The Hydrographic Society In Scotland

POSITIONING SYSTEMS

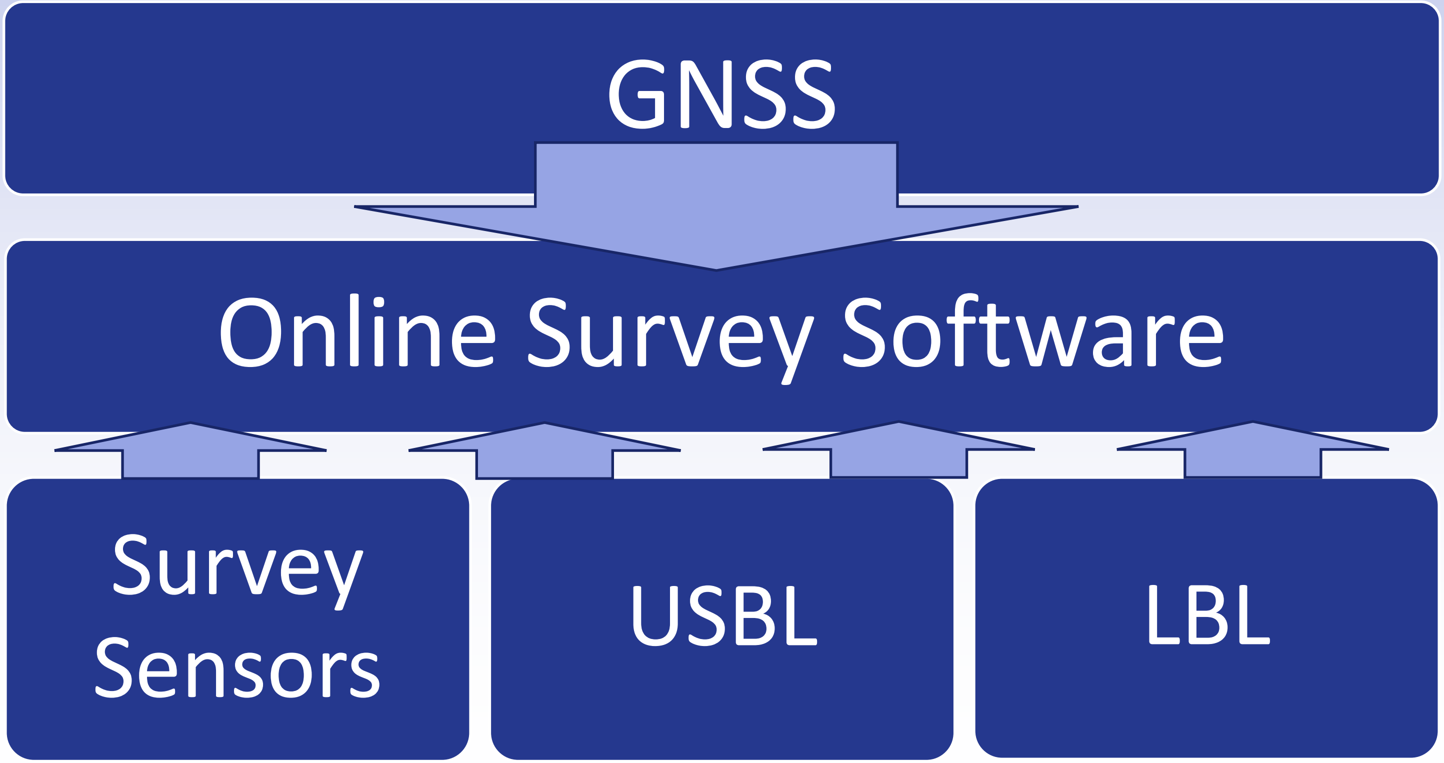
Eddie Milne

1. GNSS Positioning
2. Additional Sensors
3. Alternative Positioning
4. Bringing it altogether

Importance of GNSS

- Why is GNSS so important?

- In majority of offshore applications it is the starting point for all other sensors. If the starting point is wrong then all other points are wrong



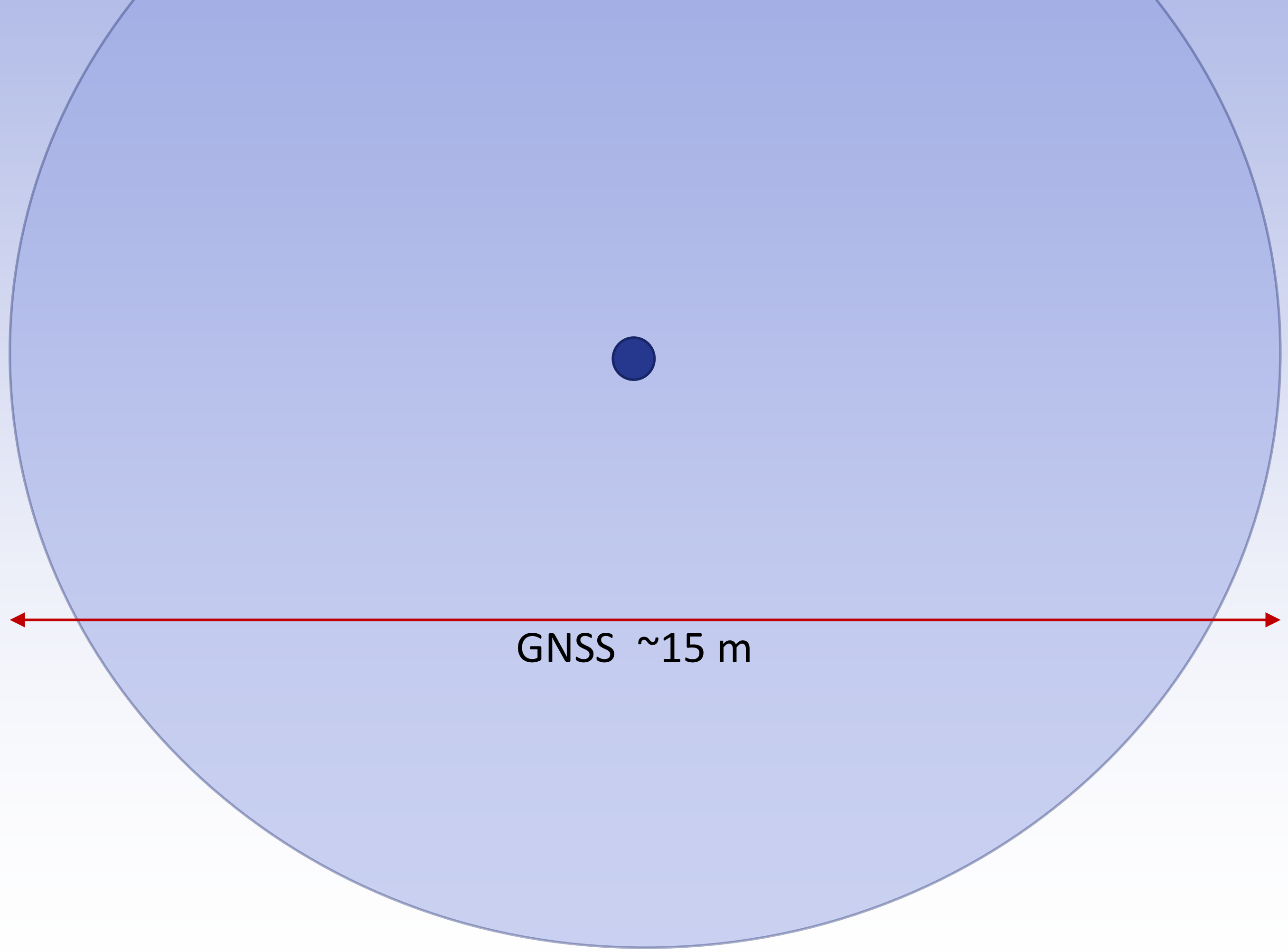

GNSS = GPS + Glonass + Galileo + Beidou

GNSS Horizontal Accuracies

95% Confidence (2σ):

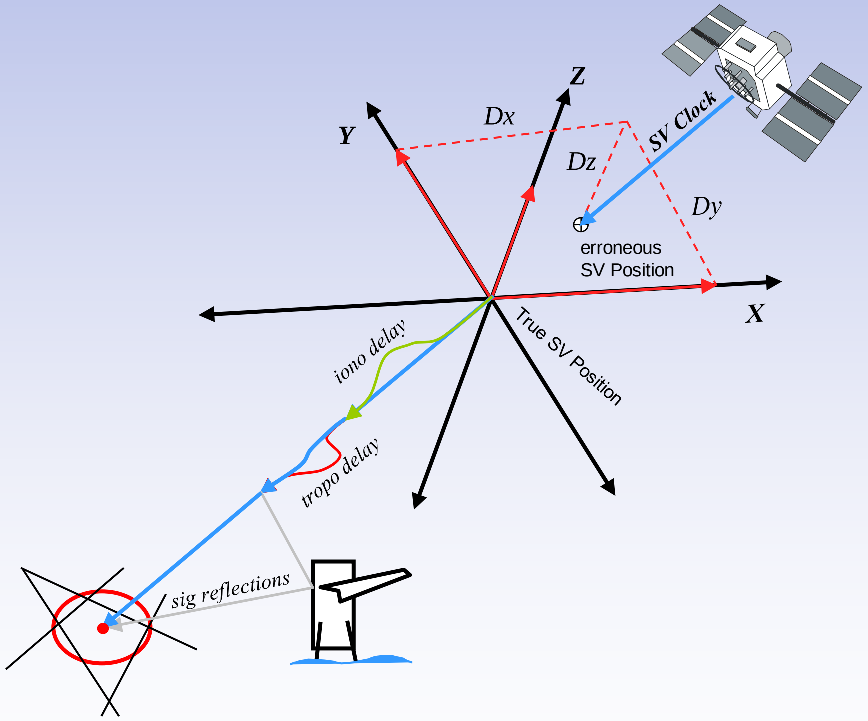
Main Error Sources:

Satellite Orbit	±2.5m
Satellite Clock	±2m
Ionosphere	±5m
Troposphere	±0.5m
Receiver Noise	±0.3m
Multipath	±1m



Removing the Errors - PPP

- Apply calculated SV clock error correction to broadcast ephemeris value
- Apply satellite orbit corrections to broadcast orbit position
- Iono error is calculated using dual-frequency mobile GPS hardware
- Tropo delays minimised using model plus residual error is estimated as part of the calculation process
- Measurement noise and multipath minimised using carrier phase observable



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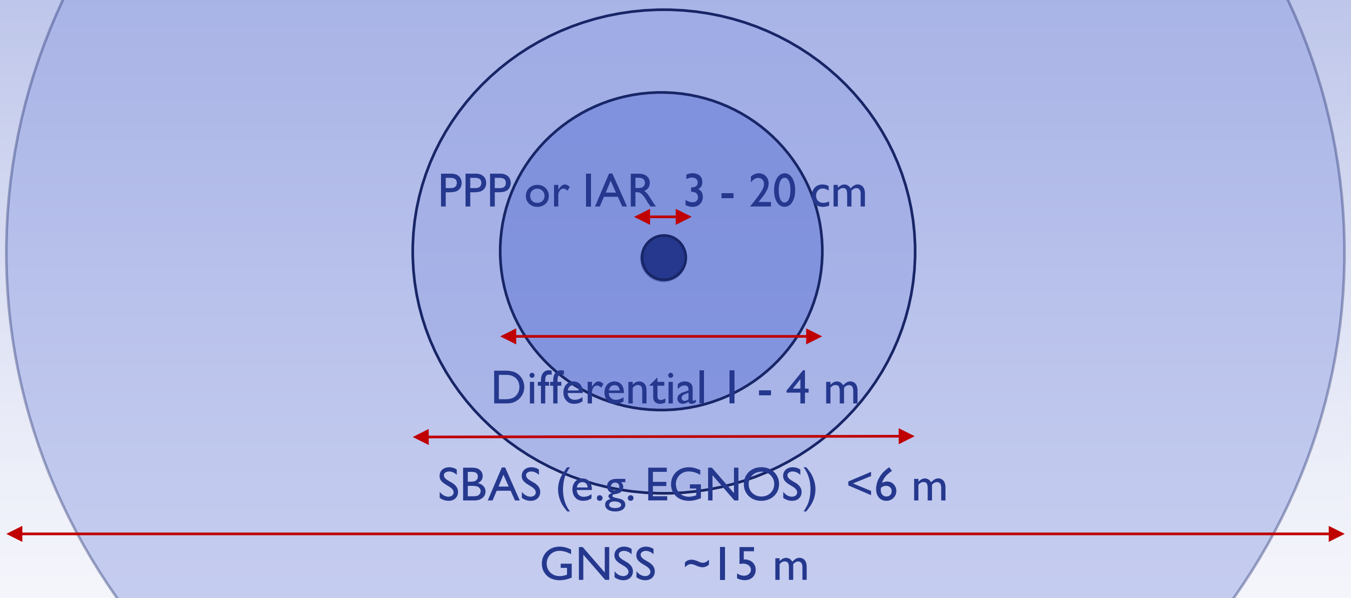


SBAS:	*Space Based Augmentation Service (Free)*
Differential:	*Pseudo Range Correction (Free and Commercial Augmentation Services)*
PPP:	*Precise Point Positioning (Commercial Augmentation Service)*
IAR:	*Integer Ambiguity Resolution (Commercial Augmentation Service)*

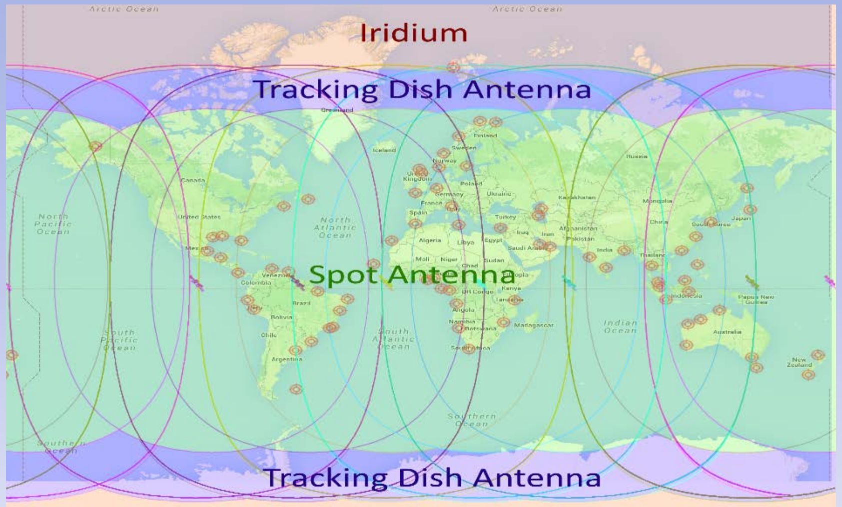
Offshore Correction Service	Correction Type	Horizontal Accuracy (95%)	Satellites
Veripos Apex[5]	PPP	5 cm	GPS, Glonass, Galileo, Beidou, QZSS
Veripos Ultra[2]	PPP	10 cm	GPS, Glonass
Veripos Std[2]	Differential	1 m	GPS, Glonass
CNav C[1]	PPP	10 cm	GPS
CNav C[2]	PPP	8 cm	GPS, Glonass
Fugro Starfix G4	PPP	10 cm	GPS, Glonass, Galileo, Beidou,
Fugro Starfix G2+	PPP + IAR	3 cm	GPS, Glonass
Fugro Starfix G2, XP2	PPP	10 cm	GPS, Glonass
Fugro Starfix HP	IAR	10 cm	GPS

Others: Positioneering, Atlas, Various Land Services

GNSS receiver Quality

- Wide range of GNSS receiver quality available
- Consumer Grade to Professional Grade Receivers
- Costs range from £xx to £xxxx
- Offshore operations should utilise Professional Grade receivers because:
  - They have lower receiver noise and greater capability to reject Multipath Errors.
  - They use dual frequency measurements to measure Ionospheric delays and are more resilient to interference.
  - They can track multiple constellation to provide more resilience against interference and Constellation issues.

GNSS Practical Considerations



Work Location

Site Conditions

Antenna Placement

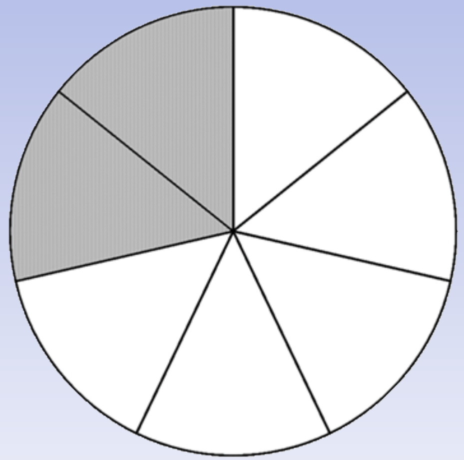
Cable Run

Threats to GNSS

- In-Band Interference
  - Re-radiating GNSS systems
    - GNSS systems, Tracking Dish Systems, Doppler Speed Logs, Heading Sensors
- Out-Band Interference
  - Communications,
    - LRIT, V-SAT, Sat-C, Iridium
  - Microwave data links
  - Radar systems
  - TV antenna amplifiers or transmitters
  - Telemetry Systems (data or video)
- Intentional Interference
  - Spoofing
  - Jamming

Controlled Reception Pattern Antennas (CRPA)

- Controlled Reception Pattern Antennas Mitigate In-Band and Out-Band Interference
- Create nulls in the antenna gain pattern in the direction of jammers
- Providing significant anti-jam protection even in dynamic multi-jammer scenarios



Picture Courtesy of Harris

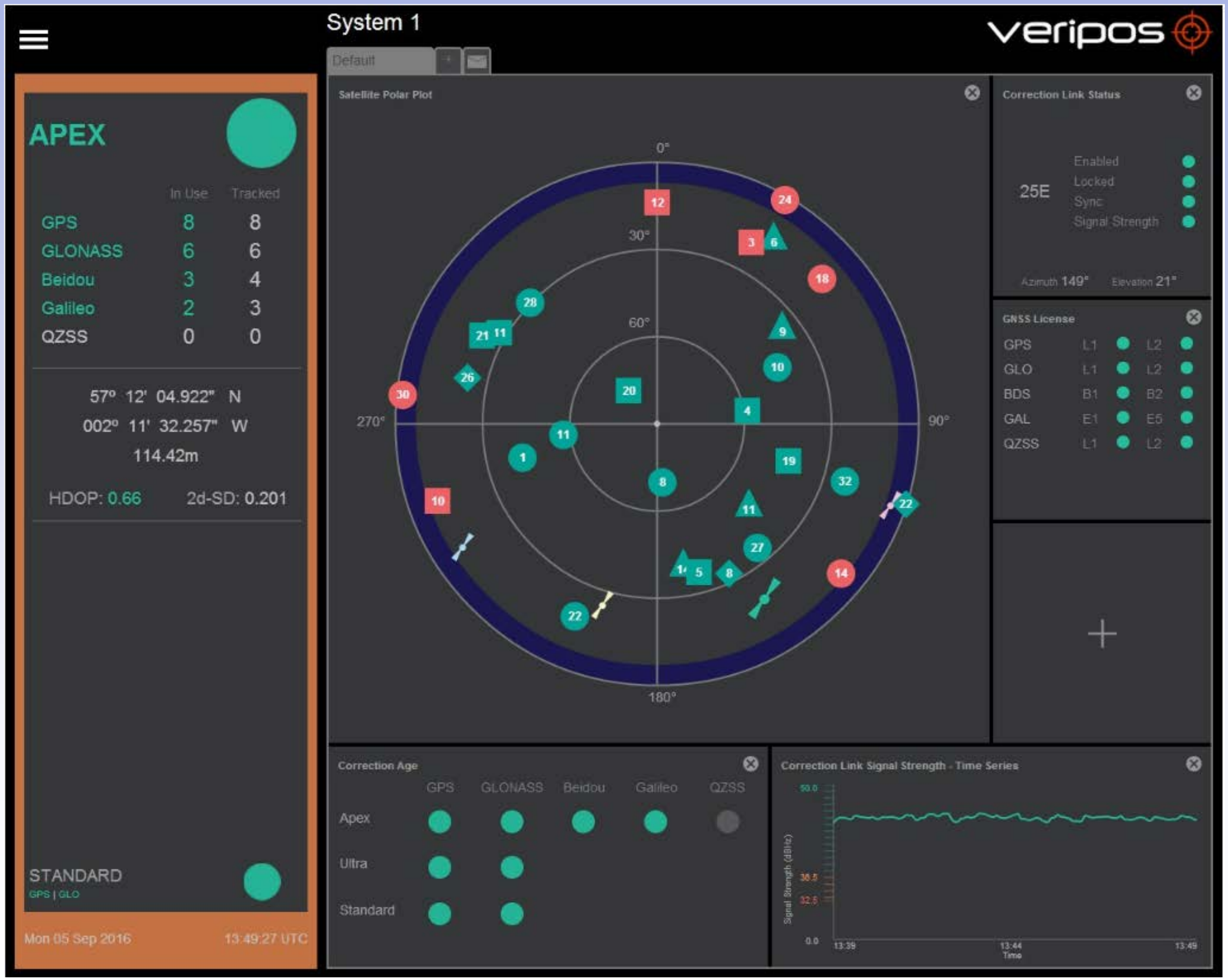
Harris N79-3

Veripos GAJT

Picture Courtesy of Cobham Antenna Systems

Cobham 20-7009

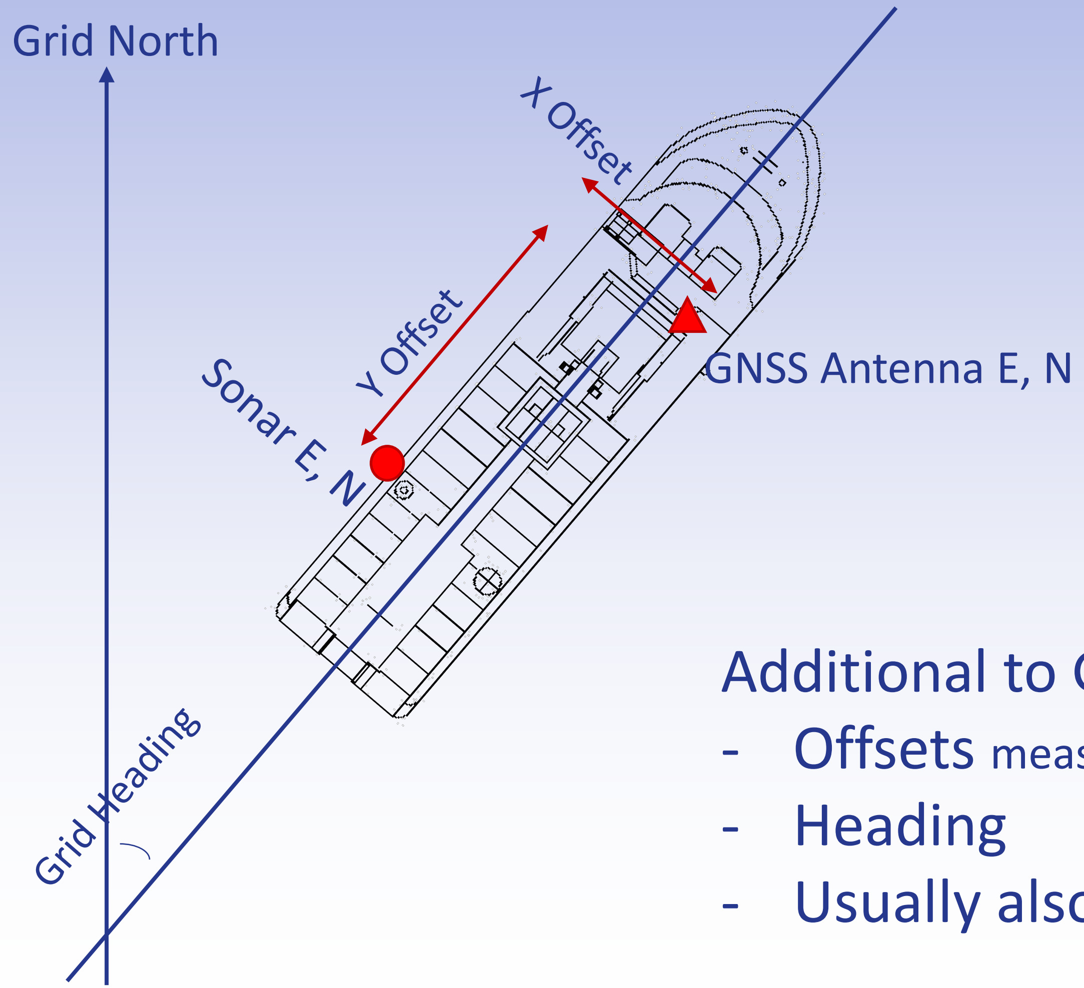
QC Software

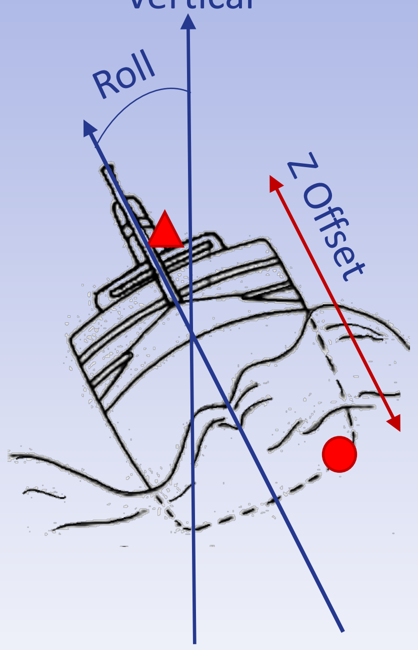

System 1
veripos
Default
APEX
In Use
Tracked
GPS 8 8
GLONASS 6 6
Beidou 3 4
Galileo 2 3
QZSS 0 0
57º 12' 04.922" N
002º 11' 32.257" W
114.42m
HDOP: 0.66
2d-SD: 0.201
STANDARD
GPS | GLO
Mon 05 Sep 2016
13:49:27 UTC
Satellite Polar Plot
0°
30°
60°
90°
180°
270°
Correction Link Status
25E
Enabled
Locked
Sync
Signal Strength
Azimuth 149°
Elevation 21°
GNSS License
GPS L1 L2
GLO L1 L2
BDS B1 B2
GAL E1 E5
QZSS L1 L2
Correction Age
GPS GLONASS Beidou Galileo QZSS
Apex
Ultra
Standard
Correction Link Signal Strength - Time Series
13:39
13:44
13:49
Time

Coordinate Systems and Transformations

- GNSS Coordinate Systems
  - GNSS receivers calculate standalone positions using WGS84 Datum
  - Commercial Augmentation Services generally utilize ITRFyy
  - RTK corrections vary dependent on the Base Station configuration
- Users Coordinate Systems
  - Vary depending on end client and location, E.G. ED50, NAD83
- Utilising wrong coordinate systems can lead to errors in positioning of hundreds of meters.

GNSS alone is not enough





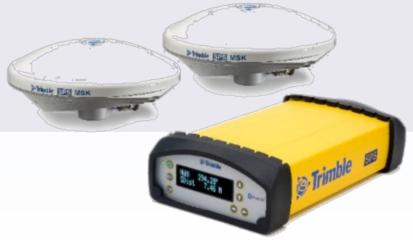
Additional to GNSS you need:

- Offsets measured by tape measure or total station
- Heading
- Usually also Pitch, Roll and Heave

Heading Sensors

	Technology	Accuracy 2σ	Examples	Remarks
Spinning Mass Gyro	Gimballed spinning gyroscope	0.2° static * 0.4° dynamic	TSS Meridian Surveyor	
Fibre Optic Gyro	Laser interferometer measuring Sagnac effect in a fibre coil	0.2° *	IXSEA Octans, CDL TOGS	Also does Pitch, Roll, Heave
Ring Laser Gyro	Laser resonance in a clockwise and anticlockwise beam	0.3°-0.1° *	CDL Mini RLG, Sonardyne Lodestar, Kearfott T16, T24	Also does Pitch, Roll, Heave
Hemispherical Resonator	Flexural resonance of dome moves with rotation	0.2° *	Sagem BlueNaute	Also does Pitch, Roll, Heave
GNSS Vector Heading	Relative GNSS positioning	0.6° **	Hemisphere V series	
GNSS RTK heading	Carrier Phase count between base and rover	0.1° **	Trimble SPS361, Fugro, Cnav, Veripos	





* Depends on latitude ** Depends on baseline length

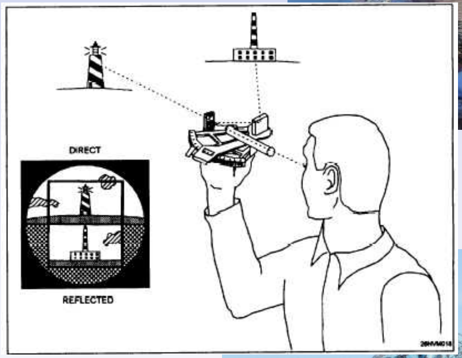
Heading Sensors Practical Considerations

Aligning the gyro with the local Y-axis

(usually the vessel longitudinal axis)

Alongside

- Dual antenna GNSS RTK heading
- Land surveying vessel bow and stern
- Tape measurement to known quayside heading



Offshore

- Dual antenna GNSS RTK heading
- Sextant measurement to known points e.g. platforms
- Sunshot

Motion Sensors
(Pitch, Roll, Heave)

“AHRS” Attitude & Heading Reference System
(~0.02° / 5 cm 2σ)


Ixblue Octans


Sonardyne Lodestar

MEMS Pitch, Roll, Heave Sensors
(~0.1° / 10 cm 2σ)


TSS DMS-05


Kongsberg MRU-5


SBG Ekinox

Combined GNSS and IMU Systems


Applanix POS-MV


Coda Octopus F180

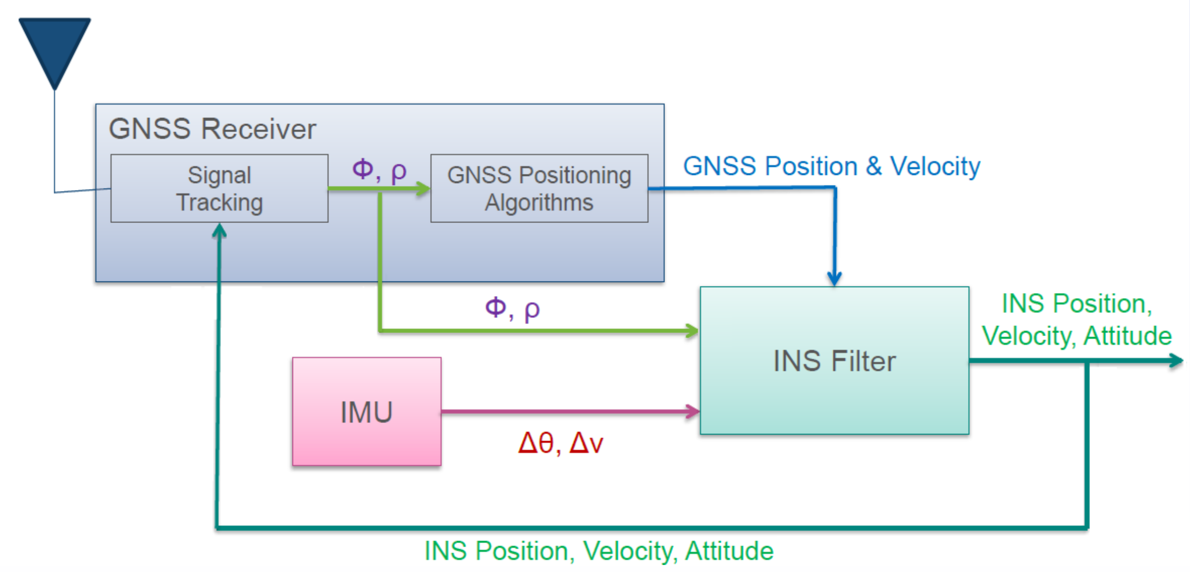
GNSS / IMU Integration

- Bridges outages in GNSS availability
- Intelligently removes GNSS Position Jumps
- Faster Output Rates
- Constrains drift with only 2 satellites
- Intelligent measurement selection
- Faster re-acquisition of satellites and convergence

Loose - Position (first three bullets)

Tight - Measurement (first five bullets)

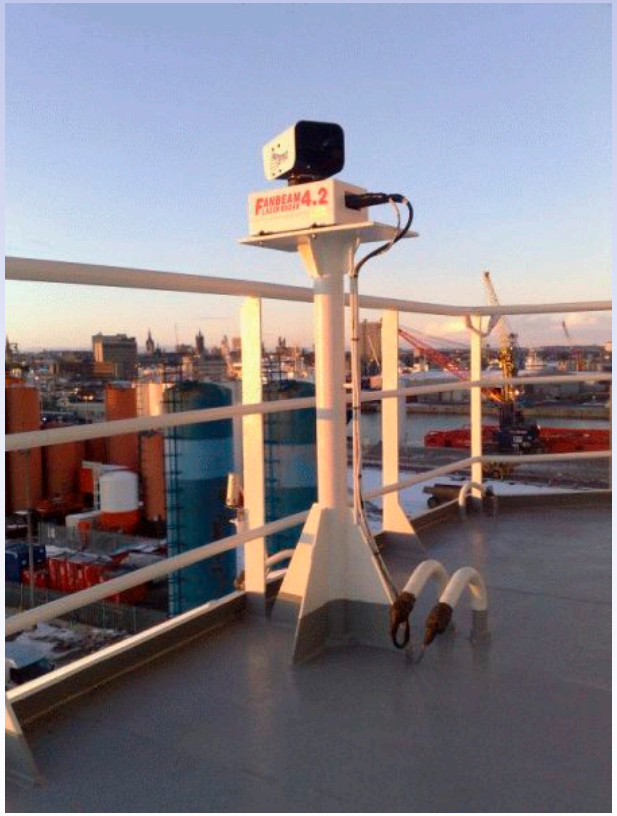
Deep - Tracking Loop Parameters (all six bullets)



Relative Positioning

Applications:
- Rig Positioning alongside a Platform
- Platform Installation
- Seismic Streamer Tailbuoy Positioning
- Dynamic Positioned vessel close to platform

Methods:
- Total Station
- Relative GNSS
- Fanbeam, Radascan



Putting It All Together: Nav Software

GNSS (PPP)

Heading

Pitch/Roll/Heave

- Geodetic Parameters
- X,Y, Z Offsets
- Calibrations (C-O)
- Vessel Graphics
- Background Files
- Planning Lines/Points

Multi Purpose Nav Software:

- EIVA NaviPac
- QPS Qinsy
- Fugro Starfix
- Others: Hypack, NavView, legacy software Winfrog, Hydropro, 4DNav etc

Putting It All Together: Error Budget

Example at 60° Latitude	Standard Deviation (deg)	Offset (m)	Standard Deviation (m)	Variance (m^2)
GPS position			0.05	0.003
Offset measurements			0.10	0.010
TSS Gyro Dynamic error	0.40*	50	0.35	0.123
TSS Gyro Settling error	0.20*	50	0.17	0.029
Gyro Cal error	0.20	50	0.17	0.029
Total	σ	(68% conf)	0.44	0.194
	2σ	(95% conf)	**0.88**	

* RMS error secant latitude so divided by cos(60)

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And Other Sensors…

Q&A