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DYNAMIC POSITIONING CONFERENCE
October 9-10, 2012

SENSORS SESSION II

Acoustically Aided Inertial Navigation – Proven, Robust and Efficient Positioning Systems

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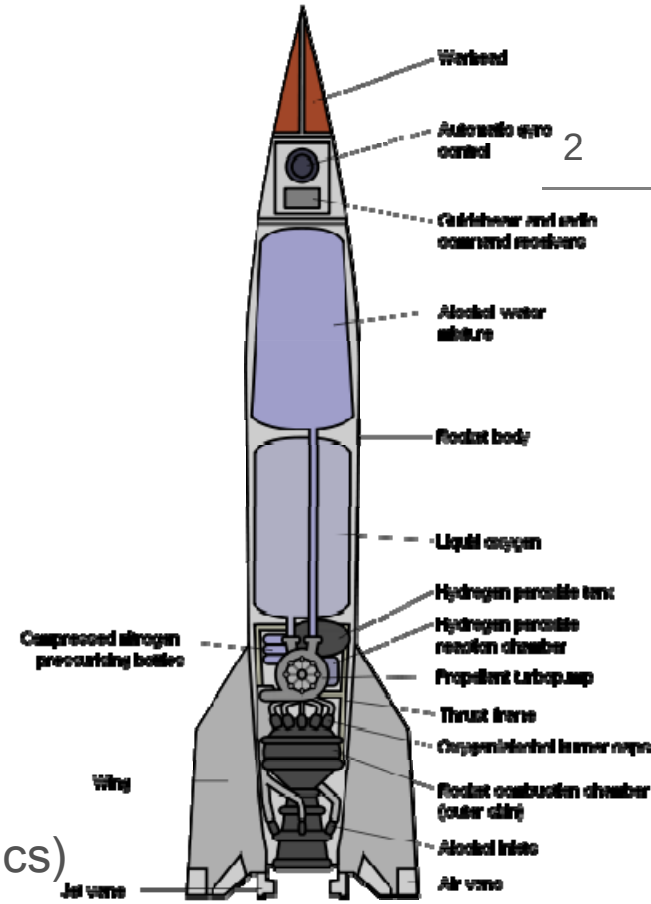
Acoustically Aided Inertial Navigation - Proven, Robust, and Efficient, Positioning Solution

MTS DP Conference, 10th October 2012, Jim Titcomb

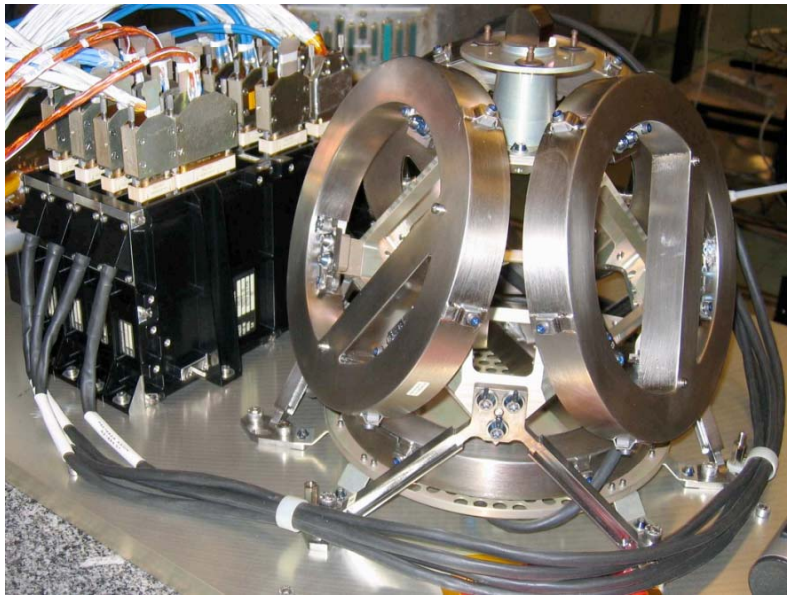
Inertial Navigation Track Record.

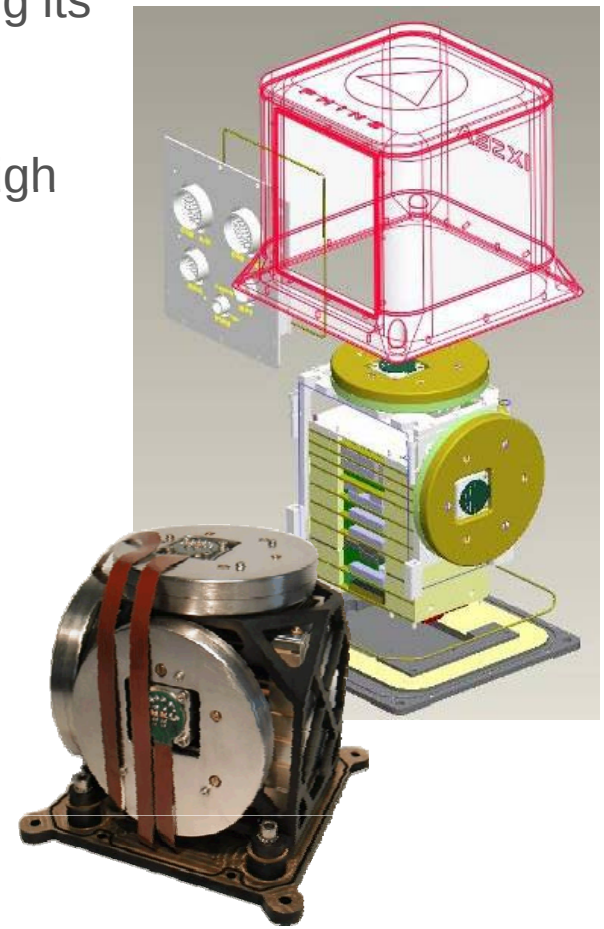
- 1944 German V2 hitting London and Antwerp
- 1950's Atlas ICBM
- 1958 USS Nautilus to North Pole
- 1961 Apollo program
- 1969 Commercial Navigation Boeing 747
- 1980's Practical ring laser gyro systems
- 1985 Development of FOG starts at iXBlue (then Photonetics)
- 2011 High performance Earth-observation Pléiades satellites
- 2011 iXBlue MARINS chosen for Royal Navy nuclear attack submarines.



INS Introduction

- What is an Inertial Navigation System (INS)?
  An instrument (electronic + sensors) which is using its initial state (position) and internal motion sensors (gyroscopes + accelerometers) to measure and calculate its subsequent positions in space with high accuracy, stability and update rate



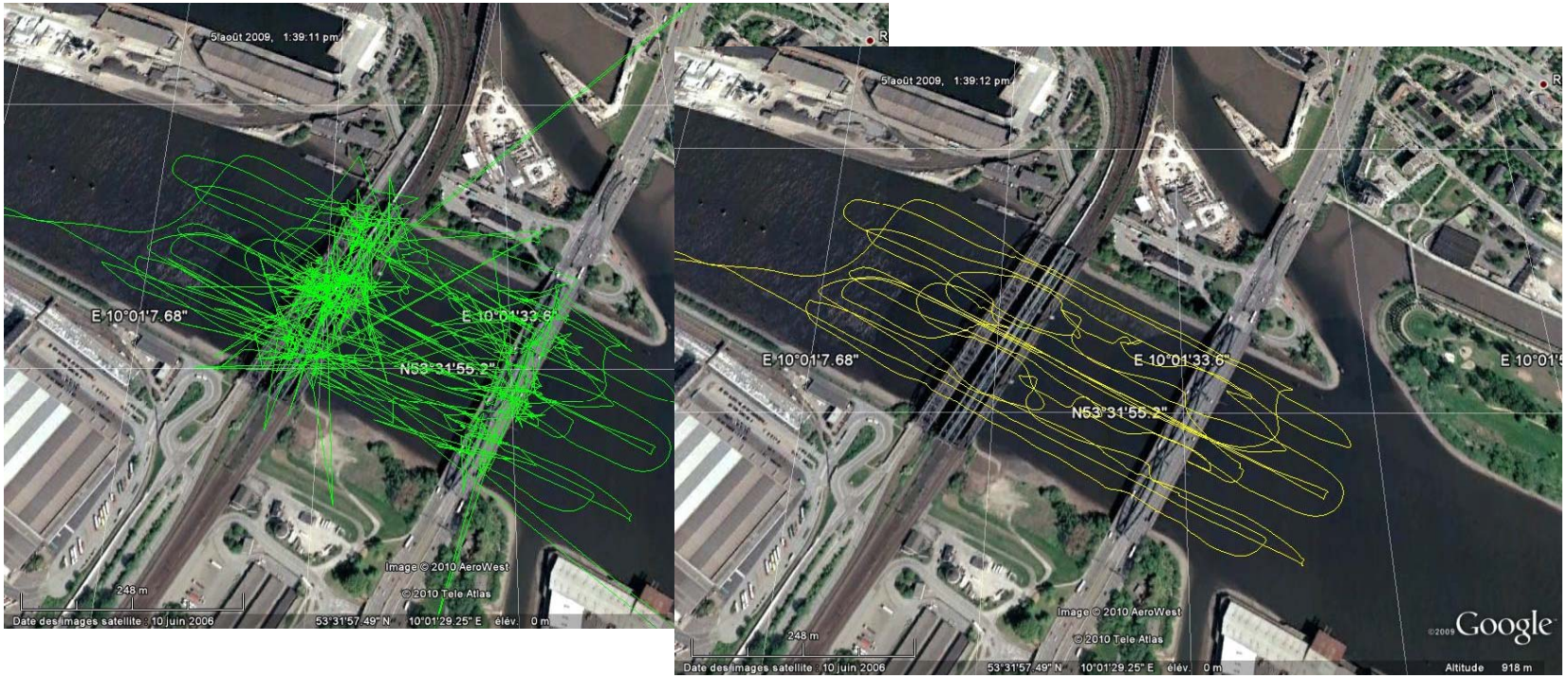


INS Introduction

- What makes an INS good.. or not?
  - Internal sensors (gyroscopes & accelerometers) are never perfect, bias and scale factors accumulate over time
  - Navigation is mostly about Gyroscopes
- Gross figures:
  - Accelerometers errors are not heavily involved in the position drift – 4m – Schuller period
  - Gyroscope are heavily involved in the drift – 400 m
- Drift is directly related to gyro performance.
  - INS drift Nmi/hr = 60 x Gyro Bias in deg/h
  - 0.01deg/h gyro = 0.6Nmi/h drift rate.

Dealing with Drift.

- GPS, DVL, LBL, USBL, EM Logs, etc. Are all routinely used for aiding an inertial navigation system.
- The classic example when discussing INS aiding is GPS

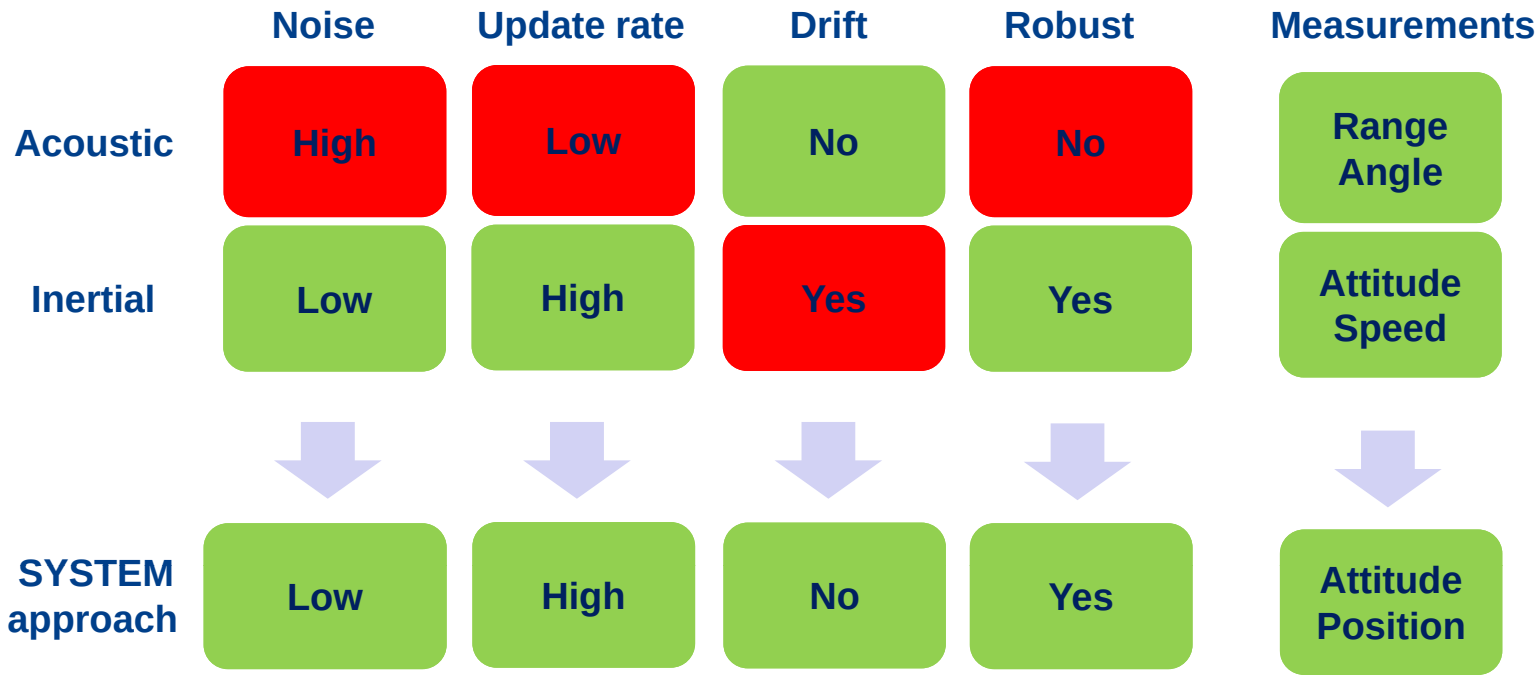


The Problem with GPS aiding

- GPS can be unreliable for significant periods of time.
  - Next to structures – multipath
  - Scintillation effects
  - System Failures
- GPS can drift before failure.
  - Scintillation can cause ranges to increase slowly leading to incorrect positioning prior to a total failure.
  - INS will tend to follow a drifting aiding sensor.

- Conclusion
  - INS aided GPS can only be good for a few moments of GPS outage.
  - INS aided GPS can be severely effected by scintillation.

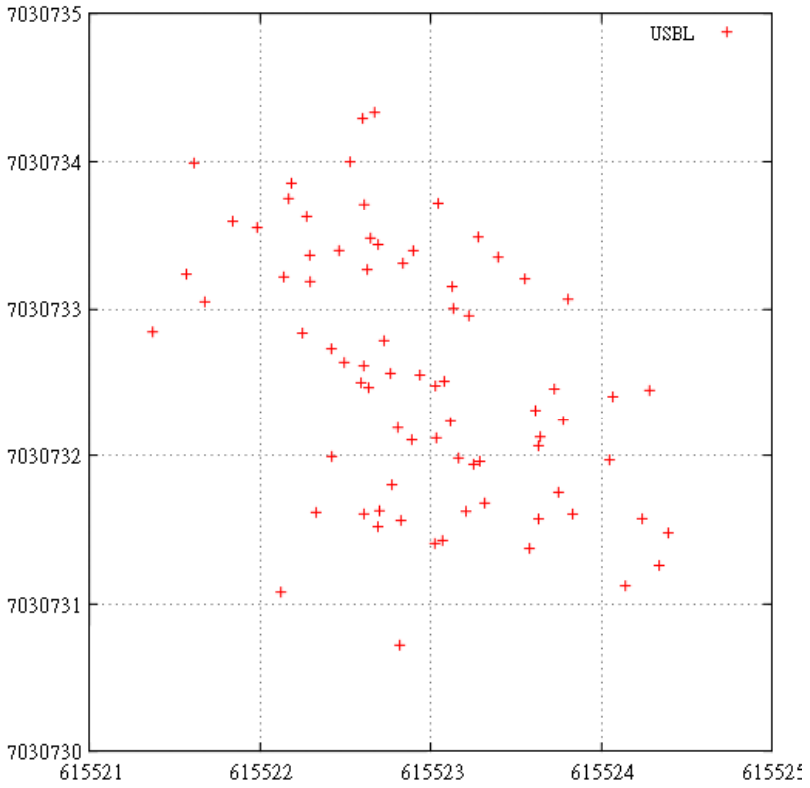
Acoustic Aiding

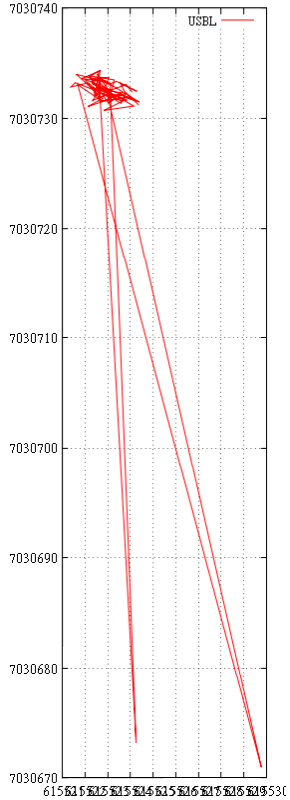


Acoustic Aiding Examples

- ROV on Seabed.
- 850m water depth
- Well calibrated USBL
- About as good as it gets with USBL

Standard Deviation	X	Y	Position
USBL	1.03	0.86	1.34





INS Aided with USBL

- Spikes in USBL rejected Automatically.
- Much higher update rate.
- Smoother positioning.
- Reduced spread of positions.

Standard Deviation	X	Y	
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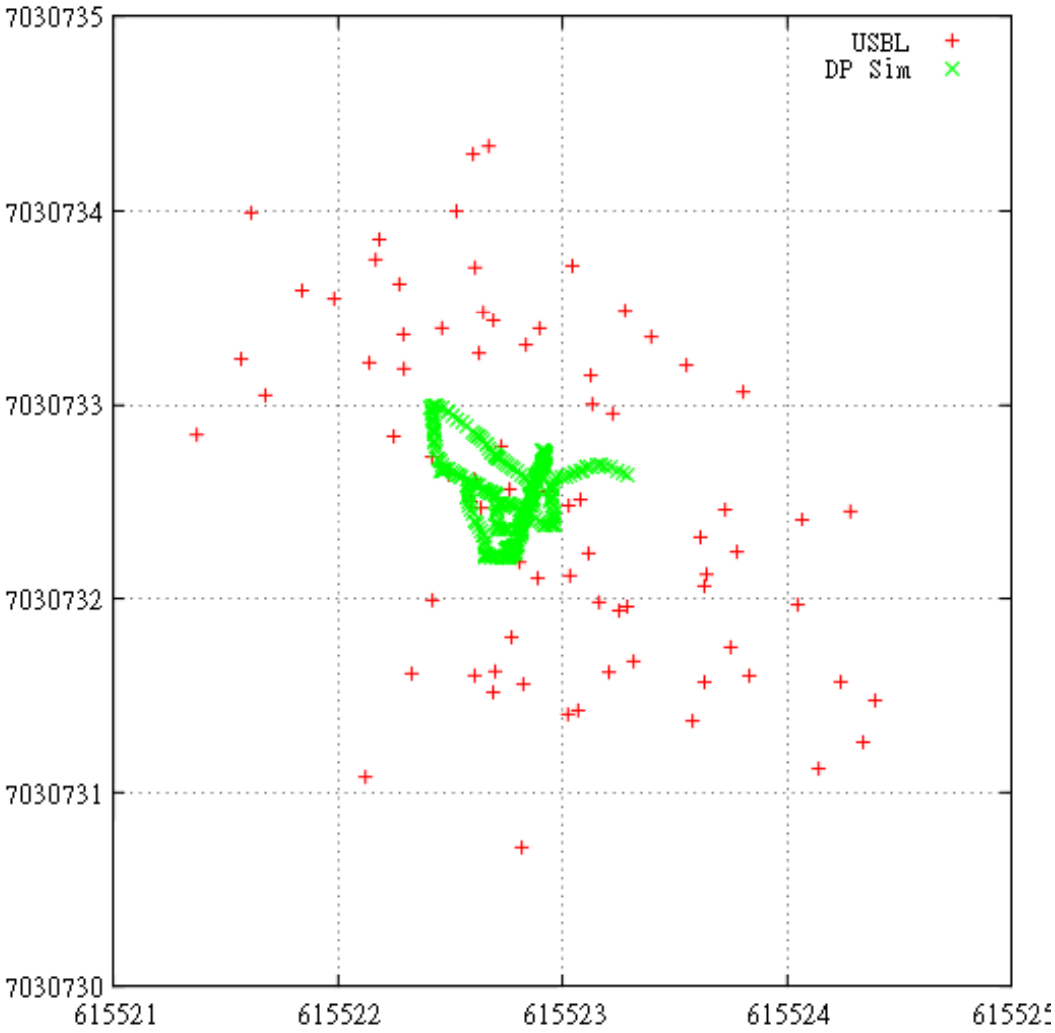
INS	0.16	0.2	0.26

- 5 X improvement with INS



INS aided Acoustics - Conclusions

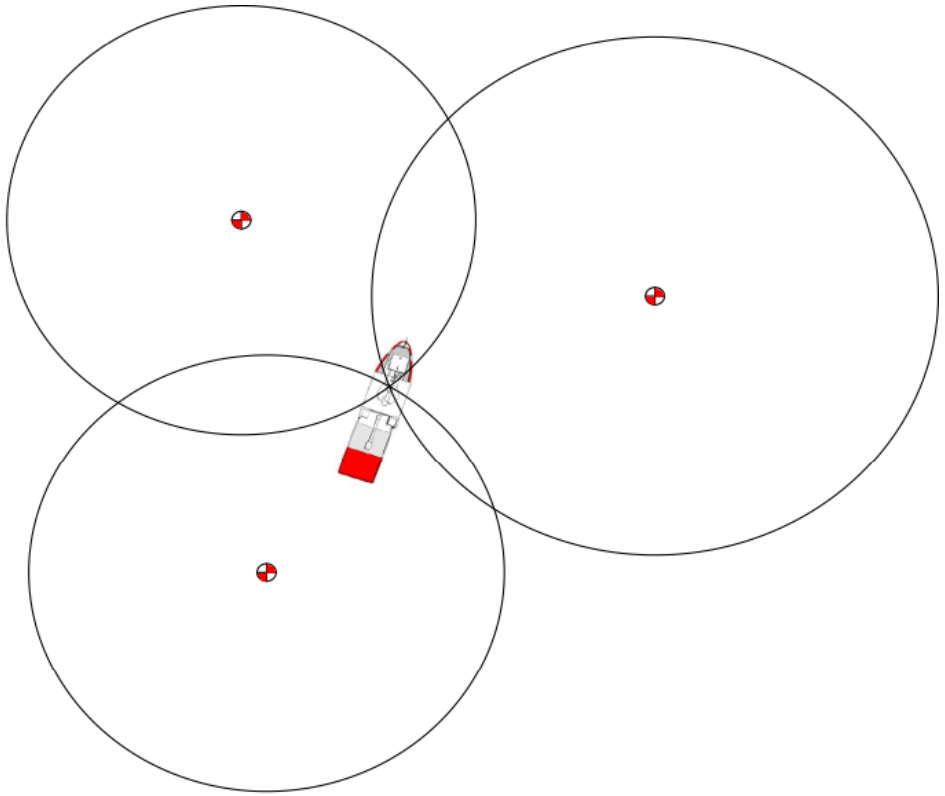
- INS improves acoustics
- Acoustics improve INS
- We still have a single point of failure
  - INS will drift quickly if the acoustics fail.
    - 3m in 2 min,
    - 20m in 5 min.
    - 0.6Nmi in an hour.

- INS can make acoustics almost as good as GPS.
- Adding INS alone does not increase redundancy.

- What else is available?

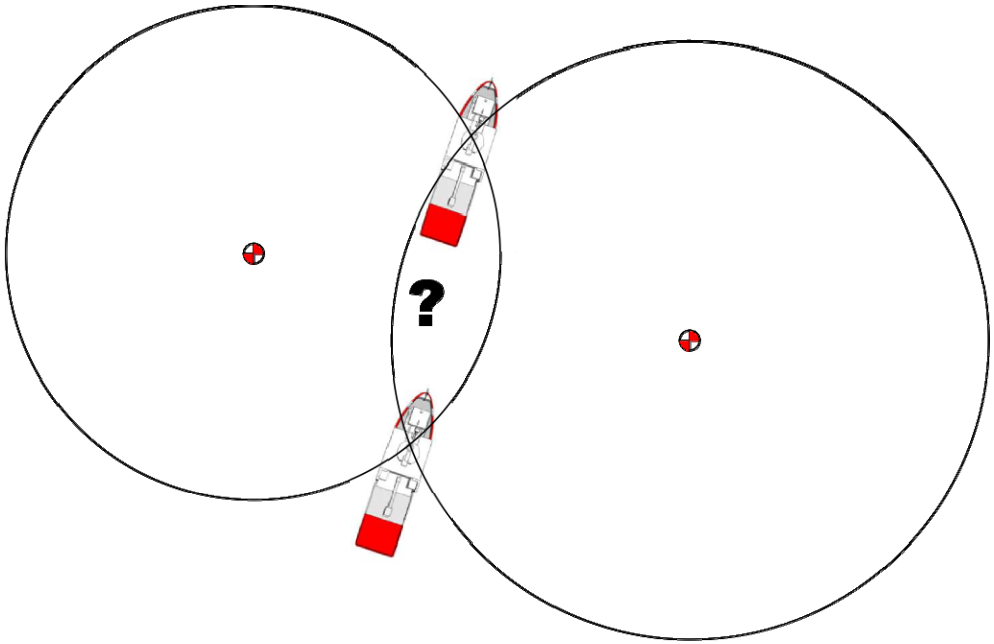
What about LBL?

- At Least three ranges are required for LBL positioning.



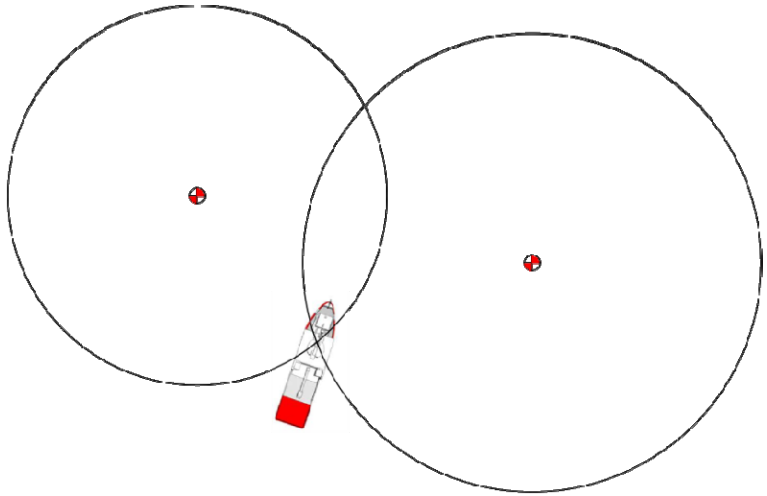
Pure LBL

- With only two ranges positioning is not possible
- There are two possible locations which match the received ranges.



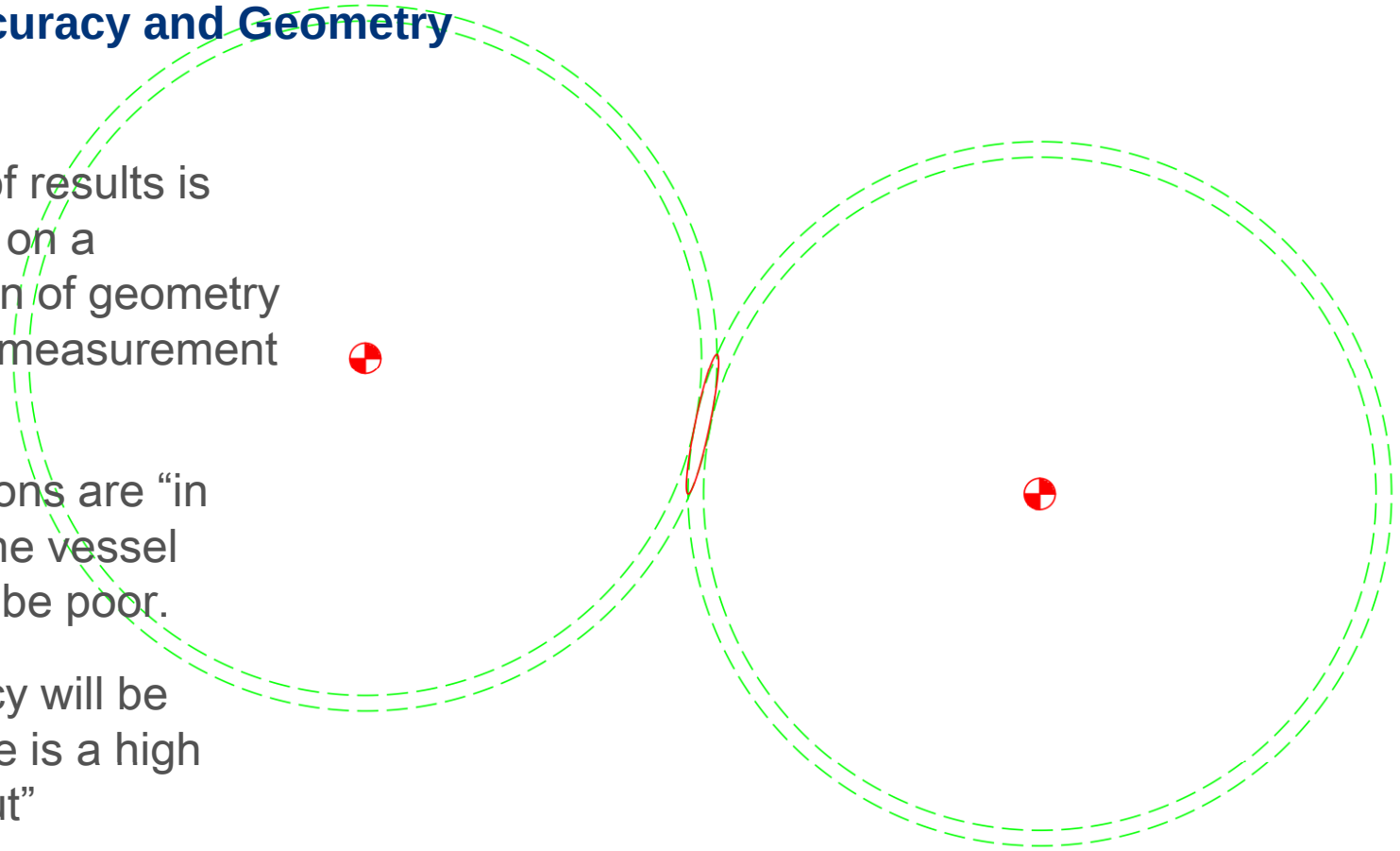
INS aided by LBL

- Station keeping with only two ranges is possible with INS and LBL combined.
- The system must be initialised to the correct position first.
- The two ranges will constrain the INS drift.
- Positioning accuracy is directly related to the range measurement accuracy.



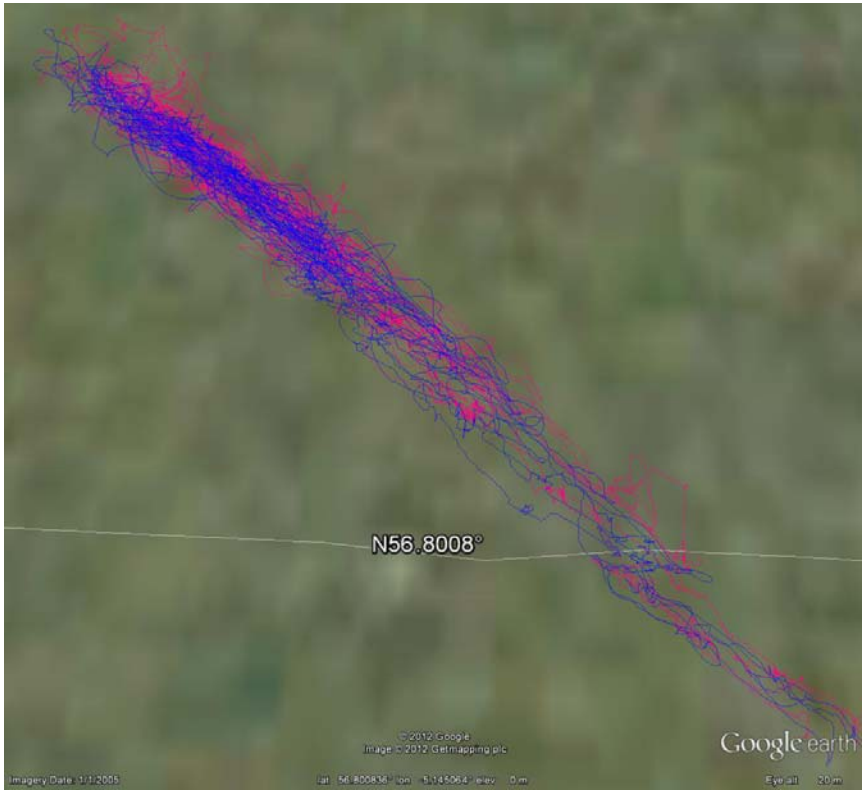
INS LBL Accuracy and Geometry

- Accuracy of results is dependant on a combination of geometry and range measurement accuracy
- If the beacons are “in line” with the vessel results will be poor.
- But accuracy will be good if there is a high “Angle of cut”



LBL Trials

- Barge Moored in Loch Linnhe
- Anchors fore and aft.
- Barge drifting across the loch with the tide



- Red Track is GPS
- Blue Track is PHINS aided with only two acoustic ranges.
- Note the spread of the INS LBL data is narrower than that of the GPS

INS Velocity Aiding

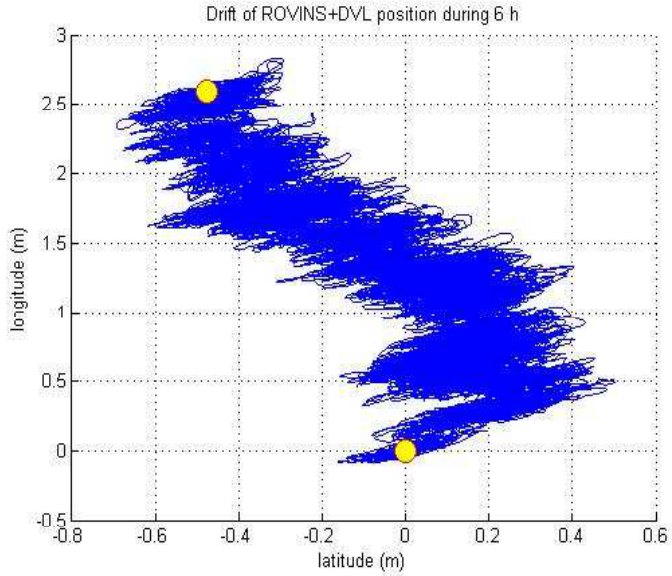
- INS measures rotation rate and acceleration.
- First integration produces heading and velocity
- Second integration produces position

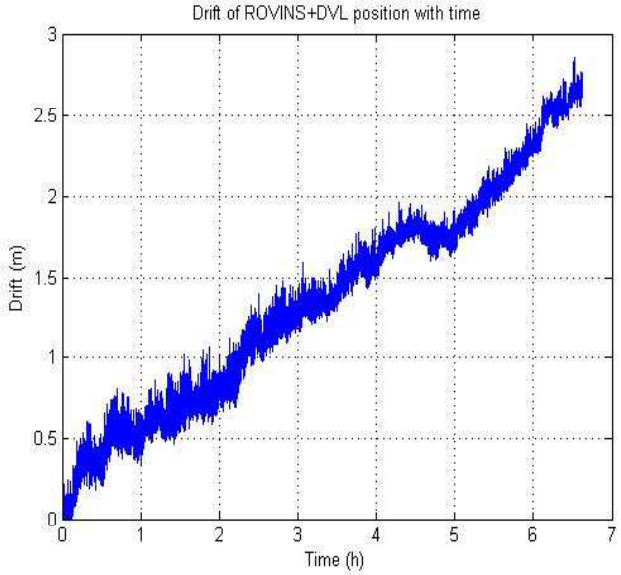
- USBL aids INS at the second integration level
- DVL aids INS at the First integration level.

- INS aiding data is used to estimate errors. The errors are fed back in to the calculation in order to correct at a low level.
- Aiding at the first integration level has more effect than aiding at the second integration level.

Effect of Velocity Aiding

- INS free inertial specification is based on time. The more time, the greater the drift.
- DVL aided INS specification is based on distance travelled. If you don't move the error can't grow (as much).

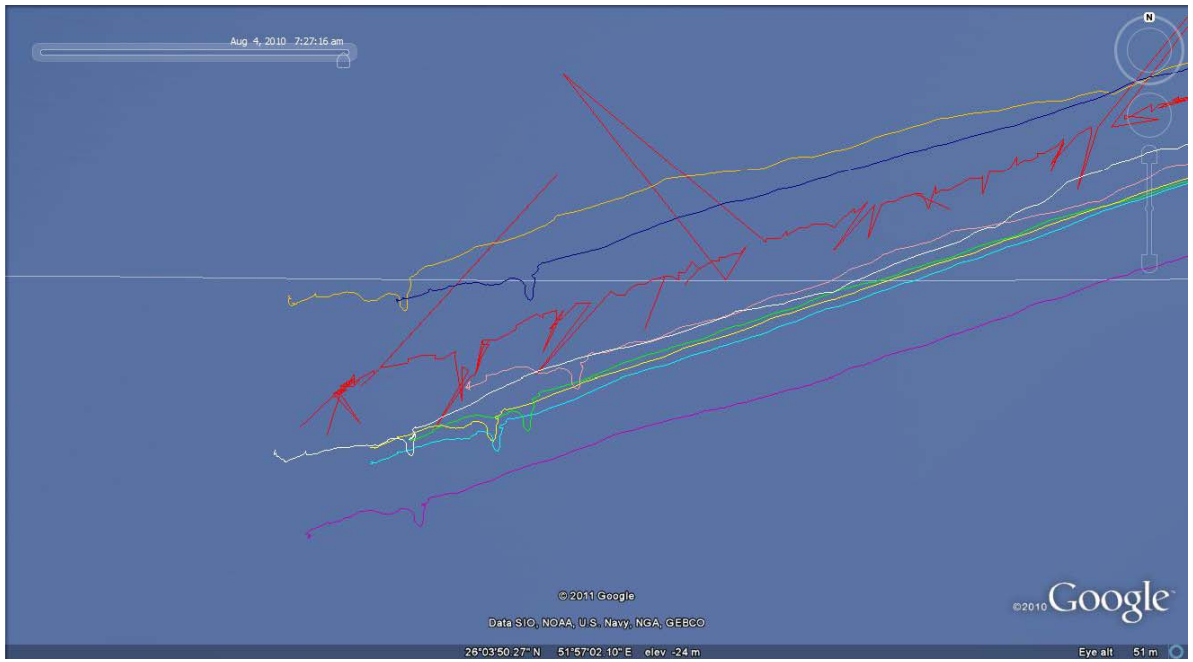




The problem with DVL

- Deep water.
  - DVL is only available in water depths up to around 1,000m.
  - In deeper water DVL update rate will be slow.
- Remember DVL aids INS at a more fundamental level than other sensors.
- The INS only needs a velocity aiding input infrequently in order to correctly estimate the error on the sensors.

DVL Update Rate	Error, % distance travelled.	Drift speed m/h
1S	0.03%	0.18
2S	0.13%	0.82
3S	0.26%	1.67
4S	0.27%	1.77
6S	0.32%	2.08
8s	0.30%	1.98



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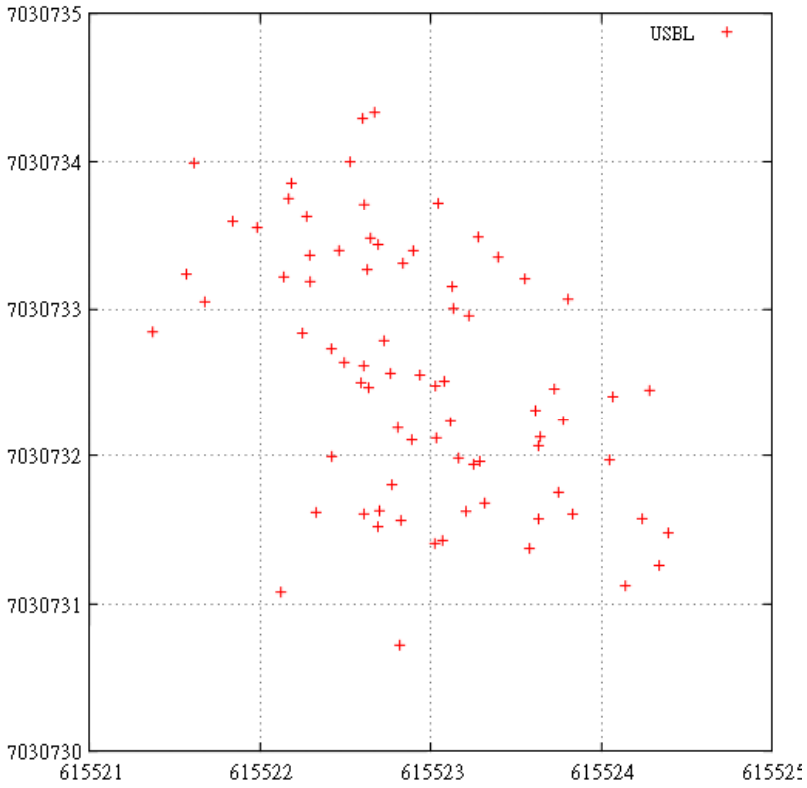

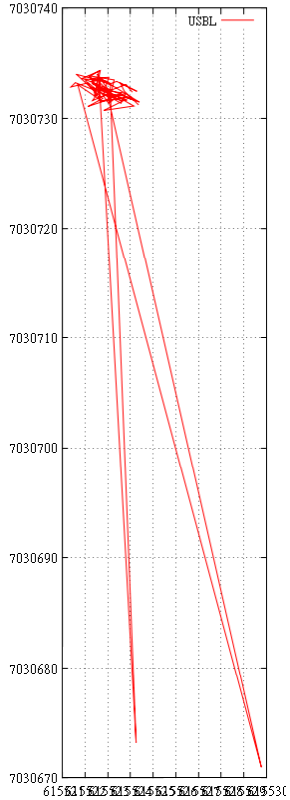

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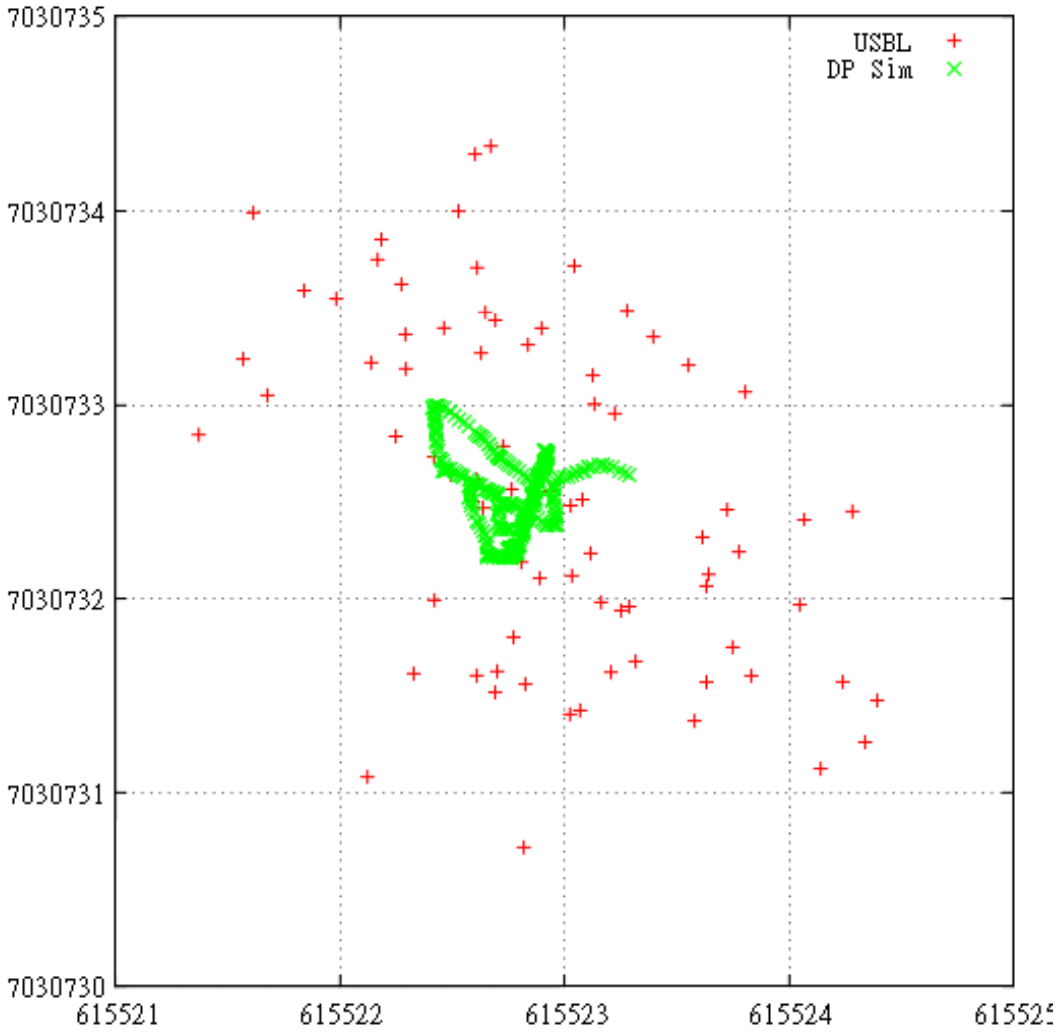
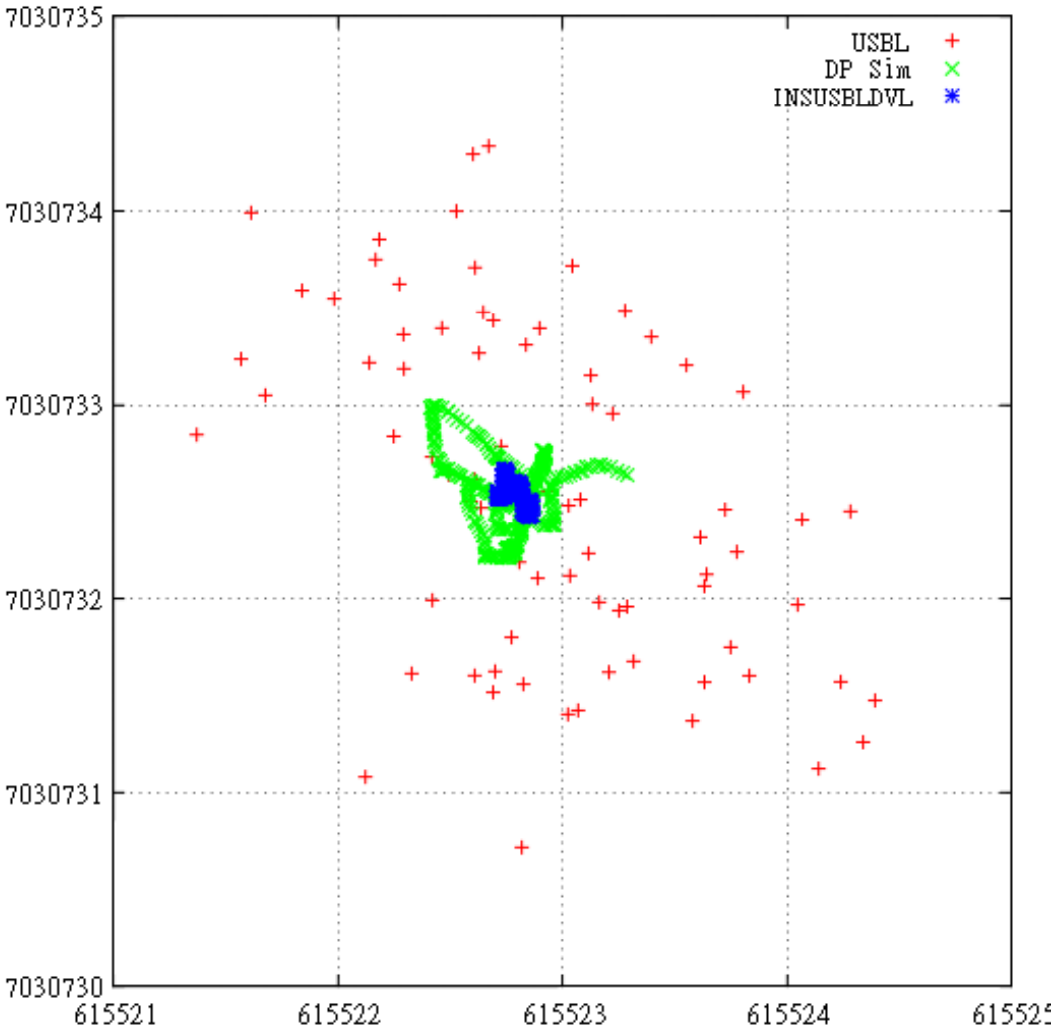


INS Aided with USBL & DVL

- DVL update only every 3 seconds
- Positioning now better than high accuracy GPS even in 850m

Standard Deviation	X	Y	
USBL	1.03	0.86	1.34
INS	0.16	0.2	0.26
With DVL	0.05	0.06	0.07

- 17 x Better than raw acoustics.



What if we lose acoustics?

- DVL update only every 3 seconds
- Positioning now better than high accuracy GPS even in 850m

Standard Deviation	X	Y	
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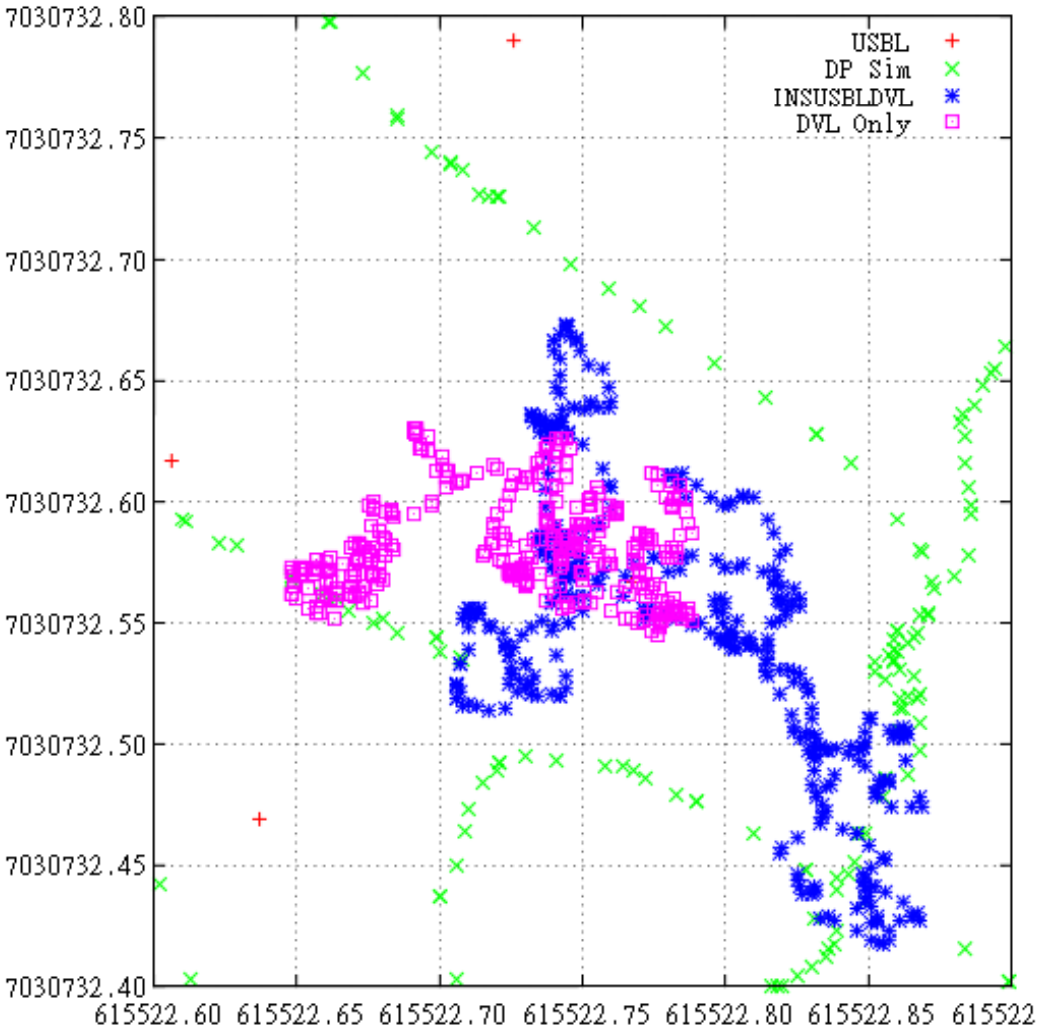
With DVL	0.05	0.06	0.07
INS DVL	0.04	0.02	0.05



Conclusions

- INS is a proven technology on Land, Under water, in Space, why not in DP?
- INS has a long track record, Modern FOG based systems bring extreme robustness and reliability.
- INS can produce heading and attitude data as well as positioning.
- INS Should not be aided just by GPS for DP applications.
- INS can make your acoustics as good as high accuracy GPS.
- The biggest benefits can be obtained by combining aiding sensors.
- With the addition of DVL, INS can now be considered a stand alone PME for a significant period of time.

Announcement

- IXBLUE is proud to announce DP-PHINS.
  - World class PHINS inertial navigation system.
  - DP specific interface unit.
  - Aiding from typical DP acoustics, GPS, DVL, and any other PMEs.
  - Outputs tailored for compatibility with typical DP systems.

- Now delivering to select customers.
- Ready to discuss your requirements.