Adapting Aerospace Technology to DP Vessels for Safe and Stable Station Keeping

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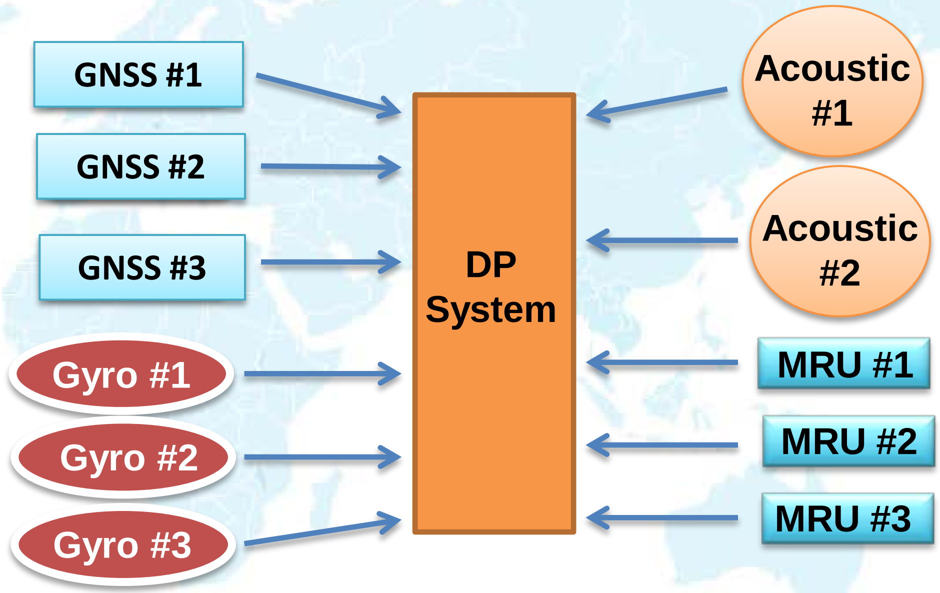
Introduction

- Commercial aviation has benefitted from the safety and reliability of modern navigation systems:
  - For example, Honeywell's commercial aviation INS (Inertial Navigation Solution) Laseref™ family has fielded over 75,000 units and accumulated over 2.5 billion successful operating hours
- The marine industry, like commercial aviation, has stringent reliability needs related to safety of life, in addition to environmental and profit motivations.
- The same system used for aircraft navigation is ideal for use in marine applications.
- This presentation will cover how commercial aviation navigation technologies can be best applied to the marine industry.

Typical Construction Vessel Position Reference Systems

- 3 GNSS Receivers
- 3 Gyros
- 3 MRU
- 2 Acoustic Systems
- All aid the DP System



DP Loss Of Position (LOP)

According to IMCA's DP incident database; the most common cause of "loss of position" is a short-term "Trigger Event", like GNSS error. This trigger event, coupled with a DPO's failure to recognize and mitigate the trigger event, results in LOP.

Potential Fixes

Training:

- Continues training on all the DP sensors with simulations of all combinations of system errors so DPO's can learn to pick the good from the bad sensors; so trigger events can be mitigated.

Technology:

- **Run the positioning sensors through INS's to prevent "Trigger Events" from being seen by the DP.**

Cost:

- Preventing the trigger events from going to DP will cost less than learning to mitigate them.
- For the cost of one disconnect, you could buy 20-Navigation grade INS.

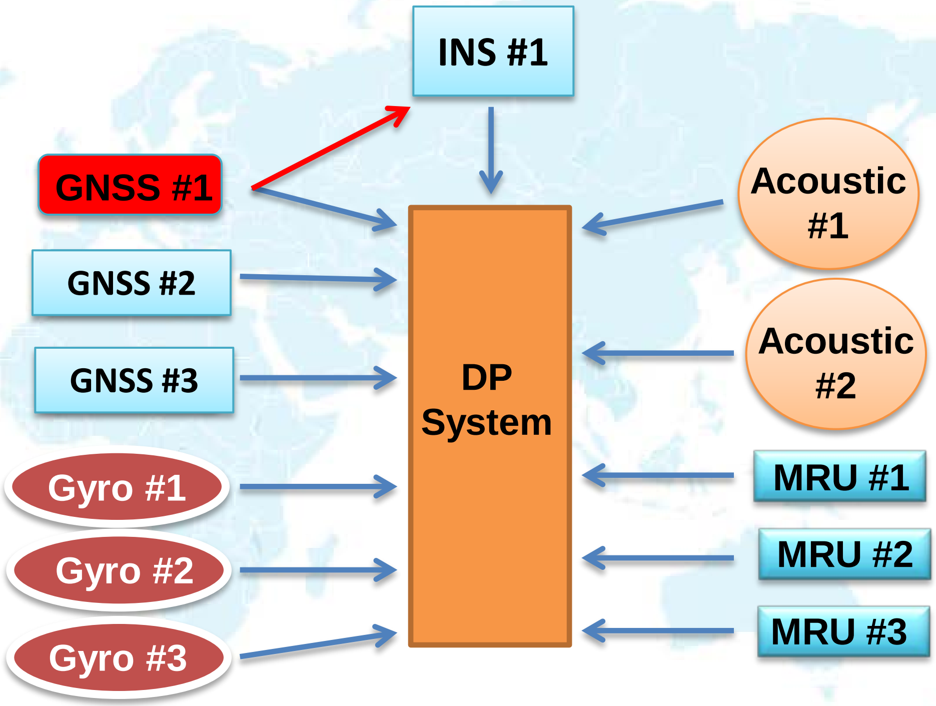
One INS Aided by One GNSS Receiver

Strengths:

- INS is a dissimilar position reference for the DP.
- INS protects against GNSS#1 position jumps.
- INS provides additional attitude/ **heading** to DP.
- 5-10 mins. coasting capabilities.

Weaknesses:

- Only one GNSS is monitored for Position jumps.
- Acoustic system can still have slow update intervals or jumps.
- Cost of INS.



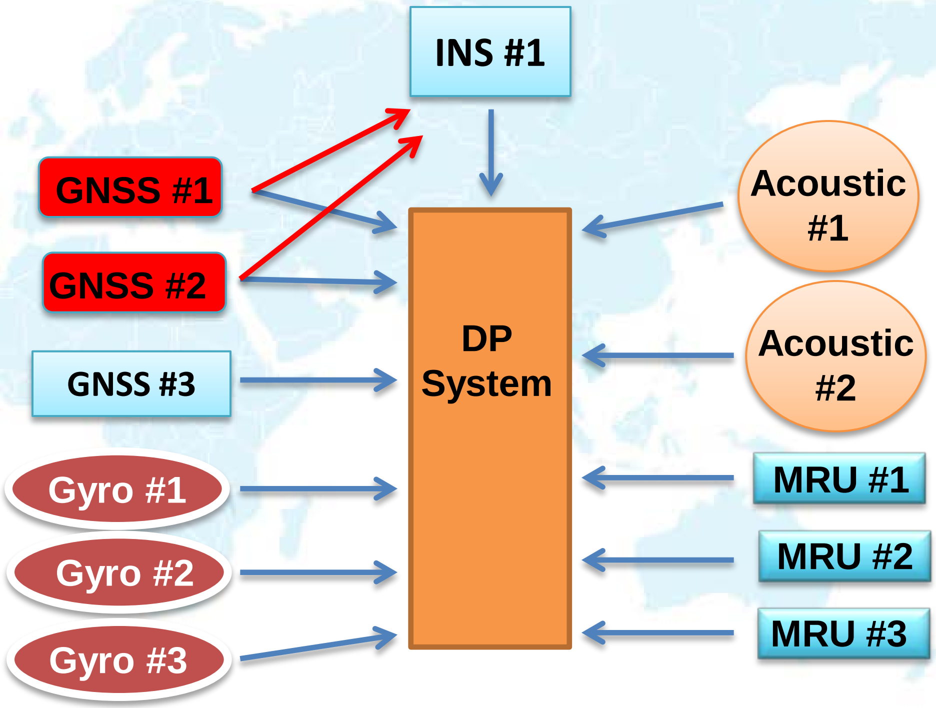
One INS Aided by Two GNSS Receivers

Additional Strengths:

- Stable position from INS even if GNSS 1 or 2 is lost.
- Seamlessly handle dual GNSS inputs (outages, errors, etc.).

Weaknesses:

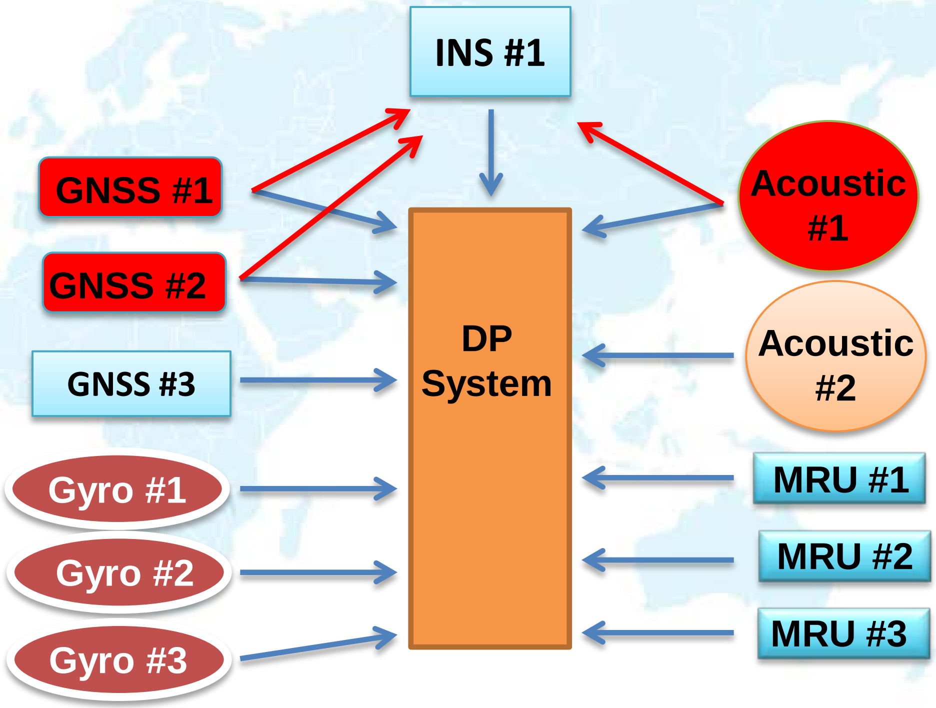
- Position jumps from GNSS#3 will impact DP.
- Position jumps/gaps from Acoustics can still impact DP.



One INS Aided by Two GNSS Receivers and One Acoustic System

Additional Strengths:

- Stable position from INS even if all GNSS are lost.
- INS will eliminate jumps/gaps in Acoustic #1 position.
- GNSS/INS can be used to calibrate beacon position.



Weaknesses:

- Position jumps from GNSS#3 will impact DP.
- Position jumps/gaps from Acoustic #2 can still impact DP.

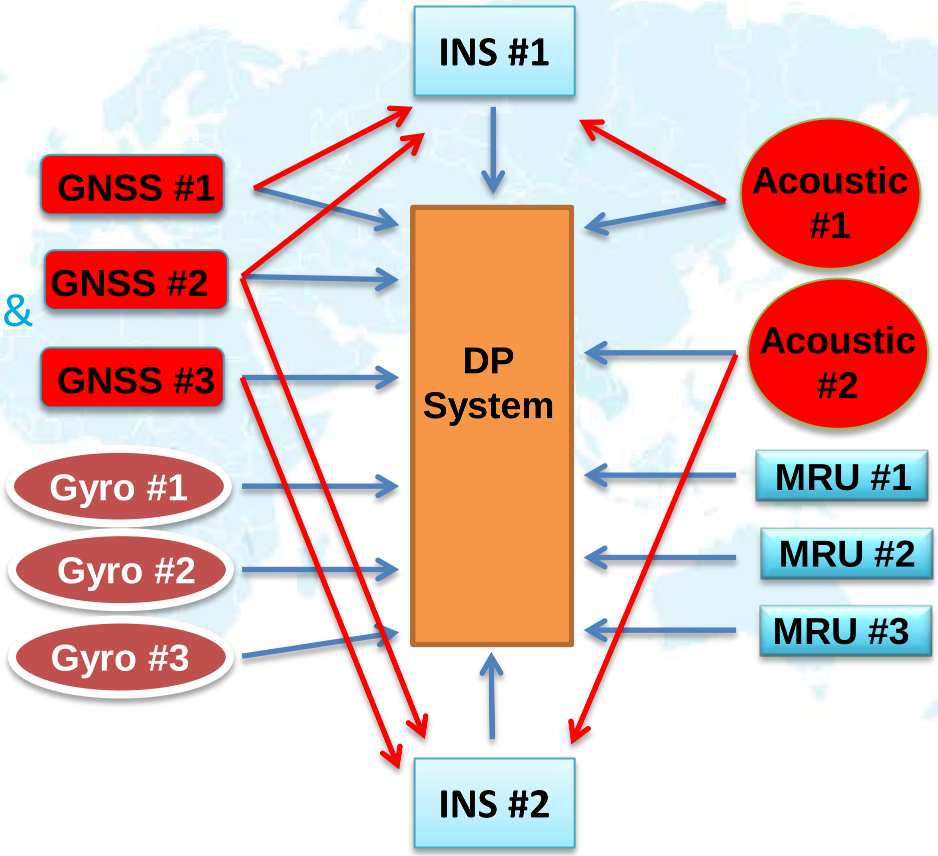
Two Triple Aided INSs

Strengths:

- Dual INS will minimize position loss to DP.
- All GNSS and Acoustics are monitored for jumps.
- 2 additional high accuracy Gyro's & MRU's available to DP.
- Improves Safety and reduce down time.
- Low cost protection against position loss.

Weakness:

- There is a cost.



How INS Differs from DP Blending of Reference Sensors

- In traditional DP, sensors blended to calculate a datum (e.g. COG) using inputs from reference sensors using a 3 step process:
  - Outliers eliminated by range gating process
  - Calibration process to eliminate errors in offset values
  - Correct positions weighted by inverse of their variance

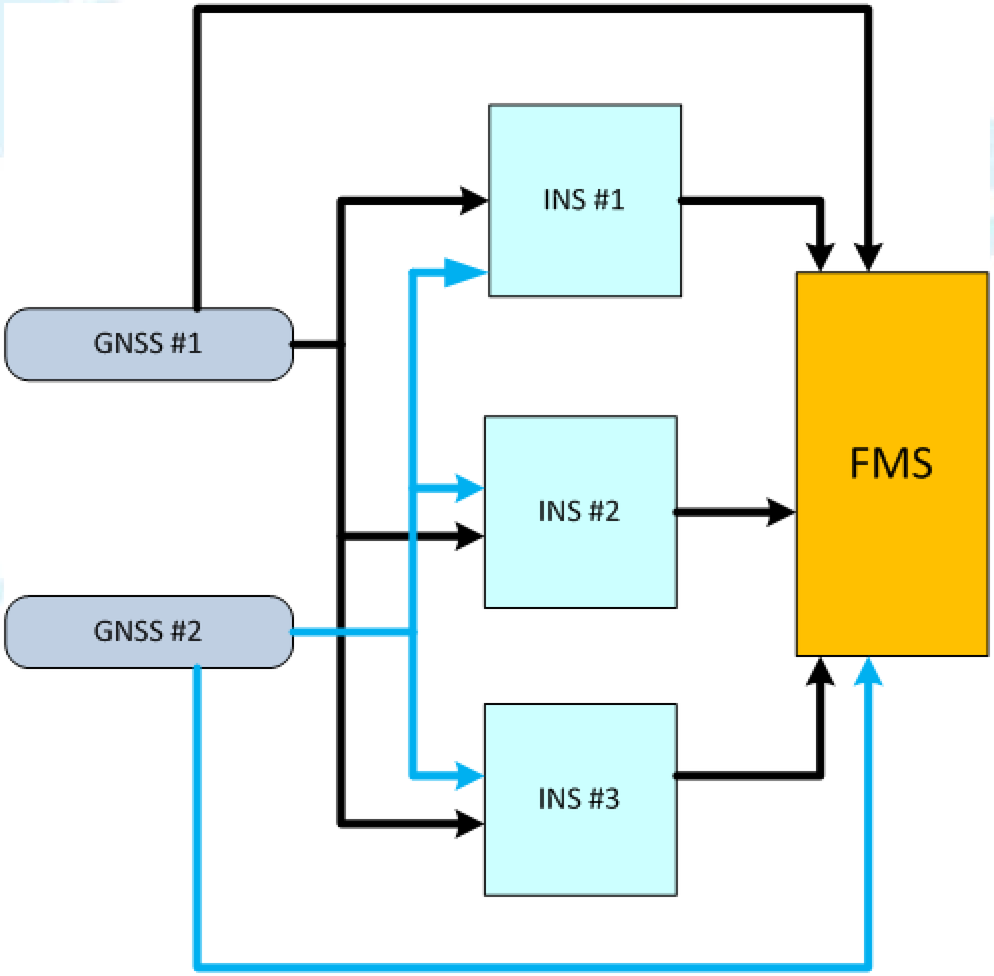
- Process has error sources which blending process tends to mask.

- INS does the above with significant advantages at each step:
  - Sensors measured together using 1PPS signal
  - Outliers eliminated on a by axis basis
  - Calibration performed to each sensor with user feedback
  - Aiding sensors are weighted by their expected or measured accuracies

Aircraft Configuration

- A typical aircraft architecture has 3 INS's.

- The integration of these sensors within an FMS provides a solution that maximizes the strengths of the inertial sensors and the GNSS receiver.

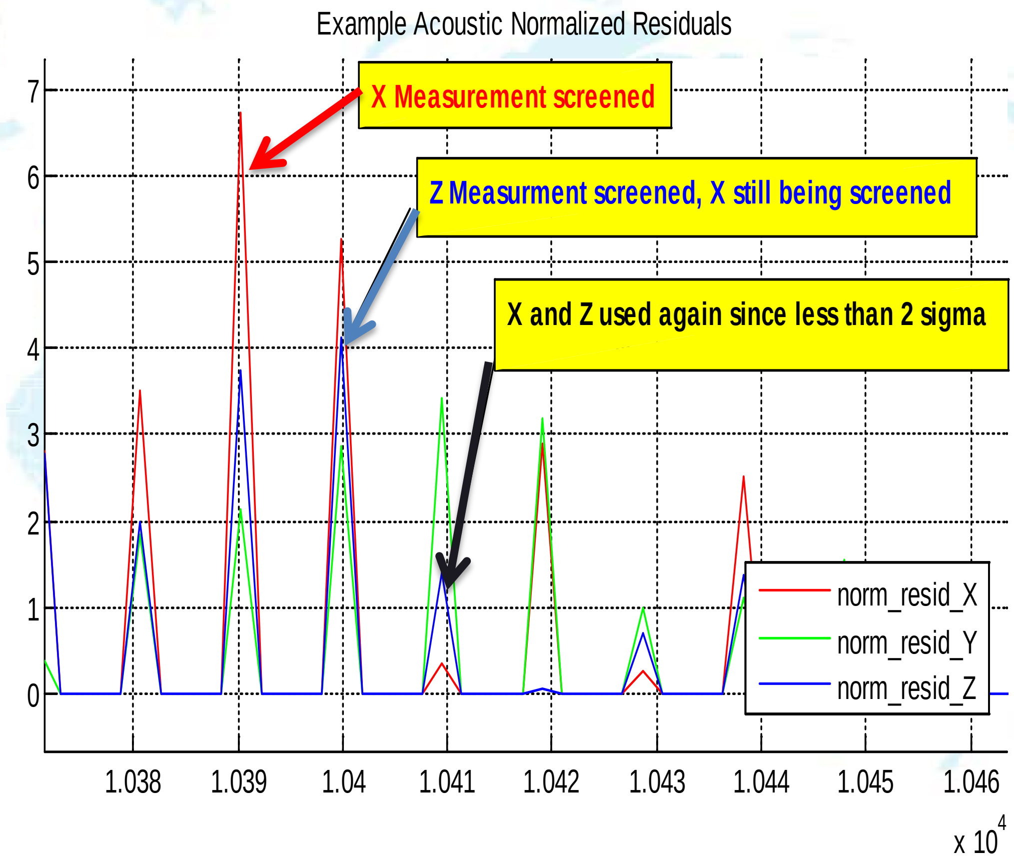


INS Screening Aiding Measurements

- Residual calculated for every measurement received.

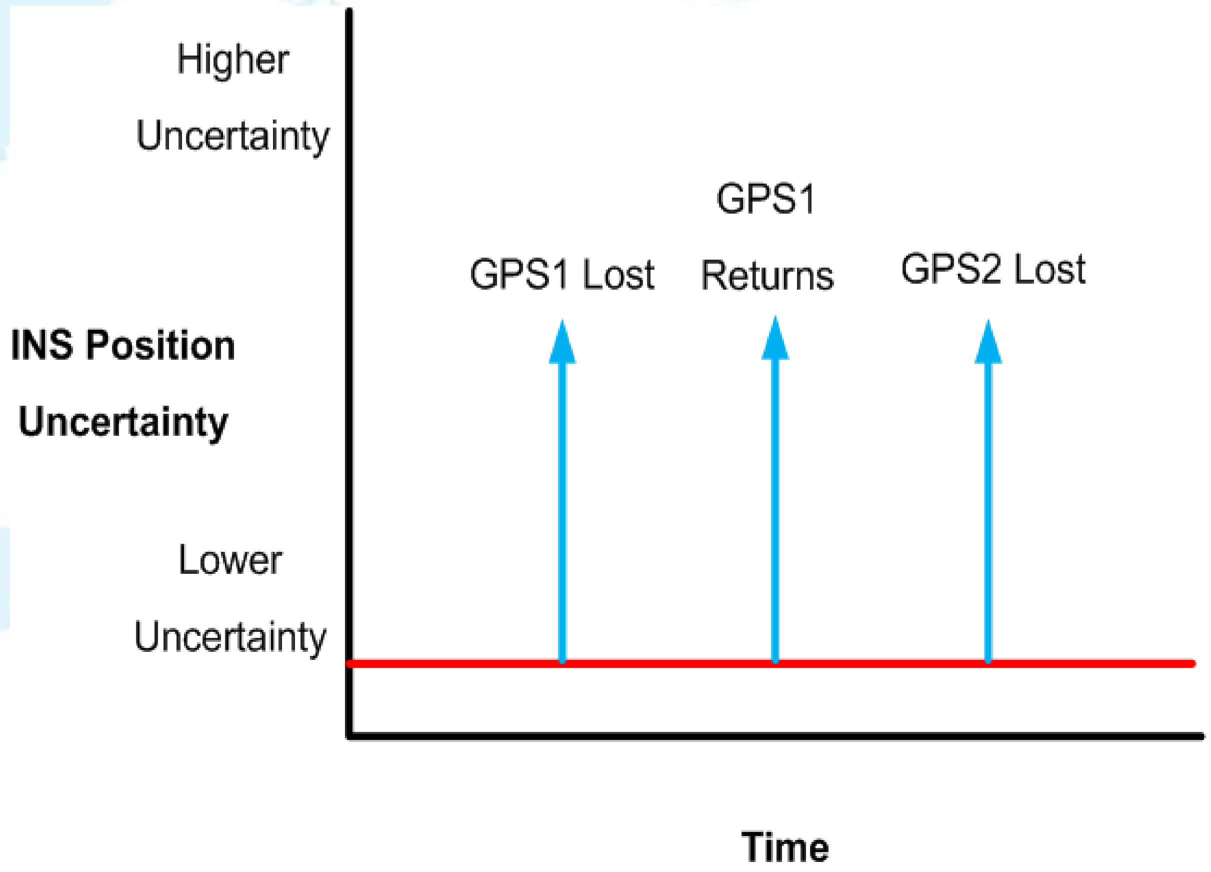
- If the residual is above the threshold (e.g., 4 sigma), the current measurement update for that component is skipped (i.e., screened).

- Once a measurement is screened, the future normalized residuals must fall below a lower sigma multiple (e.g., 2 sigma) before it is used again.



Dual GNSS Configuration

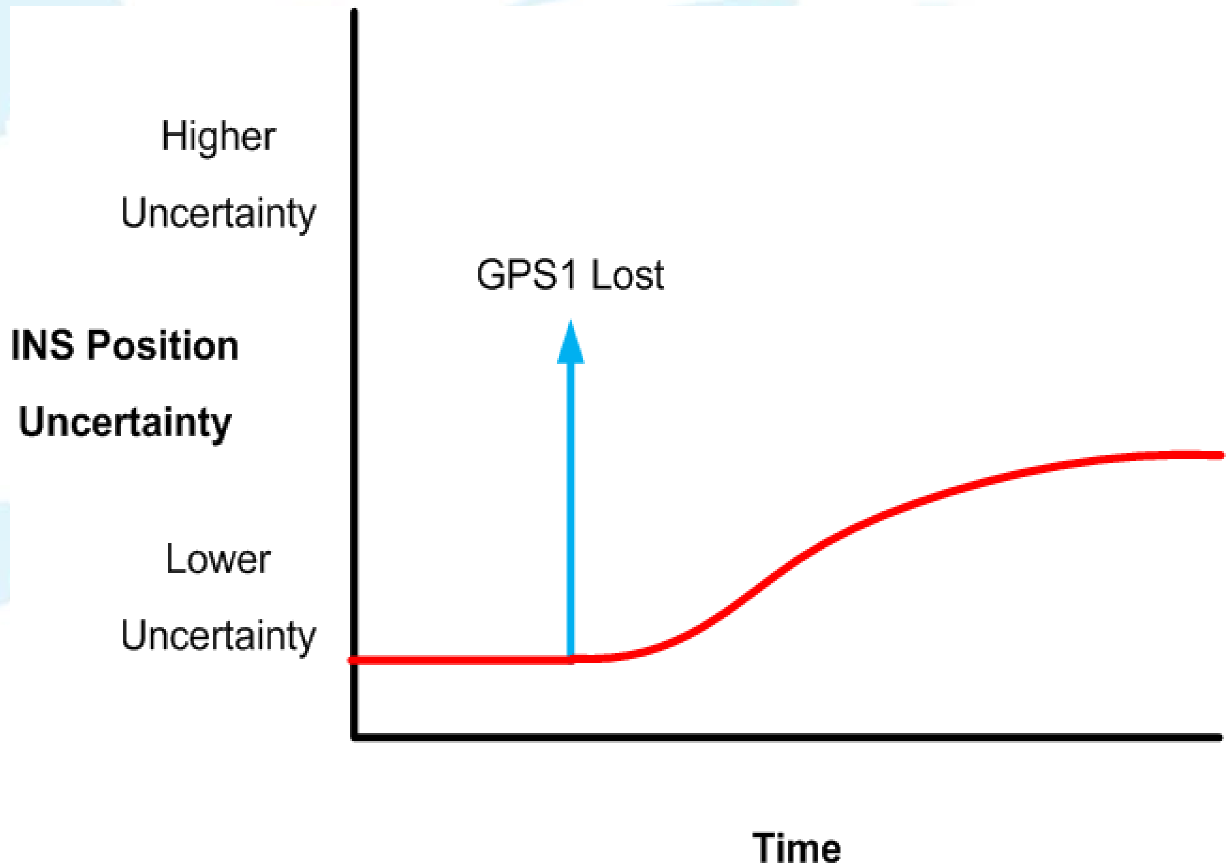
- The red line is the INS position uncertainty and it isn't noticeably impacted under this scenario.
- The GNSS dropouts could also overlap and the INS would be able to keep a stable and usable position for a period of time.
- To allow proper safety decisions to be made, the INS is always outputting the INS position uncertainty to the DP system.



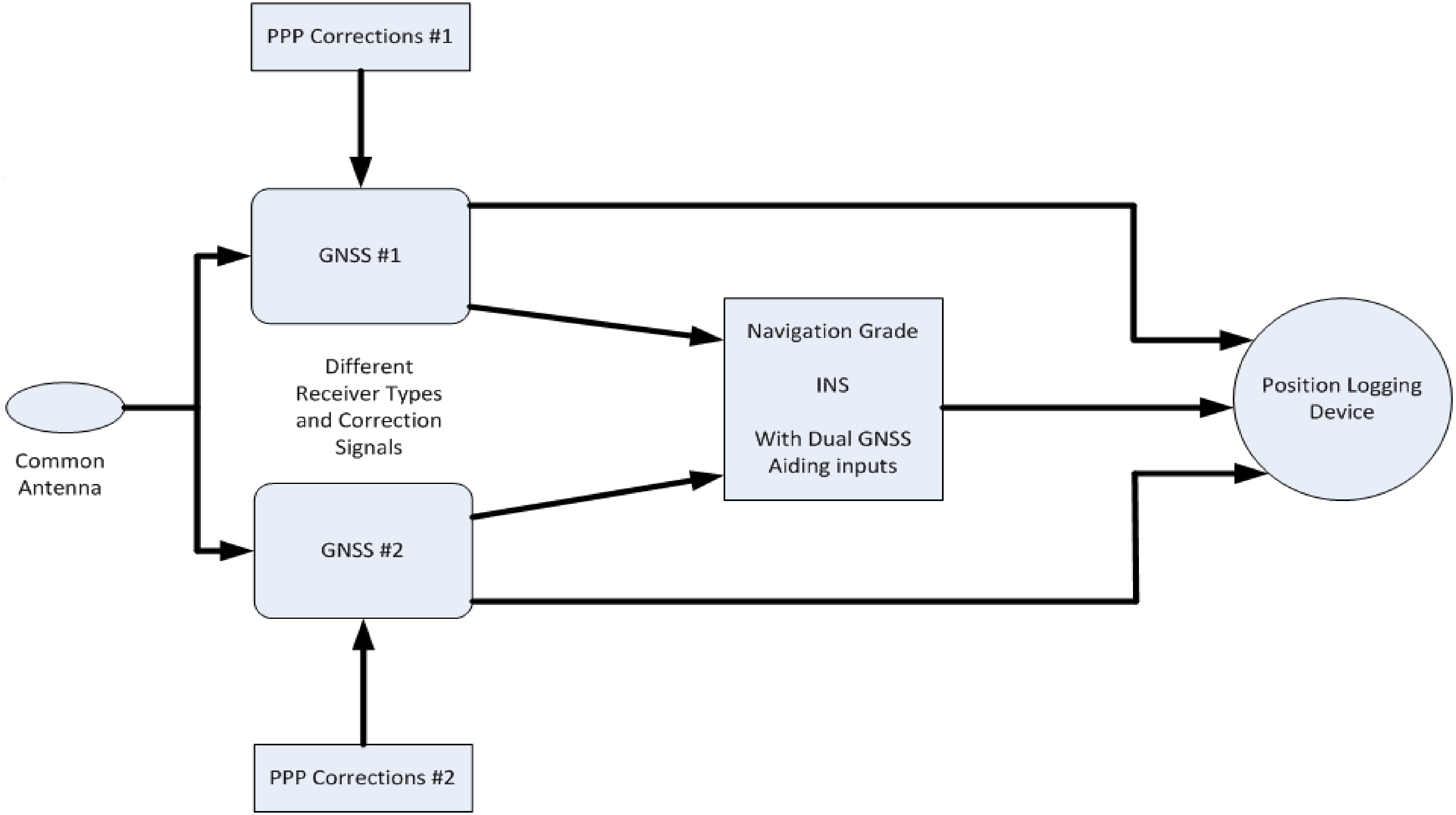
GNSS/Acoustic Configuration

- A loss of functionality of acoustics would have minimal impact to the INS solution.

- A loss of GNSS, the INS uncertainties will increase due to the loss of the higher accuracy aiding of GNSS, but it will level off and still be a viable position solution to the DP.



Practical Testing I



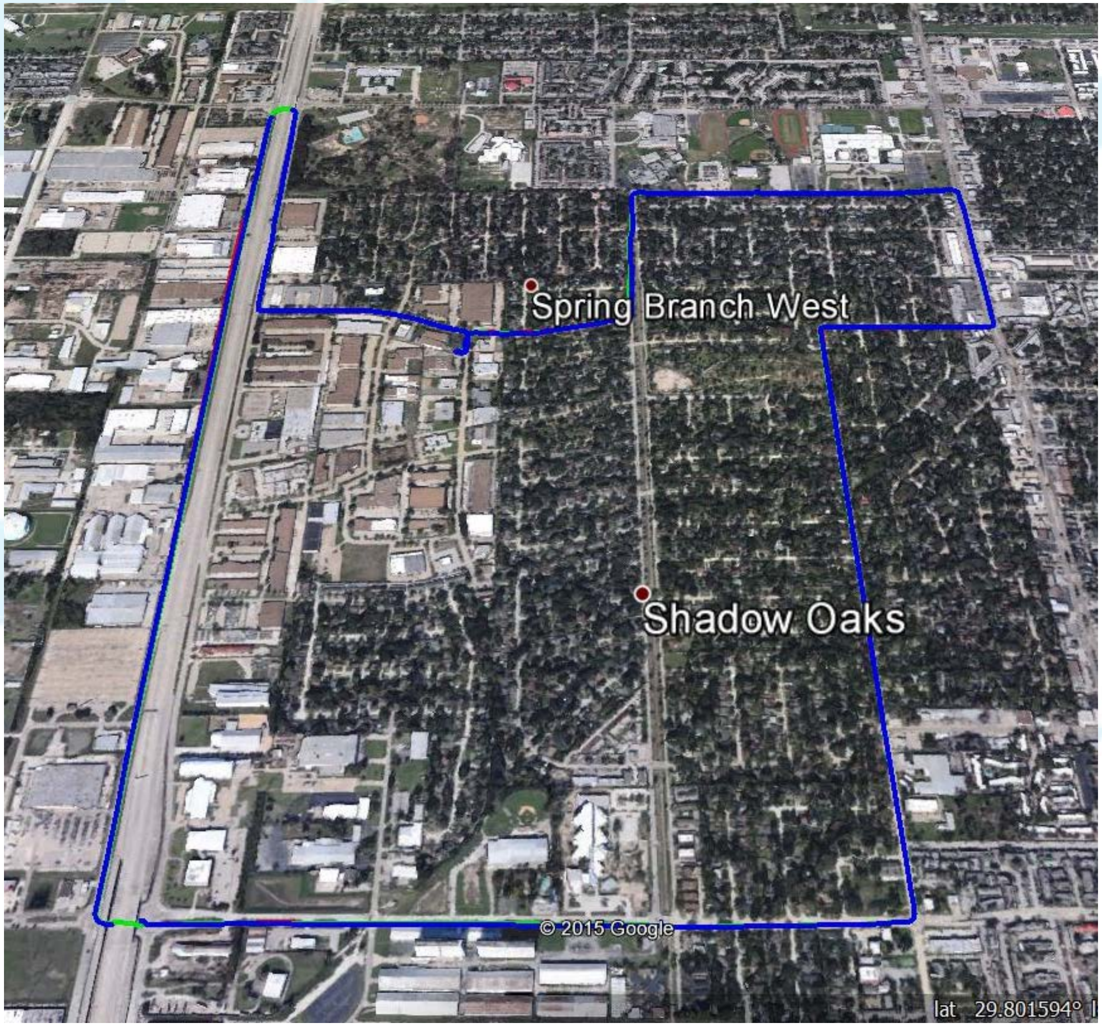
Practical Testing II

- Testing at sea difficult due to lack of truth position.

- On shore testing done with results displayed on Google Earth.

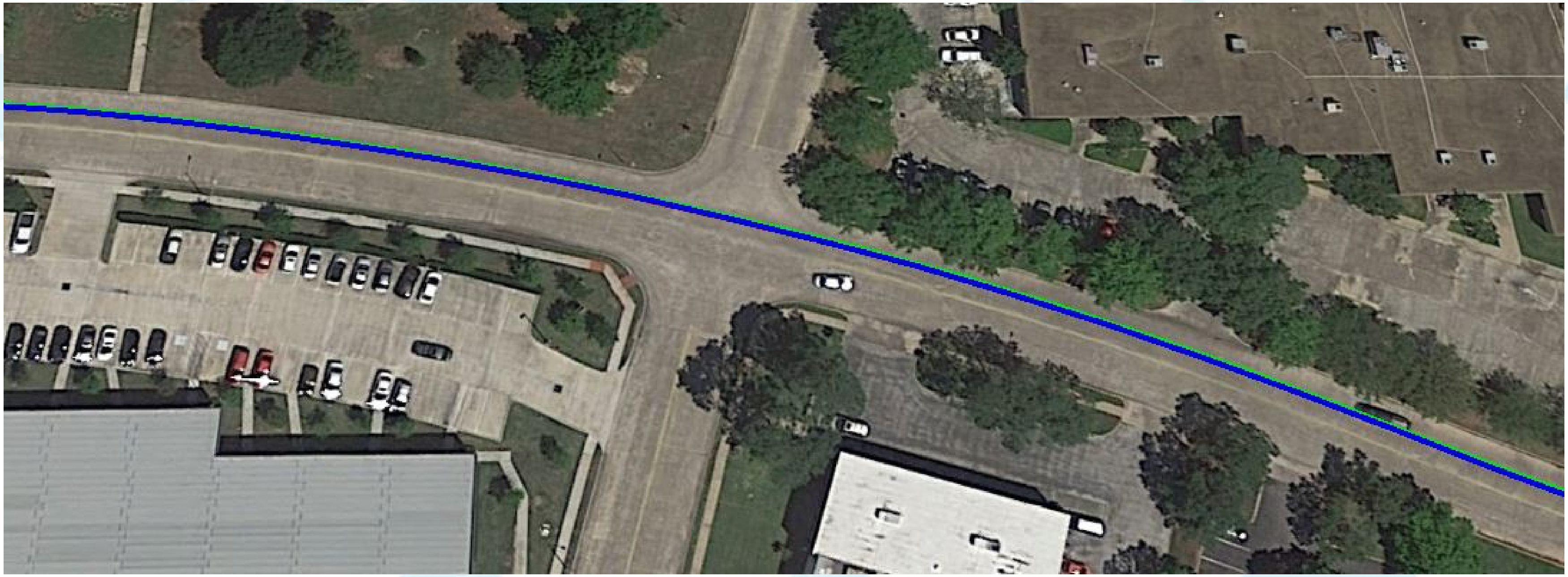
- This gives us a truth position to a few feet, and the ability to run a route with known problems such as interference and multipath.

West Houston – Beltway 8 North of I 10



Practical Testing III

Good Data Example



GNSS #1 – Red Track GNSS #2 – Blue Track INS – Green Track

Here with good data the blue track overlies the red track showing agreement between the two GNSS units.

Practical Testing IV

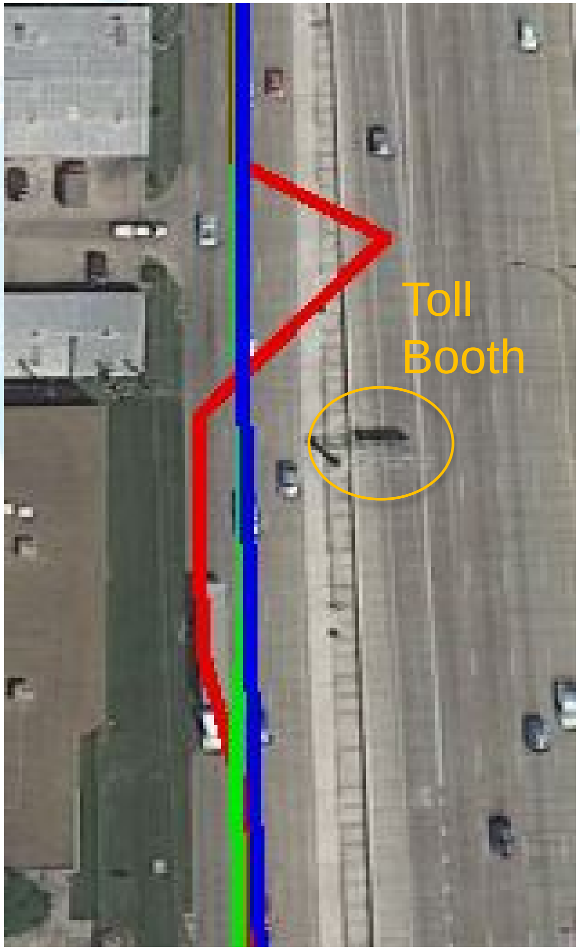
Loss of GNSS Signal

- Both GNSS receivers lose signal as the truck goes under the freeway. However they each handle the loss of signal differently.
- The Red receiver loses position as soon as the antenna is covered and restores position later than the blue receiver.
- The Blue receiver outputs position much sooner but with a significant error.
- Both receivers output the correct position at about the same time.
- The INS position is correct throughout the maneuver.

Practical Testing V

Interference

- The tollbooth has RFID interrogating equipment which causes problems for the Red GNSS receiver.
- The Blue receiver seems unaffected.
- The INS rejects the large initial position jump and the continued offset beyond the booth.



Practical Testing VI

Shading

- Here both receivers are affected by the trees.

- The INS keeps to the real track of the truck.

Practical Testing VII

Shadowing

- Here the Blue receiver position is distorted by the "shadow" of the building.
- The Red receiver is also slightly affected.

- The INS follows the true track round the corner.

Practical Testing VIII

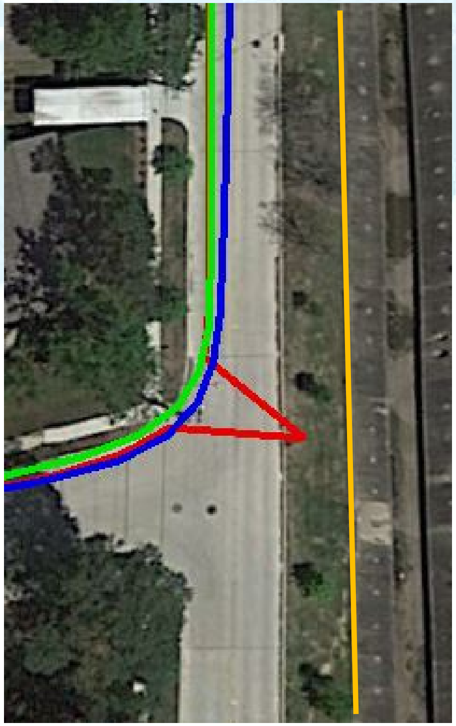
Multipath

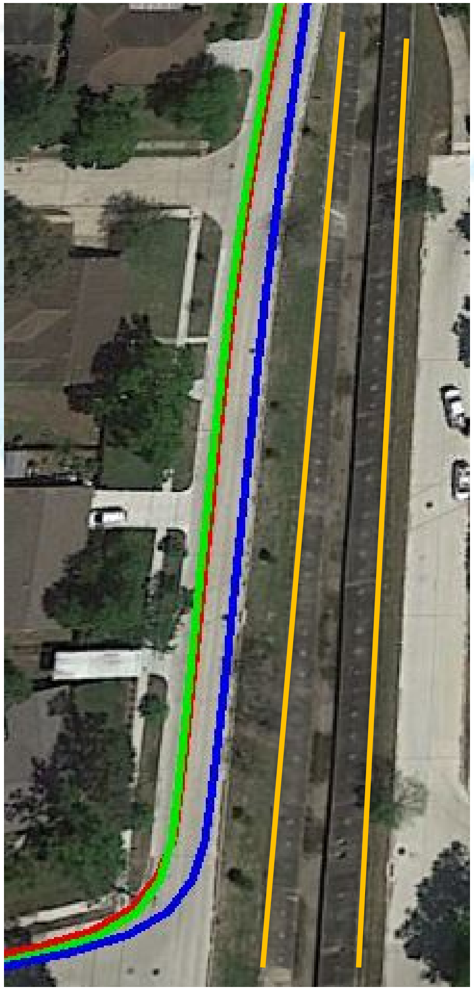
• Both images show the truck travelling down the two lane road with the drainage ditch to the left. They illustrate two different runs.

• On the first the Red receiver has a large initial jump, while the Blue has a constant offset.

• On the second the Blue receiver has a much larger offset while the Red is closer to the true track shown by the Green INS.

Orange outlines a concrete "v" shaped drainage ditch





Practical Testing IX

Conclusions

- In all these examples we are seeing significant position errors in the order of several metres.
- These would not have been flagged as poor by the traditional GGA string quality metrics.
- The positioning problems illustrated on the test route are similar to those found on DP vessels and they are what IMCA refers to as “Trigger Events” that can lead to LOP; if not handled correctly.
- In all fault cases the INS output was significantly closer to the true position than either of the GNSS units.

Output Formats

Most INS units interfaced to DP systems mimic a GPS receiver and send GGA, and perhaps VTG, ZDA and GST.
This is done to ease integration of the sensor with existing DP system, but has significant disadvantages.

Many of the GGA fields are irrelevant to INS:

- DOP
- Number of Satellites
- Differential correction information

Key INS parameters have no equivalent:

- INS Mode
- Status of aiding devices
- Quality of aiding devices

Need for a NMEA message for navigation quality INS outputs.

Conclusion

- As demonstrated on the prior slides, an INS fitted with dual GNSS receivers and acoustic aiding would mitigate many issues, including:
  - Short term acoustic outages
  - Long acoustic update periods
  - INMARSAT GNSS interference
  - GNSS masking
  - GNSS loss of correctors
  - GNSS errors (scintillation)
  - Multipath

- INS can help prevent trigger events from getting to the DP.

- By leveraging high volume avionics hardware, the marine industry can benefit from aviation's manufacturing processes and proven approach to stable, robust, reliable positioning.

Questions?