Integrity and Interoperability for

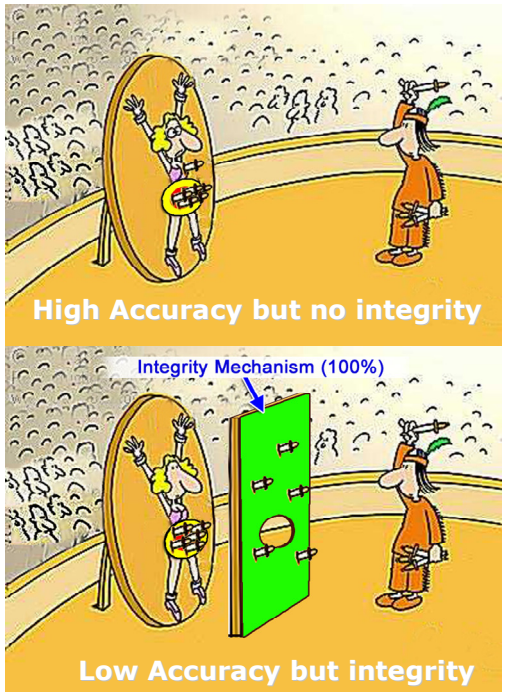
LIABILITY-CRITICAL APPLICATIONS

INNOVATING SOLUTIONS

LIABILITY CRITICAL APPLICATIONS (OF GNSS POSITIONING)

Those in which large unnoticed navigation errors may have legal or economic implications

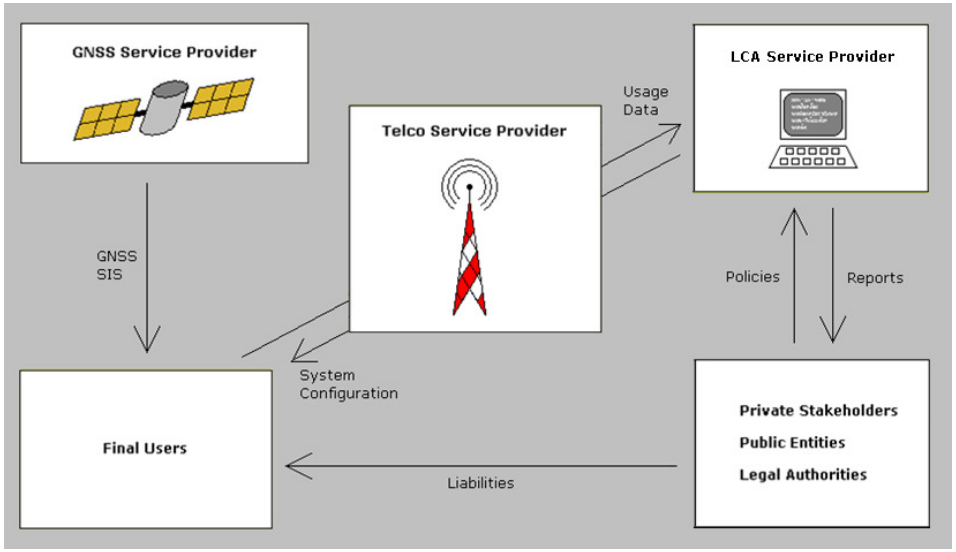
- Hence similar to safety critical in what integrity is the key enabler
- No risks for human life or health involved
- Economic implications may demand similar integrity levels



EXAMPLES OF LCA

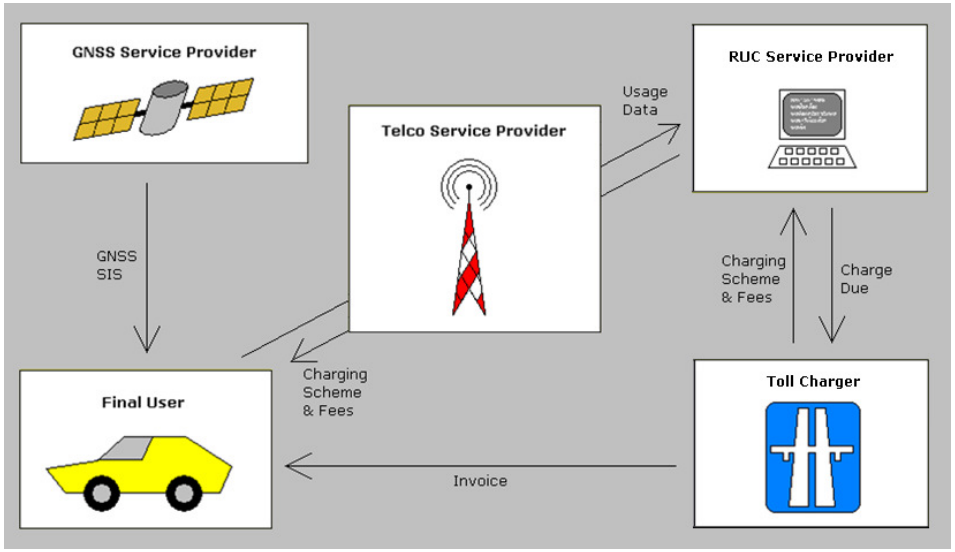
- Road user charging (road tolling)
- Pay-As-You-Drive (PAYD) insurance
- On-street parking pricing
- Traffic law enforcement (e.g. speed fining)
- Surveillance of Parolees
- Fleet management (special vehicle classes)
- …

LCA SCHEME



Generic scheme

Example: RUC



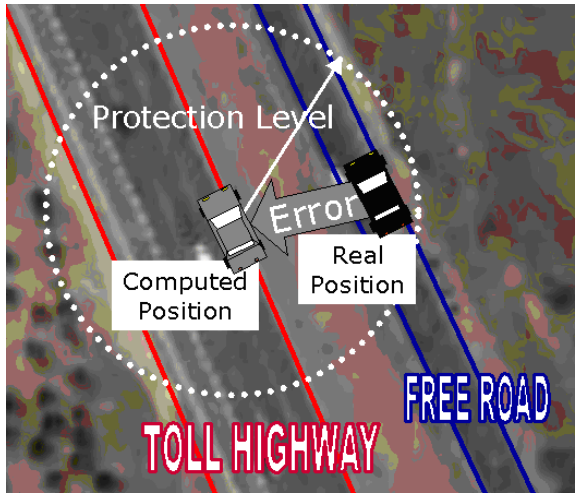
WHY INTEGRITY IS NEEDED IN LCA?

- The system needs credibility, must be reliable:

> Users won't admit being charged "by mistake"

- Thus we must be really sure when we charge a user

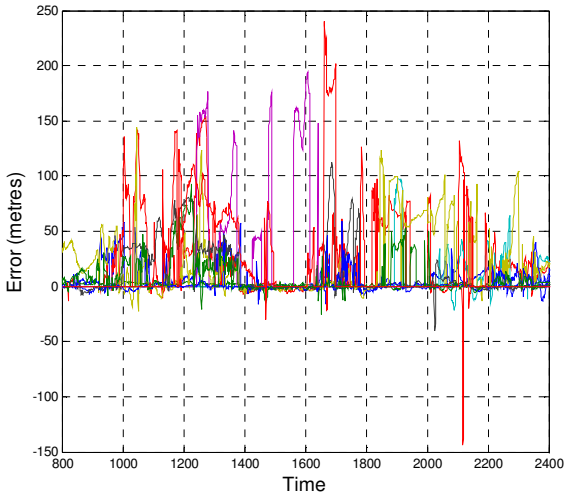
- RUC example: make sure that the vehicle is using the toll road

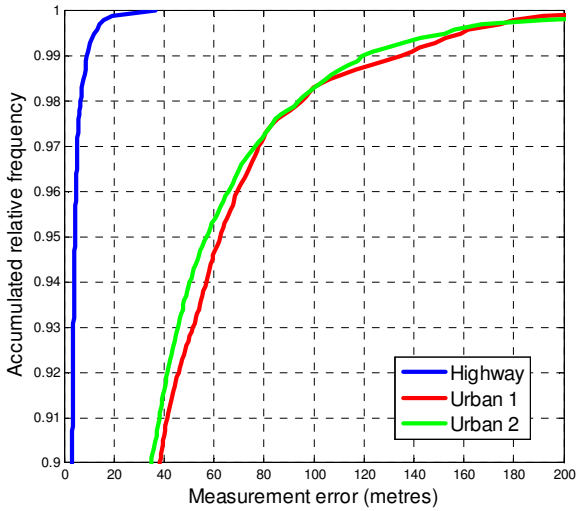


Protection levels alert when there is a chance that the vehicle is NOT using the toll road, but a nearby one

CHALLENGING LCA SCENARIOS

- Dirty compared with aeronautical (multi-path, interference…)
- Especially in urban and suburban areas
- Main challenges in urban scenarios are:
  - Reduced satellite visibility
  - Heavy multi-path (especially NLOS threat)





TWO DIFFERENT APPROACHES

- Measurement Rejection Approach (MRA):

  Throw away NLOS measurements, then compute protection levels.

  – Advantage: (almost) only healthy measurements used => smaller PL's

  – Drawbacks:

    - Needs a powerful FDE
    - Few measurements in urban environments:
      - High DOP
      - Less epochs with enough satellites to navigate

- Error Characterisation Approach (ECA):

  Protection levels account for NLOS measurement errors.

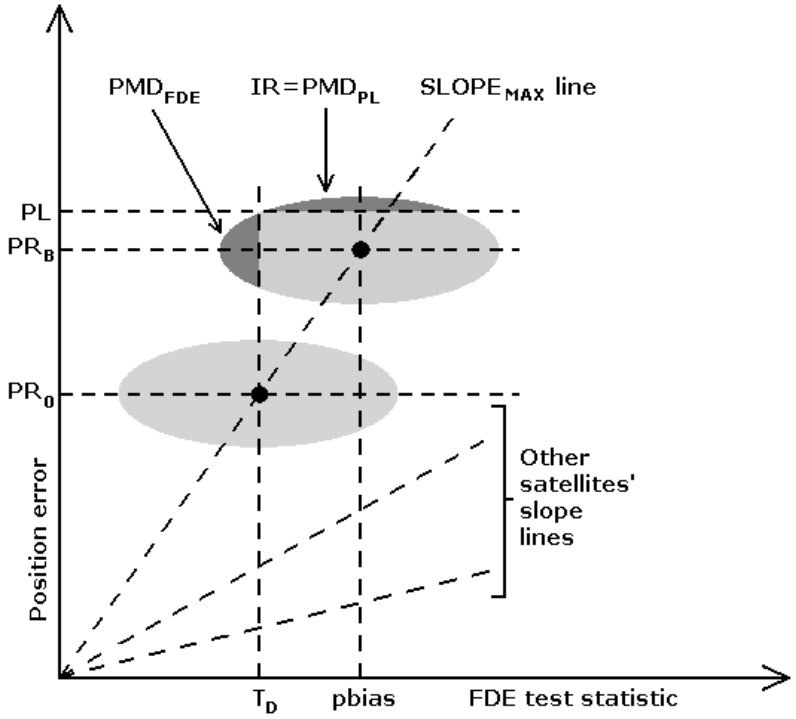
  – Drawback: larger position errors caused by NLOS => larger PL's

  – Advantages:

    - Needs no FDE
    - Many satellites to navigate (especially with HS Rx):
      - Lower DOP
      - More epochs with enough satellites to navigate

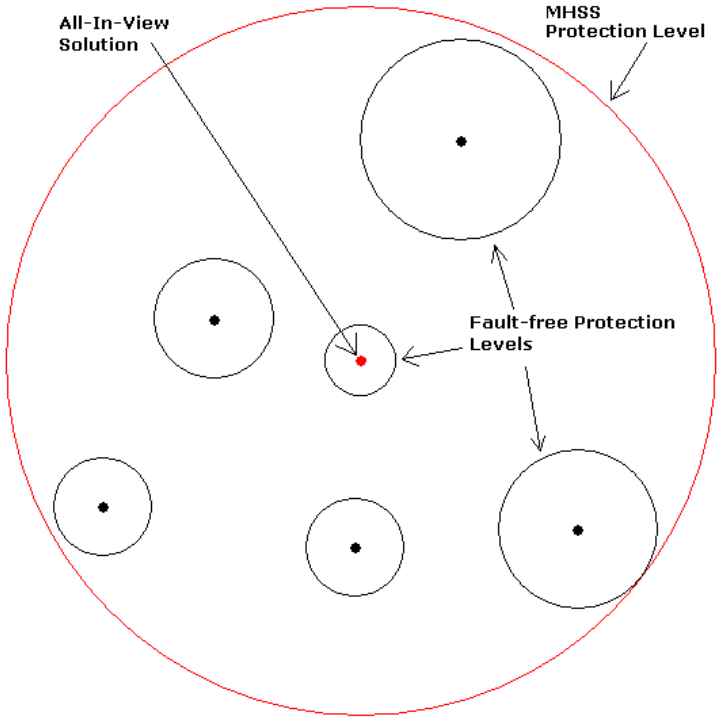
MRA EXAMPLES (I)

- Traditional RAIM techniques (e.g. parity space):
  - Version for multiple fault conditions (needed to handle urban NLOS)
  - FDE needed to ensure an upper bound to the number of faults
  - GIC can help characterising the remaining "fault-free" errors



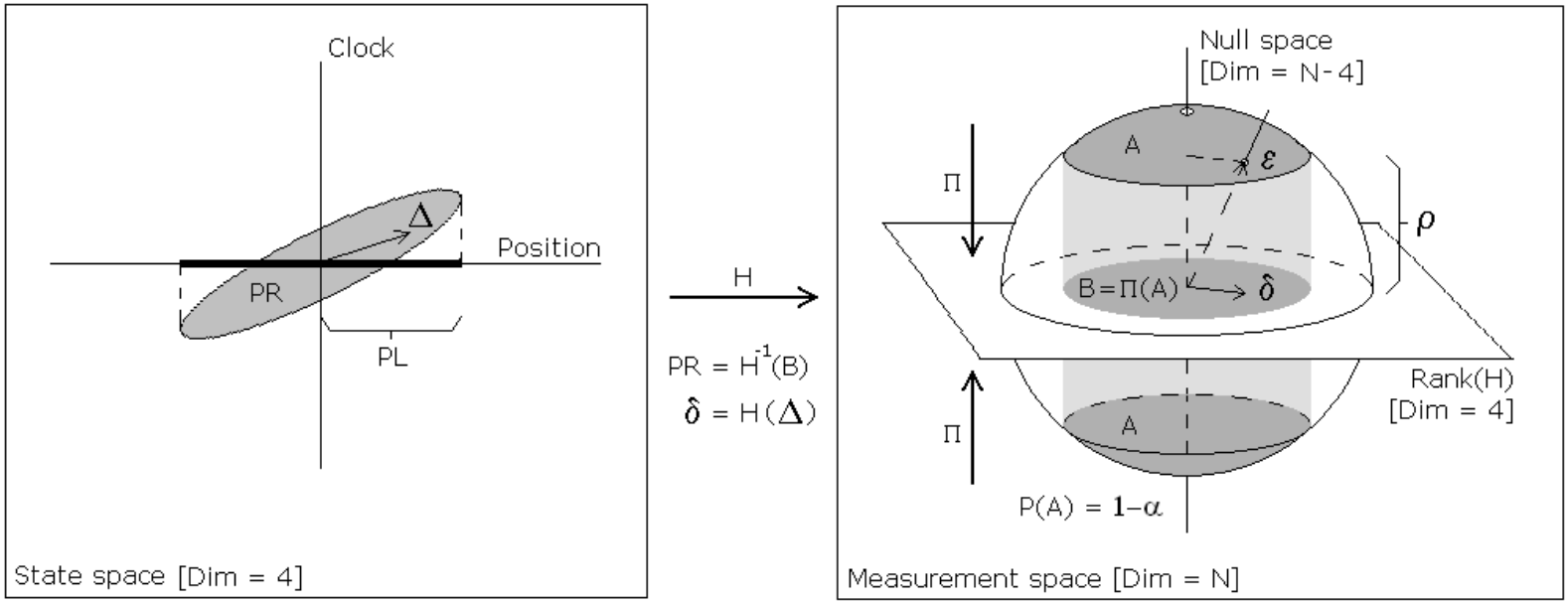
MRA EXAMPLES (II)

- Multiple Hypothesis Solution Separation (MHSS):
  - Prepared for multiple faults
  - FDE needed to ensure a minimum amount of healthy measurements
  - GIC can help characterising the remaining “fault-free” errors



ECA EXAMPLES

- Isotropy-Based Protection Level (IBPL):
  - Use residuals to compute adaptive PL's that account for all errors
  - Residuals retain error statistics under some assumptions (error isotropy)
  - NLOS seems to violate the isotropy assumption
  - However this assumption can be relaxed

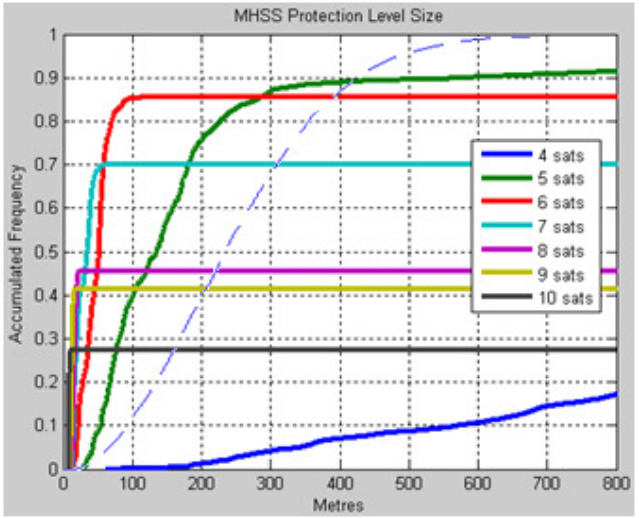


OBSERVATIONS

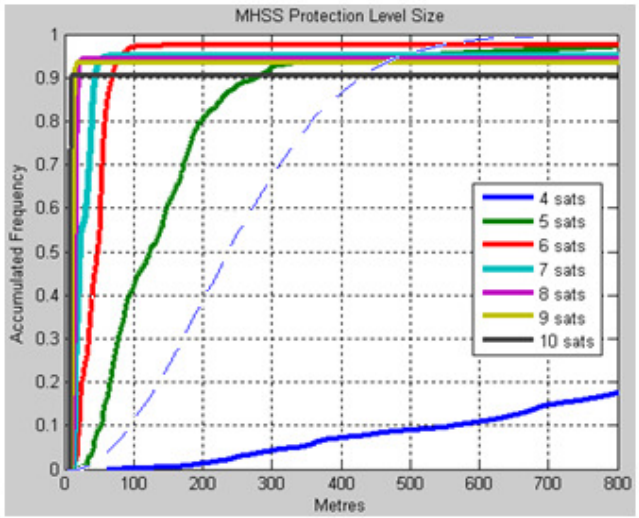
- MRA needs a powerful FDE. No such FDE is known (to the authors) so far !!
- Can GNSS infrastructure help user-level FDE? (e.g. polarisation)
- Only ECA has been implemented so far through IBPL
- Isotropy is apparently violated by NLOS, but this assumption can be relaxed
- Both IBPL (ECA) and MHSS (MRA) performance depends on the number of satellites

MHSS PERFORMANCE RESULTS

- Different HPL size statistics for different FDE capabilities and constellation sizes:



Integrity availability in urban canyon GPS+Galileo

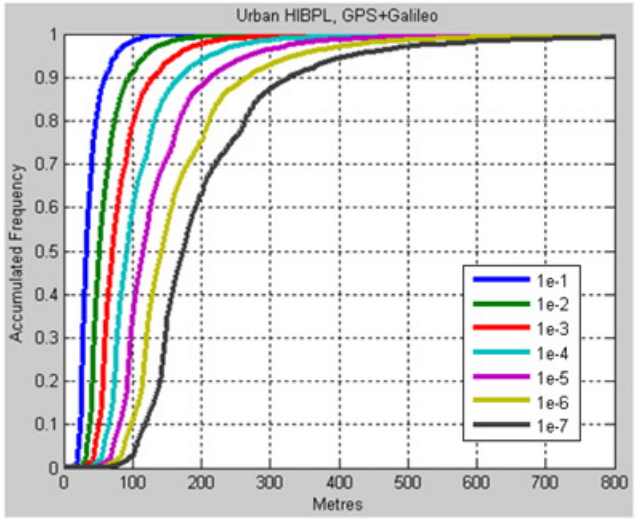


Integrity availability in urban canyon GPS+Galileo+GLONASS

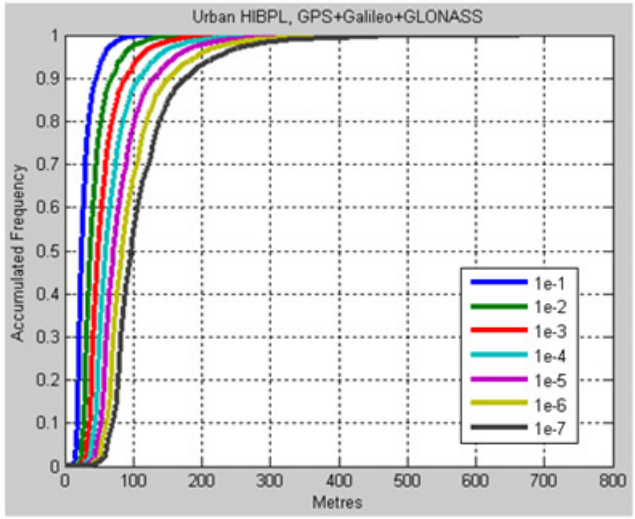
- Note the improvement achieved by passing from two to three constellations

IBPL PERFORMANCE RESULTS

- Different HPL curves correspond to different confidence levels. Only the leftmost two can be compared with previous slide



Integrity availability in urban canyon
GPS+Galileo



Integrity availability in urban canyon
GPS+Galileo+GLONASS

- Note also the improvement achieved by passing from two to three constellations

MAIN CONCLUSIONS

- LCA needs integrity
- Integrity in road applications faces challenges that in civil aviation can be disregarded (local effects)
- Mission segment-provided integrity is not enough due to local effects
- Hence, mission segment support to LCA cannot be oriented to error monitoring
- Different strategies analysed (MRA, ECA)
- The benefits of multiple constellations became clear in both cases

Thank you

Miguel Azaola
GNSS Business Unit
Email: asaenz@gmv.com
www.gmv.com

INNOVATING SOLUTIONS

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