



Resilience by Design in CNS Systems

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Challenges in CNS are changing

- Challenges in Performance:

- **GNSS disruptions from ionospheric activity**

- Increased dependence on GNSS (also for COM and SUR) makes outages more impactful

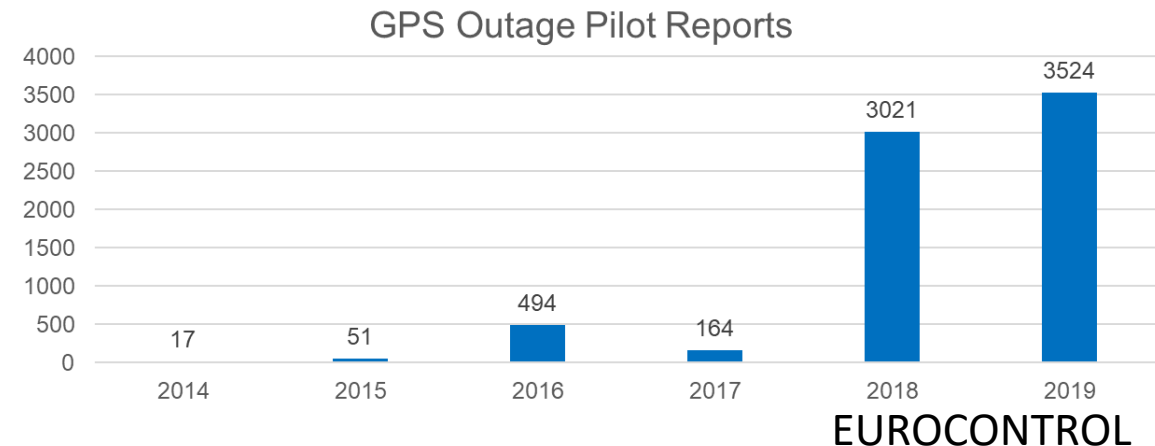
- **New operating environments for UAS**

- Other presentations in this series

- Cyber threats:

- **Reduction in price (and complexity) of Software-Defined Radios (SDR)**

- Proliferation of RFI



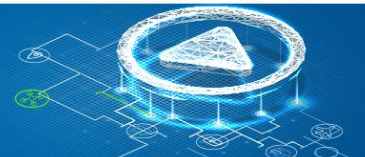
Aircraft are cyber-physical systems

- A mechanism controlled by algorithms
- Physical and software components are deeply intertwined
- Aircraft are cyber-vulnerable
→ Need to be designed with resilience in mind.



The human threat to CNS

- Access to software-defined radio (SDR) technology has simplified
- Know-how on standardized CNS signals and systems is accessible on the internet
- Systems are backwards-compatible and were mostly not designed to be radio-tamper-proof
 - **Safety**
 - **Security**
- Two significant types of threats:
 - **Denial of service: jamming**
 - **Purposeful misleading: spoofing, man in the middle**



Jamming CNS Systems

- VDL2 relies on Carrier-Sense multiplexing
 - ➔ can be filibustered without knowing waveforms
- GNSS signals are faint that
 - ➔ pocket-sized transmitter can deny service to large areas
- SSR can be jammed by flooding an interrogator with fake responses

+ GPS SIGNAL INTERRUPTIONS HAVE BEEN REPORTED WITHIN NICOSIA FIR.
PILOTS ARE REQUESTED TO PROMPTLY REPORT TO ATC ANY GPS SIGNAL
INTERRUPTION EXPERIENCED.
FROM: 11 FEB 2020 12:30 **TO:** PERM

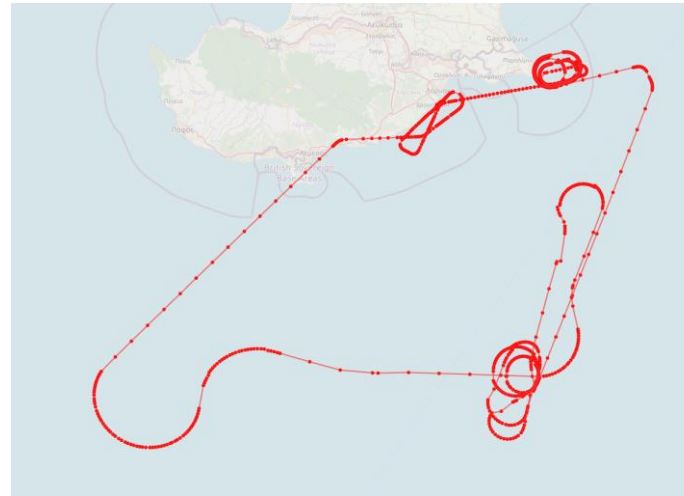
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- Does this kind of stuff happen?
 - ➔ Measurement flight with D-ATRA

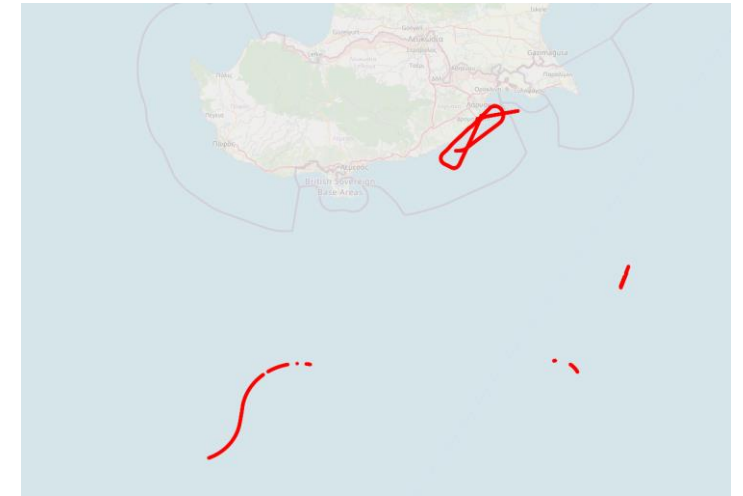
Osechas, O., M. Mostafa, T. Gräupl and M. Meurer:
Addressing Vulnerabilities of the CNS Infrastructure to
Targeted Radio Interference". *IEEE Aerospace and Electronic
Systems Magazine*. Vol 32, No. 11, November 2017.

We measured interference with our A-320

- Flight with DLR-operated Airbus 320
- Prolonged RFI event for entire duration of flight (approx. 1,5 h)



Flight track



GPS solution available

Impact on avionics

- Operational awareness in the cockpit
 - Challenging for pilots
 - Can be disconcerting
 - ATC reports go-arounds



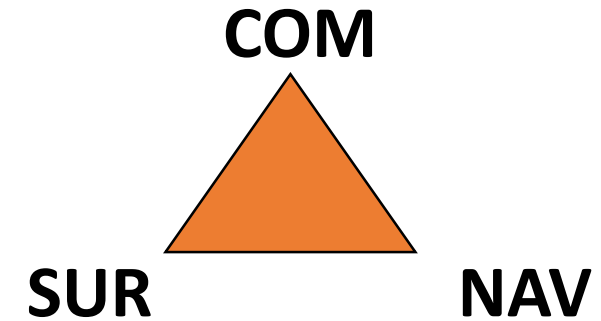
New Poll: have you seen this happen?

Operational Impact

- Not currently an acute threat to safety!

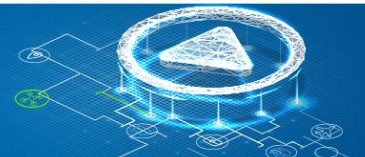
- However:

- Increased workload to ATC from go-arounds
→ Degraded efficiency and capacity of the airspace
- CNS Safety triangle: near-permanent outage of primary NAV removes one layer of redundancy. Not a sustainable strategy.
- Hindering PBN implementation



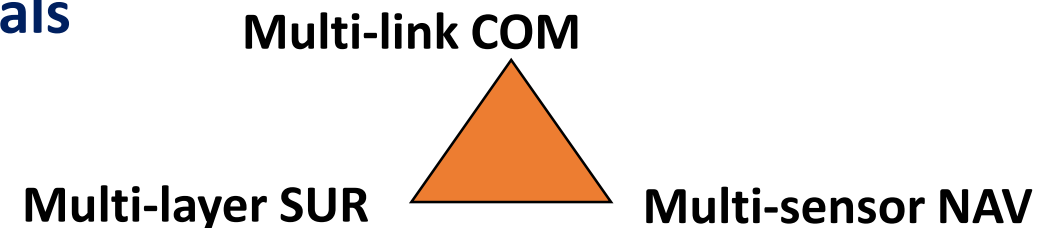
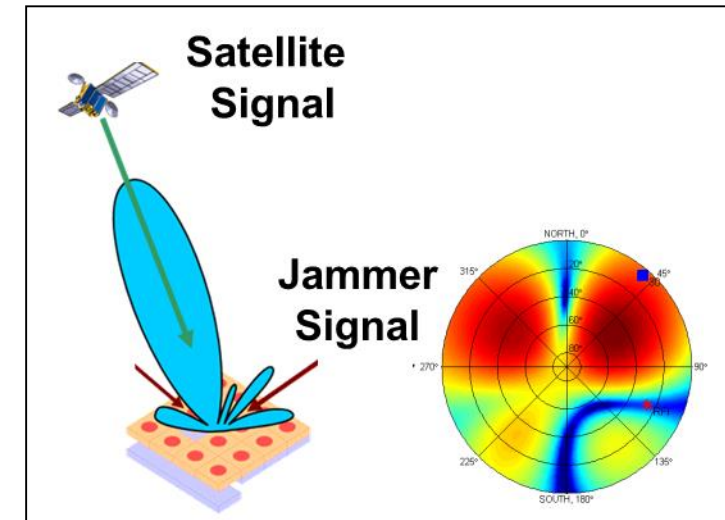
Does this translate to COM and SUR?

- These events are collateral to the geopolitical reality
 - **That changes faster than aviation standards**
- No reason to believe in an action targeted at aviation
 - **No spoofed GNSS/GPS signals identified so far in D-ATRA recordings**
- However:
 - **Aviation has shown itself hugely vulnerable to the good-will of others**
 - **No technical SOLUTION has been implemented (they exist, but not for aviation), only ALTERNATIVES have been found**
 - **COM and SUR are preparing for resilience now**



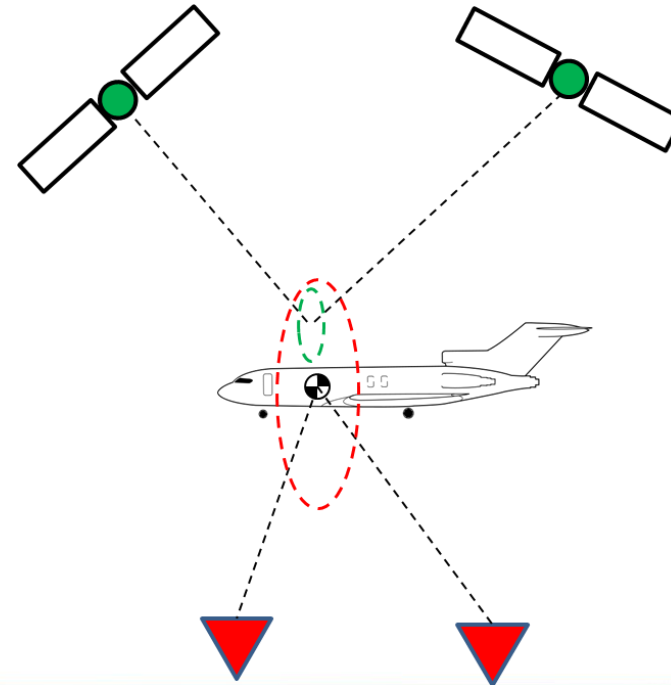
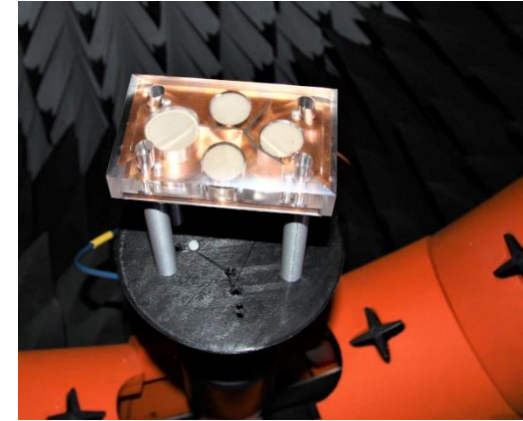
Technical solutions exist, but certification and deployment are challenging

- Use smarter antennas
 - Airborne side: validate DoA, reject RFI
 - Ground side: detect and localize RFI, validate/multilaterate signals
- Exploit redundancy and consistency. Examples:
 - COM: Complement VDL with LDACS or other
 - NAV: APNT and GNSS solutions
 - SUR: SSR broadcast vs. time-of-flight of signals



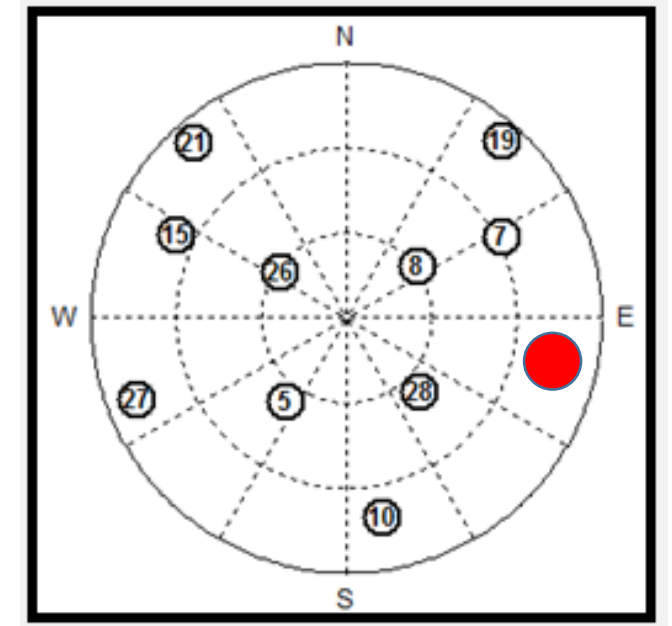
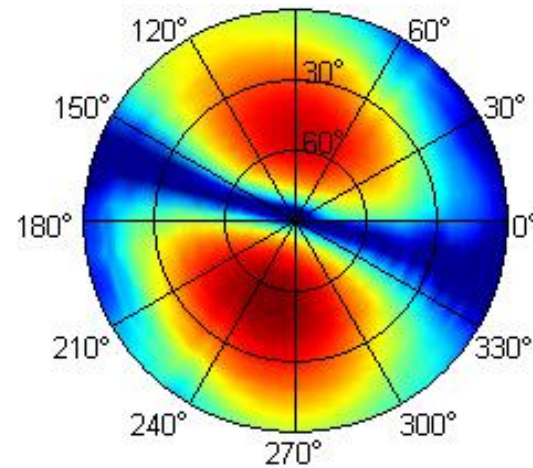
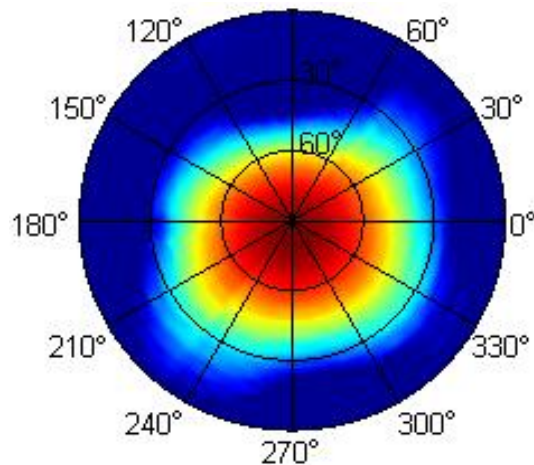
DLR is involved in developing solutions

- Physical Layer: Multi-element antennas
 - Beamforming
 - DoA Estimation
- System Layer: Functional redundancy
 - GNSS: Navigation high performance
 - APNT: Backup with less performance



Array Antennas: Two different principles can be exploited

- Beamforming
- DoA Estimation

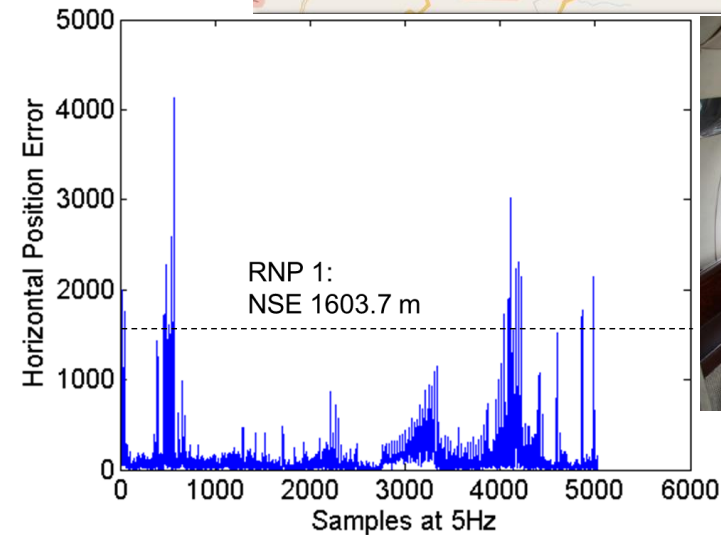
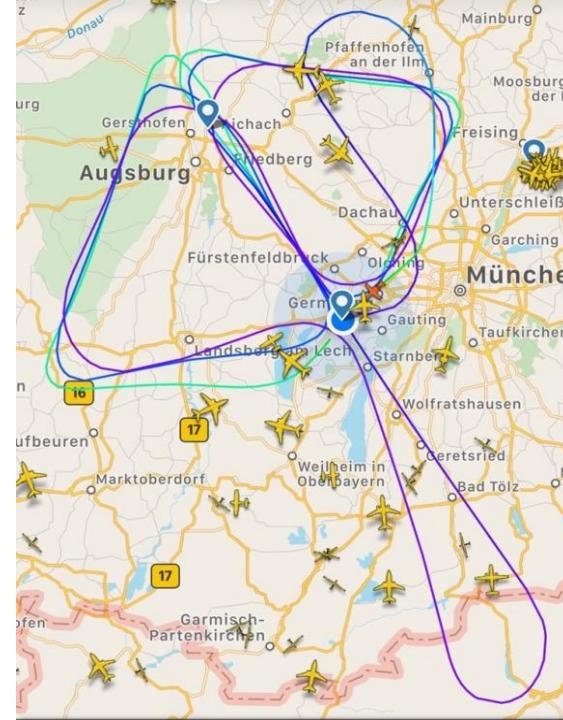


Terrestrial Radionavigation: Improving the performance of alternatives

- GNSS provides unbeatable navigation performance
 - **Enables integrity**
- In its absence, integrity services are lost
 - **Degraded airspace efficiency**
 - **Potentially increased controller workload**
- Alternative PNT with integrity
 - **Under development**

Enter LDACS-NAV

- LDACS is a COM system
 - Under standardization
- Re-use as a NAV system
 - Promising navigation performance
 - RNP 1/RNAV 1: Feasibility shown in 2019
 - RNP 0.3: Subject of SESAR PJ14-W2-Sol-81c
- Flight tested in 2018



Summary

- Aviation is a cyber-physical system
 - **That comes with its own set of vulnerabilities**
- Conventional CNS Signals and Systems were not designed with cybersecurity in mind
 - **We need cybersecurity thinking**
- Disruptions show vulnerability to geopolitical reality
 - **We need stronger solutions**
 - **We need more effective backups and alternatives**
 - **Not only in NAV, but also in COM and SUR**



Thank you for your attention!

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What are your questions?

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