Chart Accuracy Limits – Project Data

|	
Title:	Nautical chart accuracy limits (aka: how to stay afloat)
Objective:	Discuss the limitations and related safety aspects of navigation charts and electronic chart plotters
Speaker:	Kevin Jones and Mark Charnews
QYC Only?:	No
Date:	5 April, 2017
Time:	7 – 9 PM
Duration:	120 minutes
Location:	Vashon Library (Meyers Hut as backup)
Space Required:	Room with tables, chairs and projection screen
Supplies to bring:	Laptop & power cable, projector & power cable, laptop/projector cable
Handouts:	None
Tools to bring:	None
Props & Examples:	None
Advertising plan:	Advertise tech talk w/ flyer at QMM, library, grocery store, HW store, Burton Boat, QYC (Meyers Hut, top of hill bulletin board, dock gate), preview at QYC meeting
	Flyer with picture of grounded racing sailboat with "How Could This Happen?" and text "How to keep it from happening to you"
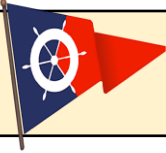
Chart Accuracy Limits – Agenda

|	
7:00	Welcome / Overview / Introduce experts
7:05	Chart Accuracy Limits Overview
7:15	Horizontal Accuracy
7:25	Vertical Accuracy
7:35	Chart plotter accuracy issues
7:50	Vestas Wind Grounding
8:05	Joe Cove Example / Other chart quilting errors
8:15	Mark Charnews GPS accuracy and projection coordinate systems
8:40	Summary / Questions / Start teardown / Complete surveys
9:00	Depart
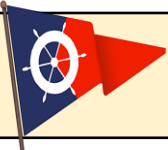
WELCOME to QYC Tech Talks!

- A Tech Talk is…

  - An <u>exchange</u> of information, ideas and experience

  - More dialogue than "teaching"

  - A little structure

- We encourage…

  - Listening, learning & contributing

  - Discussion and debate

  - Questions

- Our next Tech Talk is:

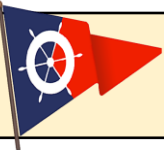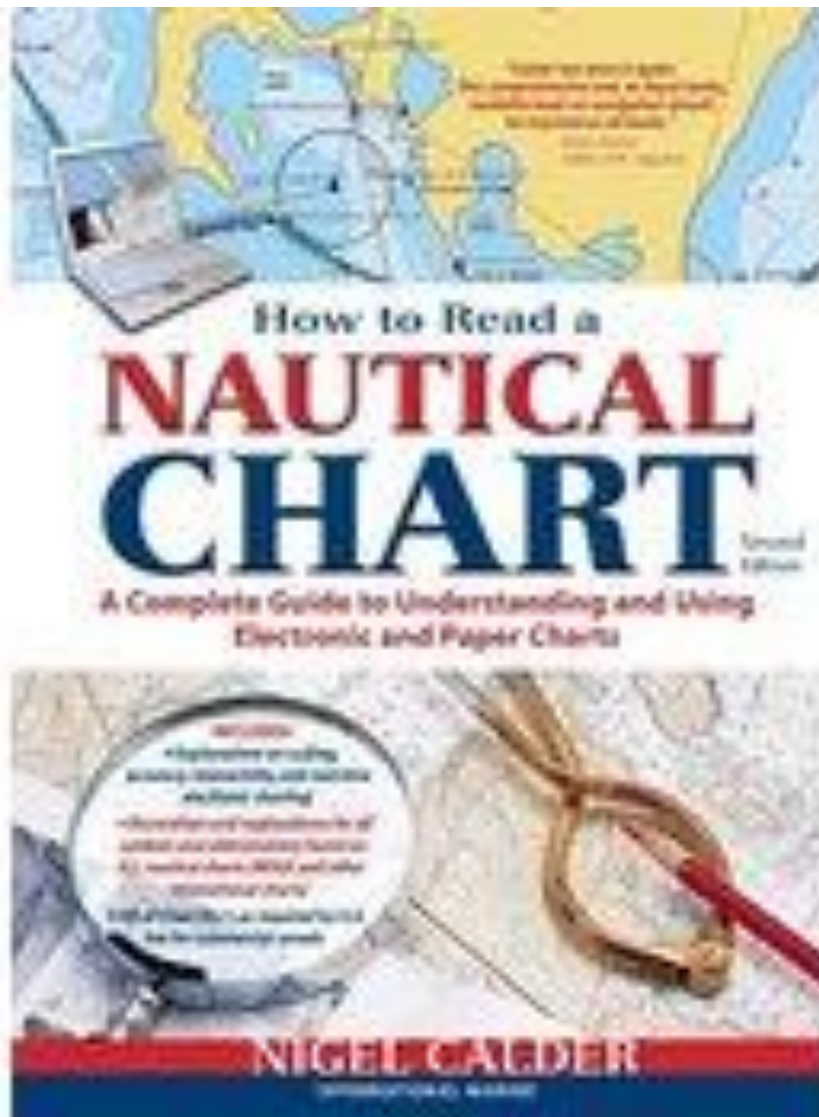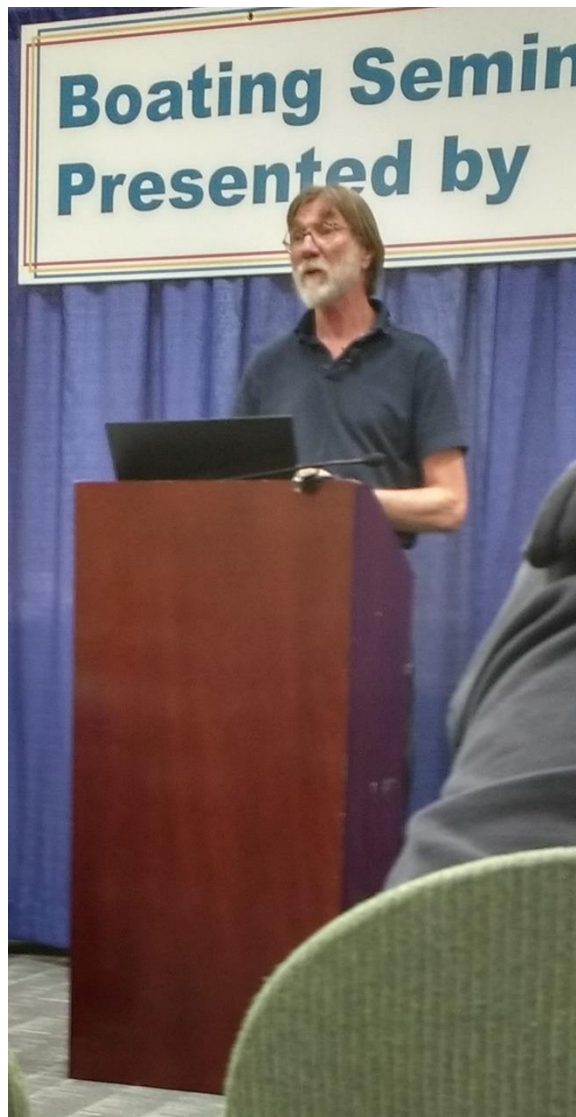 - 10 May at 7PM – Safe Trip Planning

Together, to Learn From Each Other
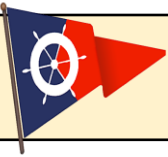
- Volvo Ocean Race: Vestas Wind aground, middle of the Indian Ocean
  - What lead to this accident?
  - Is this a boating risk in the Pacific Northwest? (Yes)
  - You can avoid this situation!

- This Tech Talk is based on the Nigel Calder book…
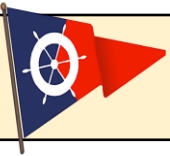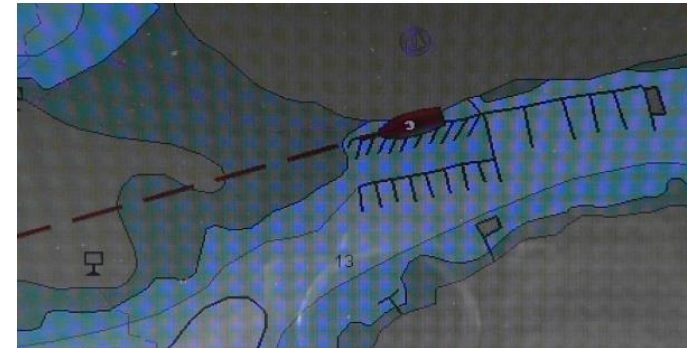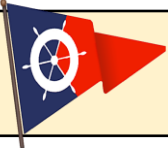
Chart Accuracy Limits - Overview

- Accuracy limitations of the underlying chart data

  - Horizontal position errors

  - Depth errors

- Errors introduced by electronic chart plotters

  - Chart data issues

  - Overzoom issues

- The Vestas Wind example illustrated

- A local example – Joe Cove, BC

- Summary

Raster vs Vector Chart
Secret Cove, BC

Keep in Mind...

- Our current charts are most likely developed from survey data that is decades old

- Survey ships used non-GPS systems to determine shoreline and sounding locations

- GPS can now determine boat position within 50ft

- This accuracy is well in excess of the requirements imposed on the survey data collected years ago!

GPS allows us to know the position of our vessel with more accuracy than most of the survey vessels that provided data for today's charts
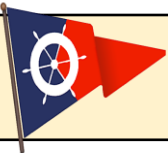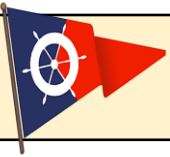
Survey Data Accuracy Limits - Horizontal

- **Four categories of surveys (Calder):**

Survey Category (1)	Usage	Horizontal Position Accuracy	Vertical Position Accuracy (2)	OPUS V comparison
Special Order	harbors & channels	6.6 ft	10 in	0.2 boat lengths
First Order	less critical habors & channels & coastal areas up to 330ft deep	16.5ft + 5% of the water depth	20 in	0.5 boat length
Second Order	coastal areas up to 660 ft deep	66ft + 5% of the water depth	3.3 ft	At least 2 boat lengths
Third Order	All other areas	492ft + 5% of the water depth	3.3ft	At least 17 boat lengths

(1) NOAA has adopted First Order survey category for all surveys
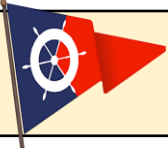(2) Depth error allowed to increase as depth increases

Survey Data Accuracy Limits – Horizontal

- **NIMA statement of accuracy for pre-1990 surveys:**
  - **Chart scale: 1:15,000   Horizontal error: 48ft**
  - **Chart scale: 1:80,000   Horizontal error: 259ft**

- **To meet the new standards, new surveys are required. How many, per Calder in 2011?**

Country	% adequately surveyed	% requiring resurvey	% never adequately surveyed
US	60	35	5
Canada (1)	30	10	30

(1) Table error? Numbers to not add to 100%

A significant portion of Canadian waters have not been adequately surveyed. Wonder where they are?

Survey Data Accuracy Limits - Vertical

- **Some interesting data points:**

    - **50% of US chart soundings gathered using a lead line**

    - **Aug 1992: Queen Elizabeth II hit an uncharted rock off Block Island, East US coast last surveyed in 1939**

    - **2005: Submarine USS San Francisco hit a seamount in the Caroline Islands in water charted at over 7000 ft deep. The sub was at 525 ft depth**

- **Multiple factors influence the reporting of water depth**

- **Multiple factors influence the actual water depth**

    - **Wind, Barometric pressure, Fresh water runoff, etc**

Have a depth sounder? Use it.

Let's Build Some Charts

- **Paper Charts – built by cartographers**

    - **Subject to survey data errors and chart space limits**

- **Raster Charts – not built by cartographers**

    - **"Bit Map" of paper charts (not from the raw data)**

    - **Small to large scale chart transition is a particular problem**

- **Vector Charts – not built by cartographers**

    - **Data file of chart features, locations and characteristics**

    - **Sometimes built from Raster Charts (compounding errors)**

    - **Location of features / soundings left to the chart developer**

Only the paper charts are based on the survey data! This may be changing...
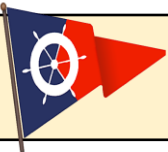
And Put Them in a Chart Plotter!

- **Surveys: limited ability to DETECT objects / non-GPS accuracy**

- **Paper charts: limited ability to DEPICT objects**

- **Electronic charts: typically developed from paper charts**

- **Raster overzoom: enlarges objects & apparent water between them**

  - **Channels look larger but obstructions are still also large**

- **Vector overzoom: retains object size and <u>increases</u> the apparent water between them (Calder assertion – I'm not so sure…)**

  - **Channels look much larger than on a paper chart from which the vector chart was derived**
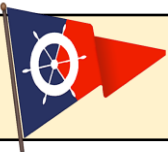
Rocks DETECTED by the survey but not DEPICTED on the paper chart WILL BE MISSING from the electronic chart!
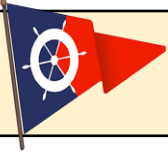
Overzoom Awareness

- **"OVERZOOM" label appears on chart display (OpenCPN)**

- **Restrict zoom level based on underlying chart scale (RL70C)**

- **Raster charts likely show distortions of the text**

- **Vector charts, always redrawn at different zoom levels, will not show any distortion**

Demonstrate using OpenCPN

Vestas Wind Grounding (16°32′0.0″S 59°32′0.0″E)

The navigator, Wouter Verbraak, was highly qualified. He was part of the 2010-11 Barcelona World Race (double-handed) onboard Hugo Boss, and had competed in a couple of VOR campaigns as either navigator or co-navigator. Also, the guy has a master's degree in physics, "completed in Sydney with sea breezes as his thesis."

"We are offshore in the middle of nowhere, and on the chart, if you don't go on the maximum zoom you can't see anything."

An independent report into the grounding of Team Vestas Wind … released today.

"The team was unaware of any navigational danger in its vicinity, incorrectly assessed the minimum charted depth at Cargados Carajos Shoals to be 40 metres and understood that it was safe to sail across the shoals," summed up the panel.

The panel … made the following conclusions:

i. *There were deficiencies in the use of electronic charts …*

ii. *There were also deficiencies in the cartography presenting the navigational dangers*
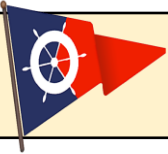
Joe Cove, BC ~ Un-depicted Rocks

- **Vector chart missing two rocks in the entrance to inner Joe Cove**

- **Raster chart "Queen Charlotte Strait, Eastern Portion" clearly shows these rocks (chart scale 1:40000, date 1996-02-02)**

- **Raster chart "Knight Inlet" does not include these rocks (chart scale 1:80000, date 1995-11-15)**

  - **Conclude: Vector chart built from "Knight Inlet" paper chart**

Demonstrate using OpenCPN
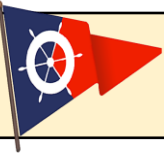
Vector chart quilting error

Helm View

Raster Chart

Vector Chart
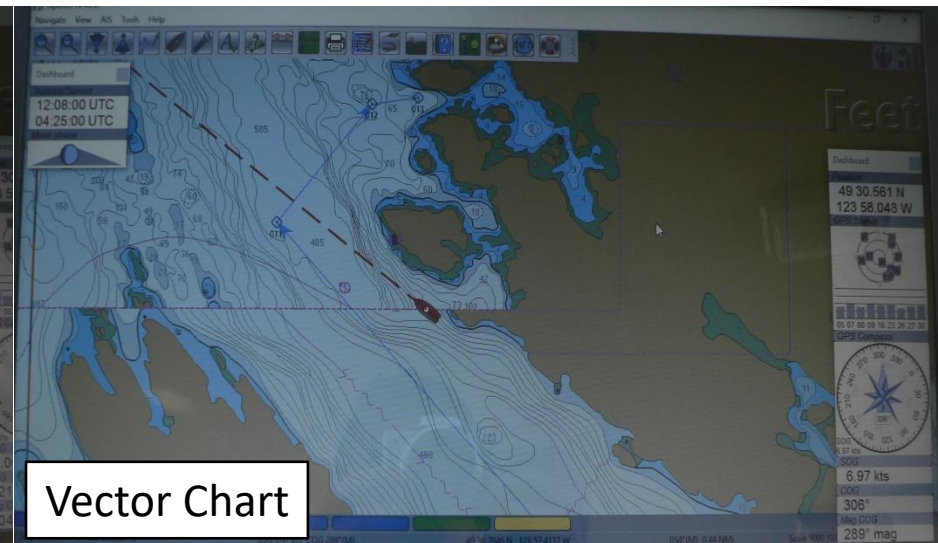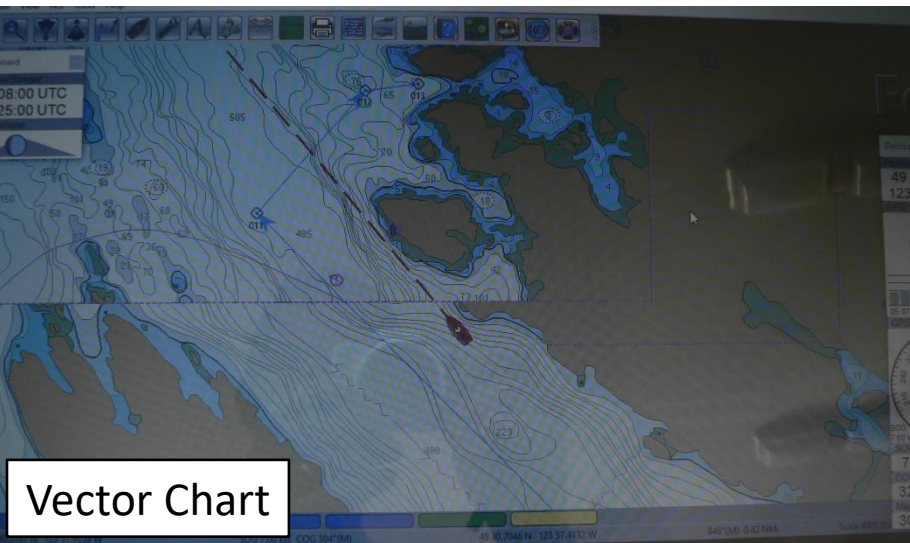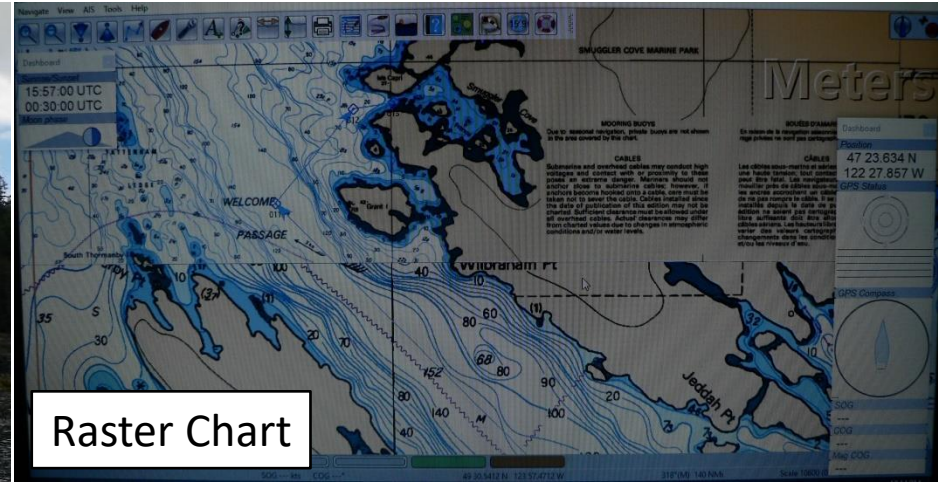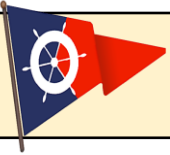
Vector Chart

Chart position data inaccuracies ~ Secret Cove

Vector Chart
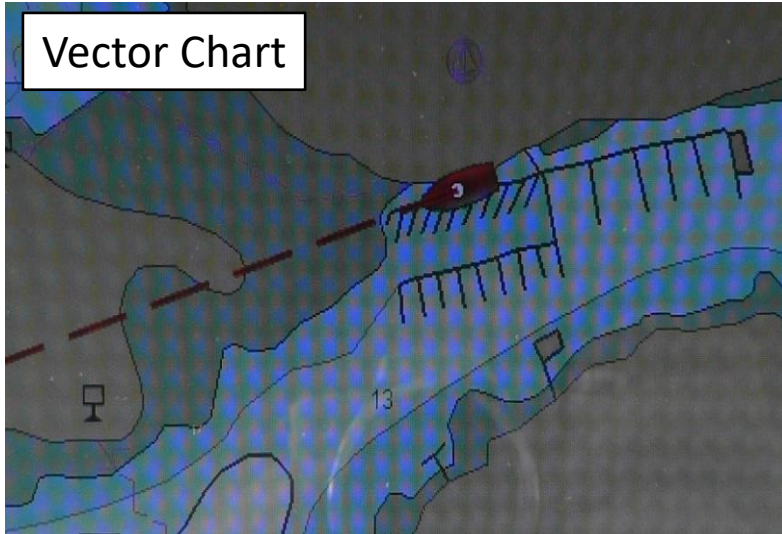
Raster Chart
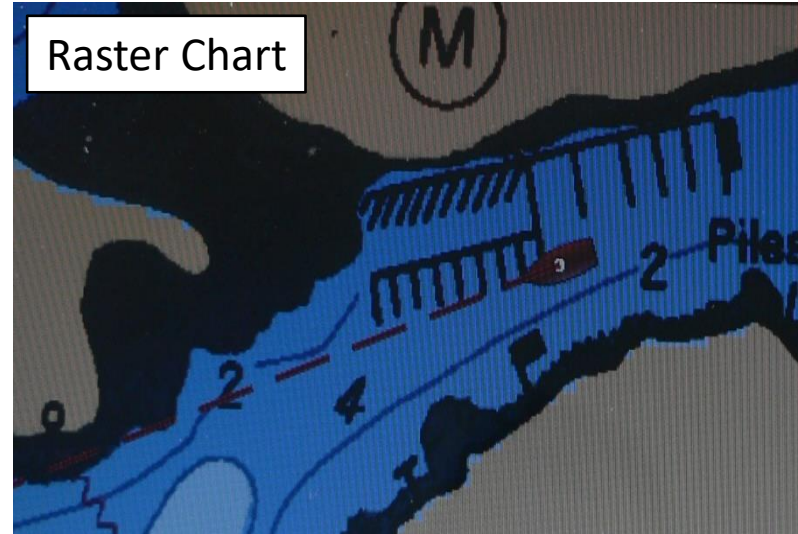
Helm View
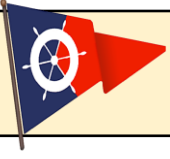
Chart Accuracy Limits ~ GPS

A computer algorithm takes distance and time readings from four satellites and estimates location.

It refines the estimate through an iterative process using the location estimate based on three satellites with the fourth satellite until an estimated solution (your location) is achieved within an acceptable level of error. One meter?

Position x,y,z,t which is transformed into Lat,Long
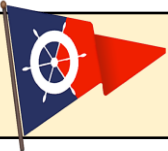
Chart Accuracy Limits ~ GPS

A Geographic Positioning System estimates your location in space and time.

Measured Range

Receiver Clock Bias

POSITION and TIME

The GPS Navigation Solution
The estimated ranges to each satellite intersect within a small region when the receiver clock bias is correctly estimated and added to each measured relative range.

P. H. Dana 5/10/98

The accuracy of the GPS Position can be further tweaked by comparing your position to a known position
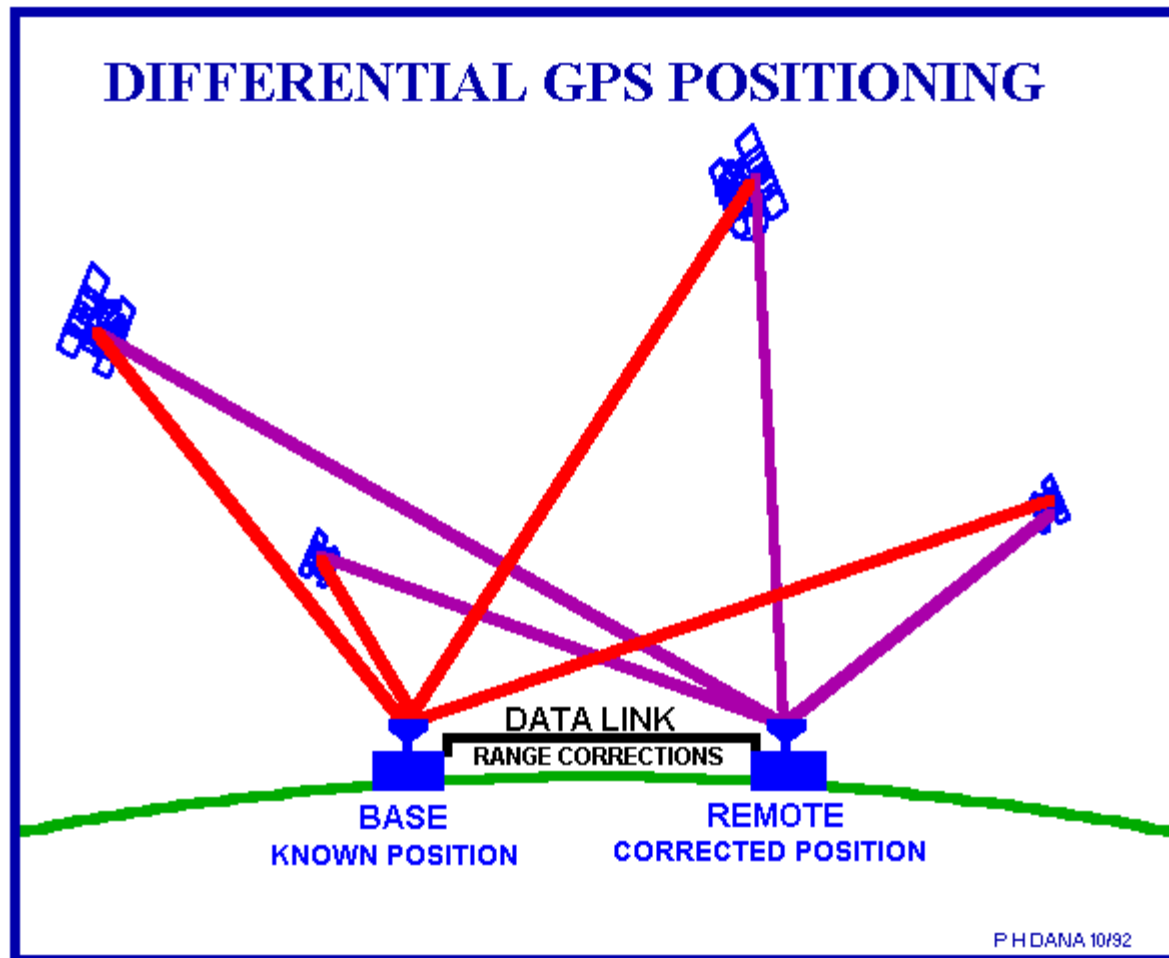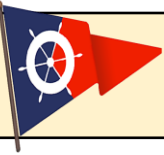
Chart Accuracy Limits ~ GPS

Peter H. Dana 9/22/98
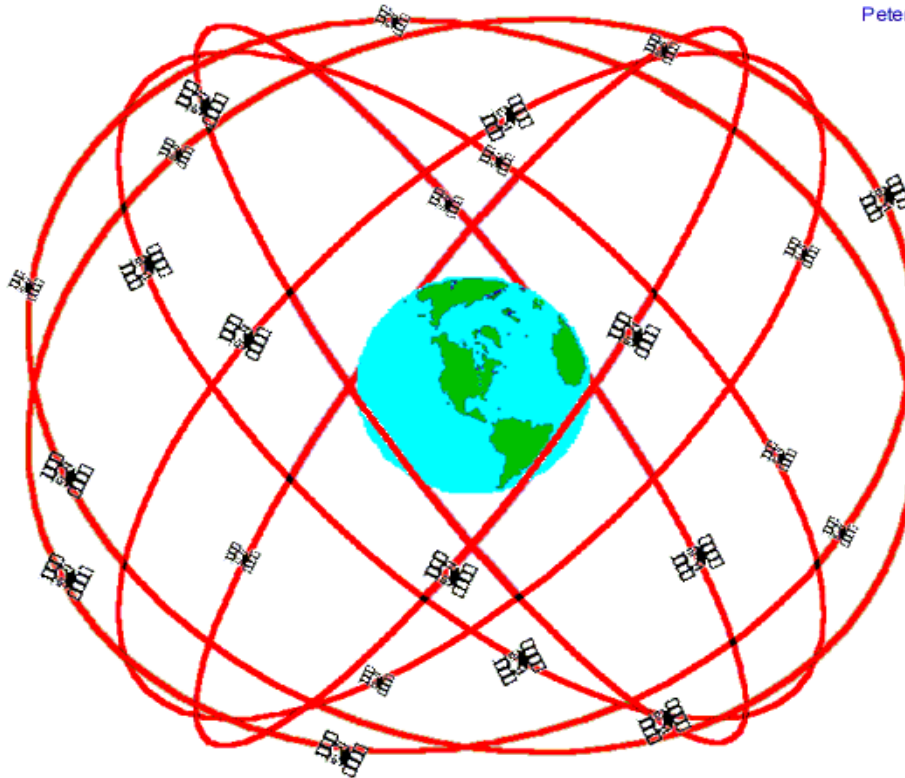
GPS Nominal Constellation
24 Satellites in 6 Orbital Planes
4 Satellites in each Plane
20,200 km Altitudes, 55 Degree Inclination

Chart Accuracy Limits ~ Projections
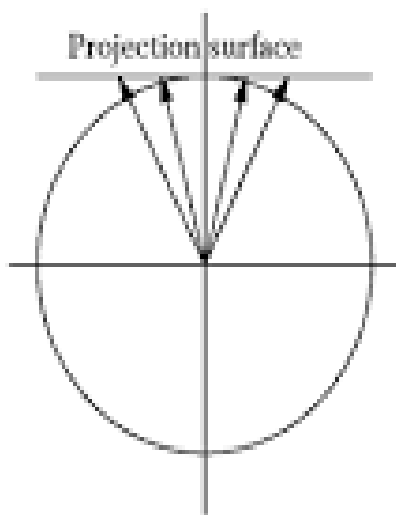
(a) Gnomonic
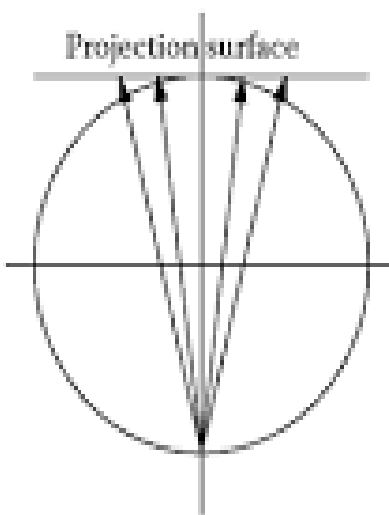
(b) Stereographic
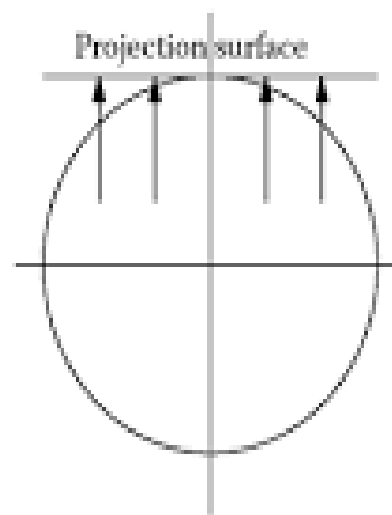
(c) Orthographic
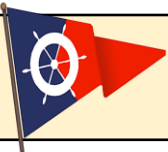
Chart Accuracy Limits ~ Projections
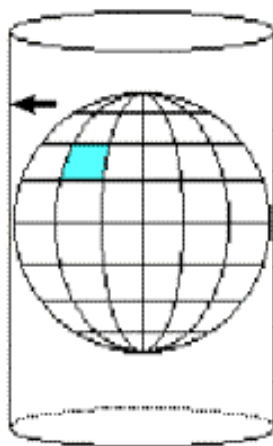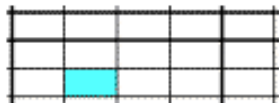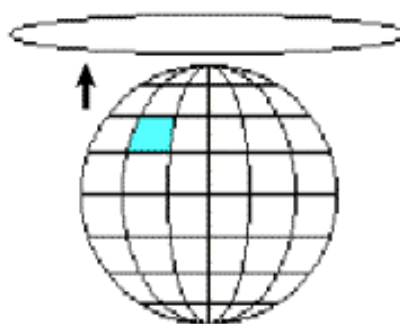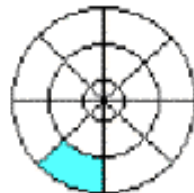
CYLINDRICAL   AZIMUTHAL   CONIC
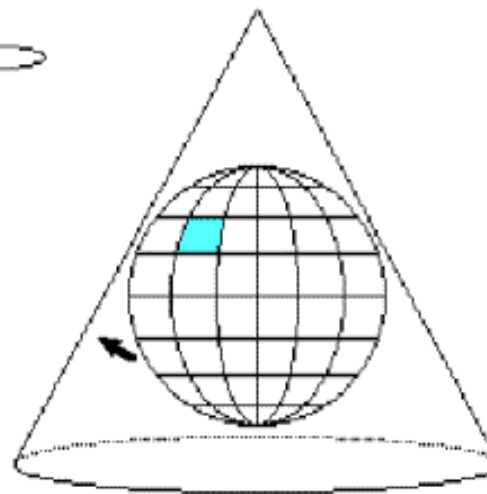
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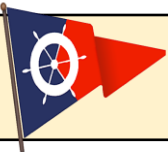
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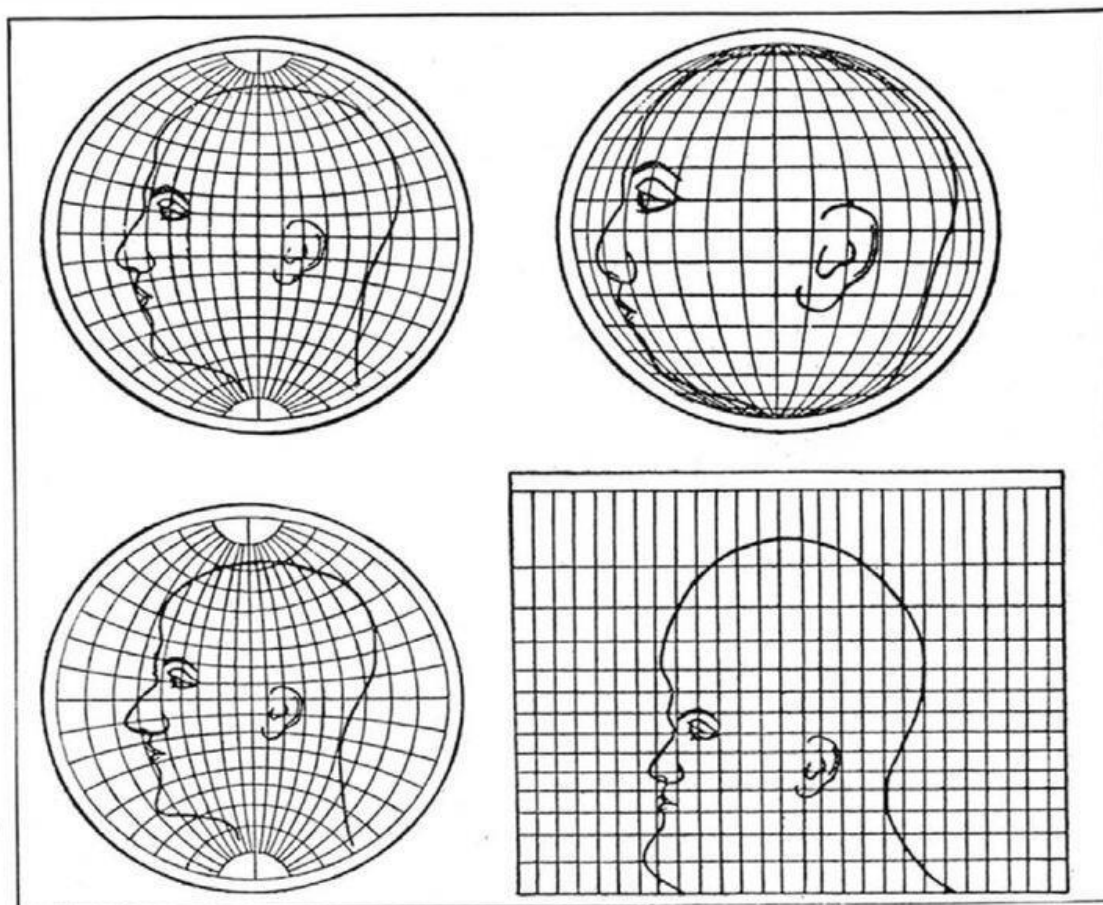
Upper left: Globular.   *Upper right:* Orthographic.   *Lower left:* Stereographic.
Lower right: Mercator

What four commonly used projections do, as shown on a human head

Chart Accuracy Limits ~ Projections
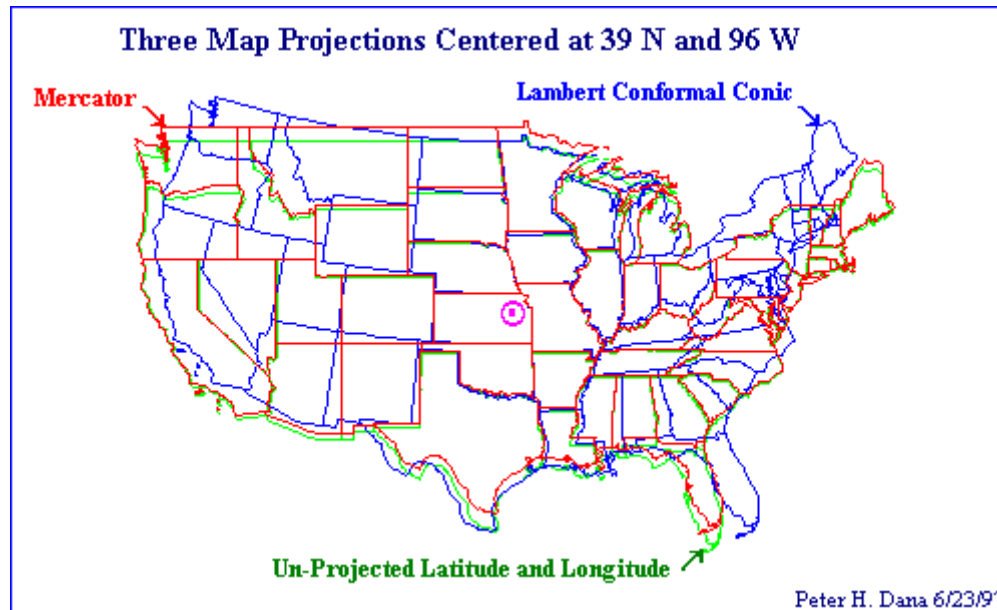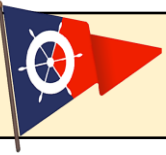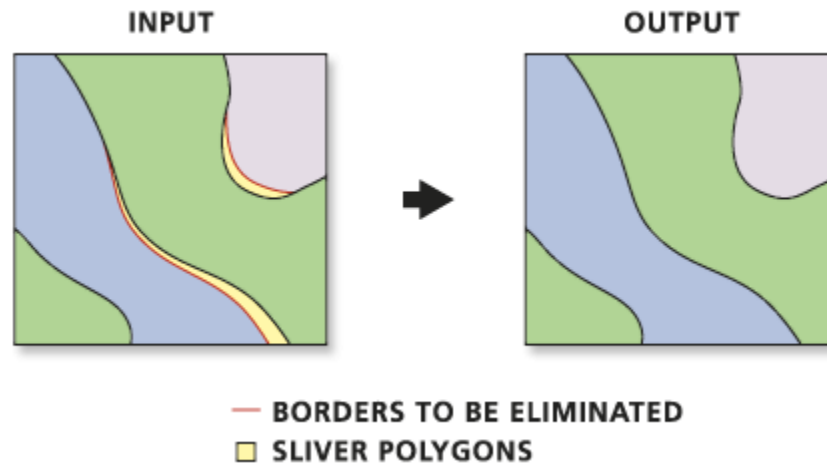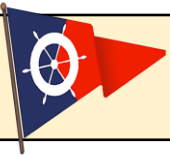
Three Map Projections Centered at 39 N and 96 W

Mercator

Lambert Conformal Conic

Un-Projected Latitude and Longitude

Peter H. Dana 6/23/97

Chart Accuracy Limits ~ Projections

INPUT → OUTPUT

— BORDERS TO BE ELIMINATED
□ SLIVER POLYGONS

Chart Accuracy Limits ~ GIS Layers
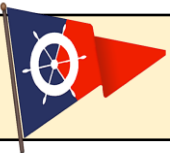

Roads

Land use

Boundaries

Hydrography

Elevation

Image base
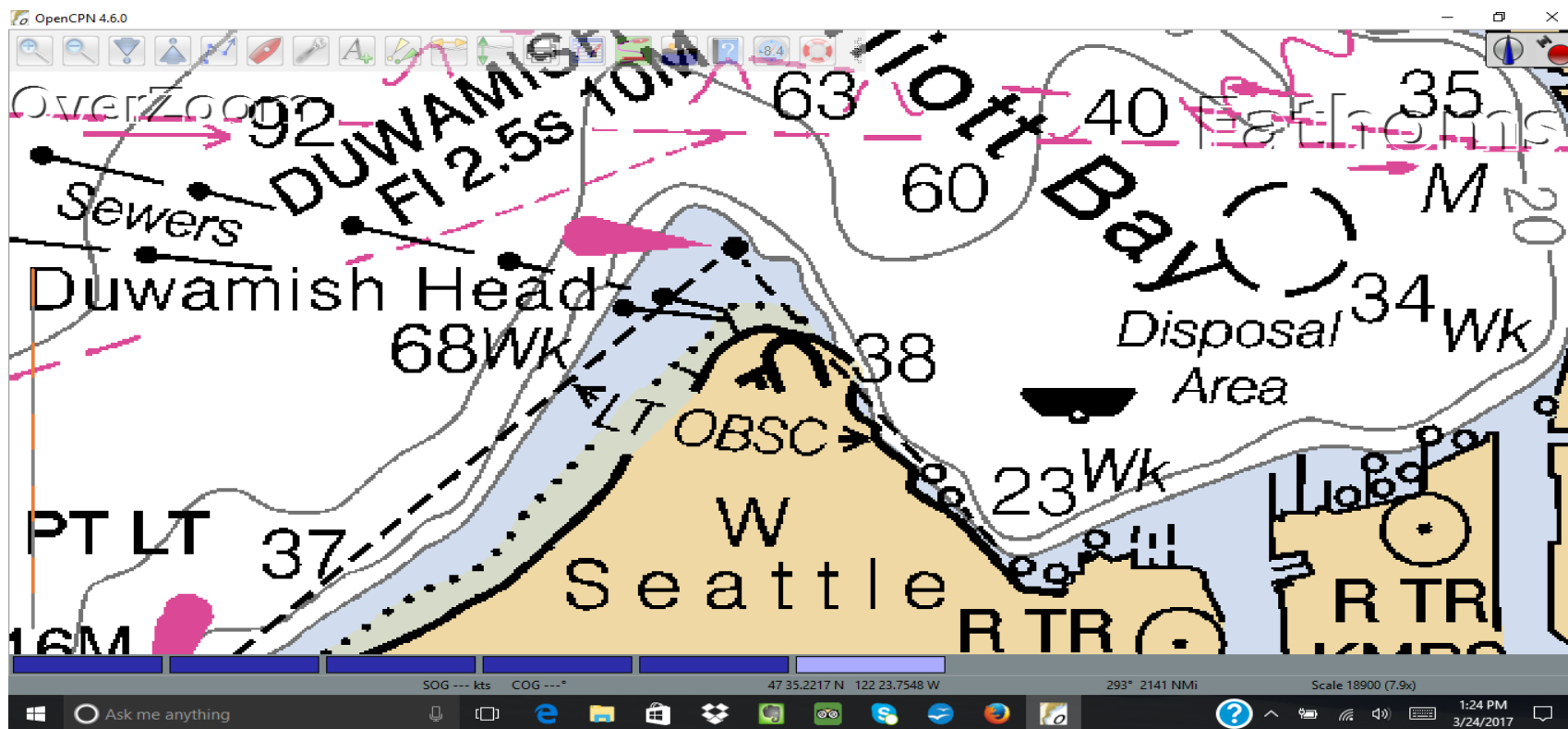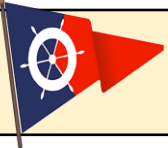
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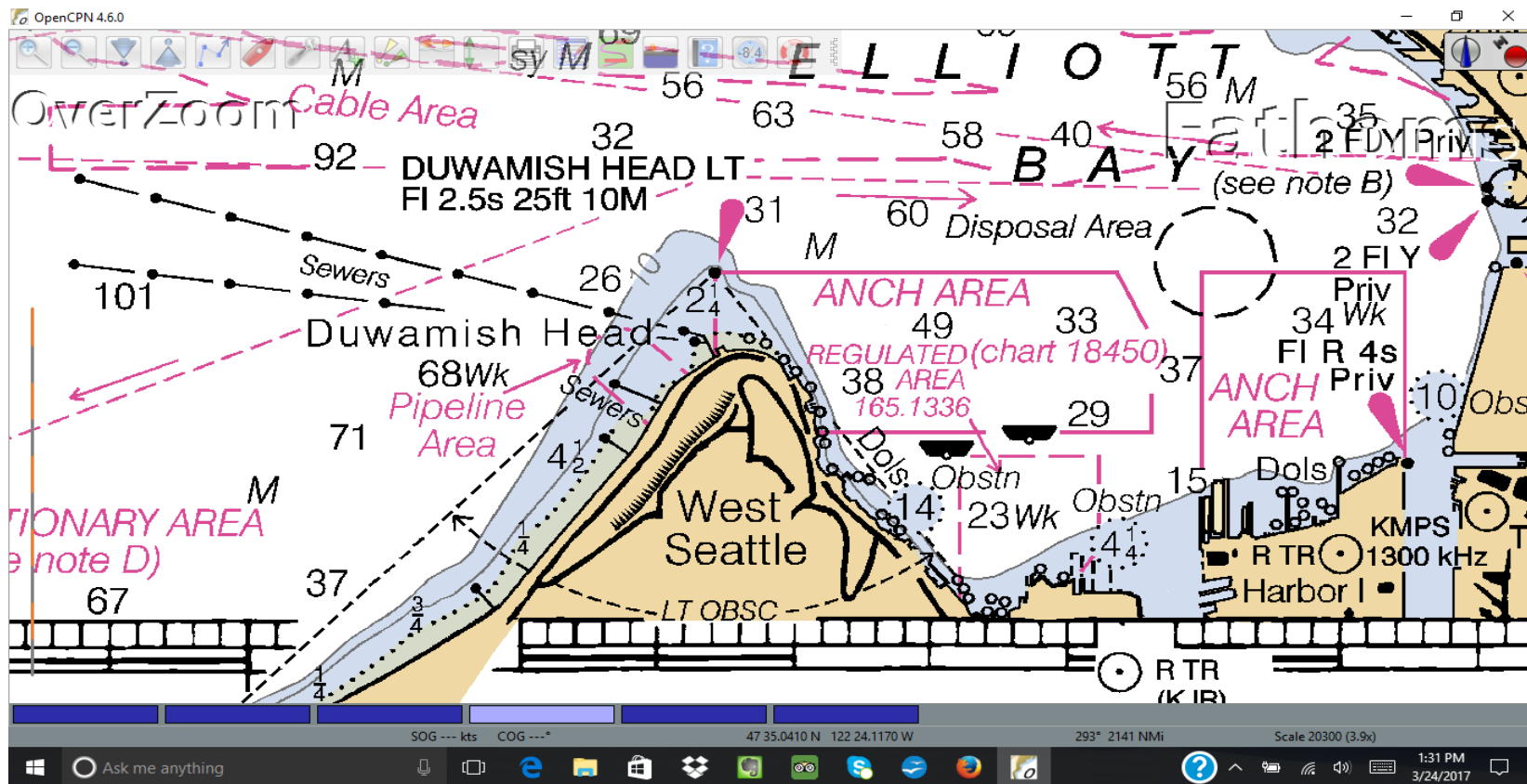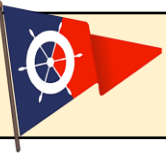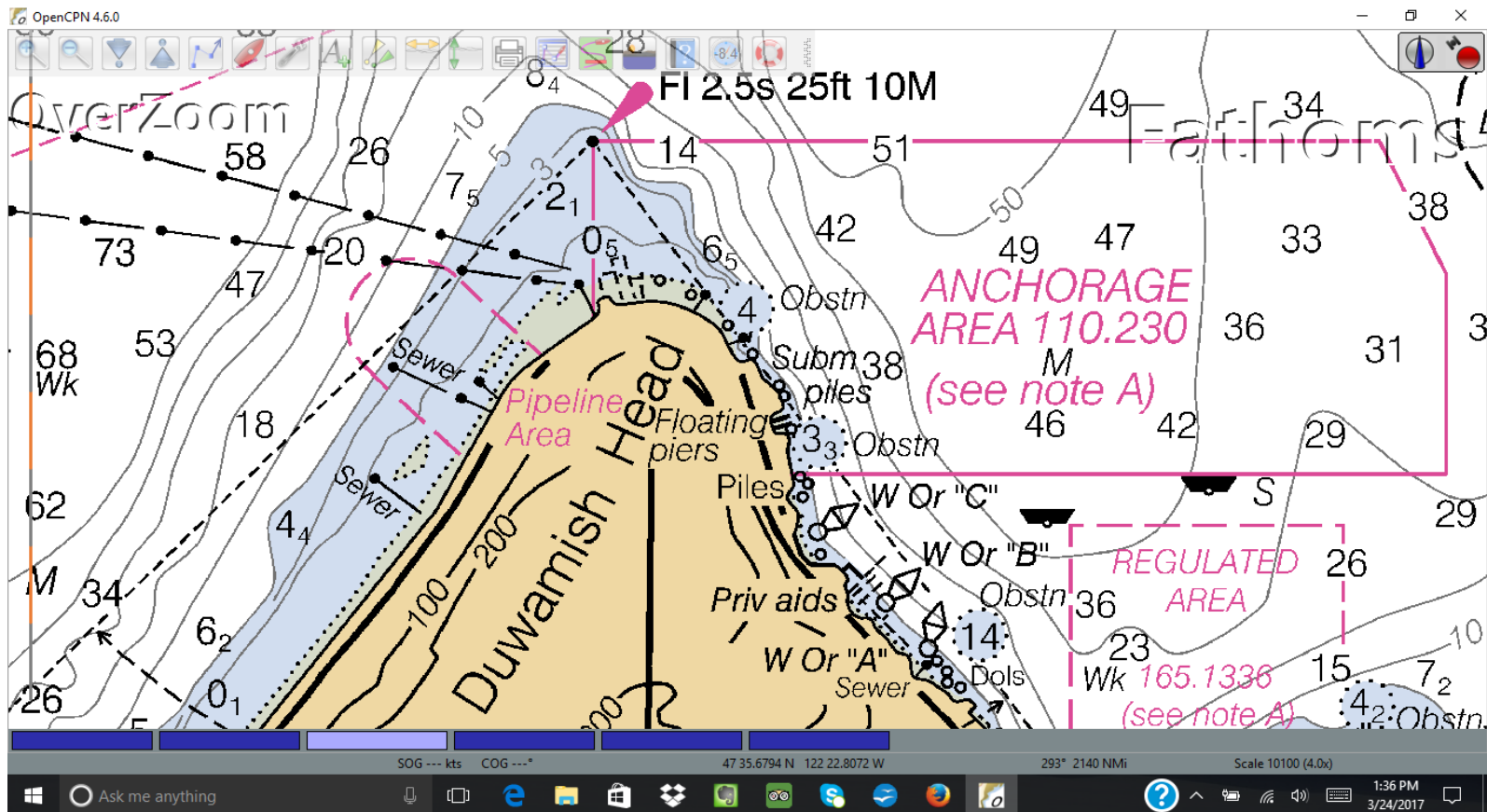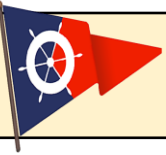
Chart Accuracy Limits ~ GIS Layers

Chart Accuracy Limits ~ GIS Layers

Chart Accuracy Limits ~ GIS Layers

QUARTERMASTER YACHT CLUB – Chart Limits Tech Talk
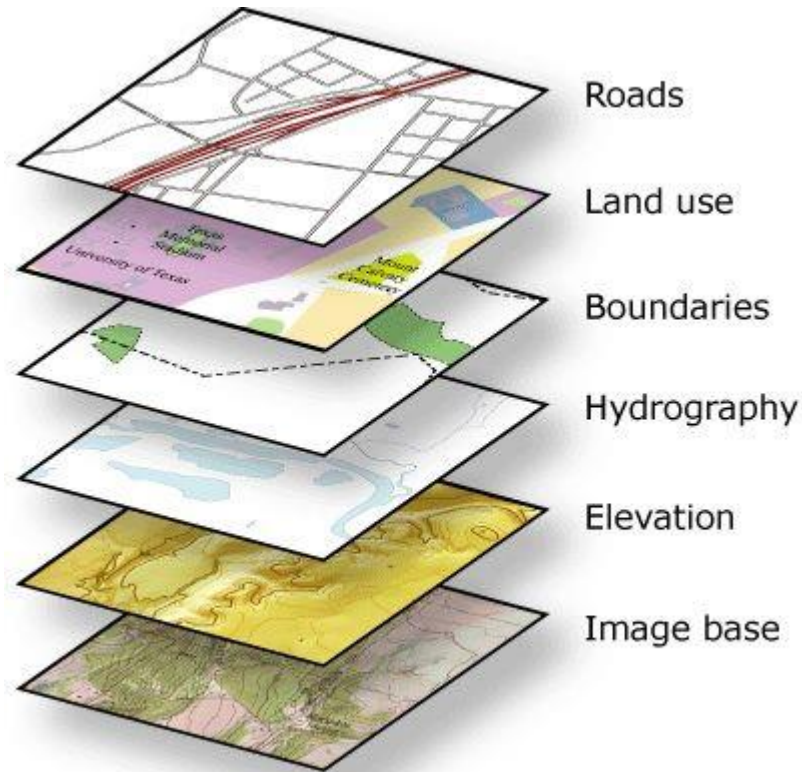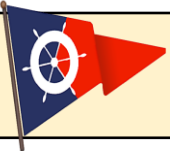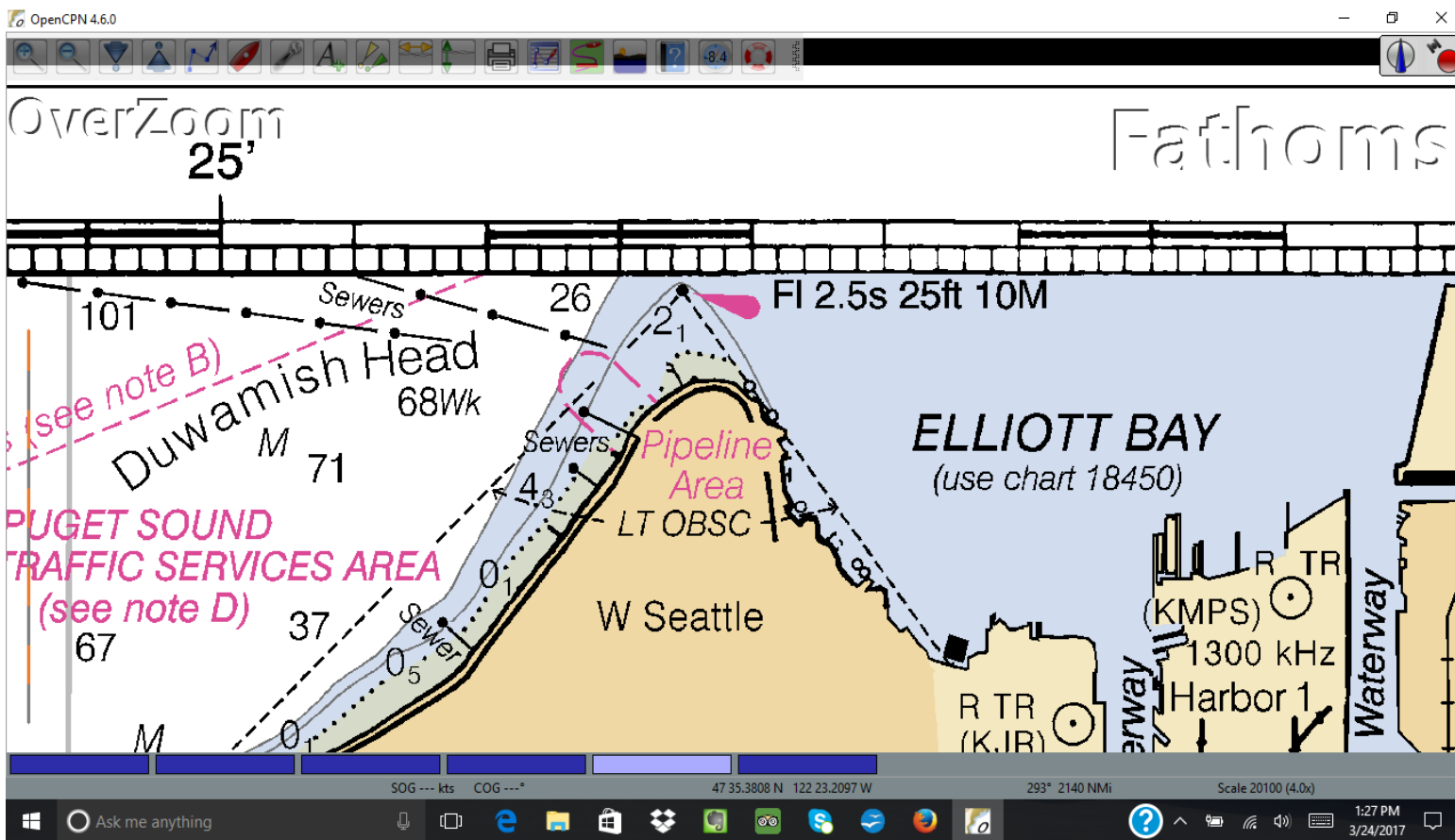
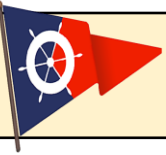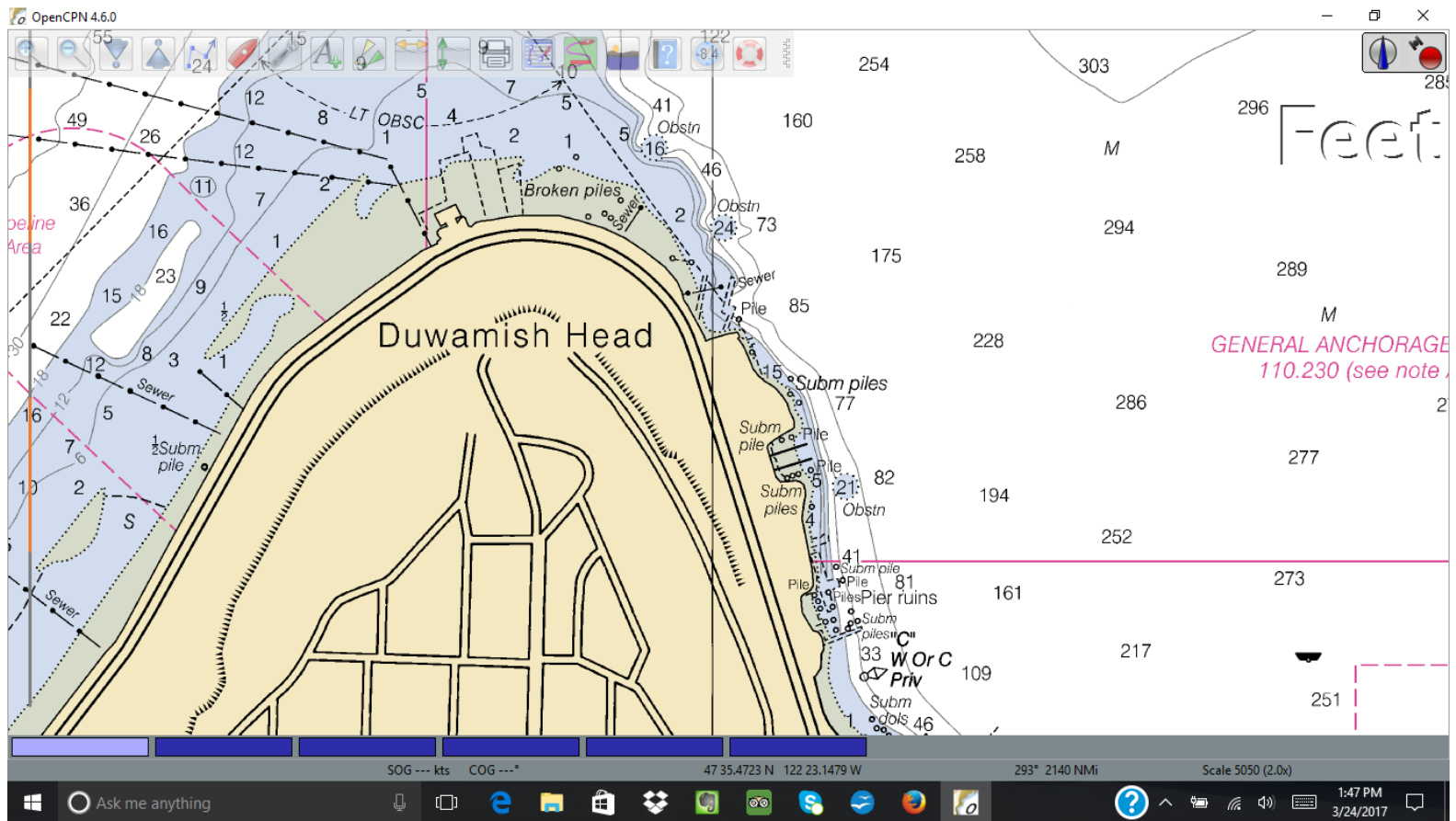# Chart Accuracy Limits ~ GIS Layers
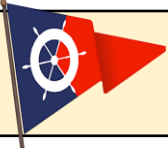
Chart Accuracy Limits ~ GIS Layers

Chart Accuracy Limits ~ GPS GIS Summary

GPS first finds your location on a globe

The location is transferred to a point represented on a map

Depending upon the zoom level the map contains data at various levels of detail and accuracy
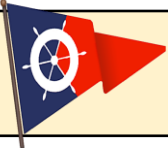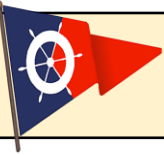
Errors can occur

Chart Accuracy Tech Talk Summary

- **Key point: GPS accuracy is much higher than the survey data in our navigation charts**

- **Electronic charts give few warnings that the position of objects on the screen may not be precisely located**

- **A false sense of navigational certainty leads to attempting narrower channels and closer approaches than would have ever been attempted when our boat positions were less well known**

Chart Accuracy Limits

QUESTIONS?