

DLR VIRTUAL TOWER PROTOTYPE

**Jörn Jakobi, Julia Schön, Tim Rambau, Helena Opower,
Lucas Thielmann, Liam Brown, Fabian Reuschling,
Christian Blessmann, Andreas Nadobnik, Aamir Basha
Mosa, Yash Pahariya, Felix Timmermann**

German Aerospace Center DLR



1000+ German Aerodromes could benefit from Virtual Tower

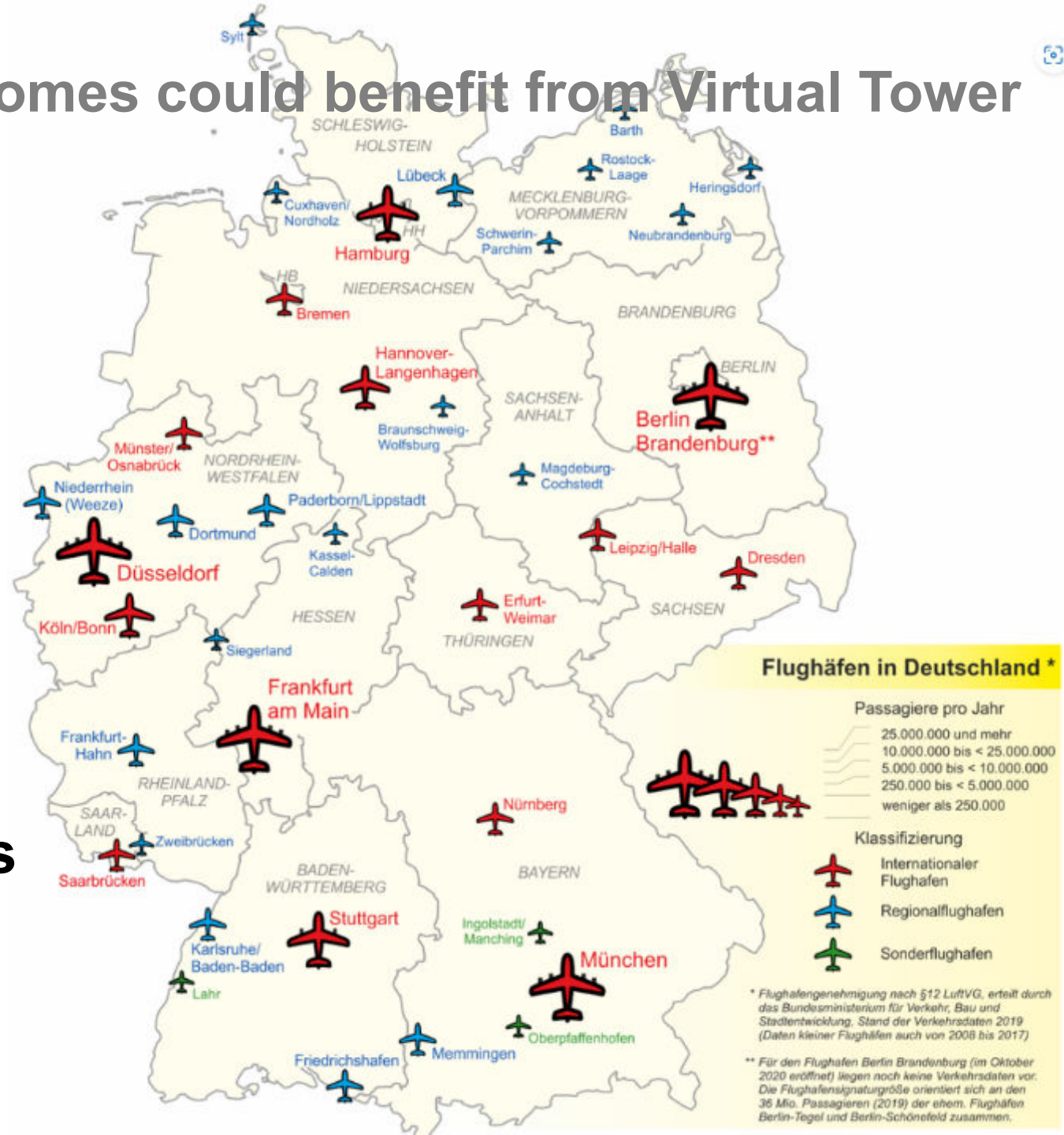
Service: 34 ATC / 25 AFIS

Classification:

- 36 Airports
 - 15 International
 - 19 Regional
 - 2 Sonder
- 395 Airfields and special landing sites

Source: Wikipedia: Liste der Verkehrsflughäfen in Deutschland
<https://www.gesetze-im-internet.de/flusaagv/anlage.html>

Jakobi (DLR) - DLR Braunschweig / 2026



State of the art Remote Tower Optical Systems (RTOS)

Kongsberg RTOS at
Kjeller Air Force Base



Copyright: FREQUENTIS

Copyright: DFS

Conventional Remote Tower (> 1M€ investment)



Jakobi (DLR) - DLF



Remote Tower Controller Working Position at RTC Leipzig
Source: DFS GmbH

Motivation



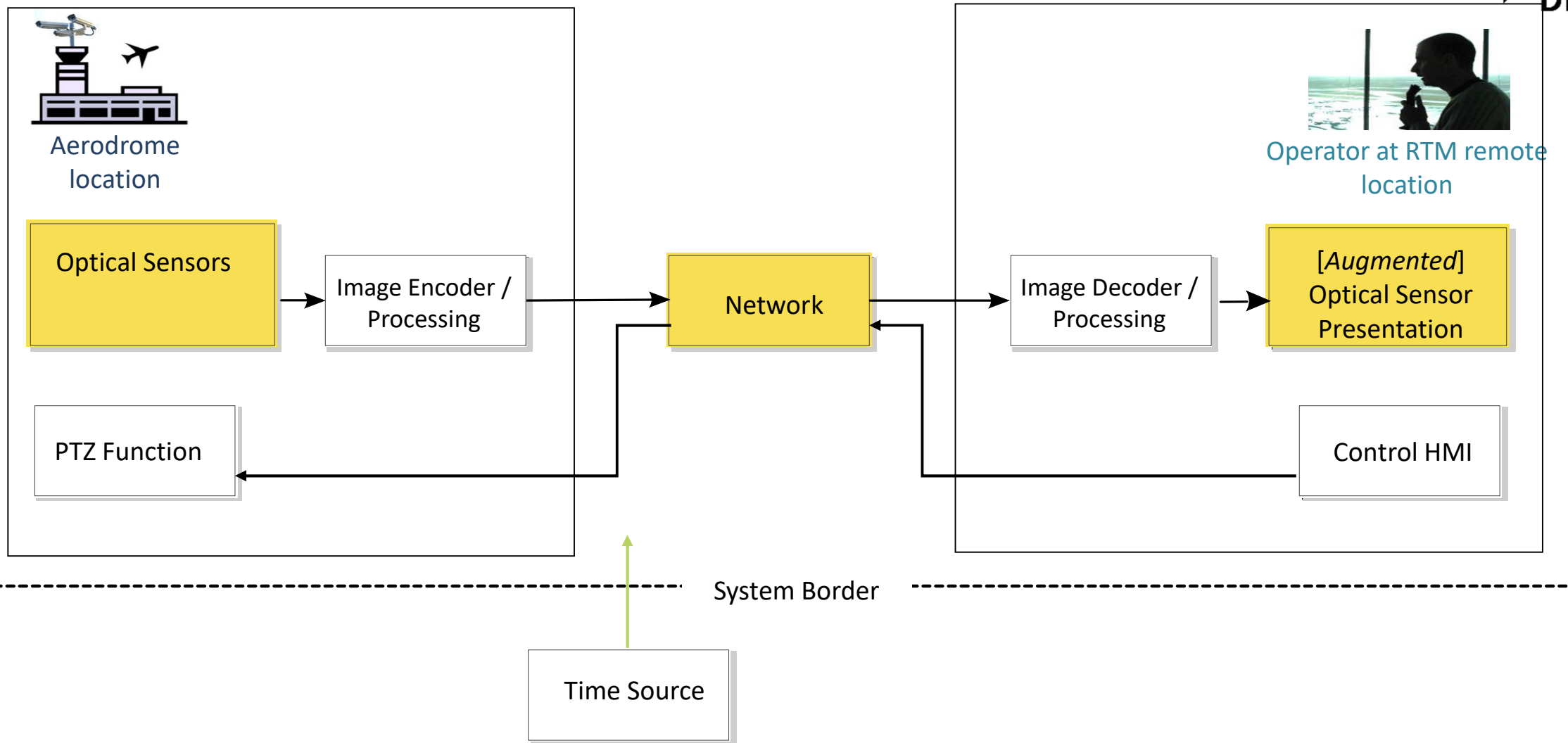
How can we make it even cheaper?

Smallest Aerodrome:

- Lower Service Level (no ATC but AFIS/RADIO)
- Less traffic, less commercial air traffic, less IFR operation
- Less complex and time critical

➔ Less sophisticated remote tower setups may be sufficient possibly

System Architecture – Where can be saved cost?



Typical Remote Tower Installation vs. Virtual Tower Low Cost Sensors



Optical Sensors	Horizontal x Vertical	Pixel per degree & (Total MP)	Average bits/pixel ratio (12 = standard)	Frames per second (fps)	H.264 1:125 (standard)	Erforderliche Bandbreite
Rotating Camera Sensor	360° x 60°	60 (~78 MP)	~12	5	~1:125	~37 Mbit/s
Fixed Full HD ~14x HD Cameras (portrait)	360° x 45° 25° x 45° per cam	43 (~30 MP)	~12	30	~1:125	~86 Mbit/s
Fixed 4K ~11x 4K Cameras (portrait)	360° x 60° 34° x 60° per cam	64 (~88 MP)	~12	30	~1:125	~255 Mbit/s
PTZ Camera HD 30x zoom	64° x 36° (wide) 2,2° x 1,2° (tele)	30 (~2 MP) 873 (~2 MP)	~12	30	~1:125	~6 Mbit/s
Low Budget Pano 2x HD Cameras (landscape)	360° x 90° 180° x 90° per cam	22 (~14 MP)	~12	15	~1:600	~5 Mbit/s

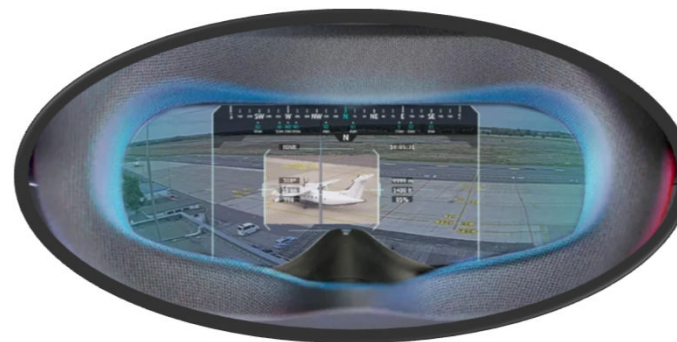


PTZ-Camera

3.000 €

2x Panorama-Camera (= 360°)

3.200 €



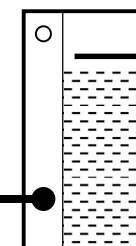
VR-headset

600 €



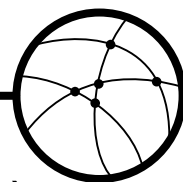
Computer

ca. 2.000 €



bandwidth

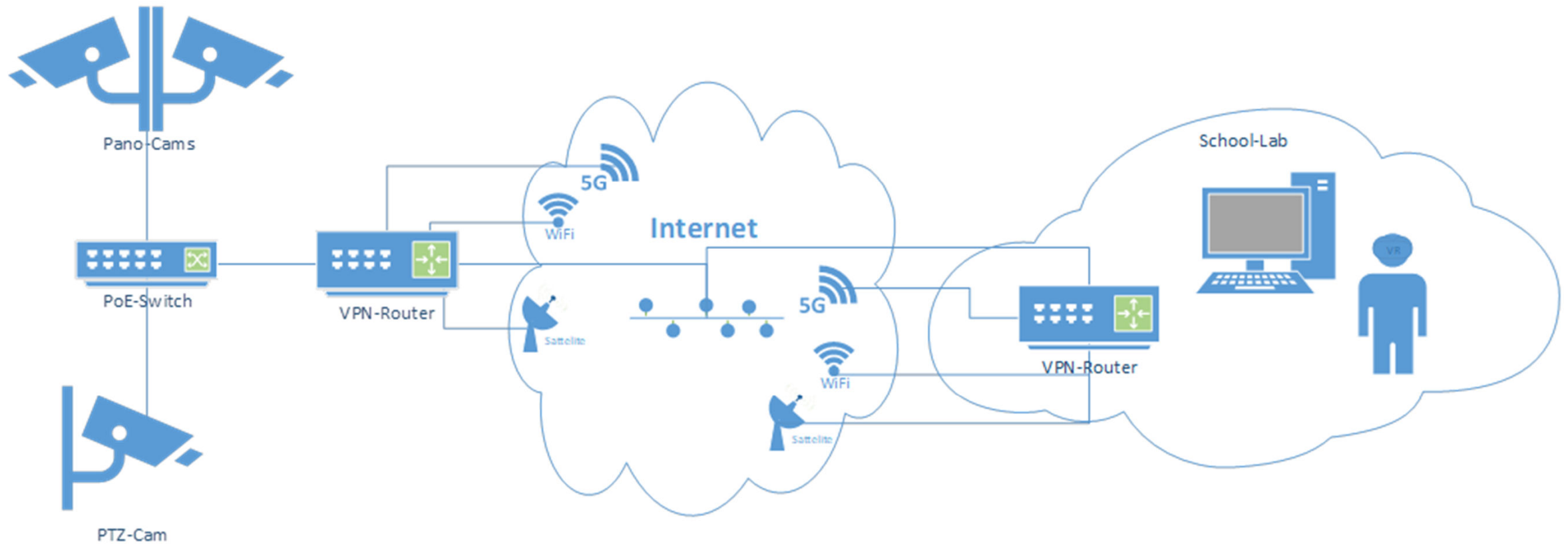
ca. 11 Mbit/s
(3G+ possible)



Total costs: ca. 10.000 €

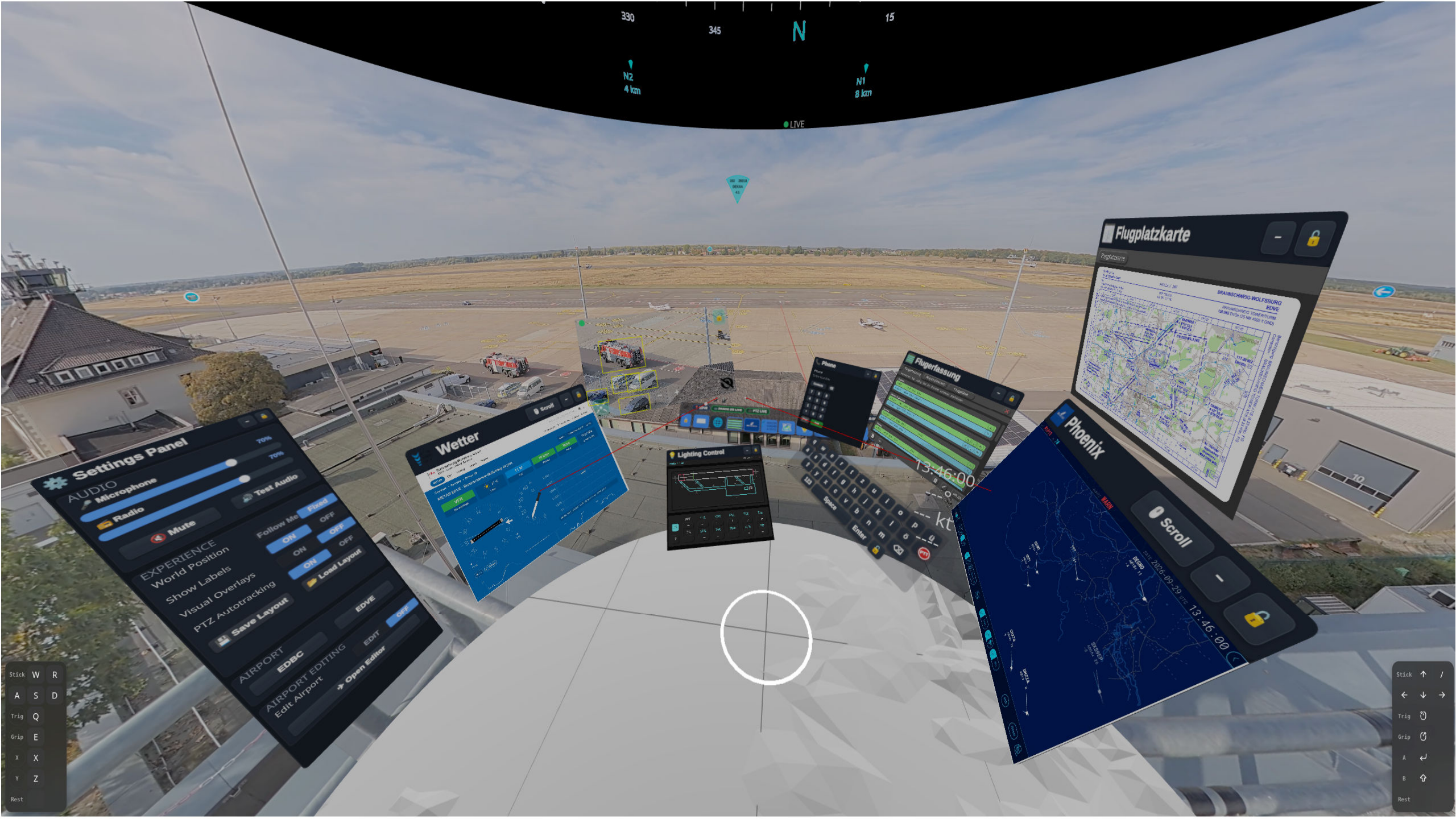
+ network costs
+ camera set-up
+ others

Virtual Tower Building Block



VIRTUAL TOWER

Remote-controlled airports ('remote towers') operated from a central remote tower centre are already in use around the world and are becoming increasingly important. Researchers at the DLR Institute of Flight Guidance are now going one step further: what if an air traffic controller's entire workplace, including the view from the tower and all necessary interactions and information, were transferred to a virtual environment, allowing them to work from anywhere? Instead of being tied to the airport tower or a remote tower centre, air traffic controllers or AFISOs could control aerodrome traffic from anywhere in the world. Expensive and maintenance-intensive hardware and infrastructure would no longer be necessary. All that would be needed is a VR headset and a secure internet access.



330

345

15

N

N2
4 km

N1
8 km

LIVE

Flugplatzkarte

Flugplatzkarte

-

🔒

Wetter

Lighting Control

Flugplatzkarte

Phoenix

Scroll

-

🔒

Settings Panel

AUDIO

Microphone

Radio

Mute

EXPERIENCE

World Position

Show Labels

Visual Overlays

PTZ Autotracking

Save Layout

AIRPORT

EDBC

AIRPORT EDITING

Edit Airport

Stick W R
A S D
Trig Q
Grip E
X X
Y Z
Rest

Stick ↑ /
← ↓ →
Trig ⏻
Grip ⏻
A ↶
B ↷
Rest

PTZ View from EDVE to Brocken (55km away)

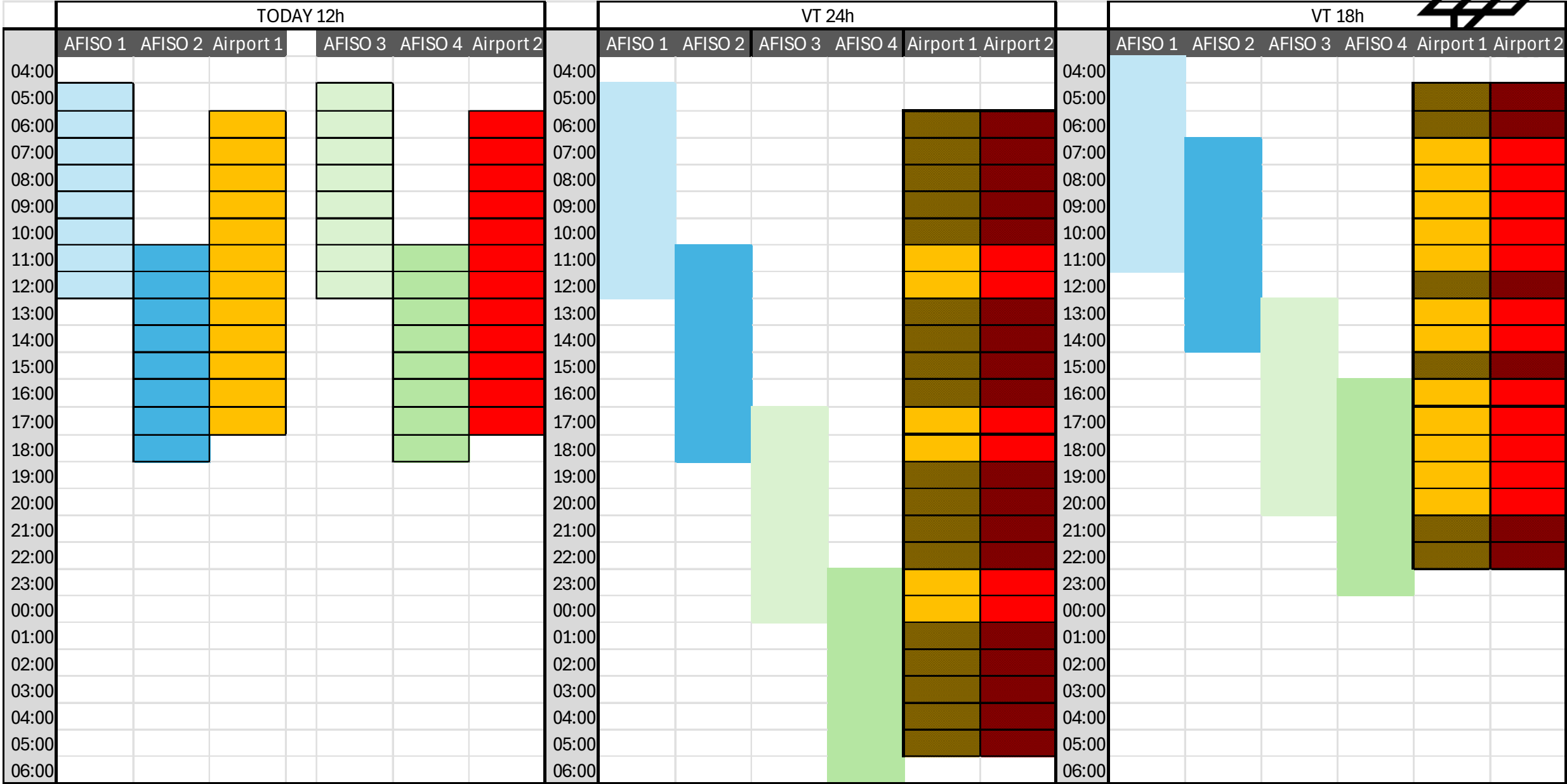




Use Cases

- Cost-effective Multiple Remote Air Traffic Service (ATS) to small airports, particularly during off-peak hours
- Flexible Prior Permission Requests (PPRs) during Tower off-shift times (during night for instance) to serve them from a remote position (from an RTC or even from home)
- ATC or AFIS on demand
Airports often face the challenge of needing higher service levels (e.g., ATC instead of AFIS) only at specific times. Permanently maintaining such capabilities can be costly and inefficient.
- Increased Versatility for Training and Contingency Operations
- Emergency responsiveness
Virtual Tower allows additional ATS support to be deployed instantly from remote locations
- Enhanced Situational Awareness for other Stakeholders
such as fire brigades, search and rescue (SAR) teams, and ground operations
- Automatic Detection & Tracking
Advanced sensor integration within the Virtual Tower enables automatic detection and tracking of objects such as operational traffic, but also drones or other potential security threats

Use Case: Cost-effective Multiple Remote Air Traffic Service (ATS) to small airports, particularly during off-peak hours



- Complete Tower CWP in Virtual Reality
incl. 360° Panorama + PTZ, Radar, interactive e-Flight Strips, Radio, VCS, Light Board, charts, MET, ambient sound (all web based panels – easily to be integrated and fully interactive)
- Location independent (VR glasses wireless via WiFi / VPN and batterie)
- No hardware, except of VR glasses, a server and cameras
- CWP updates and harmonization via software updates

= much more flexible and
much more cost-effective (factor 10+)

Study at the DLR site in Braunschweig (2023)* with 15 ATCOs & 7 AFISOs in shadow mode with life EDVE traffic



- Cyber sickness within acceptable levels ✓

- Usability ✓

- Very good results for UI
- Good results for PTZ camera movement



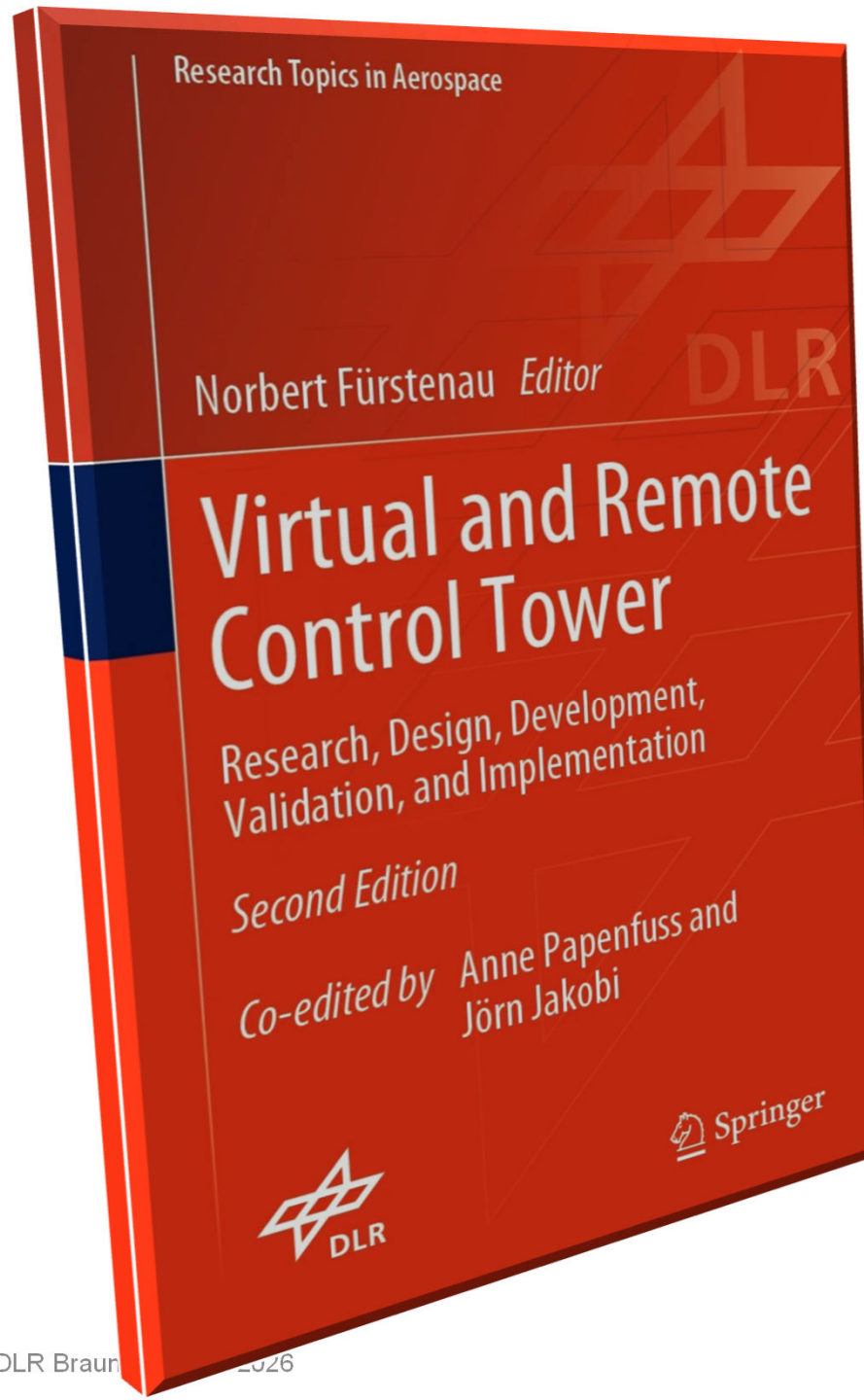
- ATCO/AFISO's found the freehand interactions with the panels very intuitive ✓

- Compared to a traditional RTS with monitors the Virtual Tower felt like being in a real tower ✓

*Schön, Julia and Thielmann, Lucas and Nadobnik, Andreas and Rambau, Tim and Jakobi, Jörn (2025) Prototyping and Evaluation of a Virtual Tower Work Station. In: 35th Conference of the European Association of Aviation Psychology, EAAP 2024. European Association for Aviation Psychology Conference EAAP 35, 2024-09-23 – 2024-09-26, Athen, Griechenland. doi: [10.1016/j.trpro.2025.05.024](https://doi.org/10.1016/j.trpro.2025.05.024). ISSN 2352-1457.

- Jakobi, J., Schön, J., Bagassi, S., Fadda, T. (2026). Presenting ADS-B Labels in a Conventional and in a Remote Virtual Tower Environment: Beneficial or Disruptive?. In: Tareq Ahram and Tibor Barath (eds) Human Interaction and Emerging Technologies (IHET-FS 2026): Future Systems and Design Applications. AHFE (2026) International Conference. AHFE Open Access, vol -1. AHFE International, USA. <https://doi.org/10.54941/ahfe1007282>
- P. S. Nonis, J. Schön, A. Nadobnik, T. Rambau and J. Jakobi (2025) "Performance Differences Between H. 264 and H. 265 Video Compression Standards in the Context of a Remote Tower Optical System," *Integrated Communications, Navigation and Surveillance Conference (ICNS)*, Brussels, Belgium, 2025, pp. 1-8, doi: 10.1109/ICNS65417.2025.10976897.
- Schön, Julia and Thielmann, Lucas and Nadobnik, Andreas and Rambau, Tim and Jakobi, Jörn (2025) Prototyping and Evaluation of a Virtual Tower Work Station. In: 35th Conference of the European Association of Aviation Psychology, EAAP 2024. European Association for Aviation Psychology Conference EAAP 35, 2024-09-23 – 2024-09-26, Athen, Griechenland. doi: [10.1016/j.trpro.2025.05.024](https://doi.org/10.1016/j.trpro.2025.05.024). ISSN 2352-1457.
- Schön, Julia und Jakobi, Jörn und Felten, Sina und Troyer, Giulia und Nadobnik, Andreas und Rambau, Tim und Timmermann, Felix (2024) *HD vs. 4K Driven Remote Tower Optical Systems What is the better Optical Sensor?* ACHI 2024 The Seventeenth International Conference on Advances in Computer-Human Interactions, 2024-05-26 – 2024-05-30, Barcelona, Spain. doi: [10.60575/cr9e-t795](https://doi.org/10.60575/cr9e-t795). ISBN 978-1-68558-163-3. ISSN 2308-4138.
- Tews, L., Jakobi, J., Hamann, A., Lenz, H. (2023). Effects of Radio Frequency Cross-Coupling in Multiple Remote Tower Operation on Pilots. In: Harris, D., Li, WC. (eds) Engineering Psychology and Cognitive Ergonomics. HCII 2023. Lecture Notes in Computer Science(), vol 14018. Springer, Cham. https://doi.org/10.1007/978-3-031-35389-5_12
- Opower, Helena and Jakobi, Jörn (2022) Design Study for a Virtual Work Station for Aerodrome Air Traffic Service Officers. In: 34th European Association for Aviation Psychology, EAAP 2022. The 34th EAAP Conference, 26.09.2022 – 30.09.2022, Gibraltar. doi: [10.1016/j.trpro.2022.12.012](https://doi.org/10.1016/j.trpro.2022.12.012). ISSN 2352-1457
- Reuschling, Fabian and Jakobi, Jörn (2022) Designing a low-cost Remote Tower Solution. In: Virtual and Remote Tower (2nd edition) – Research, Design, Development, Validation and Implementation Research Topics in Aerospace. Springer Publishers. Seiten 543-566. doi: [10.1007/978-3-030-93650-1_22](https://doi.org/10.1007/978-3-030-93650-1_22). ISBN 978-3-030-93649-5. ISSN 2194-8240
- Jakobi, J., Hagl, M. (2022). Which Minimum Video Frame Rate is Needed in a Remote Tower Optical System?. In: Fürstenau, N. (eds) Virtual and Remote Control Tower. Research Topics in Aerospace. Springer, Cham. https://doi.org/10.1007/978-3-030-93650-1_17
- Jakobi, J., Meixner, K.L. (2022). Which Minimum Visual Tracking Performance is Needed in a Remote Tower Optical System?. In: Fürstenau, N. (eds) Virtual and Remote Control Tower. Research Topics in Aerospace. Springer, Cham. https://doi.org/10.1007/978-3-030-93650-1_15
- Friedrich, M., Timmermann, F., Jakobi, J. (2022). Active Supervision in a Remote Tower Center: Rethinking of a New Position in the ATC Domain. In: Harris, D., Li, WC. (eds) Engineering Psychology and Cognitive Ergonomics. HCII 2022. Lecture Notes in Computer Science(), vol 13307. Springer, Cham. https://doi.org/10.1007/978-3-031-06086-1_20
- Hamann, A., Jakobi, J. (2022). Changing of the Guards: The Impact of Handover Procedures on Human Performance in Multiple Remote Tower Operations. In: Fürstenau, N. (eds) Virtual and Remote Control Tower. Research Topics in Aerospace. Springer, Cham. https://doi.org/10.1007/978-3-030-93650-1_14
- Reuschling, Fabian and Jakobi, Jörn (2022) Remote AFIS: Development and Validation of low-cost Remote Tower Concepts for uncontrolled Aerodromes. CEAS Aeronautical Journal, Seiten 1067-1083. Springer. doi: [10.1007/s13272-022-00613-2](https://doi.org/10.1007/s13272-022-00613-2). ISSN 1869-5590
- Friedrich, M., Hamann, A., Jakobi, J. (2020). An Eye Catcher in the ATC Domain: Influence of Multiple Remote Tower Operations on Distribution of Eye Movements. In: Harris, D., Li, WC. (eds) Engineering Psychology and Cognitive Ergonomics. Cognition and Design. HCII 2020. Lecture Notes in Computer Science(), vol 12187. Springer, Cham. https://doi.org/10.1007/978-3-030-49183-3_21
- Reuschling, Fabian and Jakobi, Jörn (2020) Remote AFIS: Entwicklung und Validierung kostengünstiger Remote Tower-Konzepte für unkontrollierte Flugplätze. DLRK 2020, 1.-3. September 2020, Online (originally Aachen, Deutschland)
- A. Papenfuss, F. Reuschling, J. Jakobi, T. Rambau, E. Michaelsen and N. Scherer-Negenborn (2020) "Designing a fusion of visible and infra-red camera streams for remote tower operations," *IEEE Aerospace Conference*, Big Sky, MT, USA, 2020, pp. 1-11, doi: 10.1109/AERO47225.2020.9172645.
- M. Hagl, M. Friedrich, J. Jakobi, S. Schier-Morgenthal and C. Stockdale (2019) "Impact of Simultaneous Movements on the Perception of Safety, Workload and Task Difficulty in a Multiple Remote Tower Environment," *2019 IEEE Aerospace Conference*, Big Sky, MT, USA, 2019, pp. 1-9, doi: 10.1109/AERO.2019.8741904.
- Hagl, M. et al. (2018). Augmented Reality in a Remote Tower Environment Based on VS/IR Fusion and Optical Tracking. In: Harris, D. (eds) Engineering Psychology and Cognitive Ergonomics. EPCE 2018. Lecture Notes in Computer Science(), vol 10906. Springer, Cham. https://doi.org/10.1007/978-3-319-91122-9_45

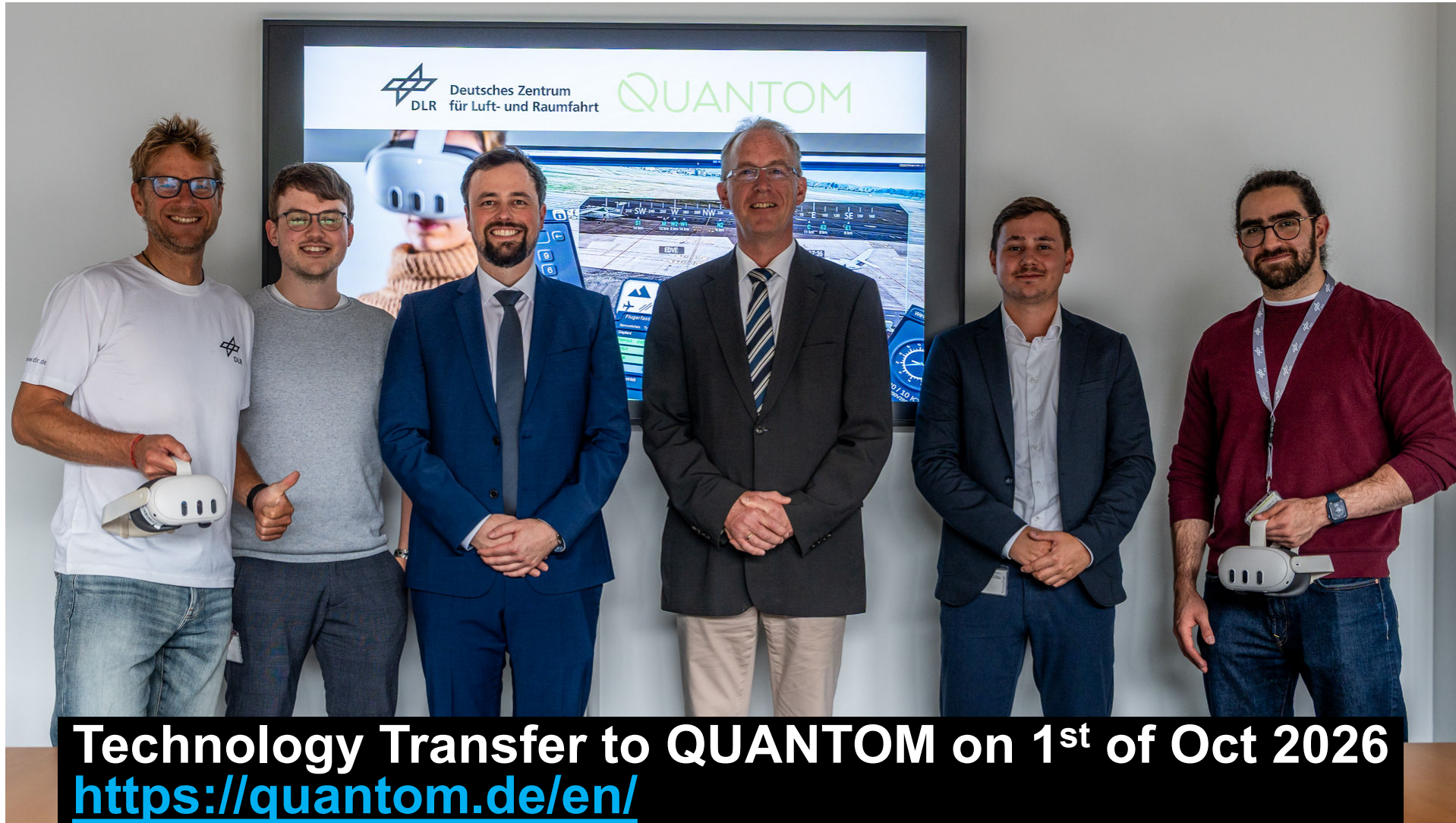
2nd Edition (2022)
„DLR Remote Tower Book“



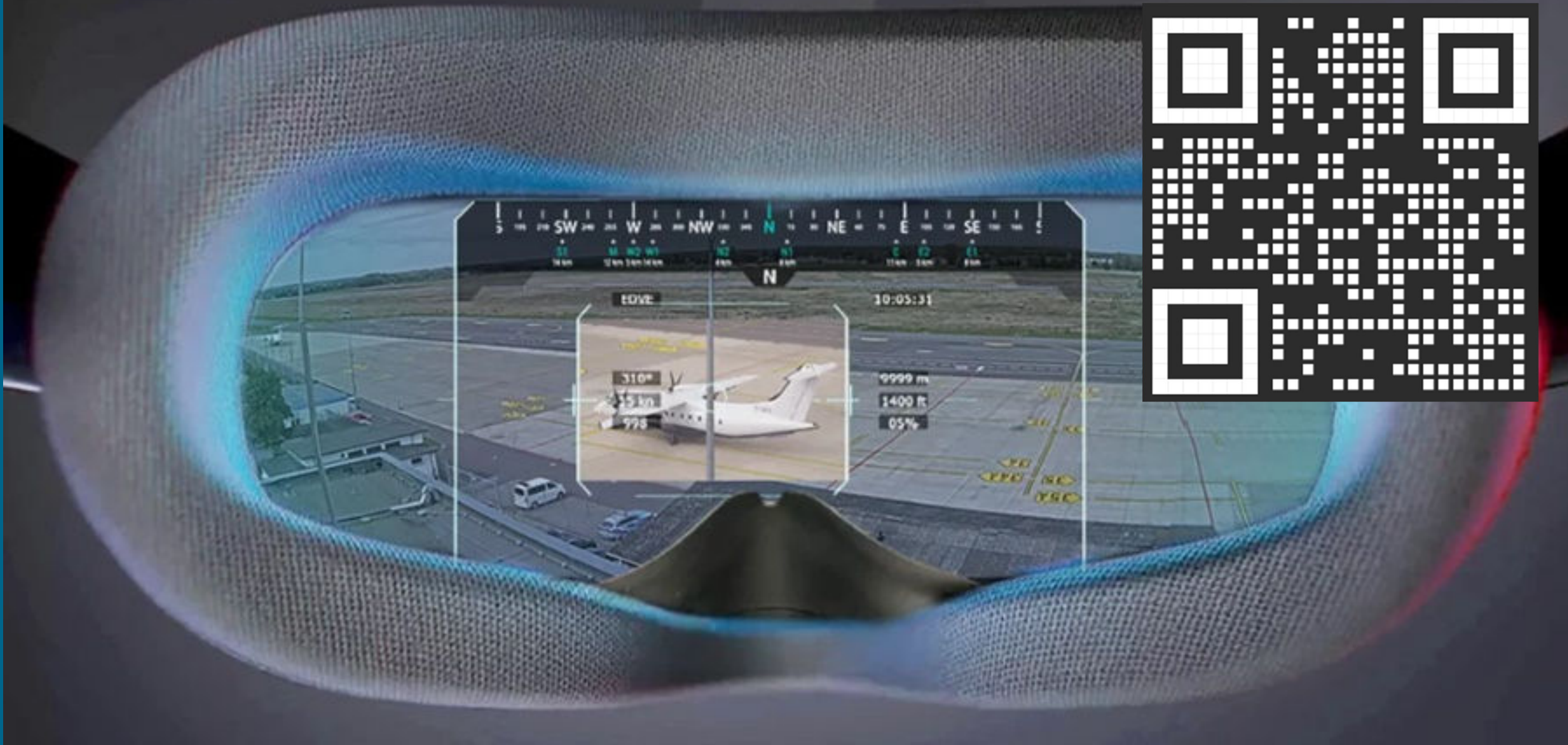


Deutsches Zentrum
für Luft- und Raumfahrt

QUANTOM



Technology Transfer to QUANTOM on 1st of Oct 2026
<https://quantom.de/en/>



www.virtual-tower.de

[joern.jakobi \(at\) dlr.de](mailto:joern.jakobi@dlr.de)