RISK MANAGEMENT IN GNSS MALFUNCTIONING
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GNSS: WHAT CAN GO WRONG AND WHAT ARE THE RISKS?

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GNSS: What can go wrong and what are the risks?

• Content of presentation
  • Introducing GNSS
  • GNSS vulnerabilities and risks
  • Mitigation GNSS vulnerabilities and risks
• Conclusion
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GNSS: What can go wrong and what are the risks?

• **We all are navigators**

• Timing, orientation, positioning and navigation are deeply embedded in our lives
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GNSS: What can go wrong and what are the risks?

- Business environment for GNSS
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GNSS: What can go wrong and what are the risks?

• End-user's perspective of GNSS
  • End-user does not understand and care for the technology and its vulnerabilities
  • End-user assumes absolute GNSS robustness and limitless performance
  • Urban legends prevail
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GNSS: What can go wrong and what are the risks?

• How GNSS works?
• Propagation time measurement-based
• Time synchronisation and common reference framework (WGS84) are essential
• Four non-linear equations of four un-knows yield: 3D position, time
GNSS: What can go wrong and what are the risks?

- GNSS architecture
- Space (satellite) segment (GPS: 31, Glonass: 23)
- Ground (control) segment
- User segment
- Propagation media
- Advanced systems: DGNSS, A-GNSS, SBAS (EGNOS)
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GNSS: What can go wrong and what are the risks?

- GNSS vulnerabilities and risks

**Sources of GNSS Vulnerabilities**

**Positioning Errors**
- Dilution of Precision
  - satellite ephemeris
  - satellite clock
- User Equivalent Ranging Error
  - multipath
  - receiver noise
  - ionospheric delay
  - tropospheric delay

**Reduced Service Availability**
- Natural Causes
  - geomagnetic storms
  - ionospheric storms
  - volcanic eruptions
  - earthquakes
- Artificial Causes
  - intentional (jamming)
  - non-intentional (non-EMC)
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GNSS: What can go wrong and what are the risks?

- **Reduced service availability** - GNSS vulnerabilities and risks related to utilisation and environment for satellite positioning

- Natural causes

- Artificial causes

Source: [c2h2.ifa.hawaii.edu](http://c2h2.ifa.hawaii.edu)

Source: Wikimedia
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- Space weather and ionospheric disturbances

Source: Lucent Technologies
GNSS: What can go wrong and what are the risks?

- Artificial causes of reduced GNSS service availability
- Deliberate or unintentional interference:
  - Jamming
  - Re-broadcasting (*meaconing*)
  - Spoofing
  - EMC issues
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GNSS: What can go wrong and what are the risks?

- Mitigation GNSS vulnerabilities and risks
- Growing reliance on GNSS
- Awareness and impact assessment
- Policy response
- Increasing resilience
Conclusions

Satellite navigation technology matured to the level where numerous technology, economic and safety systems comprise it.

Satellite navigation becomes a component of national infrastructure.

Technological, business and legal issues are to be resolved in order to allow for continuous sustainable market growth.
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• Reference

• RIN GNSS Vulnerabilities and Solutions Conference, Baska, Krk Island, Croatia (http://bit.ly/t1E41m)


THANK YOU FOR YOUR ATTENTION!

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GNSS: What can go wrong and what are the risks?

- **APPENDIX: Vulnerabilities by GNSS segments**
- Ground and satellite segment
- User segment
- Propagation media segment
GNSS: What can go wrong and what are the risks?

- Ground and satellite segment
- Too few satellites
- Incorrect navigation data
- Jump or drift of satellite clock
- Distorted signal waveform
- Service interruption or satellite loss due to space weather effects
- Attack on ground/space segment
- Augmentation and assisting systems
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GNSS: What can go wrong and what are the risks?

- User segment
- Leap seconds and roll-overs
- System up-grades
- Receiver software bugs
- Multipath
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GNSS: What can go wrong and what are the risks?

- Propagation media segment
- Slow variation in ionospheric TEC
- Fast variation in ionospheric TEC
- Ionospheric scintillation
- Local patterns of ionospheric dynamics
- Space weather storms
- Deliberate modification of the ionosphere