Technology for Surveying

Technical Workshop
9th South West Pacific Hydrographic Commission Conference
Port Moresby, Papua New Guinea

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Overview

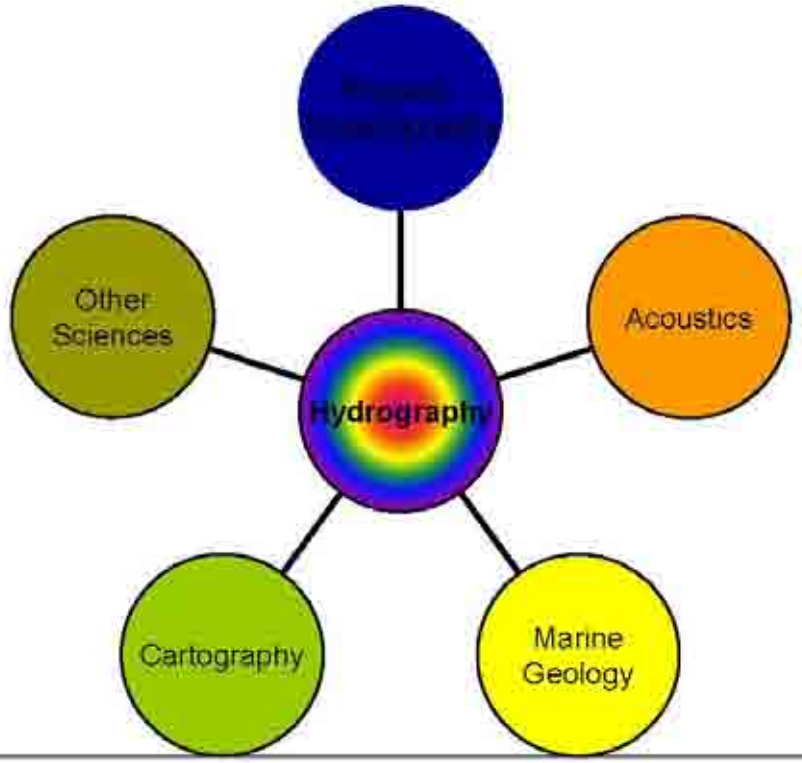
- The Basics…
- Evolution of sounding equipment
- Examples of equipment
- Standards, Uncertainties, and Sources of Errors

Defined…

- **Hydrographic surveying:**
  - **Gathering information about navigable waters for safe navigation of vessels.**

Hydrographic Science

- Encompasses several sciences



The Basics…

- **Collect the data, with the goal of:**
  - Knowing exactly where you are
  - Knowing exactly where the sounding is being taken
  - Knowing exactly how deep the water is
  - Understanding extent of your uncertainty
- **Publish the chart/make available**
  - Quality control…
- **Ensure the chart and relevant maritime safety information updated.**

History of Sounding Methods

- Early Sounding Methods

Positional fix, using a sextant

eline: early 1800's –

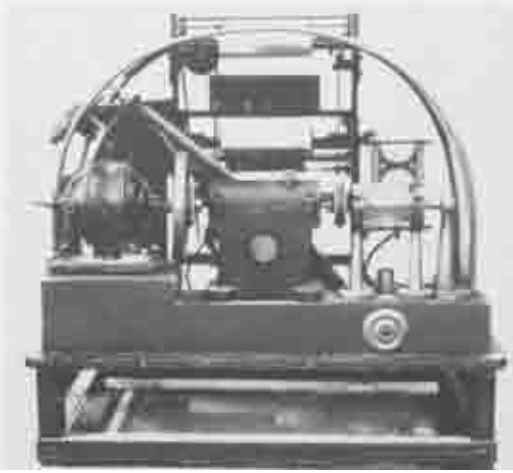
History of Sounding Methods

In 1850 LT John Mercer Brooke, USN invents the first successful deep-sea sounding device.

1850 – 1920—era of advanced innovations in echo sounding

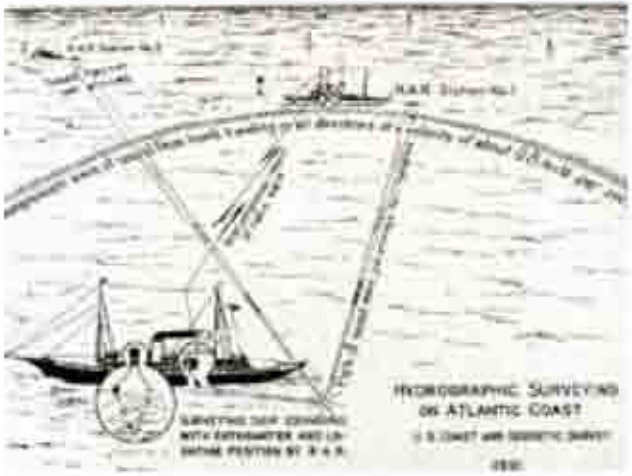
History of Sounding Methods

In 1919, Frenchman Pierre Marti began designing a sounding machines based on acoustic methods.



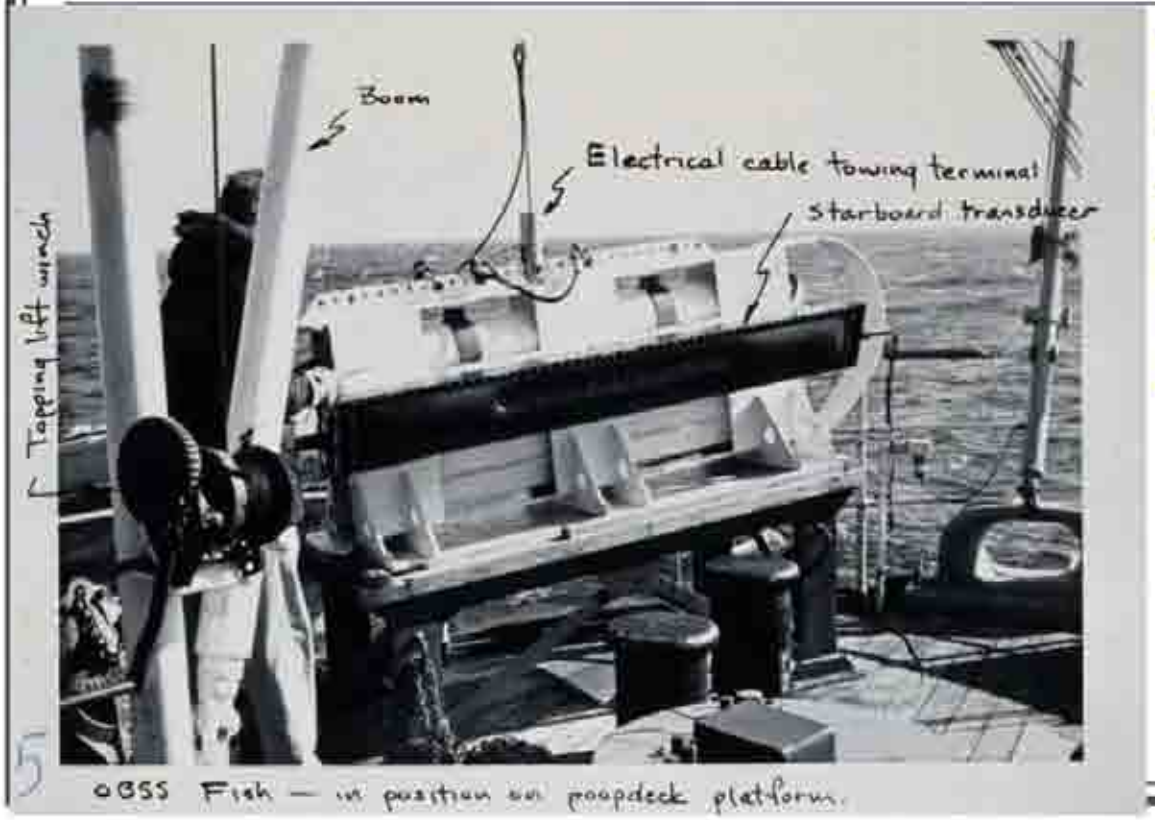
History of Sounding Methods

- 1919 Dr. H Hayes invents the Sonic Depth Finder



History of Sounding Methods

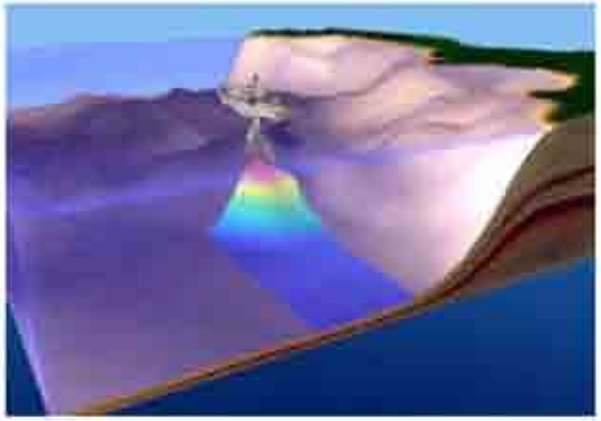
- Side Scan Sonar



The first commercial side scan system was the Kelvin-Hughes "Transit Sonar".

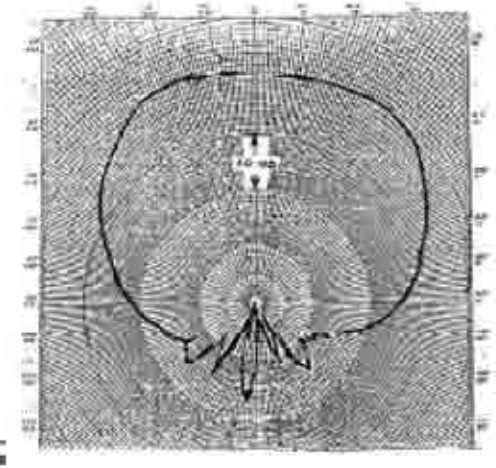
History of Sounding Methods

- Multibeam



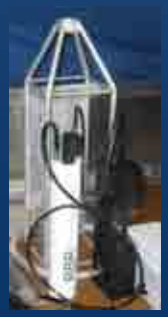
The first multibeam sounding system, known as the Sonar Array Sounding System (SASS)

Sonar Beam Pattern



Survey Equipment

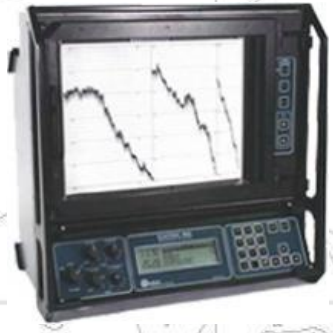
- Singlebeam Echosounders
  - Odom Hydrotrack
  - CeeDucer Pro
- Multibeam Echosounders
  - Reson 8125 (shallow water)
  - Reson 8101 (deep water)
- Side Scan Sonars
  - Klein
  - Marine Sonics
  - EdgeTech
- GPS
  - NAVCOM
- Sensors & Measuring Devices
  - Tide Gauges
  - CTDs
  - ADCPs
  - Digibar SVP



Standard Hydro Equipment

9M SAFEBOAT
Weight: 14,000 lb

Klein 3000
Side Scan



Odom MKIII
Single-Beam

Reson 8101 or 8125
Multi-Beam

Navcom 2050M GPS

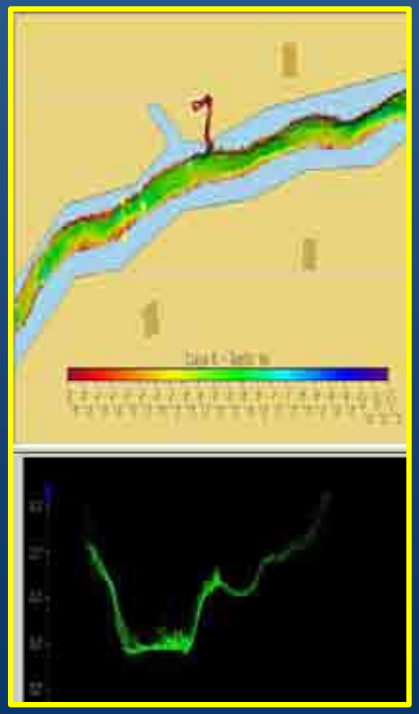
In Situ Tide gage

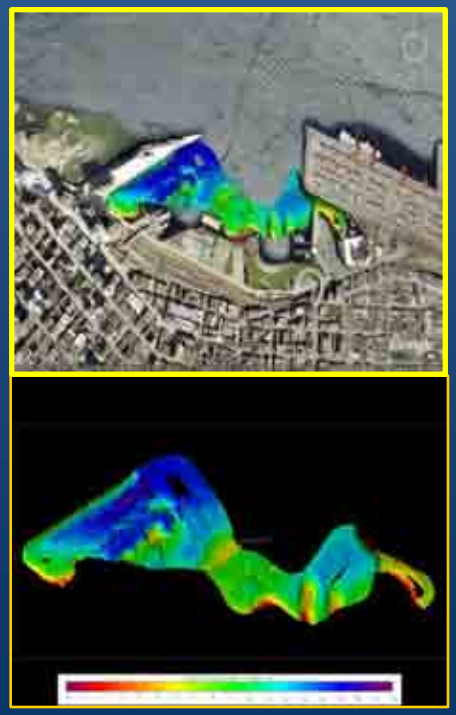
Expeditionary Multibeam Kit (EMK)

The EMK-1 is an effective alternative for rapid deployment shallow water expeditionary surveys.

- Small, lightweight and low cost.
- Easy to use, minimum configuration.

EMK Specifications	
Frequency	260 KhZ
Transducer Beam Width	Receive: 120° x 3°
	Transmit: Receive: 120° x 3°
Effective Beam Width	3°, 1.5°, 0.75°
Beams	120, 240, 480
Min. Detectable Range	0.1 m
Max. Detectable range	100 m

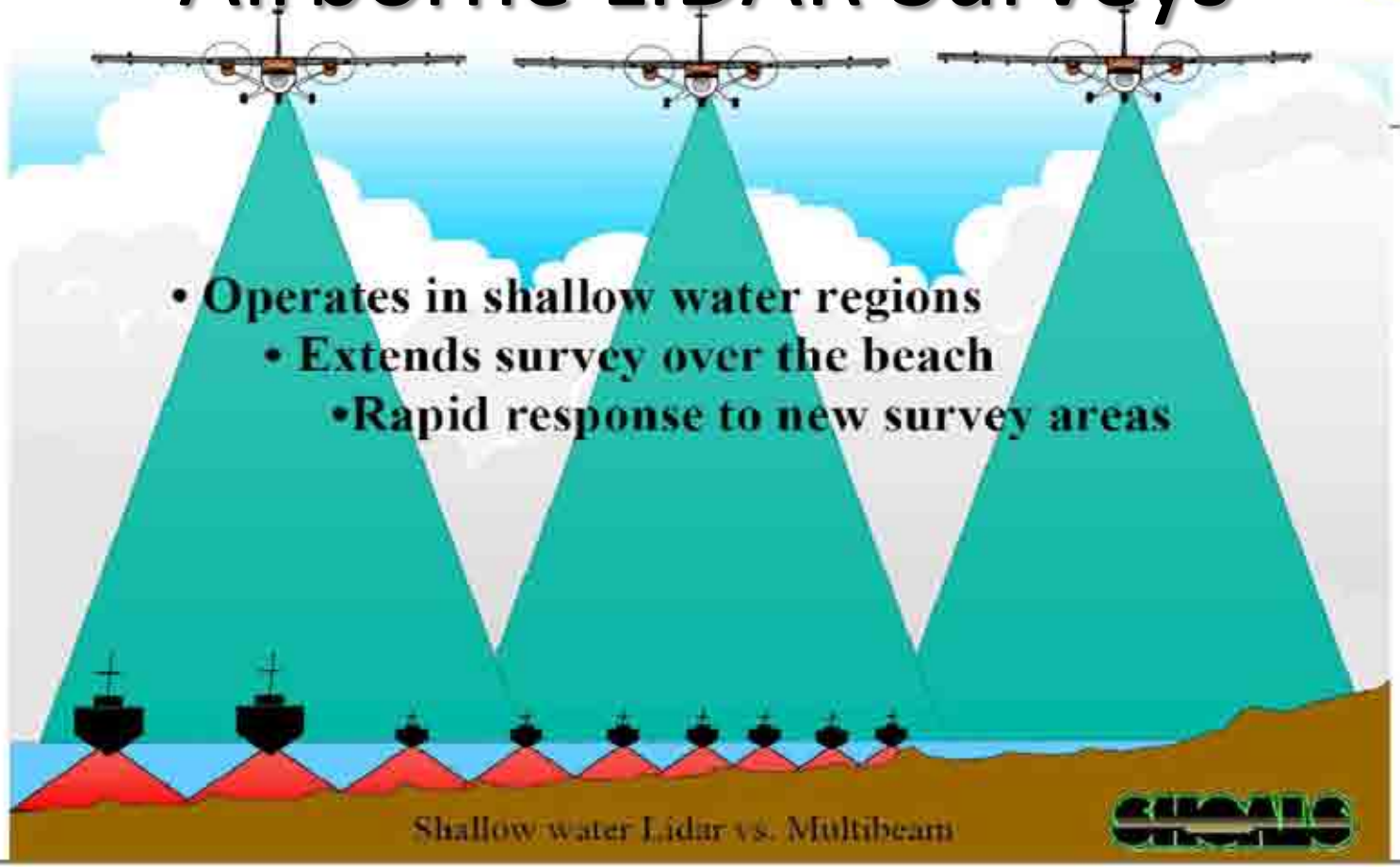




Amphibious/Riverine Support

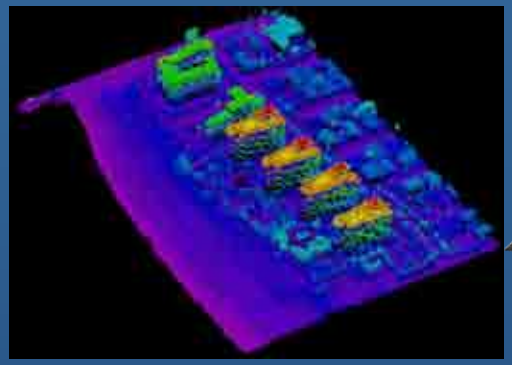
- Amphibious Operations / Riverine Assessment
  - Surf Zone Bathymetry
  - Riverine Bathymetry
  - Jet Ski Survey
  - Beachmaster surf observations
  - Beachmaster camera system (visser)

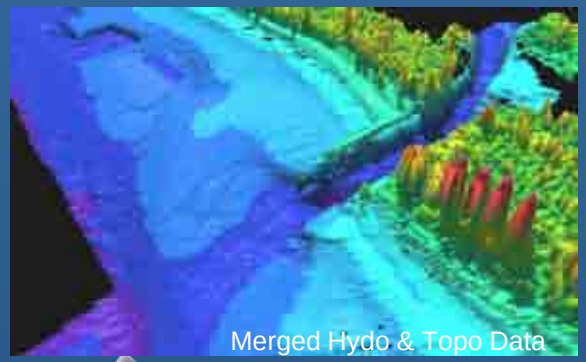
Airborne LIDAR Surveys

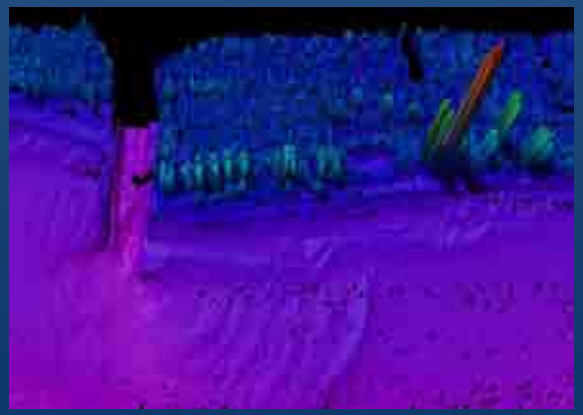


Airborne Lidar

Joint Airborne Lidar Bathymetry Technical Center of Expertise







System 3 Specifications

- Hydrographic Lidar (3,000 Hz Pulse Rate)
- Topographic Lidar (20,000 Hz Pulse Rate)
- 1 Hz Digital camera (~20 cm pixel)
- CASI-1500 Hyperspectral Imager

Typical Survey Crew

3 Contract Aircrew
4 Contract Data Collectors/Processors
2 JALBTCX Personnel

9 Total Personnel

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- **Publish the chart/make available**
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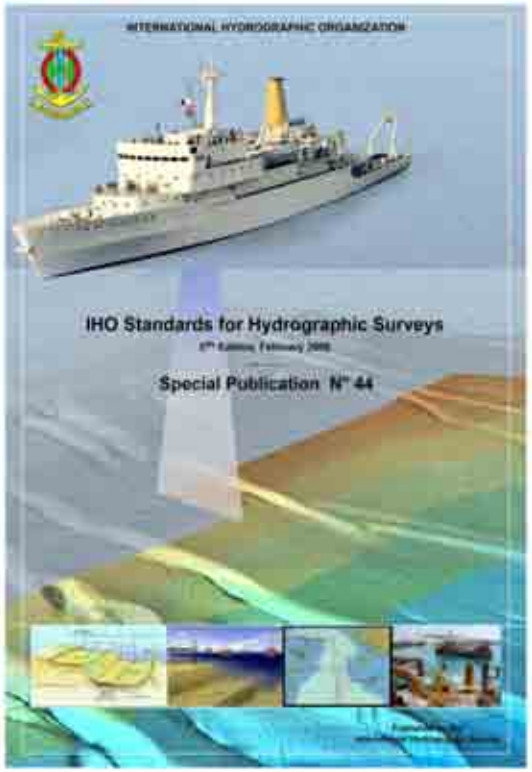
S-44 Hydro Survey Standards

- Standards defined by S-44
  - Classification of Surveys
  - Various measurements
  - Positioning methods
  - Data Attribution
  - Depths



Basic Definitions

- **Feature detection**
  - Detect features of a defined size which, for safety of navigation, should be detected.
- **Full sea floor search**
  - A systematic method of detecting as many features as possible.
  - Often misstated as 100% ensonification /coverage.)
- **Reduced depths**
  - Including all corrections related to the survey and post processing and reduction to the used vertical datum.

Survey Classification

- **Special Order: ports/harbors**
  - Full sea floor search; critical areas for shipping.
  - Typically less than 40 m depth
- **Order 1: Typically less than < 100 m depths**
  - 1a: Full sea-floor search required. Natural or man-made features on the seabed are of concern to the type of surface shipping expected to transit the area, but where the under-keel clearance is less critical than for Special Order
  - 1b: Full sea-floor search not required. General depiction of the seabed is considered adequate for the type of surface shipping expected to transit the area.
- **Order 2: Depths > 100 m; full sea floor search not required.**

S-44 Survey Standards

Reference	Order	Special	1a	1b	2
Chapter 1	**Description of areas.**	Areas where under-keel clearance is critical	Areas shallower than 100 metres where under-keel clearance is less critical but *features* of concern to surface shipping may exist.	Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area.	Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate.
Chapter 2	**Maximum allowable THU 95%** *Confidence level*	2 metres	5 metres + 5% of depth	5 metres + 5% of depth	20 metres + 10% of depth
Para 3.2 and note 1	**Maximum allowable TVU 95%** *Confidence level*	a = 0.25 metre b = 0.0075	a = 0.5 metre b = 0.013	a = 0.5 metre b = 0.013	a = 1.0 metre b = 0.023
Glossary and note 2	*Full Sea floor Search*	Required	Required	Not required	Not required
Para 2.1 Para 3.4 Para 3.5 and note 3	*Feature Detection*	Cubic *features* > 1 metre	Cubic *features* > 2 metres, in depths up to 40 metres; 10% of depth beyond 40 metres	Not Applicable	Not Applicable
Para 3.6 and note 4	**Recommended maximum Line Spacing**	Not defined as *full sea floor search* is required	Not defined as *full sea floor search* is required	3 x average depth or 25 metres, whichever is greater For bathymetric lidar a spot spacing of 5 x 5 metres	4 x average depth
Chapter 2 and note 5	**Positioning of fixed aids to navigation and topography significant to navigation. (95%** *Confidence level***)**	2 metres	2 metres	2 metres	5 metres
Chapter 2 and note 5	**Positioning of the Coastline and topography less significant to navigation (95%** *Confidence level***)**	10 metres	20 metres	20 metres	20 metres
Chapter 2 and note 5	**Mean position of floating aids to navigation (95%** *Confidence level***)**	10 metres	10 metres	10 metres	20 metres

Uncertainty

- **Total propagated uncertainty (TPU)**
  - Includes all contributing measurement uncertainties, both random and systematic, in the propagation.
- **Total horizontal uncertainty (THU): component of TPU calculated in the horizontal plane (navigation)**
  - Impacts position of soundings, dangers, other significant submerged features, navaids (fixed and floating), features significant to navigation, the coastline and topographical features
- **Total vertical uncertainty (TVU) (tides, depth measurement):**
  - The component of TPU calculated in the vertical dimension.

Horizontal Uncertainty

- Positioning system errors
- Range and beam errors
- Error associated with the ray path model (including the sound speed profile), and the beam pointing angle
- Error in vessel heading
- System pointing errors resulting from transducer misalignment
- Sensor location
- Vessel motion sensor errors i.e. roll and pitch
- Sensor position offset errors
- Time synchronisation / latency

Example – Special Order

- **Special Order Survey; average water depth of 40 m:**

  a = constant depth error (sum of all constant errors)

  b = factor of depth dependent error

  d = depth

$$\pm\sqrt{\left(0.25^2 + (.0075 * 40)^2\right)}$$

Error Budget (40 m depth) = .2489 m ≈ 25 cm depth error

Vertical Uncertainty

- Vertical datum errors
- Vertical positioning system errors
- Tidal measurement errors
- Instrument errors
- Sound speed errors
- Ellipsoidal / vertical datum separation model errors
- Vessel motion errors, i.e. roll, pitch and heave
- Vessel draught
- Vessel settlement and squat
- Sea floor slope
- Time synchronisation / latency

Multibeam Echosounder (MBES) Calibration

- **What are the effects on depth and position uncertainty of errors in sensor locations and alignments within the vessel reference frame?**

Integrated Multibeam Survey System

- Vessel
- MBES
- Navigation System (GPS)
- Heading Sensor
- Attitude Sensor(s)
  - Position-Marine Vessel (PosMV)
  - Heave Sensor
- Separate coordinate systems

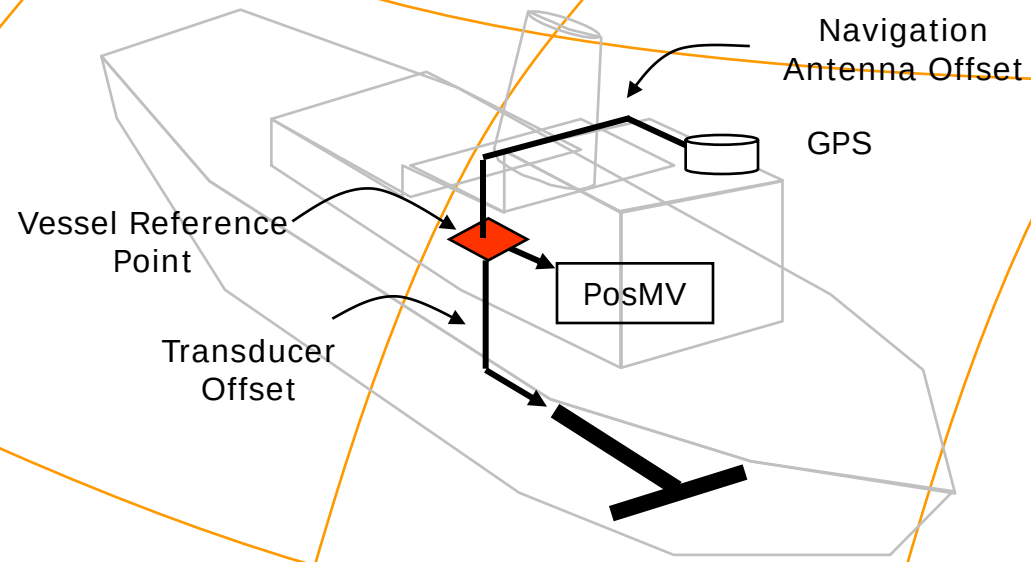
Potential Errors

- Positioning system error
- Depth measuring error
- Ray Path uncertainty/Sound Velocity Profile error
- Heading accuracy
- Transducer misalignment and pointing errors
- Vessel attitude accuracy
- Time latency

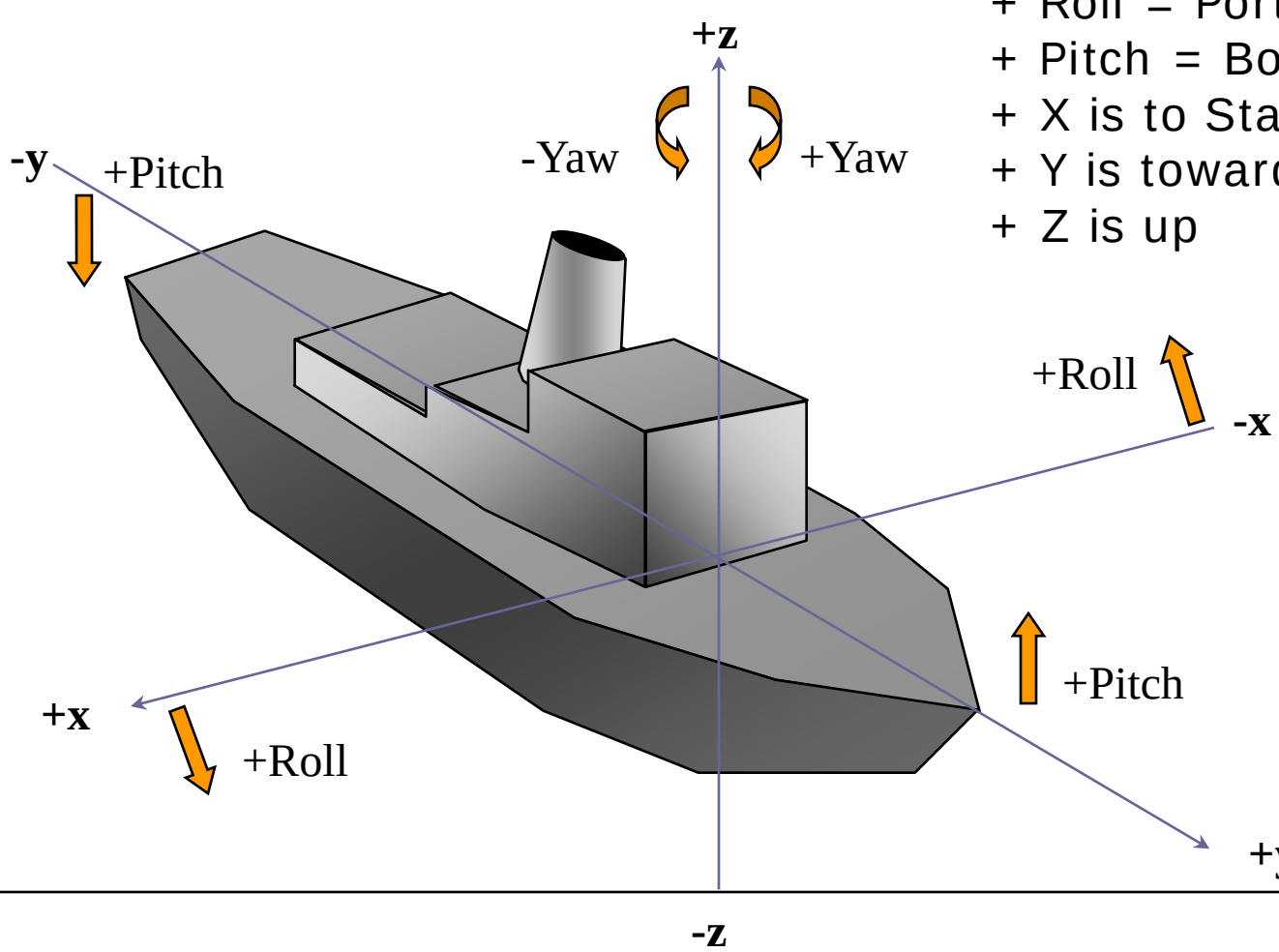
Main Sources for Error

- **Timing Error**
  - Between positioning system and the sonar
- **Roll Bias**
  - Atwarthship alignment of receiver array
- **Pitch Error**
  - Fore and Aft steering of transmitted ping
- **Heading (Gyro) Offset**
  - Alignment between MBES and navigation systems

Multibeam Survey System Offsets



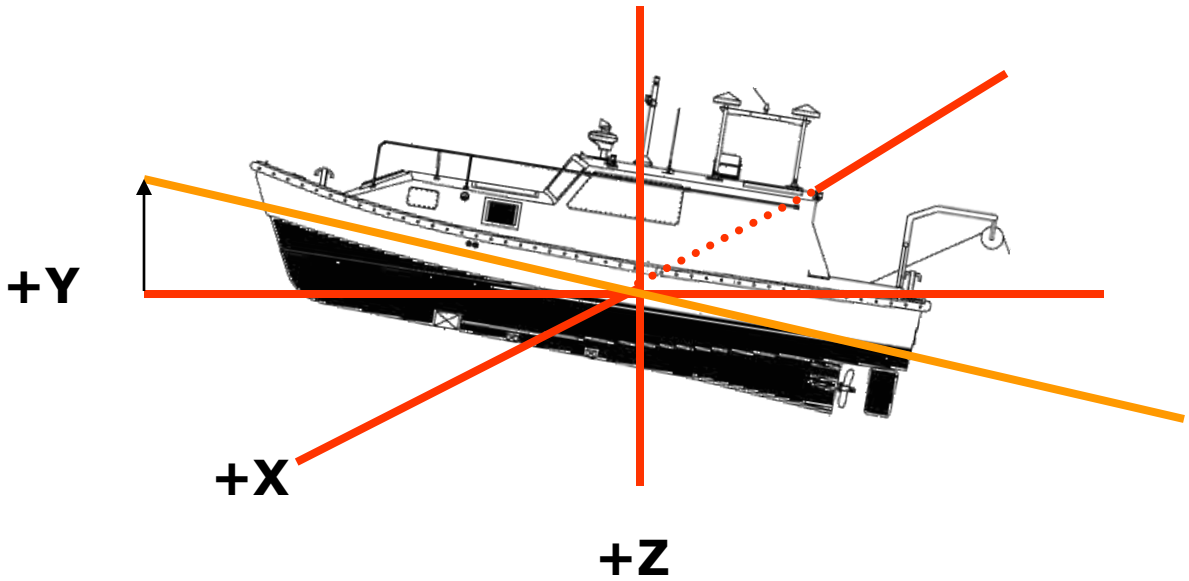
Vessel Co-ordinate System



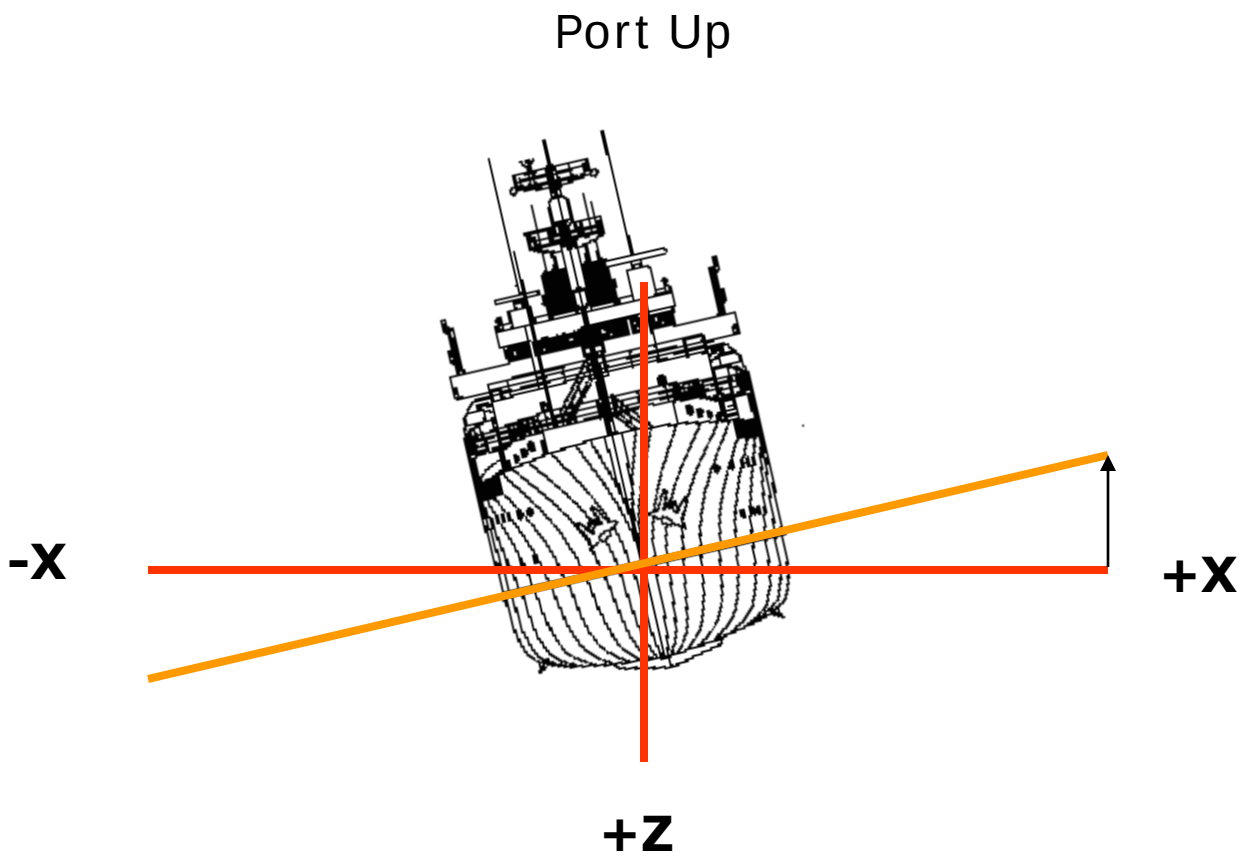
+ Roll = Port Up
+ Pitch = Bow Up
+ X is to Starboard
+ Y is towards the bow
+ Z is up

Positive Pitch Error

Bow Up

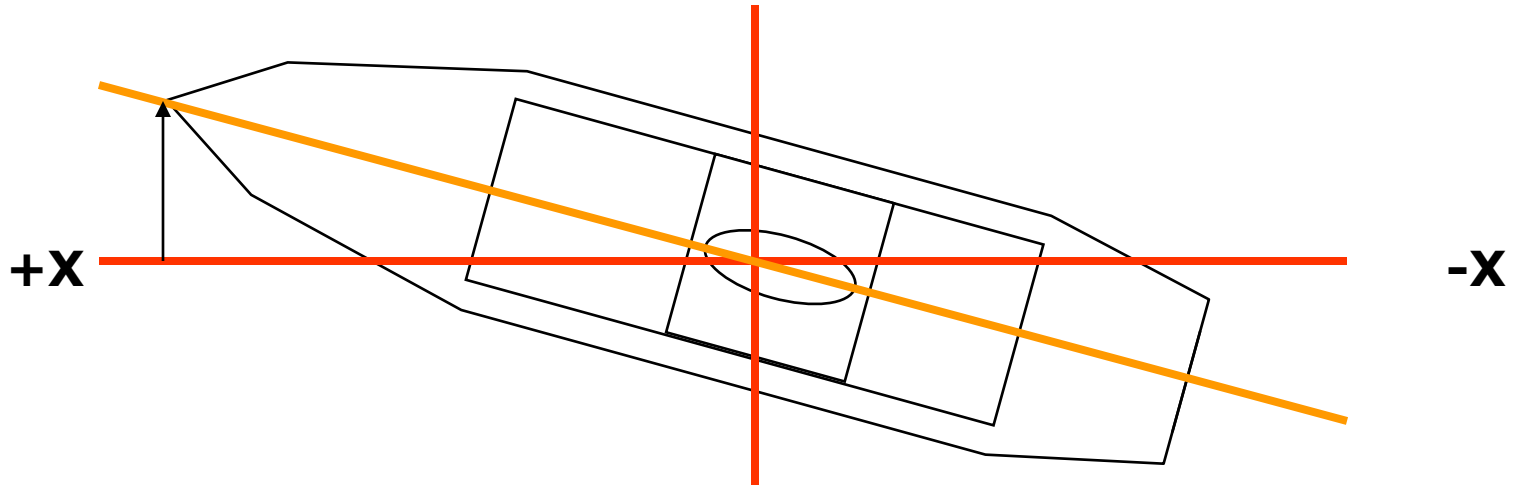


Positive Roll Error



Positive Yaw Error

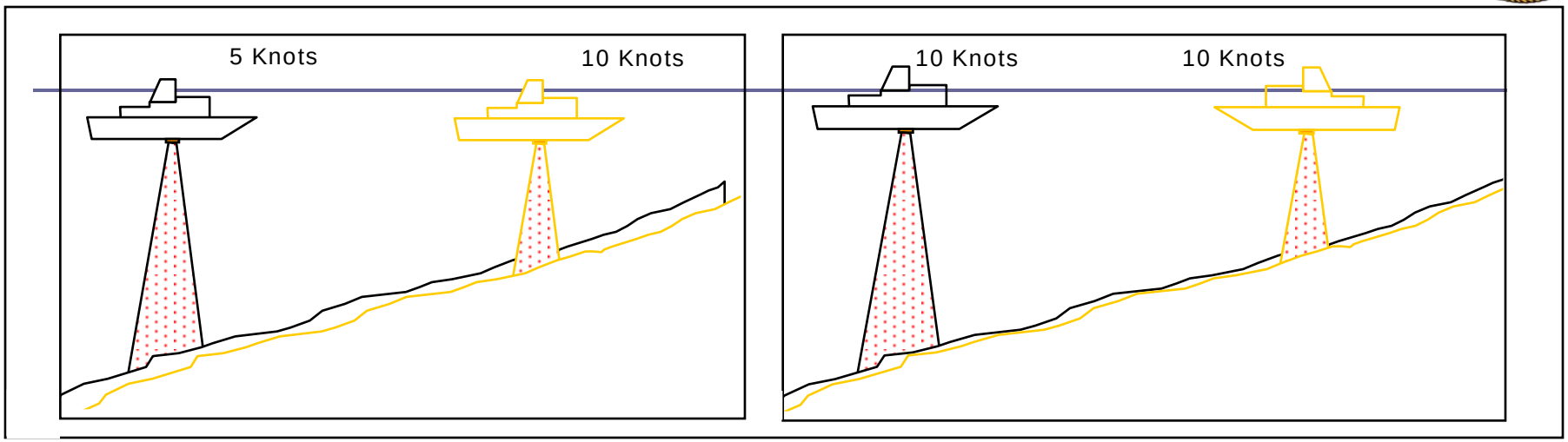
Clockwise Rotation



Error Mitigation Through Calibration

- Determination of sensor locations and alignments within vessel reference frame
- Proper calibration of the multibeam sonar to eliminate biases

Timing Bias Calibration

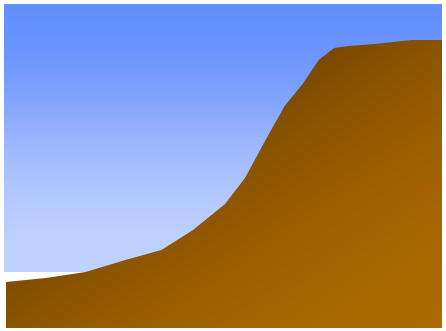


- A time delay exists between 'most' GPS units and the data collection system - generally 0.1 to 1.2 seconds
- One trackline 200 to 500 meters in length perpendicular to a slope or distinct feature
- Survey trackline three times:
  - Two lines same direction, one at 5 knots and one at 10 knots
  - One line the opposite direction at 10 knots
- If a time delay exists, the feature will show a horizontal offset between each profile line

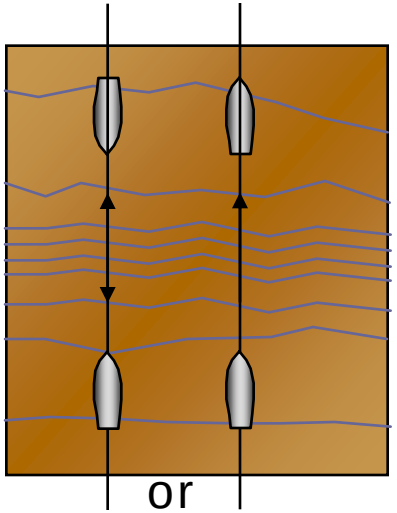
Timing Bias Calibration

Survey Line

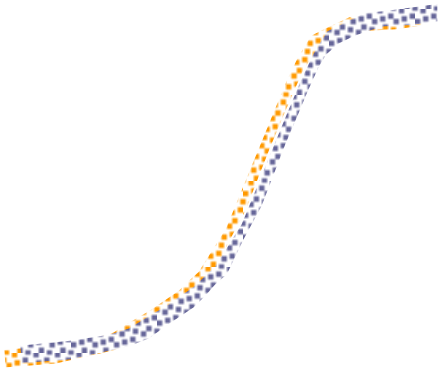
Side



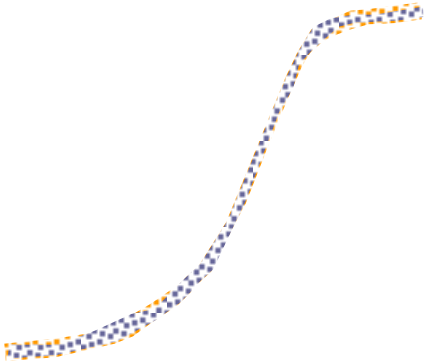
Plan



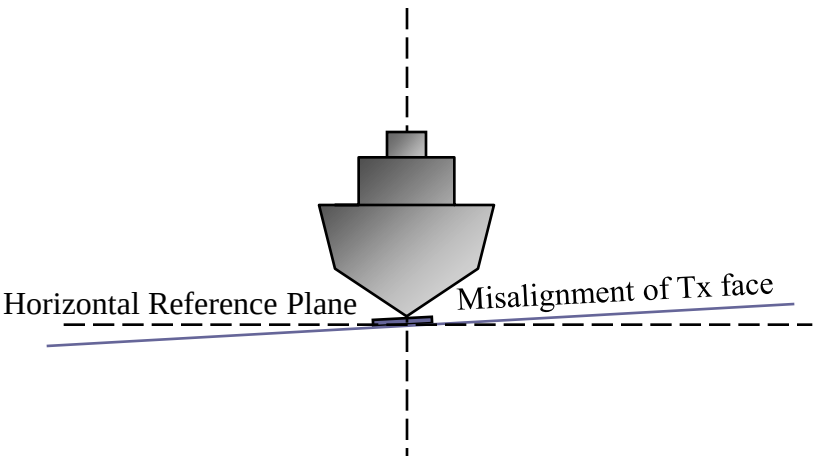
Before Calibration

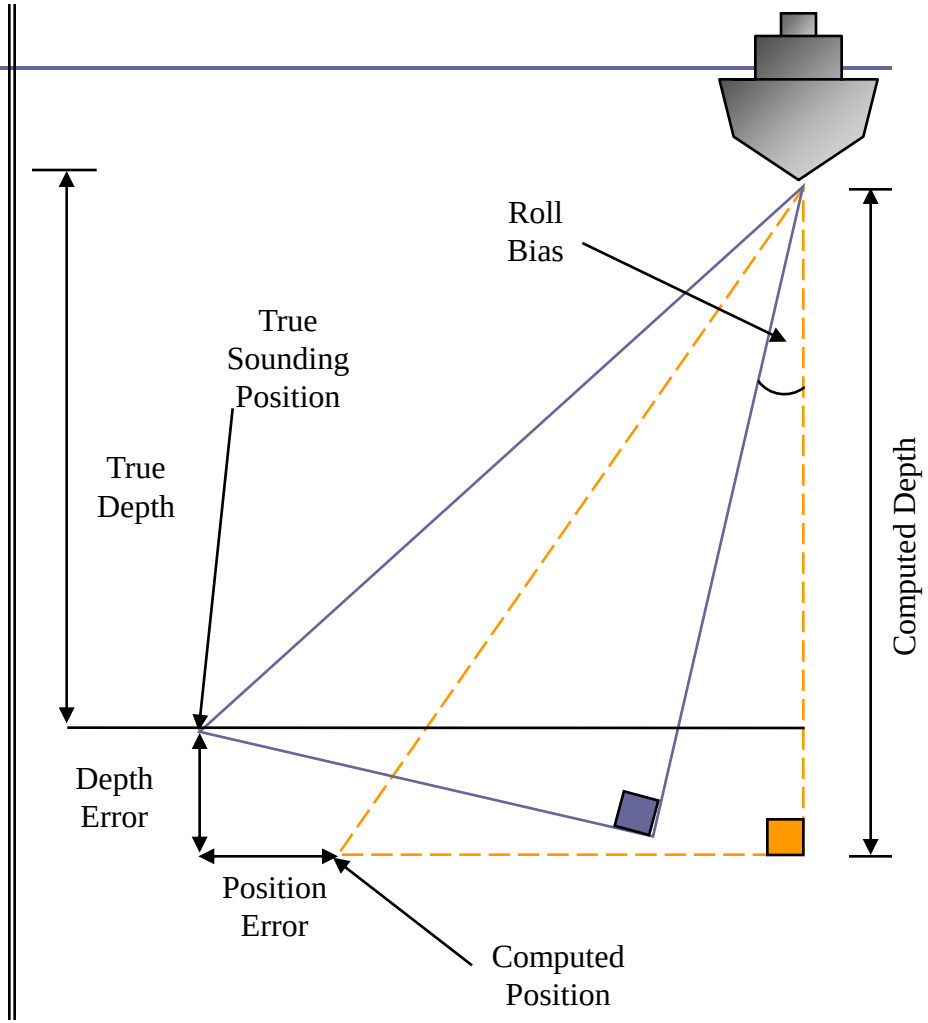


After Calibration



Roll Bias Error





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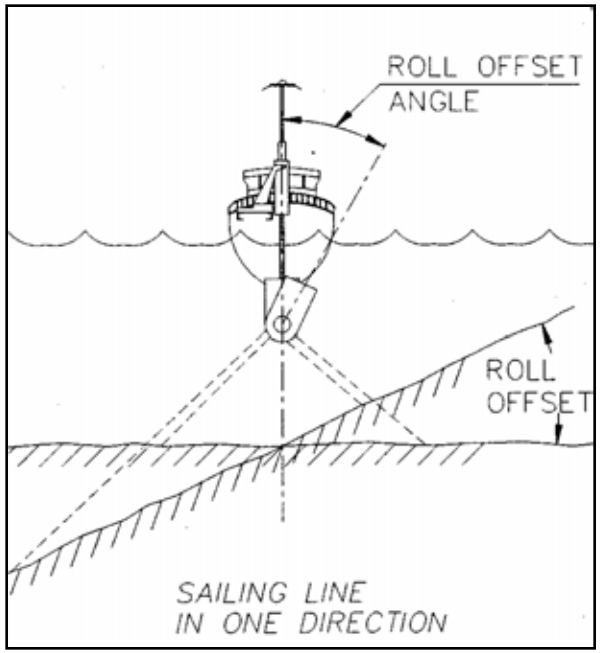

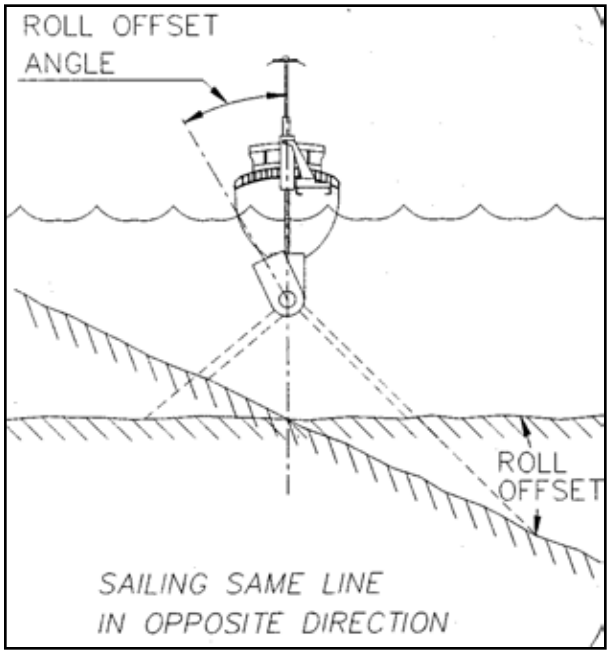

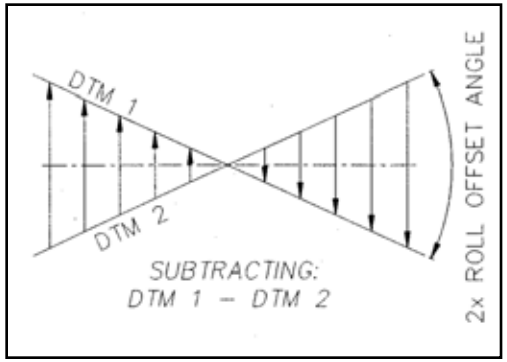

Roll Bias Calibration

Survey Line

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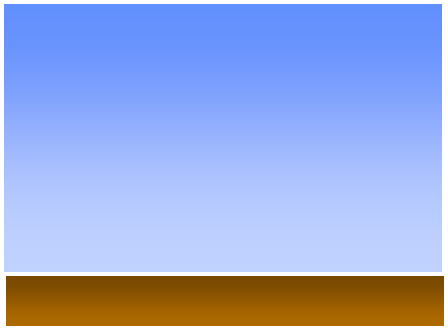

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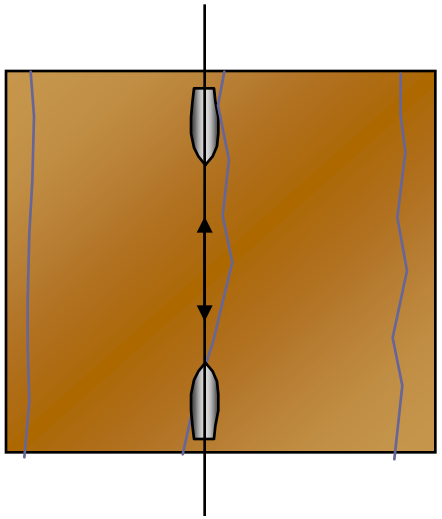
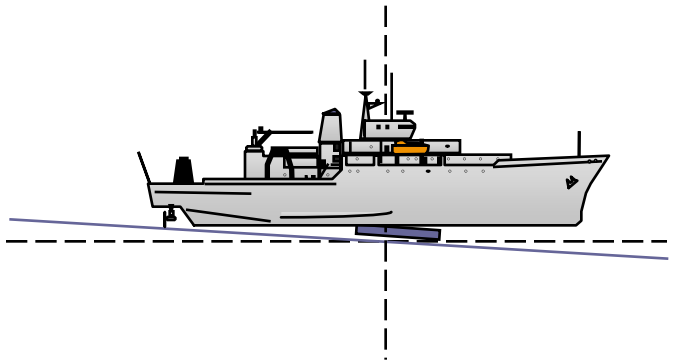
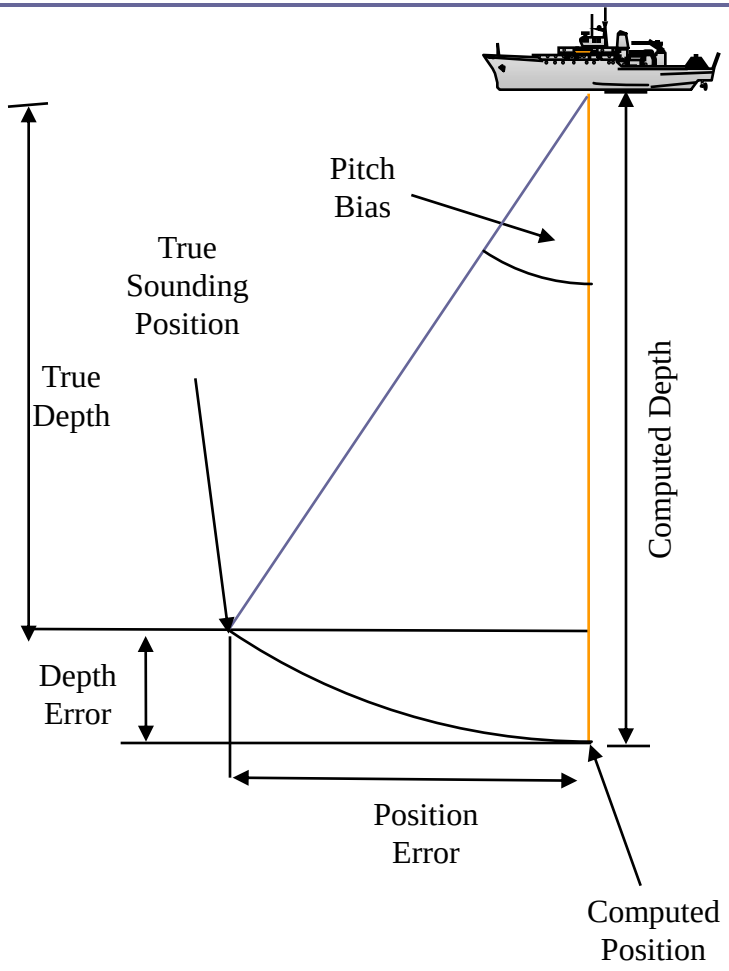


Before Calibration

After Calibration

Pitch Bias Error





Pitch Bias Calibration

Survey Line

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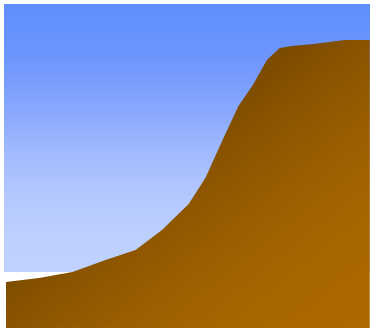

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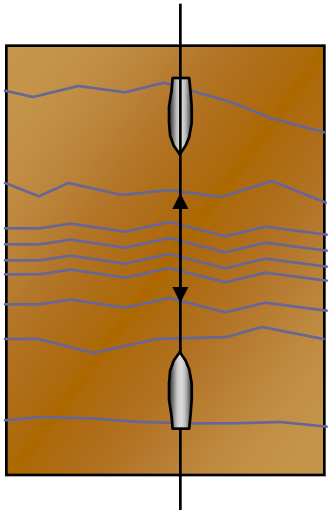

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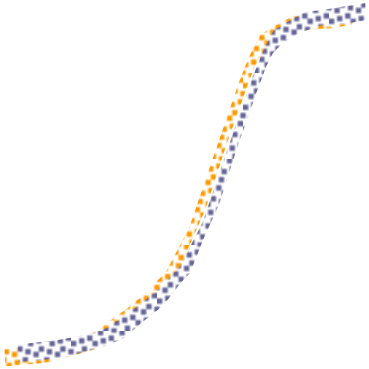

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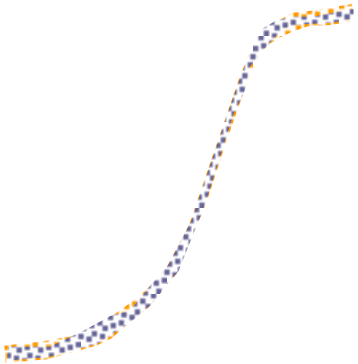
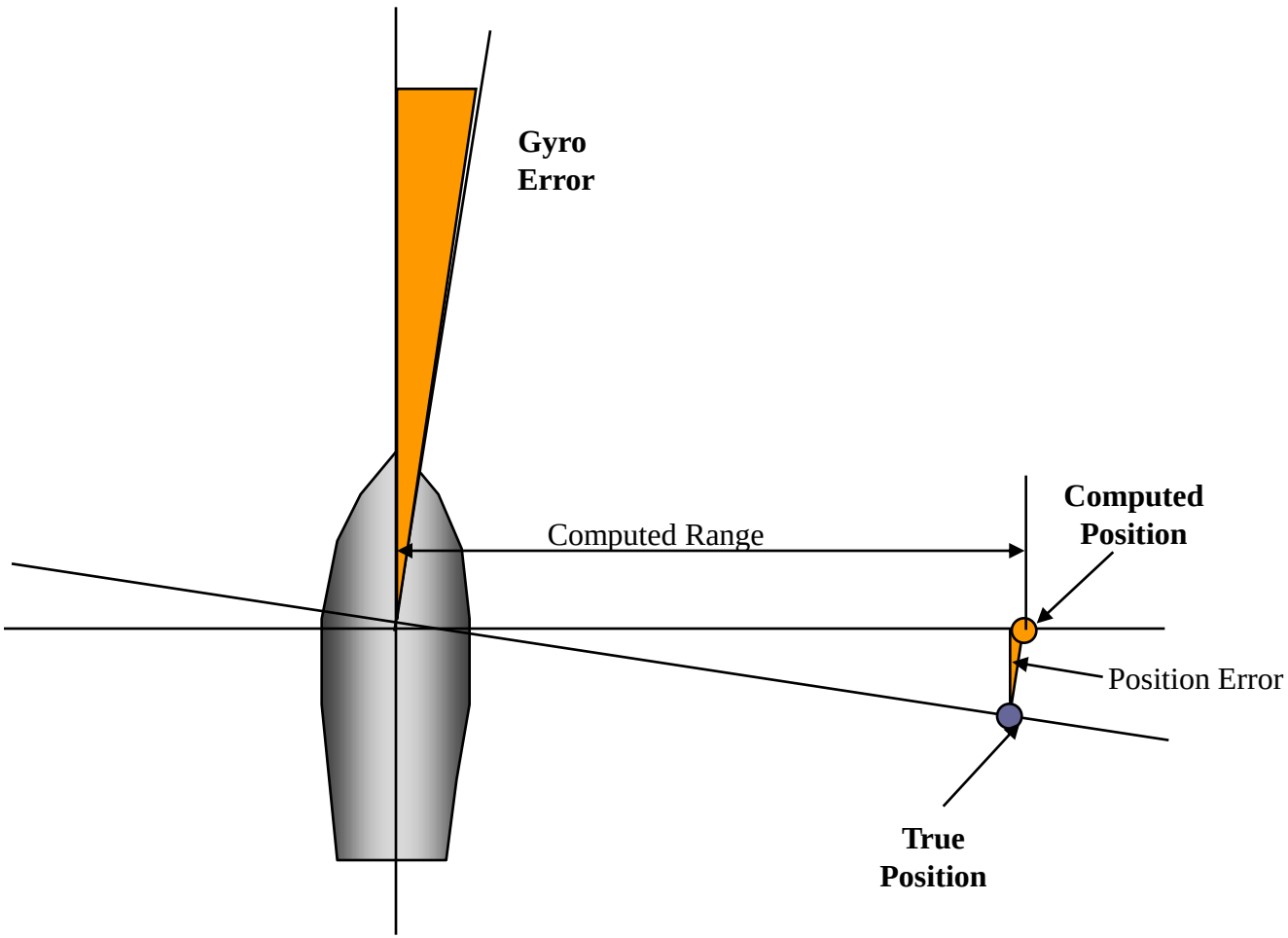
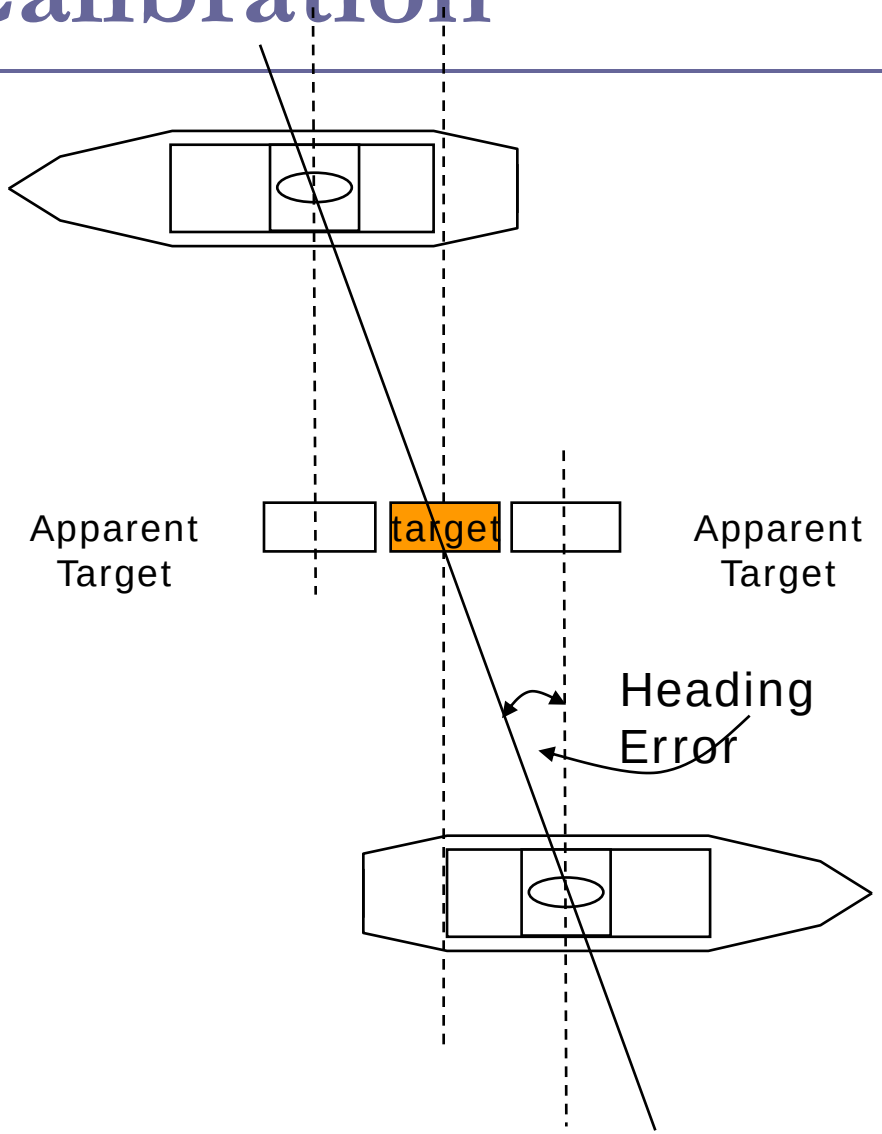


Heading (Gyro) Bias Error



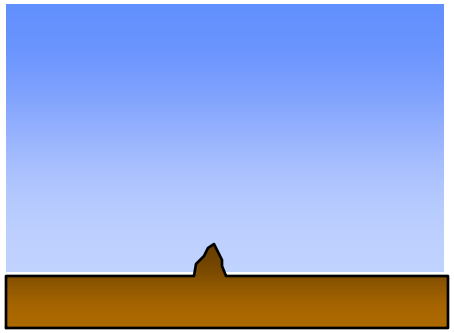
Heading (Gyro) Bias Calibration



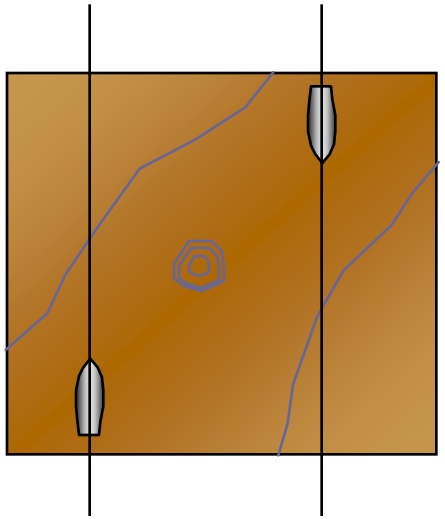
Heading (Gyro) Bias Calibration

Survey Line

Side



Plan



Before Calibration

After Calibration

Summary

- Select the right platform and systems for the survey
- Adhere to S-44 standards
- Calibrate carefully
- Identify all error sources

Thank you