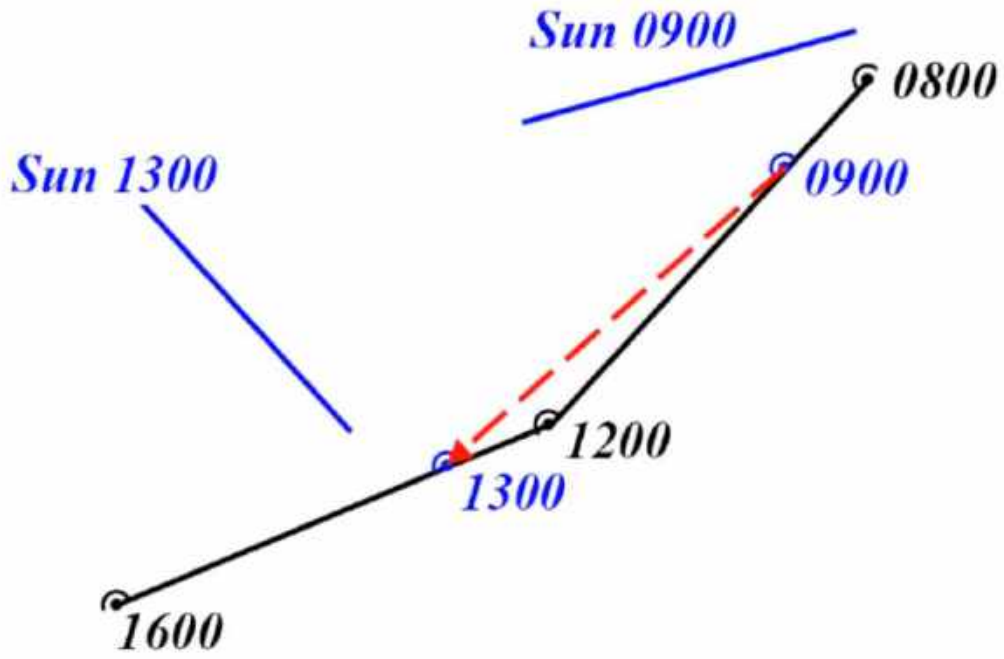
Plot 1200-1600 DR



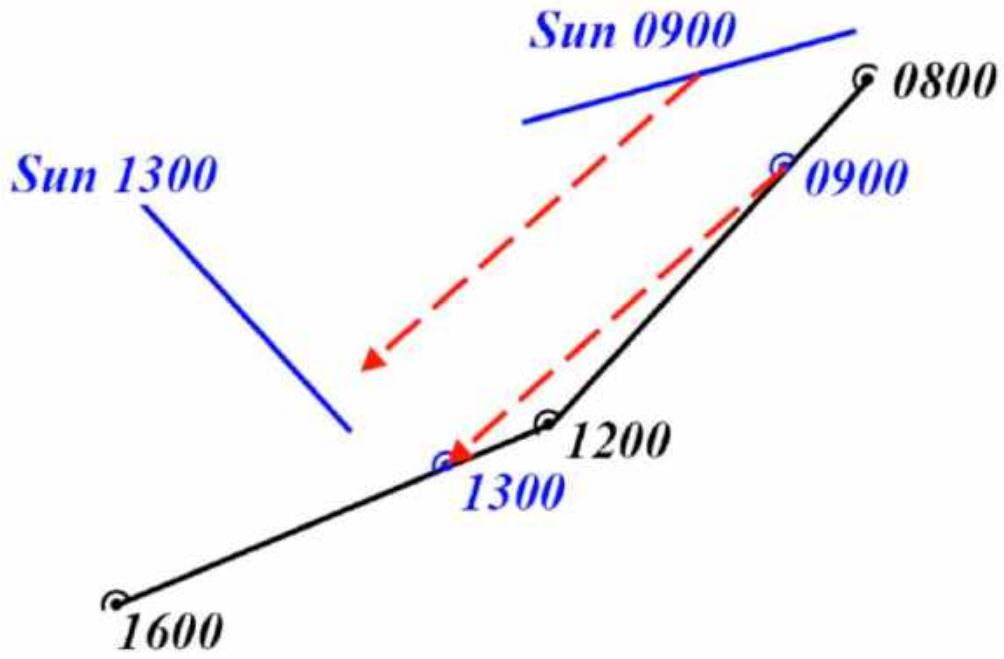
Mark 1300 DR Point



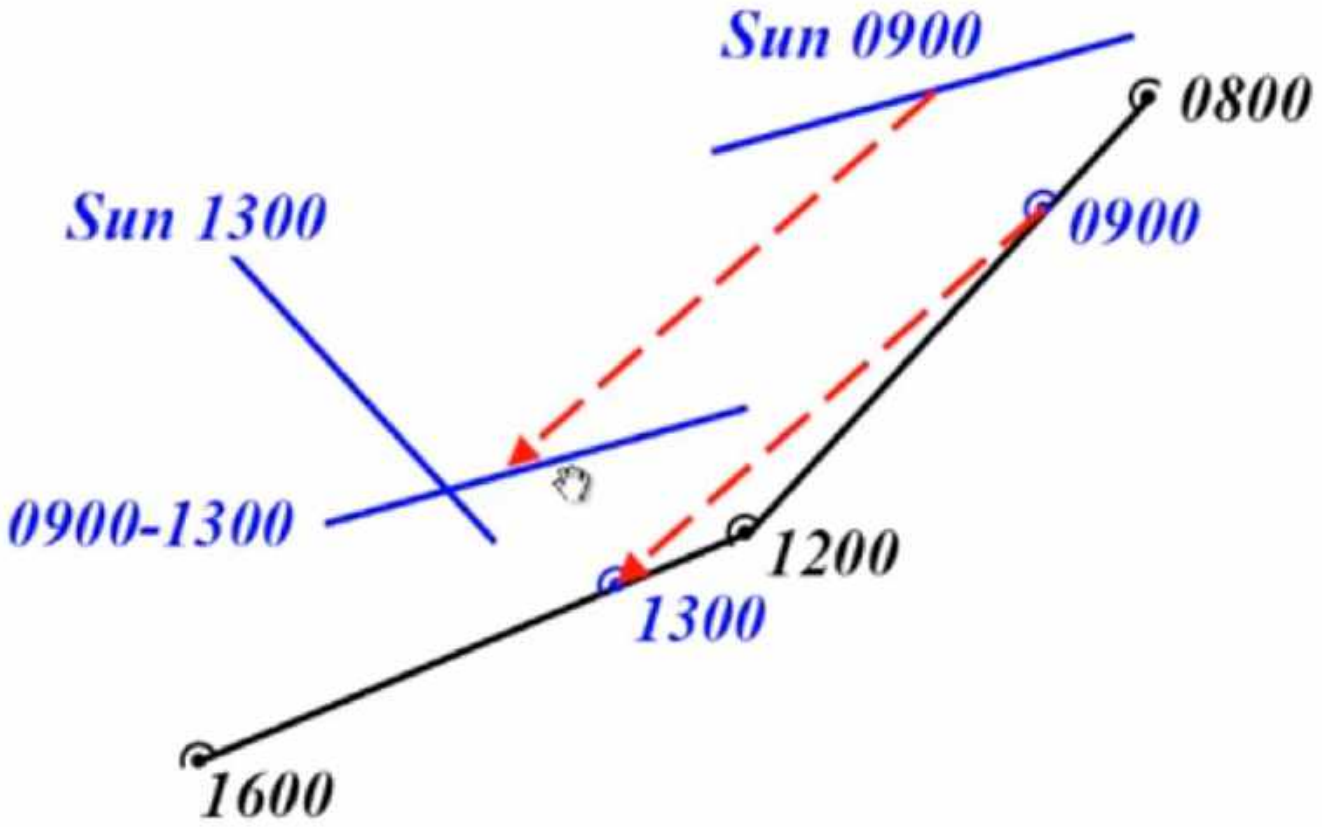
Measure Average Course



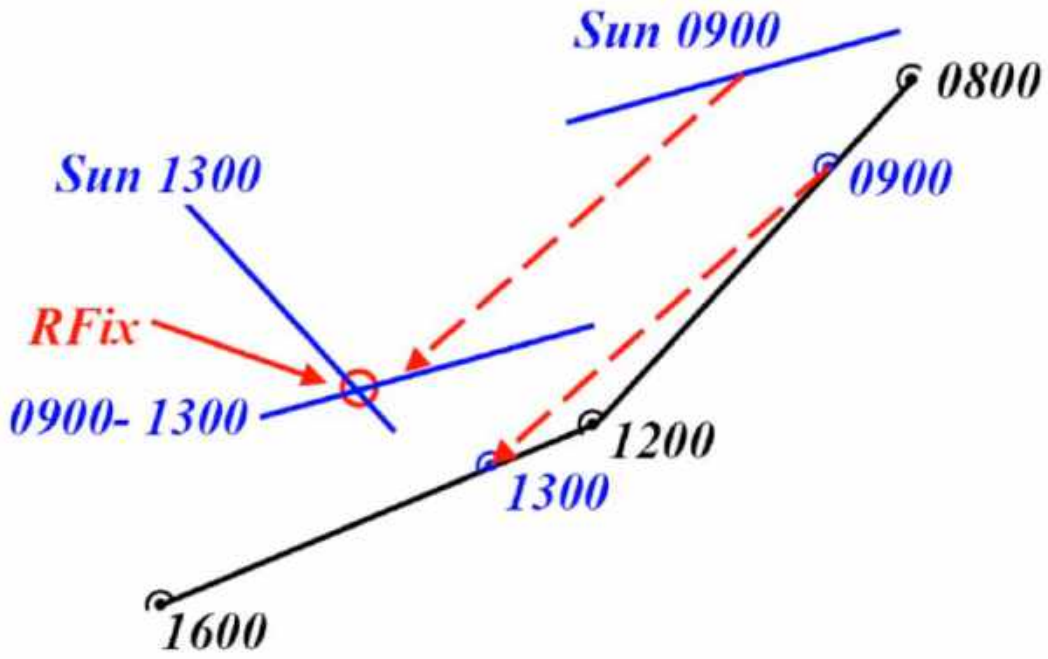
Transfer Average Course Line



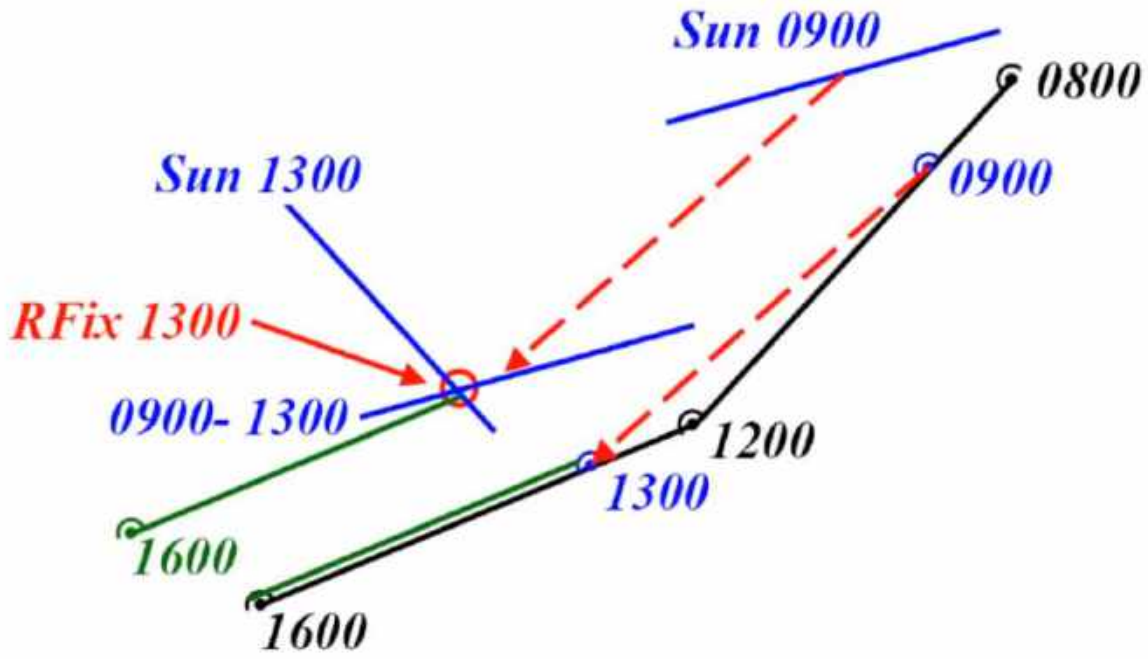
Advanced 0900 LOP to 1300

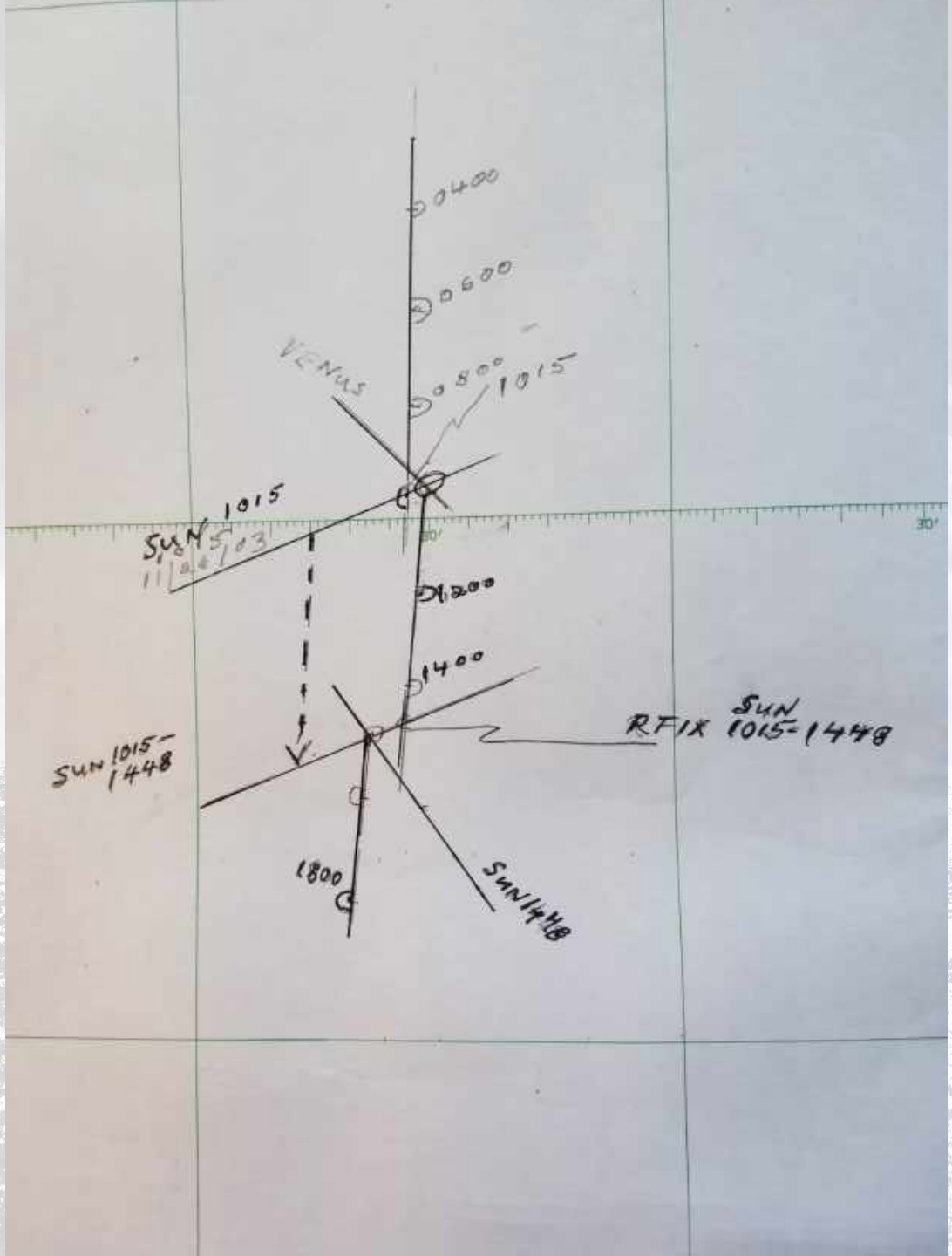


Mark Running Fix



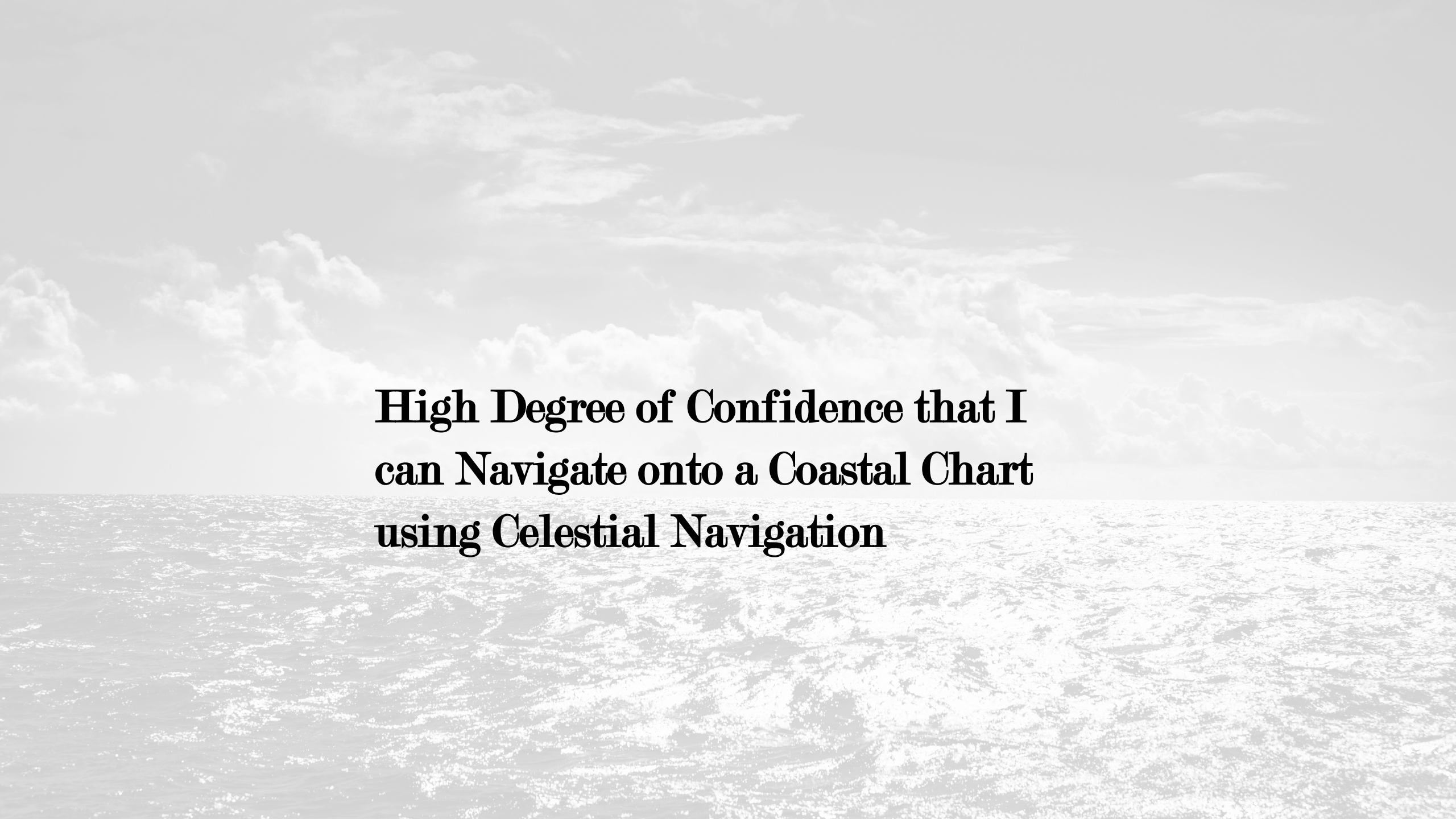
Plot New DR to 1600




0400
0600
0800
1015
VENUS
SUN 1015
1200
1400
SUN 1015-1448
RFIX SUN 1015-1448
1800
SUN 1448

What About Accuracy using a Sextant?

- Skill and Experience are Factors
- 10 % Certainty that I'm Within a One-Mile Square
- 90 % Certainty that I'm Within a Ten-Mile Square


High Degree of Confidence that I
can Navigate onto a Coastal Chart
using Celestial Navigation

MyChart - Login Page | Chart 25650

charts.noaa.gov/OnLineViewer/25650.shtml

Apps | World Cruising Club -... | MICROSOFT Account... | National Weather Ser... | Maritime Safety Infor... | National Passport Vid...

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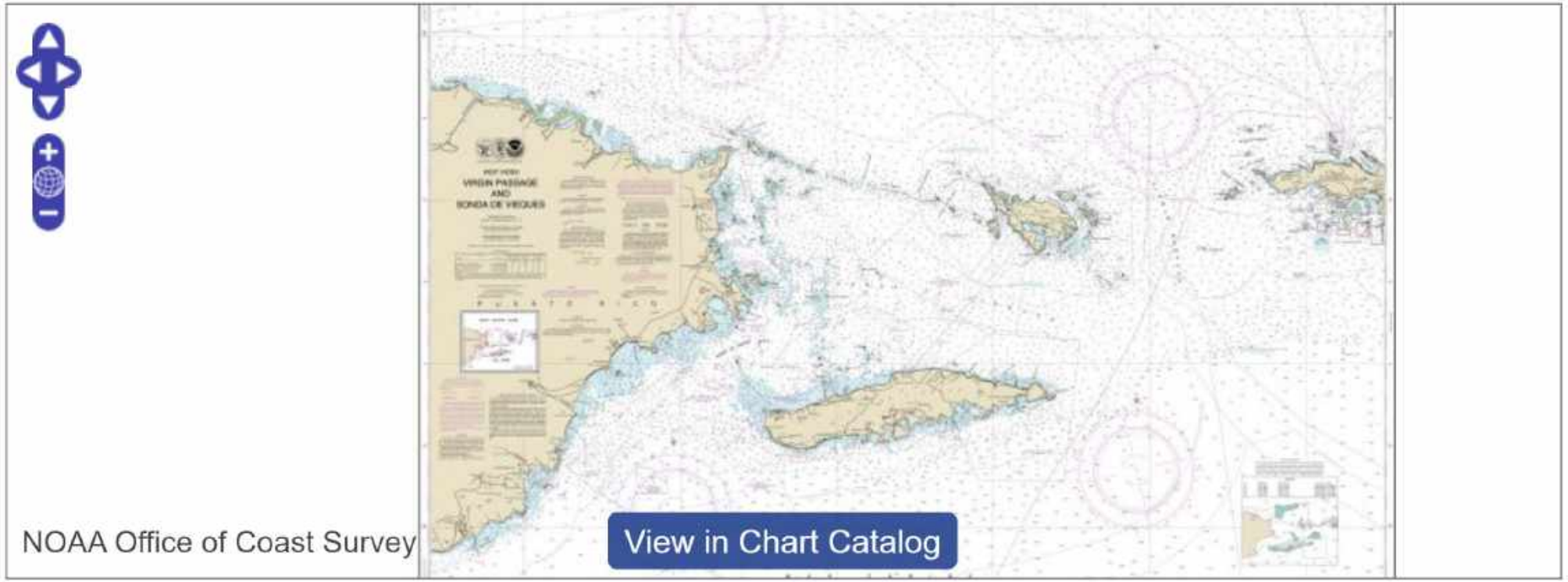
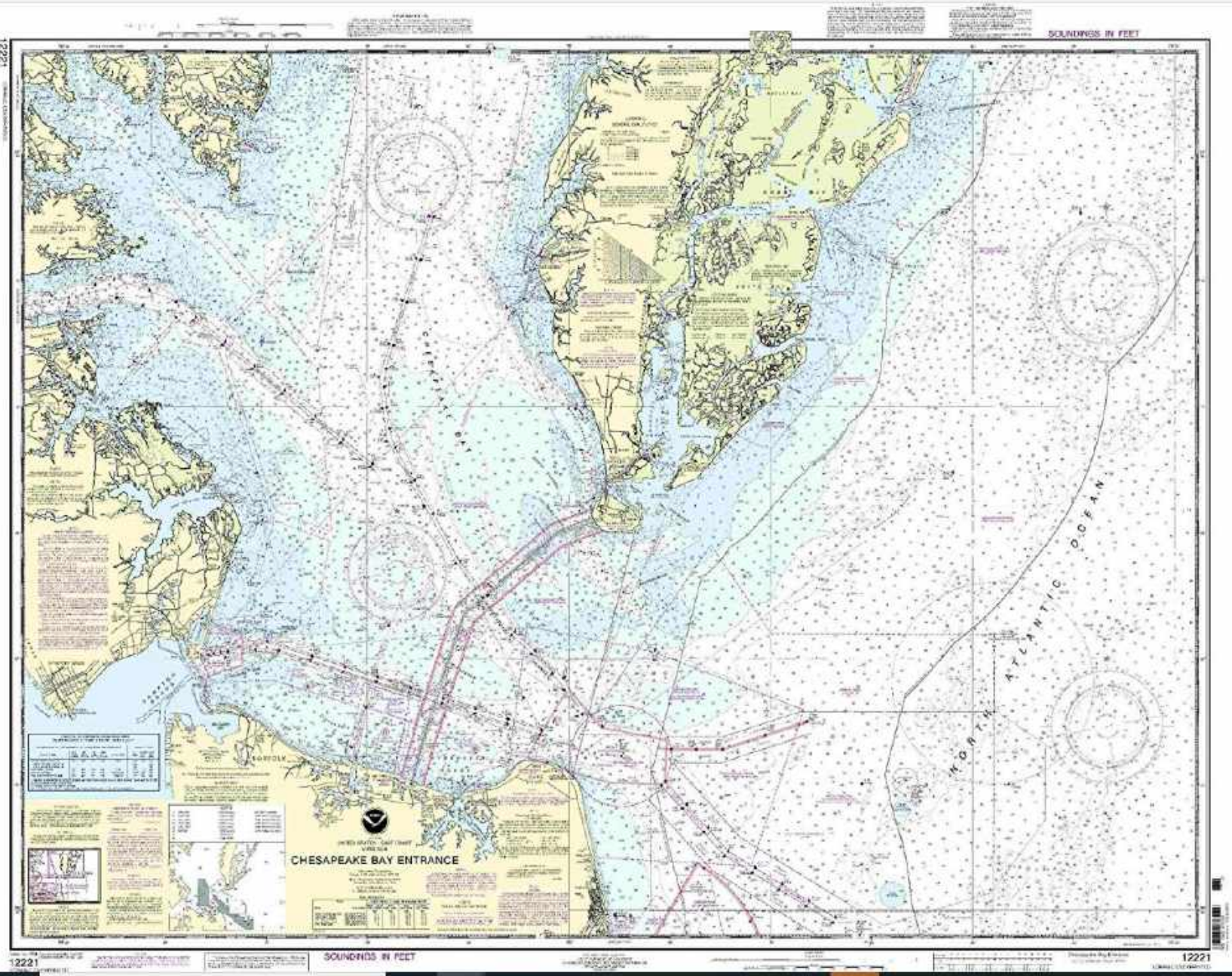


This chart display or derived product can be used as a planning or analysis tool and may not be used as a navigational aid.

Type here to search

10:52 AM
10/23/2019


DUTCHCAP PASSAGE
SALT CAY PASSAGE
SALT CAY
SOUTHWEST ROAD

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THANK YOU AND FAIR WINDS, ALWAYS!