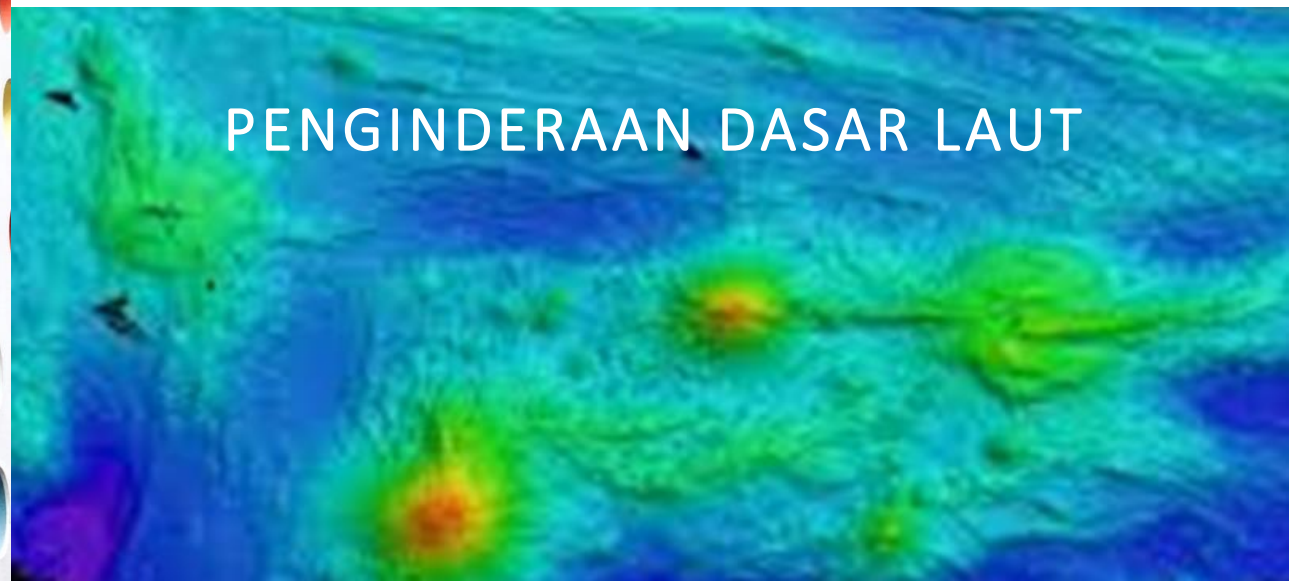
Lab 1:
Ship Reference Frame



Labs

1. Ship Reference Frame Integration

   Lever arm a coordinate from the mast head to sonar

7%

2. Harmonic Sound Speed and Tide Correction

6%

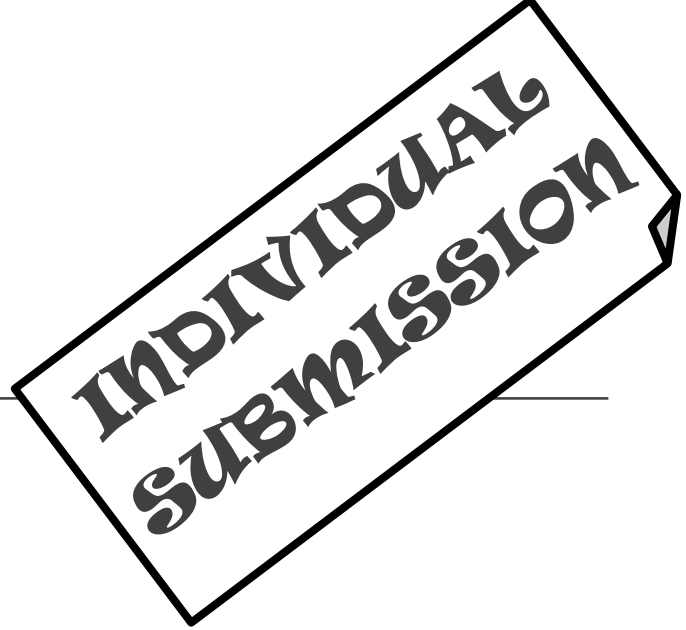
3. Multibeam Cone to Cone Intersection

   Intersection of steered beams

7%

20%

Submission Guidelines



Brevity is encouraged

Units and Significant Digits

Late Submission → don't be late 

Plagiarism

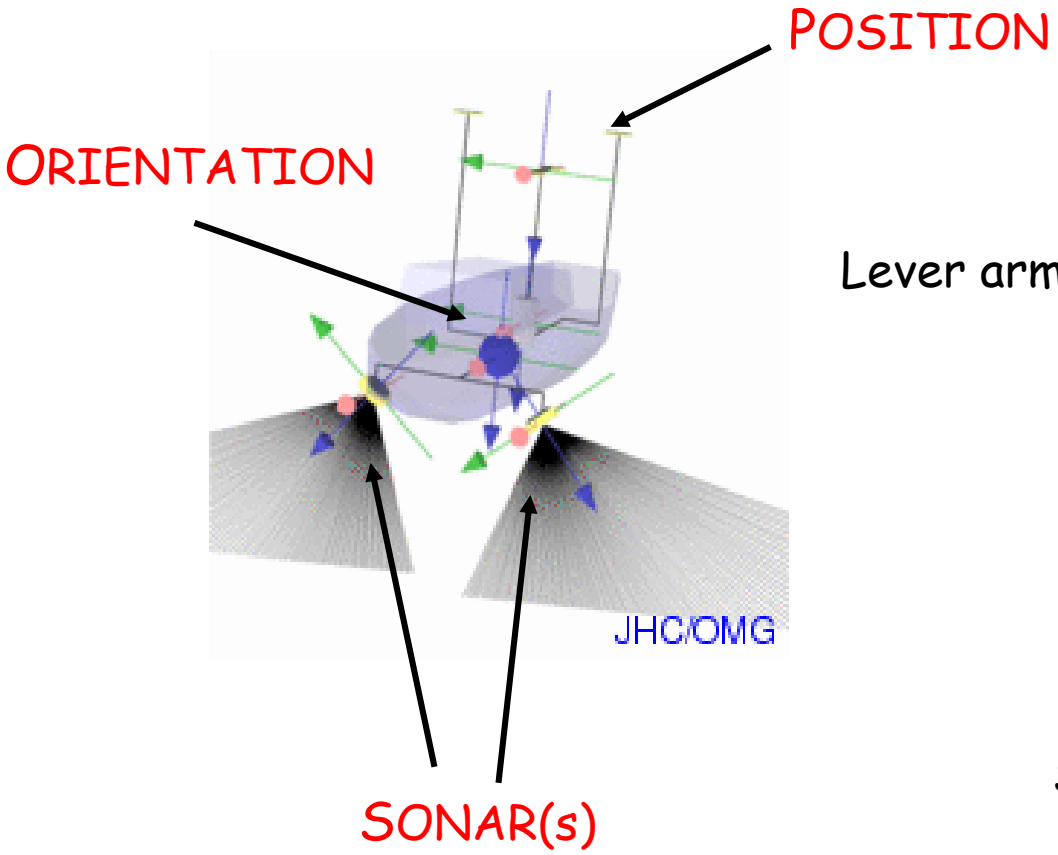
Code:
- Matlab (*.m) or C (*.c) or Python (*.py)

File name:
- Lab#_StudentID (exp: Lab1_1234567.pdf)

Files for submission:
- Lab1_1234567.pdf (include: deliverables, discussions and CODE)
- Lab1_1234567.m (code only)

Please submit in myClassroom dropbox!

Ship Reference Frame Integration



Lever arm a coordinate from the mast head to sonar

Sonars coordinates

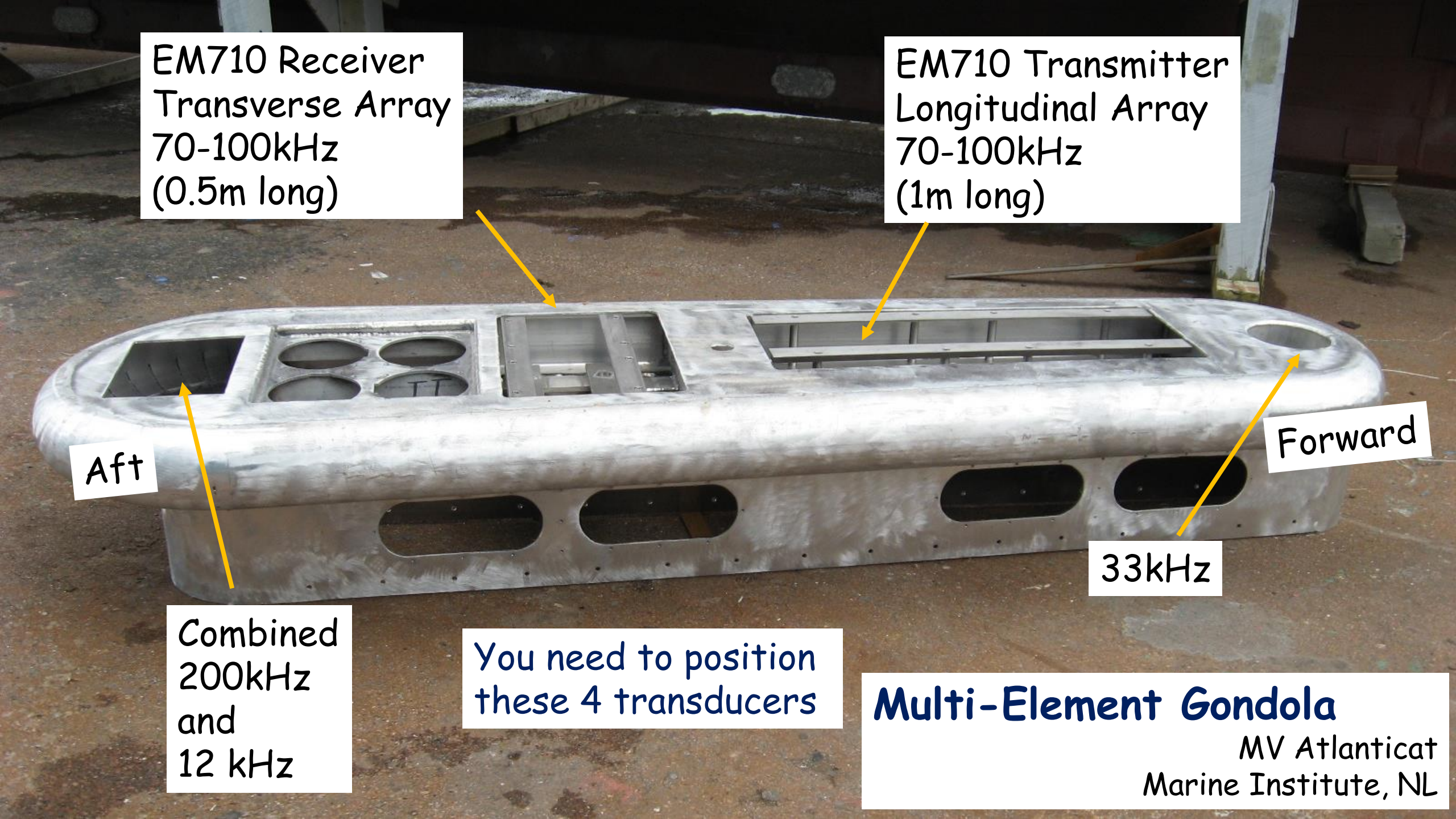
MV Atlanticat

Marine Institute, NL

Multi-Element Gondola

MV Atlanticat

Marine Institute, NL



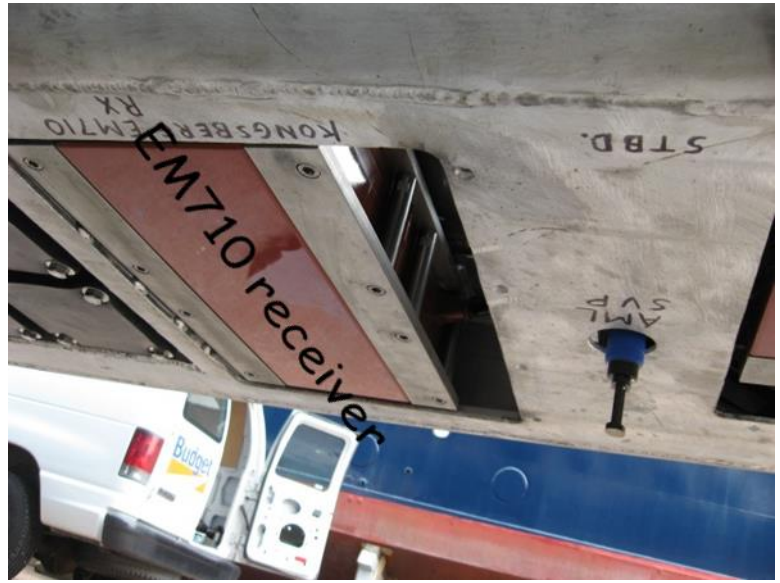
Multi-Element Gondola

MV Atlanticat
Marine Institute, NL

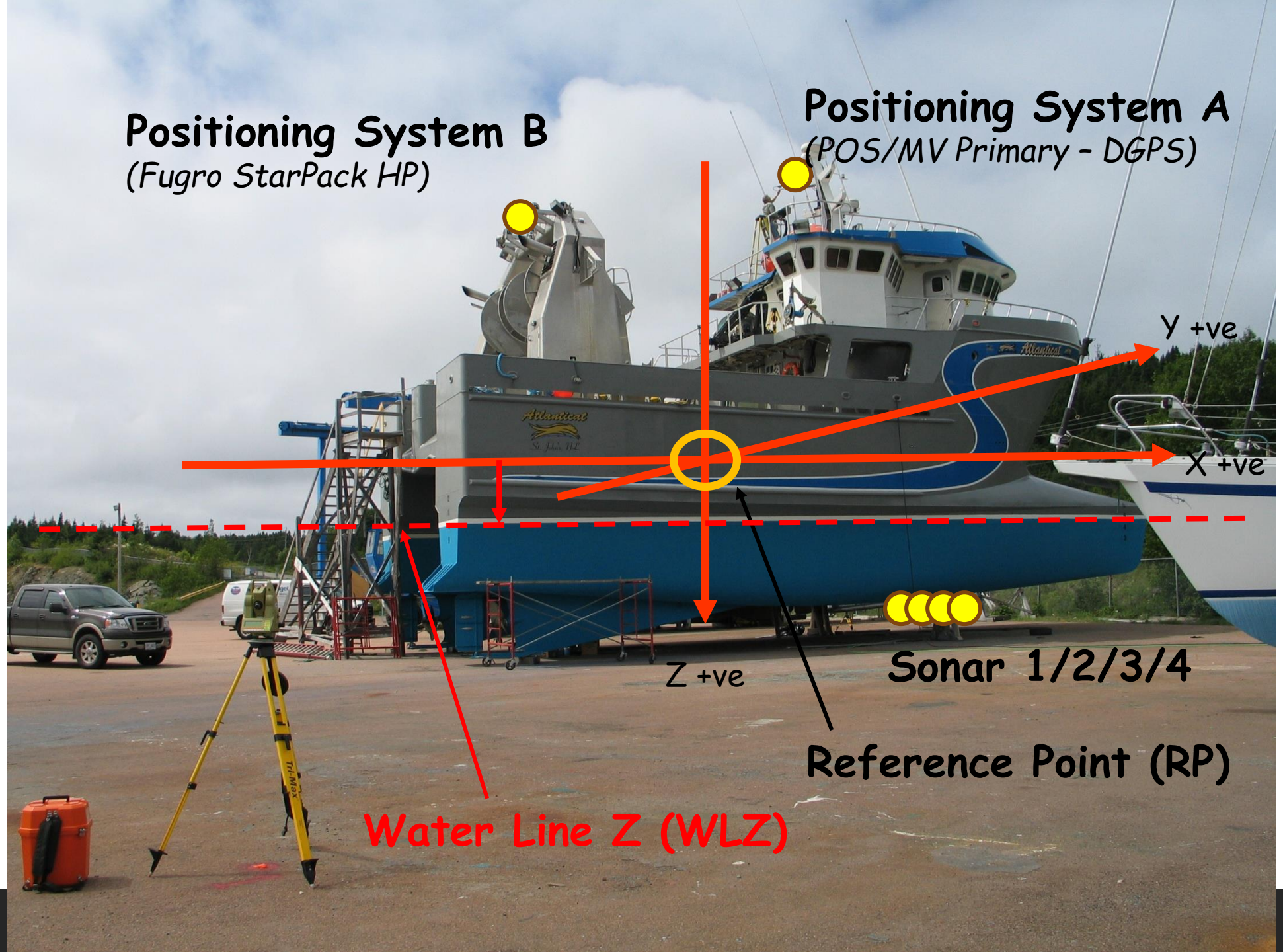
Element Installation

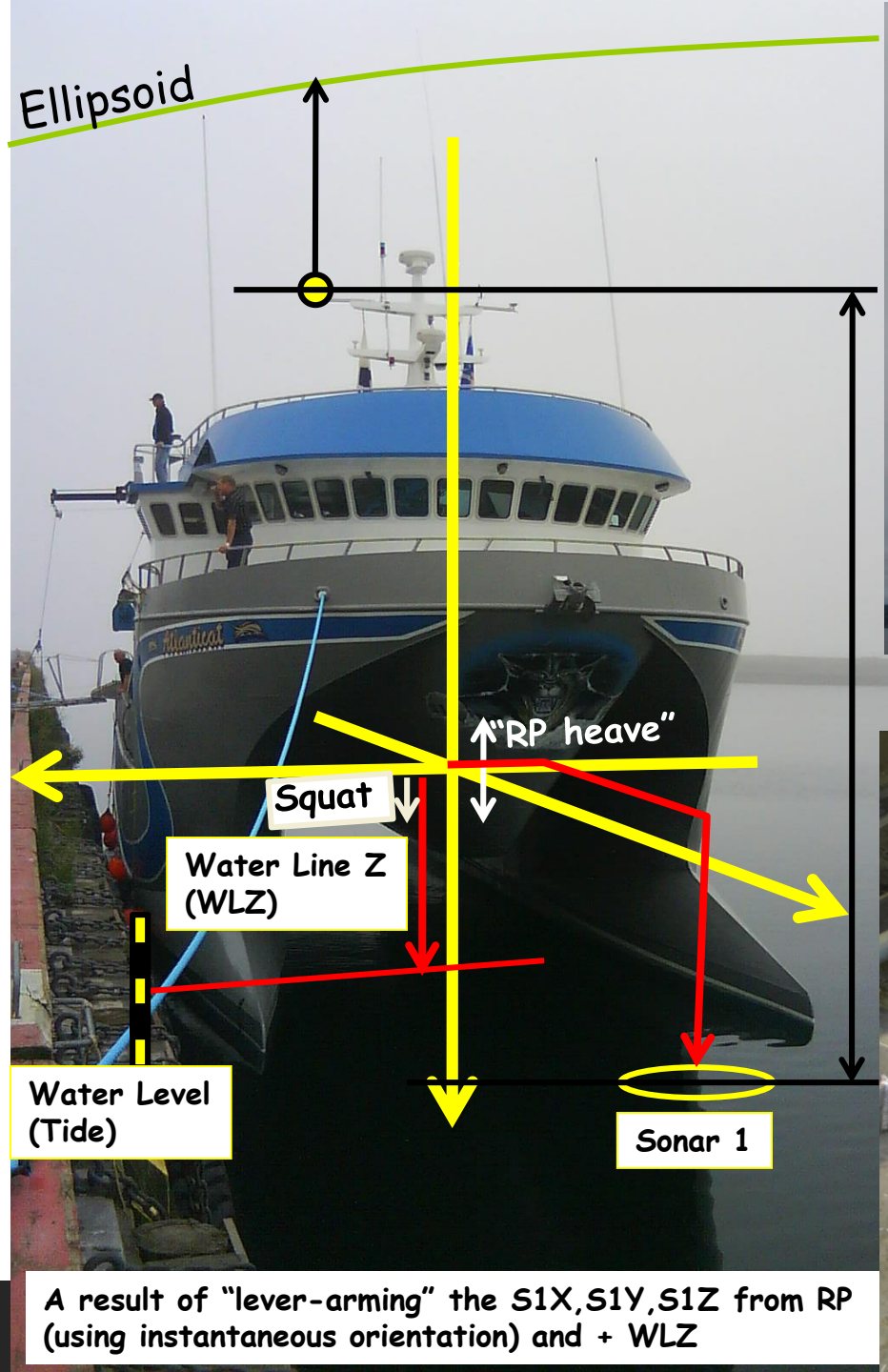
MV Atlanticat
Marine Institute, NL

Knudsen
33kHz

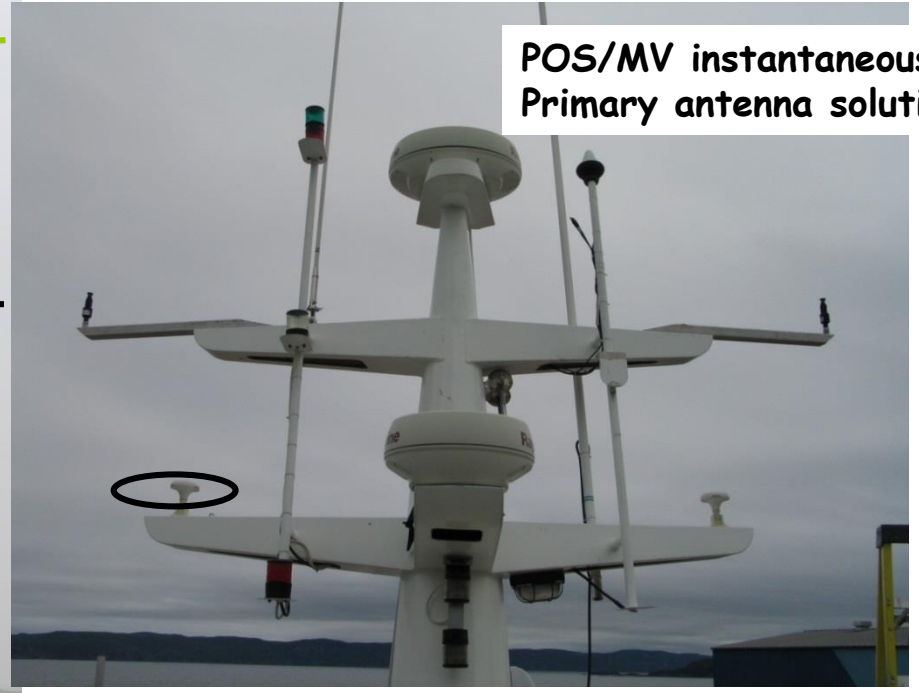


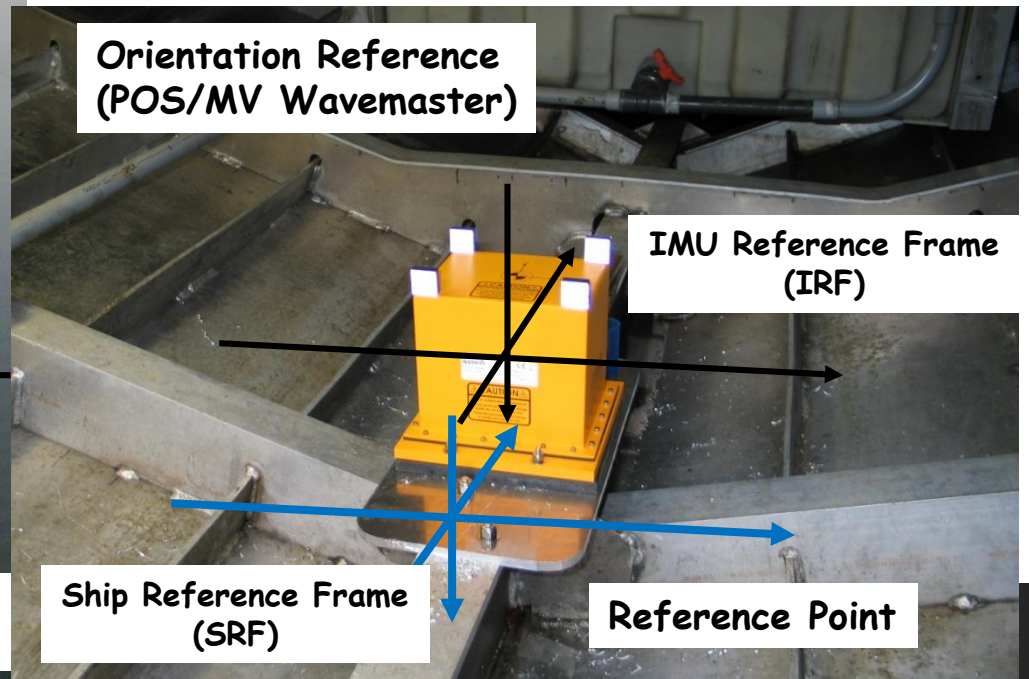
Knudsen
200kHz and 12kHz


Positioning System B
(Fugro StarPack HP)
Positioning System A
(POS/MV Primary - DGPS)
Y +ve
X +ve
Z +ve
Sonar 1/2/3/4
Reference Point (RP)
Water Line Z (WLZ)



A result of "lever-arming" the S1X,S1Y,S1Z from RP (using instantaneous orientation) and + WLZ



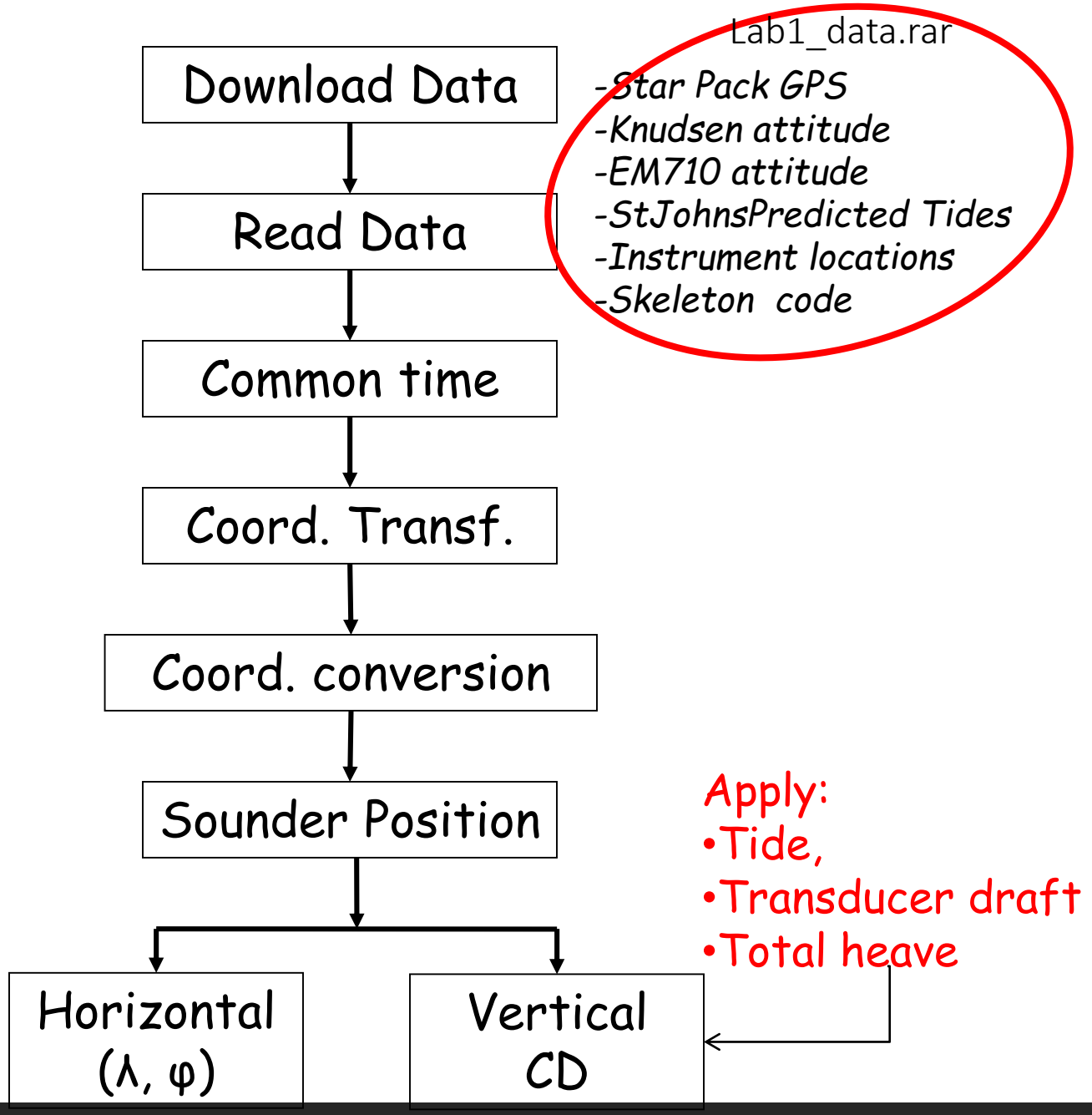


What you need:

- Transfer 3D position from the GPS antenna to each sounder. Only use the ellipsoidal height for a comparison.
- Calculate the induced heave
- Calculate the correction which reduces the raw depth measurement to chart datum. This is what we use for vertical positioning.

Lab instructions and files are on myITS Classroom

- *Star Pack GPS*
- *Knudsen attitude*
- *EM710 attitude*
- *StJohns Predicted Tides*
- *Instrument locations*


Lab1_data.rar
Download Data
-Star Pack GPS
-Knudsen attitude
-EM710 attitude
-StJohnsPredicted Tides
-Instrument locations
-Skeleton code
Read Data
Common time
Coord. Transf.
Coord. conversion
Sounder Position
Horizontal
(λ, φ)
Vertical
CD
Apply:
•Tide,
•Transducer draft
•Total heave

```
Vostro-A840 radian 90 % head StarPack.ascii
-52.50406377 47.57415364 2010 233 12 10 0 17.04 0.00
-52.50414179 47.57417386 2010 233 12 10 1 16.89 12.33
-52.50421959 47.57419360 2010 233 12 10 2 16.88 12.18
-52.50429692 47.57421693 2010 233 12 10 3 16.60 12.11
-52.50437365 47.57424086 2010 233 12 10 4 16.26 12.34
-52.50445347 47.57425791 2010 233 12 10 5 16.55 12.32
-52.50453746 47.57427264 2010 233 12 10 6 16.75 12.20
-52.50461579 47.57429404 2010 233 12 10 7 16.90 12.65
-52.50468846 47.57432295 2010 233 12 10 8 17.16 12.32
-52.50476737 47.57434495 2010 233 12 10 9 17.07 12.30
Vostro-A840 radian 91 % head StJohnsPredictedTide.ascii
233 00 00 0.500
233 00 15 0.540
233 00 30 0.530
233 00 45 0.530
233 01 00 0.570
233 01 15 0.650
233 01 30 0.590
233 01 45 0.620
233 02 00 0.710
233 02 15 0.750
```

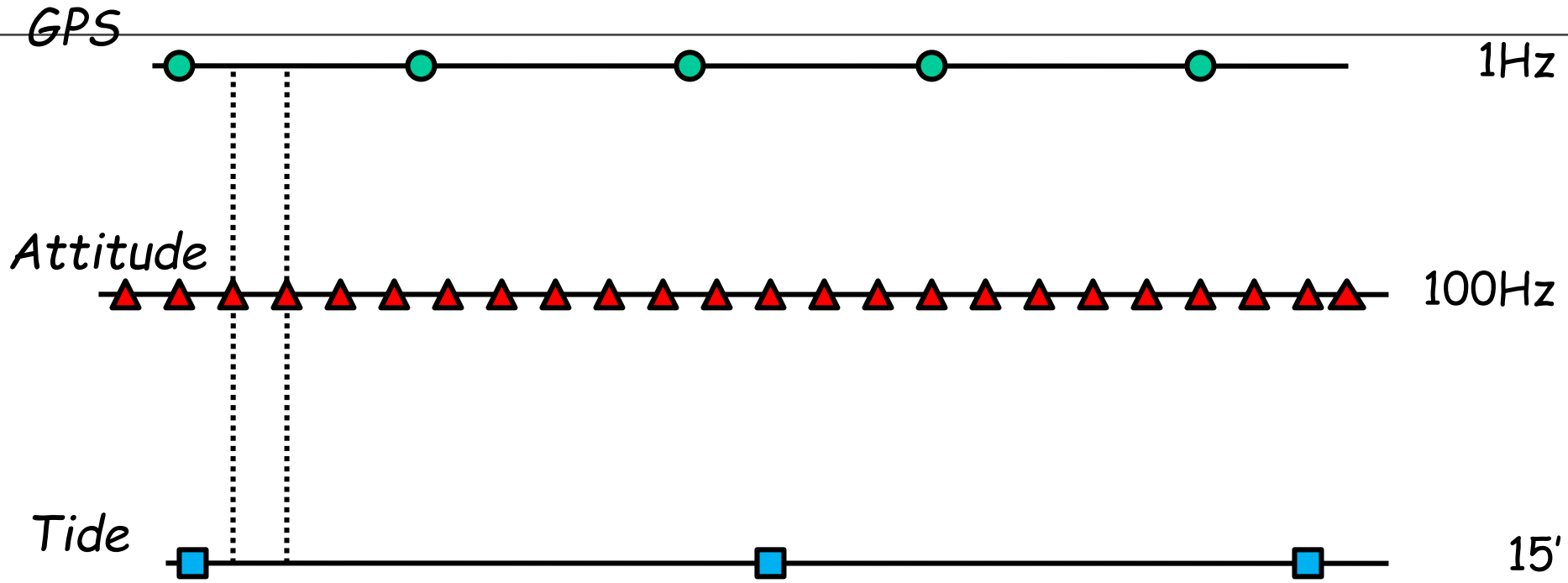
H_E CoG

Altitude

γ θ φ h

```
Vostro-A840 radian 94 % head KnudsenAttitude.ascii
233  9  41  9  0.23  1282383669  292.88  0.95  -0.37  -0.52
233  9  41  9  0.7   1282383670  292.81  2.6   0.32   -0.5
233  9  41  10 0.17  1282383670  292.9   3.41  0.64   -0.32
233  9  41  10 0.62  1282383671  293.09  2.19  0.49   -0.09
233  9  41  11 0.07  1282383671  293.37  -0.42 0.15   0.09
233  9  41  11 0.54  1282383672  293.65  -3.05 -0.31  0.19
233  9  41  12 0.01  1282383672  293.86  -4.42 -0.87  0.23
233  9  41  12 0.46  1282383672  293.88  -3.96 -1.19  0.21
233  9  41  12 0.93  1282383673  293.75  -2.05 -0.92  0.16
233  9  41  13 0.39  1282383673  293.73  0.5   -0.26  0.14
Vostro-A840 radian 95 % head EM710Attitude.ascii
233  12  10  57  0.875  1282392658  293.23  1.27  0.28  0.09
233  12  10  57  0.886  1282392658  293.23  1.22  0.29  0.09
233  12  10  57  0.895  1282392658  293.23  1.18  0.3   0.09
233  12  10  57  0.905  1282392658  293.24  1.13  0.31  0.1
233  12  10  57  0.915  1282392658  293.24  1.09  0.33  0.1
233  12  10  57  0.925  1282392658  293.25  1.04  0.34  0.1
233  12  10  57  0.935  1282392658  293.25  1     0.35  0.1
233  12  10  57  0.945  1282392658  293.25  0.96  0.36  0.1
233  12  10  57  0.954  1282392658  293.26  0.91  0.37  0.1
233  12  10  57  0.966  1282392658  293.26  0.87  0.39  0.1
```

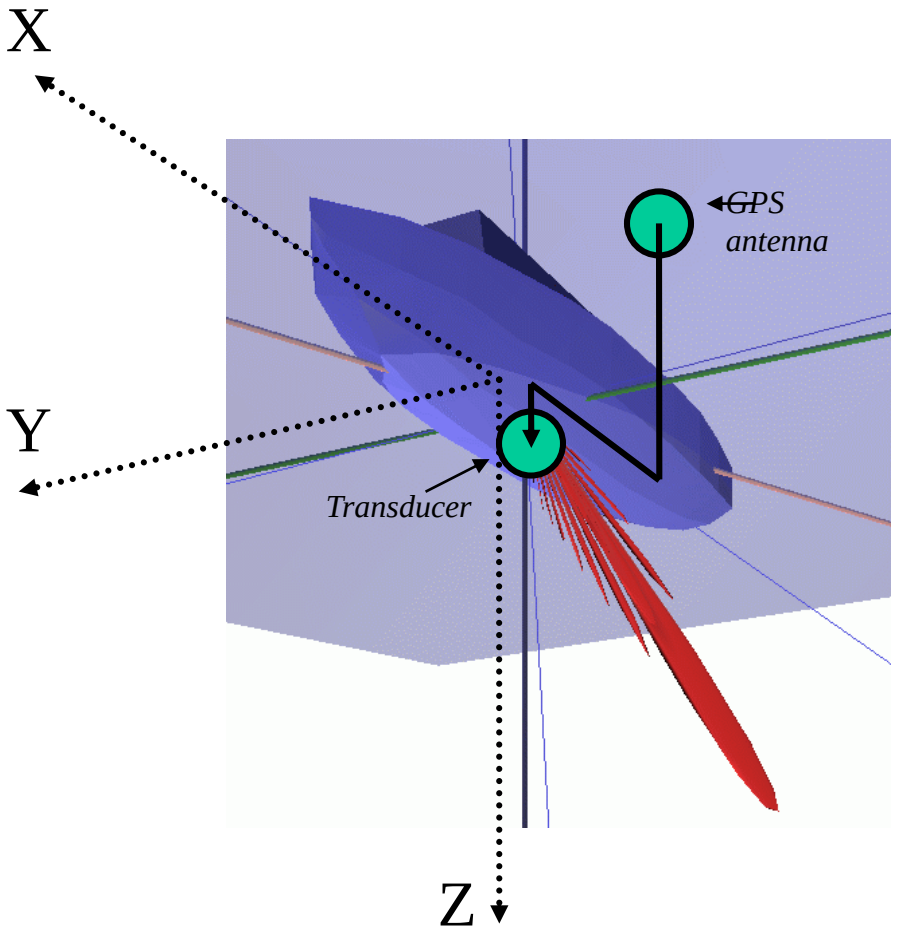
Common Time Format



using linier interpolation

to calculate position and tide for each epoch of attitude data

Offsets from GPS Antenna to Transducer

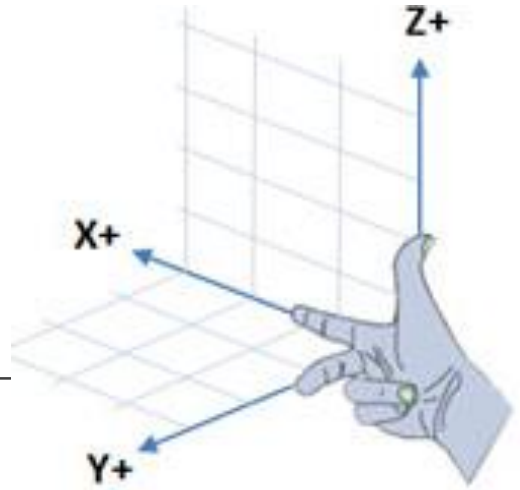


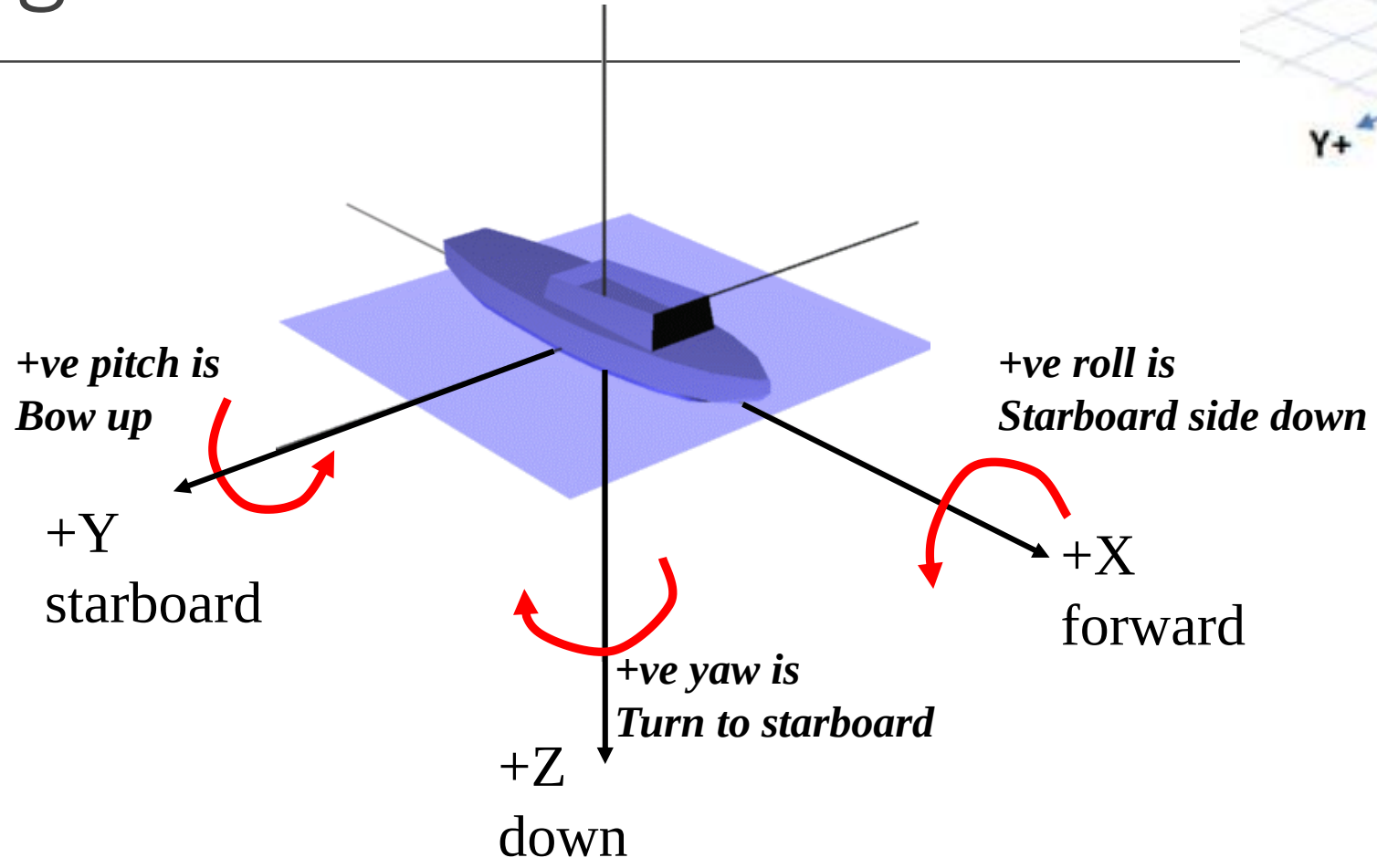
- Define a vessel coordinate system
- Measure positions of all sensors in the vessel coordinate system
- Measure heading, pitch, and roll .

  The physical offsets in the ship reference frame remain constant, but as the ship moves the dLat, dLong, and dH change.
- Calculate the dLat, dLong, and dH for each sounding.

Instrument Positions

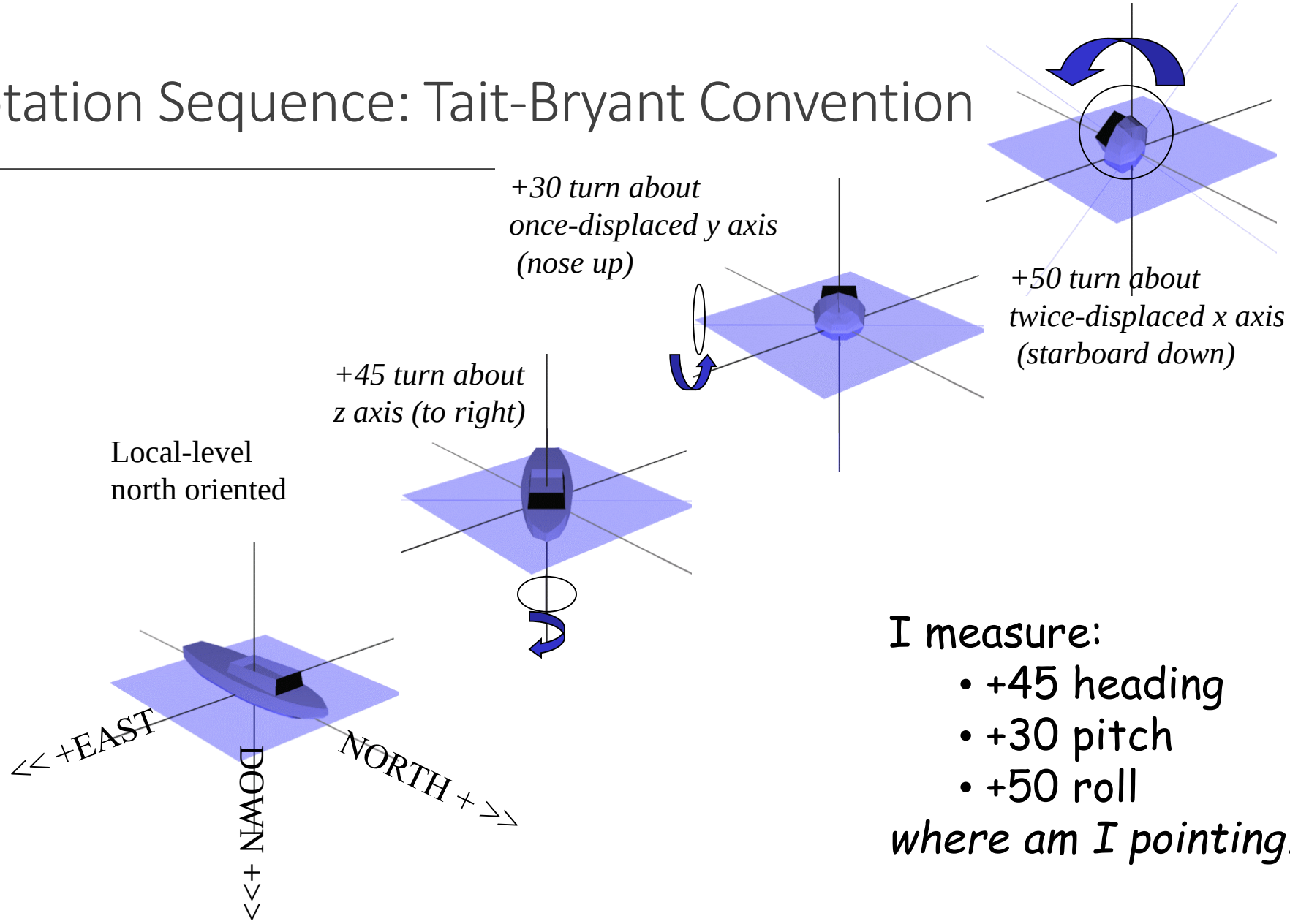
Right Handed CS





Note: Not everyone uses the same convention, e.g. CARIS HIPS swaps X and Y and positive Z points “up”)

Rotation Sequence: Tait-Bryant Convention



I measure:

- +45 heading
- +30 pitch
- +50 roll

where am I pointing?…

Rotation Matrices

(θ,φ,γ) represent roll, pitch & heading, respectively

$$R(\theta) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix} \quad R(\phi) = \begin{bmatrix} \cos\phi & 0 & \sin\phi \\ 0 & 1 & 0 \\ -\sin\phi & 0 & \cos\phi \end{bmatrix} \quad R(\gamma) = \begin{bmatrix} \cos\gamma & -\sin\gamma & 0 \\ \sin\gamma & \cos\gamma & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\underline{R} = \underline{R}_{\vartheta} * \underline{R}_{\varphi} * \underline{R}_{\gamma}$$

Horizontal Positions

$\underline{R} = \underline{R_\vartheta} * \underline{R_\varphi} * \underline{R_\gamma}$

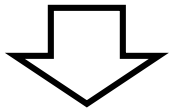
$\underline{X'} = \underline{R} * \underline{X^o}$

I measure:

- +45 heading
- +30 pitch
- +50 roll

where am I pointing?…

X^o (5.000; -3.000; 3.000)



X' (5.920; -0.057; -2.820)

Check…

Convert from *dE; dN* to *dφ; dλ*

$d\varphi = dN / (M)$

$d\lambda = dE/(N * \cos(\varphi))$

Which:

$$N(\phi) = \frac{a}{\sqrt{1 - e^2 \sin^2 \phi}}$$

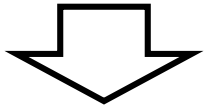
$$M(\phi) = \frac{a(1 - e^2)}{\left(1 - e^2 \sin^2 \phi\right)^{3/2}}$$

See: Krakiwsky & Thomson, 1974, *Geodetic Position Computation*, UNB

Vertical Positions

Use the new offset to reduce the GPS Position to RP

then from RP to the sounders

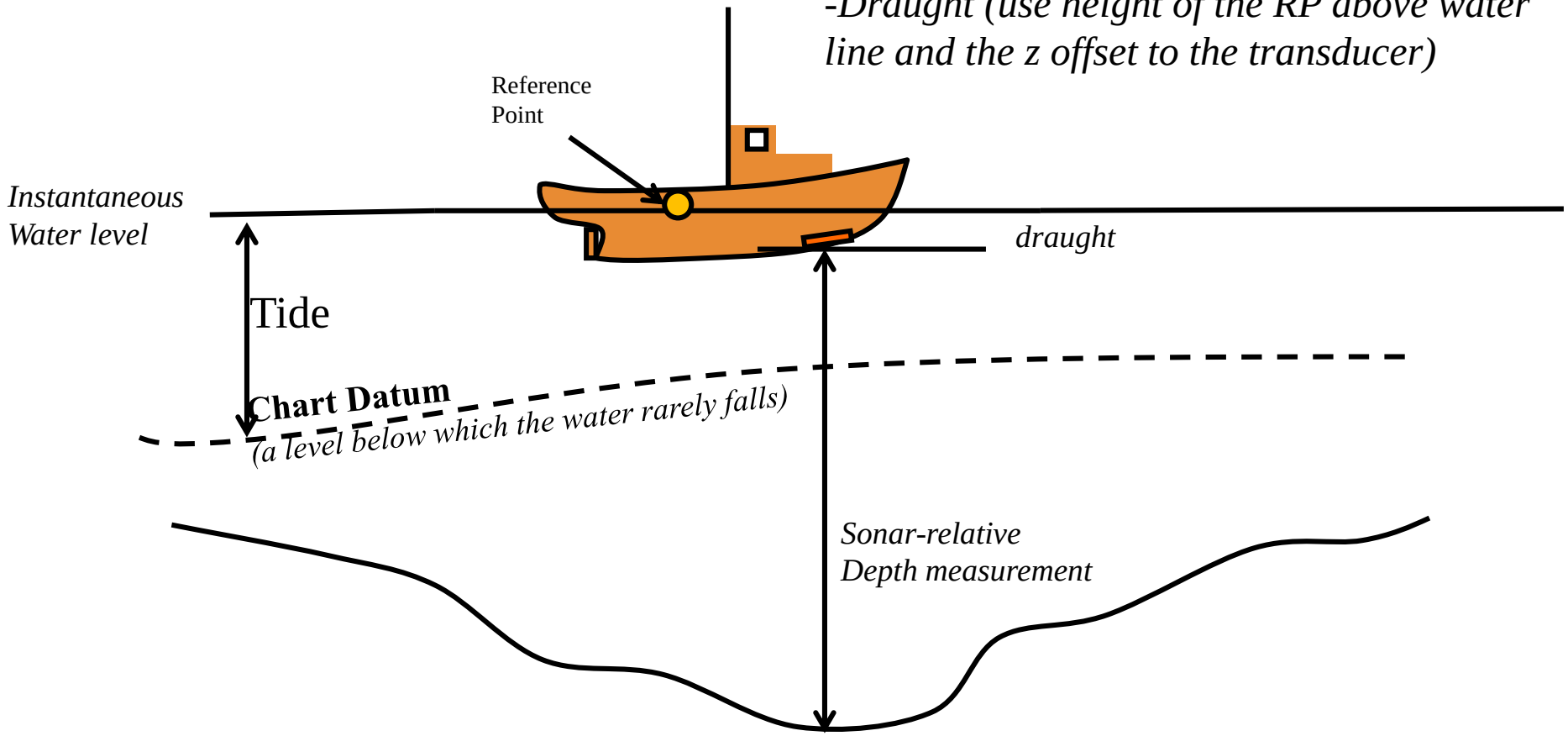


Calculate the height of each sounder above CD

Remember to apply heave, tides and draft

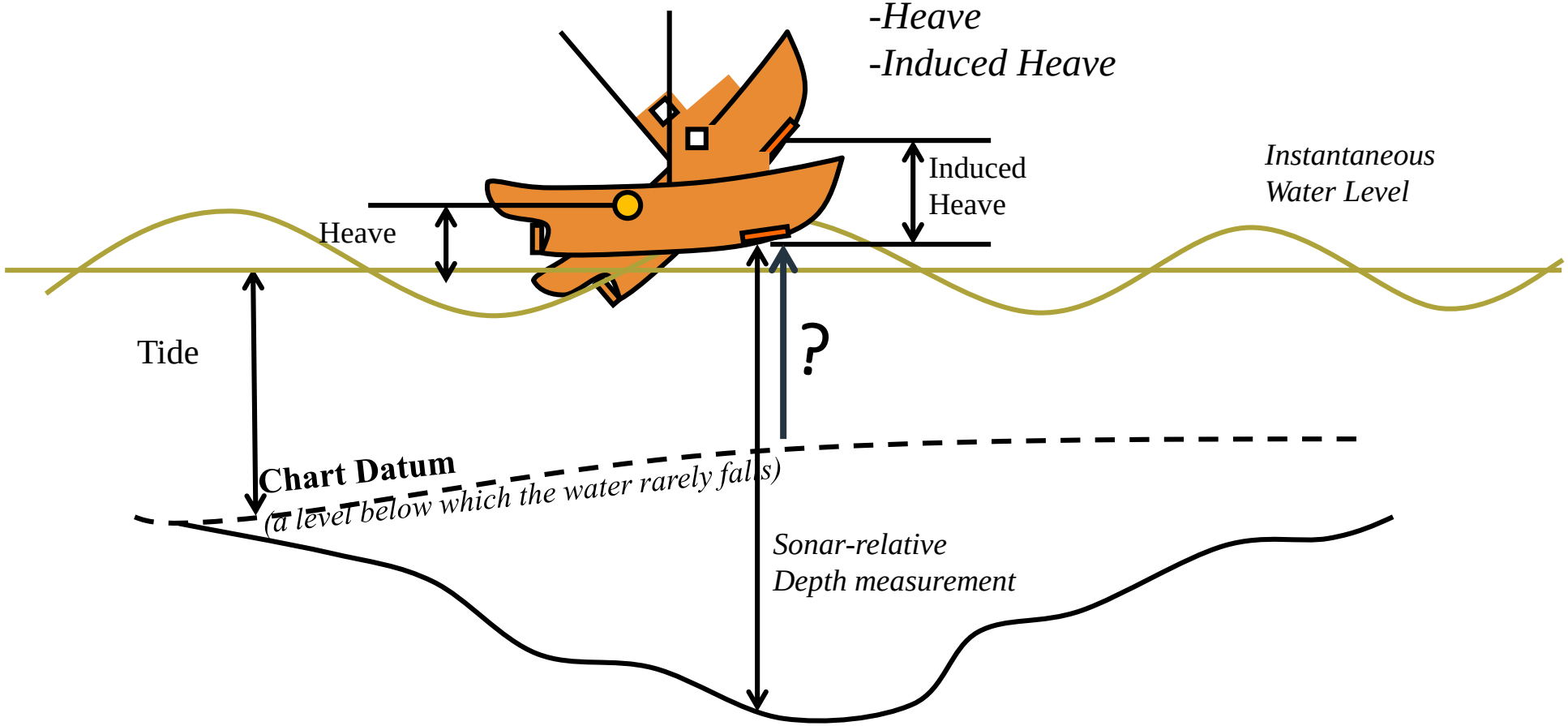
Need to reduce our depth measurements to Chart Datum

<u>Correct for low frequency variations</u>
-Tide
-Draught (use height of the RP above water line and the z offset to the transducer)



Need to reduce our depth measurements to Chart Datum

Correct for high frequency variations
-Heave
-Induced Heave



NOTE: EM710 heave already has induce heave included

due: April 19th, 2022