Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

Flight Calibration Services

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Institut für Grundlagen der Elektrotechnik und Messtechnik
Fachgebiet Elektromagnetische Verträglichkeit

Leibniz Universität Hannover

# WERAN

## Interaction of Wind Turbines and Terrestrial Navigation / Radar Systems

**T. Schrader, J. Bredemeyer, C. Stupperich, H. Garbe**

EMWT 2017
Braunschweig, 6.-7.12.2017

Gefördert durch:

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

FKZ: 0325644A-D

# Programm EMWT 2017


## 06.12.2017

| | |
|---|---|
| 13:00 – 13:15 | Einführung WERAN Abschluss-Workshop<br>*PTB Braunschweig, Dr. T. Schrader* |
| 13:15 – 13:45 | Entwicklung der Flugmessplattform<br>*PTB Braunschweig, Dr. M. Mihalachi* |
| 13:45 – 14:15 | Messtechnik Radar und Ergebnisse<br>*FCS Flight Calibration Services GmbH, Dr. J. Bredemeyer* |
| 14:15 – 15:00 | Messtechnik Drehfunkfeuer und Ergebnisse<br>*PTB Braunschweig, Dr. T. Schrader* |
| 15:00 – 15:30 | Kaffeepause |
| 15:30 – 16:00 | Messtechnik Windprofiler und Wetterradar<br>*FCS Flight Calibration Services GmbH, Dr. J. Bredemeyer* |
| 16:00 – 17:00 | Numerische Simulationen<br>*Leibniz Universität Hannover, S. Sandmann/D. Härke* |
| 17:00 – 17:30 | Abschlussdiskussion |
| Ab 17:30 | Get together/Imbiss |

20:00 and 21:00 Bustransfer to Braunschweig City

# Programm EMWT 2017


## 07.12.2017

| | |
|---|---|
| 9:00 – 9:30 | Verträglichkeit von radioastronomischen Messungen und Windenergieanlagen<br>*Max-Planck-Institut für Radioastronomie, Dr. B. Winkel* |
| 9:30 – 10:00 | Über Numerische 3D-Systemsimulationen und Systeme für Windkraftanlagen<br>*NAVCOM Consult, Dr. G. Greving* |
| 10:00 – 10:30 | Einfluss von Windparks auf moderne ASR Radarsysteme<br>unter Berücksichtigung von Multilevel-Doppler-Filterprozeduren<br>*Airbus Defence and Space, Dr. A. Frye* |
| 10:30 – 11:00 | Kaffeepause |
| 11:00 – 11:30 | Elektromagnetische Modellierung von zeitvarianten Effekten durch Windenergieanlagen<br>*Fraunhofer Institut, Dr. F. Weinmann* |
| 11:30 – 12:00 | Richtungsabhängiges Radarecho von Windenergieanlagen<br>*Jade Hochschule, Wilhelmshaven, K. Schubert* |
| 12:00 – 12:30 | Analysis and simulation of micro-Doppler features of wind turbine's clutter:<br>recent progress in extensions of TU Delft's simplified model<br>*TU Delft, Dr. O. Krasnov* |
| 12:30 – 13:00 | Abschlussdiskussion |

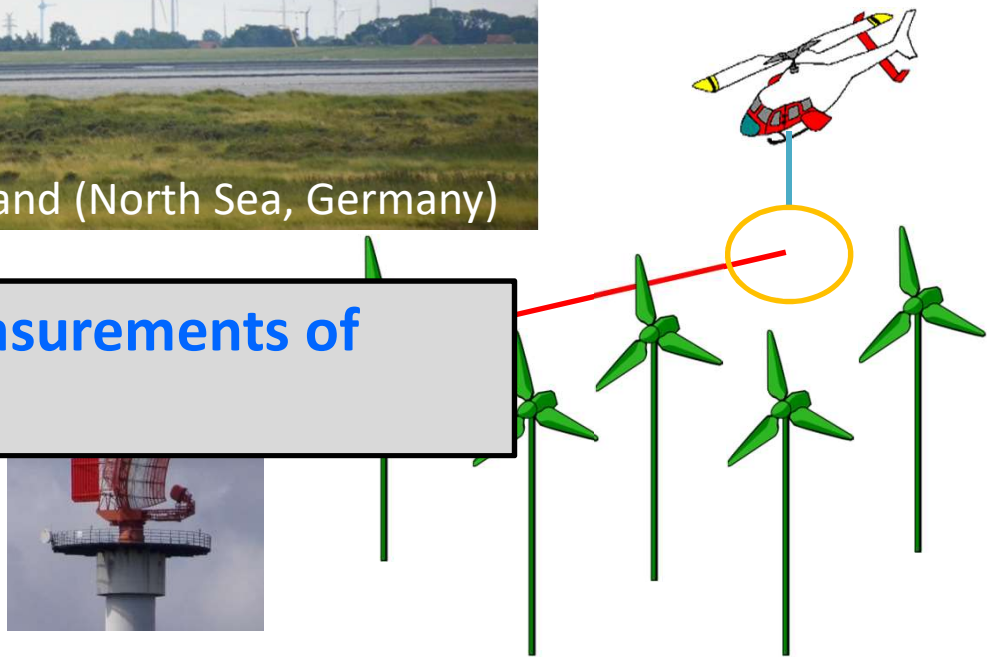
# Content

- EMC Problem and Background
- Economic Dimension
- Technical systems
- Scientific Approach
- Project team

# EMC Problem and Background


View southwards from Langeoog island (North Sea, Germany)

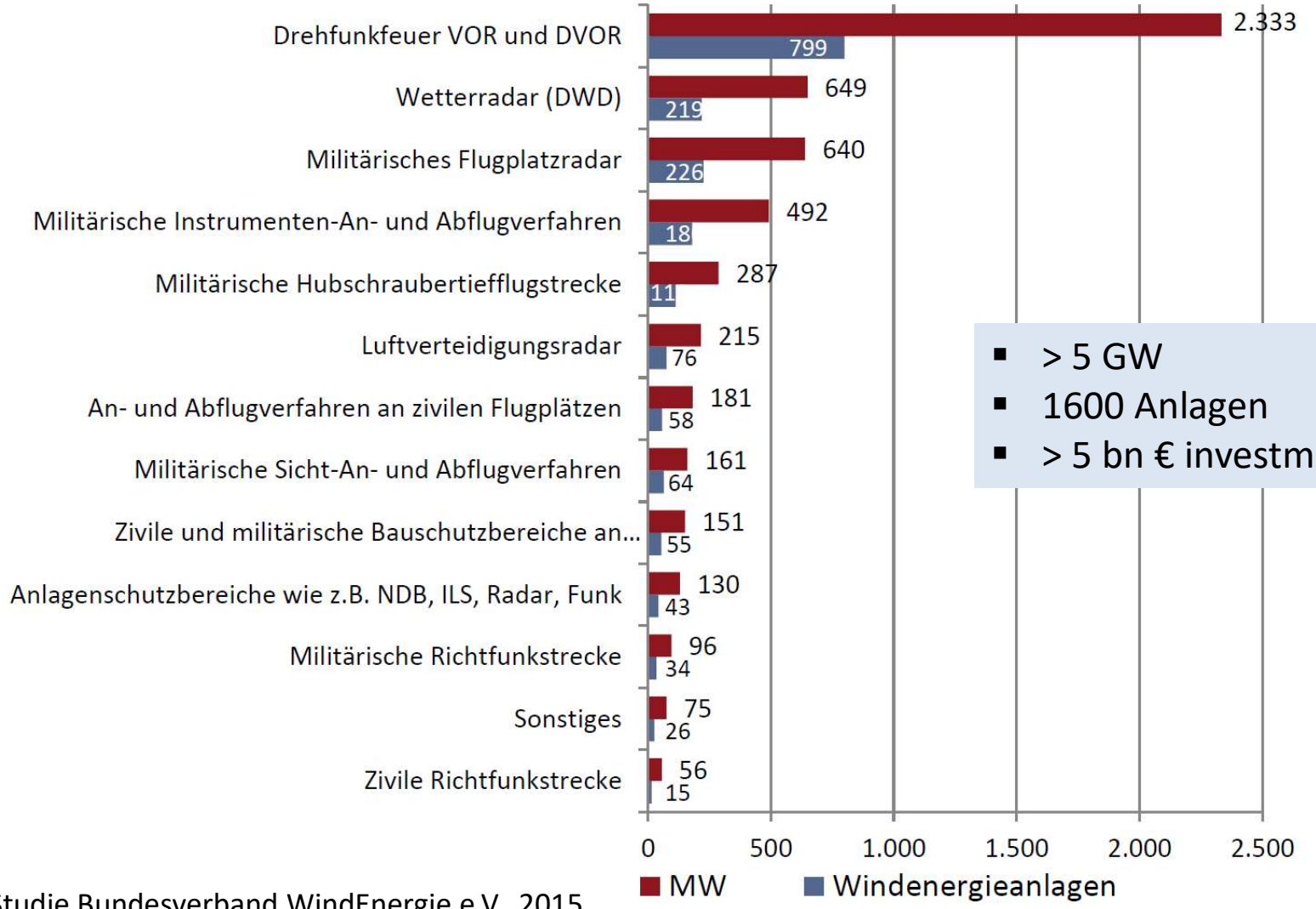
**Need for On-Site measurements of signal integrity**





- Area within 15km (10 km) radius around navigation aid or radar subject to survey per ICAO EUR DOC 015. National law per LuftVG §18a.
- „Safety radius“ also requested by DWD for weather radar / wind profiler.

# Economic Dimension



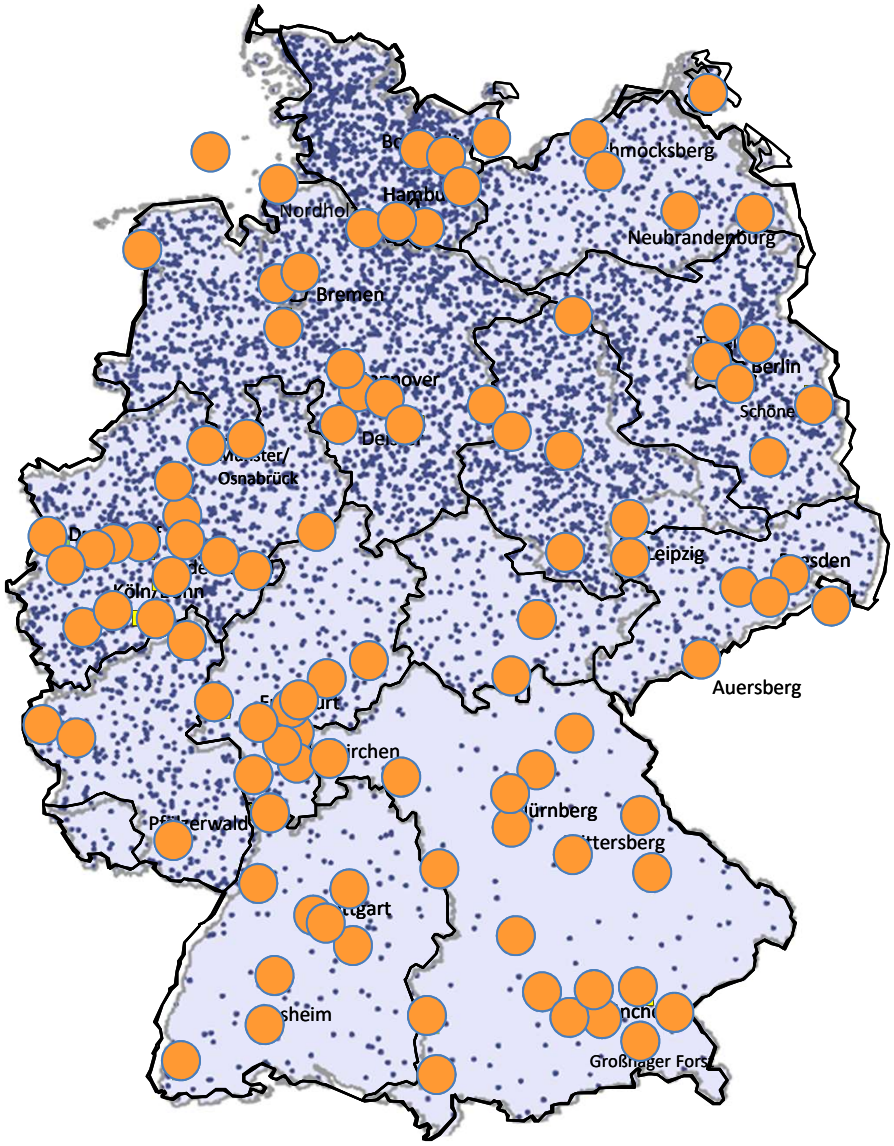

- > 5 GW
- 1600 Anlagen
- > 5 bn € investments

Source: Studie Bundesverband WindEnergie e.V., 2015

# Technical Systems

| | |
|---|---|
| Non-directional beacons (NDB) and direction finder (ADF) | 500 kHz |
| VHF Omnidirectional radio range (CVOR, DVOR) | 112 MHz |
| Airport surveillance radar (ASR) | 2,7 GHz |
| Military radar systems (LVR) | some GHz |
| DWD weather radar (C-Band precipitation radar) | 5,6 GHz |
| DWD UHF Wind profiler | 482 MHz |

# Map of Wind Turbines, VOR and Radar systems, 2009




DFS-Radaranlagen ASR
Airport surv. radar 100 km

Weather radar 150 km

VOR / DVOR

15 km radius

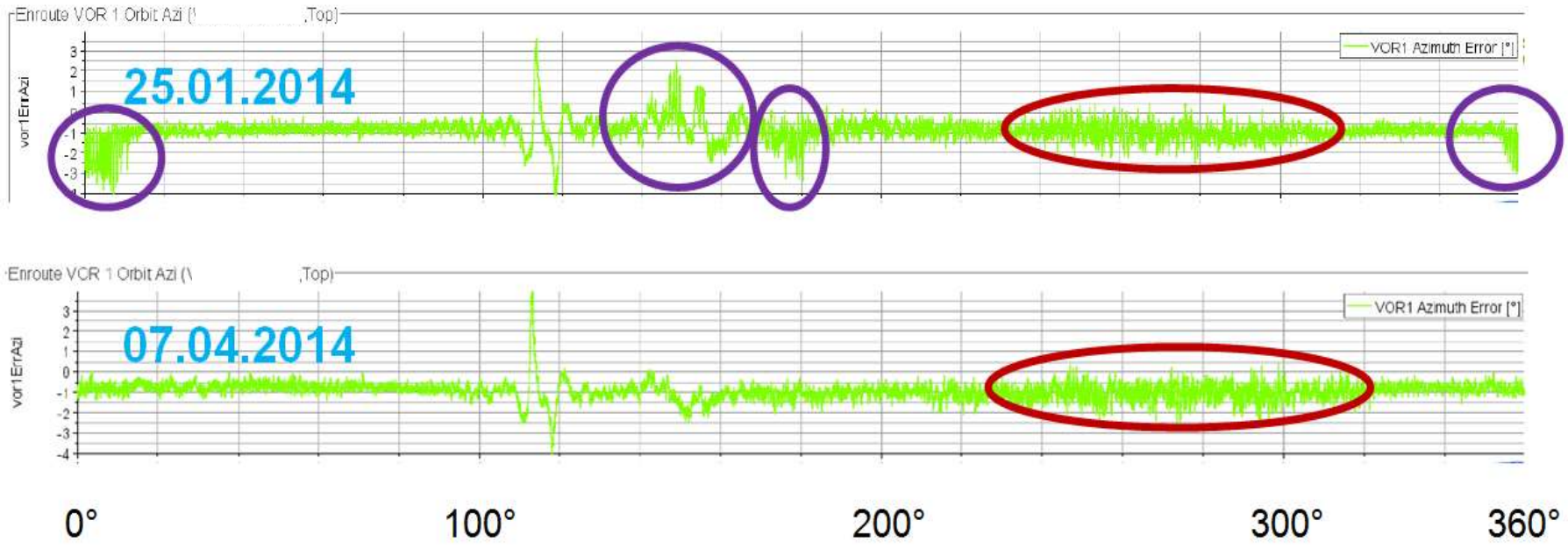
One point = 3 WT

22.000 WT total in DE, 2016

## Doppler-VOR (D-VOR) groundstation w/ DME

source: Wikipedia

# Observation: Noise of Bearing Error




Conventional Flight inspection:

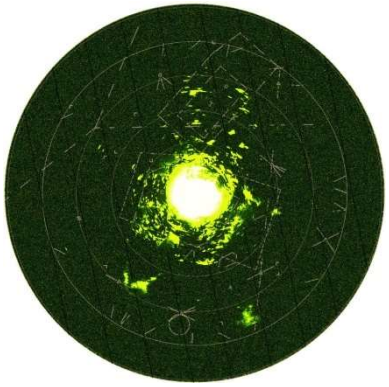
- Aircraft is flying in a circle (orbit) around the DVOR, radius 10 NM
- Two subsequent observations
- Line 2 shows improvements (antenna repair, cut of trees)
- What influence is caused by additional WT or Repowering?

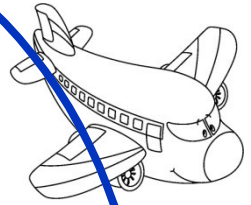
# Scientific Approach

parts of the communication channel

nonlinear part
(radar signal processing)

linear part
(channel, wave propagation)

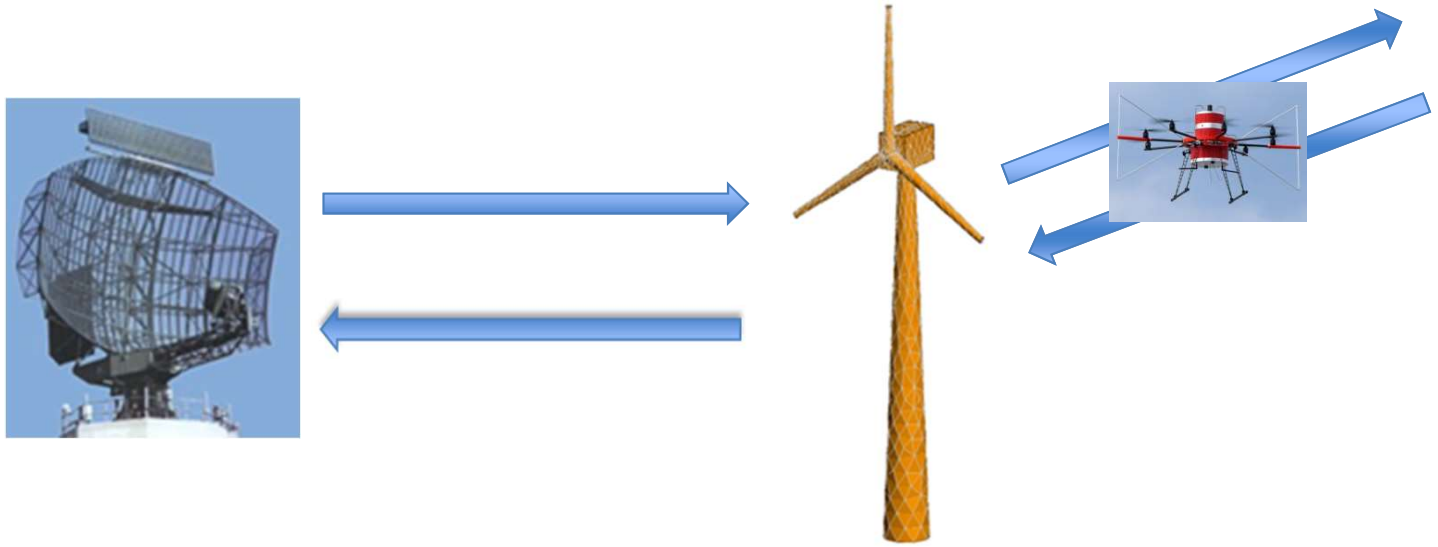




# Scientific Approach

linear part of signal propagation channel:

on-site measurement of wave propagation and numerical simulation



# Aim of the project WERAN regarding DVOR

**Identification & quantification of the additional bearing error caused by interference of wind turbines with DVOR.**

- Determine change of signal content of electromagnetic fields behind wind turbines (signal integrity)
- Where possible: Obtain impact on key value such as bearing error
- Conventional flight inspection using typical VOR receiver can not dissolve this issue:
  - as only processing the full bandpass signal renders the information on AM and FM separately.
  - aircraft can not hover in critical area behind WT to show the effect
- Understanding of the complete problem (signal-in-space consist of FM and AM).
- Design of measurement procedure, UAS-based instrumentation and data evaluation software.
- Numerical simulations

**Agreement between measurement and numerical simulation → probing suitable signals (EM fields)**

UAS: unmanned aerial system

# Project Partners of WERAN

| Partner | Ansprechpartner | Adresse |
|---|---|---|
| Physikalisch-Technische Bundesanstalt (PTB) Fachbereich 2.2: Hochfrequenz und Felder | Dr. Thorsten Schrader (Verbundkoordinator) | Bundesallee 100 38116 Braunschweig |
| Leibniz Universität Hannover Institut für Grundlagen der Elektrotechnik und Messtechnik | Prof. Dr. Heyno Garbe | Appelstraße 9a 30167 Hannover |
| FCS Flight Calibration Services GmbH | Dr. Jochen Bredemeyer | Hermann-Blenk-Str. 32A 38108 Braunschweig |
| steep GmbH | Christoph Stupperich | Justus-von-Liebig-Str. 18 53121 Bonn |

Non-funded Partners:
German Air Traffic Control (Dt. Flugsicherung)
German Weather Service (DWD)

Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages
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# Summary

- Investigation of interaction between WT und terrestrial nav / radar
- Measurement of the linear part of the „communication channel“
- On-Site Measurements of signal integrity
  - with and w/out wind turbines
  - rotating turbines vs. static objects
  - conventional and radar flight inspection
- Realistic numerical simulation of the linear part of the RF channel
- Validation of numerical results by measurements
- Determine signal integrity
- Operator decides about tolerable „change“ of key value such as bearing error

# Acknowledgement - Team of WERAN project



Christoph Stupperich
Christoph Brenner


Heyno Garbe
Sergei Sandmann
Dominic Härke


Jochen Bredemeyer
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