INTERNATIONAL ENERGY AGENCY

Implementing Agreement for Co-operation in the Research, Development and Deployment of Wind Turbine Systems
Task 11

60th IEA Topical Expert Meeting

"Radar, Radio links and Wind Turbines"

November 18-19, 2009
Marine Kazerne, Kattenburgerstraat 7, Amsterdam

SENTERNOVEM - NETHERLANDS

Organized by: CENER


Scientific Co-ordination:

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For more information about IEA Wind see www.ieawind.org

International Energy Agency

Implement Agreement for Co-operation in the Research, Development and Deployment of Wind Turbine Systems: IEA Wind

The IEA international collaboration on energy technology and RD&D is organized under the legal structure of Implementing Agreements, in which Governments, or their delegated agents, participate as Contracting Parties and undertake Tasks identified in specific Annexes.

The IEA's Wind Implementing Agreement began in 1977, and is now called the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems (IEA Wind). At present, 24 contracting parties from 20 countries, the European Commission, and the European Wind Energy Association (EWEA) participate in IEA Wind. Australia, Austria, Canada, Denmark, the European Commission, EWEA, Finland, Germany, Greece, Ireland, Italy (two contracting parties), Japan, the Republic of Korea, Mexico, the Netherlands, Norway (two contracting parties), Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States are now members.

The development and maturing of wind energy technology over the past 30 years has been facilitated through vigorous national programs of research, development, demonstration, and financial incentives. In this process, IEA Wind has played a role by providing a flexible framework for cost-effective joint research projects and information exchange.

The mission of the IEA Wind Agreement continues to be to encourage and support the technological development and global deployment of wind energy technology. To do this, the contracting parties exchange information on their continuing and planned activities and participate in IEA Wind Tasks regarding cooperative research, development, and demonstration of wind systems.

Task 11 of the IEA Wind Agreement, Base Technology Information Exchange, has the objective to promote and disseminate knowledge through cooperative activities and information exchange on R&D topics of common interest to the Task members. These cooperative activities have been part of the Wind Implementing Agreement since 1978.

Task 11 is an important instrument of IEA Wind. It can react flexibly on new technical and scientific developments and information needs. It brings the latest knowledge to wind energy players in the member countries and collects information and recommendations for the work of the IEA Wind Agreement. Task 11 is also an important catalyst for starting new tasks within IEA Wind.

IEA Wind TASK 11: BASE TECHNOLOGY INFORMATION EXCHANGE

The objective of this Task is to promote disseminating knowledge through cooperative activities and information exchange on R&D topics of common interest. Four meetings on different topics are arranged every year, gathering active researchers and experts. These cooperative activities have been part of the Agreement since 1978.

Two Subtasks

The task includes two subtasks. The objective of the first subtask is to develop recommended practices for wind turbine testing and evaluation by assembling an Experts Group for each topic needing recommended practices. For example, the Experts Group on wind speed measurements published the document titled "Wind Speed Measurement and Use of Cup Anemometry". A document dealing with Sodar measurements are presently under development.

The objective of the second subtask is to conduct topical expert meetings in research areas identified by the IEA R&D Wind Executive Committee. The Executive Committee designates topics in research areas of current interest, which requires an exchange of information. So far, Topical Expert Meetings are arranged four times a year.

Documentation

Since these activities were initiated in 1978, more than 60 volumes of proceedings have been published. In the series of Recommended Practices 11 documents were published and five of these have revised editions.

All documents produced under Task 11 and published by the Operating Agent are available to citizens of member countries participating in this Task.

Operating Agent

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Canada	National Resources Canada
Denmark	Risø National Laboratory - DTU
European Commission	European Commission
Finland	Technical Research Centre of Finland - VTT Energy
Germany	Bundesministerium für Unwelt , Naturschutz und Reaktorsicherheit -BMU
Ireland	Sustainable Energy Ireland - SEI
Italy	CESI S.p.A. and ENEA Casaccia
Japan	National Institute of Advanced Industrial Science and Technology AIST
Republic of Korea	POHANG University of Science and Technology - POSTECH
Mexico	Instituto de Investigaciones Electricas - IEE
Netherlands	SenterNovem
Norway	The Norwegian Water Resources and Energy Directorate - NVE
Spain	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas CIEMAT
Sweden	Energimyndigheten
Switzerland	Swiss Federal Office of Energy - SFOE
United Kingdom	Uk Dept for Bussines, Enterprises & Regulatory Reform - BERR
United States	The U.S Department of Energy -DOE

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1. INTRODUCTORY NOTE

Prepared by SenterNovem, in cooperation with the Dutch Ministry of Defence and the Dutch Ministry of Economic Affairs

1.1 INTRODUCTION

Two IEA Topical Expert Meeting on the Topic "Radar, Radio Links and Wind Turbines" were organized in March 2007 (Oxford, UK) and March 2005 (London, UK). The last meeting was very well-attended with 34 participants, representing seven countries. There was general consensus that the meeting brought to light the varying methods and attitudes, adopted by IEA member countries, in handling issues that exist as a result of interference between radar/radio link systems and wind turbines.

One of the main conclusions about the continuation actions within this area was to arrange future TEM's in this issue, that should include a session for 'break-out' workshops to enable technical Sub Groups to discuss specific topics.

Since the development of wind energy there seems to be a conflict between a sustainable energy supply and air traffic safety as well as safeguarding national security.

The development of wind farms onshore and offshore as a rational and sustainable source of renewable energy interferes with radar surveillance and radio communications. Wind turbines produce shadow in radar beams, the moving blades cause reflections and the intermittent clutter can create false tracks, obscure or seduce real targets. The rotating blades defeat traditional Moving Target Indicator processing. In short: wind turbines cause a lot of trouble.

As the wind turbines and the wind energy sector are the new-comers many wind energy initiatives are frustrated or even put on hold. Different countries apply different rules but as wind energy booms, methods for dealing with the conflict are emerging.

As renewable energy supply, national security and air traffic safety are all of high public interest, it is important to find solutions that satisfy all interests. In the last decade a dialogue has evolved and we see new developments in energy, in air surveillance system as well as new scientific insight. This dialogue and technical developments lead to new possible policies and technical solutions to resolve the conflict.

1.2 EXCHANGE OF KNOWLEDGE

In the previous IEA R&D Topical Expert Meetings on the subject "Radar, Radio and Wind turbines" the effects of wind turbines on radar and radio systems have been presented from the perspective of wind farm and radar system operators. Mitigating techniques and ways to work around the policy issues have been discussed.

The exchange of knowledge and ideas proved to be fruitful as it helped to achieve a common understanding and to overcome differences in the perception of the problem. It was helpful also to share knowledge of the differences in national (planning) policies.

The latest Topical Expert Meeting concluded that further research was needed and that an international standard for safety and acceptance would be helpful. The questions put on the agenda were:

- What criterion /specification is needed to be met by technologies?
- What is an acceptable limit of interference?

What is the situation two years on? What new insights have occurred and what answers to these questions have been found. What are the developments in the conflicting systems (radar and wind)?

In the meeting to be organised in November 2009 experts on this subject from science, radar industry, wind turbine industry, radar system operators and policy makers are invited to exchange knowledge and to come to a common understanding of the developments, conflicts and their solutions.

1.3 RECENT DEVELOPMENTS

Without being exhaustive several developments show that the challenges of enabling radar surveillance to coexist with wind energy development are on the brink of being found.

In the USA new energy policy promotes the proliferation of wind farms and new rules for siting are discussed. In Sweden research projects lead to the conclusion that a more flexible approach will enable resolution of more conflicts between wind turbines and radar.

In the UK new Guidance to air traffic and wind turbine industries has been developed and published.

The radar industry is actively developing mitigation strategies to counter the negative effects of Wind Farms upon radar coverage. BAE Systems, Raytheon, Thales and others all work hard on new techniques for enabling continued aircraft detection within wind turbine clutter. But also knowledge institutions develop new insights which are of increasing interest to the radar and wind turbine communities.

Within NATO dedicated SET group meetings on the subject were organised between air traffic controllers and radar industry.

In responses to increasing reports of interference between surveillance sensors and wind turbines, the EUROCONTROL Surveillance Team established a Wind Turbine Task Force. In June 2009 EUROCONTROL presented draft “Guidelines on how to assess the potential impact of wind turbines on surveillance sensors”. The consultation process has started and will end on 29 January 2010.

1.4 TOPICS 2009

When wind turbines are located in the line of sight of a radar system a variety of interference effects may occur, as shadowing, cluttering, false tracks, loss of track etc. These phenomena have an effect on the air surveillance system and can therefore adversely affect wind farm development. The main topic for this meeting is therefore the emerging standards for safety and security.

Topics for the discussion at this meeting will be:

- Policies
    - Development of standards and measuring tools

  - Terms and definitions for safeguarding the level of performance of air surveillance systems
  - Planning policies, institutions and tools
  - Expanding the energy system and increasing safety and national security
- Types of interference
  - Interference between a single turbines or a farm and radar systems
  - Understanding explanation
  - Categorizing, calculating
  - Predicting
- Technical possibilities to mitigate
  - Software & technology in the radar system
  - Location & shielding in the energy system
  - Stealth technology, materials
  - Other Innovations

1.5 PAPERS AND PRESENTATIONS

Experts who plan to attend the meeting are invited to write a paper and/or present their findings in the two day meeting. The presentation and paper should address one of the topics above and might answer one of the following questions:

1. *Process and policy*

- What standards are formulated by whom to safeguard the level of performance of air surveillance systems, and in what terms and definitions;
- How are these standards integrated in planning policies and institutions;
- What kind of tools are used to measure the standards, or the performance;
- Which policies meet the challenge to expand the energy system whilst maintaining required levels of air safety and national security;
- Which effects are acceptable and to what extent; can their impact on the mission of the radar-system be negligible;
- In what terms and how are the aim and expected results of the respective mission (ATC, Weather forecast, national security) formulated;
- For each country is there a process of formulating mission standards and what does this process look like;
- How can formulated safety standards be translated into a level of probability of detection;
- What effects influence the probability of detection most and when concurrently;
- Which effects occur with just one turbine and which effects occur for multiple turbines.

2. *Technical issues*

- How is energy system technology evolving with respect to stealth design, use of materials and sitting;
- What recent research has been done;
- How is radar system technology evolving with respect to data fusion, multi radar tracking, software, filters etc. and hardware;
- What kind of mitigating measures are effective and feasible;
- What questions have still to be answered by whom (further research).

AGENDA

Wednesday, November 18, 2009

9:00 **Registration**. Collection of presentations and final Agenda

9:30 **Introduction by Host**
Jansen Albert, Senior Programma Adviseur , SenterNovem , NL

9:50 **Introduction by AIE Task 11 Operating Agent. Recognition of Participants**
Felix Avia, Operating Agent Task 11

10:10 **Presentation of Introductory Note**
Jansen Albert, Senior Programma Adviseur , SenterNovem , NL

10:30 **Overview of Present Situation**
Mike Watson, Pager Power Limited

11:00 Coffee Break

1st Session Individual Presentations:

11:30 **Wind Radar Issues in the USA: a 2009 Update**
Gary Seifert, Idaho National Lab, USA

12:00 **Impact of Wind Farms on Marine Radar**
Anthony Brown, Univ.of Manchester-Faculty of Engineering & Physical Sciences, UK

12:30 **On the need to identify small, slow & low flying targets**
L.S Buurma, Military Aviation Authority NLD, Netherlands

13:30 Boat Trip and Lunch

2nd Session Individual Presentations:

16:00 **Development of a wind turbine acceptance tool**
Arne Theil,

16:30 **Radar disturbances by obstacles**
Gert Brussard, Radicom Consultant, Netherlands

17:00 **The position of the European Wind Industry**
Nicolas Fichaux,

17:30 **Coffee Break**

18:00 **Monitoring effects of wind parks at sea**
Anton Klip

18:30 **Wind Turbines in the radiation field of systems from an analysis and coexistence point of view " / EUROCONTROL Guidelines**
Gerhard Greving, NAVCOM Consulting; Germany

19:30 Adjourn
20:00 Dinner at Marine Kazerne

Thursday, November 19, 2009

4th Session Individual Presentations

09:00 **EUROCONTROL Guidelines**
Michel Borely, Eurocontrol, Belgium
09:25 **Theoretical and Measurement results of the effects of wind turbines of military radar systems and technical assessment methods**
Andreas Frye, EADS Deutchland GmbH, Germany
09:50 **Simulating the electromagnetic interaction between wind turbines and radars**
Markku Sipilä, VVT Technical Research Centre of Finland, Finland
10:15 **Measures in 2D Primary Air Surveillance Radars to Reduce Wind Turbine Echo Interferences**
Chistoph Neumann, EADS Deutchland GmbH, Germany

10:40 Coffee Break

5th Session Individual Presentations

11:00 **Gapfiller concept solution - Sheringham Shoal offshore wind farm**
Eldar Aarholt, Teleplan Consulting, Norway
11:25 **Radar shadow and how it affect surveillance of the sea**
Kjell-Ake Eriksson, Swedish Defence Materiel Organisation, Sweden
11:50 **The effects of wind turbines on the operational use of a radar: a case study**
Mathisi Shouten, TNO, Netherlands
12:15 **Radar and Wind Turbines**
Rene de Jongh, Thales Netherland, B.V.
12:45 **Microwave links and UHF Telemetry**
Kai Frolic, Pager Power Limited, UK

13:15 Lunch

14:00 Discussion

15:30 Summary of Meeting

16:00 Adjourn

1.6 EXPECTED OUTCOME

The goal of the meeting is to gather knowledge on recent developments to make maximum growth of wind energy possible whilst maintaining an acceptable level of safety and security.

By gathering and exchanging information we hope to achieve a common understanding of issues.

These issues are the way wind turbines interfere with radar systems and the developments to handle this interference be it via process, workaround, changing standards, hardware or software of radar systems or via mitigation and developments of wind turbines and farms.

1.7 INTENDED AUDIENCE

The national members will invite potential participants from research institutions, utilities, government other organizations willing to participate in the meeting by means of presenting proposals, studies, achievements, lessons learned, and others.

Summary of IEA RD&D Wind – 60th Topical Expert Meeting

Michael Watson (Pager Power), and Félix Avia (CENER; OA Task 11 IEA Wind),

Background

The development of wind farms interferes with radar surveillance and radio communications. Wind turbines produce shadow in radar beams, the moving blades cause reflections and the intermittent clutter can create false tracks, obscure or seduce real targets. The rotating blades defeat traditional Moving Target Indicator processing.

As renewable energy supply, national security and air traffic safety are all of high public interest, it is important to find solutions that satisfy all interests. In the last decade a dialogue has evolved and we see new developments in energy, in air surveillance system as well as new scientific insight. This dialogue and technical developments lead to new possible policies and technical solutions to resolve the conflict.

Participants / Presentations

A total of 27 persons registered for this meeting. They represented the following countries: Belgium, Finland, Germany, Sweden, Netherlands, Norway, UK and the USA. A total of 18 presentations were given.

The participants represented a great variety of stakeholders related to the topic. Those were: research organizations, universities, consultants, government and military organizations and some manufactures of equipment.

Presentations covered the following topics:

- Policies
  - Planning policies, institutions and tools
  - Terms and definitions for safeguarding the level of performance of air surveillance systems
  - Development of standards and measuring tools
- Types of interference
  - Interference between a single turbines or a farm and radar systems
  - Microwave links and UHF Telemetry
- Technical possibilities to mitigate
  - Software & technology in the radar system
  - Location & shielding in the energy system
  - Stealth technology, materials
  - Other Innovations

A total of 18 presentations were given by:

- *Michael Watson (MW), Pager Power, UK*
- *Gary Seifert (GS), Idaho National Lab, USA*
- *Anthony Brown (AB), Univ. of Manchester-Faculty of Engineering & Physical Sciences, UK*
- *Luit Buurma (LB), Military Aviation Authority, Netherlands*
- *Arne Theil (AT), TNO Defence, Security and Safety, Netherlands*
- *Prof.dr.ir. Gert Brussaard (GB), Radicom Consultants, Netherlands*
- *Nicolas Fichaux (NF), Head of Policy Analysis, European Wind Energy Association*
- *Ir. Anton Klip (AK), Movares Netherland B.V. – MBM, Netherlands*
- *Dr.-Ing. Gerhard Greving (GG), NAVCOM Consult, Germany*
- *Michel Borely (MB) – Secretary of the EUROCONTROL Wind Turbine Task Force, Belgium*
- *Dr- Ing. A. Frye (AF), EADS – MAS, Signature Technology, Germany*
- *Markku Sipilä (MS), Johan Sten, VTT Technical Research Centre of Finland, Finland*
- *Christoph Neumann1 (CN), EADS Deutschland GmbH*
- *Dr Eldar Aarholt (EA), Statoil ASA / Teleplan AS, Norway*
- *Kjell-Ake Eriksson (KE), Swedish Defence Materiel Organisation, Sweden*
- *Mathijs W. Schouten (MW), TNO, The Netherlands*
- *Rene de Jongh (RJ), Thales Netherland, B.V.*
- *Kai Frolic (KF), Pager Power Limited, UK*

Discussion

Following the two days of presentations the floor was opened and a general discussion took place. A number of different topics were handled. The discussion was coordinated by Michael Watson (MW).

In particular, the following topics were discussed:

- Air Traffic Control (ATC) and National Security
- Assessment Methodology
- Mitigation options
- Who has to pay the cost of mitigation options?
- Future actions under the umbrella of IEA Wind

Air Traffic Control ATC and National Security

First topic discussed was the different approaches for air traffic control [ATC] and National Security. The conclusion is that both sectors are working in parallel directions, trying to find solutions.

The solutions should be available in a short period of time, not longer than two years. The progress needs time, but comparing the situation two years ago when the Oxford meeting was held to the present time, it is clear that we have moved from the discussion about ideological positions to the present situation, where the problem is clearly identified and the work is focussed on finding solutions. It is clear that there is a real problem and real work has been done, and now it is time to move one step further, working out how to develop and implement the existing and identified solutions to solve the problem. Publication of the draft EUROCONTROL guidelines is a good example that real progress has been made.

There are different problems and solutions for both ATC and National Security. The tools and approach used for both are similar although acceptance criteria are different.

One of the first issues discussed was the size of the targets to be detected. For ATC in general larger target sizes are of interest, whereas for National Security, there is requirement to detect smaller targets with radar cross section below $1m^2$.

It was concluded that it is very important to coordinate the work in the two sectors, stimulating the cooperation between the responsible organizations.

Assessment Methodology

The participants agreed that it is crucial to have a harmonised assessment process, in all countries, to analyse the impact of wind turbines on radar and to facilitate the understanding between air traffic control entities, national security organizations and wind developers. The actual situation is that several assessment methodologies are used, as was evident from the various studies presented.

In 2005 the EUROCONTROL Wind Turbine Task Force (WTTF) was established, to define a common ECAC methodology for assessing and avoiding or minimising the potential impact of wind turbines on ATC Surveillance systems. This methodology aims to maintain the necessary levels of safety and efficiency of surveillance related Air Traffic Services whilst supporting to the maximum extent possible the installation of wind turbines. The WTTF has published the “Guidelines on How to Assess the Potential Impact of Wind Turbines on Surveillance systems”, that is now open for consultaion until January 2010, before being approved. These guidelines define a flow diagram of the impact assessment process, but not the assessment methodology to be used.

It was discussed a specific assessment methodology should be recommended under the umbrella of IEA Wind, or if it would be better to adopt the existing EUROCONTROL methodology focussing any IEA activityon improving it. The conclusion was that the EUROCONTROL guidelines are a good starting point and resources would be best spent on improving these.

Mitigation options

Data fusion is an excellent option to mitigate and solve the interference to radar systems from wind turbines. One of the main limitations is that no process is defined covering different aspects of data fusion, for example reliability requirements, the level of information required to pass, the acceptability of data (what data is valid or not), etc.

The first option discussed was the possibility to share data between the ATC sector and National Security sector. The problem is that for security reasons, it is sometimes not possible to share this data.

Several European Radar networks already exist in different sectors, (OPERA in meteorology, RADNET for air traffic control, etc) with the target of harmonizing and improving the operational exchange of radar information between national organizations. The air traffic control organizations of the Netherlands, Belgium, Luxembourg and Germany, and the EUROCONTROL Agency jointly operate the RADNET network for supplying control centres with radar data.

The problems associated with data communication were also discussed. There are already different options and in particular the use of optic fibre for data transfer, but in general there is a consensus that communication it is not going to be an important problem (GB). The RADNET network, that connects different radar stations located in the four states, converts different radar data formats into one standard, as well as into different output formats.

The option of using an additional radar was also analysed. The solution presented by EA on the Gapfiller concept solution for the Sheringham Shoal offshore wind farm, is a clear option to solve the problem, but it is an expensive solution.

Who has to pay the cost of mitigation solutions?

As renewable energy supply, national security and air traffic safety are all of high public interest, it is important to find solutions that satisfy all interests. However, the general assumption is that wind farms developers should have to pay the cost associated with the required mitigation solutions, due to the fact that aviation and radar installation were installed first. However, some of the radar installations that could be affected are old installations (more than 30 years old) and will need to be modernised, irrespective of any adverse wind farm effects.

Due to environmental and strategic reasons, society clearly requires wind energy systems to be developed over the coming decades. Consequently governments should provide funds to stimulate the development of these systems. The sectors affected by these new installations should take the actions required and should ask their governments for support to cover tassociated costs. The idea of having a centralised funding body in Europe to cover the cost does not seems viable.

In the UK the Crown Estate will cover the initial cost of the modifications required to guarantee ATC systems and National Security, and subsequently will charge the cost to the developers by yearly payments.

All sectors require wind farm developers to pay costs associated with any indirect impacts. It is necessary to reach a reasonable agreement between different groups (developers, manufacturers, airport authorities, national security organizations, etc.) negotiating the contribution that should be paid by each actor. As an example reported, it has been stated that the cost associated with the modifications required to connect a wind farm to the grid has been shared between TSO and wind farms developers (NF).

However no solution seems easy to find, and any solution will require a clear organizational process involving all actors.

Future actions under the umbrella of IEA Wind

At the end of the meeting future actions that could be done under the IEA Wind umbrella were discussed. Most participants were in favour of the establishment of a new Task Group within the IEA's R&D Wind Task 11, to analyse the impacts on radar systems of wind turbines at selected sites, using the same assessment methodology. The output of the study would be very useful for developers, air traffic control organizations and national security departments.

A working group to put forward a proposal to set up a 'new' task area, which specifically addresses Radar, Radio and Wind Turbines topics and issues will be created to prepare the Task document to be distributed at the next Ex Co meeting. Gary Seifert will coordinate this action. The IEA operating agent offered assistance to progress documentation and to facilitate these process.

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November 18-19, 2009 Amsterdam

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ARNE THEIL

PRESENTATIONS

IEA, Amsterdam

18 November 2009

PAGERPOWER aviation studies

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Wind and Radar - Worldwide

PAGERPOWER aviation studies

- Its a big issue and its getting bigger
  - More than 20GW wind affected
  - More countries getting concerned every year
  - More radar being impacted every year
- No silver bullet as far as technical solutions
- Appears to be a much larger issue in some countries [UK and USA]
- Smaller issues in others [Denmark]
- Many bodies looking at the problems
- Some common issues

Wind and Radar - Worldwide

PAGERPOWER aviation studies

- IEA 3rd Meeting
- Eurocontrol
- NATO SET-128
- EWEA
- BWEA and AWEA
- Joint MOD and DOD working

Wind and Radar – Common Issues

PAGERPOWER aviation studies

- On-Line Assessments
- National Security
- Safety
- Cumulative Assessments

Overview of Situation in UK

-Main concerns

-MOU and Guidance

-MOD infeed project

-Threat Radar

-Lighting

-PAR

-Raytheon Upgrade

-SSR distances

-Stealth

-Country by Country

Main Concerns PSR - UK

•Clutter

•Desensitization – also known as Overhead Obscuration – different from Clutter

•Little concern about site monitors in UK

•Belgium – concerns about site monitors

•Netherlands – concerns about shadowing

•Cumulative effects

PAGERPOWER aviation studies

MoD: Bullamoor windfarm could lead to catastrophic crash

CONTROVERSIAL plans to erect four 120-metre wind turbines on farmland could lead to a catastrophic mid-air collision, the MoD says.
Army experts said the planned development, at Bullamoor, near Northallerton, North Yorkshire, could interfere with radar equipment, putting military and civilian lives at risk.
In a meeting of Hambleton District Council's planning committee yesterday, councillors were told the location of the wind farm could affect systems at nearby RAF Leeming.
Squadron Leader Gavin Pattinson, an air traffic control expert, said aircraft safety was paramount.
He said: "**Make no mistake that the worst-case scenario is a mid-air collision between two aircraft, with burning wreckage falling to the ground.**

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Memorandum of Understanding

- Signed in 2008
- Defence, Transport, Business
- CAA, NATS, BWEA
- Commitment to work together
- Vague commitment to funding
- Things are improving - slowly

PAGERPOWER aviation studies

Guidance

•Standard ICAO and CAA guidance for obstructions

•CAA CAP 764 for wind turbines

•New Eurocontrol Document for Radar

•CAP 764 used to provide a radar assessment methodology – which is now used by MOD

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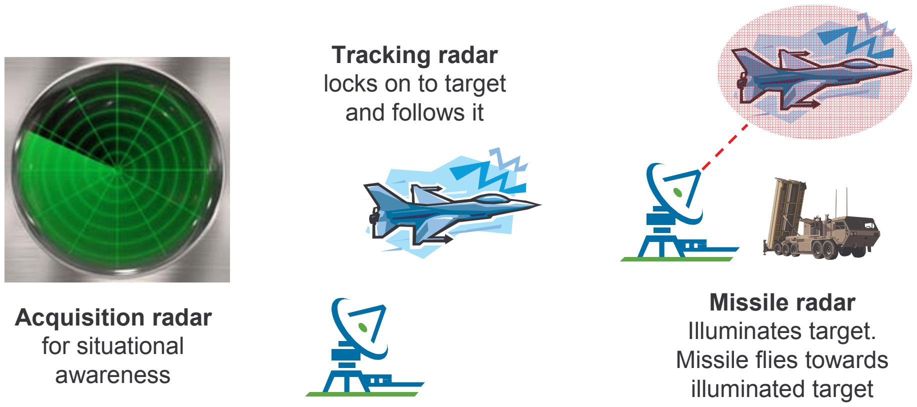
aviation studies

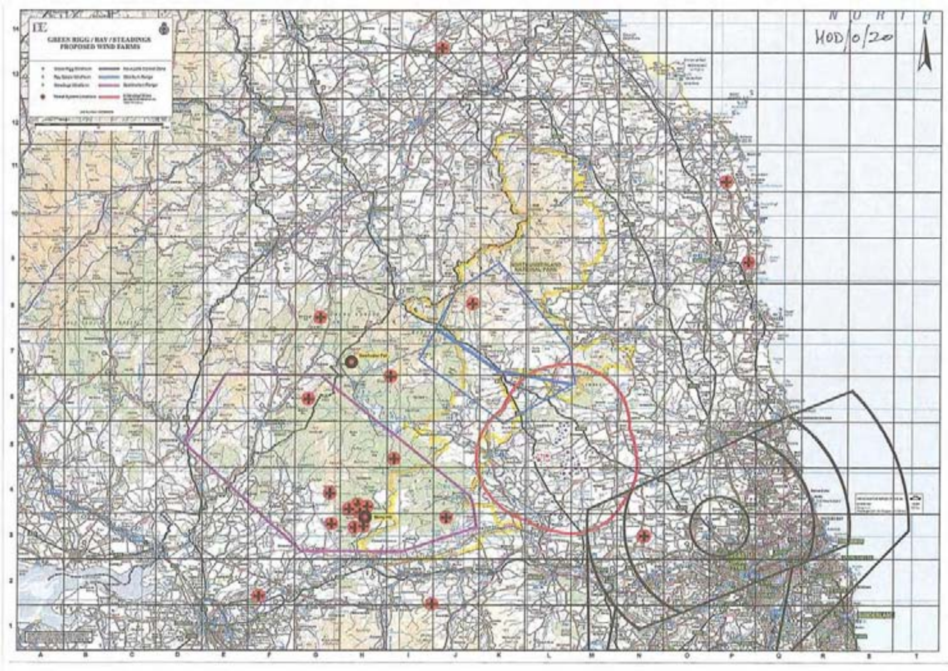
What is Threat Radar?

Three radar in one – Acquisition, Tracking and Missile



What is Threat Radar?

- Mobile radar
- Guides surface to air missiles towards target aircraft
- Used for training – pilots need to train to avoid surface to air missiles
- Typically ex-soviet radar used at Spadeadam SA-2 SA-3 SA-6 SA-8 Skyguard ZSU-23 – also European systems and simulator transmitters
- Operating ranges of 10 - 50km



Aviation Obstruction Lighting

•Traditionally onshore turbines unlit

•MOD now requesting lighting – mainly because of nighttime helicopter operations

•Concerns by developers because lighting impact has not been assessed

•Trying to get very low intensity (or even invisible) lighting. Currently at 25 Candela.

•Lighting pattern is important.

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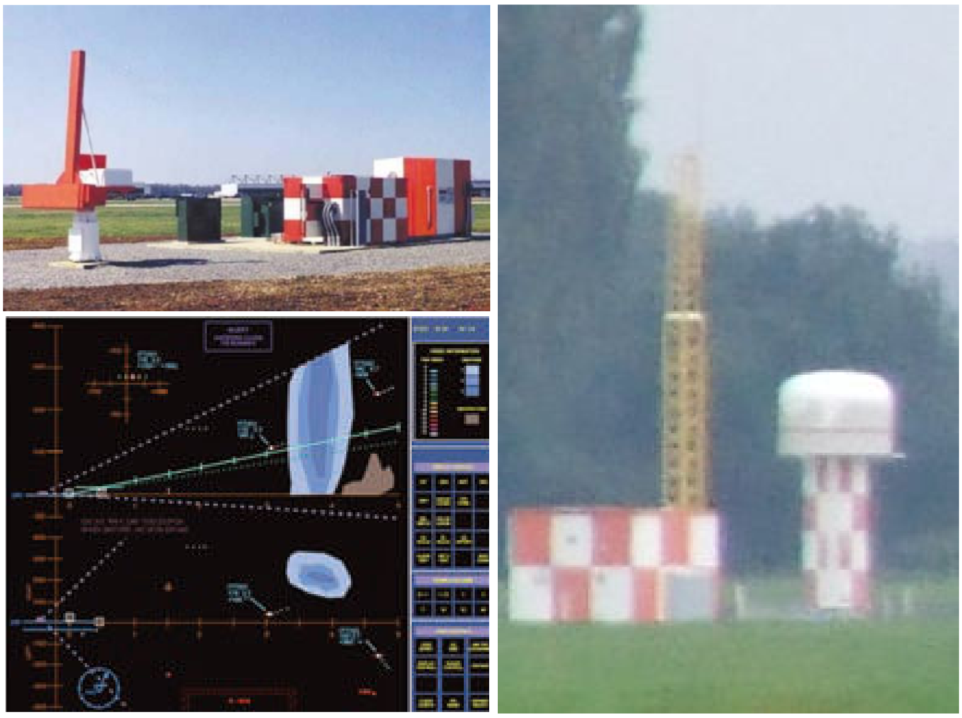

Precision Approach Radar - PAR

- Trial has been undertaken in Lossiemouth with ITT PAR
- Interference has been demonstrated
- Discussion with ITT practically impossible because of ITAR rules
- Becoming a big issue in the UK

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Raytheon Upgrade

•Raytheon ASR 23 PSR
•Project to make it more wind farm tolerant
•23 Radar
•Initial £5m has been funded
•Combination of low/high beam
•Improved processing

PAGERPOWER aviation studies

Secondary Surveillance Radar - SSR

- **Safeguarding Distances in UK**
  - **10km general**
  - **15nm CAA**
  - **16km Eurocontrol**

- **Reflections**
  - **False plots**
  - **Bearing errors**
  - **Range errors**

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Stealth Technology

- Low radar cross section blades (and towers)
- Being pursued by Vestas
- Not fully proven
- Single Blade Trial at Swaffham
  - Affects RAF Marham Radar

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Country Comments

- Czech Republic – Civil/Military
- Bulgaria - Meteorological
- France – Marine, Meteorological and other
- Belgium – Belgocontrol and Military
- Netherlands – Military
- US – Military
- Estonia – issues
- Croatia – issues
- Sweden – Military
- Germany - Military

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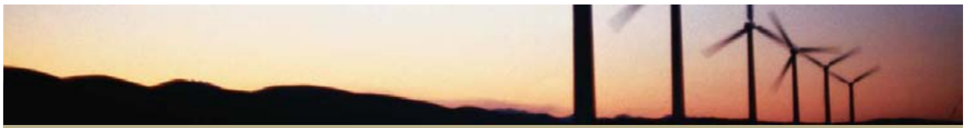

Resolving Wind Turbine Radar Interference Issues

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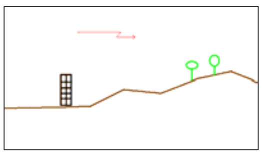
Functional Diagram

Operator Display System Radar Propagation Turbine

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Mitigation

Questions/Comments

Wind Radar Issues in the USA a 2009 Update

November, 2009

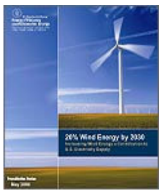
Brian Connor
Federal Agency Wind Technology Manager

Gary Seifert
Program Manager, Power Systems
Idaho National Laboratories

Jose Zayas
Manager, Wind Energy Technology Dept.
Sandia National Laboratories

Mission Need

- Responsible stewardship of national resources to increase the development and deployment of reliable, affordable, and environmentally sustainable wind and water power.
- Actively support the development of 20% U.S. electrical energy produced by wind (20% Wind Energy by 2030).
- Reduces risk to development, increasing domestic energy options (Energy Policy Act of 2005).
- Ensures that 10 percent of our electricity comes from renewable sources by 2012, and 25 percent by 2025 (President's Energy Policy)



Impact

AWEA Survey of members shows:

- **2,100+ megawatts held up**
- **5,100+ megawatts deferred**
- **2,100+ megawatt abandoned**

Yet, only 8000+ Megawatt installed the same year

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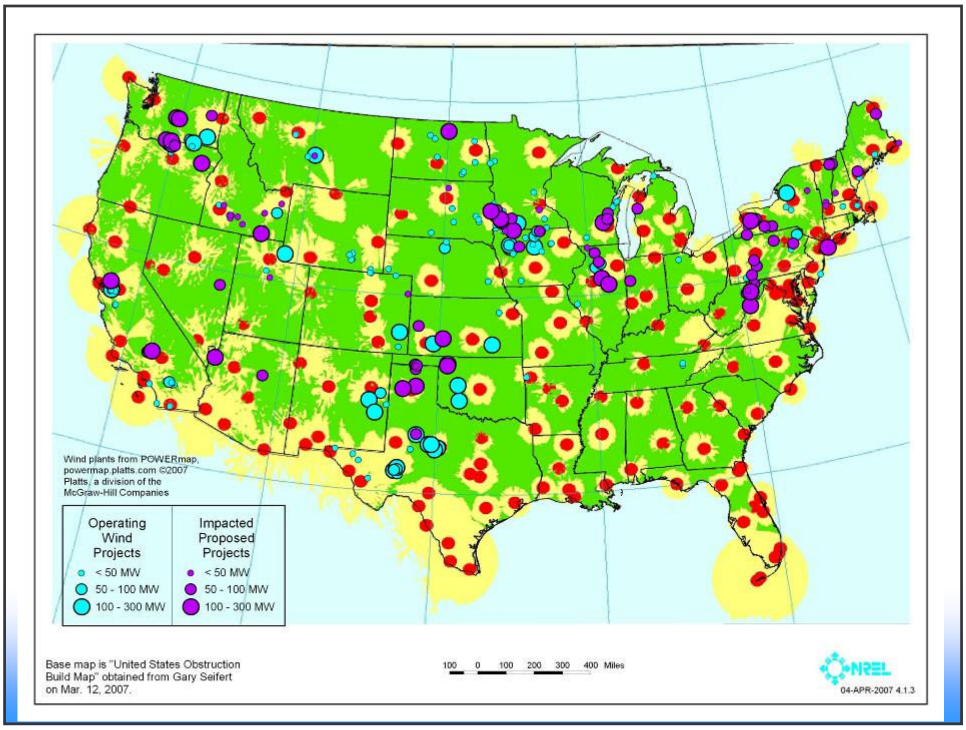
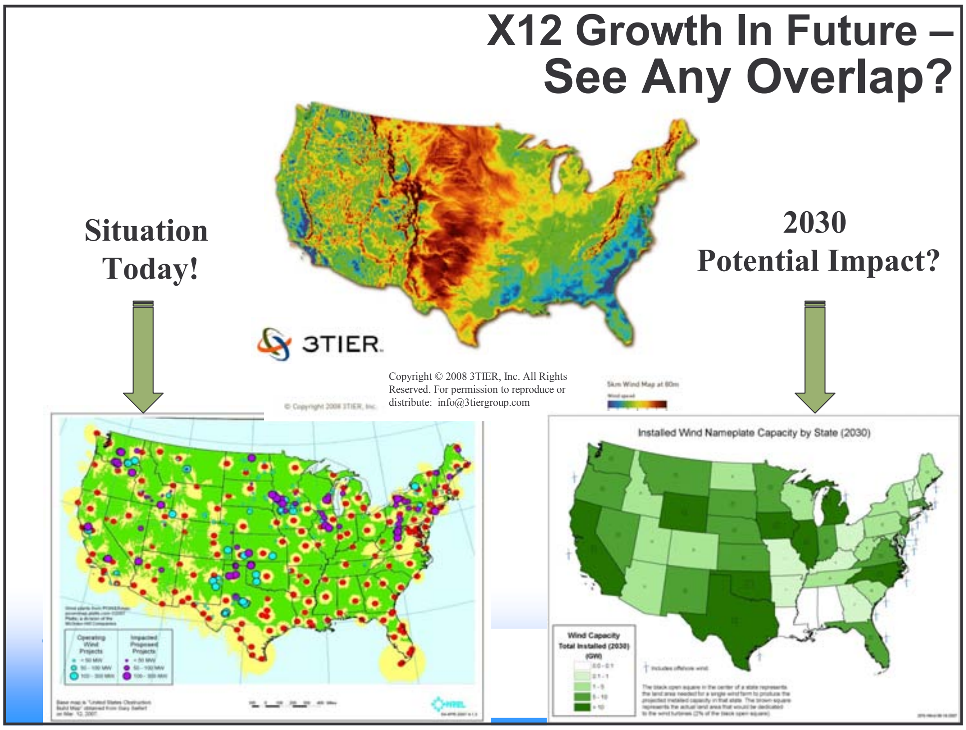

Wind plants from POWERmap,
powermap.platts.com ©2007
Platts, a division of the
McGraw-Hill Companies
Operating Wind Projects
< 50 MW
50 - 100 MW
100 - 300 MW
Impacted Proposed Projects
< 50 MW
50 - 100 MW
100 - 300 MW
Base map is "United States Obstruction Build Map" obtained from Gary Seifert on Mar. 12, 2007.
100 0 100 200 300 400 Miles
NREL
04-APR-2007 4.1.3


X12 Growth In Future –
See Any Overlap?
Situation Today!
2030 Potential Impact?
3TIER
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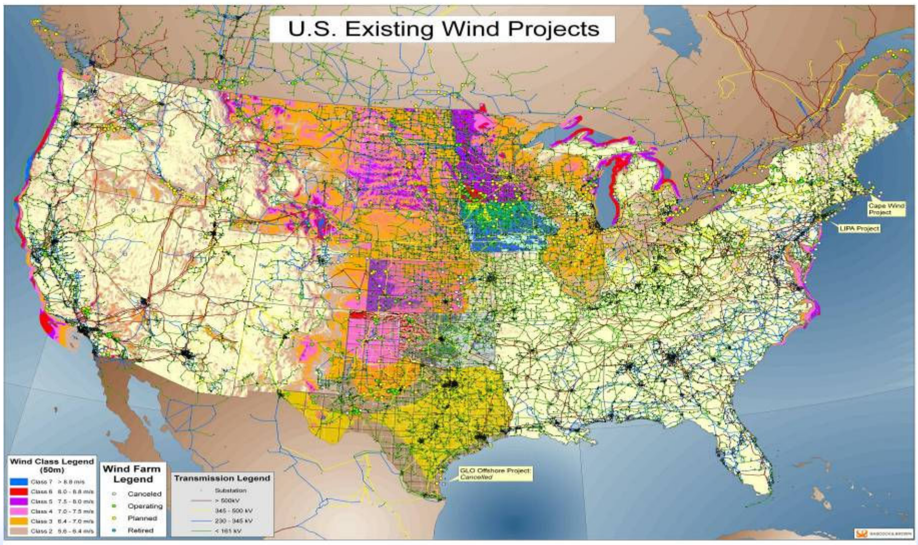
Installed Wind Nameplate Capacity by State (2030)

US WIND



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Program Strategy

DOE is Taking this Concern Seriously

Near-term:

Collaborate with government agencies, other Nations, and industry to develop mitigation approaches that reduce the impact of wind projects on radar systems.

Mid-term:

Develop wind turbine "stealth" technologies and radar gap filler approaches.

Long-term:

Provide support on the modernization of the next generation radar systems.

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Needs

- Identify and Streamline Federal Wind Siting Processes
  - Agency by agency review & publication of current requirements
  - Intra-agency streamlining/coordination/appeals
  - Identify agency wind-siting Czar
- Enhance Impacts Screening Capabilities
  - Increase # of tools
  - Develop interactive capabilities
- Increase Testing/Evaluation
  - Impact
  - Mitigation
  - Optimized layouts
- Launch R&D to Mitigate Interaction
  - Stealth Blades
  - Radar Enhancement
  - Better signal processing
- Long Term:
  - Timely, Predictable Federal Clean Energy Siting Process

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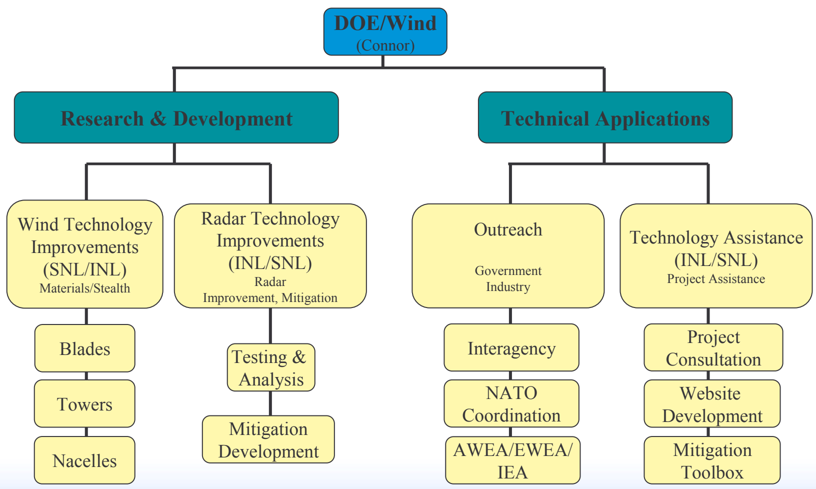
Program Structure



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Outreach Activities

Project Consultation

- At the request of project developers and radar agencies, provide independent technical support to resolve permitting delays

Website

- Update the one-stop portal for wind project developers to regulatory agencies

Mitigation Tool Box

- Develop and update a common resource for both developers and regulatory agencies that can be used to explore mitigation strategies.

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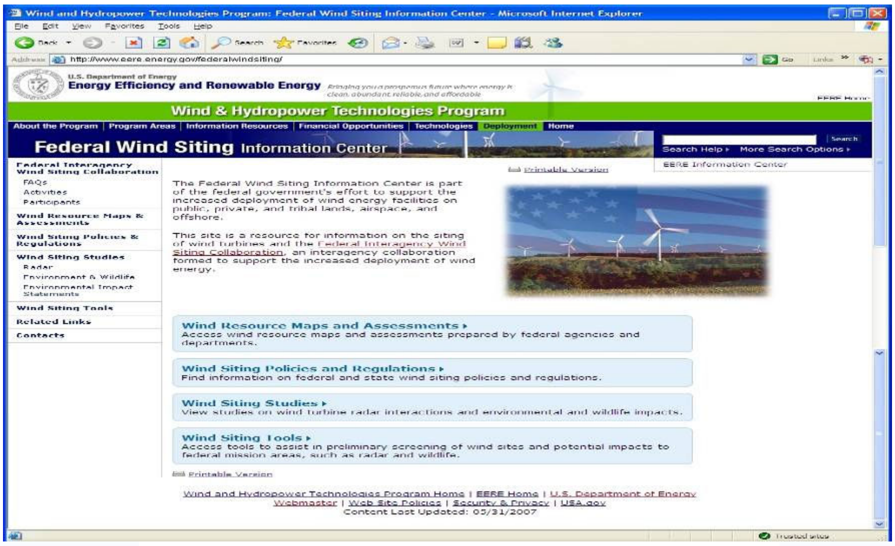
Federal Wind Info Website



www.eere.energy.gov/federalwindsiting/

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Mitigation - the Key

- FAA and/or manufacturers mitigation is often available
- Only DOD, DHS, & FAA experts can determine if mitigation is acceptable
- Examples include, but are not all inclusive
  - Impact studies
  - Farm optimization
    - Refine turbine locations
    - Checkerboard (one color with gaps)
  - Adjust look angle, use multiple beams selectively
  - Reduce RCA – Stealth the Blades
  - Transponder integration
  - Software optimization
  - Added Hardware
    - Post processors and advanced software
    - Adding transmitters and receivers

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Mitigation Being Investigated

- Software improvements being investigated
  - Enhanced clutter mapping
  - Use of RAG Mapping
  - Concurrent processing
    - Separation of high and low beams
    - Tie to advanced clutter and geo based information
  - Improved CFAR processing
  - Improved filtering algorithms
  - Advanced tracking
  - Advanced adaptive Doppler filtering techniques

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Short Term Recommendations (the whole list-brainstorm)

Track eligibility
Gap filler radar system criteria and integration
Work on Layouts (radial, checkerboard, etc.)
Quantify/model turbines
Integrate and test new algorithms (88-D)
Siting considerations and processes
Add 2 pulse cancellation to reduce STC (ASR-11)
Apply advanced tracker
Perform and share advanced wind turbine signature testing
Look at Doppler-recede vs. approach – filter out receding Doppler
Get NexRad button on OE-AAA website
Characterize signatures (include rotating effects)
Keep meetings and post minutes
Time domain excision – reduce tower return. Same for face array.
Dual pole cancellation of turbines (88-D)
Characterize spectral signatures

Wind community should fund expansion/gap fillers, including long term operations
Foster better communication with industry
Consolidate interagency support teams and fund them to get work done (FAA, DOD, DOE, etc.)
Digitizer upgrades should be developed and implemented
New processors may help all radars (many use old technology and all can benefit from increased processing power and inceased memory)
- Integrated processors
- ADSP processor
- Post processors

Need a one stop shop
- Permitting
- Need a toolbox and checklist to foster complete consistent assessment and better developer interaction
- support needed to save Gov't time and improve submittals
- Manual/guidelines needed
- NTIA, OEAAA process needs to be integrated
- Establish process

Prioritization was applied and list consolidated

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Long Term Recommendations (the whole list - brainstorm)

ASDP processor
Enhance radar
Beacon on turbine (KA band transponder, gives rpm, yaw, on/off, pitch, etc.)
Identify R&D requests
Better modeling software (expand RSS) (expand to 88-D)
Real time turbine parameters – yaw, pitch, speed, on/off
Improved signal processing/mitigation
Face array R&D – signature (multiplane, rotating, etc.)
New digital antenna – S band like Giraffe radar (poor boy 3D) (interpolate to get 3D)
Establish a tiger team – optimize what we have
Define terms – consistent line of sight
DOE – Drive industry funded and implemented solutions
Ad a carrier frequency on blade and subsequent filtering
Use new material
Apply military knowledge on other systems and apply to this problem (example – helicopter impacts on radar)
New algorithms to replace MTD
3D radars with good clutter mapping
Better multilevel radar and signal processing

Simulators – show operators what it will look like up front
Common library/web site to aid in education and assessment
Long term planning to help locate radars better
Establish low cost testing apparatus or setup?
Validated models/simulators
Test turbines in ideal areas for radar testing (OK?)
Update future radar specs/requirements
Gap fill
- Optical
- X-band
- Convent (weather gap face array/fusion)
- New/innovative
- Low cost
- Fusion

Stealth improvements
- Blades – US R&D needed
- Nacelle – skin reflection reduction
- Tower – skin, shape, or coverings

Improve algorithms
- Altitude
- Modify/change MTD/MTI
- Correlation math algorithm determination
- Switchable based on geo

Prioritization was applied and list consolidated

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Current Activities

- DOE Wind-Radar
  - Technical Assistance to Agencies & Industry
    - Weakened by recent JPO change in prescreening support
  - Mitigation Case Studies
  - Demonstrations
  - R&D (Blades, Sensors)
  - General Outreach
  - Multi-pronged approach; multi-stakeholder involvement
  - Collaborative research, case studies, radar evaluations, metrics refinements, tools, mitigation development and information sharing
  - Commission independent wind radar baseline tests
  - Foster technical solutions
  - Reduce encroachment mentality
  - Make results public and shared
  - Shadowing study underway
  - Scheduling three demonstrations
    - Advanced software on ASR-11
    - Gap filling radar on ASR-11
    - Concurrent Processing
  - ARSR-4 upgrade requirements document under evaluation

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Current Activities

- Interagency Team
  - Informal Arrangement
  - DOE-Facilitated
  - DOE, DOT, DOD, DHS, Interior, Commerce, USDA
  - Real-time interactions/info & tech exchanges/technical assistance
  - Numerous successful actions completed:
    - $1.5 B in stuck wind applications approved
    - $20 M transmission line approved
    - Archival wind data secured
    - Federal Wind Siting Information/Tools Center
      - New prescreening FAA/DOD and NEXRAD Long-Range Radar tool (Info Center)
    - Agency toolkit experts workshops
    - R&D/Testing Regime (Underway, Limited DOD and DOE)
    - Model siting protocol (under development - BLM/DOD-AF)

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Summary

- Involve all concerned parties
- Approach all issues openly and fairly
- Articulate and quantify Impact
- Address mitigation
- Communicate well and often
- Research and mitigations needed
- Technology improvements needed

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Wind and Radar can co-exist! Questions?

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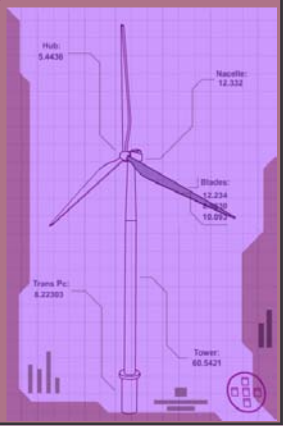
The Impact of Wind Farms on Marine Radar

Professor A. K. Brown

Mr L Rashid

Microwave and Communication Systems Group

The University Of Manchester,UK



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Marine Radar Measured Data

Target Spreading

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Marine Radar Measured Data

Mirror image of the wind farm due to reflection of radar signals off the ship's superstructure

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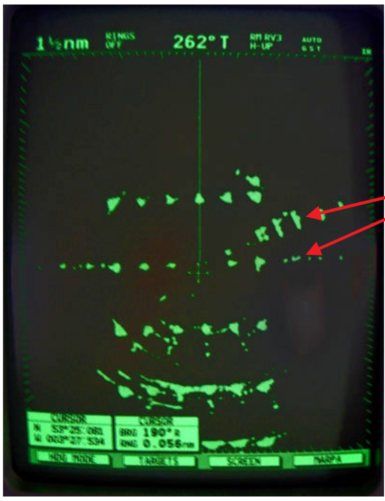
Marine Radar Measured Data



False (ghost) targets appearing on display due to multiple reflection within the wind farm

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Available Mitigation Technologies

- Advance digital signal processing tool kits are available to reduce the effect of wind-farms on radars that use Doppler to distinguish between static and moving targets- the Air Traffic Control problem
- Marine radars are simple pulsed radars that are low in complexity, price and the number of operational radars is very large

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Wind Farm Effects on Radar

- Effects on marine radars
  - Ghost targets
  - Side-lobe detections
  - Shadowing
  - Receiver limiting

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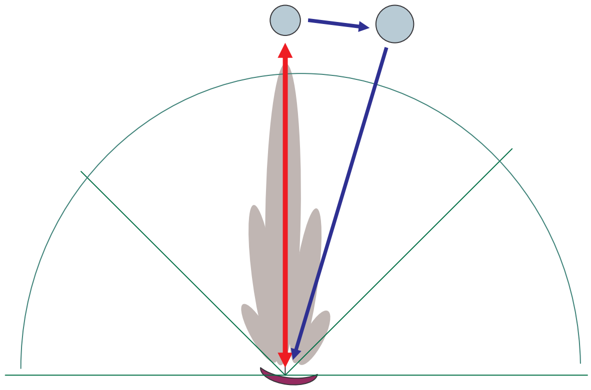
Multiple Reflections



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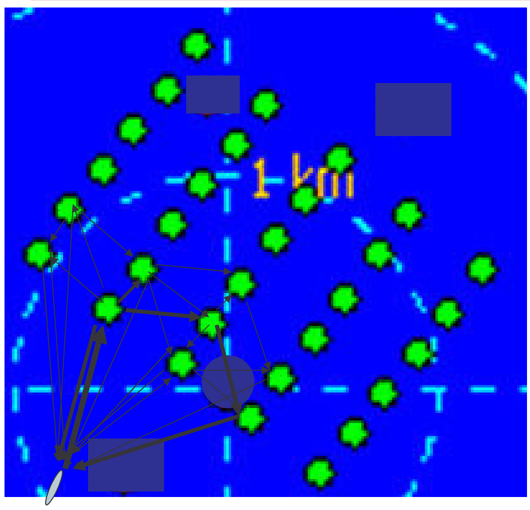

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- The wind farm will affect marine radar
  - Depends on type of turbine, the site geometry and the relative positions to the ship
- So is it operationally significant?
  - Can be safety issue
  - Affect safety case during maintenance/repair
  - Security implication

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Possible mitigation

- Change operational procedures?
- Site layout?
- RCS Reduction/shielding?

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Simulator Requirement

- A simulator is needed to model the effect on radars before the construction of a wind-farm, such that the effects of different turbine design and farm layouts can be considered
- Wind-farms can be large and complex, however we need a fast computation time, regardless of the physical size of the wind-farm, hence an **approximate** model is needed

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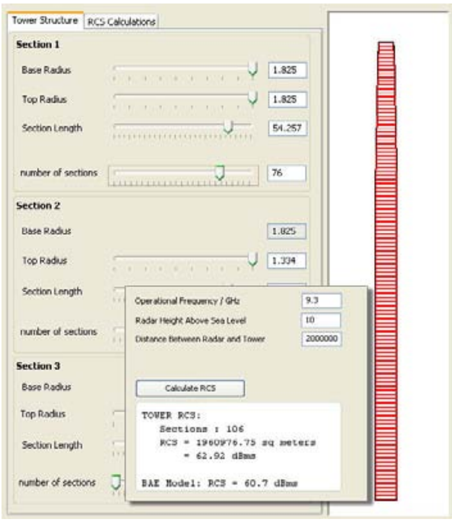

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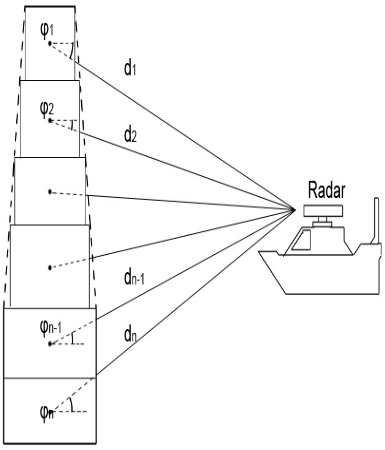
Tower RCS Calculations II



- The RCS of each segment is calculated using farfield PO approximations
- This enables fast computation of the bistatic and monostatic RCS by specifying the incident angle and scattering angles.

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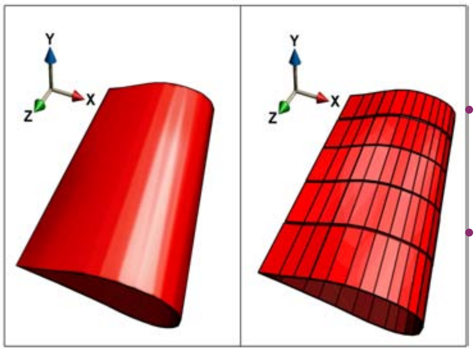
Flat Facet Approximation



- This approach uses a simple meshing algorithm to segment a shape into small flat rectangular plates
- The RCS of each facet is calculated depending on the incident angle
- The individual RCSs are then coherently added together to give the total RCS of the target

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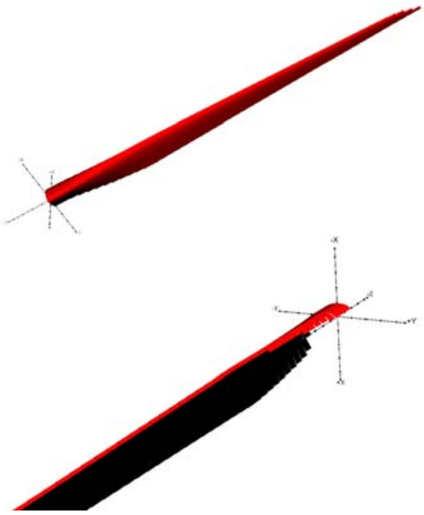
FFA Modelling of Complete Blades

- FFA starts by importing a simplified blade and tower profiles
- The blade is then segmented into small airfoil sections
- Each segment is then meshed into small rectangular facets
- Facets which are not visible to radar are then ignored to speed runtime



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RAM VS Lightning Protection

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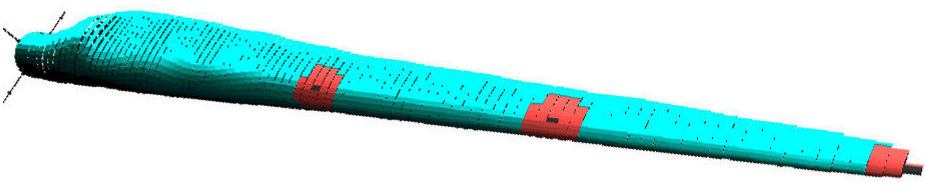

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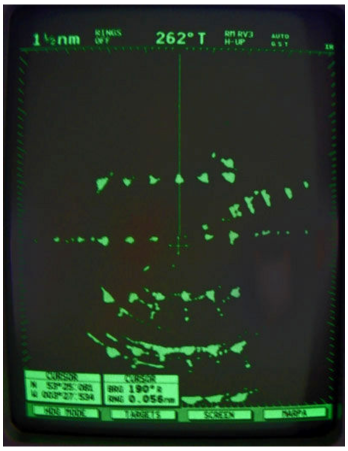
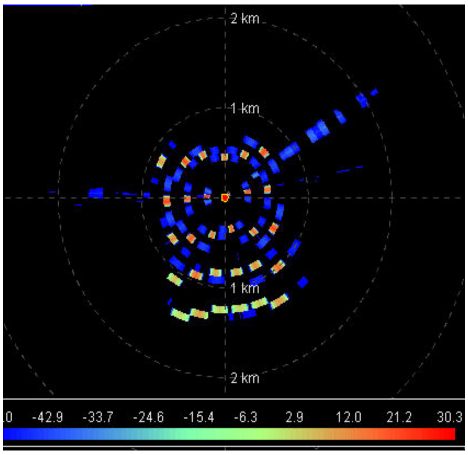
Modelling Results





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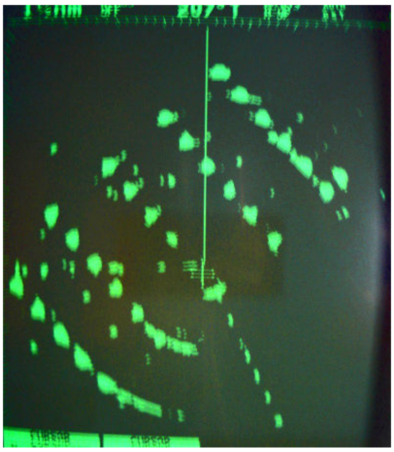
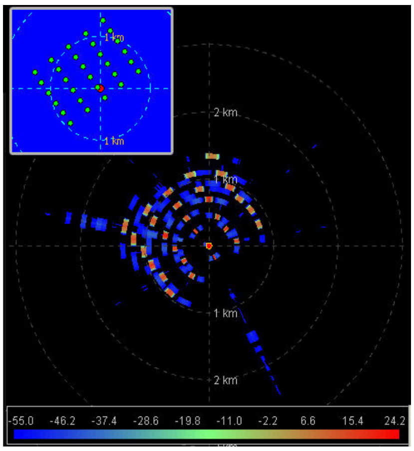
Recent Modelling Results





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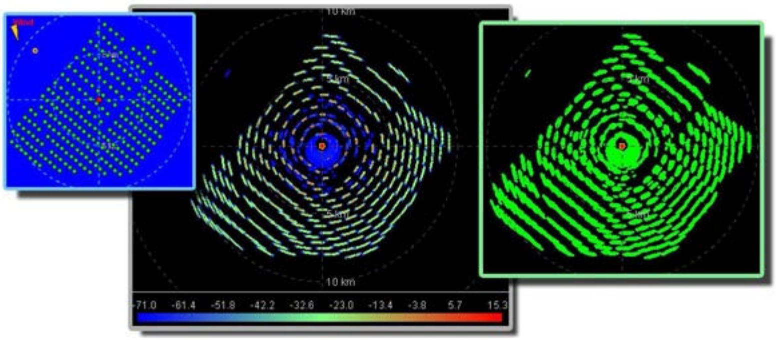

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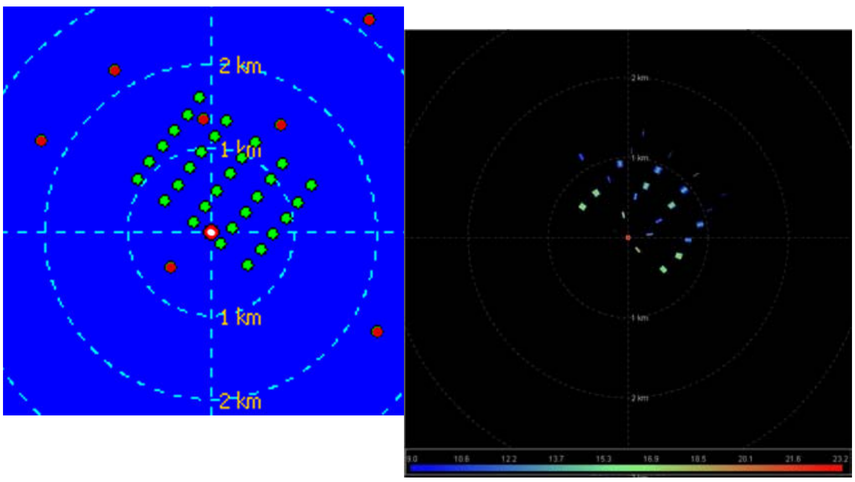

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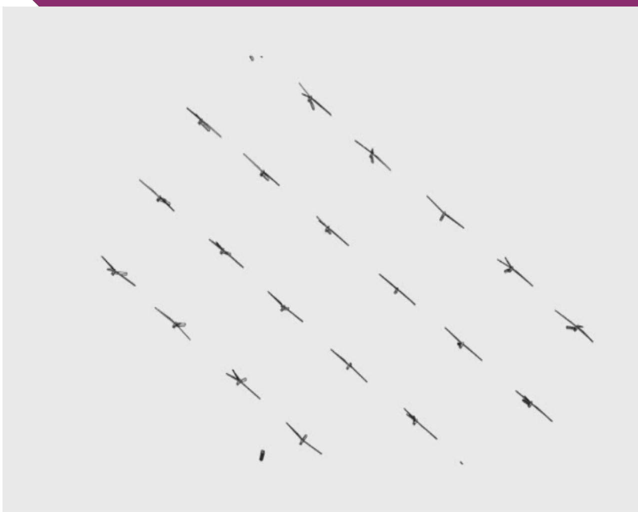

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Summary

- Wind farms potentially affect marine radar
- Evaluate operational effects
- Mitigation measures
  - Changes to operational procedures
  - Change site layout
  - Use of RCS reduction/shielding

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- Use model for air targets
- Look at lightning vulnerability of RAM blades
- Optimisation of RAM application
- Tower shaping etc

Wind Energy Technologies

SUPERGEN WIND

Supergen V - Theme Z
The Microwave and Communication Systems Group
Electrical Energy and Power Systems Group

MANCHESTER 1824

The University of Manchester

Acknowledgements

- This work has been funded by the UK Engineering and Physical Sciences Research Council under the SuperGen V programme
- Extends earlier work undertaken by the STWT consortium (BAESystems,Vestas Universities of Manchester and Sheffield) under UK DTI funding

Wind Energy Technologies

SUPERGEN WIND

Supergen V - Theme Z
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Electrical Energy and Power Systems Group

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MANCHESTER 1824

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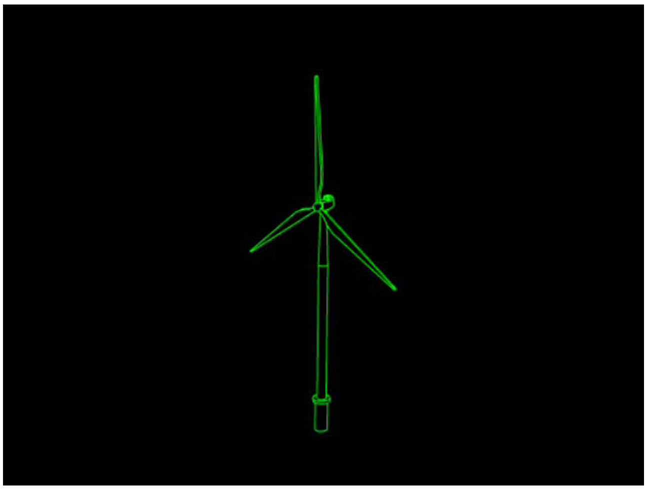

Wind Energy Technologies

SUPERGEN WIND

Supergen V - Theme Z
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Electrical Energy and Power Systems Group

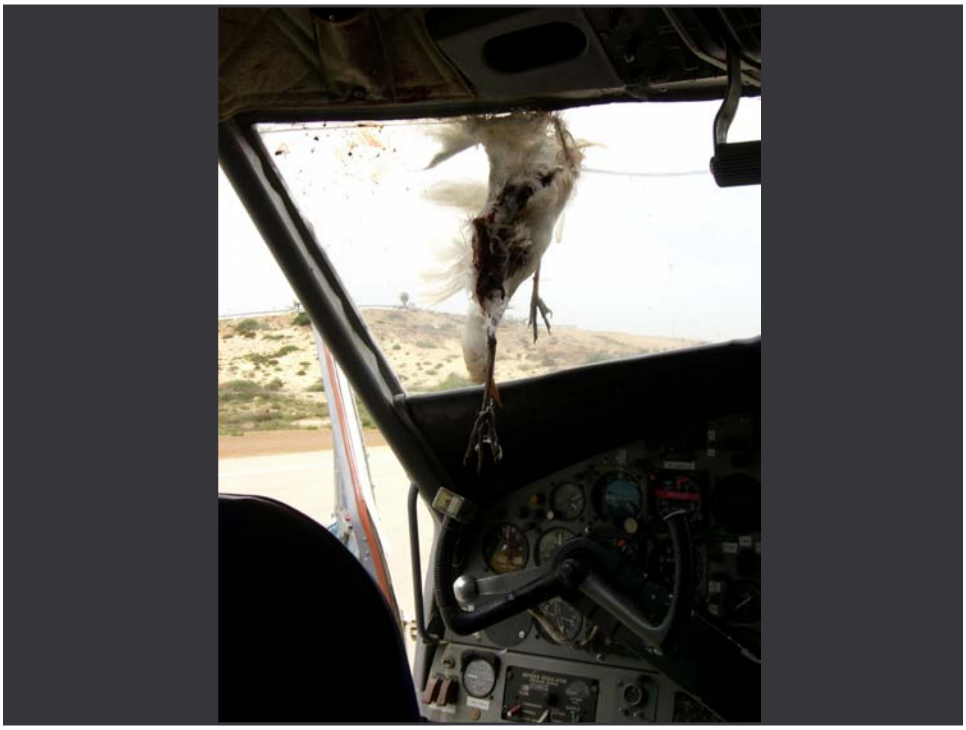
15

On the need to identify small, slow and low flying targets

Luit Buurma, Military Aviation Authority, The Netherlands

IEA radar,radio links and windturbines 18/11/09

1



Many Unmanned Arial Vehicles (UAV's) smaller than biggest bird(flock)s

Why me: 35 years digging for birds in raw radar video

UAV recognition key issue for future national security

Bird recognition key issue for future flight safety

BOTH wanted in MPR replacement programme

IEA radar,radio links and windturbines 18/11/09

2

Crux:

Tall wind turbines can be separated from groundclutter

But not from birds without knowledge of bird echo dynamics

And consequently not without knowledge of bird behaviour

IEA radar,radio links and windturbines 18/11/09

My intention:

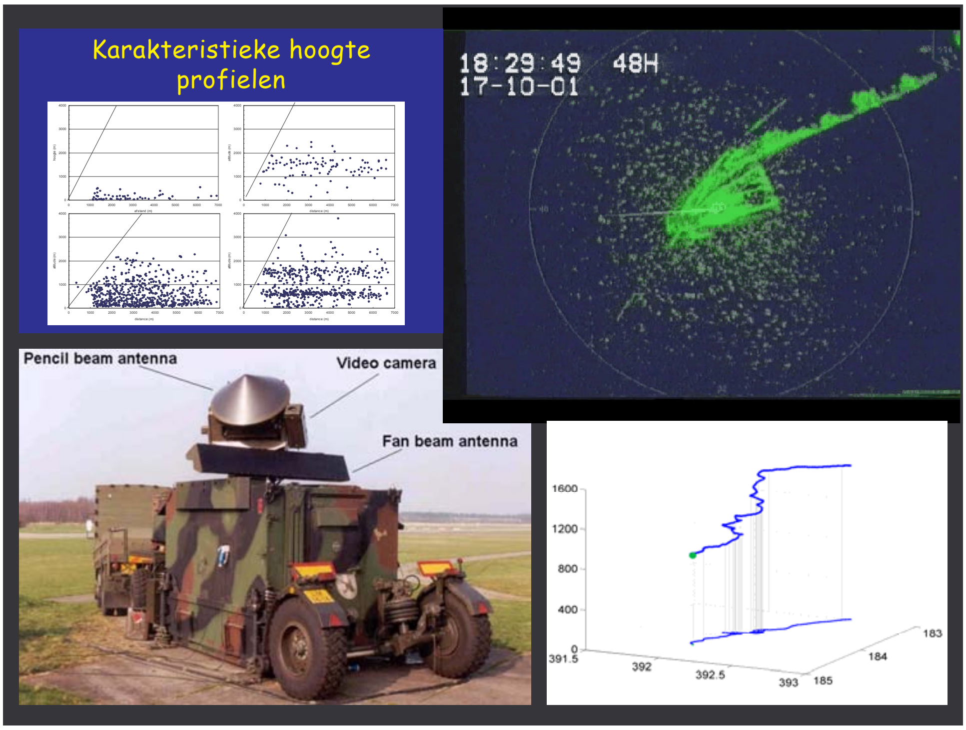
Showing an overview of main classes of bird movements

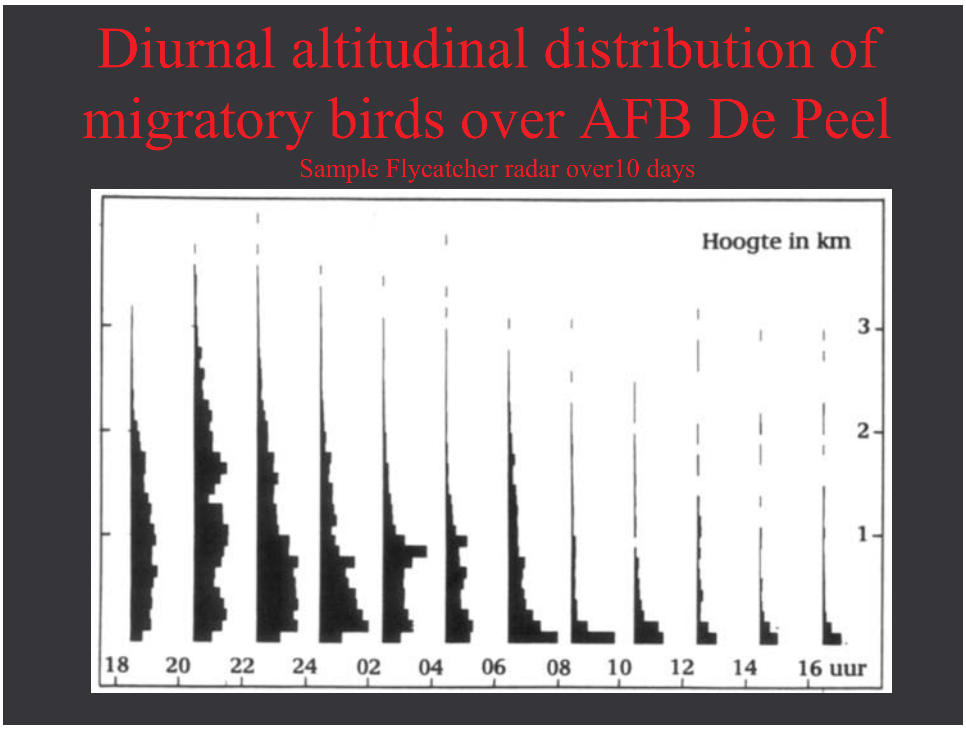
Illustrating how radar ornithologists handle bird targets

Weighing the monitoring possibilities of main radar types

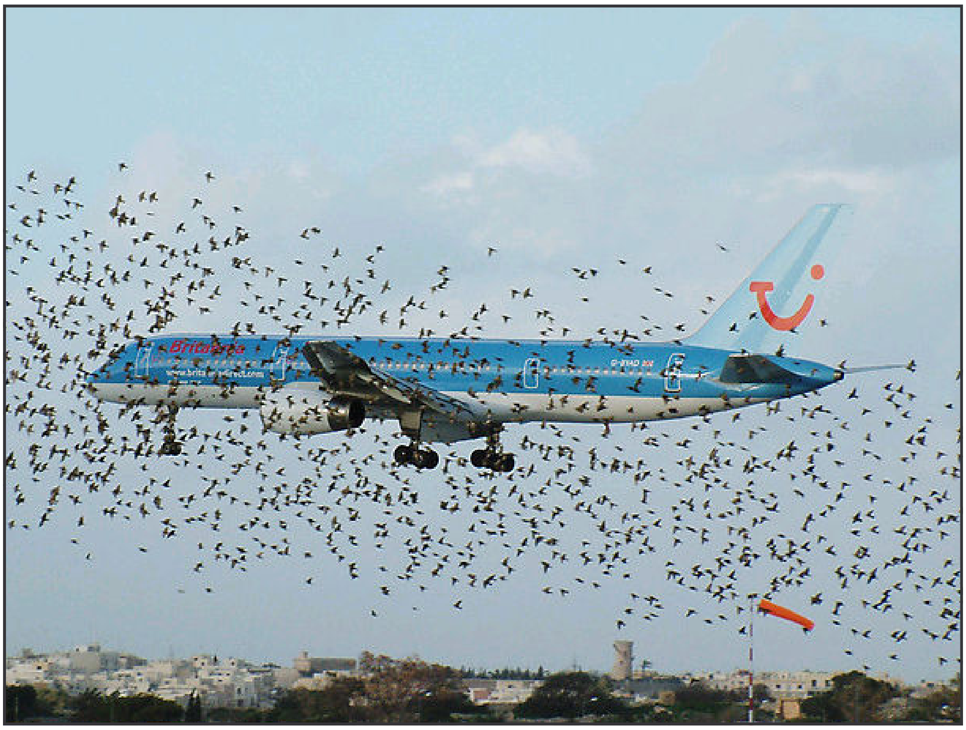
Advising policy makers how to avoid the impossible

IEA radar,radio links and windturbines 18/11/09


Karakteristieke hoogte profielen
18:29:49 48H
17-10-01
Pencil beam antenna
Video camera
Fan beam antenna
1600
1200
800
400
0
391.5
392
392.5
393
183
184
185

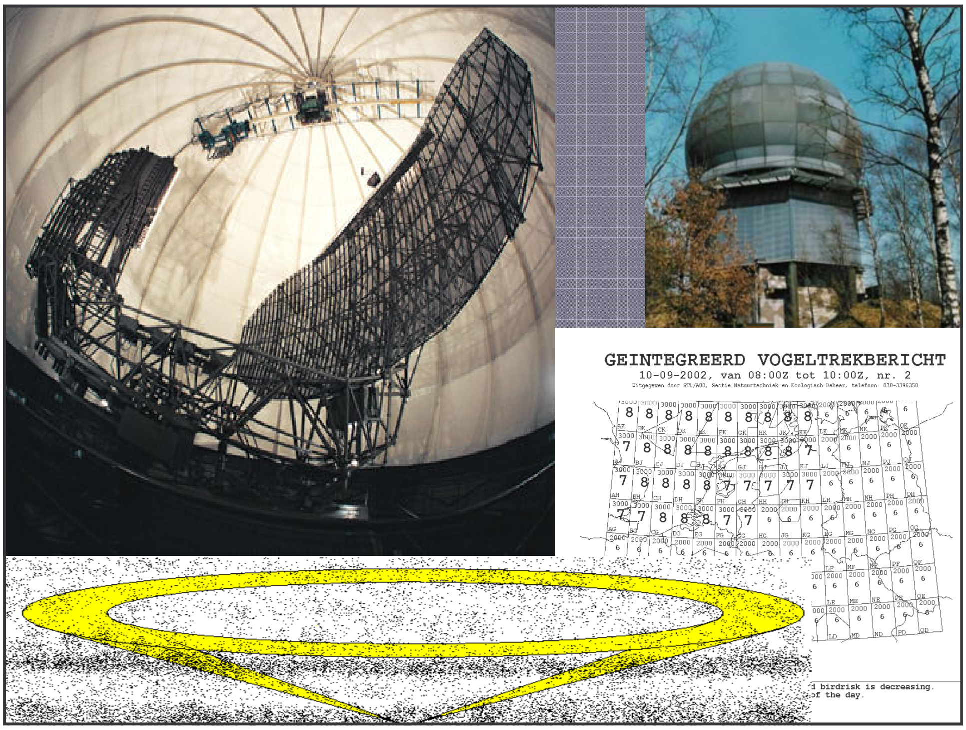

Diurnal altitudinal distribution of migratory birds over AFB De Peel
Sample Flycatcher radar over10 days
Hoogte in km
3
2
1
18 20 22 24 02 04 06 08 10 12 14 16 uur

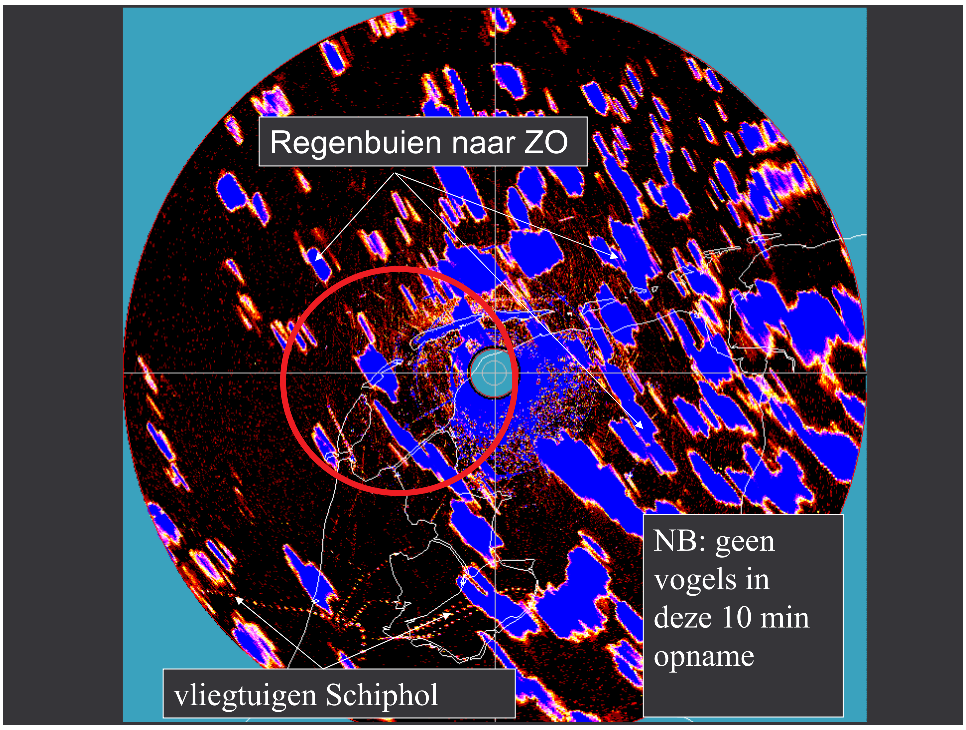
4

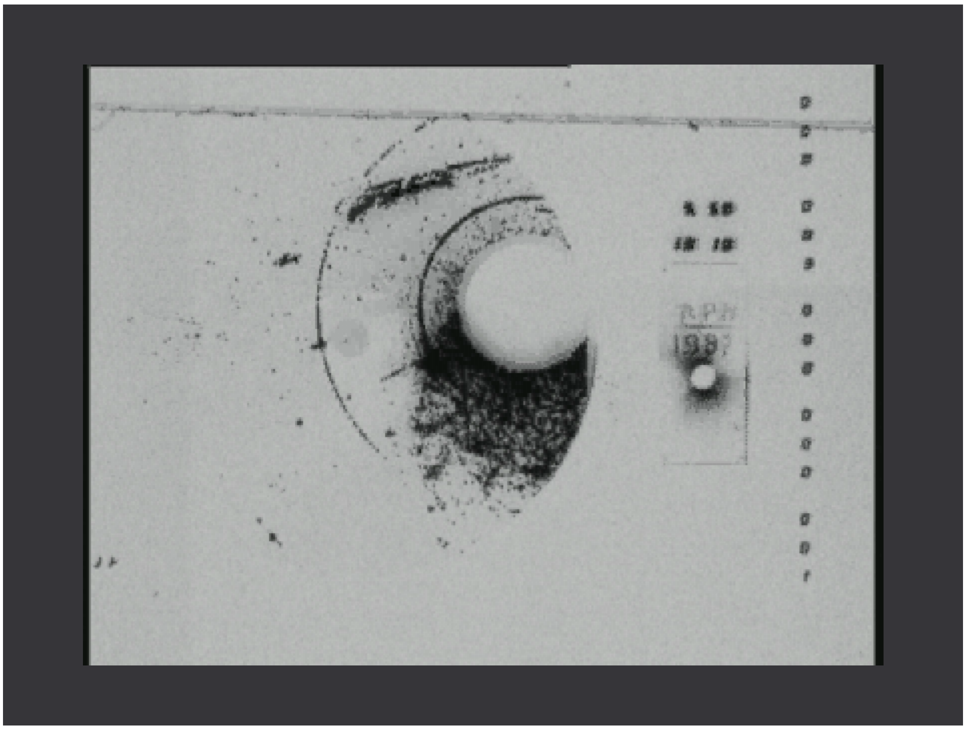


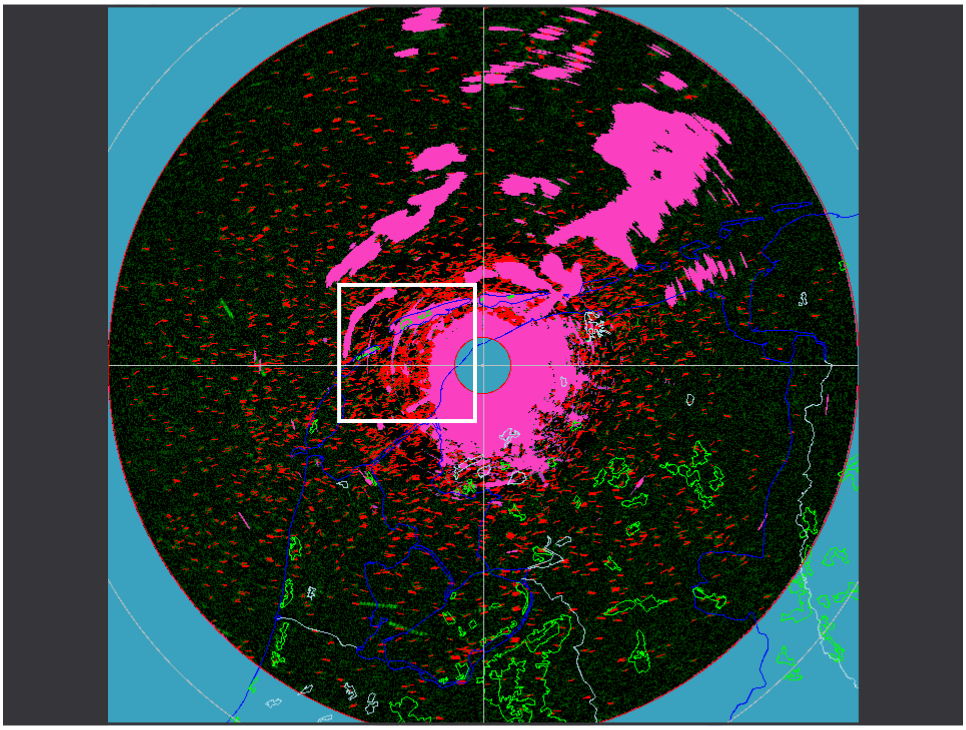
5

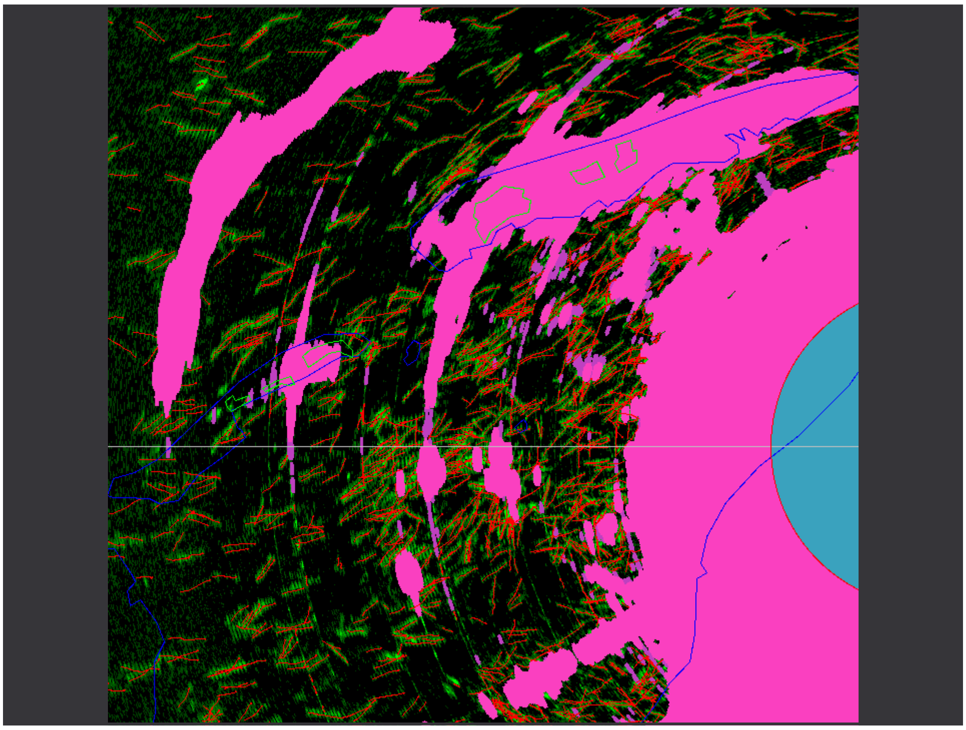

CH-06


GEINTEGREERD VOGELTREKBERICHT
10-09-2002, van 08:00Z tot 10:00Z, nr. 2


Regenbuien naar ZO
NB: geen vogels in deze 10 min opname
vliegtuigen Schiphol







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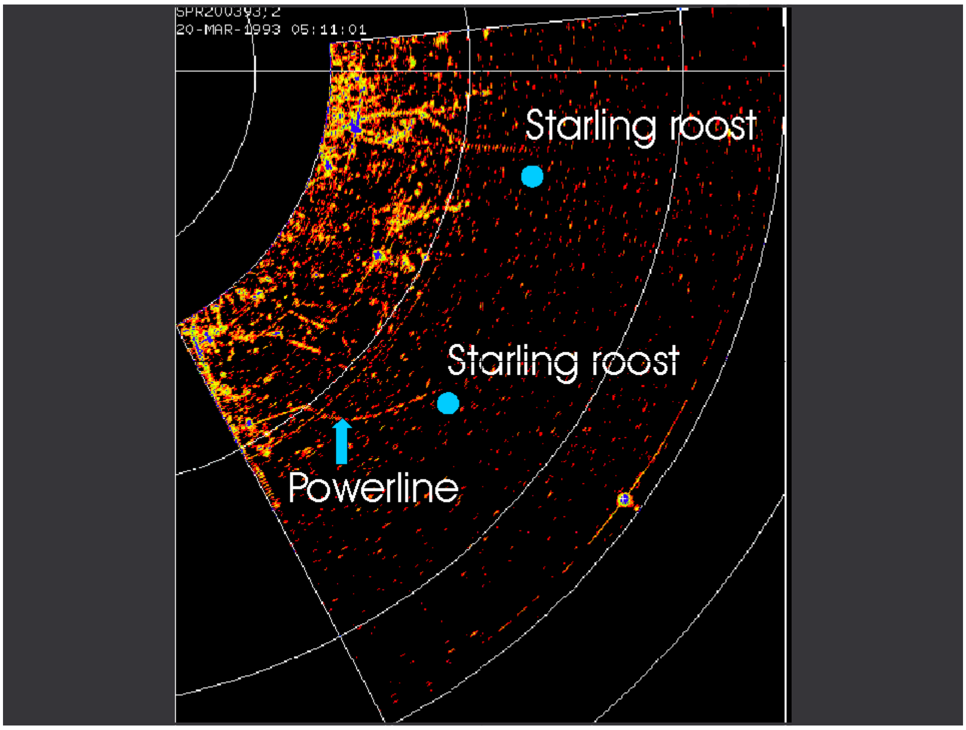
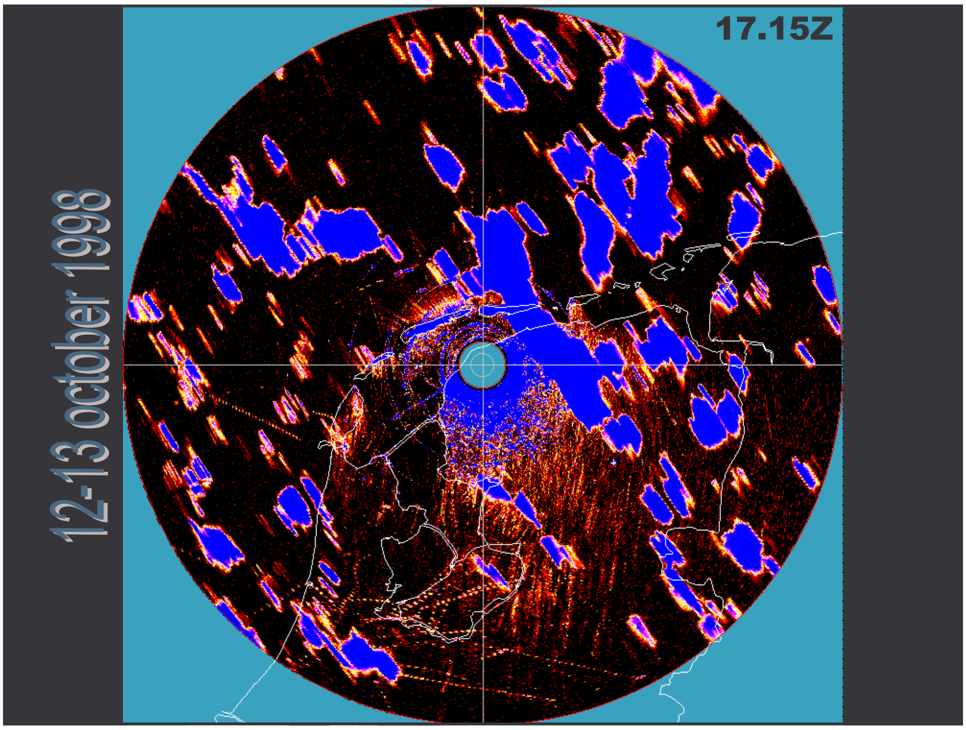
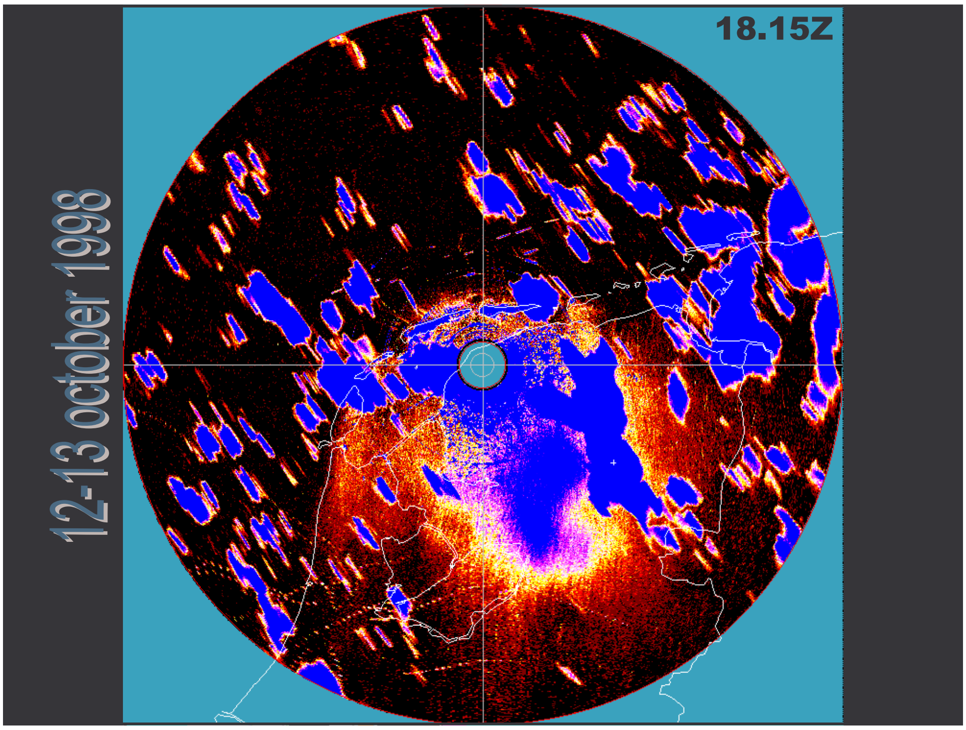

SPR200393:2
20-MAR-1993 05:11:01
Starling roost
Starling roost
Powerline

9





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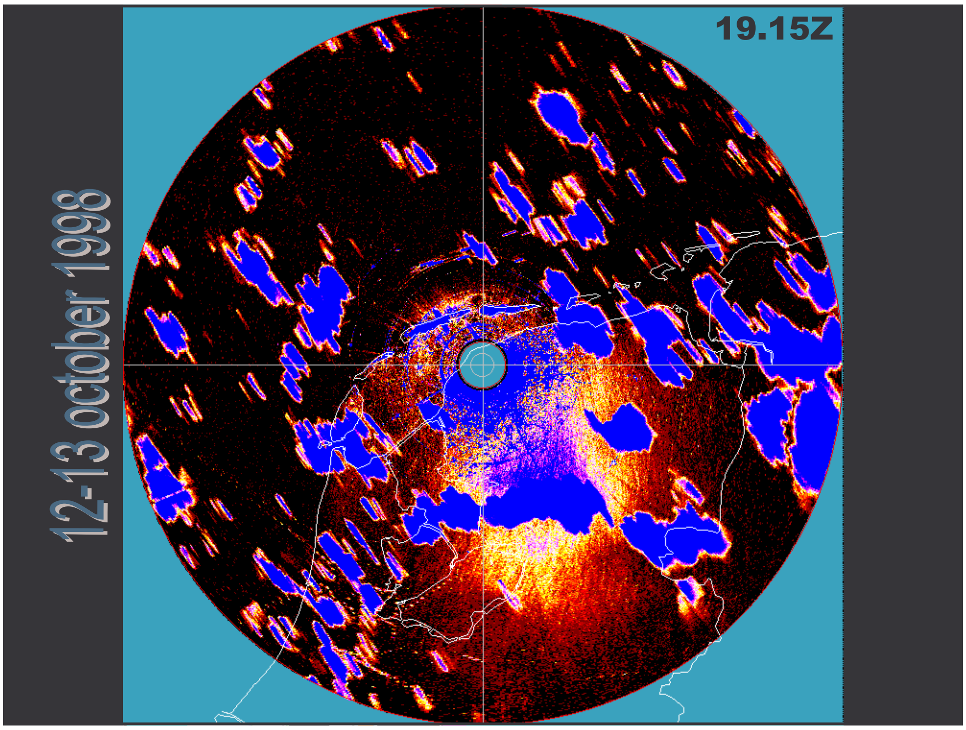

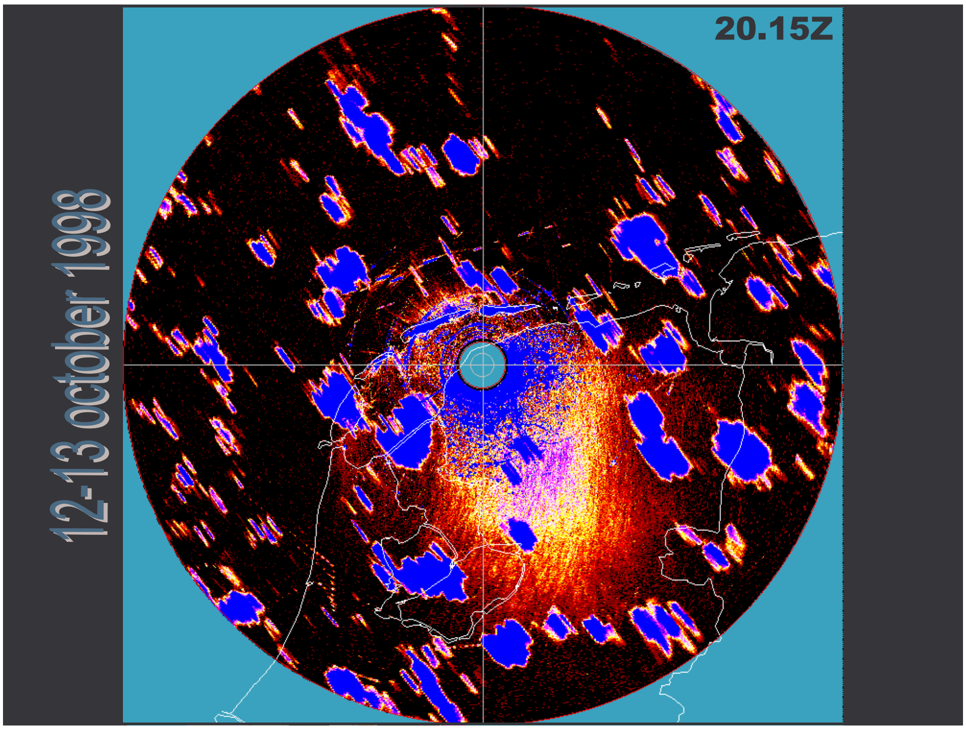

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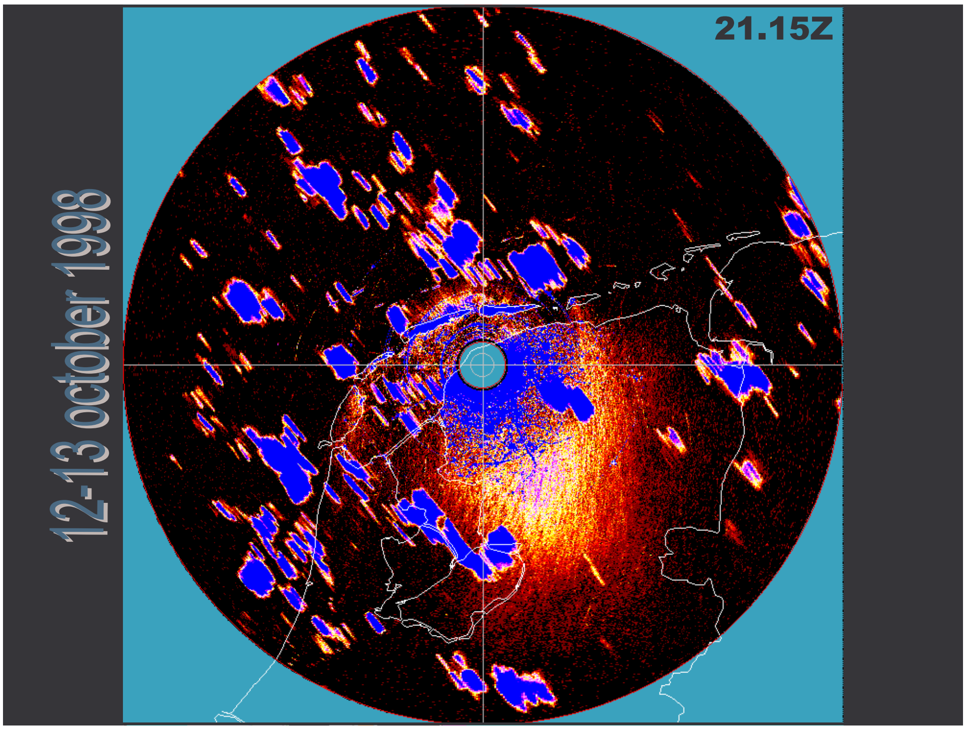

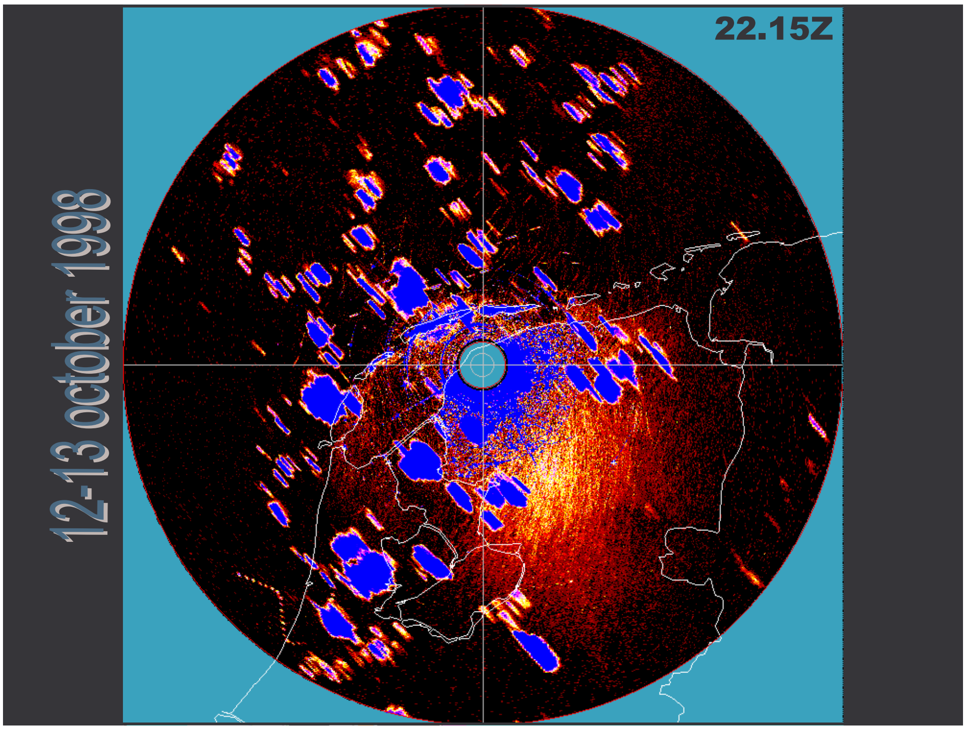

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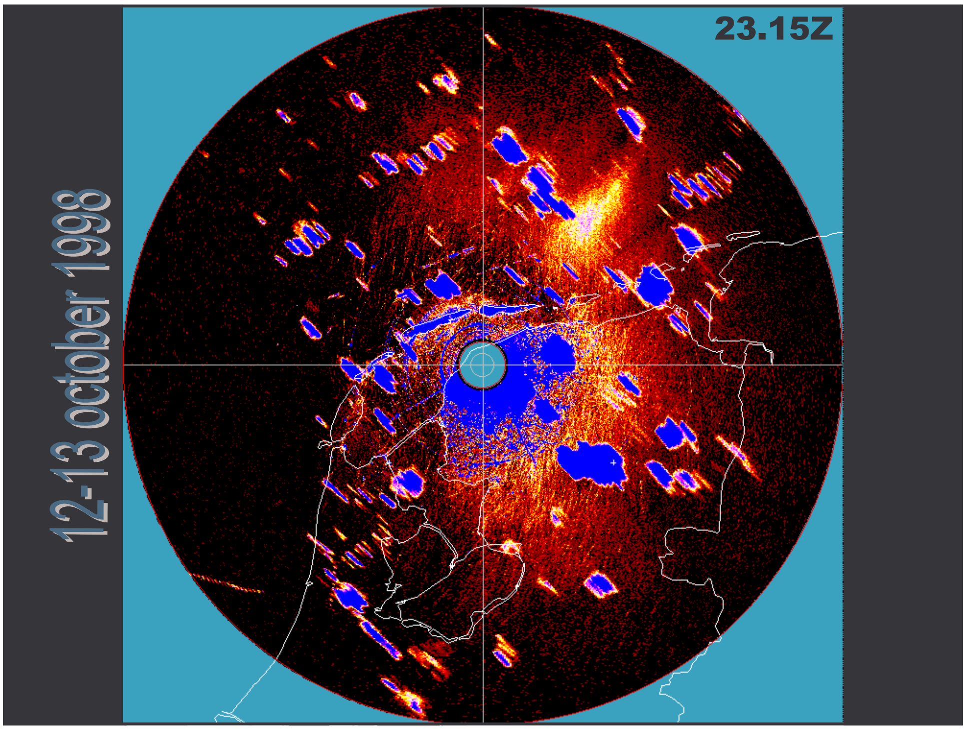

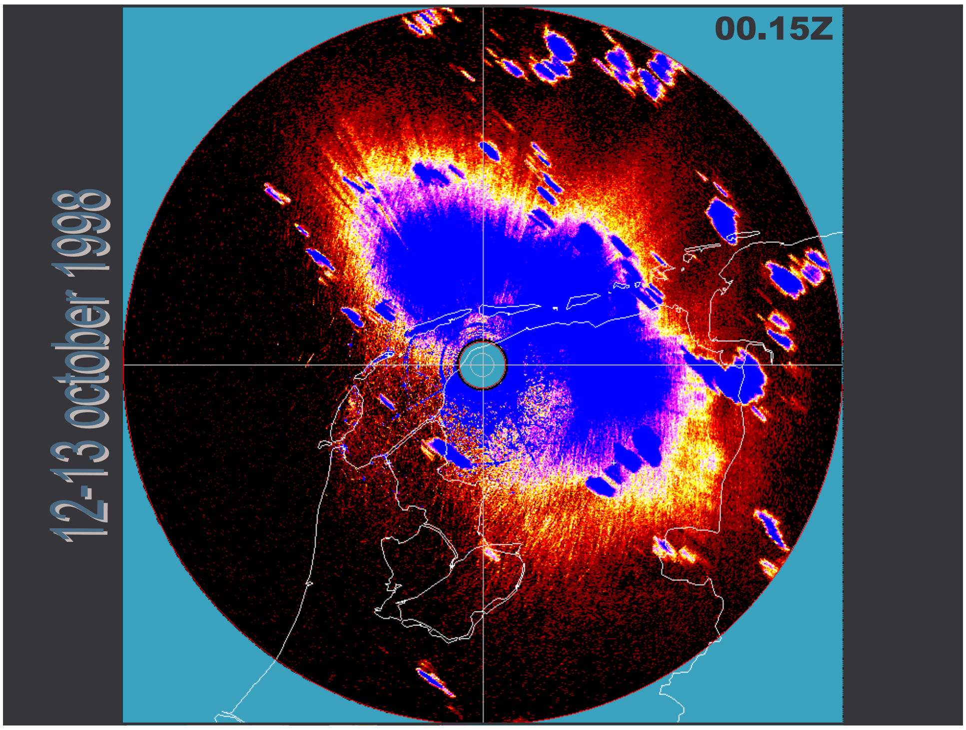

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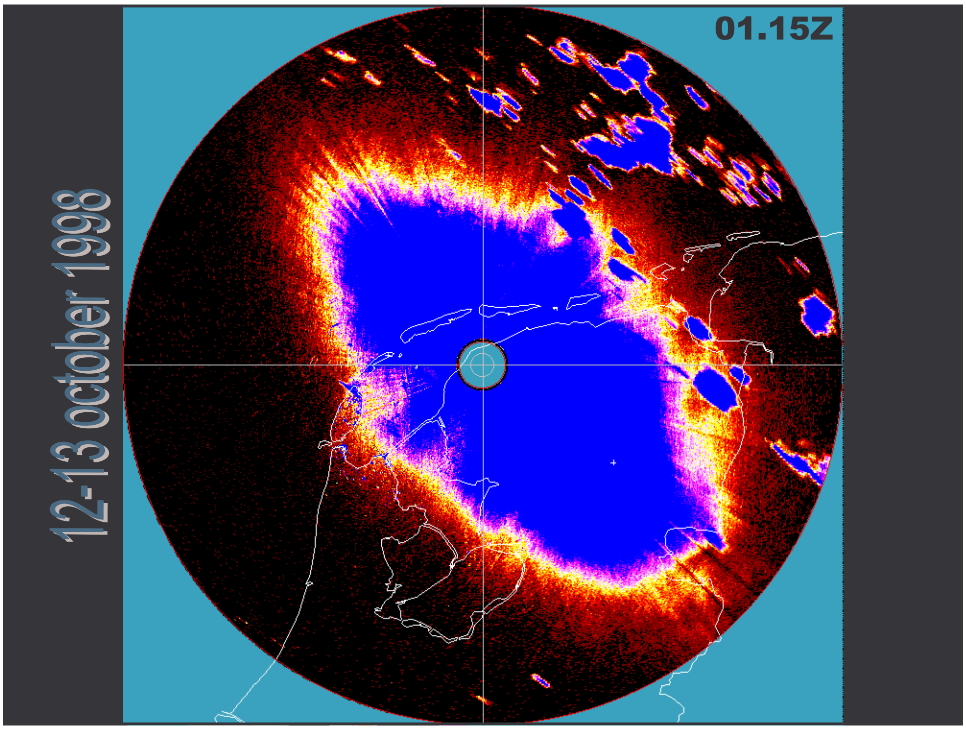
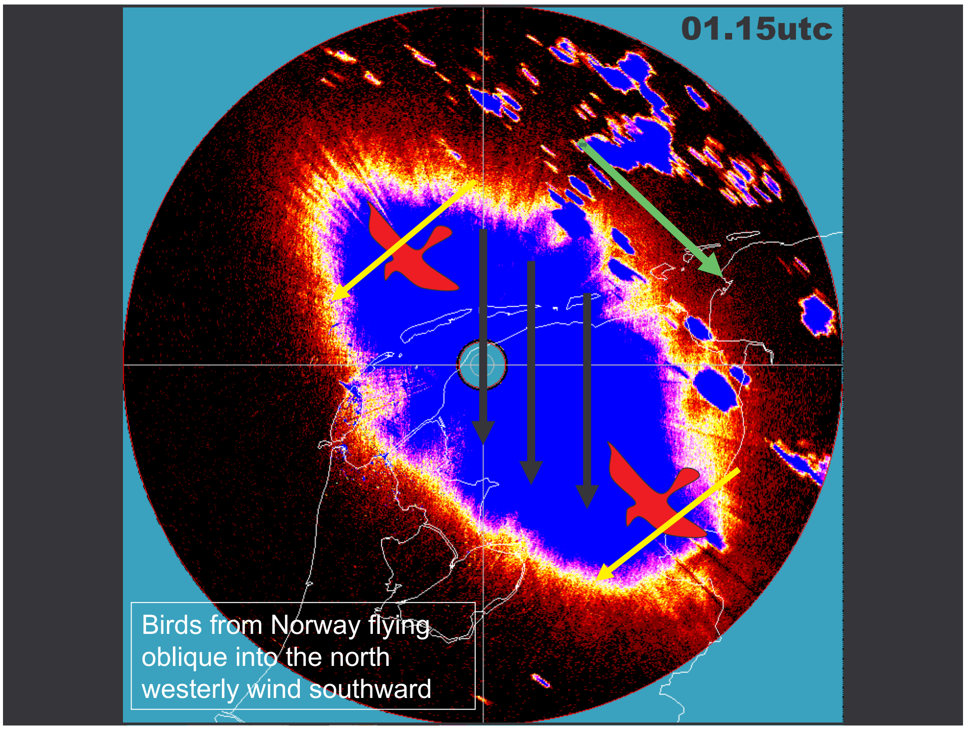
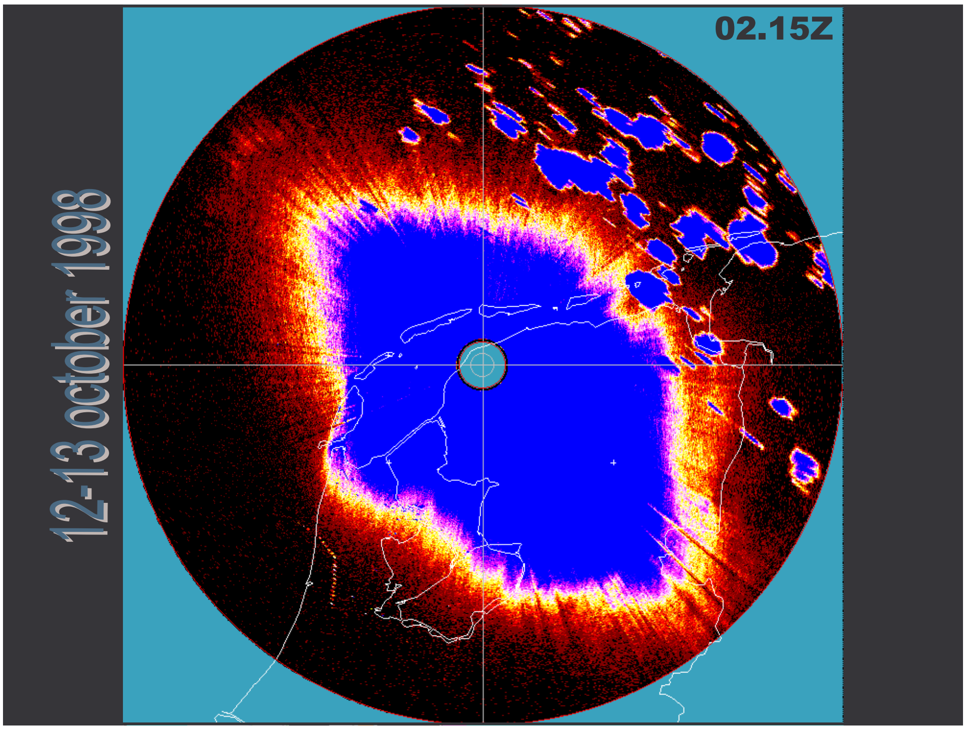
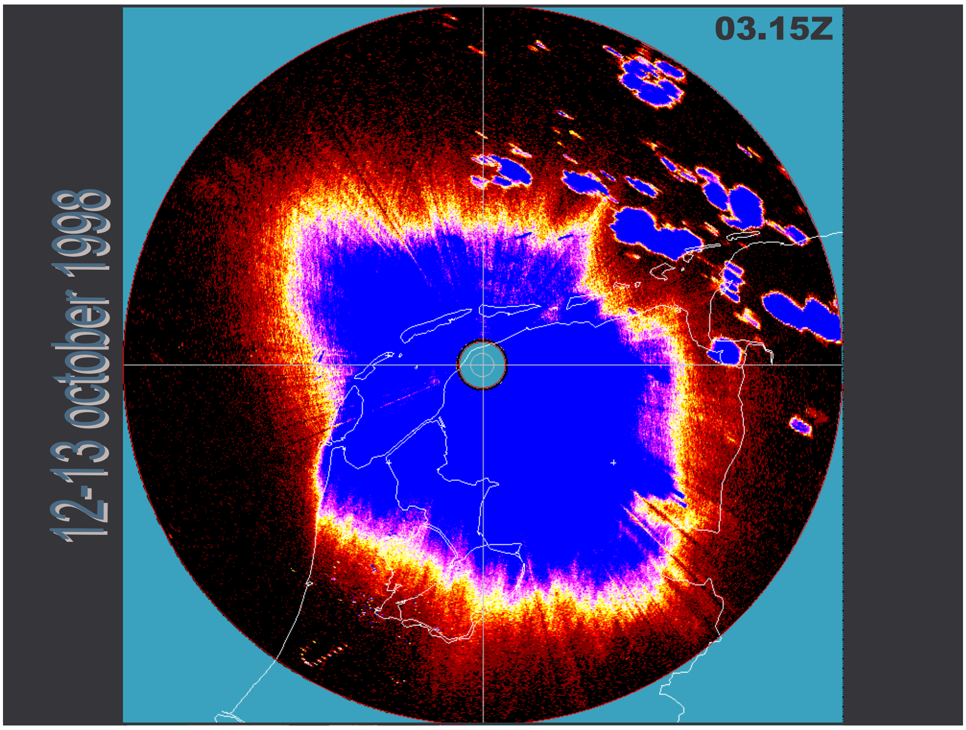

01.15Z
12-13 october 1998


01.15utc
Birds from Norway flying
oblique into the north
westerly wind southward

14





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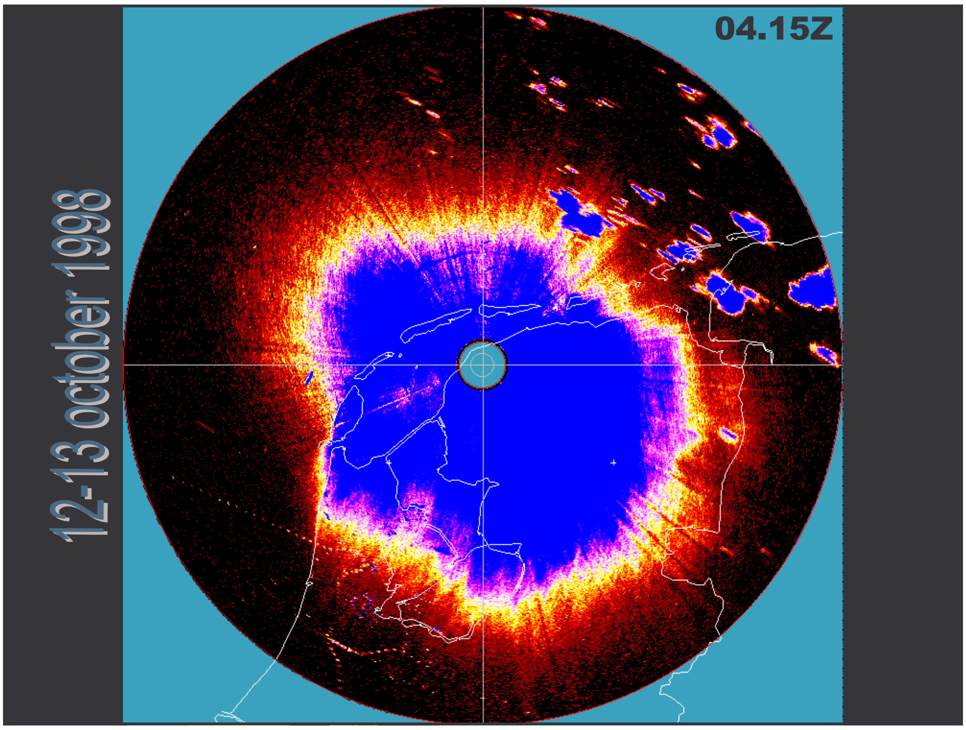

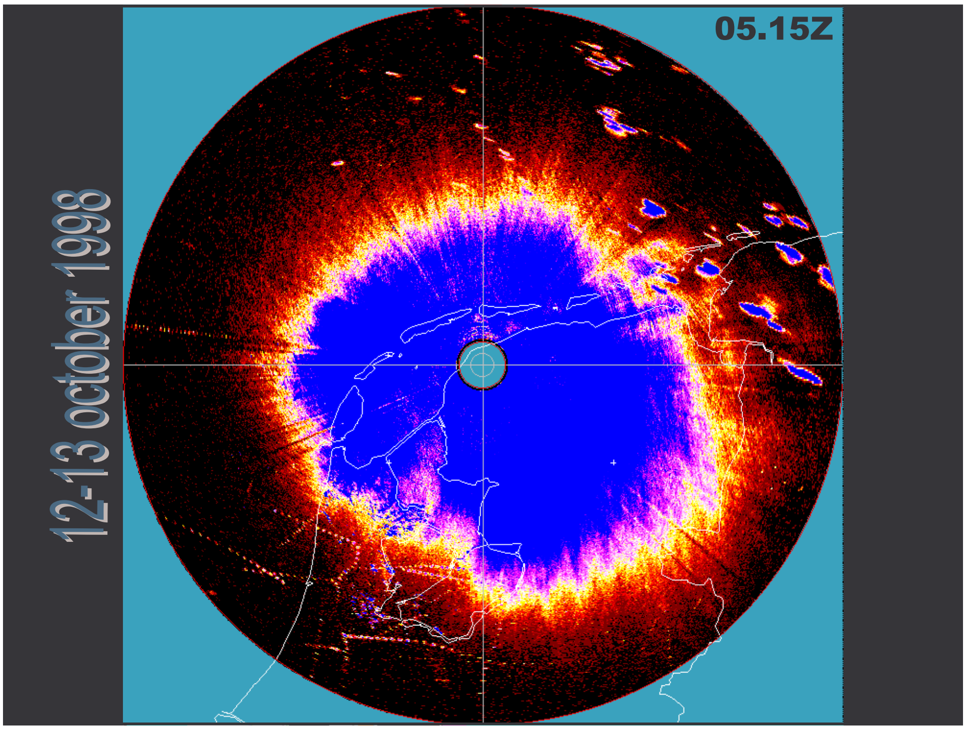

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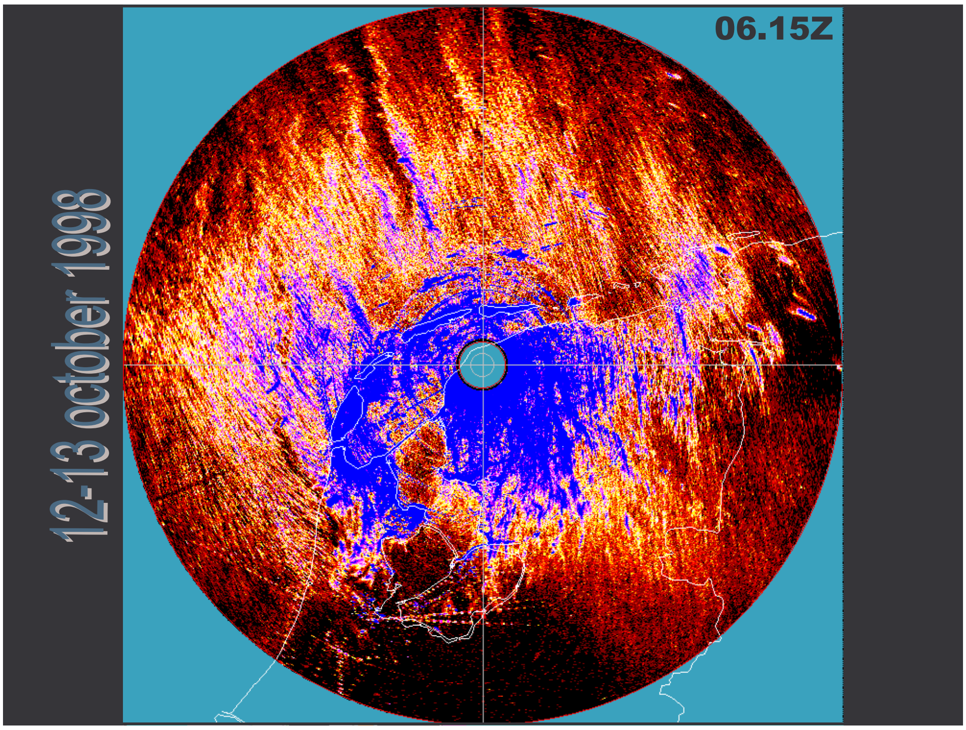

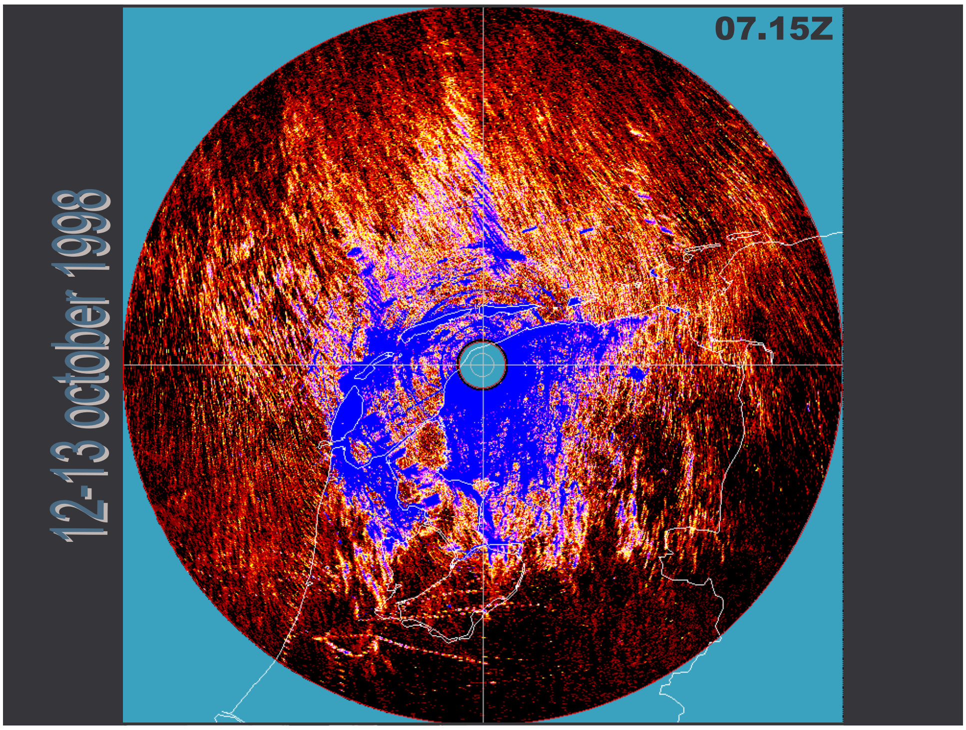

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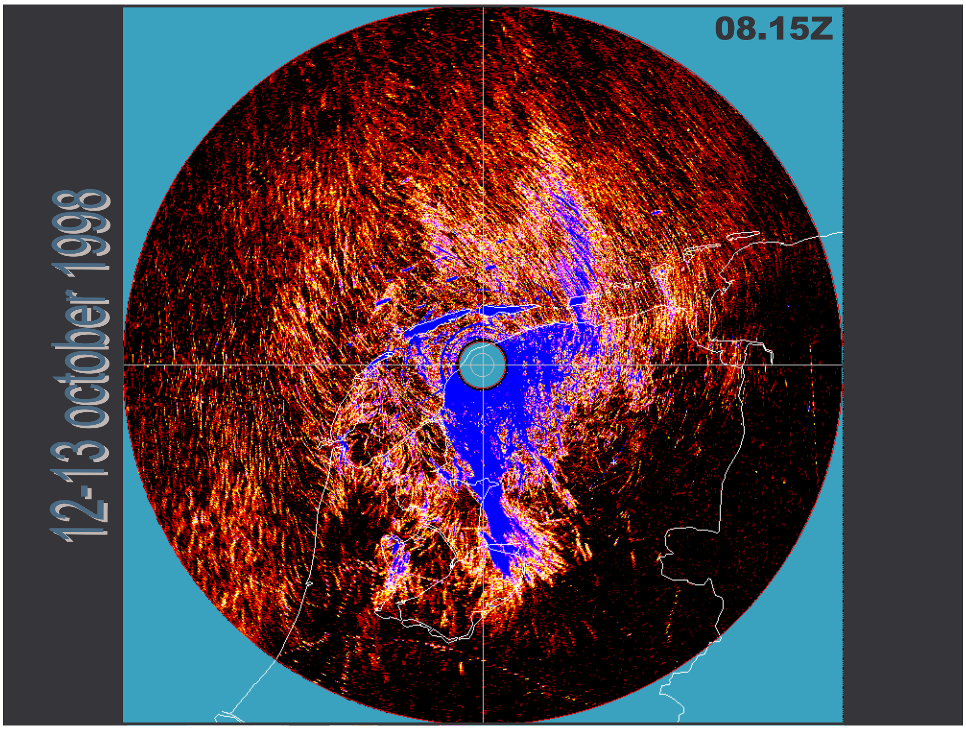

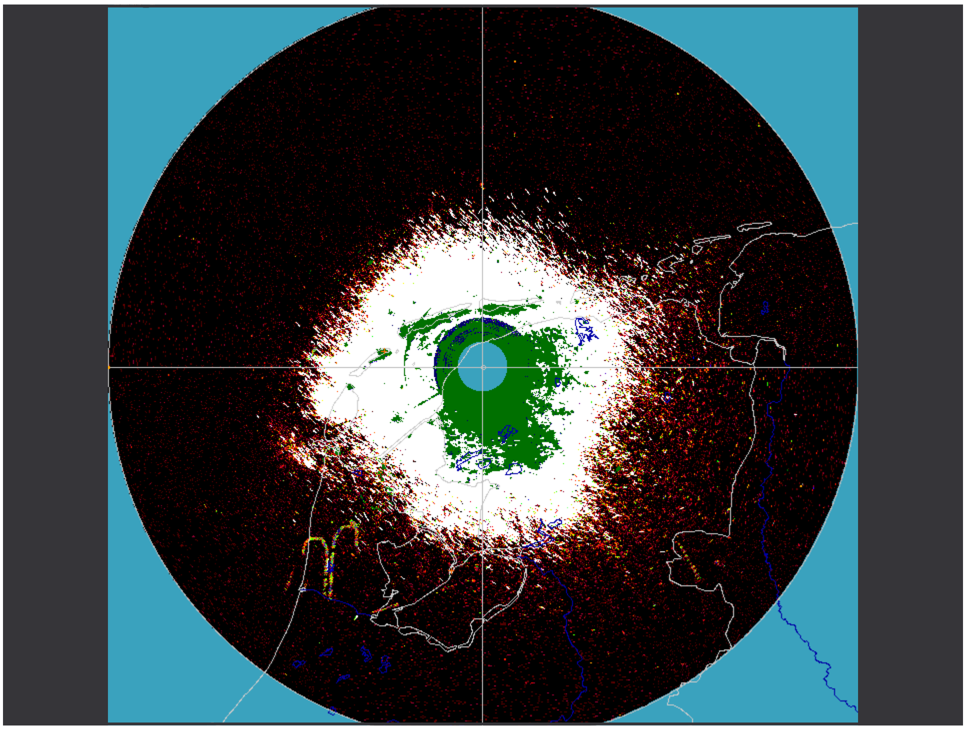

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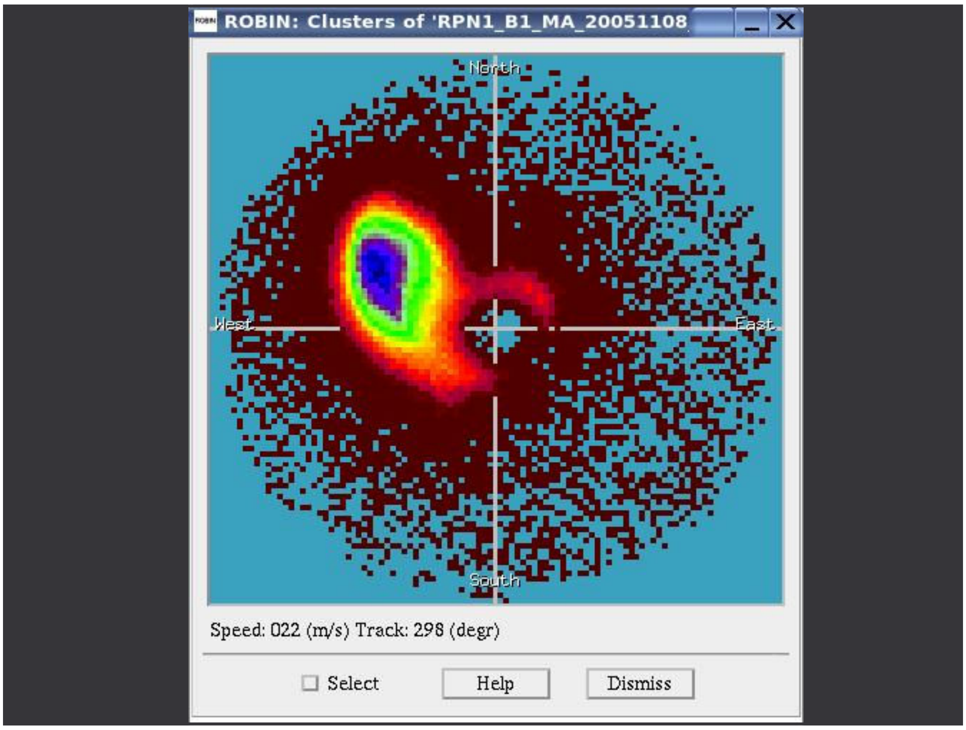
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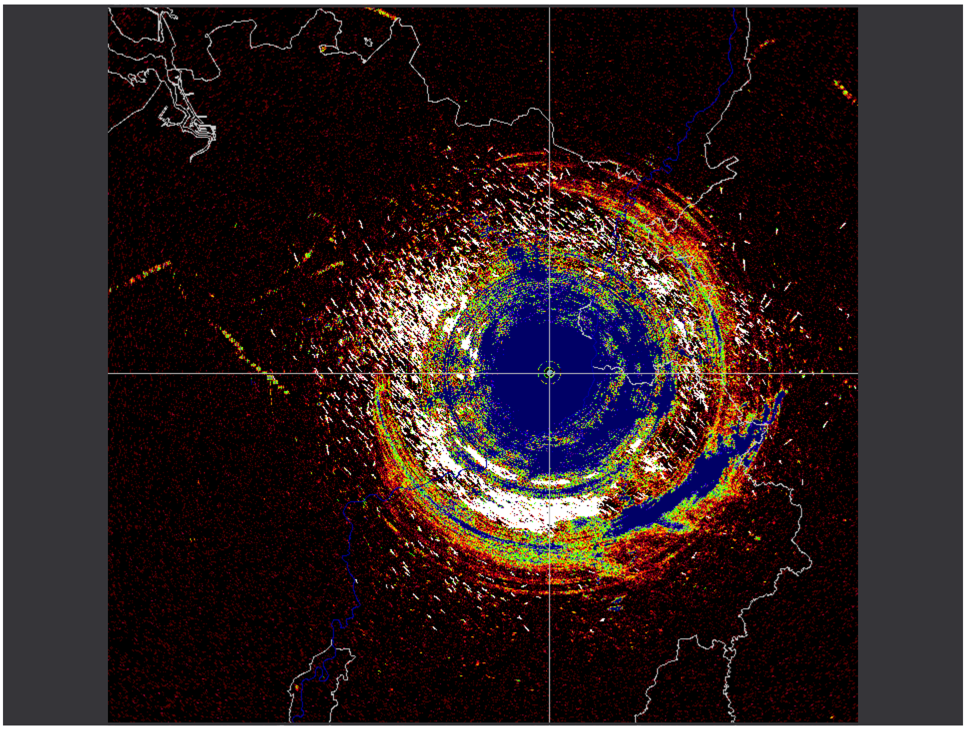
North
West
East
South
Speed: 022 (m/s) Track: 298 (degr)
Select
Help
Dismiss



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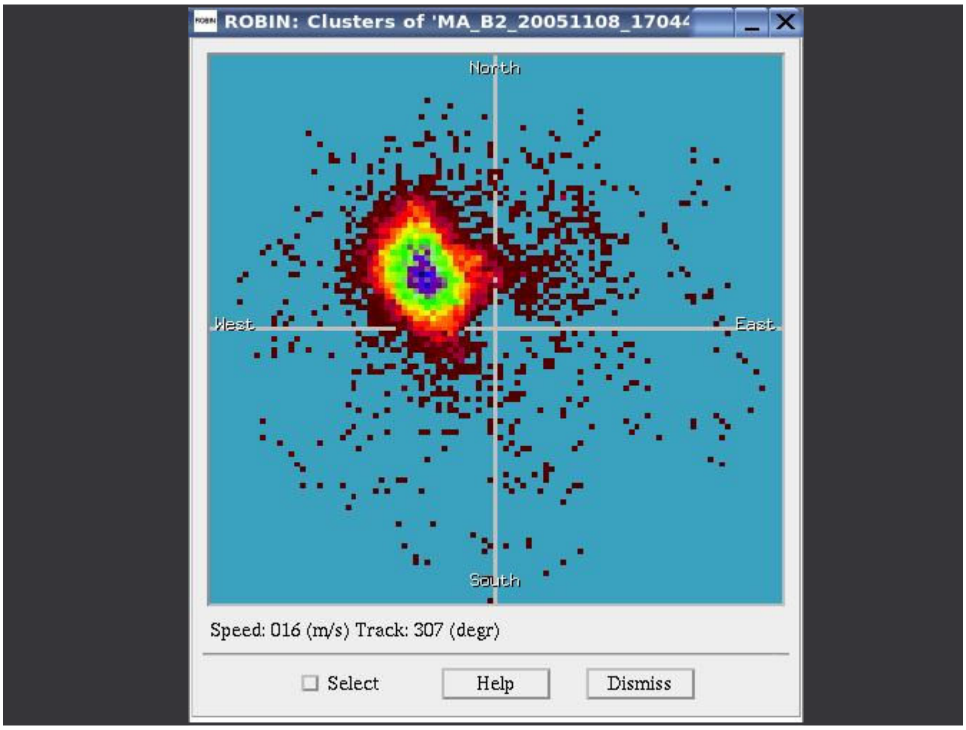
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South
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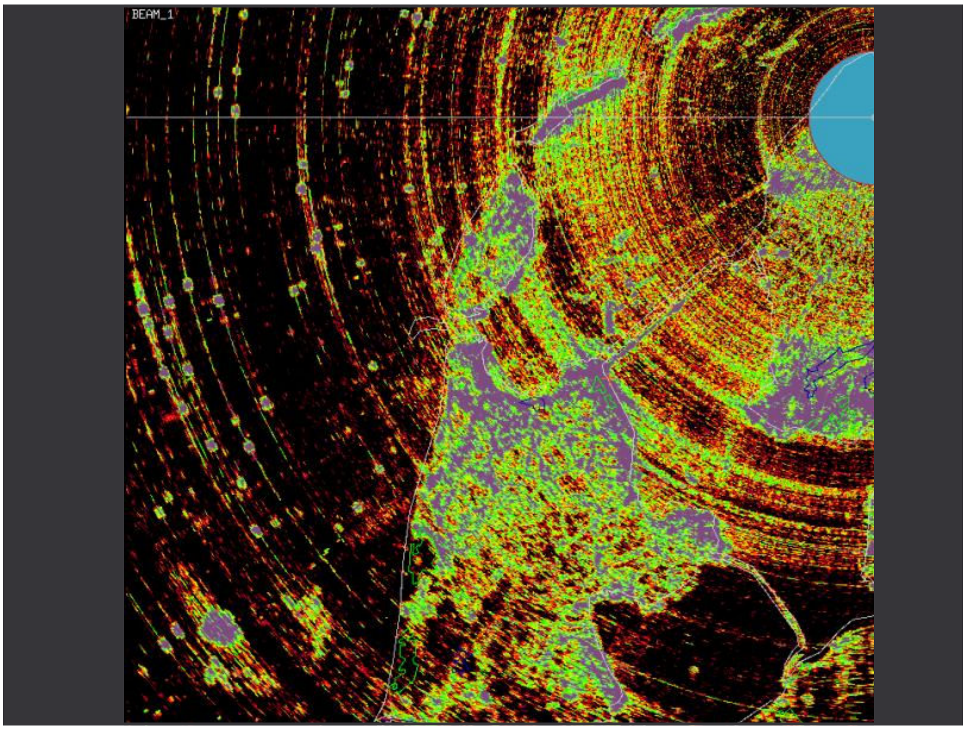
Select
Help
Dismiss


BEAM_1

20


Conclusions:
Digging still deeper in groundclutter than already done is not advisable
A separate small, slow and low target channel for bird and UAV monitoring improves safety, security and WT suppression
Additional medium range S-band 3D-radars are not a threat but a solution for more wind energy
18/11/09

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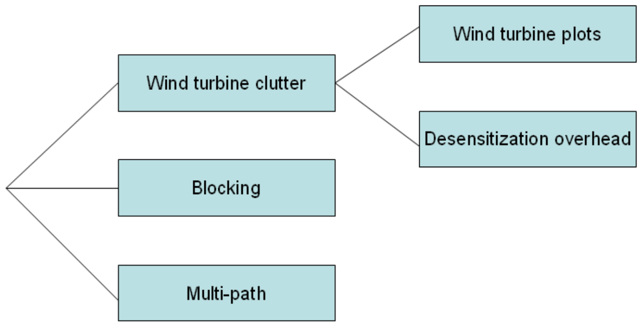
Summary

- Introduction
- Comment on the Eurocontrol draft-document
- Features of the acceptance tool
- Conclusive remarks

2 Arne Theil

Introduction

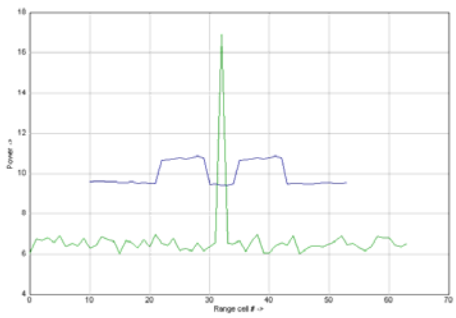


3 Arne Theil

Introduction

- Royal Dutch Airforce decides on wind turbine placement based on the shadow effect
- This policy is going to be abandoned: desensitisation overhead due to wind turbine clutter is more eminent.

Desensitization overhead



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Comment on Eurocontrol draft-document

Focussing on the PSR paragraphs, the Eurocontrol document does not provide a recipe.

- What is 'simple assessment', what is 'detailed assessment'?
- Is it sensible to have a simple assessment, why don't do it the detailed way?
- How can line-of-sight actually be determined?
- What type of terrain data is appropriate?

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Features of the acceptance tool

- Considers PSR's only
- To be used by Royal Dutch Airforce, possibly also by Air Traffic Control the Netherlands (LVNL)
- Tests buildings as well as wind turbines
- Verdict based on Detection Probability
- Demands required radar coverage as input, i.e., an altitude profile
- Can handle multiple radar coverage profiles
- For fixed buildings: supports ICAO EUR DOC 150 profile as well as other, user-defined profiles
- PSR performance assessment based on the Blake Chart

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Features of the acceptance tool

- Supports sensor fusion as remedy
- Models both the shadow effect and desensitisation above (see presentation of colleague Mathijs Schouten)
- Models line-of-sight and propagation effects with Signal Science Terpem
- Intends to use high quality altitude data (AHN)
- Obstacles can be added to the altitude data
- Models ATC as well as AD radars: Raytheon ASR-10SS (5x), Schiphol TAR4 (Grumman), Thomson MPR, also Thales SMART-S Mk2, Raytheon ASR-10SS 'upgraded' (concurrent beams, modified CFAR)

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Features of the acceptance tool

Thales SMART-S Mk 2
- The SSR is on the back
- Medium PRF waveform
- Fan beam on transmit, 12 stacked beams on receive

Raytheon ASR-10SS
- Low PRF waveform
- Low beam on transmit, low and high beam on receive, switched
- Two pulselengths

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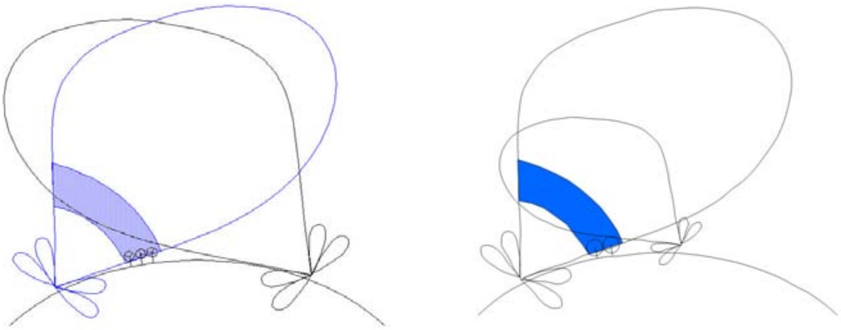
Features of the acceptance tool



Sensor fusion as remedy

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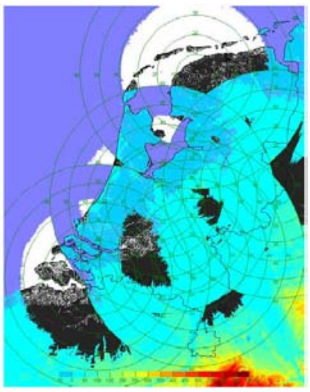
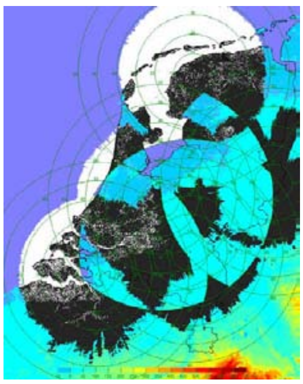
Features of the acceptance tool



One ‘overlooking’ radar



Two ‘overlooking’ radars

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Conclusions

- Modelling of the wind turbine clutter and its effect on radar coverage is seen as the most critical part of the programme
- The intention is to verify the fidelity of the model with clutter recordings from the ASR-10SS at Soesterberg
- Ready: End Q3 2010

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RADICOM
Consultants in Radiocommunication

Radar disturbance by obstacles

Prof.dr.ir. G. Brussaard
Radicom Consultants

RADICOM
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Contents

- Criterion for obstacles in vicinity of radar
- Definition of 'radar disturbance factor'
- Analysis for buildings
- Analysis for windmills

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Criterion for buildings in the vicinity of air surveillance radars

- 8 air surveillance radar locations in NL
- Area within 15 nm (28 km) of radar is protected area
- All proposals for buildings above 45 m in protected areas ‘must be evaluated’
- Criterion: “radar disturbance factor” must be below 10%
- Evaluation is carried out by TNO

18 November 2009 Radar disturbance by obstacles 3

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Range reduction by obstacle

Signal loss due to obstacle is a function of
- radar cross section of obstacle
- obstacle distance
- target range

Relative range reduction (‘radar disturbance factor’) is

$$\Delta_R = \frac{R_u - R_o}{R_u} = 1 - \sqrt{\frac{P_o}{P_u}}$$

R_o and R_u are obstructed and unobstructed range, respectively.
P_o/P_u is the (one-way) signal loss due to the obstacle

18 November 2009 Radar disturbance by obstacles 4

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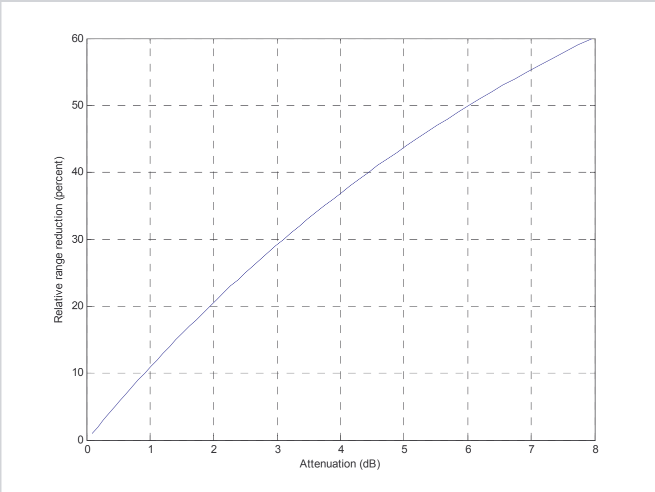

Relative range reduction vs. attenuation

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For practical cases (non-transparent objects, target distance much larger than obstacle distance):

$$\Delta_R \approx c \frac{d}{\sqrt{r_0}}$$

- *d* is the diameter of the obstacle
- r_0 is the distance between radar and obstacle
- *c* is a constant dependent on frequency, width of the radar beam, shape and material of obstacle

Criterion for high-rise buildings within 15 nm (28 km) of radar:

$$\Delta_R < 10\%$$

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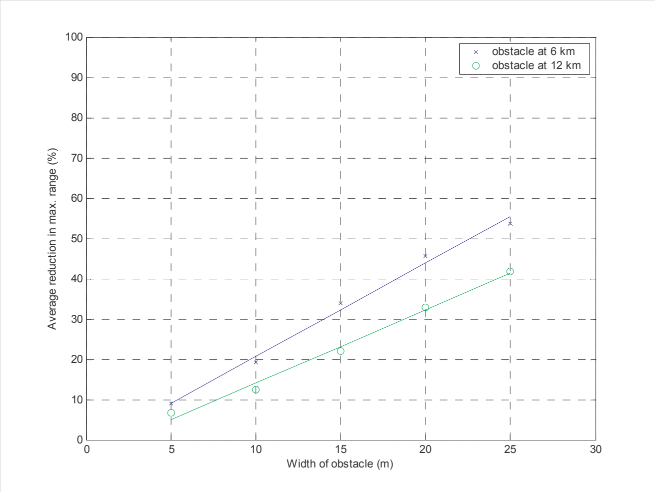

Disturbance factor vs. width of obstacle

18 November 2009 Radar disturbance by obstacles 7

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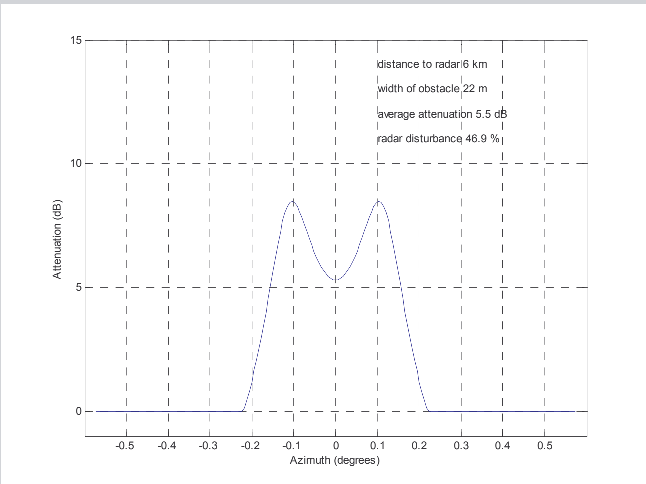
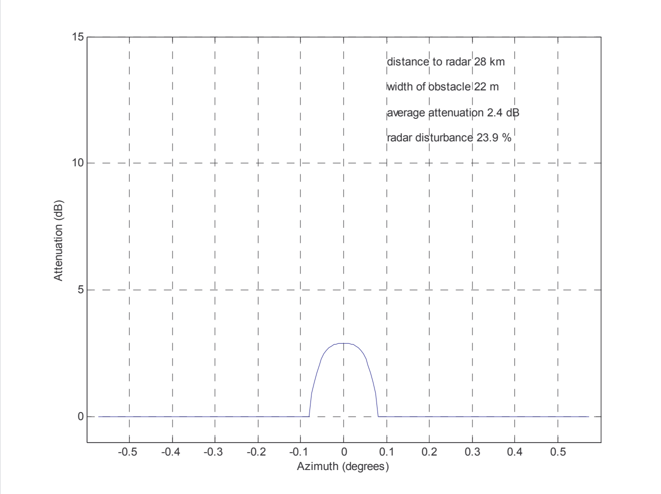


Radar disturbance / building at 6 km

18 November 2009 Radar disturbance by obstacles 8

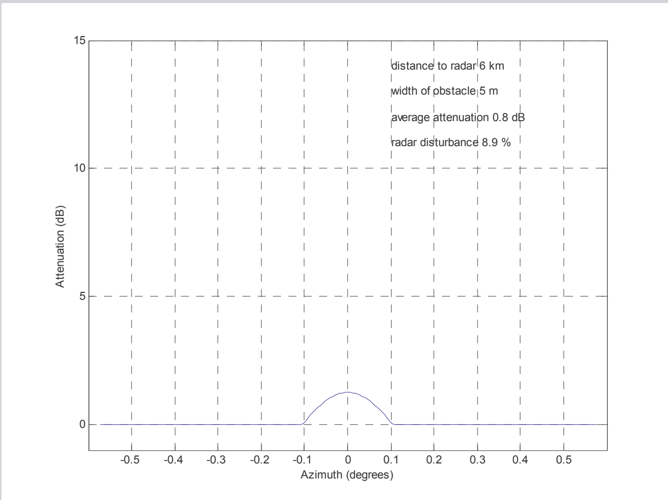
RADICOM
Consultants in Radiocommunication



Radar disturbance / building at 28 km

18 November 2009 Radar disturbance by obstacles 9

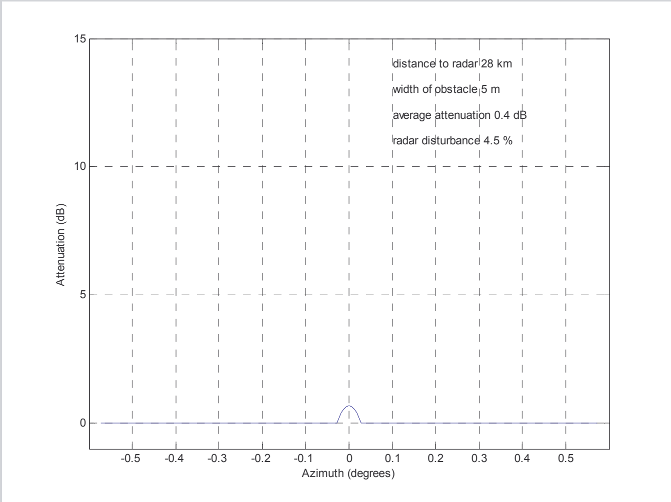
RADICOM
Consultants in Radiocommunication



Radar disturbance / windmill at 6 km

18 November 2009 Radar disturbance by obstacles 10

RADICOM
Consultants in Radiocommunication



Radar disturbance / windmill at 28 km

18 November 2009 Radar disturbance by obstacles 11

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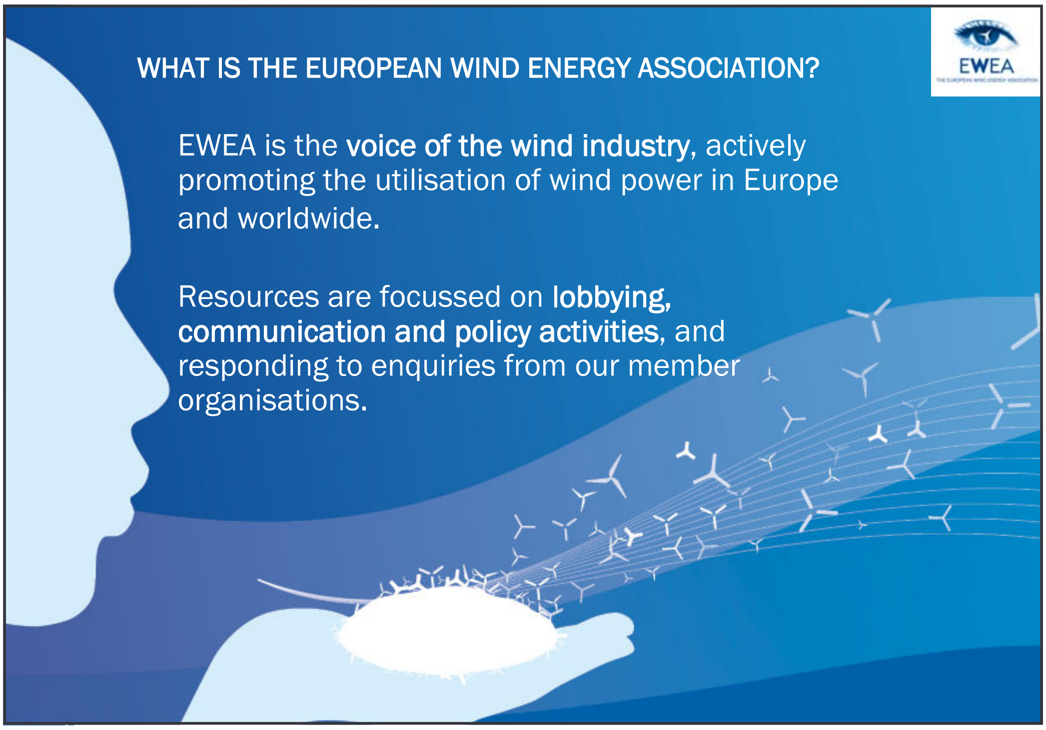
Conclusions

- Relative criterion is not related to radar specifications
- Software for evaluation of radar performance against specifications is available
- Prohibition of all high-rise buildings in protected areas is a very severe measure

18 November 2009 Radar disturbance by obstacles 12


EWEA
THE EUROPEAN WIND ENERGY ASSOCIATION
EWEA response to Eurocontrol consultation process on:
"Guidelines on how to assess the potential impact of wind turbines on surveillance sensors"
Nicolas Fichaux
Head of Policy Analysis
European Wind Energy Association
23 October 2009


WHAT IS THE EUROPEAN WIND ENERGY ASSOCIATION?
EWEA
EWEA is the voice of the wind industry, actively promoting the utilisation of wind power in Europe and worldwide.
Resources are focussed on lobbying, communication and policy activities, and responding to enquiries from our member organisations.

EWEA THE EUROPEAN WIND ENERGY ASSOCIATION

More than 600 members from almost 60 countries

- Manufacturers covering 90% of the world wind power market
- Component suppliers
- Research institutes
- National wind and renewables associations
- Developers
- Electricity providers
- Finance and insurance companies
- Consultants
- Contractors

This combined strength makes EWEA the world's largest and powerful wind energy network in the world

EWEA THE EUROPEAN WIND ENERGY ASSOCIATION

Members include the following leading players:

acciona Windpower
Airtricity
DONG energy
e·on Climate & Renewables
edp renovables powered by nature
EnBW
GE Energy
IBERDROLA
MAINSTREAM RENEWABLE POWER
res power for good
SIEMENS
SUZLON
VATTENFALL
Vestas

EWEA THE EUROPEAN WIND ENERGY ASSOCIATION

Guidelines objectives

- Guidelines to ANSPs and wind energy developers to assess the impact of the future wind farm developments.
- Consultation process is open until Jan. 10. EWEA consulted its members to build a common position, submitted to Eurocontrol in october.
- Objectives:

  1/This document aims at maintaining the necessary levels of safety and efficiency of surveillance related Air Traffic Services

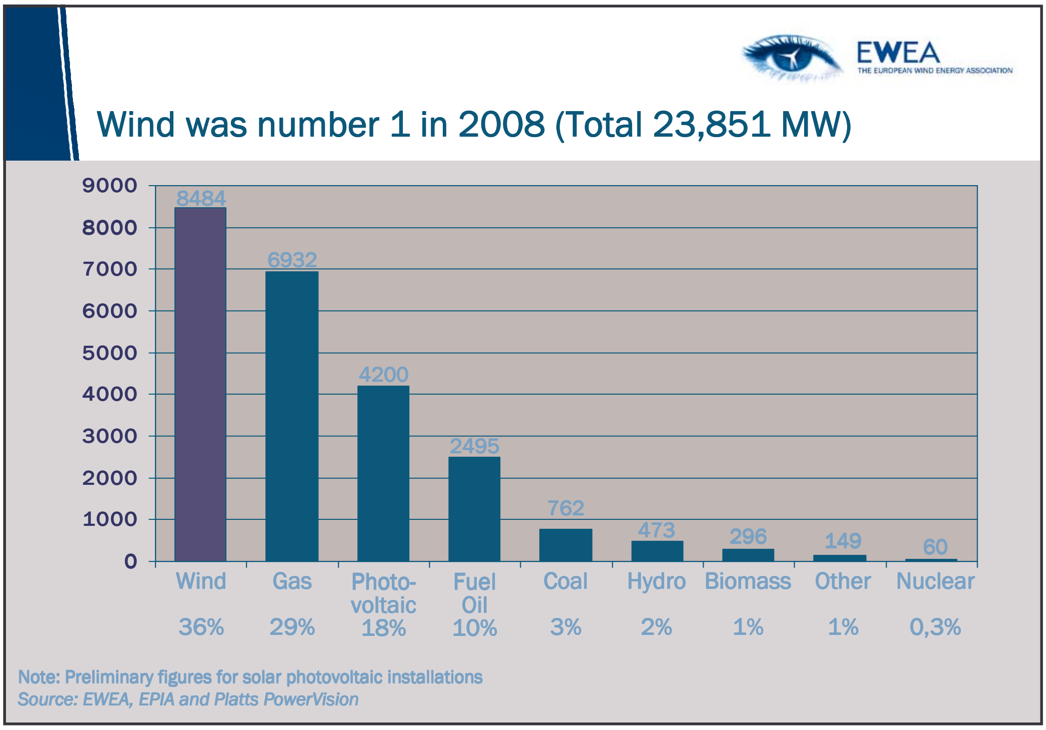
  2/ Supporting to the maximum extent possible the development of wind energy.

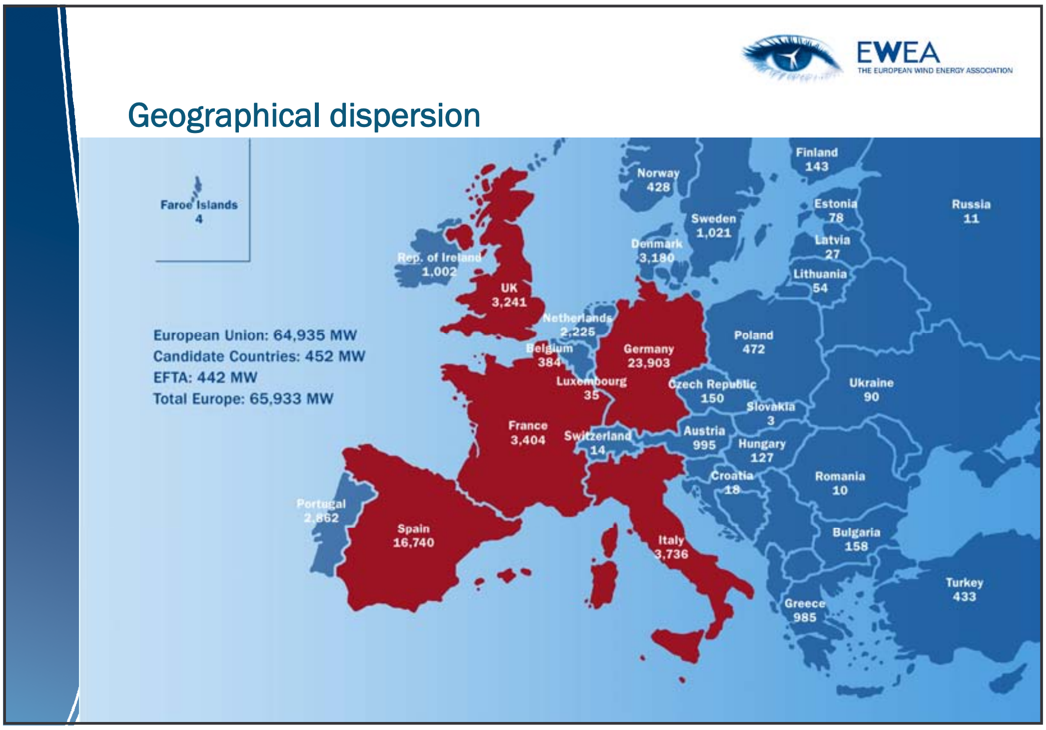
- EWEA thinks the second objective is not met

EWEA THE EUROPEAN WIND ENERGY ASSOCIATION

Wind energy context

- €9bn turnover
- 4% EU electricity
- 230 GW in 2020
- 14-18% of EU electricity consumption
- 250 000 new jobs until 2020


EWEA
THE EUROPEAN WIND ENERGY ASSOCIATION
Wind was number 1 in 2008 (Total 23,851 MW)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
8484
6932
4200
2495
762
473
296
149
60
Wind
Gas
Photo-voltaic
Fuel Oil
Coal
Hydro
Biomass
Other
Nuclear
36%
29%
18%
10%
3%
2%
1%
1%
0,3%
Note: Preliminary figures for solar photovoltaic installations
Source: EWEA, EPIA and Platts PowerVision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Geographical dispersion
Faroe Islands 4
European Union: 64,935 MW
Candidate Countries: 452 MW
EFTA: 442 MW
Total Europe: 65,933 MW
Norway 428
Finland 143
Sweden 1,021
Estonia 78
Russia 11
Denmark 3,180
Latvia 27
Lithuania 54
Rep. of Ireland 1,002
UK 3,241
Netherlands 2,225
Poland 472
Belgium 384
Germany 23,903
Luxembourg 35
Czech Republic 150
Ukraine 90
Slovakia 3
France 3,404
Switzerland 14
Austria 995
Hungary 127
Croatia 18
Romania 10
Portugal 2,862
Spain 16,740
Italy 3,736
Bulgaria 158
Greece 985
Turkey 433

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Wind farm developments, some elements

- A wind farm investment is a multi-million industrial investment
- The wind farm layout, wind turbine height, capacity and size is the result of a complex multi-parametric optimisation process:
  - Costs vs Power delivery (income and financial reliability)
  - Land property
  - Access routes
  - Grid connection
  - Visibility
  - Noise impact
  - Environment aspects: birds, bats, nature preservation..
  - Geotechnical aspects

Radars are one of the parameters to be contemplated in a global picture

STOP BUTTON? Requested for radars, birds, bats, grid operators, who else?

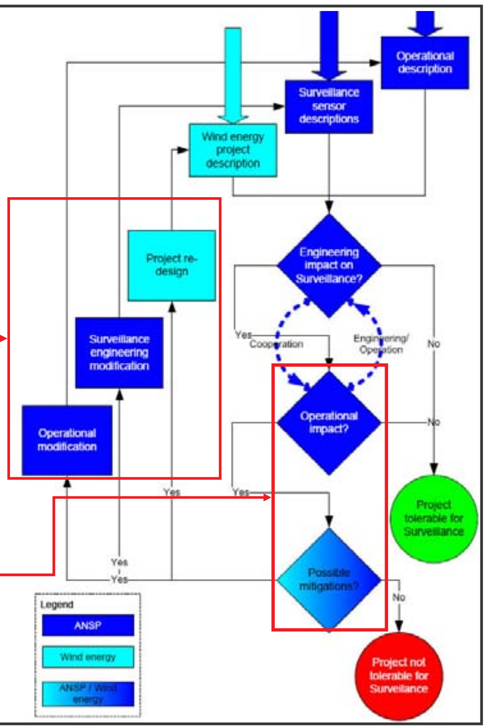
Impact assessment process

Very good proposal, will improve and streamline relationships between ANSR and Wind energy developpers

Should be evaluated on a cost/benefit basis

Needs transparency and strong involvement of wind developpers

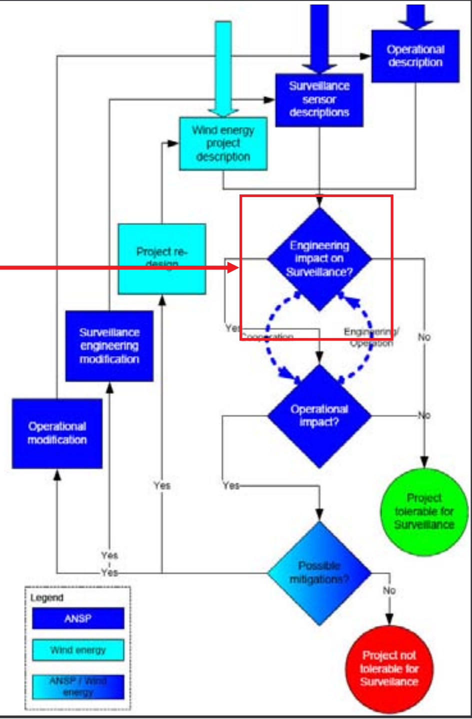
Process should be limited in time (3 months)



Engineering impact: detail

ANSR Task: Assessing the perfomance impact of the WT on the radar system.

Performed for each sensor having a turbine in sight



On the issue to work at surveillance sensor level

- *"The maximum effort should be undertaken to minimise the impact for wind turbines at the earliest stages of the surveillance chain i.e. at the surveillance sensor level"* and *"The application of specific features at surveillance data processing level is considered as a possible mitigation although "prevention is better than a cure" is the preference of the ANSPs."*

- **Conservative approach leading to unnecessary project redesign**
  - **post-processing, data redundancy and data fusion techniques might be available to solve the issue.**
  - **Should be done at system level**

- Assess the potential technical and operational mitigation measures in terms of radar engineering and operational implementation aspects. Assessment shall be based on economic analysis of the proposed mitigation measures

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Radar impact assessment – primary surveillance radar

Zone 1 Safeguarding	Zone 2 Detailed assessment	Zone 3 Simple assessment	Zone 4 No assessment
0 - 500 m	500 m - 15 km and in radar line of sight	Further than 15 km and in radar line of sight	Not in radar line of sight

« No developments shall be agreed »

Detailed assessment « difficult, time consuming, costly and complex »

Simple assessment
If contested, detailed assement needed

Open ending zone

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Radar impact assessment – secondary surveillance radar

Zone 1 Safeguarding	Zone 2 Detailed assessment	Zone 4 No assessment
0 - 500 m	500 m - 16 km and in radar line of sight	Further than 16 km or not in radar line of sight

« No developments shall be agreed »

Detailed assessment « difficult, time consuming, costly and complex »

Open ending zone

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Simple assessment – PSR « 15km and line of sight »

- Simple assessment evaluates probability of detection (geometric approach) and false target reports (any turbine in line of sight)
  – Performed for each wind turbine
  – Global impact equals sum of the impacts
  – Geometric approach do not include target characteristics
  – A wind turbine is a 'false target' by default

Main concerns – an overestimation

– Sum of the impacts is the worst case
– System redundancy is not addressed (PSR/SSR)
– Filtering, signal processing techniques are not included

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Buffer zones

- The limits of 15 and 16 km are arbitrary. Evaluation is performed at sensor level radar system, without post processing.
  – Firstly, an impact assessment of improving the current operational practices, software and technologies shall be performed. The limits shall be set on the basis of the best available technologies.
- Radar line of sight is an open-ended concept that could span for many kilometres beyond any influence to radar equipment.
  – There needs to be an outer limit for Zone 3 which would normally be the ANSP statutory consultation boundary.
- Zone 4 for PSR: it is unclear why this zone has been added if "no assessment" is necessary. ICAO EUR 15 does not have this extra zone.

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Buffer zones

- Zone 1 : ANSP do not have the mandate to forbid developments
  ANSPs give advices, but don't deliver building permits
- Zone extend: Zone 1+2 and Zone 3 shall be as limited as possible
  - adequate studies shall be undertaken beforehand to enable rapid evolutions in terms of surveillance engineering and operational modifications
  - A detailed description of the criterions of zonal limits shall be available on demand. Counter expertise shall be made possible and considered.
- In Zone 3: If the planning applicant contests the results of the 'simple assessment' it should undertake a simple assessment, with full support of ANSP.
- Zone 4 is not in line with ICAO 015 and an open ended zone based on line of sight is not relevant.

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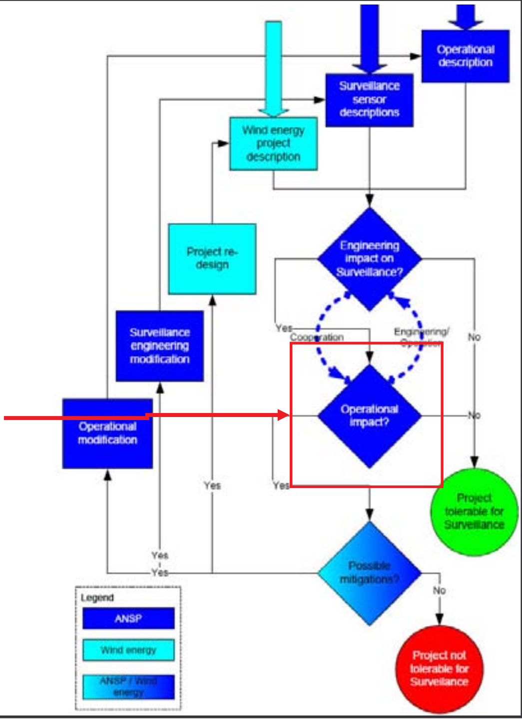
Simple assessment / detailed assessment

- Detailed assessment is the most effective way to perform the analysis – but is discouraged *»the detailed engineering assessment is a very complex and lengthy process »*
  - Eurocontrol therefore invites ANSRs to create 15km and 16km buffers around radars
  - The report indicates other sensors could be added in a later stage (« WAM, ADS-B, MSPSR »)
- EWEA recommends Eurocontrol provides all necessary tools and support for ANSRs to perform a detailed assessment
- The 15 and 16 km limits are arbitrary. A detailed assessment should help defining limits

Operational impact: detail

ANSR Task: assessing the impacts of the project on the ANSP operations based on surveillance services and/or on the surveillance data service the ANSP is providing to other users



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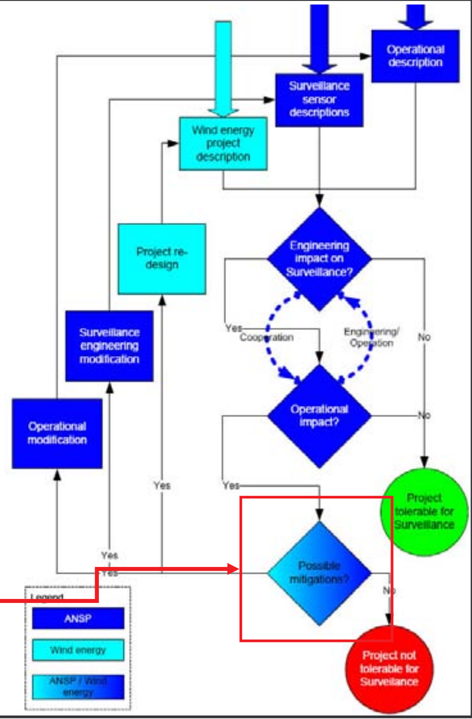
Categories

- PSR: probability of detection, false target reports, 2D position accuracy, plot/track processing capabilities
- SSR: probability of detection, false target reports2D position accuracy

« Is the effect tolerable or not » Which criterions?

- Points refer to insufficiencies of current algorithms, software, materials and processing capacities, which are empirically solved for static features, but are revealed by the presence of wind turbines.
- An urgent action is to compensate these insufficiencies by e.g. adapting tracking systems, implementing smart tracking algorithms, advanced signal processing techniques, improved processing capabilities.

Possible mitigations: detail



ANSR/developper :
potential modifications to the surveillance system and/or the operational environment and/or the wind energy project that could mitigate to a tolerable level the impact of the wind energy development project

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Possible mitigations: content

- Different solution proposed to mitigate impacts:
  - PSR probability of detection, false target reports, 2D position accuracy, plot/track processing capability
  - SSR probability of detection, false target reports, 2D position accuracy
- Proposals made at engineering, operational and wind farm level
  - E.g. Exploit multi-sensors synergies, signal processing techniques, move routes, modify WF project (low down turbines, move turbines, remove turbines)
- Constraint: changes should be carbon-neutral

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Possible mitigations: comments

- A wind farm project is a multi-million euros investment
  - Priority shall be given to surveillance engineering and operational modification.
  - Project redesign shall be proposed as the last option.
- Any project redesign will lead to a sub-optimal configuration of the wind farm, or a sub-optimal implementation of individual wind turbines.
  - Project redesign will lower the electricity production of the wind farm, and consequently lower the project benefits in terms of CO2 emissions avoidance. This issue shall be put into balance when the issue arises to compare different options of engineering / operational modification versus project redesign.
- It is welcome that modifications shall be carbon neutral
  - this argument shall not be used to favour in-action in terms of surveillance or operational modification.

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Main conclusions

- The key added value of this document is the concertation process. Such guidance is highly welcome.
  - improve dialogue and transparency between ANSPs and wind farm developers
- The draft sends contradictory messages.
  - Zoning is proposed: extended beyond what specialists consider reasonable and current practice for a detailed impact assessment, But detailed assessments are stated too complex
  - Invite the rejection of any project within 15km and in line of sight of any radar in Europe taken individually.
- If applied, would hinder EU and Member States' efforts to increase the share of renewable energy in consumption and reduce greenhouse gas and CO2 emissions.
- **EWEA urges Eurocontrol to provide all necessary methods and tools to enable ANSPs and project developers to perform detailed assessment.**

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Main conclusions

- The approach is conservative. A review of modern technologies and algorithms shall be provided.
- As mitigation measures, emphasis is put on adapting the wind farm to the radar environment.
  - Mitigation options, be it at sensor, post-processing or operational level should be considered on an economic basis and compared to the potential economic impacts on the project itself.
- The wording chosen throughout the draft document suggests that ANSPs are themselves responsible for authorising or rejecting wind farm projects.

A more balanced proposal is required. Expected after consultation process.

EWEA THE EUROPEAN WIND ENERGY ASSOCIATION

Thank you very much for your attention

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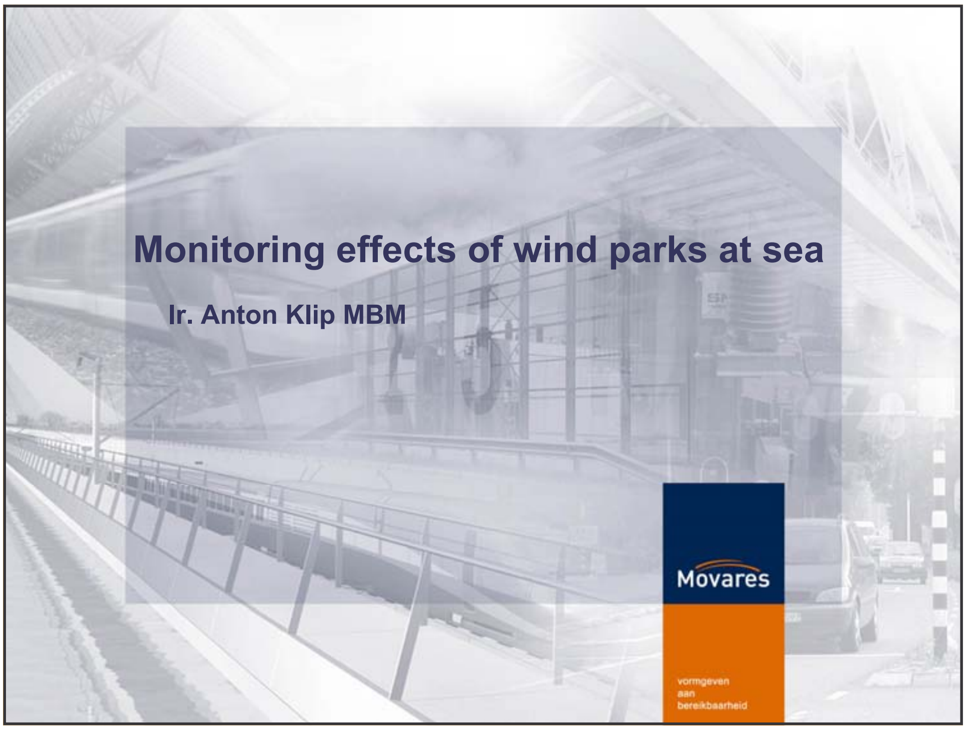
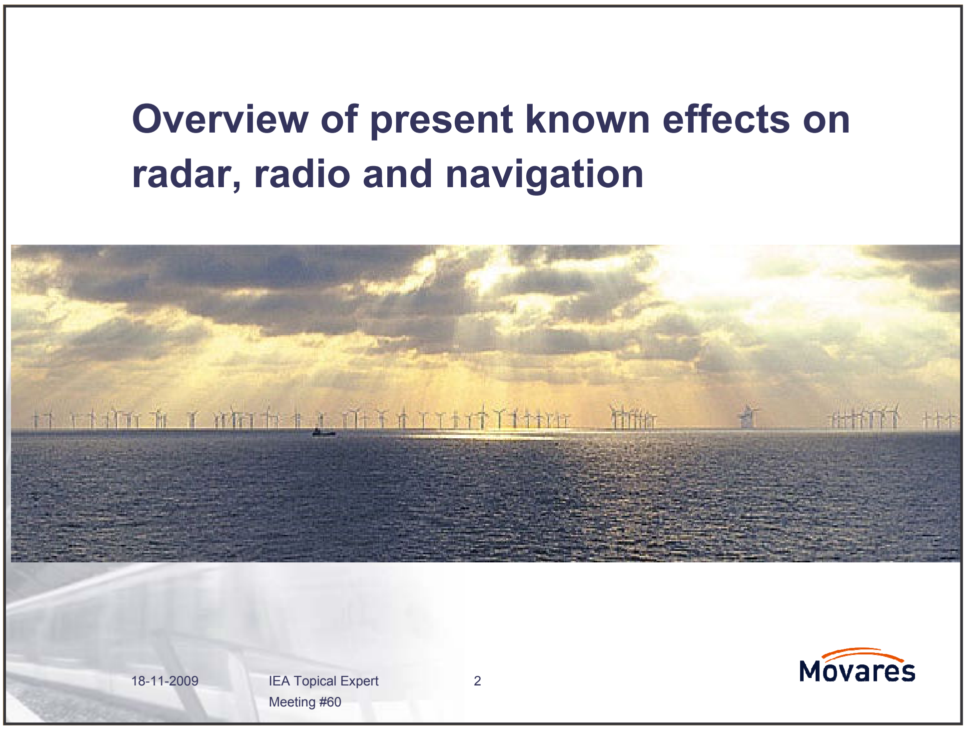

Monitoring effects of wind parks at sea
Ir. Anton Klip MBM
Movares
vormgeven
aan
bereikbaarheid


Overview of present known effects on radar, radio and navigation
18-11-2009
IEA Topical Expert
Meeting #60
2
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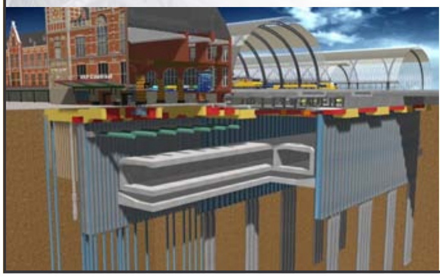
Movares Background

Engineering and consultancy

- Roots: 19th century railroads
- 1.400 people
- € 140 million turnover
- Head office: Utrecht
- Regional: Zwolle, Weesp, Eindhoven en Zoetermeer
- Europe: Poland, Portugal and Germany



Architecture and design
Railroad tracks and stations
Building and real estate
Building techniques
Consultancy
Infrastructure Installations
Light Rail
Management & processes
Energy
High voltage
Energy systems
Safety and Security
 Public safety, CCTV surveillance
 Railroad safety
 Tunnel safety
Telecommunications, GSM special coverage locations
Mobility
Visuals en Virtual Reality
Water
 Bridges, dykes
 Harbour construction
 Vessel traffic control

Movares

Desk research project August 2009

Rijkswaterstaat
Ministerie van Verkeer en Waterstaat

- Contract from Dutch Ministry of Transport and Water
- Movares preferred supplier for

 Rijkswaterstaat "Department North Sea"

This department is involved in all traffic and construction issues on the Dutch part of the North Sea, legislation and permits for drilling for gas etc. etc.

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Why this research?

Permission for wind park construction at sea is given by the Ministry with some limitations and obligations:

- Research on the effects of wind parks on the environment: fish, dolphins, bird population, yearly north/south movement etc.
- Research on the effects for vessels and aircraft on radio, radar and navigation
- Monitoring and yearly evaluation of these effects

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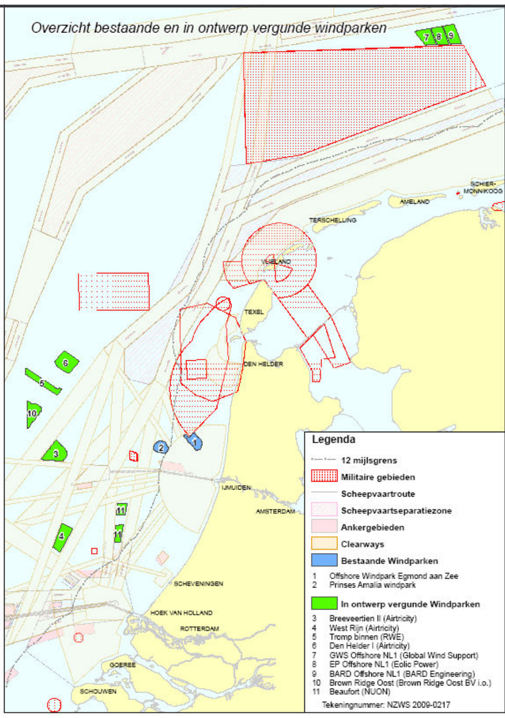

Radar influencing
Vessel traffic
Anchoring areas
Military areas
(Old) dumping areas
Etc.

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Why this research?

- 2008: 9 permits for wind park design on the Dutch North Sea.
- November 2009 final permissions for construction
- Until now broad and sometimes quite undefined requested monitoring and evaluation programs

Our mission: relevant radar and radio monitoring & evaluation proposal, based on known effects and blind spots

=> Enables to calculate costs of monitoring & evaluation in the business plan and the subsidies involved

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Requested input stakeholders:

- Dutch Coastguard
- Ecofys Netherlands (windpark development)
- Air traffic control Netherlands (LVNL, Schiphol)
- TNO Defense Safety and Security, The Hague

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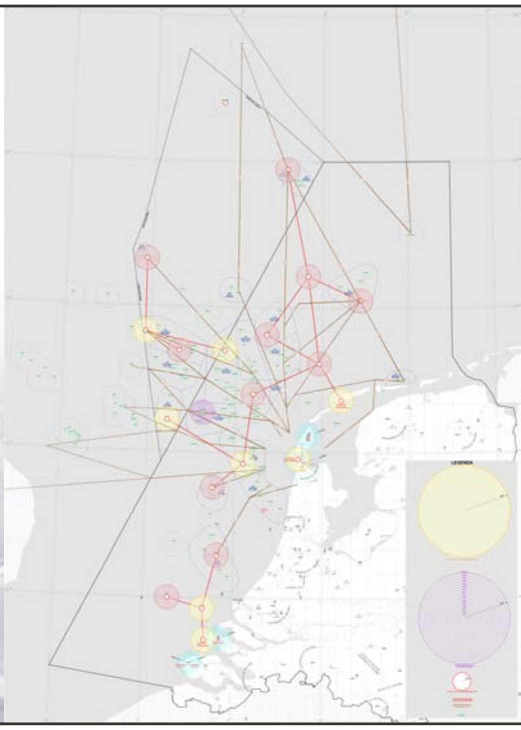

Radio links and WAM system

Free zones and flights zones

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Input research reports

1. Rapportage TNO Defensie en Veiligheid: “Risk analysis of wind turbine farms on a north sea based wide area multilateration system and on vhf/uhf radiocommunication” (13 juli 2007);
2. Advies IVW over windpark Katwijk (28 april 2009) met zienswijze LVNL Windparken Noordzee (17 april 2009);
3. Operationeel plan “Veldexperiment verstoring scheep- en walradar” van Noordzeewind (7 mei 2009);
4. Overzicht bestaande en in ontwerp vergunde windparken (tekeningnummer NZWS 2009-0217);
5. Voorbeeld ontwerpbeschikking “Tromp Binnen” (26 juni 2009).
6. Notitie vliegveiligheid in relatie tot offshore windparken, LVNL 1 december 2008
7. Berekening van de effecten van windturbines op maritieme RF systemen (SRK) van prof. E. van Lil, ir D. Trappeniers en prof A. van de Capelle (KU Leuven, november 2002);
8. Results of the electromagnetic investigations and assessments of marine radar, communications and positioning systems undertaken at the North Hoyle wind farm by Qinetiq and the Maritime and Coastguard Agency (22 November 2004);
9. Investigation of Technical and Operational Effects on Marine Radar Close to Kentisch Flats Offshore Win Farm (MARICO Marine, April 2007).
10. Offshore Wind Farm Helicopter Search and Rescue Trials Undertaken at the North Hoyle Wind Farm , Report of the trials undertaken on March 22nd 2005 by the Maritime and Coastguard Agency and C Flight 22 Squadron Royal Air Force, RAF Valley, Anglesey (2005)
11. Marine guidance note MGN 371 (M+F) Offshore Renewable Energy Installations (OREIs) Guidance on UK Navigational Practice, Safety and Emergency Response Issues (2008)
12. Marine guidance note MGN 372 (M+F) Offshore Renewable Energy Installations (OREIs): Guidance to Mariners Operating in the Vicinity of UK OREIs (2008)
13. Report on Horns Rev. (near Esbjerg) VHF Radio and Marine Radar (3 October 2004), Elsam Engineering, Fredericia Denmark, for Cape Wind Associaties (Danmark)
14. Impact of Wind Turbines on WAM, ex. Summary, Roke (Siemens) for Eurocontrol May 2009
15. Wind farm mitigation using new alternatives for radar, Roke (Siemens) research presentation 4/6/2009
16. The Effect of Windmill Farms On Military Readiness, USA Department of Defense 2006 Report to the congressional defense committees

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Research Topics

- RDF
- GPS
- DGPS
- Loran C
- AIS
- VHF communication (maritime)
- Mobile phone
- Helicopter radar
- VHF/UHF radio communication (phone) with helicopters
- Wide Area Multilateral position measurement helicopters
- Radar effects general
  - Shadow zones
  - False echoes
- Radar on small vessels
  - Blind zones
  - Shadow zones
  - Large reflections
- Shore radar (including radar support from wind parks)
  - Short range small vessels
  - Short range large vessels
  - Long range
- Radar and ARPA (automatic radar plotting aid) as available on large vessels and Vessel Traffic Services (VTS) ashore.

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Results 1

System	effect	ref	result
RDF	deviation of real ships position	Ref 7	*No hinder* - theory and observation Limited angle faults behind windparks
GPS	No, or wrong position calculation	Ref 8	*No hinder* - theory, measurement and observation
DGPS	No, or wrong position calculation	Ref 7 Ref 8	*No hinder* - theory, measurement and observation
Loran C (Long Range navigatie 100 kHz)	No, or wrong position calculation	Ref 8	*No hinder* - theory, measurement
AIS (automatic identification system)	No position receipt by observer	Ref 7 Ref 8	*No hinder* - theory, measurement and observation
VHF communication	No communication or disturbed communication.	Ref 7 Ref 8 Ref 13	*No hinder* - theory, measurement and observation (less reach close to turbines)
Mobile phone	No communication or disturbed communcation.	Ref 8 Ref 13	*No hinder* - theory and observation *(when in GSM coverage area)*

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Results 2

System	effect	ref	result
Helicopter radar	Disturbed image	Ref 10	- Observation of on screen visible reflections, shadow zones, dropping of small targets, ghost images.
VHF/UHF radio communication (incl. voice) with helicopters	No communication/ disturbed communication	Ref 1 Ref 10	*No hinder* - theory, measurement and observation Natural sea clutter and fading are major influences. Humans accept and can cope in large extend with voice disturbance.
Wide Area Multilateral position measurement	No position or false position	Ref 1 Ref 14 Ref 15	*No hinder* - theory Natural sea clutter and fading are major influences. Dropped message can be handled by multi system receipt, tracking and ADS-B messages receipt. Besides this: flight zones and planning limitations of wind parks
Radar effects general shadowing false echoes	Disturbed image	Ref 7 Ref 8 Ref 9	-theory and observation Behind wind turbines limited detection or no detection. Around wind park arise false targets. Movement of targets enables human filtering in large extend of real and false targets and effects.

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Results 3

System	effect	ref	result
Radar observation from small vessels			
Blind zones	Incorrect radar image	Ref 8 Ref 9	Observation: blind zones behind wind turbines
Shadow zones	Incorrect radar image	Ref 8 Ref 9	Observation : reduced detection behind wind turbines (shadow zone)
Radar observation influence by large reflections of wind turbines	Incorrect radar image	Ref 8 Ref 9	Observation : (multiple) false targets around wind turbines, dropping of small targets (AGC influence). Besides this false targets on other spots on the screen further away from the wind park.
Radar ashore			
Short range to wind parks observation of small vessels	Incorrect radar image	Ref 7 Ref 8 Ref 9	Observation: blind zones and reduced detection behind wind turbines (shadow zone), (multiple) false targets around wind turbines, dropping of small targets, false targets on other spots on the screen at some distance from the wind park.
Short range to wind parks Observation of large vessels	Incorrect radar image	Ref 8 Ref 9	Observation : simple detection despite of multiple and reflected targets echoes
Larger distance observation	Incorrect radar image	Ref 8 Ref 9	Observation : simple detection and tracking

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Results 4

System	effect	ref	result
Radar observation and ARPA (automatic radar plotting aid) as present on larger vessels and VTS	Incorrect radar image	Ref 8 Ref 9	Observation: blind zones and reduced detection behind wind turbines (shadow zone), (multiple) false targets around wind turbines, dropping of small targets, false targets on other spots on the screen at some distance from the wind park. Tracking (ARPA) loses targets, tracks are swapped etc. All effects are temporary with moving targets. Human eye is less influenced than the computer tracks.

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Radar observation on vessels

Large variations in effects due to:

- Enormous variation in radar equipment
- Large variation in age of the equipment
- Strong interaction with personal experience and equipment setting radar operator

General: nearby a wind park the master and the radar observer are very conscious about the effect of these large structures on radar obesrvations.

Based on operational experience the majority of them can distinguish between real targets and the false effects.

A wind park is (just) another large object on sea?

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Radar observations Waker

Weather: overcast
Wind: SW 4
Sea: small waves
Ship light rolling

Radar: Sperry Marine Bridgemaster
X band
Multipulse
Clutter Manual and AUTO
Radar set on man. clutter and normal sea operation (clutter auto)

Observations:
Head on: 2 mile
1 ½ mile
500 mtr
Parallel: 500 mtr.
1 ½ mile
2 mile
During observations no small vessel present in or near the wind parks

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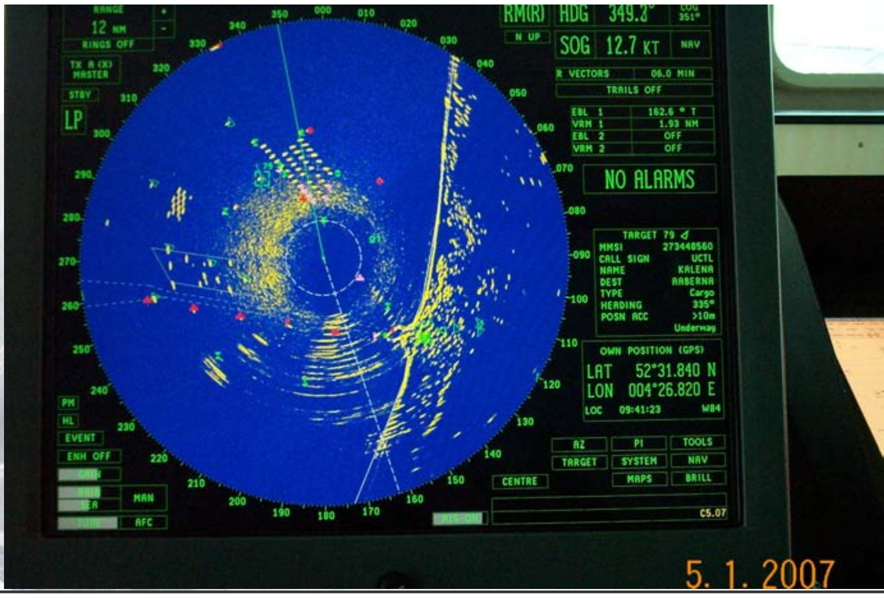
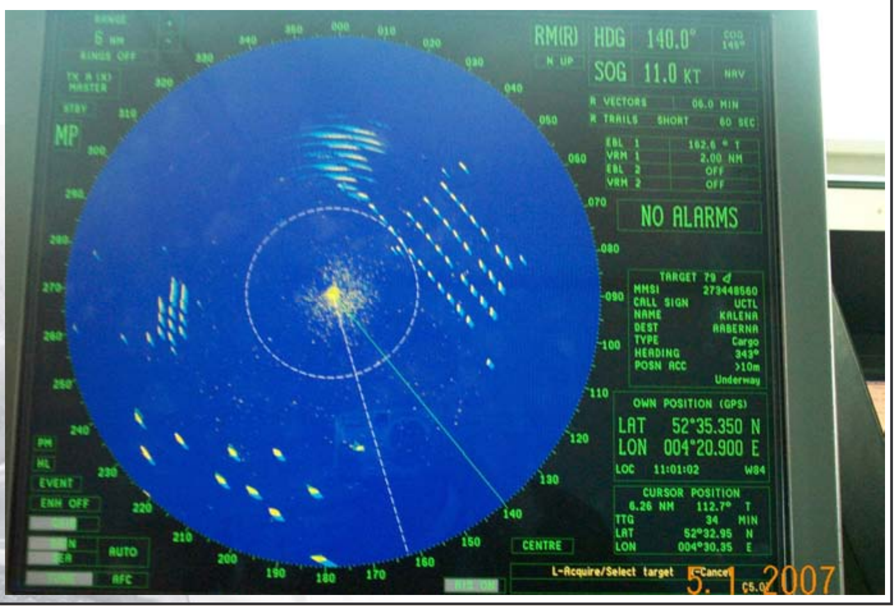
Head on: 2 mile Clutter Man. To clear center,
causes nog observations within 2 ½ -3 mile
False echoes due to anchoring area and wind parks



Head on: 2 mile
Clutter Man. Centre cleared, buoy disappeared

New park foundation

Parallel: 2 mile Autoclutter on, false echoes due to both wind park, target merging in the new park
park portside, starboard park clearly visible



Conclusions 1

All systems presently in use at sea and for helicopter operations are studied since 2000

- Only for WAM disturbance no measurement or observations
- None or hardly noticeable influence on other systems than radar.
- Known disturbance of radar observation
- Disturbance of radar observation is influenced by the equipment used, the antenna and antenna location, and the structure of the wind park and its location.
- Strong interaction of observations and obstacles on the ship like masts, lines, cranes, antennas etc. and the position of the ship versus the windpark.
- Less use in measurement or calculation of radar effects for non stationary platforms.

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Conclusions 2

Resulting research, monitoring and evaluation issues:	***Effort***
• **Wind park influence on nearby (stationary) VTS radar**	**Once**
• **Monitoring: detection and or measurement of use of the wind park area itself (now prohibited)**	**All or selected wind parks**
• **Monitoring and evaluation: the influence on ship routes taken (route changes, use of clearways etc.)**	**Rijkswaterstaat**
• **Measurement/observation of WAM disturbance**	**Rijkswaterstaat/LVNL?**

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Thank You!
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Amsterdam, November 18/19, 2009
IEA Topical Expert Meeting #59
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"RADAR, RADIO AND WIND TURBINES"

Wind Turbines in the Radiation Field of Systems from an Analysis and Coexistence Point of View

Dr.-Ing. Gerhard Greving

NAVCOM Consult
Ziegelstr. 43
D-71672 Marbach

http://www.navcom.de

NAVCOM Consult

⇨ Consultancy Company for services in aviation

Navaids -, Landing -, Radar -, Comm-Systems
3D – Numerical System Simulations

⇨ Founded by Dr.-Ing. Gerhard Greving in 1997

⇨ Team of former R&D and System Engineers (SEL, Alcatel, Thales)

⇨ Network of Specialists and cooperating companies

⇨ Worldwide activities on wind turbines since about 12 years

⇨ **Independant Consultancy/Expertises**

NAVCOM Consult

URLs for download of Technical Papers (2006ff) Radar-, Navaids-, Landing-, Comm-Systems

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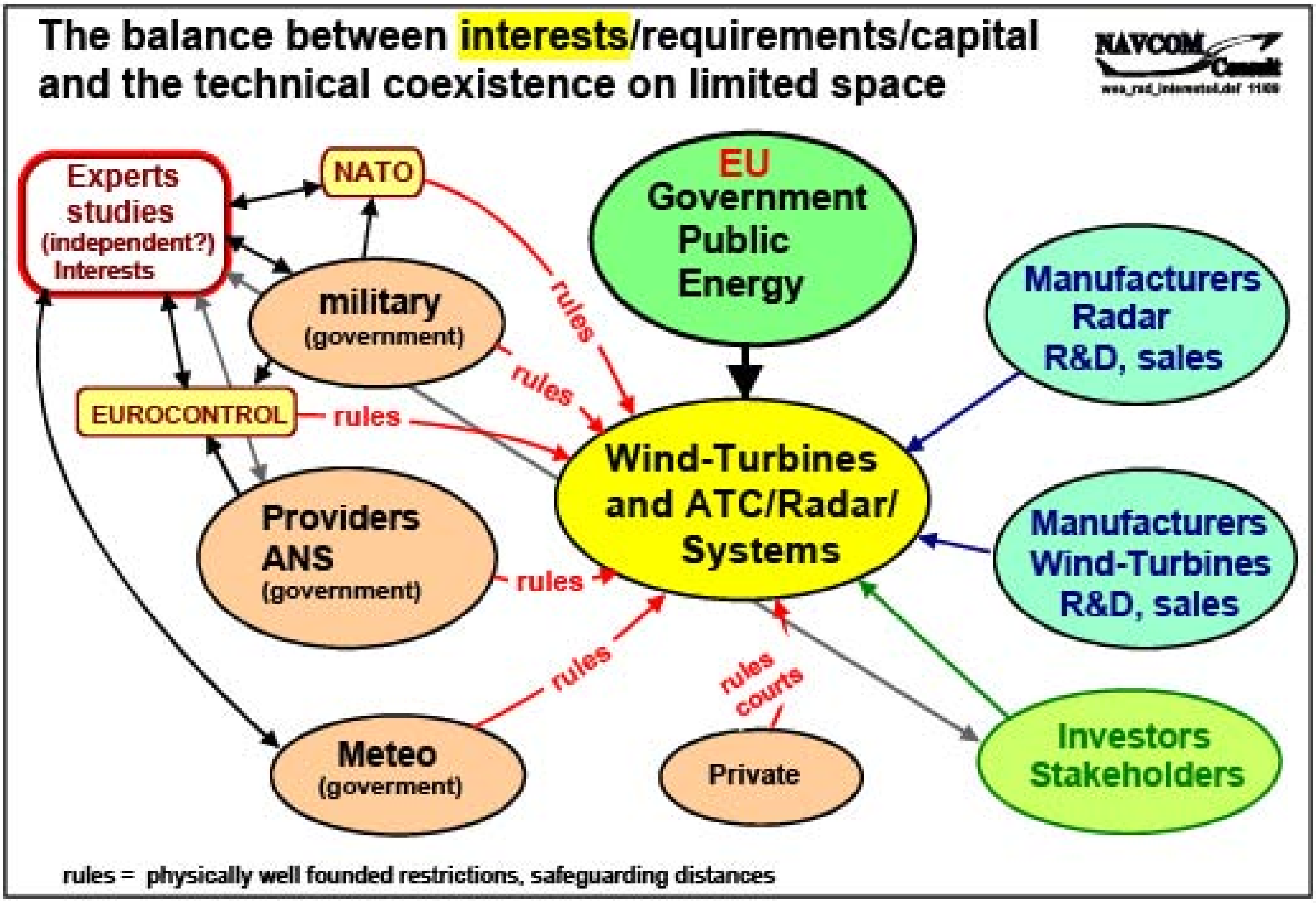
NAVCOM Consult :	http://www.navcom.de	
Presentation papers:	http://www.navcom.de/EUROCONTROL_SUR26_pr1.pdf	workshop
	http://www.navcom.de/WEA_rad_Paris_pr_271107_E.pdf	German/French workshop
	http://www.navcom.de/iea_oxford_pr_300307.pdf	more technical details
Company Profile :	http://www.navcom.de/NAVCOM_comprof20.pdf	
ERAD2006 / Barcelona	http://www.navcom.de/erad2006pt.pdf	Weather radar, WT, RCS
IFIS 2006 / Toulouse	http://www.navcom.de/ifis2006ggpt.pdf	also WT
EURAD 2006 / Manchester:	http://www.navcom.de/eurad2006pt.pdf	SSR, RCS, WT
IRS 2007 Cologne	http://www.navcom.de/irs2007pt.pdf	RCS and WT
EUCAP 2007 Edinburgh	http://www.navcom.de/eucap2007pt.pdf	also WT, measures
URSI 2008 GA/ Chicago	http://www.navcom.de/ursi2008pt.pdf	invited paper; also RCS, WT
IRS 2008 / Wroclaw	http://www.navcom.de/irs2008pt.pdf	RCS and WT
IFIS 2008 / Oklahoma	http://www.navcom.de/ifis2008ggpt.pdf	also WT
IRS 2009 Hamburg	http://www.navcom.de/irs2009pt.pdf	RCS, WT
IAIN 2009 Stockholm	http://www.navcom.de/iain2009pt.pdf	also WT, shadowing

More on request



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NAVCOM Consult

Content

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- ⇨ Introduction; Summary of Oxford 2007; RCS
- ⇨ General examples of planned/approved windparks and related systems
- ⇨ Specs and definition of distortions – effects; Safeguarding areas
- ⇨ Result 1: Shadowing in the back of WT and windparks;
- ⇨ PoD global / (local)
- ⇨ Result 2: False targets by multiple reflections at WT and aircraft
- ⇨ Measures for Improvement; Stealth, absorbers
- ⇨ Example
- ⇨ Concluding Remarks

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NAVCOM Consult

IEA Expert Meeting in Oxford 2007
Short Summary

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- ⇨ The treatment of wind turbines is different for every system
- ⇨ Simulation scheme IHSS and numerical methods available
- ⇨ System Specifications, defined operational requirements to be met
- ⇨ Field interference fluctuations are not a criterion for system effects
- ⇨ Effects vs "comfort" - Can the mission be met?
- ⇨ scattering at WT is highly time- and space-variant
- ⇨ RCS scheme (strictly speaking) not applicable for WT → ~~RCS~~
- ⇨ Modern HW/SW technology → by far better compatibility with WT
- ⇨ Examples of results for several systems presented
- ⇨ Advanced system simulations on case by case basis necessary

6/63

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Radar Cross Section RCS

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Summary RCS :

$$\sigma_{pq} = \lim_{R\to\infty}\left[4\pi R^2 \frac{\left|E_p^s\right|^2}{\left|E_q^i\right|^2}\right]$$

Plane wave

RCS strictly speaking not applicable for wind turbines above ground

Virtual availability and simplicity not a justified reason for application

RCS is highly dynamic (time, space) and a spectrum if rotating

Measurements of the RCS of WT in AEC also not relevant!

⇨ NAVCOM Consult does not work with RCS for WT!

See publications and some numerical results below

7/63

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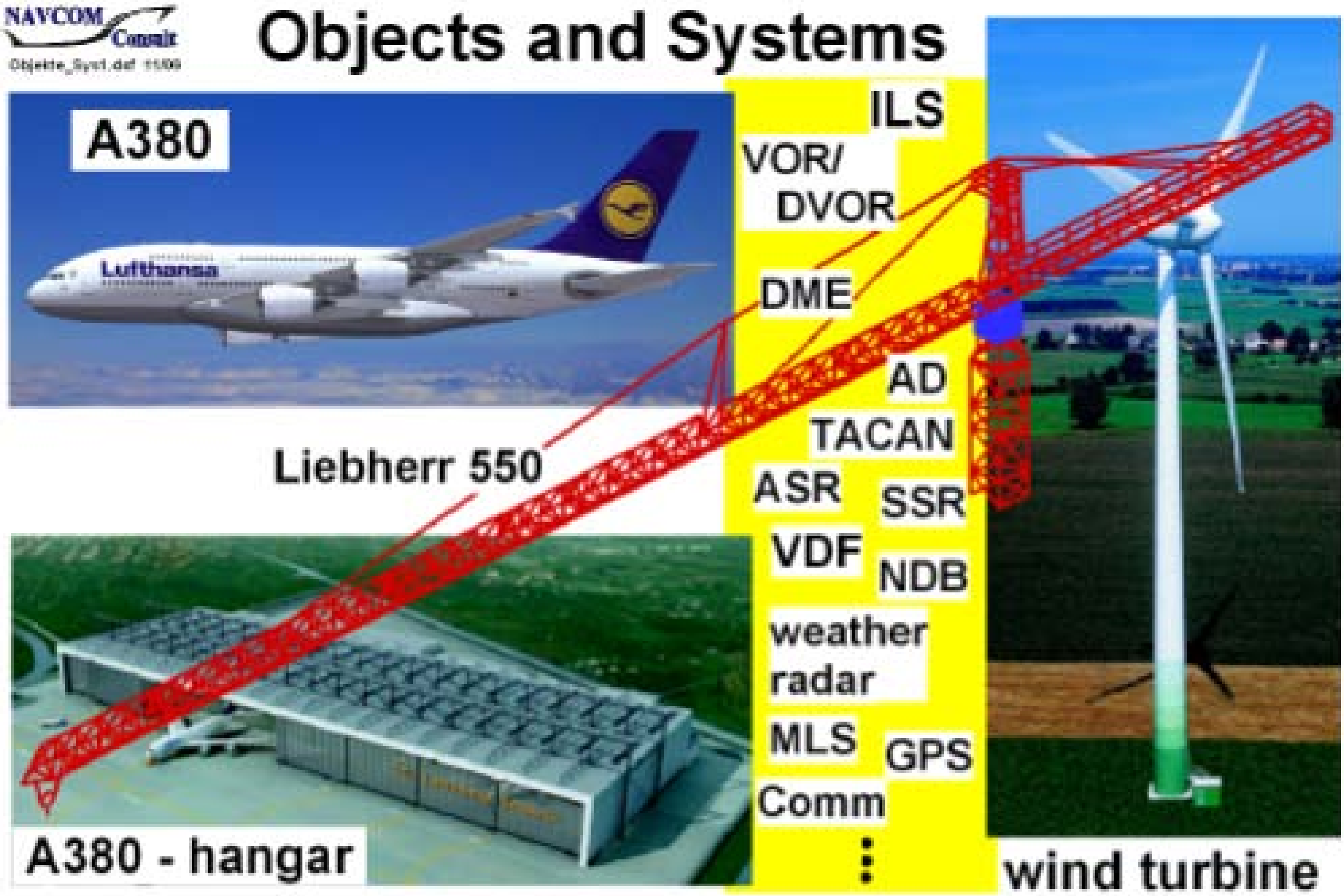
Objekte_Syst.def 11/09

Objects and Systems



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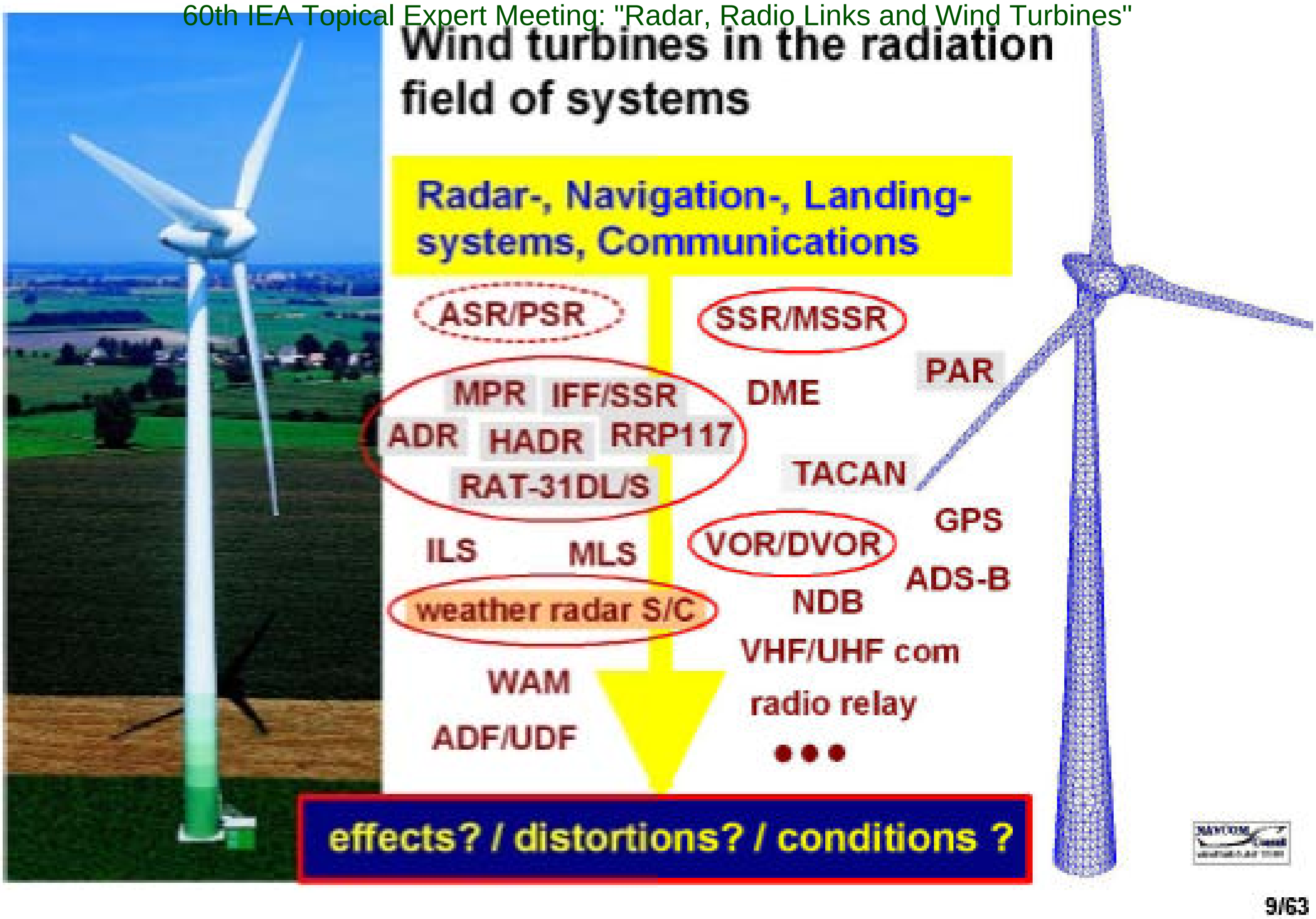

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Systems and General Classification

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Windturbines and

Navigation-

Landing-

Radar- (civilian ATC, militaryAD , Meteo)

Meteo-radar measure amplitudes/speed !

Communication- Systems

Activities of NAVCOM Consult on all fields in
A, B, CH, CZ, D, DK, F, GB, H, HK, K, L, N, NL, SK,

Off shore 200WT up to 1GW

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Content

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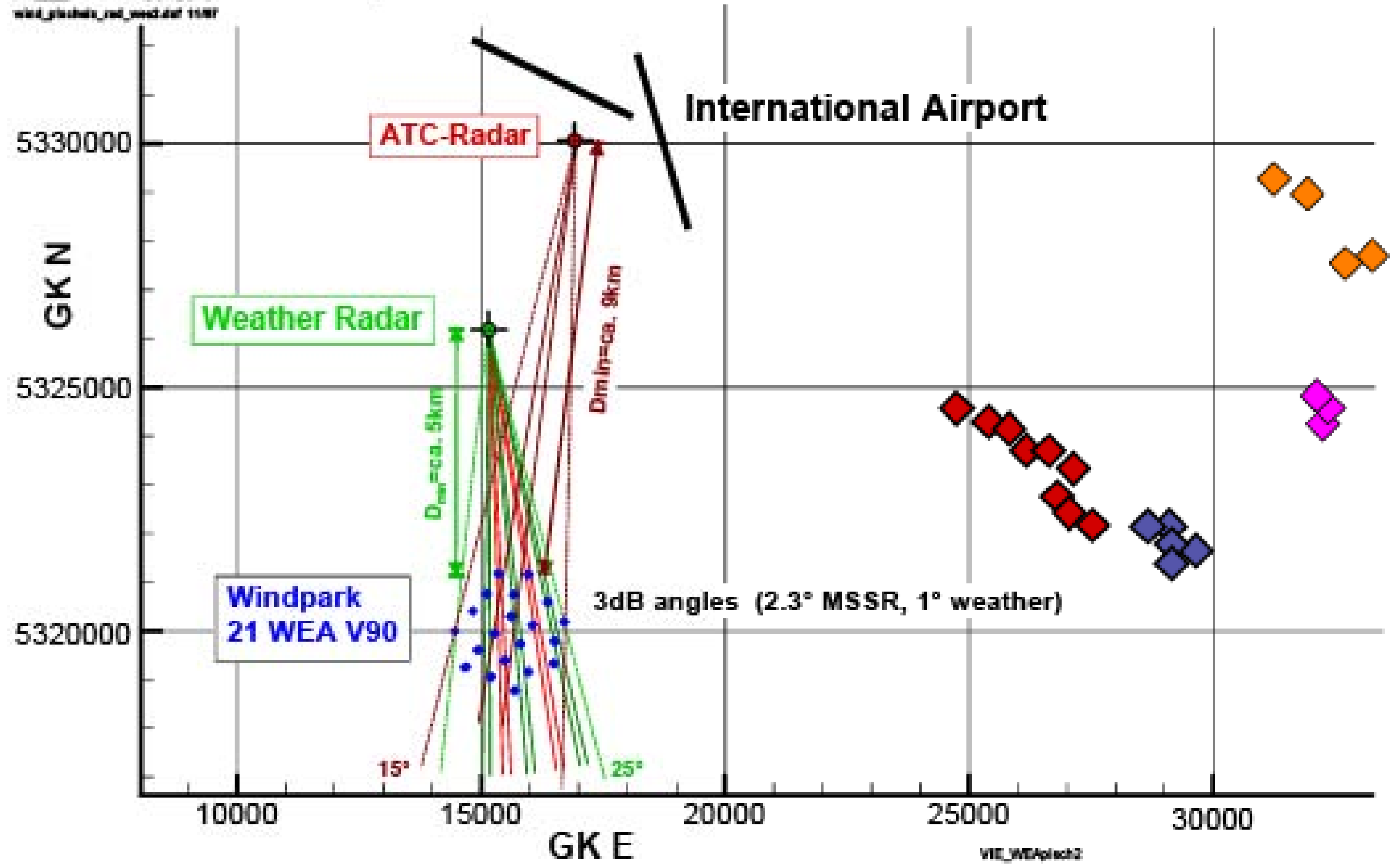
- ⇨ Introduction; Summary of Oxford 2007; RCS
- ⇨ **General examples of planned/approved windparks and related systems**
- ⇨ Specs and definition of distortions – effects; Safeguarding areas
- ⇨ Result 1: Shadowing in the back of WT and windparks;
- ⇨ PoD global / (local)
- ⇨ Result 2: False targets by multiple reflections at WT and aircraft
- ⇨ Measures for Improvement; Stealth, absorbers
- ⇨ Example
- ⇨ Concluding Remarks

11/63

Windparks close to ATC-Radar and Weather Radar



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Typical Examples and Background

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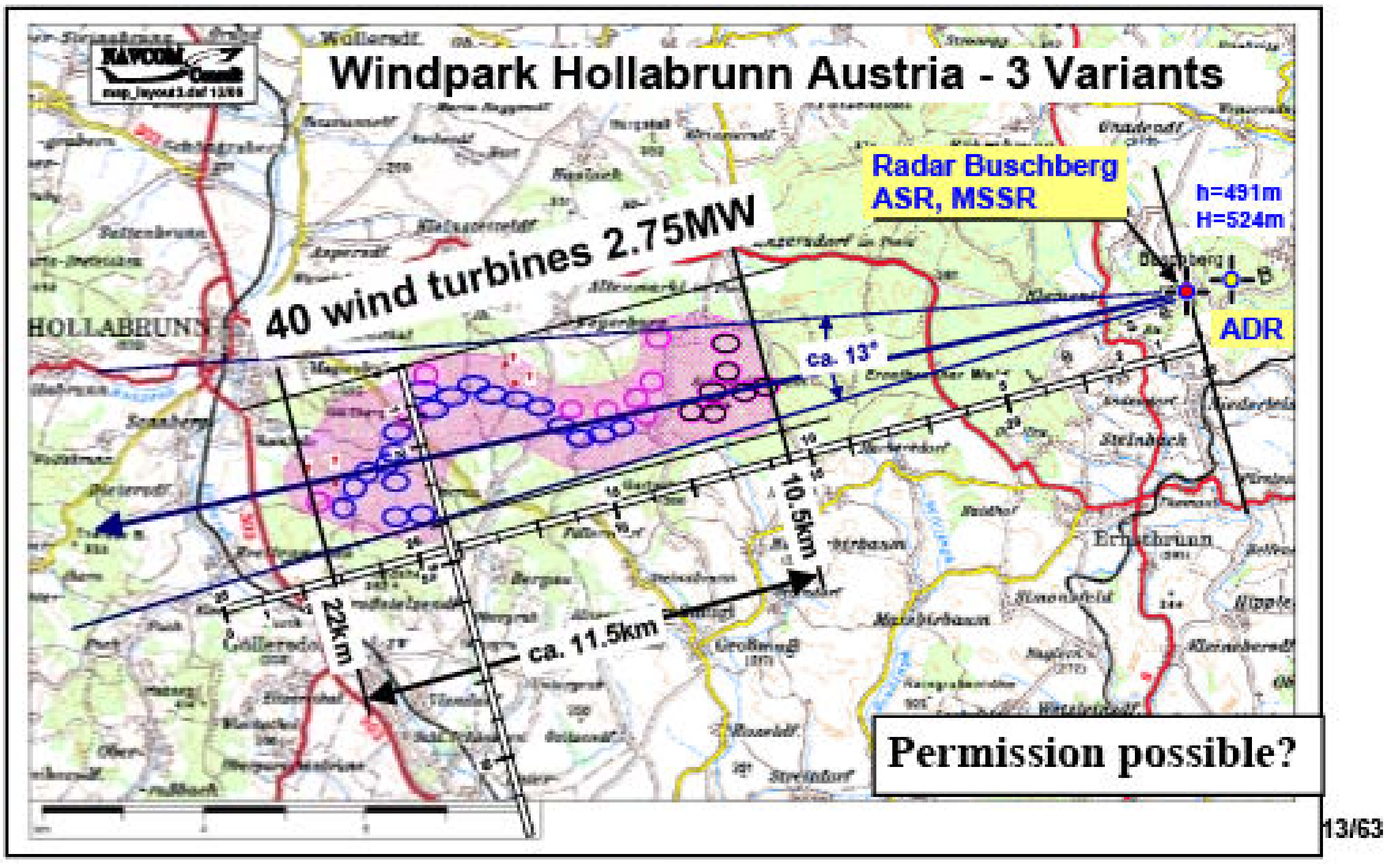

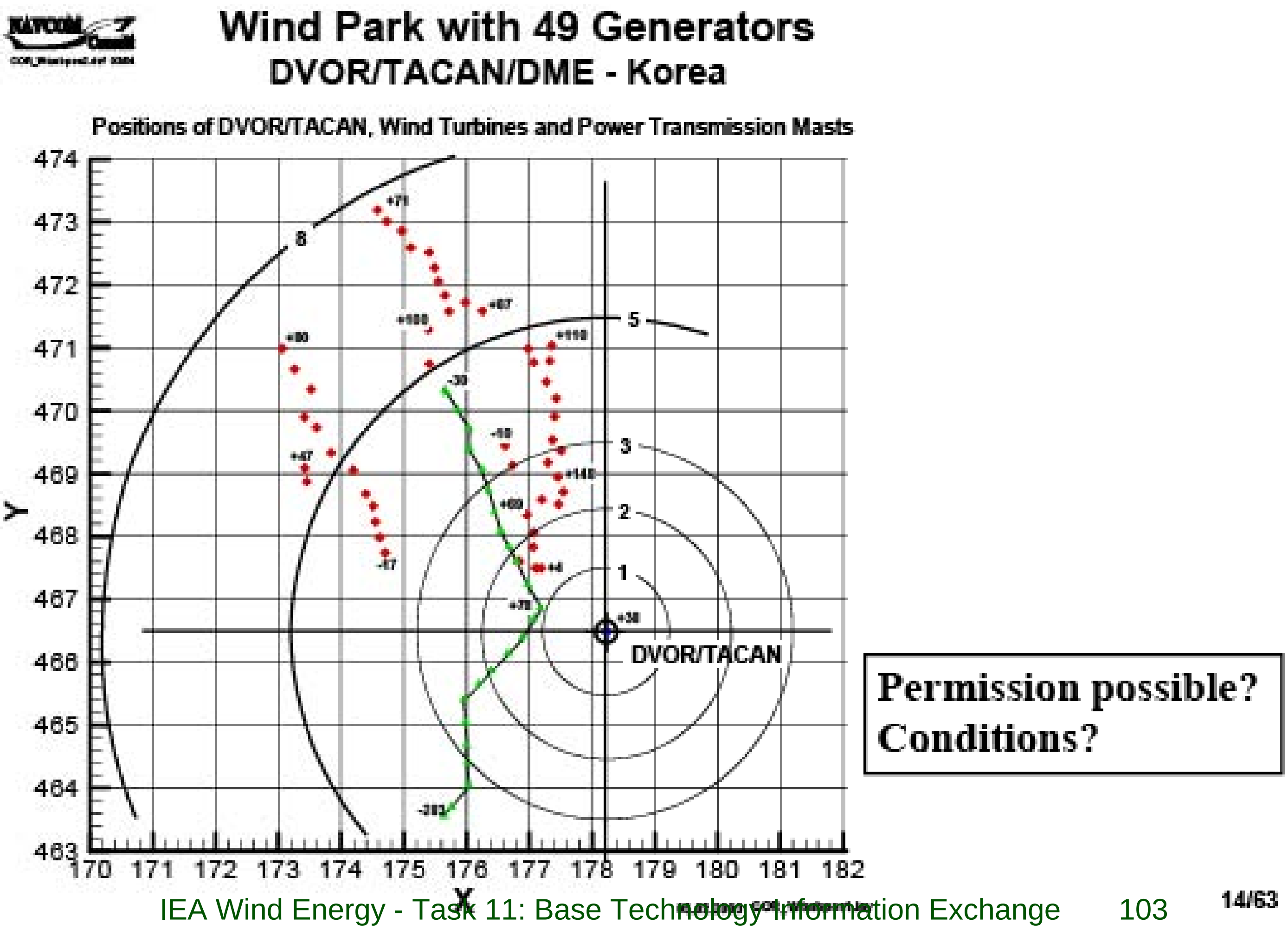


Windpark XYZ and Radar Sites
Military AD Radar
MPR/IFF/SSR
ATC Radar A ca.52km
Prim/ 2 Sek
Windpark XYZ
1
8
13.3km - 16km
ATC Radar ca. 70km
Prim
ca.6.9km
ca.9.6km
ATC-radar
Airport
ATC Radar B ca.75km
Prim / Sek
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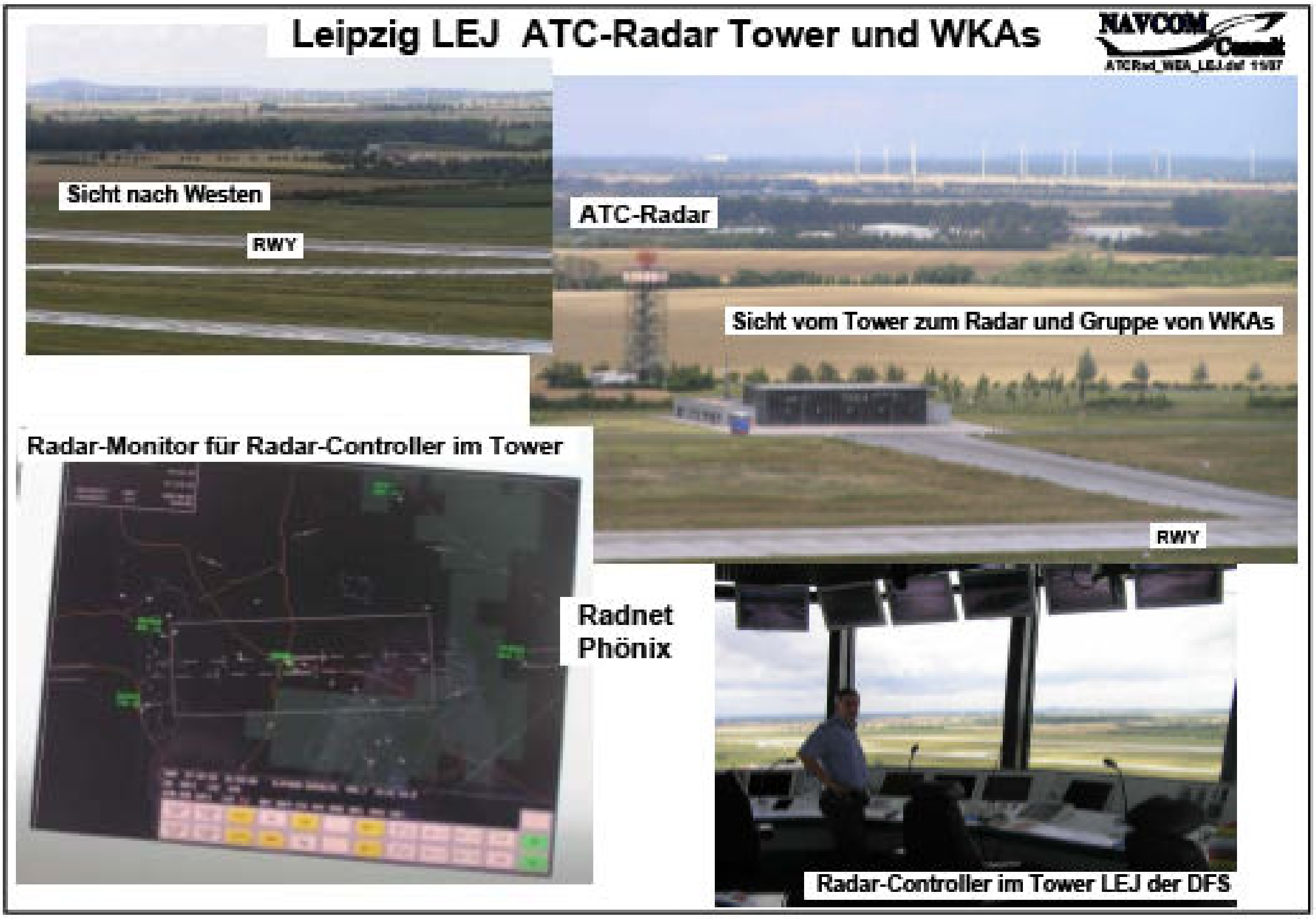
Leipzig LEJ ATC-Radar Tower und WKAs
NAVCOM Consult
Sicht nach Westen
RWY
ATC-Radar
Sicht vom Tower zum Radar und Gruppe von WKAs
Radar-Monitor für Radar-Controller im Tower
RWY
Radnet
Phönix
Radar-Controller im Tower LEJ der DFS

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WTs and Radar - European Scale

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⇨ Comparable Radar and comparable Tasks yield quite different approval and acceptance procedures and results in different, partially adjacent countries

⇨ Why these Differences ?

⇨ Are these differences technically, physically and operationally justified ?

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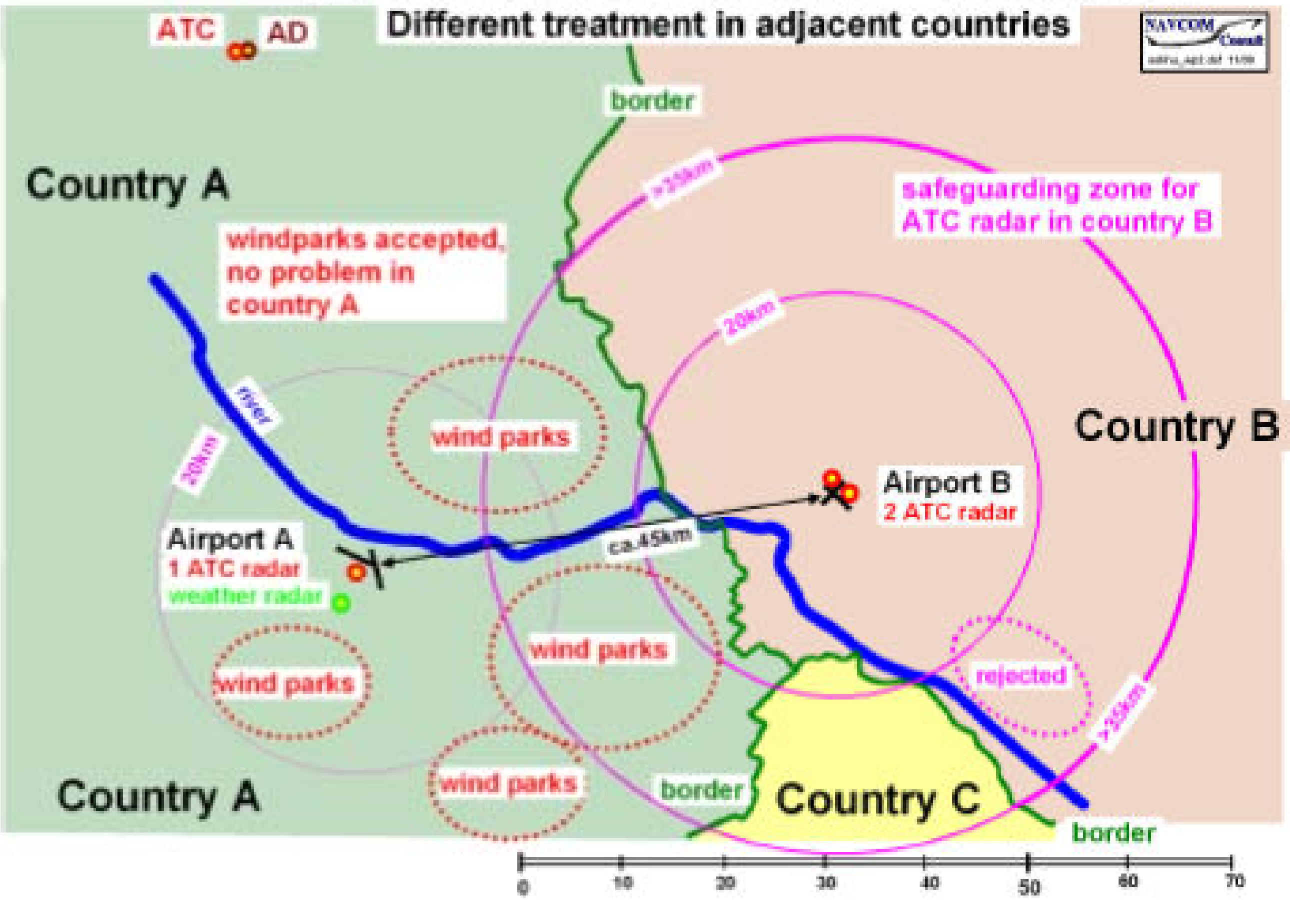
Radar and Wind Parks - EU-case 1



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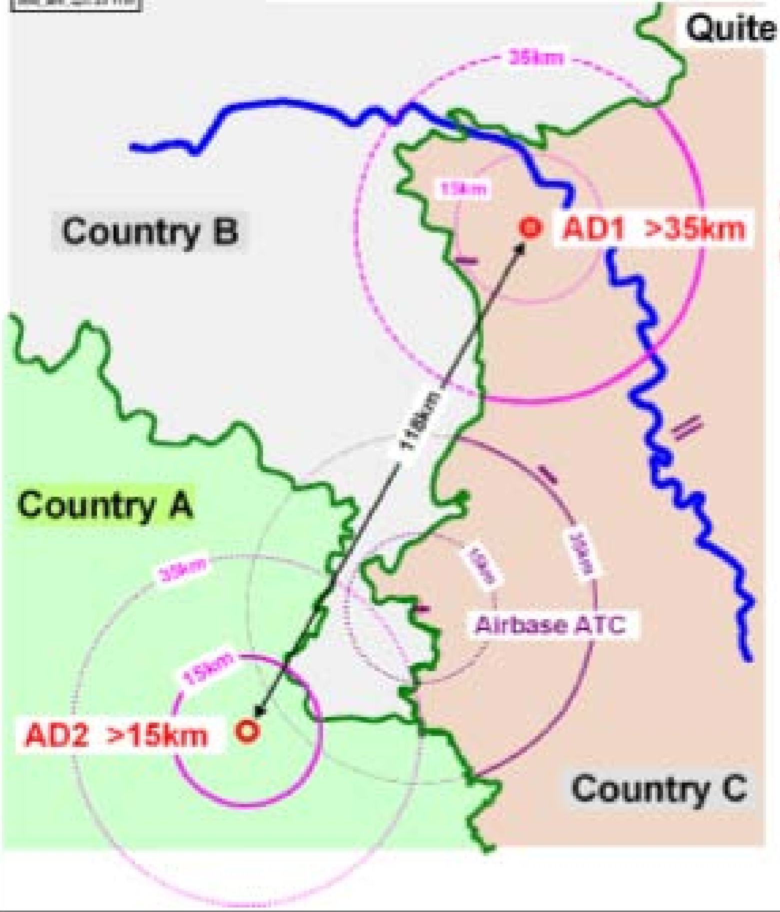
The same NATO AD Radar in adjacent countries

Quite different actual treatment of WT



>200 WT existing in the circle of 35km in country C around AD1

AD1 >35km

↕ ? (whatever is appropriate)

AD2 >15km

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WTs and Radar - European Level (3)

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⇨ These Differences are tried to be harmonized by EUROCONTROL and NATO

⇨ Result : „Least common denominator"
←→ "old analog standalone primary ATC radar"

⇨ e.g. … Primary and Secondary Radar separately treated
No collocation considered
No networking or clustering
No redundancy advantages

⇨ AD : old analog 3D-radar vs.
3D solid state Doppler pulse compression

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Content

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- ⇨ Concluding Remarks

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Distortions of Systems

- ⇨ What is a "distortion" ? ←→ violation of specification !?
  Risk, danger, safety ←→ "comfort"
- ⇨ Does a specification for the actual system exist ? ←→ Task/mission?
- ⇨ No distortions, 100% safety, 0% risk, global PoD 100% ←→ impossible
- ⇨ What is an acceptable distortion ? ←→ within specs, ...
- ⇨ Is the pure visibility of windturbines by the primary radar a distortion ?
  (no, it's the task of a radar to see obstacles?) ←→ "comfort"?
  e.g. RCS=1sqm → >100km/460km
- ⇨ Moving cars/trucks on motor ways are also "visible" ←→ mitigation?
  Treated as clutter !! ←→ wind turbines
- ⇨ Modern radar technology and modern signal processing can cope windturbines widely → better coexistence (if not too close)

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Applicable Specifications

- ⇨ ICAO Annex 10 Vol. I — SARPs
- ⇨ ICAO Annex 10 Vol. IV — SARPs, no multipath spec
- ⇨ ICAO Annex 10 Vol. V — SARPs
- ⇨ ICAO Doc 8071 — (guidance material)
- ⇨ EUROCONTROL SUR.ET1.ST01.1000-STD-01-01 Radar
  EUROCONTROL SUR.ET1.ST03.1000-STD-01-01 Radar
- ⇨ national specifications /rules may exist
- ⇨ MIL
  For military radar often no open or applicable specs exist at all

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Sys_param1.dsf 11/09

System-Simulations result in System Parameter

System distortions by Objects on the ground
For objects on the ground: RCS is not a useful parameter
Field distortions are mostly not a useful parameter
Signal processing involved

- Primary radar → shadowing, range, (PoD), ...
- Secondary radar MSSR → monopulse angle error, false targets
- VOR/DVOR → bearing error, mod-deg
- TACAN → bearing error
- DME → distance error
- VDF/UDF → angle error
- NDB → angle error
- ILS → DDM
- MLS → angle error az, el; PFE, CMN
- Comm → antenna pattern, coverage
- ⋮

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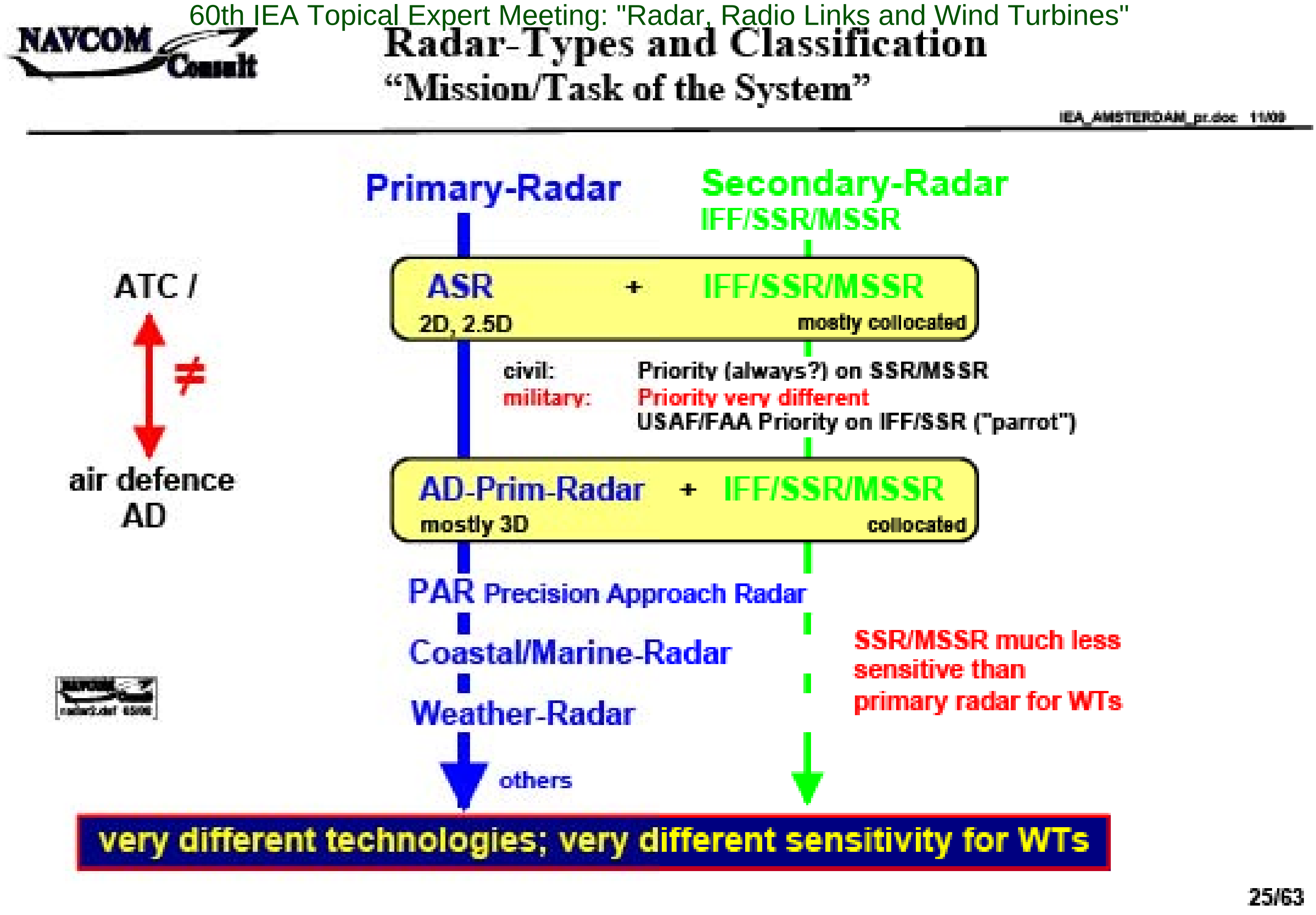
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Radar-Types and Classification
"Mission/Task of the System"
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Primary-Radar
Secondary-Radar
IFF/SSR/MSSR
ATC /
≠
air defence
AD
ASR + IFF/SSR/MSSR
2D, 2.5D
mostly collocated
civil: Priority (always?) on SSR/MSSR
military: Priority very different
USAF/FAA Priority on IFF/SSR ("parrot")
AD-Prim-Radar + IFF/SSR/MSSR
mostly 3D
collocated
PAR Precision Approach Radar
Coastal/Marine-Radar
Weather-Radar
others
SSR/MSSR much less
sensitive than
primary radar for WTs
very different technologies; very different sensitivity for WTs
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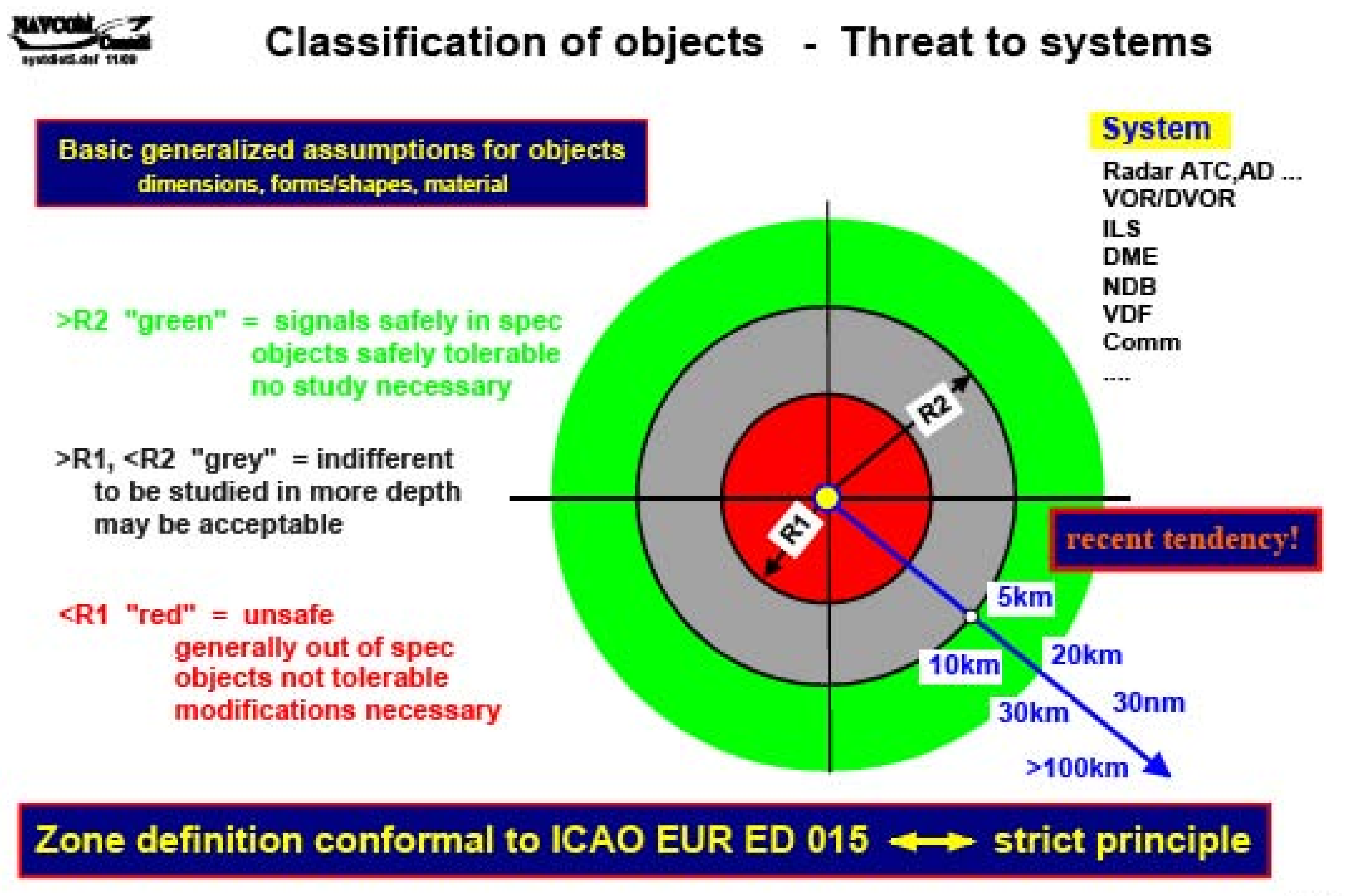
Classification of objects - Threat to systems
Basic generalized assumptions for objects
dimensions, forms/shapes, material
System
Radar ATC,AD ...
VOR/DVOR
ILS
DME
NDB
VDF
Comm
....
>R2 "green" = signals safely in spec
objects safely tolerable
no study necessary
>R1, <R2 "grey" = indifferent
to be studied in more depth
may be acceptable
<R1 "red" = unsafe
generally out of spec
objects not tolerable
modifications necessary
R1
R2
recent tendency!
5km
10km
20km
30km
30nm
>100km
Zone definition conformal to ICAO EUR ED 015 ⟷ strict principle
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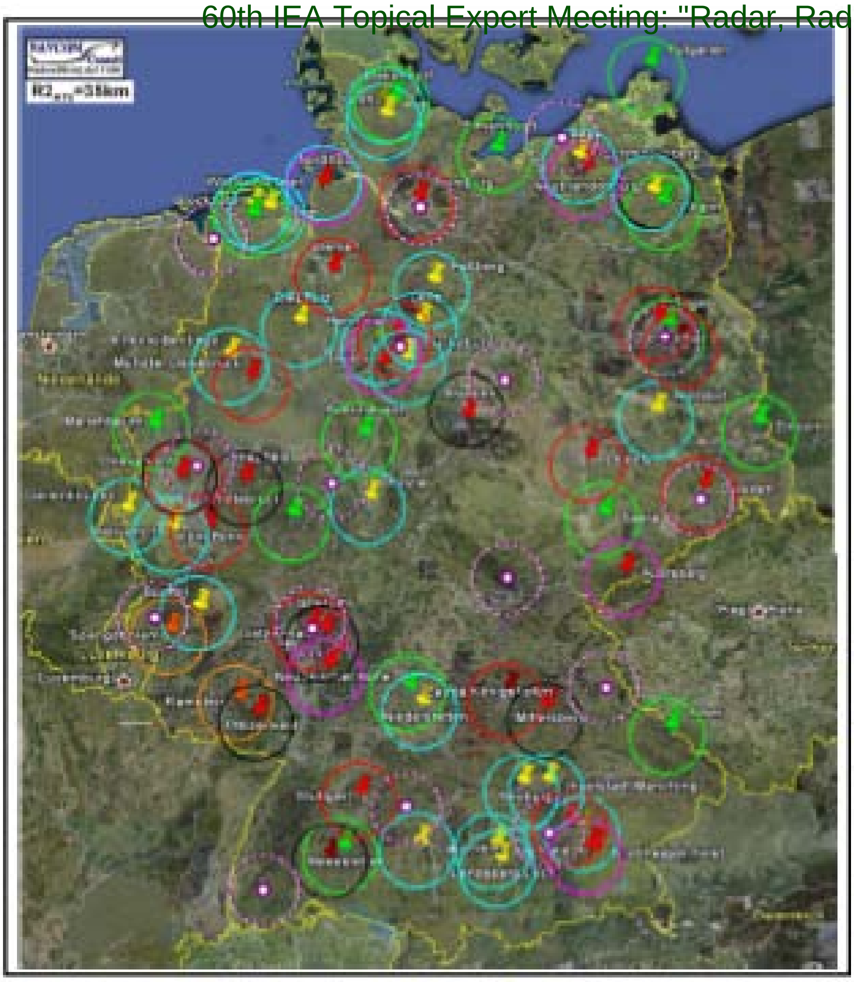

Assumption:

Safe Range R2=35km

for each Radar

Air Traffic Control Radar of DFS
(so far no general Range; ASR, SREM, MSSR)

ATC mil (general 35km?)

ATC Radar of the USAFE/ NATO
(general no problems; ←→ FAA/DFS)

Air Defence Radar of NATO/BW
(generell 35km?)

16 Weather Radar of DWD (R2 of France R2=30km!)

\+ local safeguarding areas for for Navigation-, Comm-Systems

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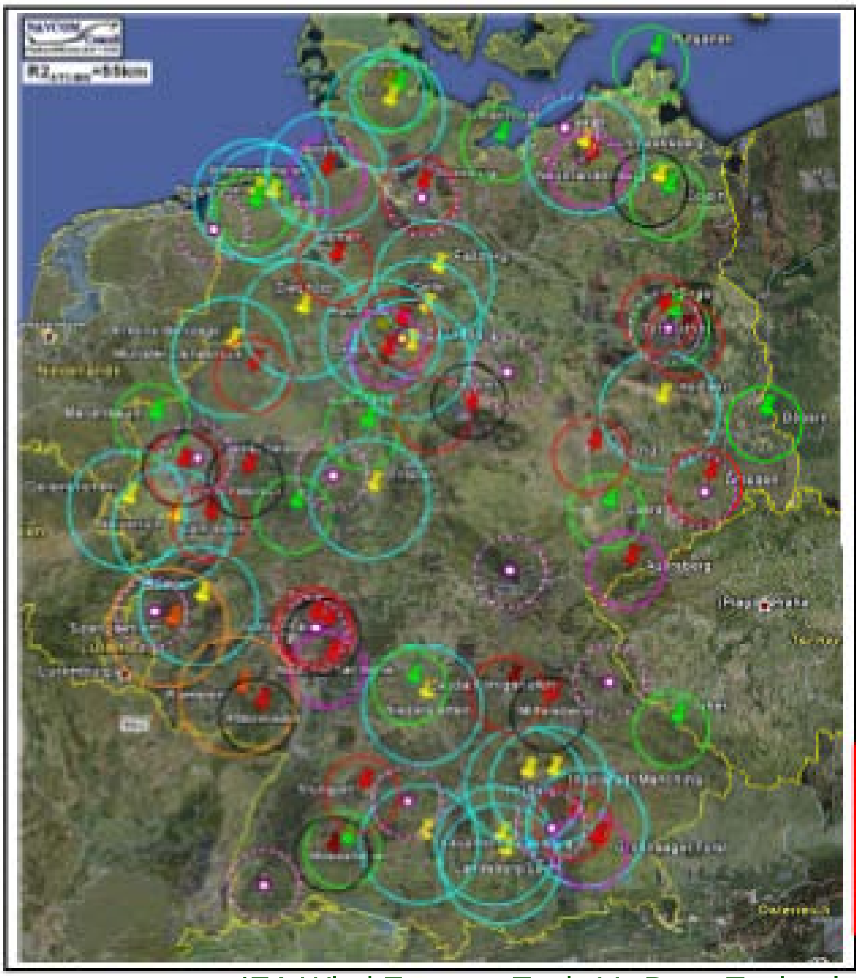

Assumption:

Safe Range R2=30nm

(R2=55km) for each mil ATC Radar

←→ „Area of responsibility“

16 Weather Radar of DWD
(in France R2=30km!)

←→ Repowering !?

The discussed „guideline“ of EUROCONTROL would enable even much larger safeguarding areas for ATC-Radar !

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Safeguarding ranges EUROCONTROL Guideline

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⇨ So far only a proposal for ATC-radar → Civ, Mil

4.2.1 Primary Surveillance Radar

Zone 1 Safeguarding	Zone 2 Detailed assessment	Zone 3 Simple assessment	Zone 4 No assessment
0 - 500 m	500 m - 15 km and in radar line of sight	Further than 15 km and in radar line of sight	Not in radar line of sight

Table 1: PSR recommended ranges

PSR

no real R2 !

4.2.2 Secondary Surveillance Radar (classical, monopulse and Mode S)

Zone 1 Safeguarding	Zone 2 Detailed assessment	Zone 4 No assessment
0 - 500 m	500 m - 16 km and in radar line of sight	Further than 16 km or not in radar line of sight

Table 2: SSR recommended ranges

(M)SSR

Practically worthless in case of collocated PSR/SSR

Range scheme for PSR not compatible with ICAO ED 015 !

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Content

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⇨ Example

⇨ Concluding Remarks

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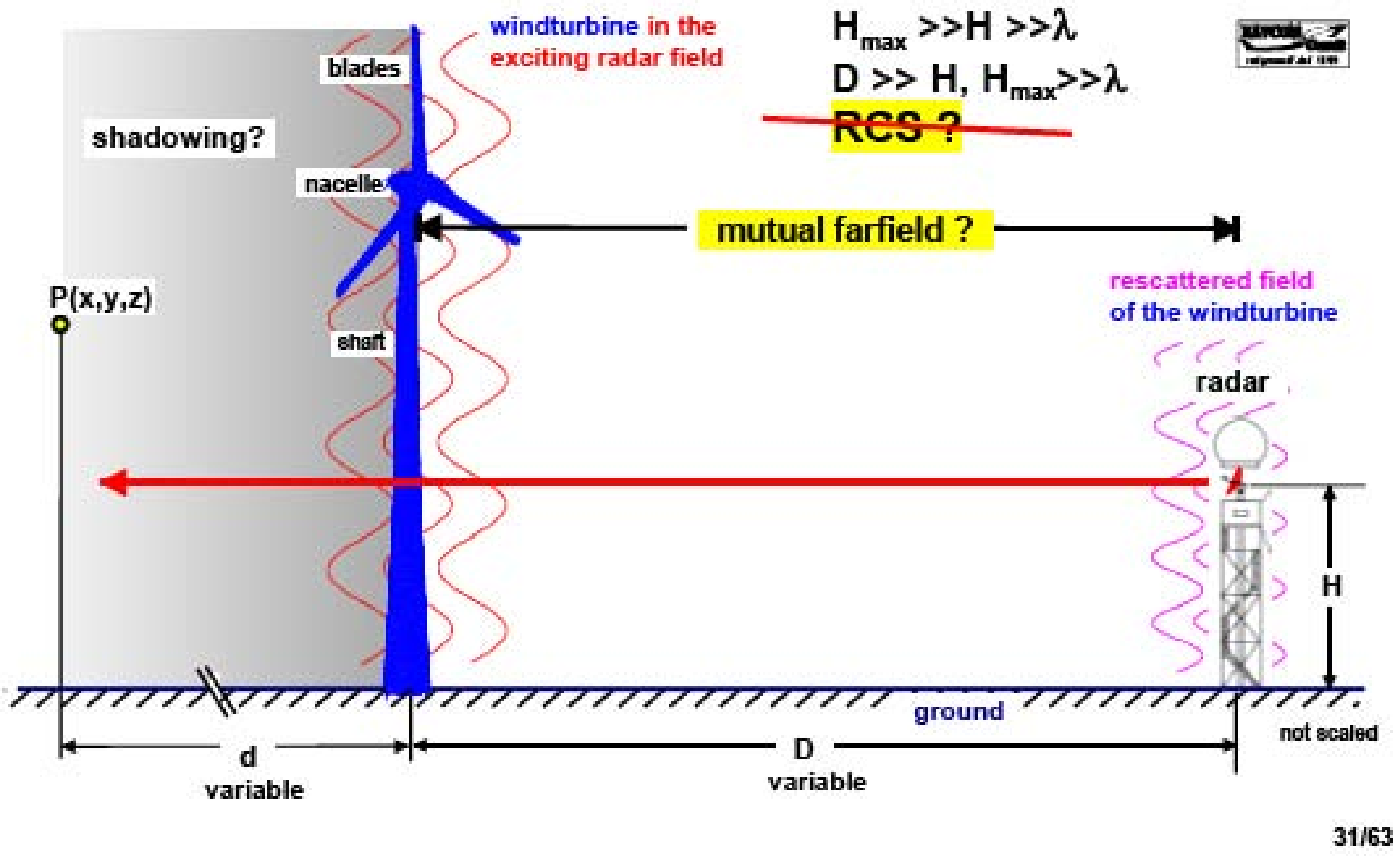
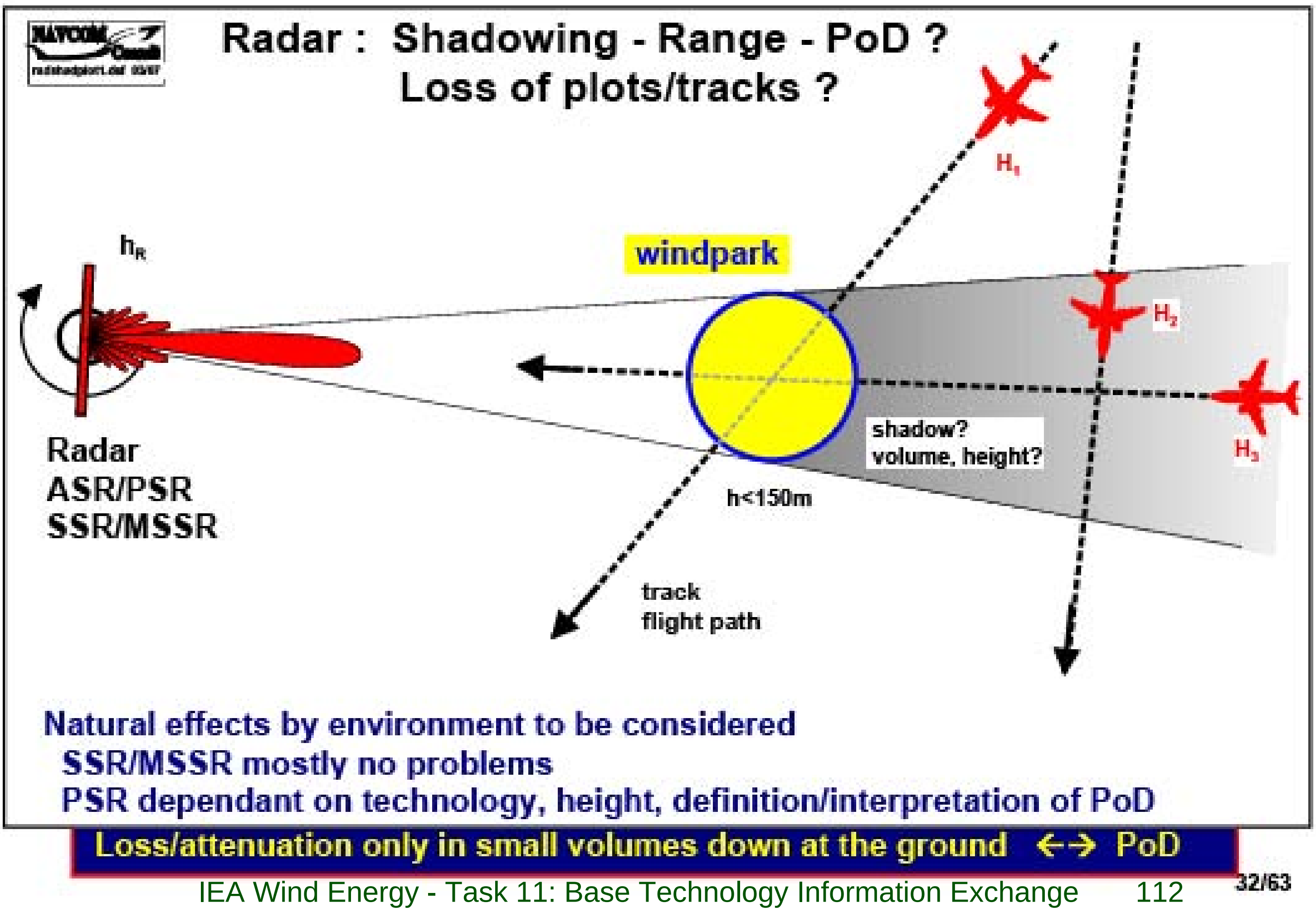
Effective „shadowing“ in the back of a wind turbine?





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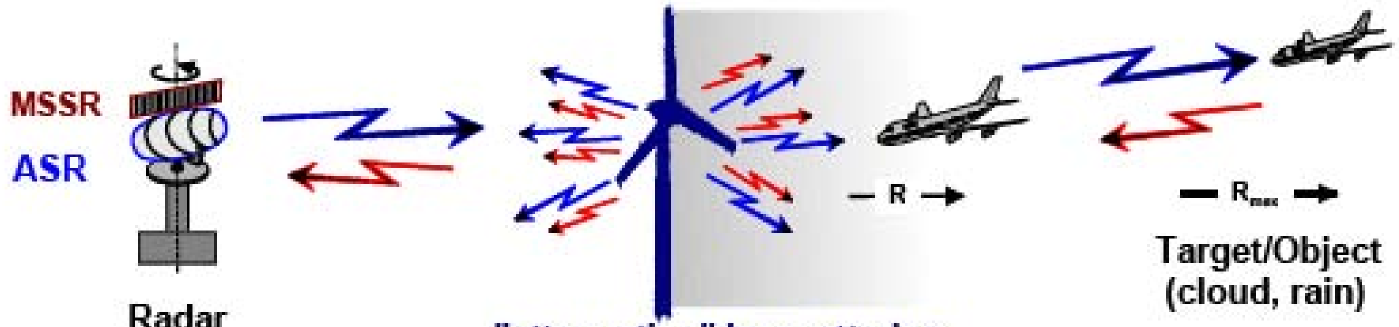
primrad_rangered1.dsf 11/08

Primary Radar - Maximum Range Reduction

Attenuation by absorption (?) or scattering



Radar Equation (maximum range)

$$R_{max} = \sqrt[4]{\frac{P_t\, G_t\, G_r\, \lambda^2\, \sigma}{(4\pi)^3\, S_{min}}}$$

...in small volumes down at the ground !

Attenuation $\delta G_t = \delta G_r$	range loss /%
0.5dB=0.89	6
1dB=0.79	11
2dB=0.63	21
3dB=0.50	29
6dB=0.25	50
10dB=0.1	68

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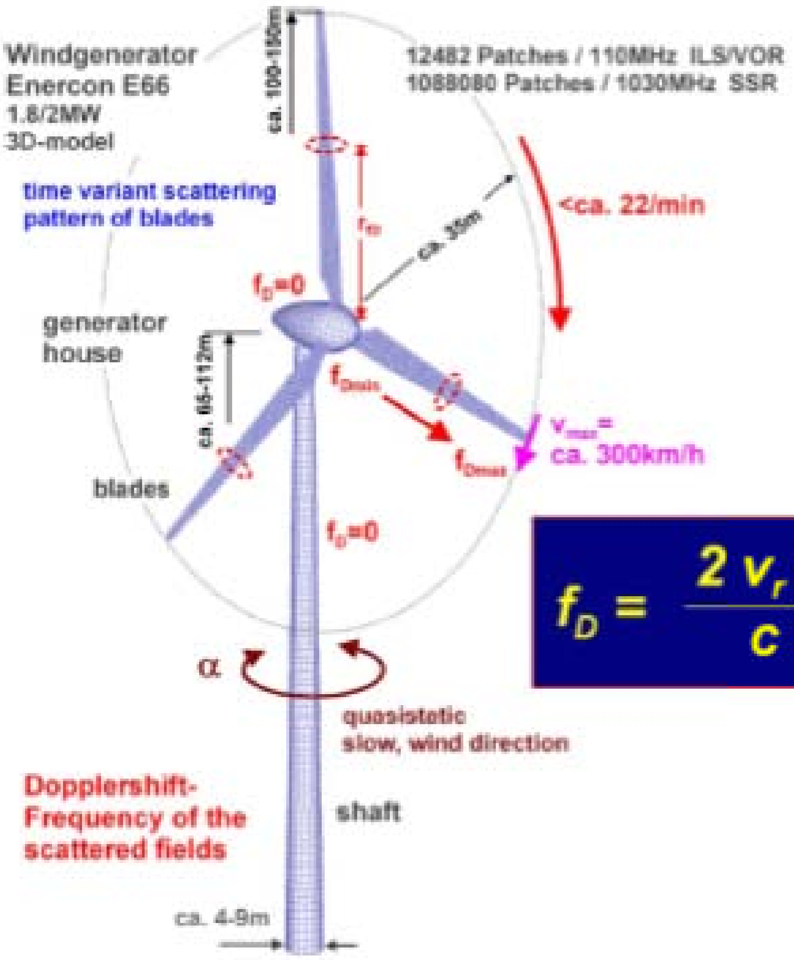

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windgenerator66.dsf 08/08

Windgenerator Enercon E66

3D-model - RCS-Doppler shift

$$f_D = \frac{2\, v_r\, f_T}{c}$$

RCS

$$\sigma_{pq} = \lim_{R \to \infty}\left[4\pi R^2 \frac{|E_p^s|^2}{|E_q^i|^2}\right]$$

RCS does not exist for real installation above ground!

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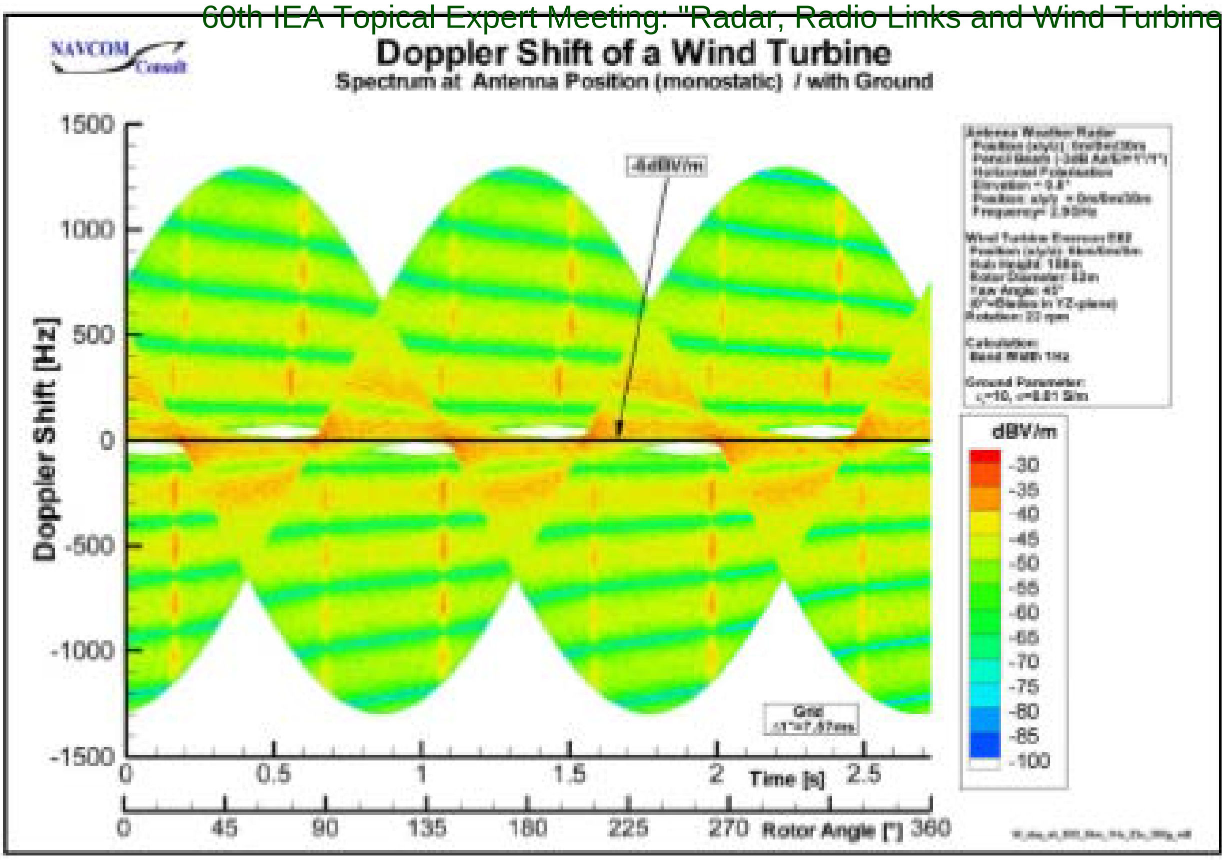

E82 22rpm

For slower rotation: Spectral width reduces, spectral amplitudes increase

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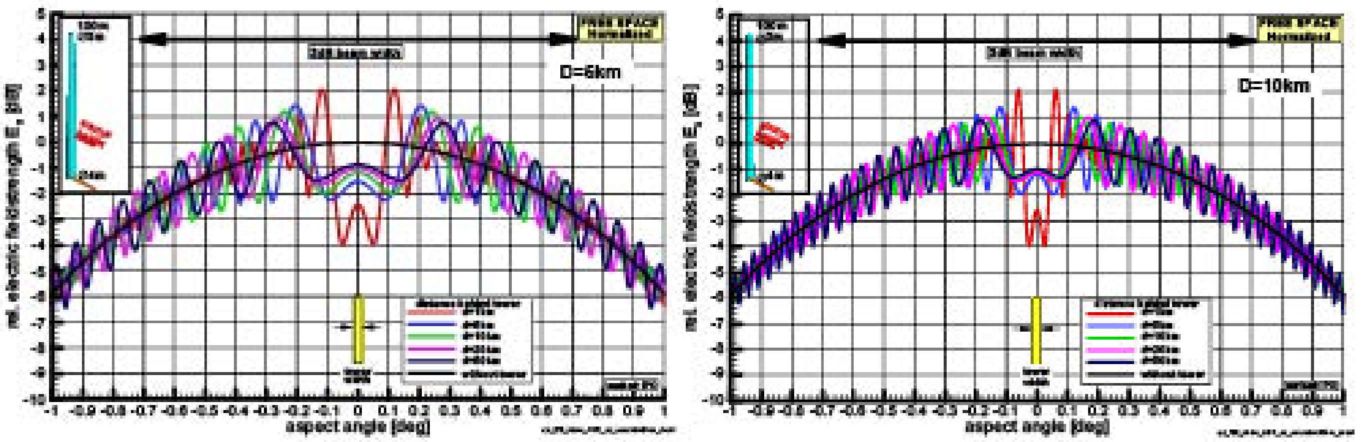
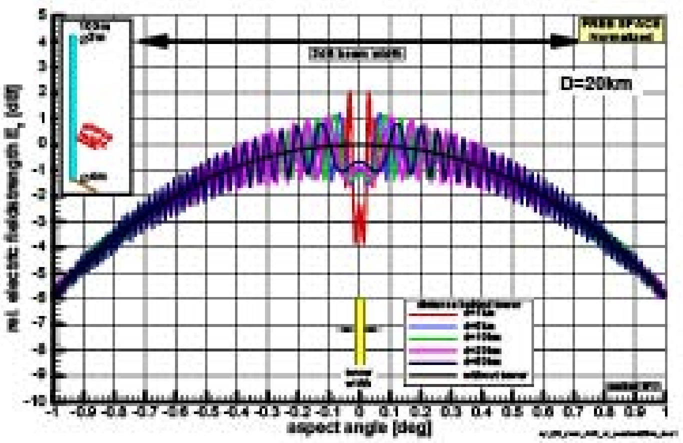
Horizontal azimuthal traces in the back of the wind turbine





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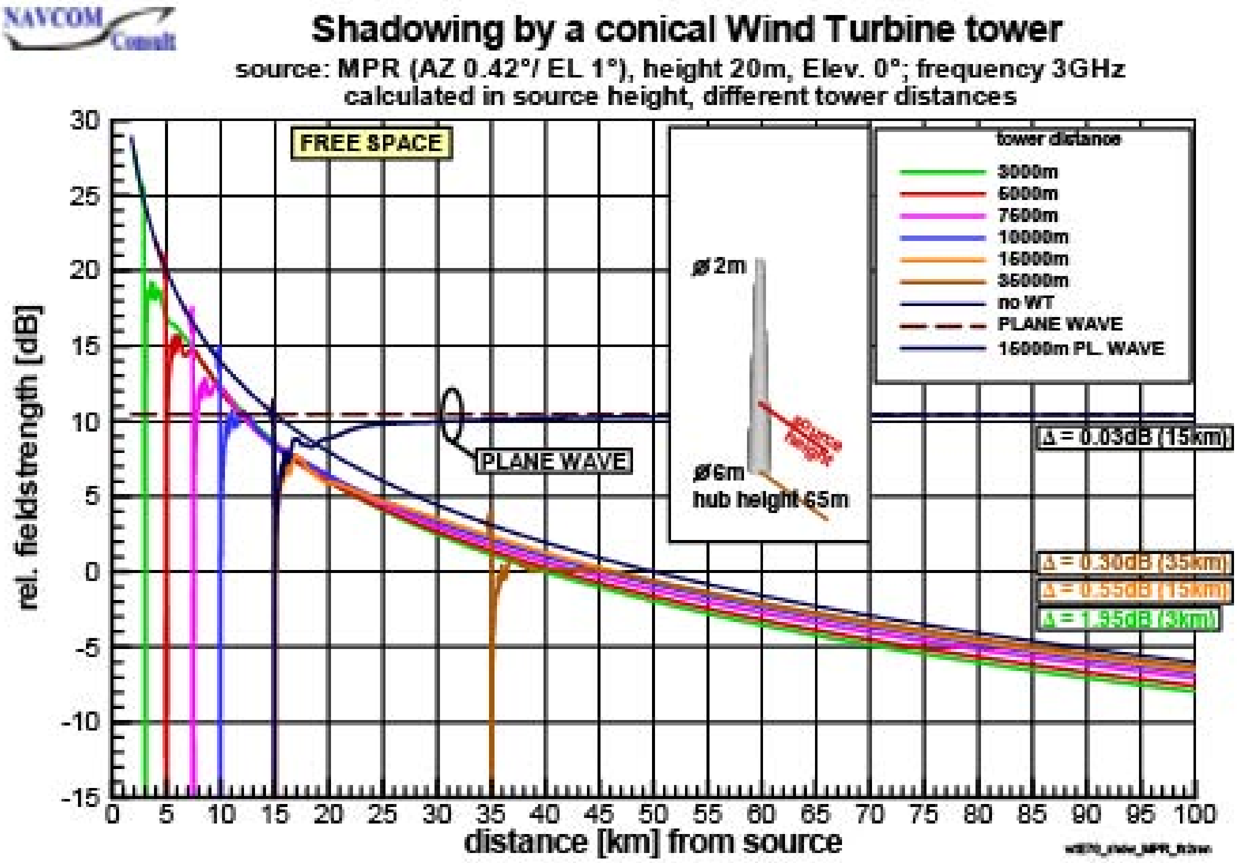
Shadowing of a Conical Wind Turbine Tower

shadowing: behind tower, at source height

source: ASR (1.4°/cosec²), height 30m, elev. 0°; frequency 2.8GHz

The wind turbine is a scatterer, not an absorber!

Horizontal radial traces in the back of the wind turbine



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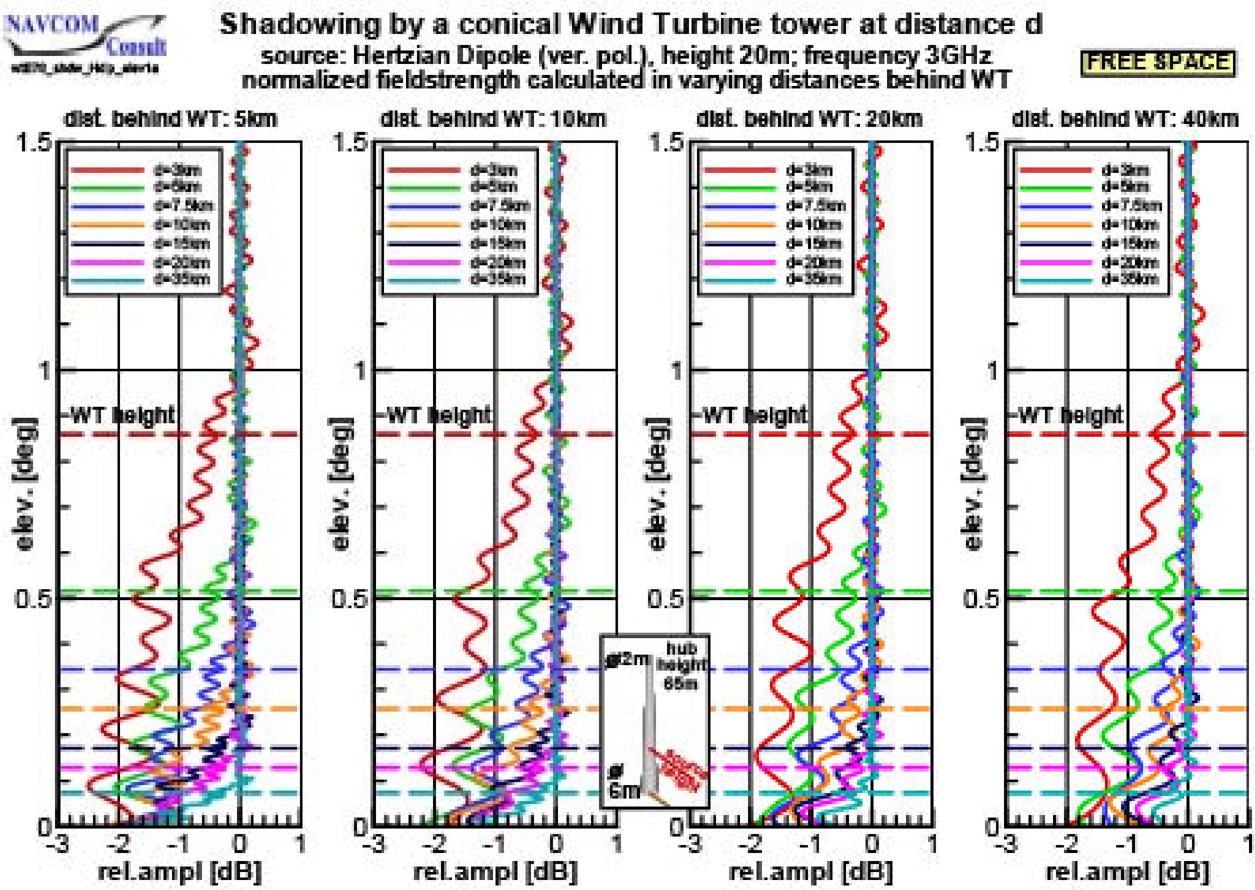
Vertical elevation traces in the back of the wind turbine



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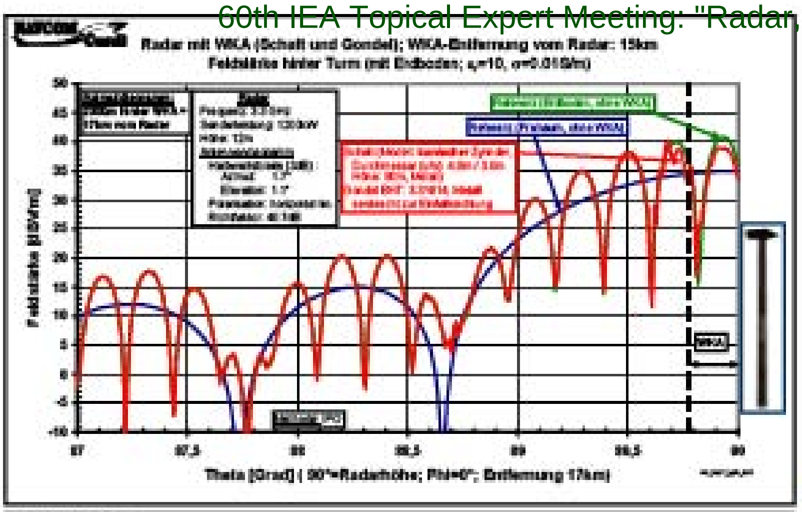

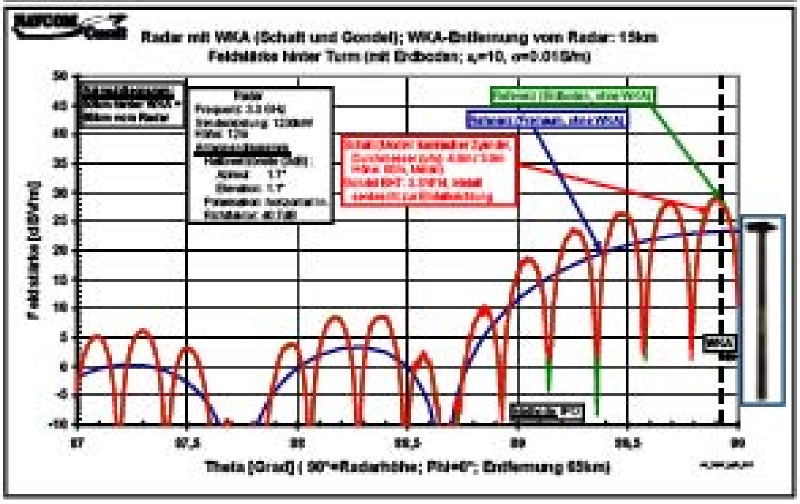

"Shadowing" in the back of a WT for an AD-Radar

Radar: Free space, ground included

Elevation trace

D1 Radar to WT : 15km
D2 in the back of WT : 2km

D1 Radar to WT : 15km
D2 in the back of WT : 50km

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Radar Basics

Probability of Detection Overall? / local?

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- PoD relevant at maximum range; complex integral term (BARTON
- (Local) PoD above a windpark arbitrary: between 0% and ~100%
- EUROCONTROL : pragmatic approach RASS
  SUR.ET1.ST01.1000-STD-01-01
  SUR.ET1.ST03.1000-STD-01-01
- Overall probability of detection measured (N→oo; Ludloff, ...)

$$\text{PoD} = \frac{\text{number of detected target reports}}{\text{number of expected target reports}}$$

- PSR → 90%, SSR → 97%, combined 95% (see SUR.ET1 ...)
- Small reductions in the back of wind turbines and "holes" above a windpark do not affect the overall PoD significantly

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- ⇨ PoD global / (local)
- ⇨ **Result 2: False targets by multiple reflections at WT and aircraft**
  Taken from: EUROCONTROL guideline version 14
- ⇨ Measures for Improvement; Stealth, absorbers
- ⇨ Example
- ⇨ Concluding Remarks

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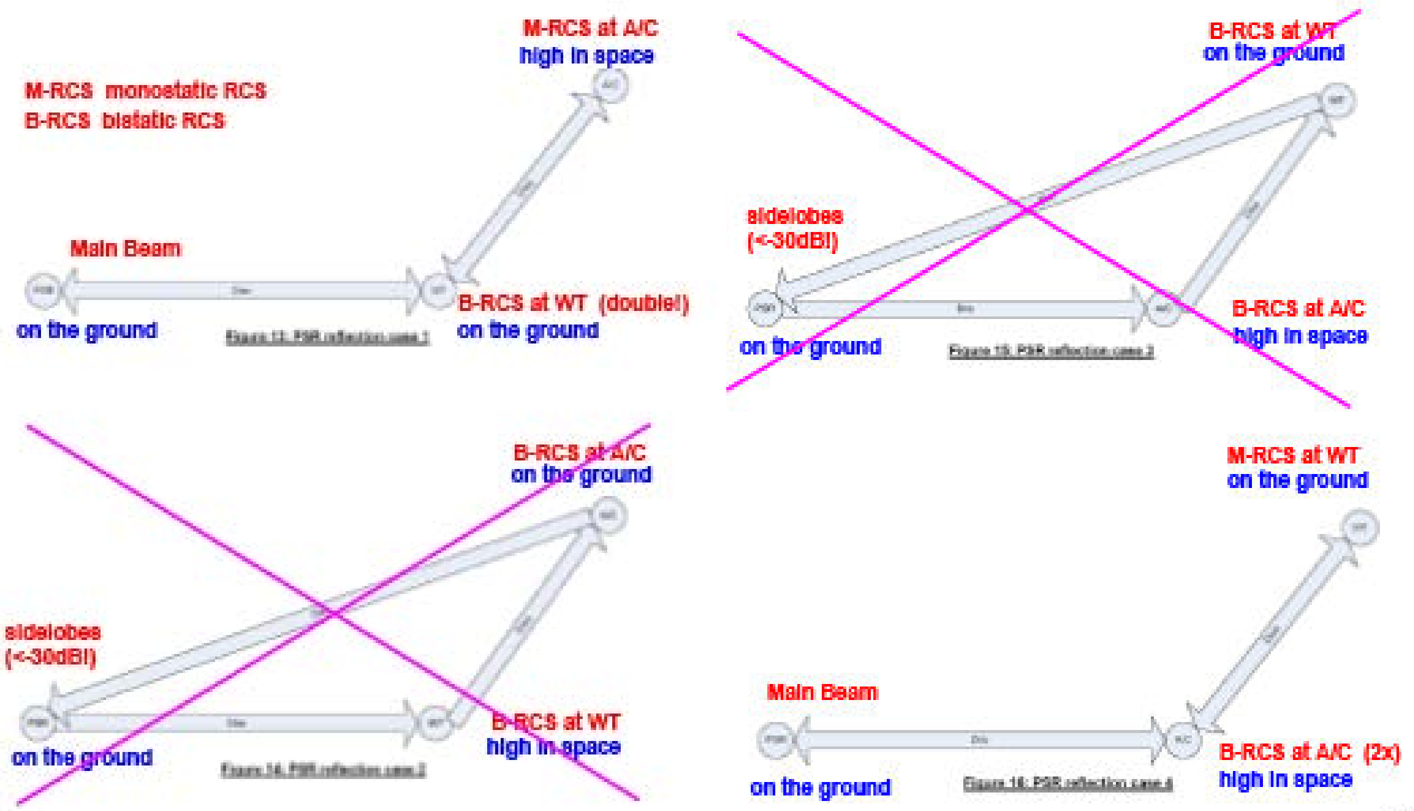
"PSR Equations (reflections)"

Taken from Annex C of the EUROCONTROL guidelines Version 14



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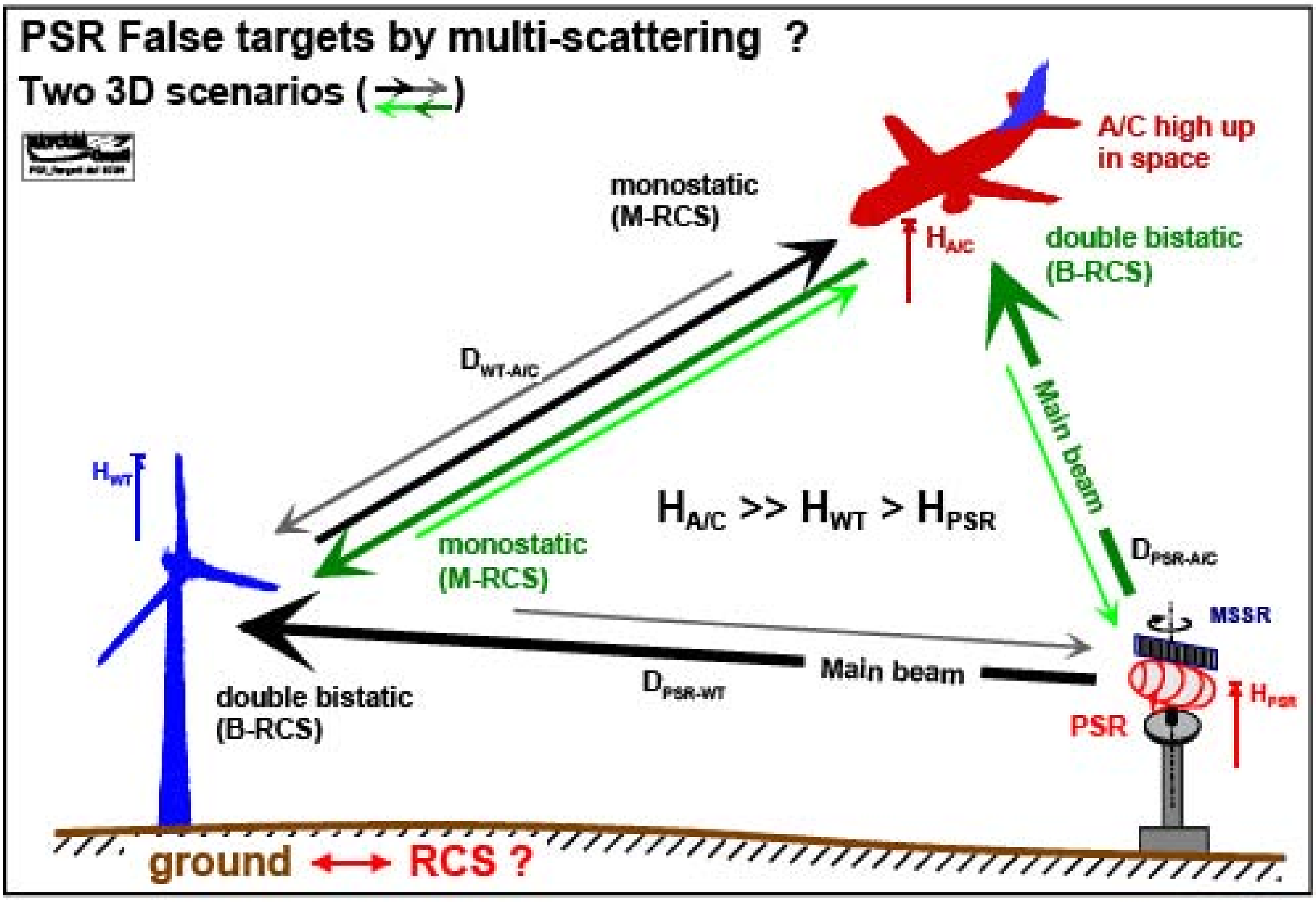
PSR False targets by multi-scattering ?
Two 3D scenarios ( )
A/C high up in space
monostatic (M-RCS)
$H_{A/C}$
double bistatic (B-RCS)
$D_{WT-A/C}$
Main beam
H_{WT}
$H_{A/C} >> H_{WT} > H_{PSR}$
monostatic (M-RCS)
$D_{PSR-A/C}$
MSSR
Main beam
D_{PSR-WT}
double bistatic (B-RCS)
H_{PSR}
PSR
ground ⟷ RCS ?

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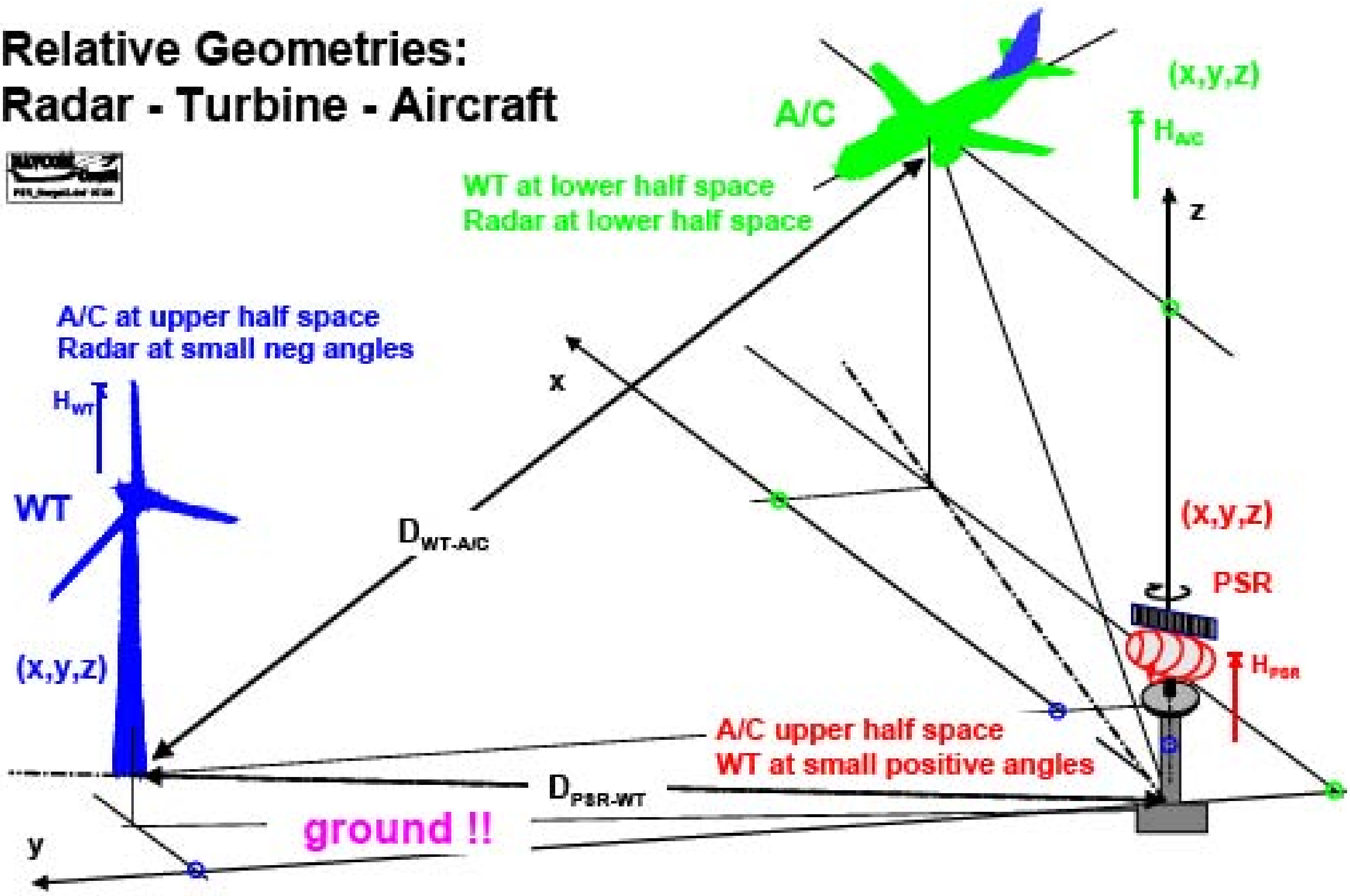
Relative Geometries:
Radar - Turbine - Aircraft
A/C
(x,y,z)
$H_{A/C}$
WT at lower half space
Radar at lower half space
z
A/C at upper half space
Radar at small neg angles
x
H_{WT}
WT
$D_{WT-A/C}$
(x,y,z)
PSR
(x,y,z)
H_{PSR}
A/C upper half space
WT at small positive angles
D_{PSR-WT}
ground !!
y

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Modified/adapted Radar Equation : Case 1

$$P_r = \frac{\boxed{\sigma_{A/C}\sigma_{WT1}\sigma_{WT2}} F_{rWT}^2 F_{tWT}^2 G_r G_t \lambda^2}{(4\pi)^5 D_{PSR-WT}^4 D_{WT-A/C}^4}$$

$\sigma_{A/C}$	**RCS of aircraft**	**mono-static**
σ_{WT}	**RCS of WT**	**bi-static**

Taken from:
[12] EUROCONTROL; Guidelines on How to Asses the Potential Impact of Wind Turbines on Surveillance Sensors; Ed. 0.14 (Draft), 17.6.09

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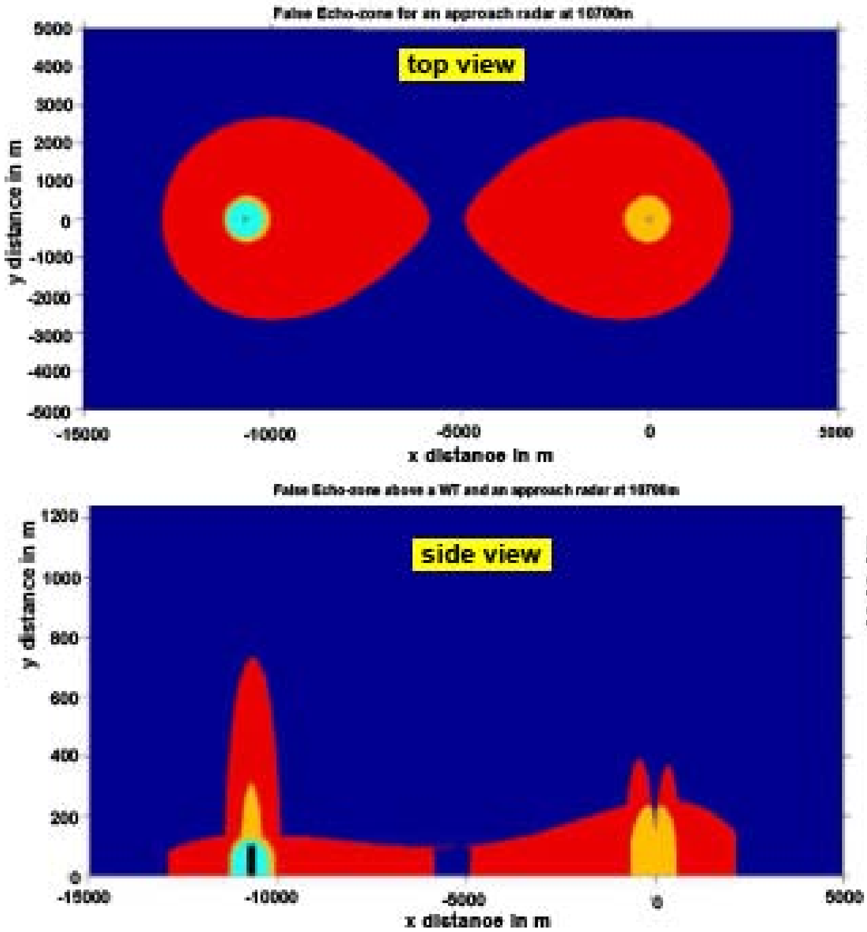

Figure 17: Example of calculation of aircraft locations where reflections can occur (horizontal)

which RCS ?
40dBsm, 50dBsm, ... ?

which SLL ?
-30dB, -40dB, ... ?

Figure 18: Example of calculation of aircraft locations where reflections can occur (vertical)

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rotor, blades

machine house, nacelle

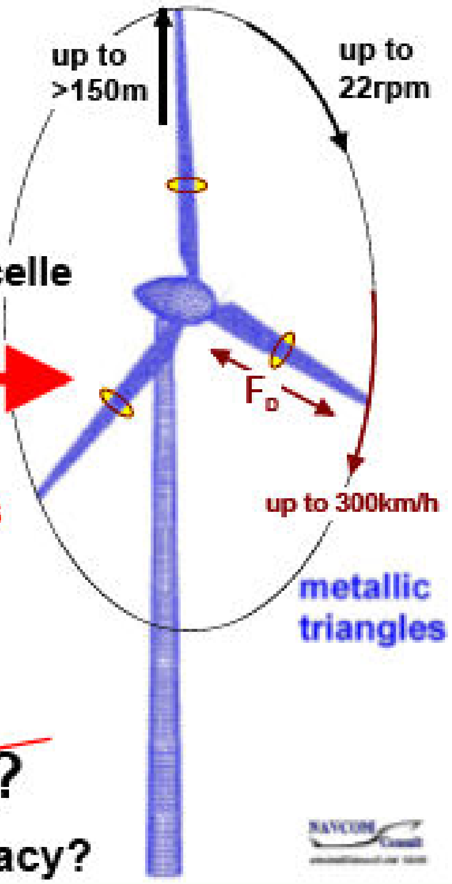
3D - model

simulations
numerical methods

shaft

~~RCS / SER~~ ?

applicable? accuracy?



RCS not applicable in general for objects on the ground !

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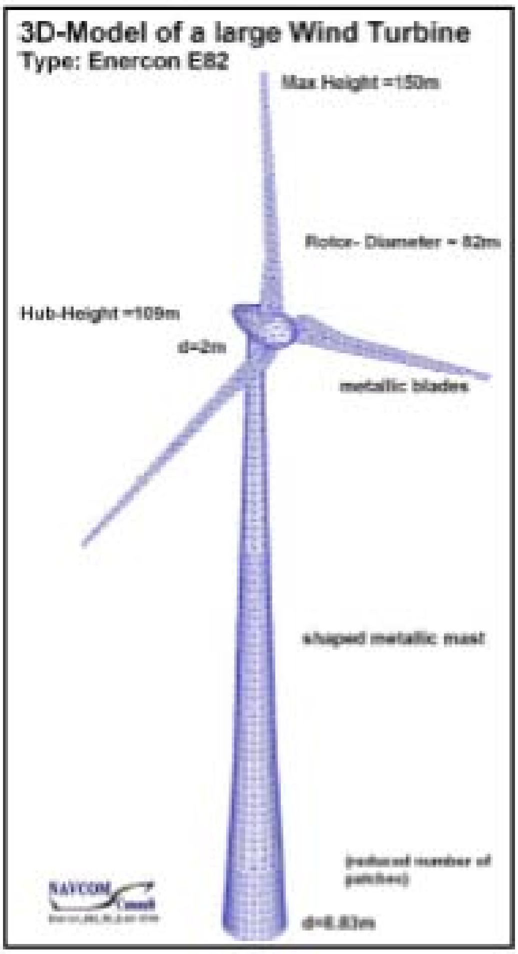


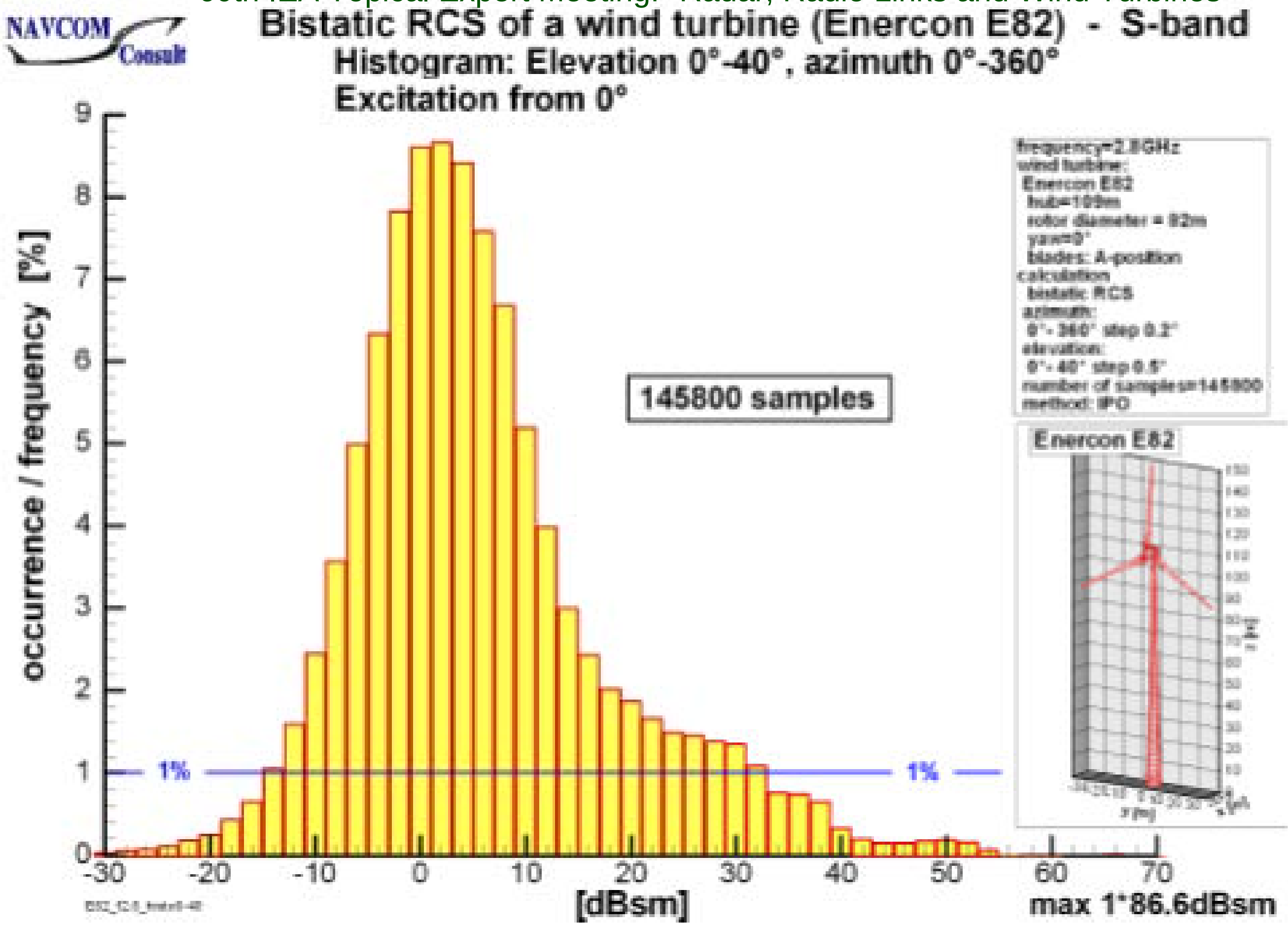
Worst case 3D model of a large Enercon E82

Fully metallic blades and nacelle

Max height : 150m → up to 200m

Calculated/measured RCS only defined in free space!

Not defined above ground!
←→ arbitrary unknown error!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Bistatic RCS of a wind turbine (Enercon E82) - S-band
Histogram: Elevation 0°-40°, azimuth 0°-360°
Excitation from 0°
occurrence / frequency [%]
145800 samples
frequency=2.8GHz
wind turbine:
Enercon E82
hub=108m
rotor diameter = 82m
yaw=0°
blades: A-position
calculation
bistatic RCS
azimuth:
0°- 360° step 0.2°
elevation:
0°- 40° step 0.5°
number of samples=145800
method: IPO
Enercon E82
1%
1%
[dBsm]
max 1*86.6dBsm

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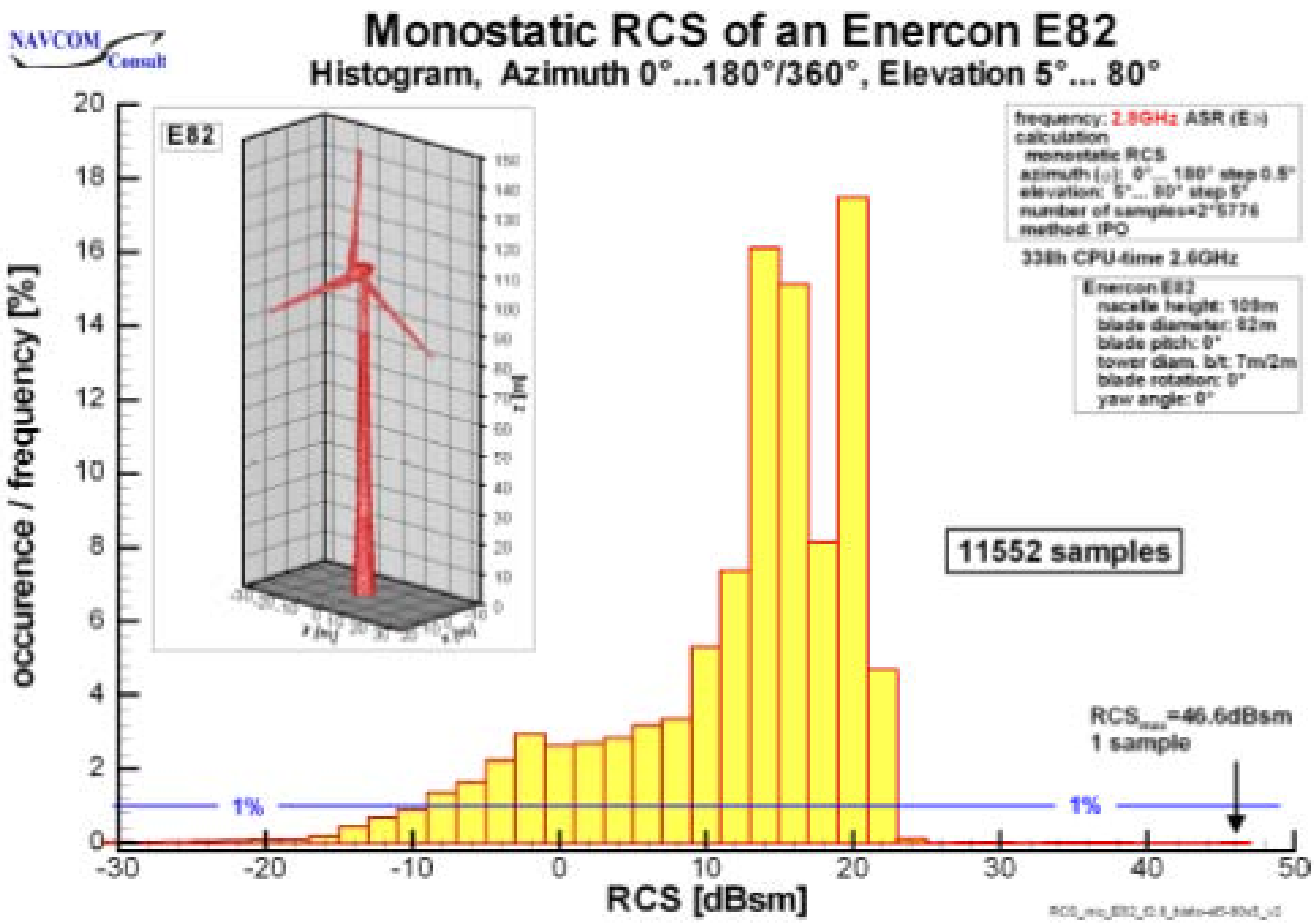
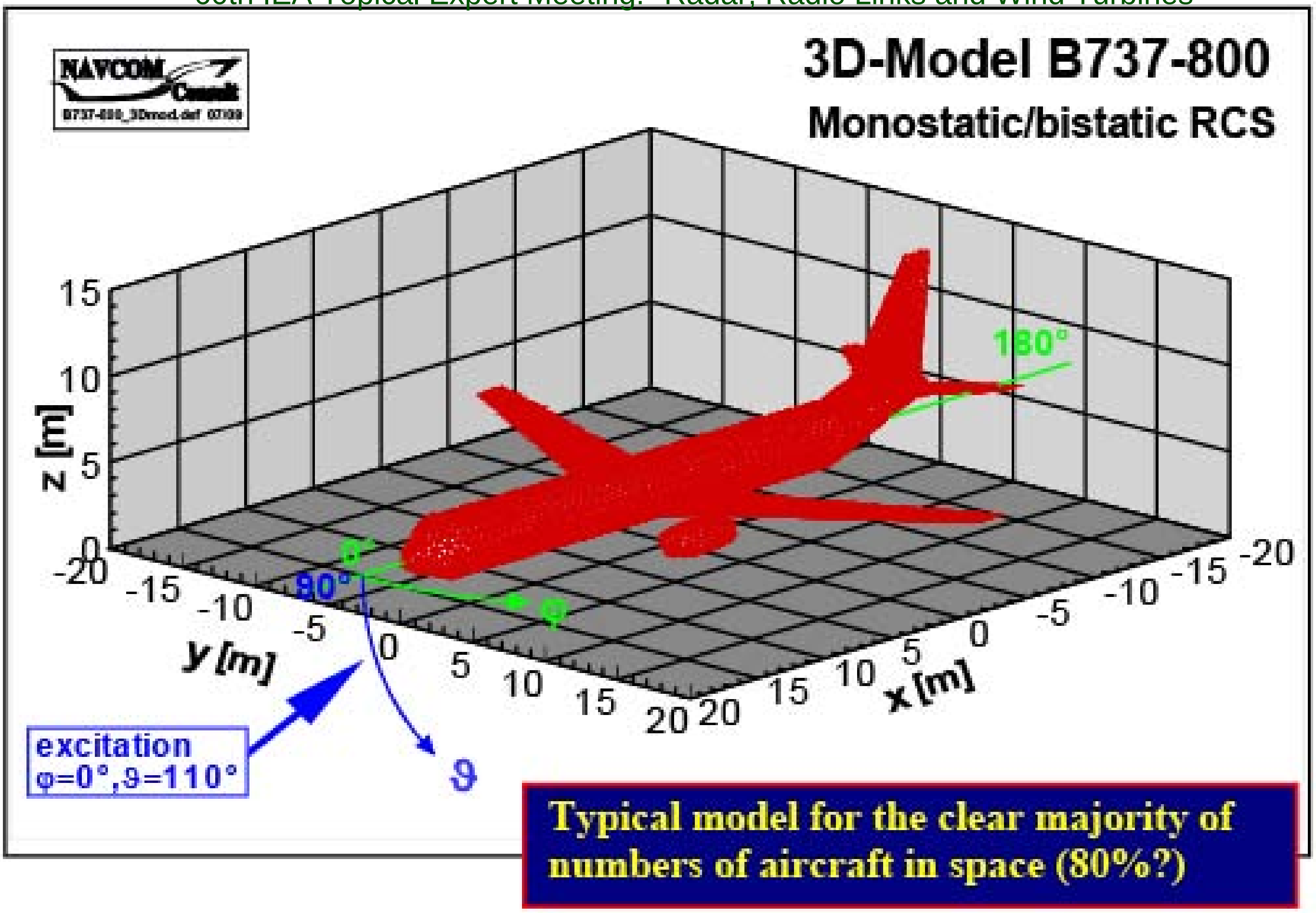
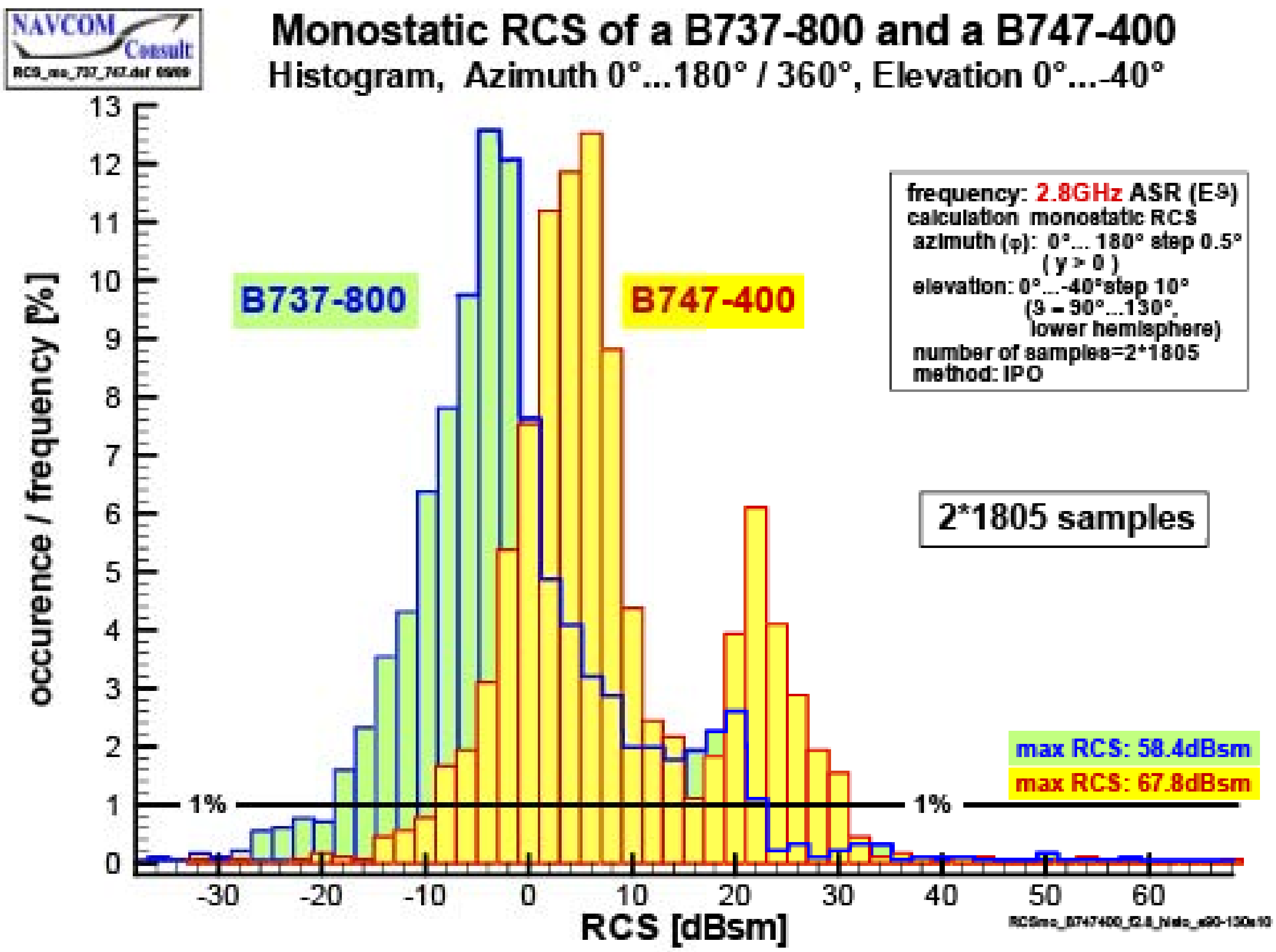

NAVCOM Consult
Monostatic RCS of an Enercon E82
Histogram, Azimuth 0°...180°/360°, Elevation 5°... 80°
E82
occurence / frequency [%]
frequency: 2.8GHz ASR
calculation
monostatic RCS
method: IPO
338h CPU-time 2.6GHz
Enercon E82
nacelle height: 108m
blade diameter: 82m
blade pitch: 0°
tower diam. b/t: 7m/2m
blade rotation: 0°
yaw angle: 0°
11552 samples
RCS$_{max}$=46.6dBsm
1 sample
1%
1%
RCS [dBsm]

50/63


NAVCOM Consult
3D-Model B737-800
Monostatic/bistatic RCS
z [m]
y [m]
x [m]
180°
0°
80°
φ
ϑ
excitation
φ=0°,ϑ=110°
Typical model for the clear majority of numbers of aircraft in space (80%?)

51/63


NAVCOM Consult
Monostatic RCS of a B737-800 and a B747-400
Histogram, Azimuth 0°...180° / 360°, Elevation 0°...-40°
B737-800
B747-400
frequency: 2.8GHz ASR (Eϑ)
calculation monostatic RCS
azimuth (φ): 0°... 180° step 0.5°
(y > 0)
elevation: 0°...-40°step 10°
(ϑ = 90°...130°,
lower hemisphere)
number of samples=2*1805
method: IPO
2*1805 samples
max RCS: 58.4dBsm
max RCS: 67.8dBsm
1%
1%
occurence / frequency [%]
RCS [dBsm]

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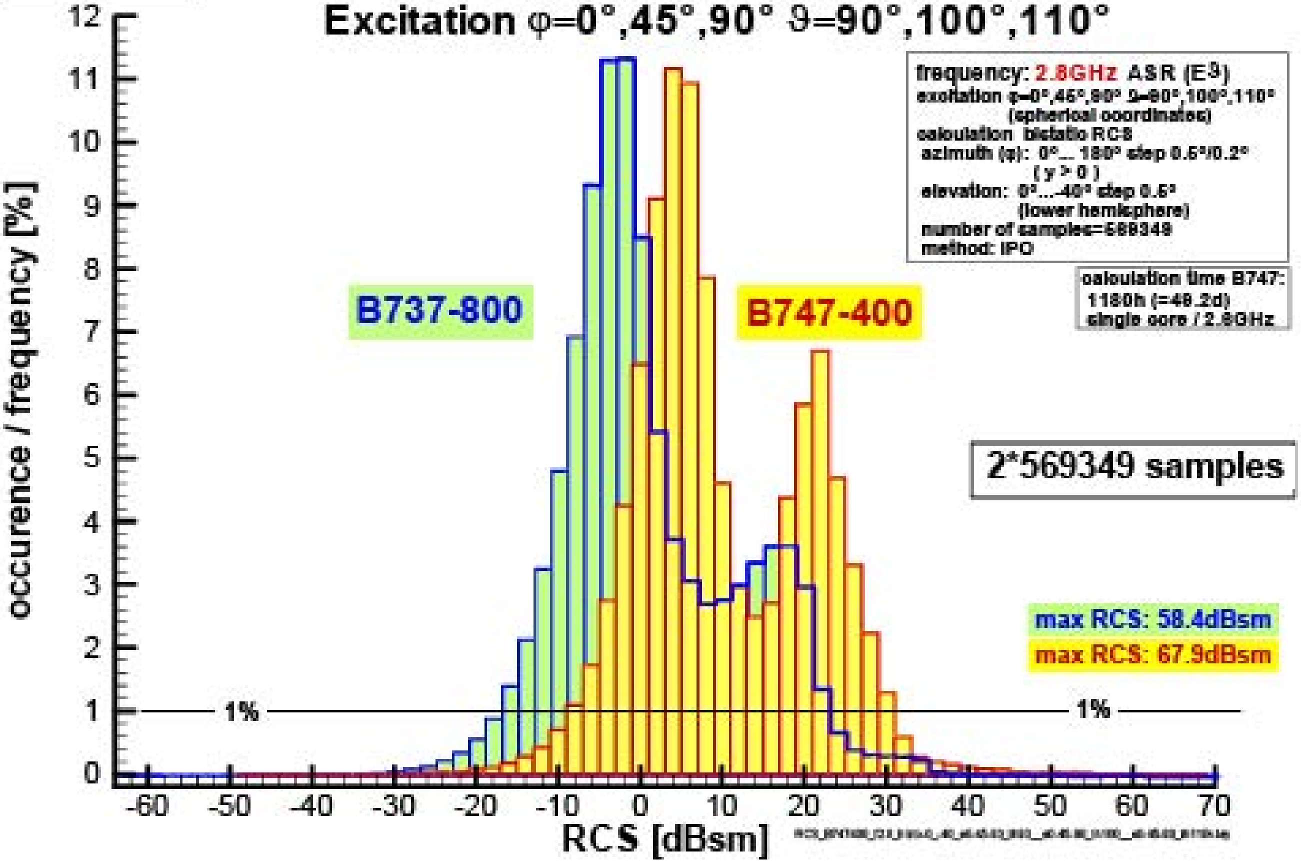
NAVCOM Consult

Bistatic RCS of a B737-800 and a B747-400
Histogram, Elevation 0°...-40°,
Excitation φ=0°,45°,90° ϑ=90°,100°,110°



NAVCOM Consult

PSR False target by Multi-scattering at WT and A/C
RCS-processing

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- ⇨ **Processed mono-static and bi-static RCS virtually, although not existing for WT**
- ⇨ **Theoretically possible only in very close unrealistic distances *and* for large RCS for WT *and* A/C**
- ⇨ **PSR False targets extremely unlikely due to triple multiplication of RCS and of the statistical occurrence**
- ⇨ **The reality:** nearfield effects at WT and A/C for typical distances
  Small distances and low heights impossible
  ground effects for a 2D-radar

←→ reduce maximum of scattering at WT and at A/C

⇨ The generation of PSR false targets by multi-scattering at the WT and at the A/C is extremely unlikely - unrealistic !

Measures to reduce/improve effects (1)

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⇨ for all frequencies ? ←→ system

⇨ under all environmental conditions ? (rain, ice, …)

⇨ Absorbing material ? ←→ "forward scatter"

inside blades for lightning arrestor ←→ rain, carbon fibre

inside the nacelle shell ←→ rain, aluminum

←→ carbon fibre

⇨ Stealth principles ? by form and construction

Effective almost only for back scatter (MTI, MTD)

Not effective for forward scatter and bi-scatter (SSR,MSSR)

Questionable solutions ←→ function / technology / cost

→ cost/effort per WT seems to be not justified

→ if at all and if it works sufficiently, last method

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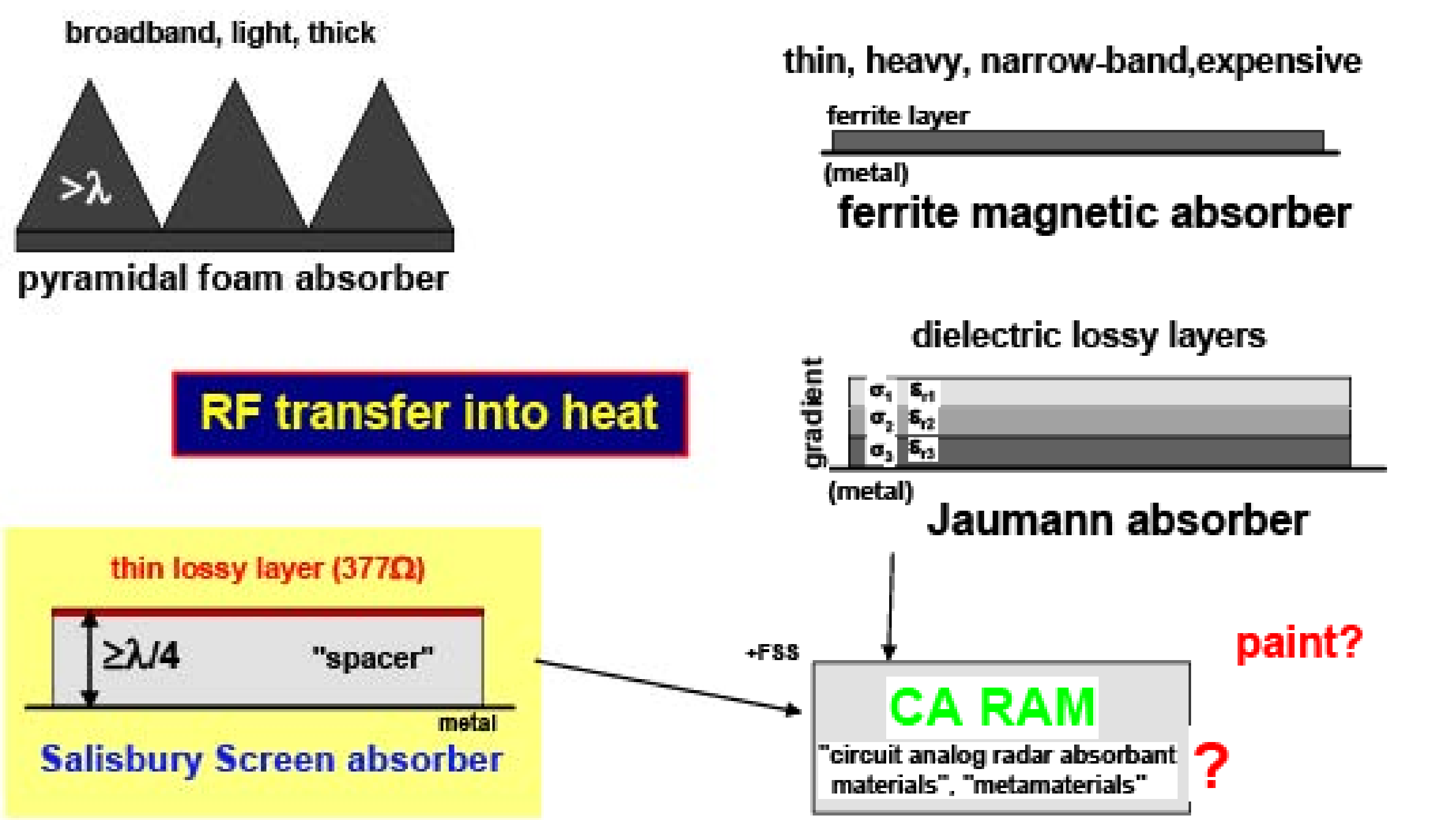
Some types of real existing absorbers

Dr.Gr. absorbtyp3.dsf 11/09



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Measures to reduce/improve effects (2)

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⇨ **Wind turbines are a special type "clutter"**
With a known position and a known scattering response (spectrum)

⇨ **Clutter suppression is a "standard task" of the radar**
e.g. moving vehicles close to a radar are "visible"
Would you try to forbid motorways ?
→ Mitigation measures in the radar
→ Challenge to radar engineers

⇨ **Plot losses and track losses are also daily facts**

⇨ **The most effective mitigation measures ATC**
Networking, clustering (realized in most countries)
MSSR has priority vs. PSR (anyhow 2D, does not know height!!)
Gain from redundancy

→ Modern radar operation

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Remarks: EUROCONTROL Guidelines V14 (1)

Civilian and military ATC ??

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⇨ **see above to the safeguarding areas**

⇨ **„simple assessment" relies fully on the RCS (see above)**
accuracy and error fully unknown → probably exaggeration
12th version contained still a critical remark (1.4.09, §4.3.1)
Some parameters do not reflect real signal processing: monopulse error

⇨ **„detailed assessment" formally impossible to carry out**
Claim: All needed data not available

⇨ **General impression: least common denominator of a group**

⇨ **worst-worst case assumptions/conditions** (e.g. -77dBm; Power)

⇨ **Most effective measures not taken into account :**
←→ MSSR priority; PSR for target reinforcement
←→
←→ networking; redundancy (DFS, FAA, USAF)

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Remarks: EUROCONTROL Guidelines V14 (1)

Civilian and military ATC ??

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- „Visibility“ is criterion for Primary radar
- Generally de facto dis-approval for R2<15km!
- Rejections possible >50km, >100km, >150km !!
- Guidelines do not reflect the modern international ATC operation
- Guidelines do not reflect the reality: e.g. 20000 turbines are in coexistence with ATC operation
- ...

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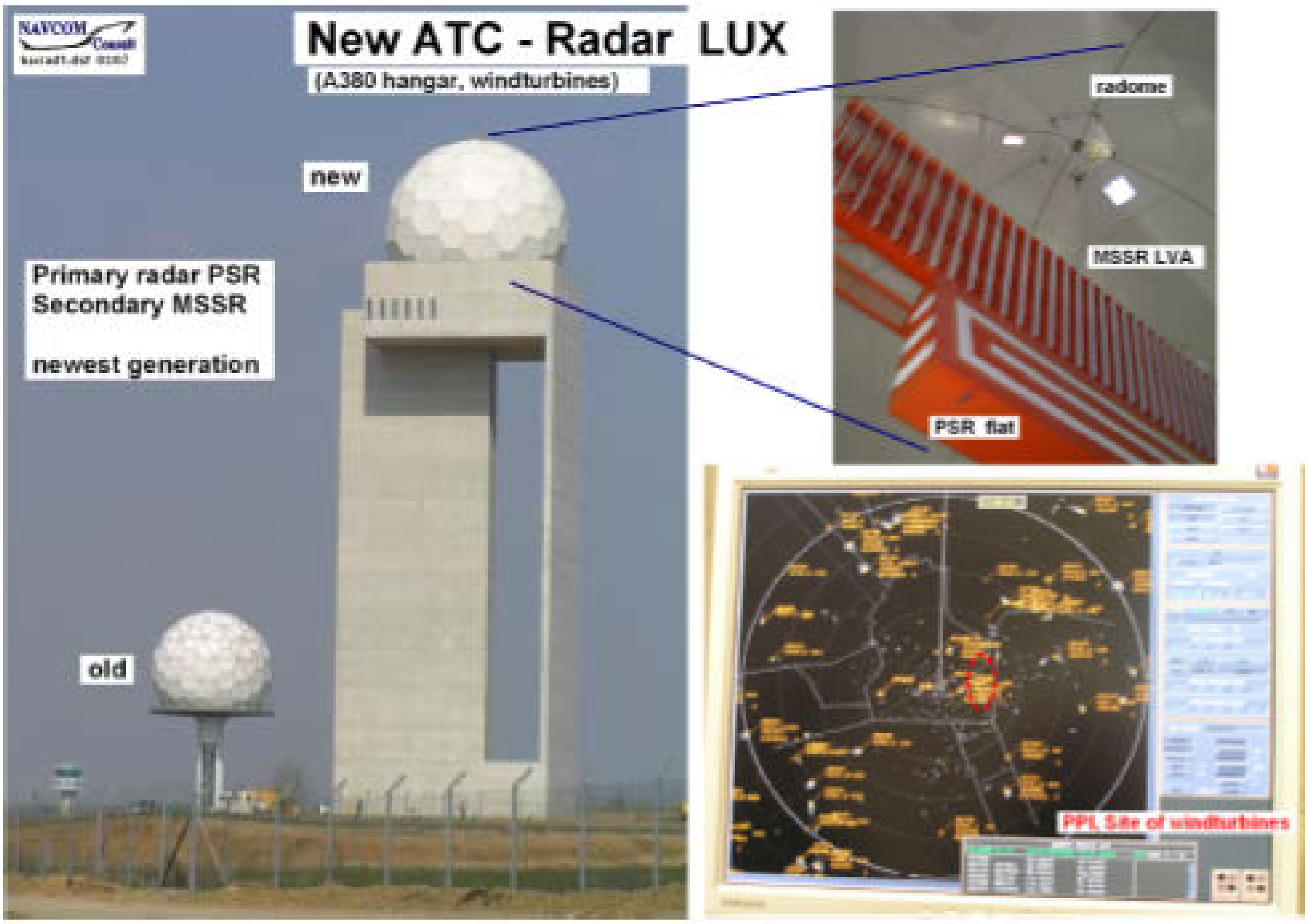

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Conclusions for Wind Turbines WT

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- The treatment of wind turbines is different for every system
  Radar, navaids, comm
- What is a "distortion" in Radar ?
- System Specifications, defined operational requirements to be met
- Effects vs "comfort" - Can the mission be met?
- scattering at WT is highly time- and space-variant; Spectrum
- RCS scheme strictly speaking not applicable for WT
- Modern existing HW/SW technology → far better compatibility with WT
- Examples and results for several systems presented
- Advanced system simulations on case by case basis necessary
- Physics should be the same in each country/organisation

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IEA - Amsterdam, November 18/19, 2009

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Wind Turbines in the Radiation Field of Systems from an Analysis and Coexistence Point of View

THX - Q&A

http://www.navcom.de

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10/12/2009

EUROCONTROL Guidelines

Michel BORELY – Secretary of the EUROCONTROL Wind Turbine Task Force

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EUROCONTROL Mission

European Organisation for the Safety of Air Navigation: EUROCONTROL

The mission of the European Organisation for the Safety of Air Navigation is to harmonise and integrate Air Navigation Services in Europe, aiming at the creation of a uniform Air Traffic Management System for civil and military users, in order to achieve the safe, orderly, expeditious and economic flow of traffic throughout Europe.

The Agency shall be the organ entrusted to undertake the Organisation's tasks.

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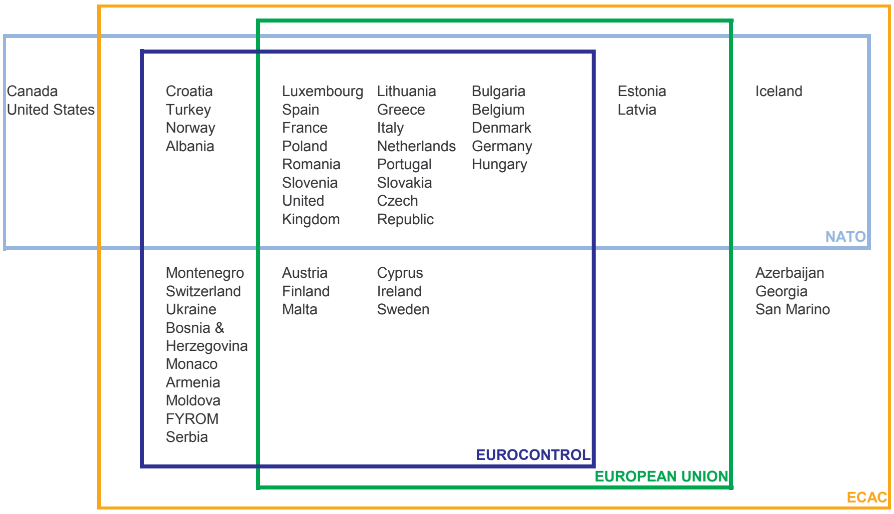
Other Organisations



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EUROCONTROL business objectives

SAFETY.-
Further improve ATM safety whilst accommodating air traffic growth

CAPACITY.-
Match capacity and air transport growth, towards the economic optimum in delays

EFFICIENCY.-
Increase the efficiency of the ATM network

SECURITY.-
Strengthen ATM's contribution to aviation security

ENVIRONMENT.-
Reduce aircraft noise and emission levels

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Surveillance programmes and projects

- Maintain Surveillance infrastructure strategy,
- Define minimum performance standards,
- Prepare implementation of ADS-B,
- Support states for implementation of WAM,
- Establish, for use by all ECAC states , procedures and methodologies covering:
  - Exchange of Surveillance data,
  - Harmonised performance assessment techniques,
  - Safeguarding assessments.

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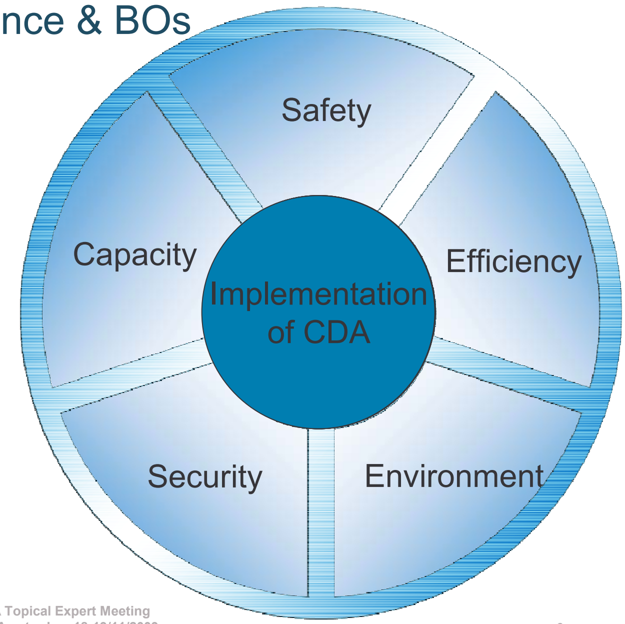
Surveillance & BOs



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EUROCONTROL Regulatory and Advisory Framework (ERAF)

Two basic categories of material:

- Regulatory Material
  - Binding provisions – EUROCONTROL Rule.
- Advisory Material
  - Non binding provisions – EUROCONTROL Specification or Guidelines.

Consultation process

Depends on the type of document:

- Specification
  - Formal consultation: EUROCONTROL Notice of Proposed Rule-Making (ENPRM) Regulatory Process.
- Guidelines
  - Informal consultation.

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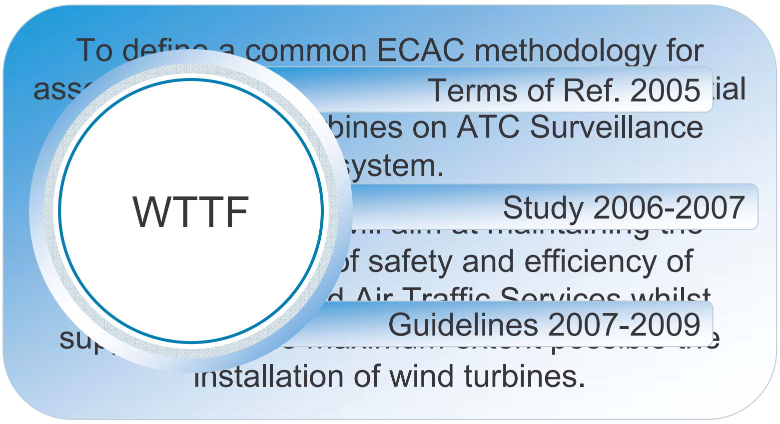
Wind Turbine Task Force



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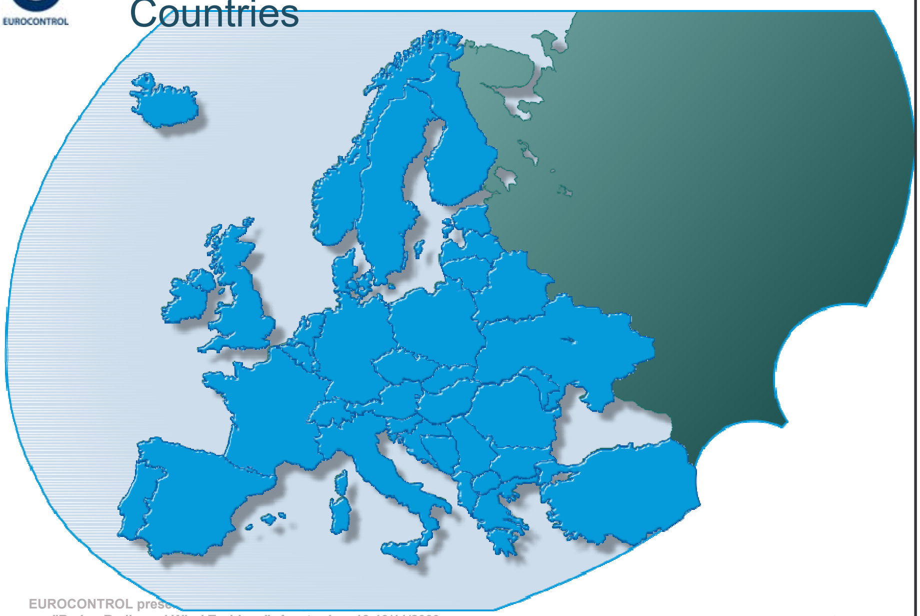
Countries



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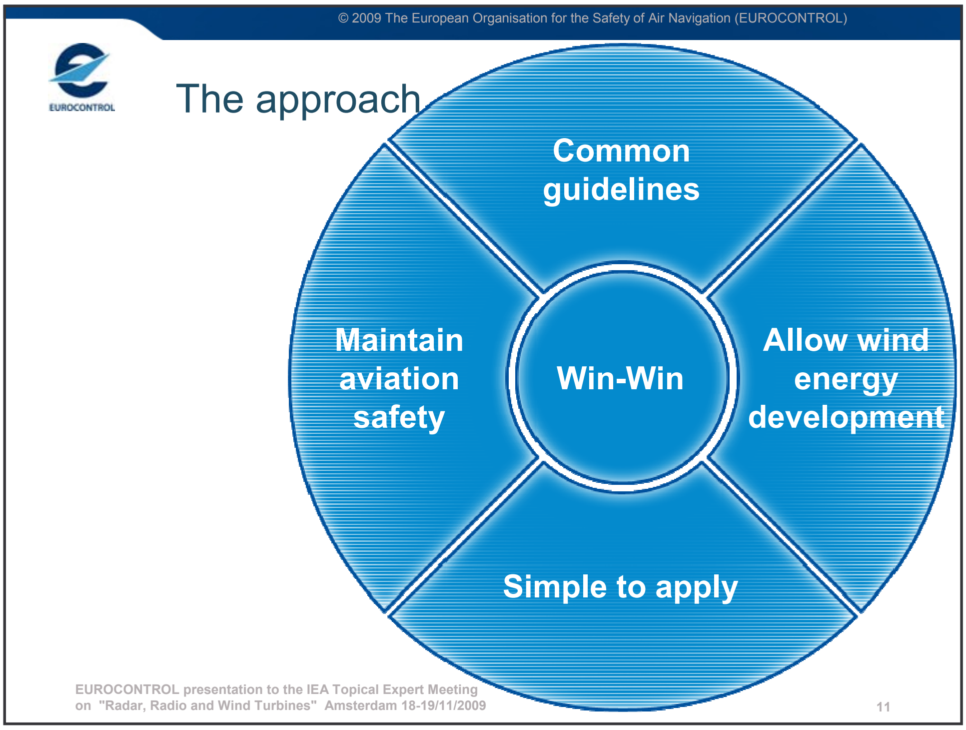
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The approach
Common guidelines
Maintain aviation safety
Win-Win
Allow wind energy development
Simple to apply
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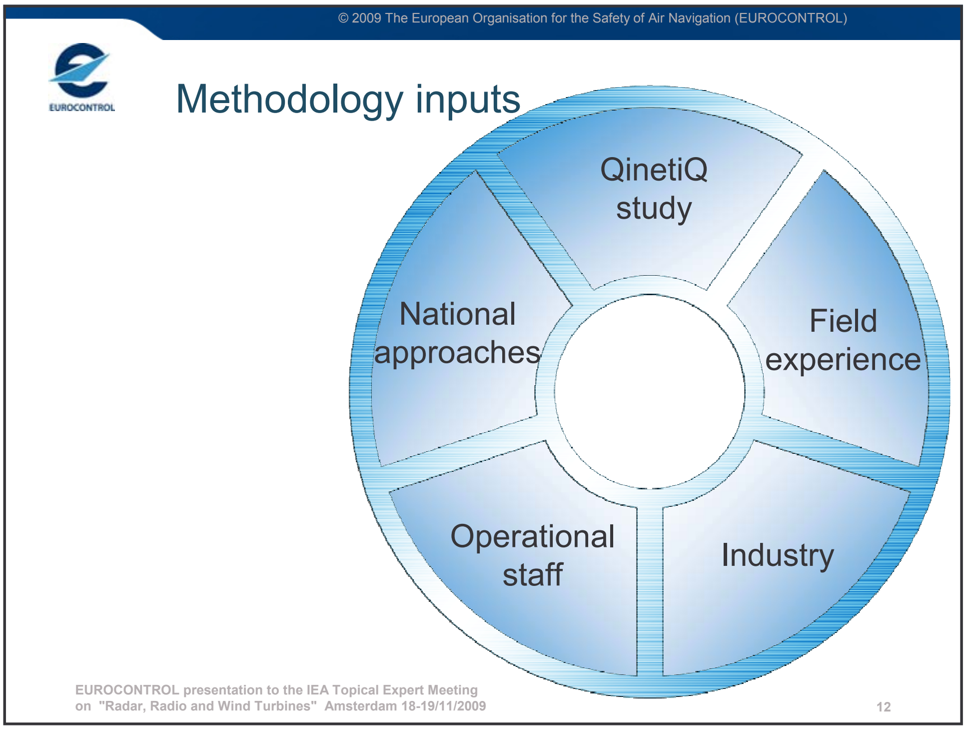
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Methodology inputs
QinetiQ study
National approaches
Field experience
Operational staff
Industry
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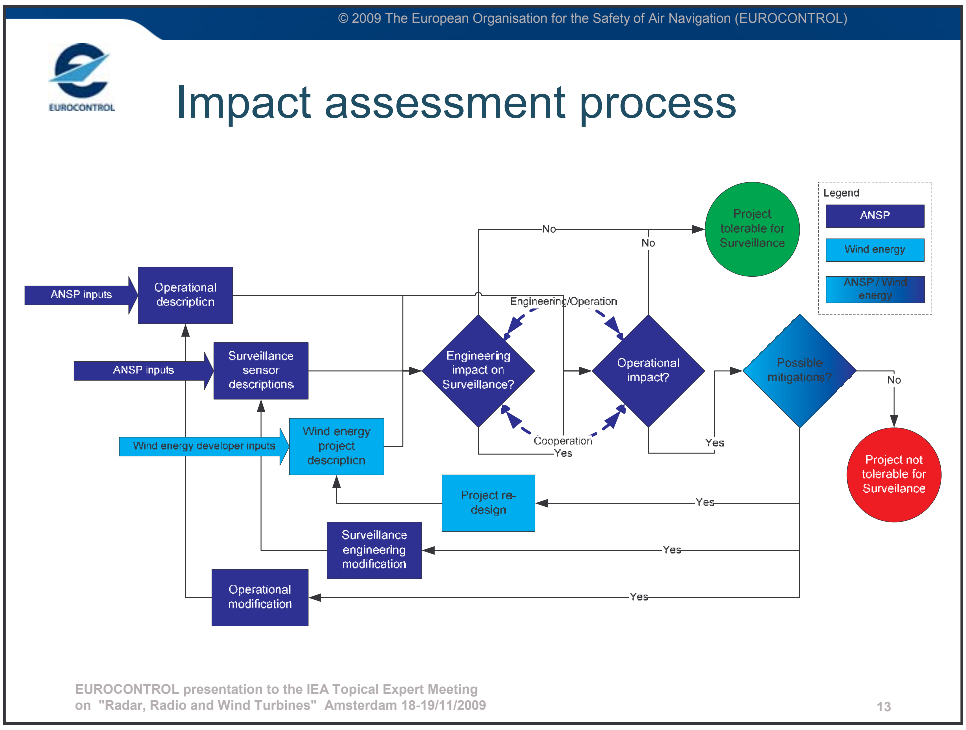

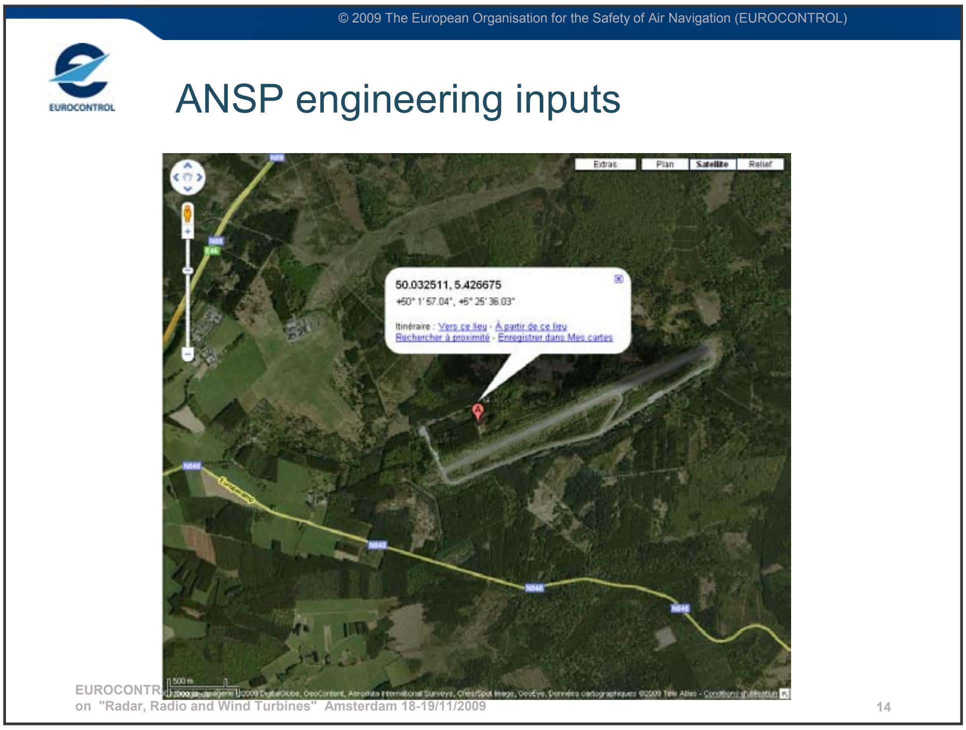

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ANSP operational inputs

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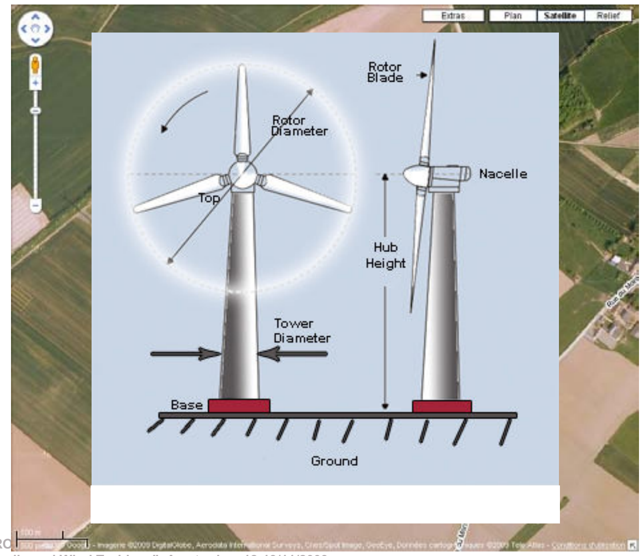
Wind energy inputs



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Guidelines status

Guidelines zones

1. Safeguarding zone
2. Detailed assessment zone
3. Simple assessment zone and criteria
4. No assessment zone

PSR recommendations

Zone 1 Safeguarding	Zone 2 Detailed assessment	Zone 3 Simple assessment	Zone 4 No assessment
0 - 500 m	500 m - 15 km and in radar line of sight	Further than 15 km and in radar line of sight	Not in radar line of sight

SSR recommendations

Zone 1 Safeguarding	Zone 2 Detailed assessment	Zone 4 No assessment
0 - 500 m	500 m - 16 km and in radar line of sight	Further than 16 km or not in radar line of sight

Consultation

http://www.eurocontrol.int/surveillance/public/standard_page/sur_rwt.html

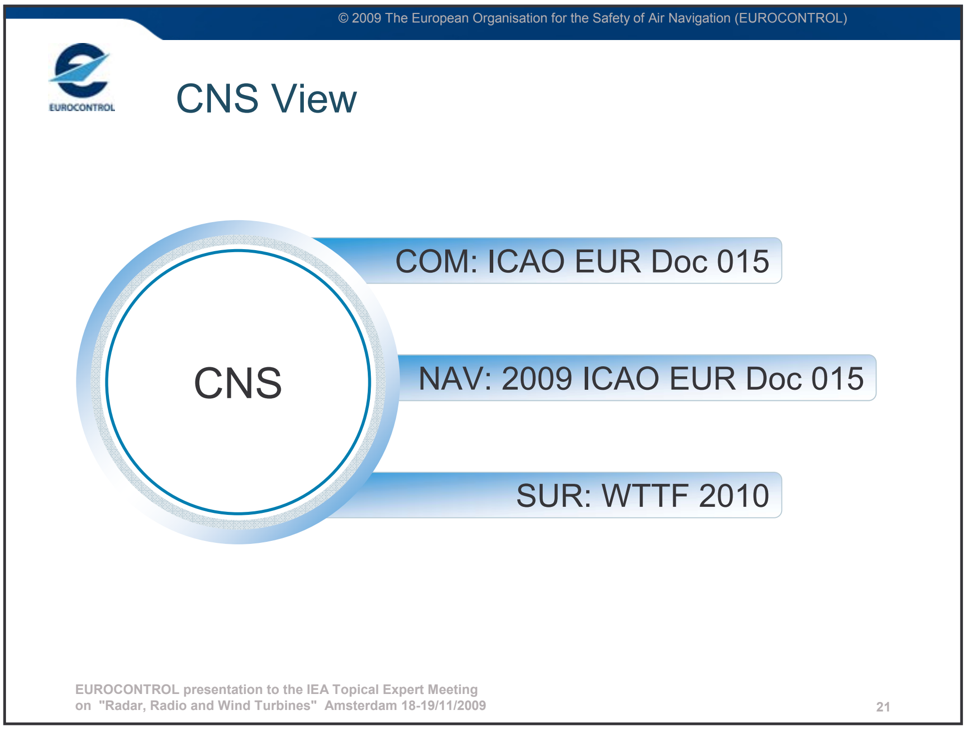
Up to the 29th of January 2010

EUROPEAN ORGANISATION
FOR THE SAFETY OF AIR NAVIGATION

Guidelines on How to Assess the Potential Impact of Wind Turbines on Surveillance Sensors

Edition Number	:	0.15
Edition Date	:	30/06/2009
Status	:	Draft
Intended for	:	General Public

EUROPEAN AIR TRAFFIC MANAGEMENT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CNS View
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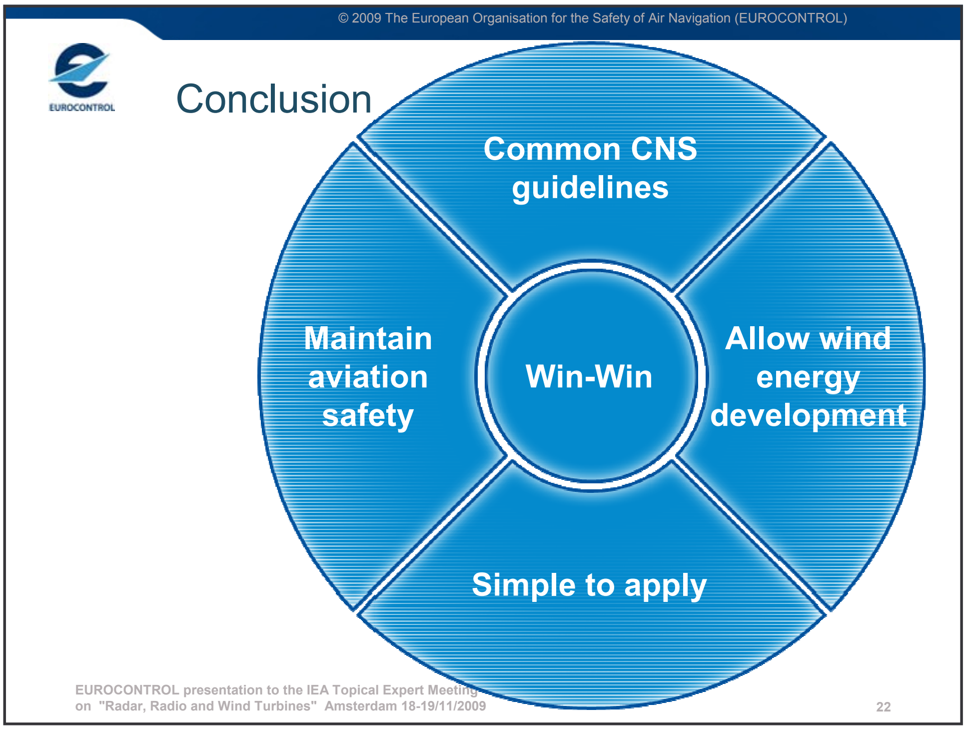
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Conclusion
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Or

windturbine@eurocontrol.int

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Theoretical and Measurement Results of the effects of wind turbines of military radar systems

and technical assessment methods

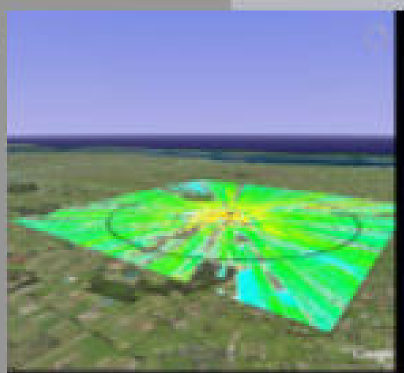
Dr- Ing. A. Frye, EADS - MAS
Signature Technolgy – Bremen / Germany

IEA Expert Meeting
November 2009

EADS – MAS Signaturtechnik, Bremen/Germany
Dr. Ing. A. Frye c/o EADS GmbH, Airbusallee 1; D - 28199 Bremen

Overview:

- Introduction to the technical Problem
- Affected military radar systems
- Disturbances caused by wind turbines / Examples
- Problemes with planning a wind turbine park
- Solutions /rules



Seite 2 Dr.- Ing. Frye , Tel. +49/ 421 / 538 – 2719 ; andreas.frye@eads.com November 2009

EADS – MAS Signaturtechnik, Bremen/Germany
Dr. Ing. A. Frye c/o EADS GmbH, Airbusallee 1; D - 28199 Bremen

Possible effects of radar equipment in connection with wind turbines :

*range reductions
*shading effects
*angle faults vs. azimuth
*angle faults vs. elevation
*false target caused by reflexions
*disturbance zone around a wind turbine
*track losses at overflight
*false tracks

3 – D – Radar systems for air defence

2–D – Radarsystems : military airports

* turbidity of the radar image
* interaction between existing and planned wind turbines,
* interactions between several plannend wind turbines and other objects.
* interactions with topography and vegatation

Seite 3 Dr.- Ing. Frye , Tel. +49/ 421 / 538 – 2719 ; andreas.frye@eads.com November 2009

EADS – MAS Signaturtechnik, Bremen/Germany
Dr. Ing. A. Frye c/o EADS GmbH, Airbusallee 1; D - 28199 Bremen

Problems in the planning of wind energy projects

1.
The Obstacle Problem

(non-technical criteria) and
Operational aspects of air traffic control

2.
Radartechnical Problems

Seite 4 Dr.- Ing. Frye , Tel. +49/ 421 / 538 – 2719 ; andreas.frye@eads.com November 2009

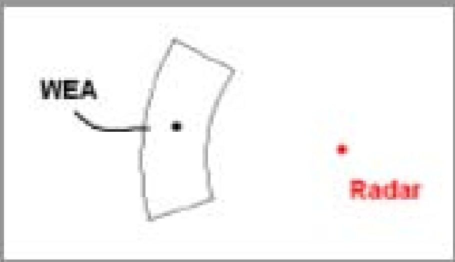
EADS – MAS Signaturtechnik, Bremen/Germany
Dr. Ing. A. Frye c/o EADS GmbH, Airbusallee 1; D - 28199 Bremen

EADS

The overflight problem at the 2 –D – atc radar

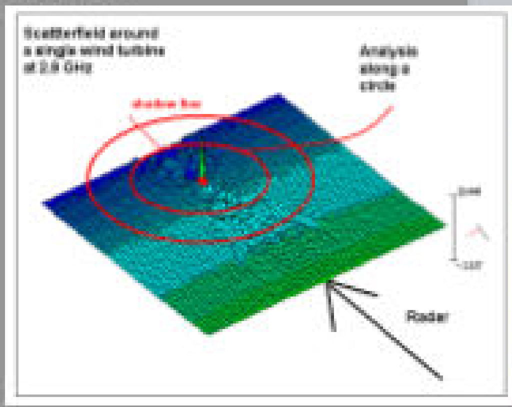
•The extension of the disturbed zone of a wind turbine is larger at larges distances.

•The „frequency" of the disturbed zone depends of the wind turbine type



The shados effects at a air defence 3-D- radar

Scatter fields cause
•range reduction and
•position errors over azimuth & elevation



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EADS

Technical problems in the planning of wind - projects

The overflight problem at the 2 –D - radar

•Intensive surface reflection
* Temporal change of reflection by moving components
* doppler nature of reflection is similar to a helicopter

*Fixed target suppression is not working

⇒Distinction between aircraft and wind turbine is not sure where within the proximity of the WEA. (applies for distances up to 30 km)

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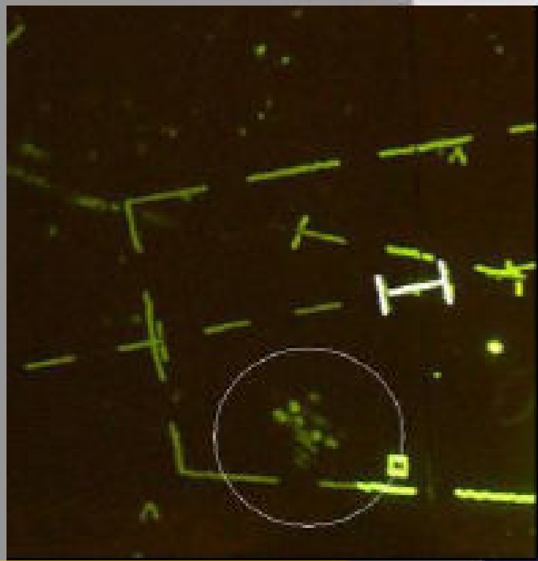
Dr. Ing. A. Frye c/o EADS GmbH, Airbusallee 1; D - 28199 Bremen

Data records from a military atc radar: Example 1:

•16 existing wind turbines (all the same WT type)
•11 ...13 wind turbines are visible at any time

⇒75% detection frequency of this turbine typ



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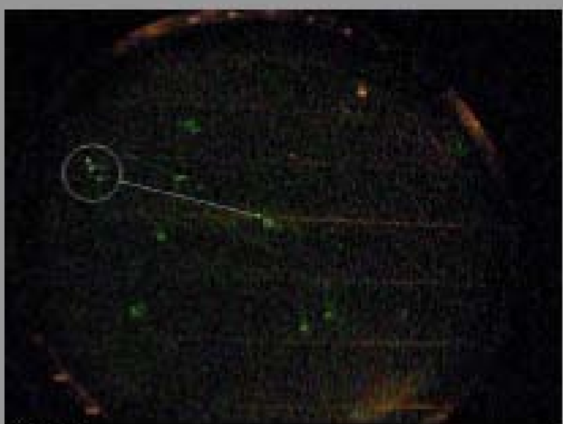
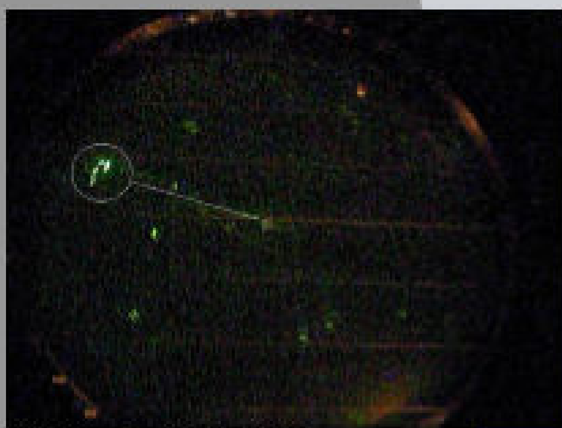
Data records from a military atc radar: Example 2:

Cluster of wind turbines
•the rcs of the wind turbines changes over the time



time 1



time 2, ca. 4 sec. later

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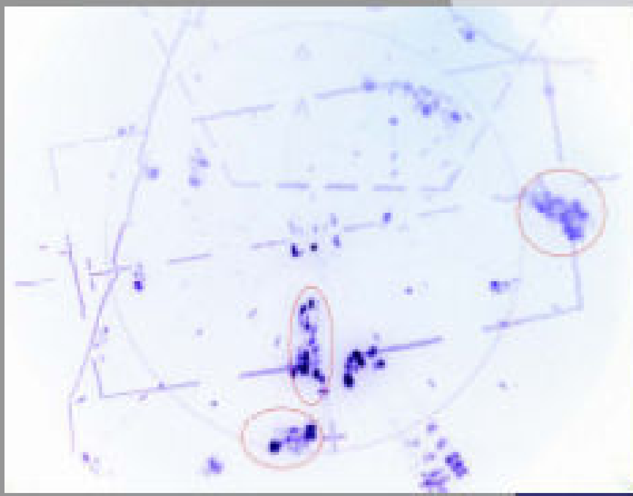
EADS

Data records from a military atc radar: Example 3:

Some clusters of wind turbines in different distances:

- The resolution of the radar is lower at larger distances
- The wind turbines don't run synchronously
- The separation of wind turbines depends from the distance



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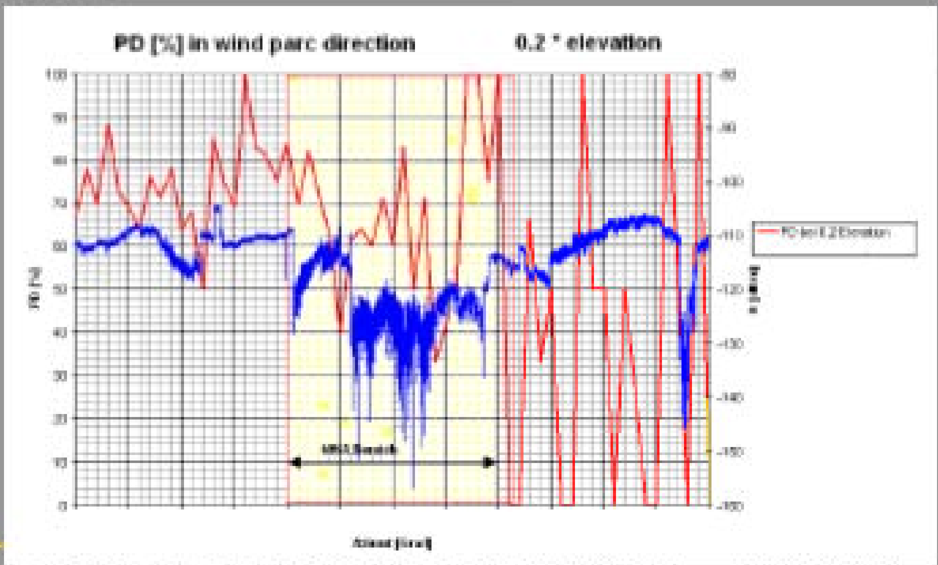
Data records from a air defence radar: Example 4:

Wind turbines in 40 km distance (random traffic recording over some weeks)



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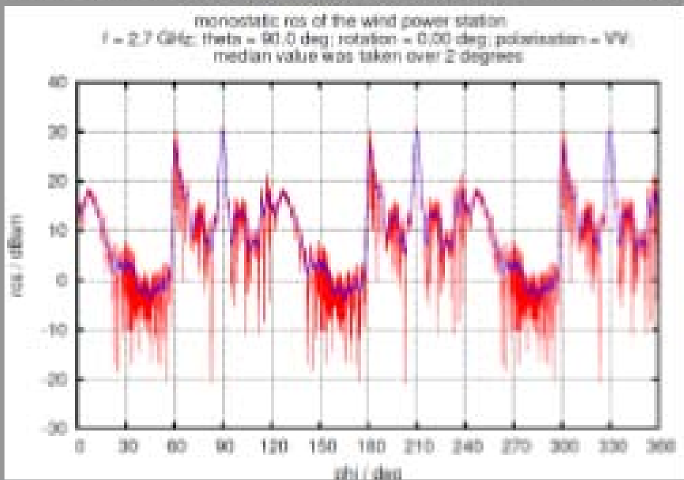
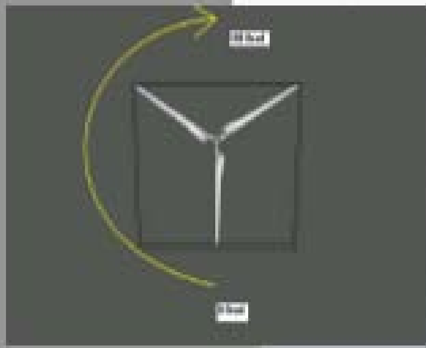
Analysis for a 2 –D- Radar: How oftens does a wind turbine shows interferences at an analog military atc radar:

Rcs of a 70m wind turbine rotor over 1 rotation





Rcs maximum value:

over 1000 sqm

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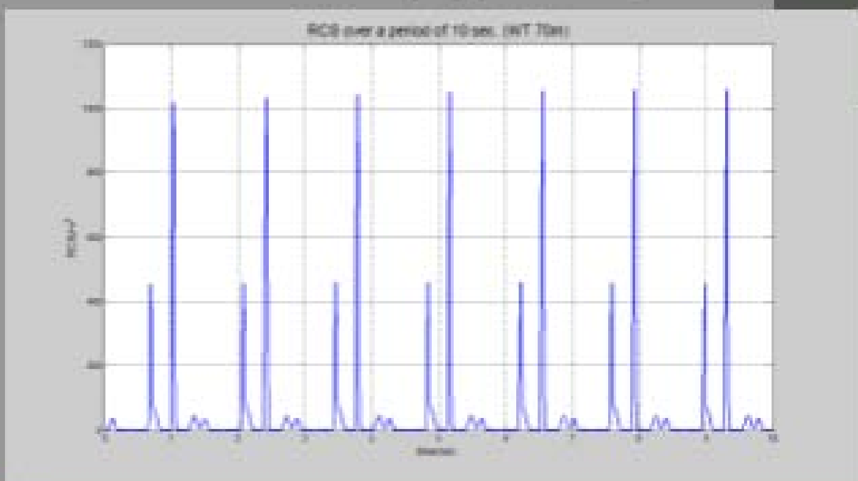
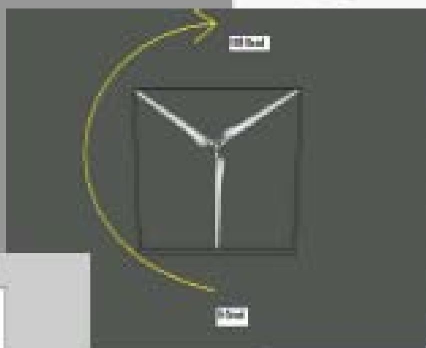
EADS

Analysis for a 2 –D- Radar: How often does a wind turbine shows interferences at an analog military atc radar ?

Linear rcs over 20 seconds by typical rotor speed





Rcs maximum over 1000 sqm

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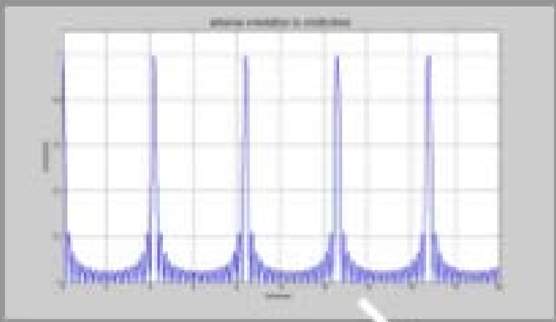
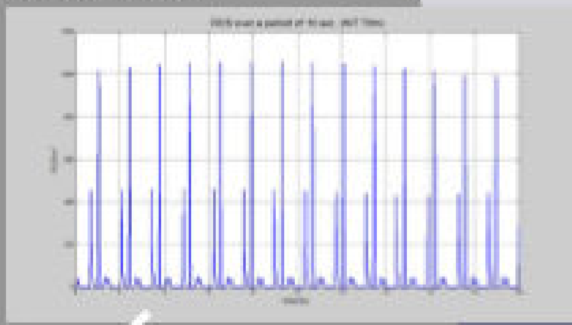
Analysis:
How oftes does a wind turbine shows interferences at an analog military atc radar ?

Correlation between radarantenna and wind turbine rcs:





correlation

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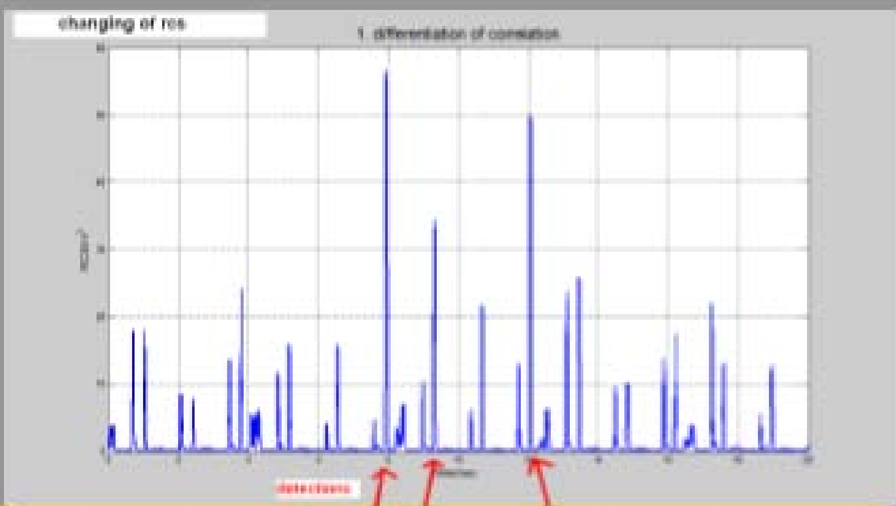
Analysis:

Correlation between radarantenna and wind turbine rcs
= > Only 3 dections within 20 sec. at 5 antenna turns



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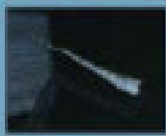
EADS

Solutions: stealth rotos blade activities at EADS since 2003 (only for 2 –D- radar systems)

Radar signature analysis of rotor blade section

Assessment of wind turbine RCS

Evaluation of LO measures for wind rotor blades



Development of RAS concepts for wind rotors blades

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EADS

Solutions for manufacturers
(only for 2 –D- radar systems)

=> There is no need for a fully stealth rotor blade
You cannot reduce the rcs over 3 decades

=> There is only a need for smart solutions:

1. To reduce the existing rate of detections

2. To change the doppler characteristic and to support the doppler identification

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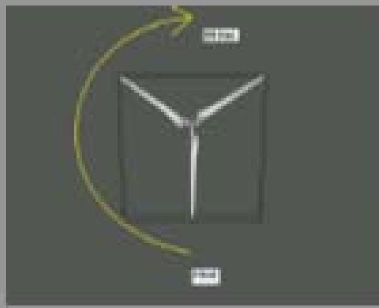
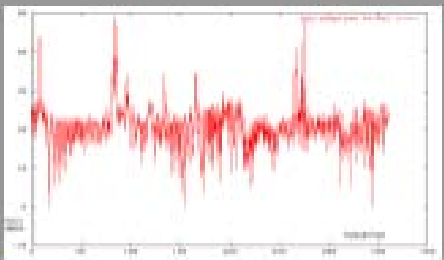
Solutions for manufacturers
(only for 2 –D- radar systems)

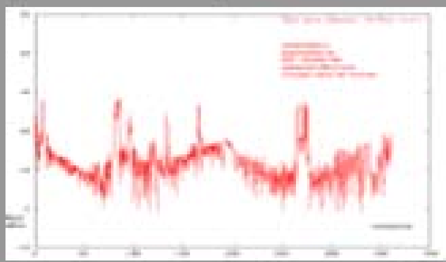


RCS of wind turbine rotor:

Conventionally rotor

reduced RCS, by lightning protection systems or low reflecting surfaces (smart solutions)





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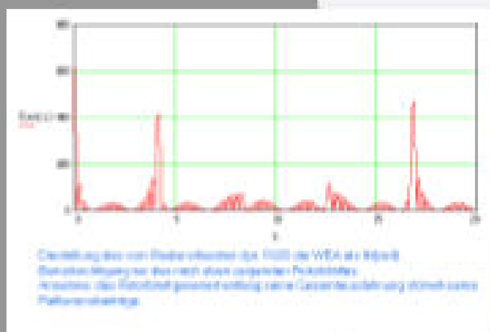
Solutions for manufacturers
(only for 2 –D- radar systems)

Example:

Result for a low speed rotor together
With today's radar system

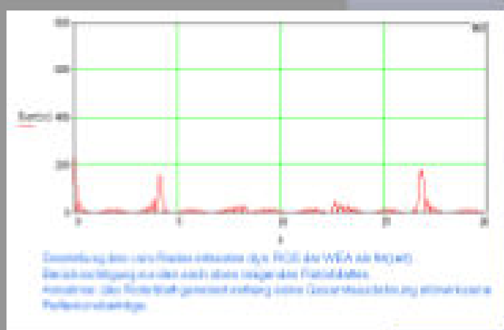
=> 3 „Blips" in 20 sec.



Example below:

Result for a low speed rotor with reduces
reflexion surfacestogether with
today's radar system

=> 1 „Blip" in 20 sec.



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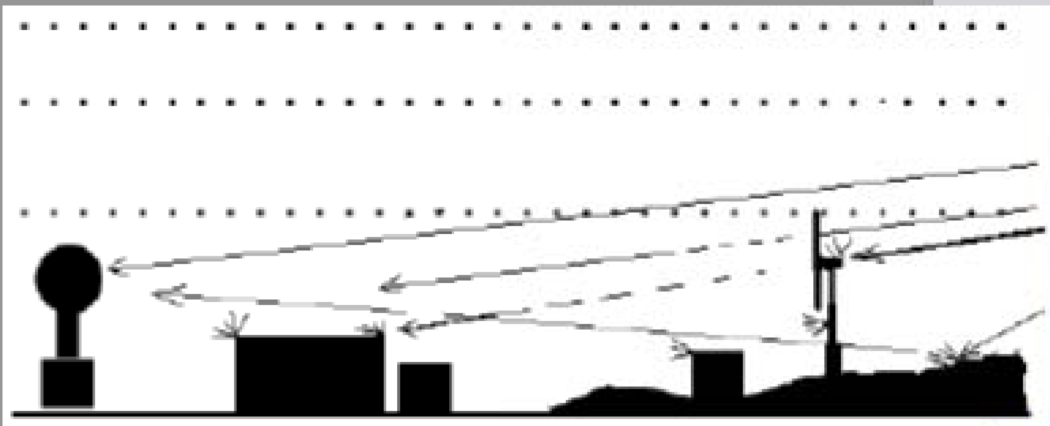
The shading problem at the 3 – D – air defence radar system

path of the
propagation



Influences by all obstacles and structures !!

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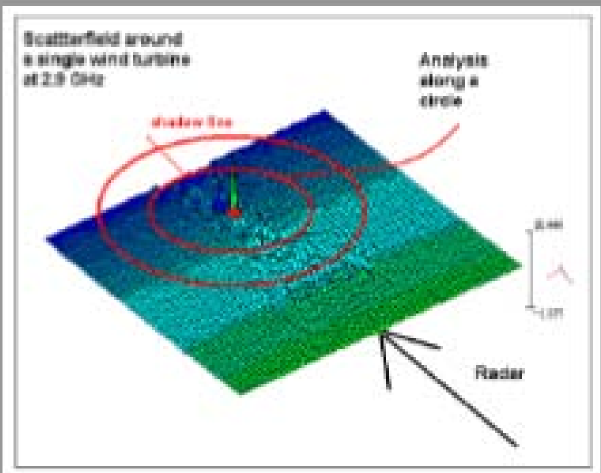
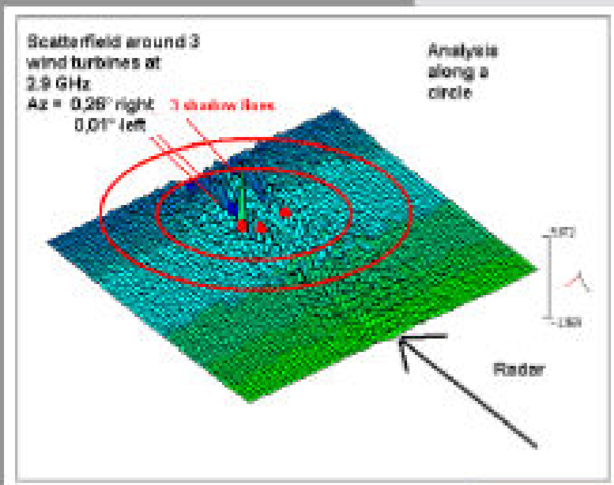
The shading problem at the 3 –D- Radar system:

- Single wind turbines are most non-critical
- Interactions at groups of wind turbines are critical





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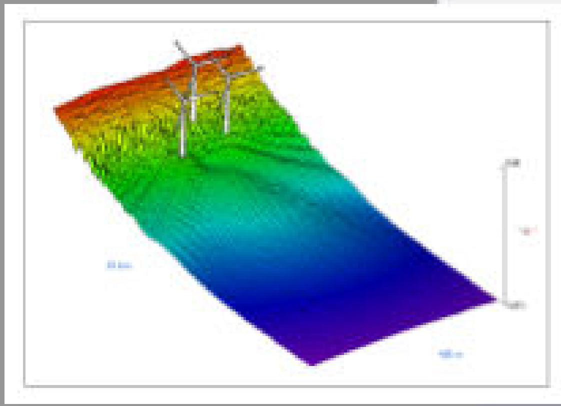
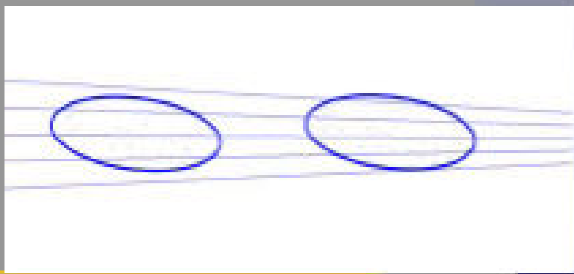
The shading problem at the 3 –D- Radar system:

•Wind turbine park in large , but different distances

The density and the interactions are changing over the distance

The interactions betwen the wind turbines are changing over the distance





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Solutions for wind park planners for 3 –D- Radar systems:

(for this radar type there are rules in Germany)

1. Radar optimised arrangement
2. Radar optimised size

⇒ There are no technical reasons to define forbidden areas

For 2 –D- Radar systems:

⇒ use of wind turbines with a low rotor speed
⇒ use of a radar optimised arrangement
⇒ ask for wind turbines with smart radar
⇒ absorbing solutions

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Perspecitves / Outlook for the authorization process process

1. Predictable rules are in process for 2-d-_radars, based on measurement results. (like a checklist for the legal process)
2. Considerartion of the charakteristika of the wind turbine type
3. Integration of the influence of terrain and shading

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Thank yor

for your

attention

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Simulating the electromagnetic interaction between wind turbines and radars

Markku Sipilä, Johan Sten

IEA Topical Expert Meeting, Amsterdam
November 18-19, 2009

VTT
Business from technology

VTT TECHNICAL RESEARCH CENTRE OF FINLAND

EFFECT OF WIND TURBINES ON RADAR

Situation in Finland

- Substantial increase in wind power planned in near future
- Research work on radar effects started in June 2009 at VTT Technical Research Centre of Finland, a pre-study was made during summer 2009
- A larger research project planned to start in winter 2009-2010
- Goal of the work: The Finnish Air Force needs to know what the effects are, in order to give acceptance to planned wind power projects
- Work financed by the wind power industry

2

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MAIN EFFECTS

- Radar reflections from the wind turbine
- Shadowing of radar targets behind the wind turbine
- Lose of tracking of targets above the wind turbine

3

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RESEARCH APPROACH

Electromagnetic theory and calculation methods are used to study the interaction of the radar and the wind turbine

- Analytical methods (worst case analysis)
- Numerical method using the CAST software (more accurate method)

4

REQUIRED INFORMATION FOR CALCULATIONS

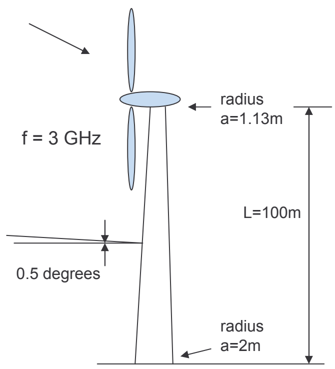
- About the radar:
  - Position
  - Frequency
- About the wind turbine:
  - Shape
  - Dimensions
  - Materials (metals, insulators)
  - Possibly also inner structure
  - Wind directions
  - Speed of rotation
- About the terrain:
  - (Digital) map information
  - Vegetation

Estimating the radar cross section (σ) of the wind turbine

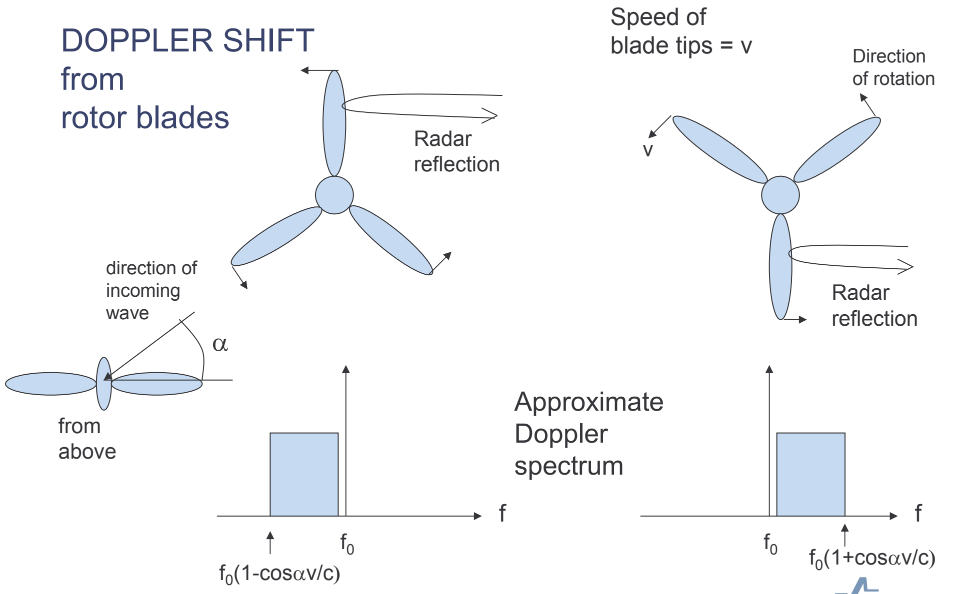
- Moving turbine blades cause Doppler shift
- The stationary tower has no Doppler shift, but σ can be very large for the perpendicular direction, $\sigma = 2\pi a L^2/\lambda$ (metal surface)

Example: For the tower, with the given values
σ~ 1.000.000 m^2 (= 1 km^2)
In reality, σ is somewhat smaller, because the wind turbine is not in the far field of the radar, but still very large.

Can cause saturation in the radar receiver, disturbs signal processing functions.



DOPPLER SHIFT from rotor blades



EFFECT OF SHADOWING ON RADAR RANGE

Simplified radar equation

$$R_{max} = \sqrt[4]{\frac{P_t G A_e \sigma}{(4\pi)^2 S_{min}}}$$

Two-way attenuation has the same effect as other factors in the numerator, as for example σ

Example: One-way attenuation is 6 dB => two-way attenuation is 12 dB. Received signal power is reduced to 1/16. Radar range (for a small target) is reduced to ½ (= by 50 %).

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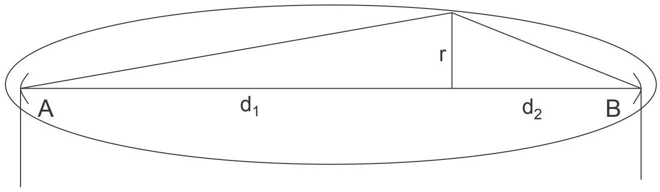
Line-of-sight radio propagation



For unobstructed radio propagation between A and B, it is required that the first Fresnel zone (with radius r) is free from obstacles.

$$r = \sqrt{\lambda d_1 d_2/(d_1+d_2)}$$

A can be radar, B can be target

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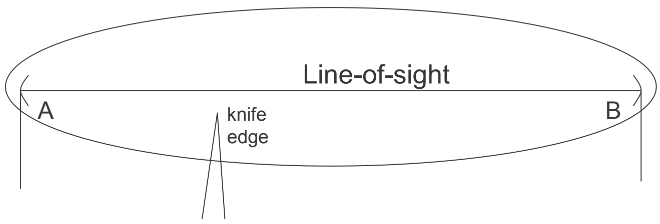
Attenuation caused by an obstacle near line-of-sight



Conducting sheet near the line-of-sight (inside 1st Fresnel zone) causes attenuation.

For the attenuation caused by this knife-edge diffraction, an analytical solution exists.

In this case, the obstacle is the wind turbine between radar and target.

10

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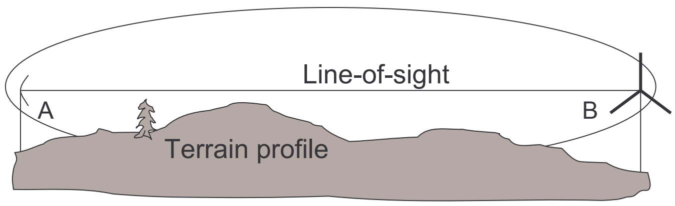
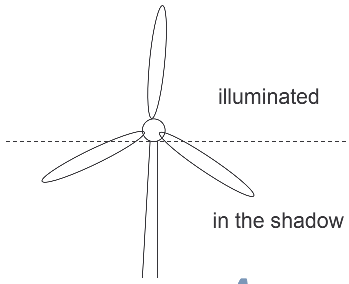
Effect of terrain



Terrain profile between radar and wind turbine is determined from digital map. Vegetation is taken into account.

“Illuminated” part of the wind turbine is determined.



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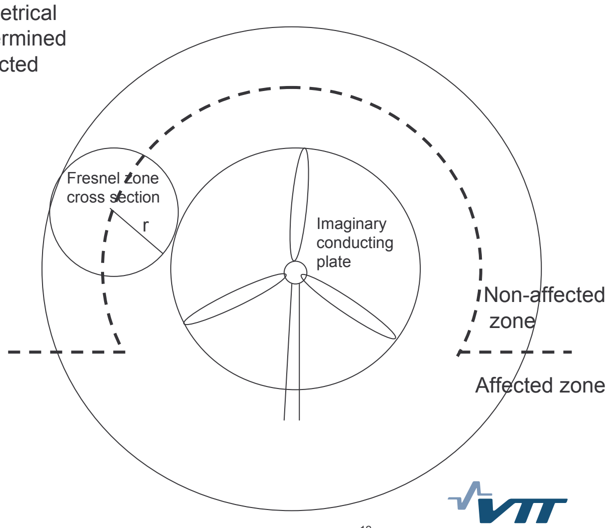
Worst-case attenuation determination

By using Fresnel zone and geometrical considerations, zone can be determined where target detection is not affected (above the dotted line)

Worst case attenuation within the affected zone can be determined by knife-edge diffraction formulas

Area swept by the rotor blades is assumed be covered with a conducting plate



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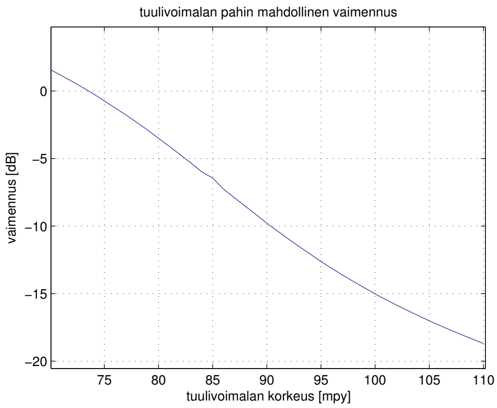
Example worst case calculation by analytical methods

worst-case one-way attenuation / dB



Wind turbine height / m

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Numerical versus analytical simulation

- The disadvantage of the analytical method is that the worst-case results are too pessimistic, too much on the safe side
- This leads to rejection of wind power projects, which could have been accepted with a more accurate simulation method
- A more accurate numerical simulation method is clearly needed

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Numerical simulation method

- VTT has developed radar cross section simulation software CAST, funded mostly by Finnish Navy
- CAST is capable of accurate and fast simulation of complex targets described by their 3D CAD models
- CAST can be used to simulate the electromagnetic scattering of wind turbines, if their CAD models are available
- For accuracy, near field effects should be included. CAST can be modified to take that into account.

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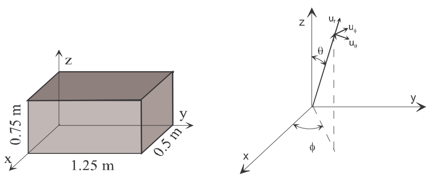
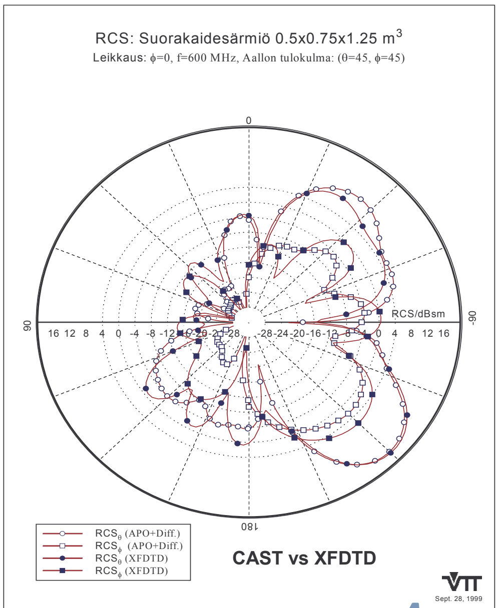
Rectangular prism:

Incidend wave θ_i=45, ϕ_i=45

Biscattering patterns





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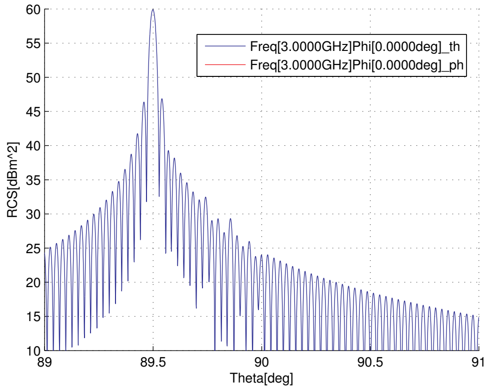
Radar Cross Section (σ) of the wind turbine tower, CAST simulation



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Thank you

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18

Research Study "Wind Turbines – Radar – Compatibility"

Measures in 2D Primary Air Surveillance Radars to Reduce Wind Turbine Echo Interferences

IEA R&D Wind Task XI - Topical Expert Meeting on
"Radar, Radio links and Wind Turbines", Amsterdam, 18-19.11.2009

Christoph Neumann[1], Patrick Perez[2], Michael Weber[3]
EADS Deutschland GmbH
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Research Study "Wind Turbines – Radar – Compatibility"

Content

- Wind Turbine (WT) Echo Analysis from Radar Measurements
  - Measurements with the Air Surveillance Radar "ASR-S" Büchel
  - Signal Evaluation & Modelling
- Radar Optimisation Potential
  - Antenna Characteristics
  - Signature Classification
  - Tracking
- Simulated Performance of WT hardening Measures in modern 2D- Air Surveillance Radars
  - Recognition of WT echoes and WT affected areas
  - Tracking of Aircrafts (AC) over WT affected areas
- Conclusion

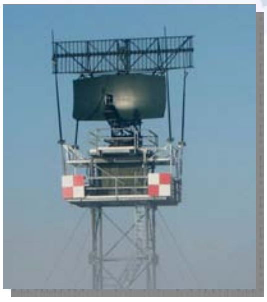
This presentation shows results from the study „*WEA Radar Verträglichkeit*", performed in 2008 by *EADS Deutschland GmbH Ulm* and *Bremen* and supported by the *German Ministry of Environment* and the *German Ministry of Defence*

Research Study "Wind Turbines – Radar – Compatibility"

Radar Measurements

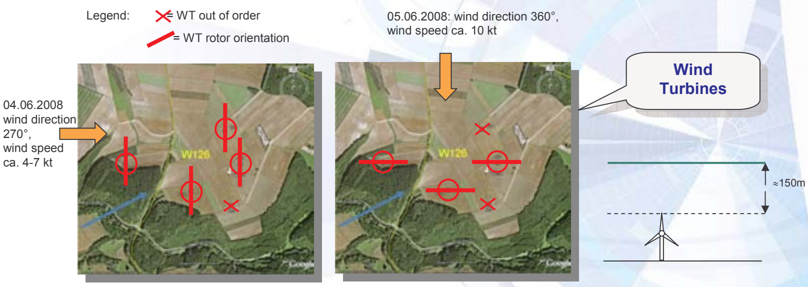
Purpose of the Measurements:

- Evaluate the WT Disturbance Impact
- Assess the dedicated Clutter Suppression Algorithms already implemented in the ASR-S
- Radar Signal Recording for the Algorithm Development and Model Validation



Research Study "Wind Turbines – Radar – Compatibility"

Example:
Measurement of WT and crossing Aircrafts



Research Study "Wind Turbines – Radar – Compatibility"

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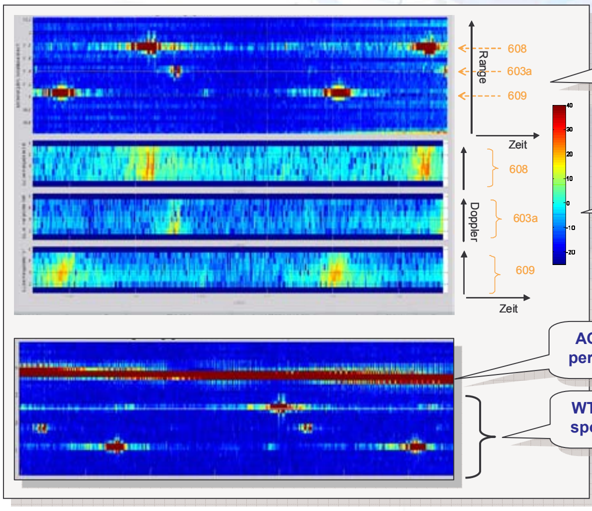
WT and Target Measurements with **starring** (non-rotating) Radar Antenna



WT Echoes

Doppler Spectra from WT Echoes

AC Target, permanently

WT Echoes, sporadically

Not so easy to separate when the antenna is rotating!

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Research Study "Wind Turbines – Radar – Compatibility"

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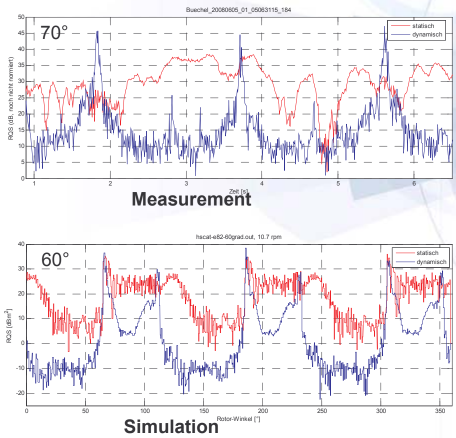
Signal Analysis and Model Validation Example "Dynamic RCS behaviour of the WT"



— = "static" contribution: F within ca. +/- 150 Hz
— = "dynamic" contrib.: F outside ca. +/- 150 Hz

⇨ Characteristics and strength of the simulated Radar receive signals are in agreement with the measurements

rotor angular velocity: 10.7 rpm

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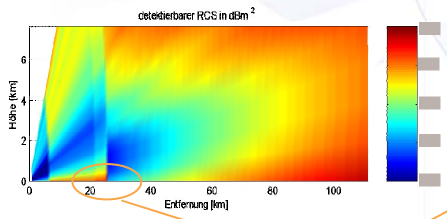
Research Study "Wind Turbines – Radar – Compatibility"

Radar Optimisation Potential (1)
Antenna Characteristics

- Avoid targets being masked by WT echoes
  ⇨ **Reduce WT receive signal power**
  ⇨ **Maintain target receive signal power**
- **Solution**: Electronic Beam Steering in Elevation
  ⇨ **STC on the Antenna diagram!**



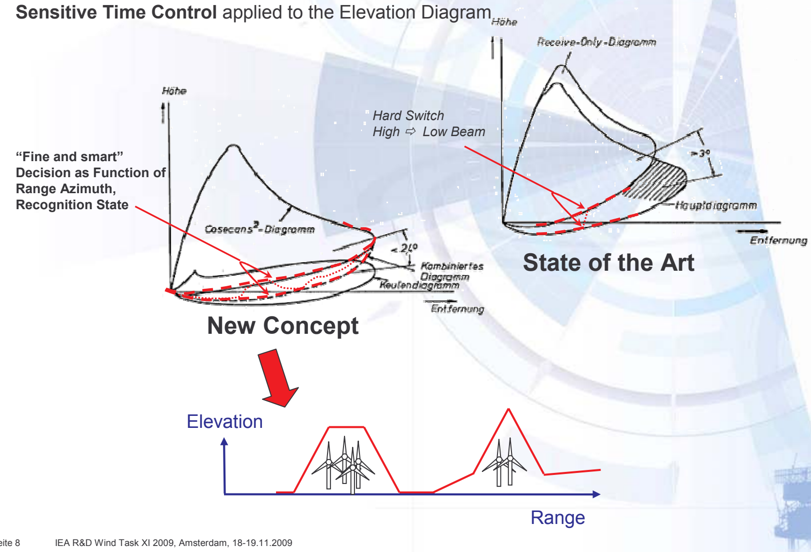
Most common: **One big Step** at given Range per azimuth sector, only few sectors.

Proposal: Many fine steps at arbitrary ranges and azimuth positions

Research Study "Wind Turbines – Radar – Compatibility"

Radar Optimisation Potential (1)
Antenna Characteristics, Realisation

Sensitive Time Control applied to the Elevation Diagram



Radar Optimisation Potential (2)
Object Recognition by Signature Classification

Characteristics and Benefit:

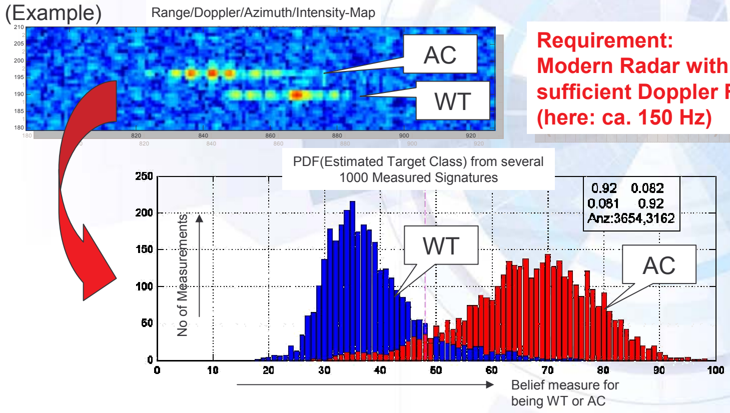
- Distinguish between Radar-Echoes from:
  - Target Class: Aircraft (AC)
  - Target Class: mixed Signature AC + WT
  - False Target Class: Wind Turbine (WT)
  - False Target Class: Group of WTs
  - (…)

  Recognition Basis: Processed Radar Receive Signal (Doppler Spectra, time variant behaviour during Time on Target)
- Target Classification is necessary, because:
  - WT Echoes cannot be eliminated by Detection threshold or Doppler filtering
  - WT Echoes must be reduced significantly to be able to track targets at presence of high WT echo density

➢ **Signature Classification is essential for trustable Target Tracking Capability of the Primary Radar**

Signature classification
Principal Approach and expected Performance

Echo Signatures in the Range-Doppler-Azimuth Domain (Example)



Requirement:
Modern Radar with sufficient Doppler Resolution (here: ca. 150 Hz)

⇨ **The Signature Classification will reduce the WT Plot Load of the Radar drastically**

Research Study "Wind Turbines – Radar – Compatibility"

Radar Optimisation Potential (3)
Tracking Mechanism in Air Surveillance Radars

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State of the Art:

- Kalman-Filter Tracking (optimal-Filter)
- **T**raffic Density **M**ap Considering
- **S**hort **T**rack **I**nitialisation **M**ap to prevent false tracks

Additionally in ASR-S:

- **M**ulti (Dual) **H**ypothesis **T**racking
- ***Self learning*** **TM**
- ***Self learning*** **STIM**
- **I**nteracting-**M**ultiple-**M**odel to minimise prediction errors

ASR-ES for WT compatibility will contain in addition:

- Signature based **Plot Classification** as **Distance Measure**
- Self learning and **adaptive** **WT area regions recognition & consideration**

Research Study "Wind Turbines – Radar – Compatibility"

Simulation Example: Tracking of a Manoeuvring Aircraft flying over a Wind Turbine Farm

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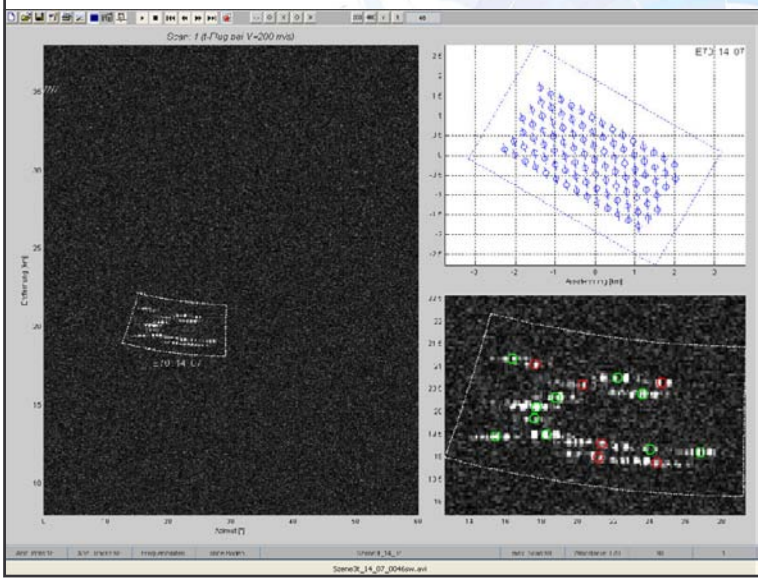


Display of the Radar Receive Signal

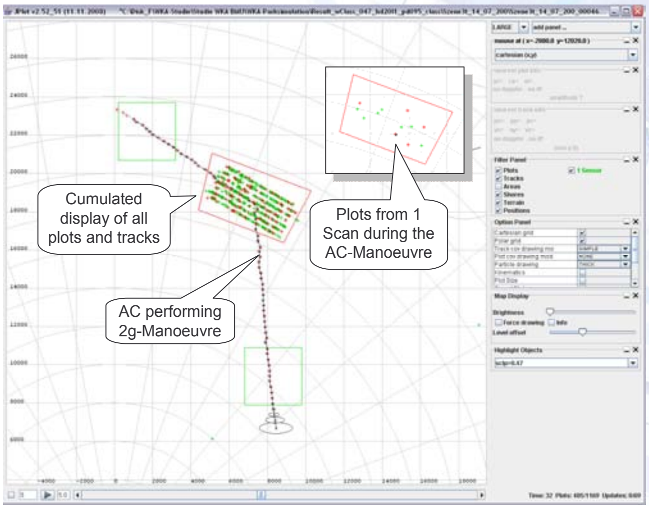
Symbols from Sign. Processing:

+ = classified as AC
+ = classified as WT
+++ ⟨◊⟩ = Track

Research Study "Wind Turbines – Radar – Compatibility"

EADS DEFENCE & SECURITY

Example Result from Tracking Evaluation
AC Manoeuvring over a Wind Turbine Area



Display of the Tracking Input / Output

Symbols from Sign. Processing:

+ = classified as AC

+ = classified as WT

= Track

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Research Study "Wind Turbines – Radar – Compatibility"

EADS DEFENCE & SECURITY

Conclusion
„Compatibility 2D Primary ASR ⇔ WT Farms"

- By Means of **Antenna Design**, **Signal Processing** and **Data Processing**, Air Surveillance Radars can be tuned to:
  - **Reduce WT disturbances significantly**
  - **Track Aircrafts flying over WT Areas by the Primary Radar only**
- These capabilities were tested in Simulations using measured WT echoes and derived WT RCS and Doppler behaviour modelling
- The Measures were combined to a Radar Add On to be implemented into existing ASR Radars ("WT hardening Kit")
- The Validation and Realisation is going on

Thank You for Your Attention

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Contents

- The problem
- Site description
- Policy solution
- Technical solution
- The way ahead

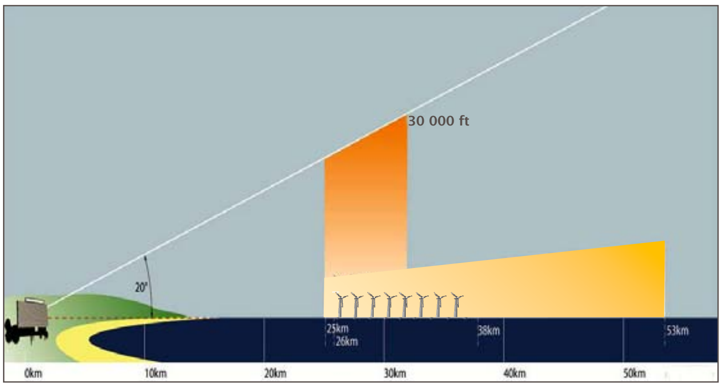
2 Statoil

UK Air Defence radar sites relevant for offshore wind farms

3 Statoil

The problem

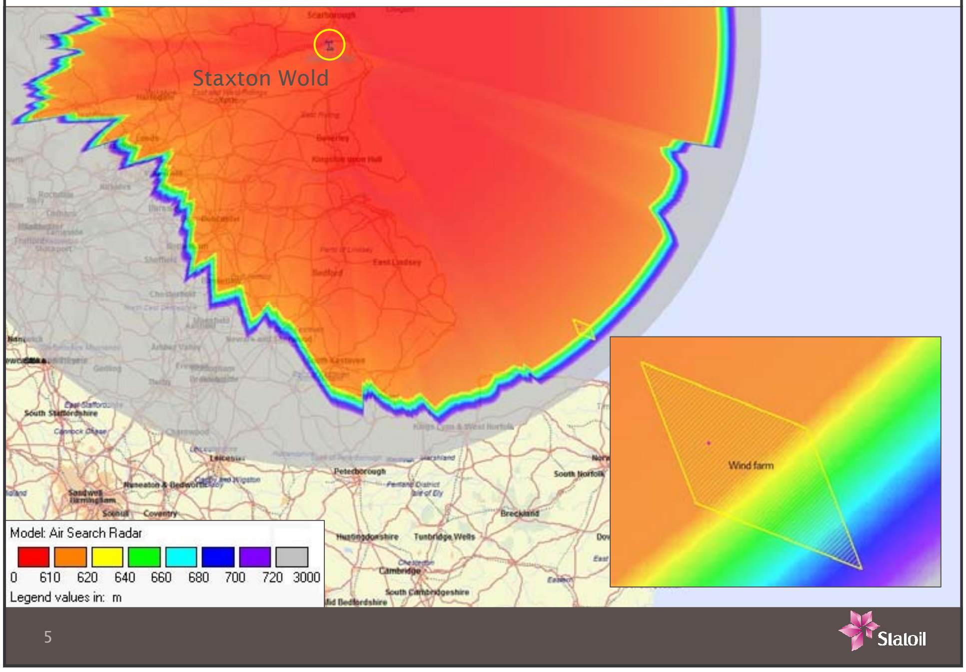
- Volume with reduced radar performance resulting from Sheringham Shoal Offshore Wind Farm



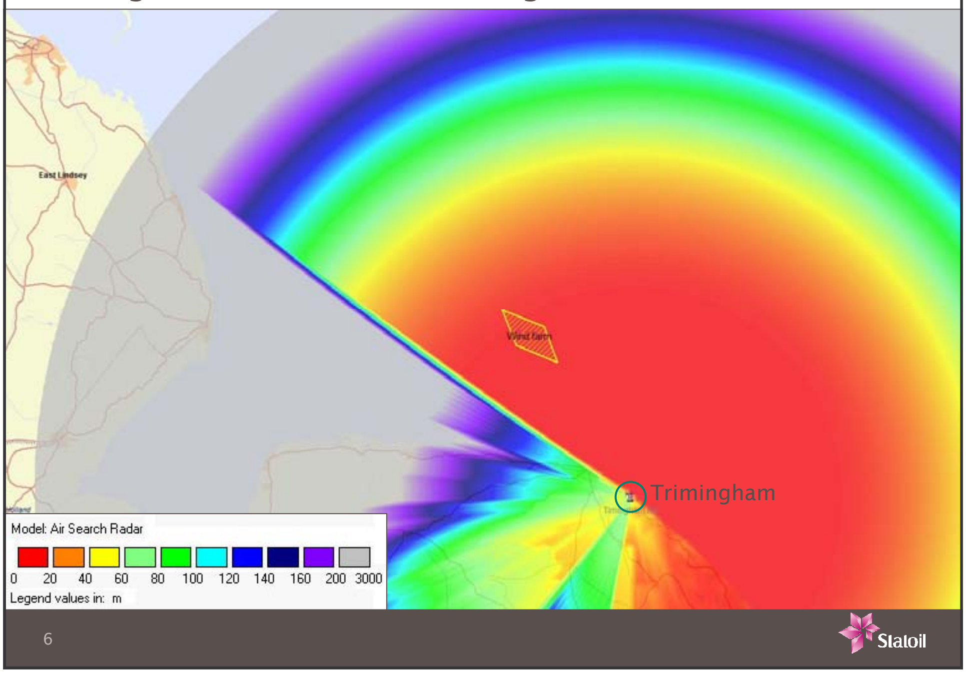
From BAE Systems feasibility study on contract with Statoil

4 Statoil

Staxton Wold has coverage down to about 750 masl

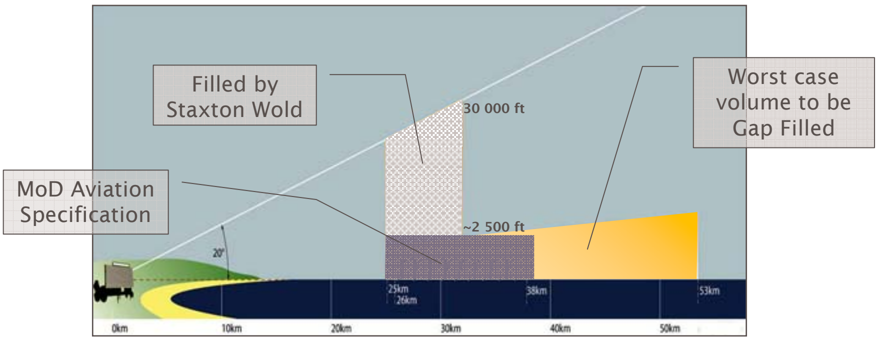


Trimingham has direct line of sight to the wind farm



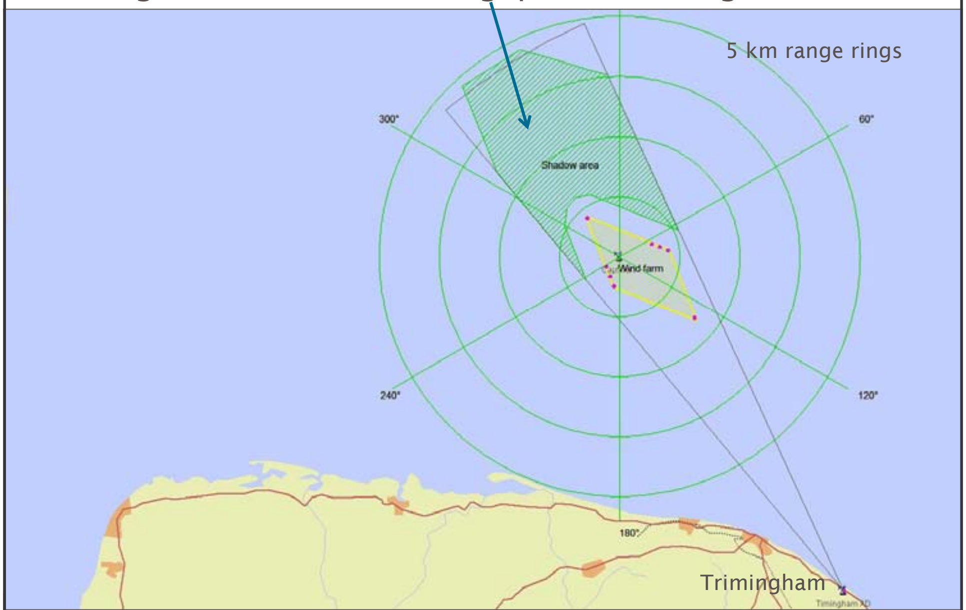
The solution

- The volume above 2 500 feet (750 m) is filled by Staxton Wold
- UK MoD has no surveillance requirements within the wind farm volume
- The volume behind the wind farm from sea level up to 2500 feet to be covered by gapfiller



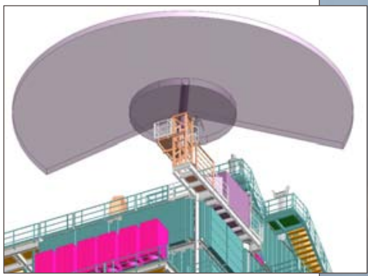
7 Statoil

Trimingham radar shadow / gapfiller coverage area



8 Statoil

Site description



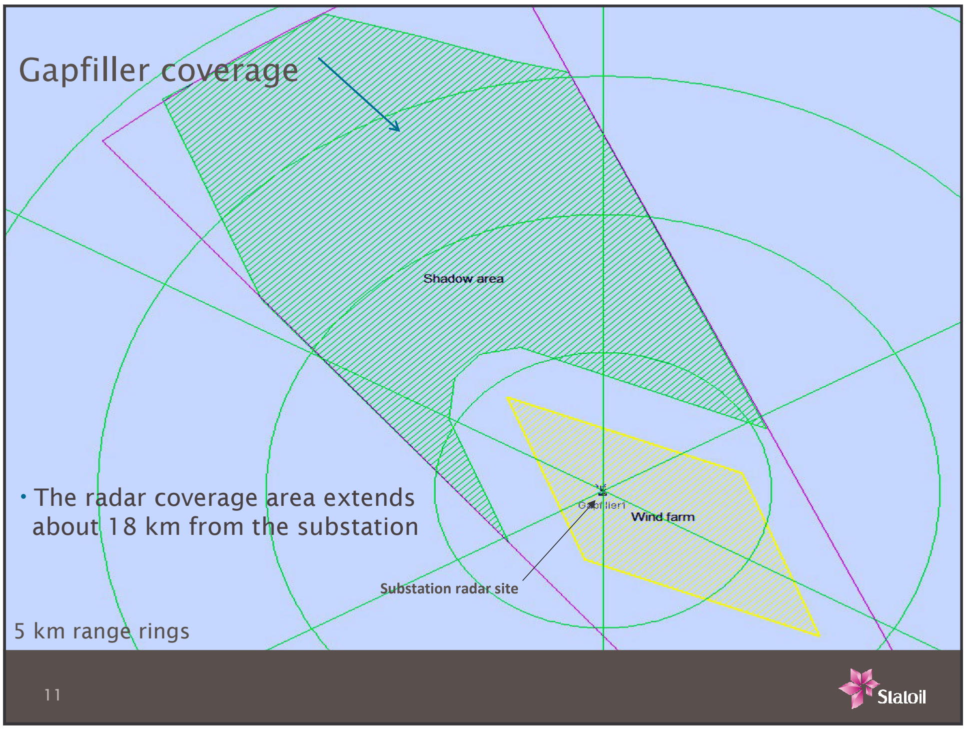
- The gapfiller location is a monopole substation 25 m above sea level within the wind farm area

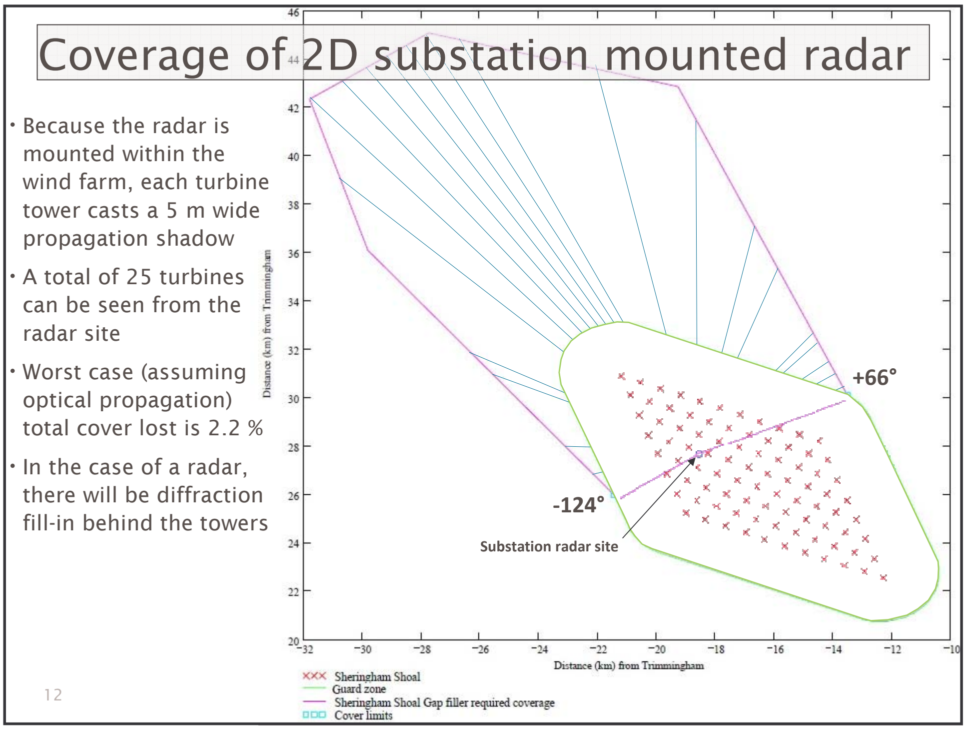
9 Statoil

The policy solution
The aviation specification

- Full radar performance outside a volume defined as 2 km around the wind farm area - between sea level and 2500 feet altitude
- Probability of detection $P_D \geq 80$ % of 1 m^2 Swerling case-1 target outside a volume limited by horizontal distance of 2 km from a turbine and a horizontal plane at 2500 feet (750 m) above mean sea level.
- Within the above volume, a probability of detection $P_D > 0$ % is not required
- This is the result of negotiated compromise between what can be achieved (mitigation measures) and what can be accepted by UK MoD

10 Statoil


Gapfiller coverage
Shadow area
• The radar coverage area extends about 18 km from the substation
Wind farm
Substation radar site
5 km range rings
11
Statoil

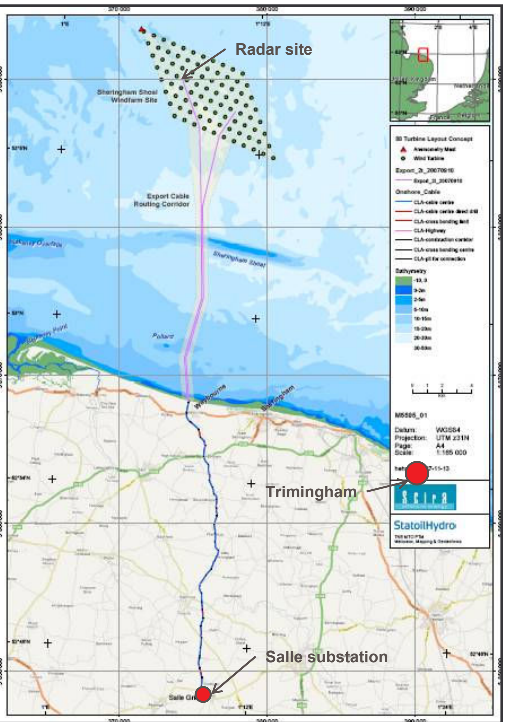

Coverage of 2D substation mounted radar
• Because the radar is mounted within the wind farm, each turbine tower casts a 5 m wide propagation shadow
• A total of 25 turbines can be seen from the radar site
• Worst case (assuming optical propagation) total cover lost is 2.2 %
• In the case of a radar, there will be diffraction fill-in behind the towers
+66°
-124°
Substation radar site
Distance (km) from Trimmingham
Distance (km) from Trimmingham
Sheringham Shoal
Guard zone
Sheringham Shoal Gap filler required coverage
Cover limits
12

Technical solution

- Main features
  - Probability of detection $P_D \geq 80$ % of 1 m^2 Swerling case 1 target
  - Coherent pulse Doppler system
  - Short pulses (≥ 0.1 μsec)
  - High range accuracy
  - Narrow antenna beam width (0.4°-0.8°)
  - X-band and/or S-band
  - High availability (≥ 99.995 %)
  - Plot extractor and data feed connected to the UCCS
- The identified solution has high performance, solid state, no radhaz, low weight and volume, low power consumption, short lead times, high availability and low price

Signal transfer

- The gapfiller will be remote controlled through a local area network.
- Gapfiller signals will be transferred ashore through an optical fibre cable to the Salle substation control centre.
- A leased line from British Telecom will transfer the gapfiller signals to the UCCS at Trimingham radar head.
- Crypto will not be required.



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Current issues

- Two studies initiated by BWEA are under way on contract with UK MoD:
  - One ADATS study will investigate what needs to be carried out to increase number of data ports available within the UCCS to receive data from 2D ATC radar systems; f.ex. gapfillers.
  - One IBM study will specify the data transport from a gapfiller to the UK Air Surveillance Command and Control System (UCCS). It will assess the feasibility of data transport from ATC radar systems into the UCCS software.
  - The studies will specify technical considerations as well as cost estimates and are expected to be finished by the end of 2009.
  - Any cost related to gapfillers are expected to be covered by utilities.

15 Statoil

The way ahead

- Gapfiller concept solution defined Q4 2009
- Gapfiller system integration contract signature Q2 2010
- Gapfiller lead times of 6-9 months
- Gapfiller installation Q2 2011
- Wind farm test operation from Q4 2011
- Flight trials Q4 2011 – Q1 2012
- Approved system Q2 2012

16 Statoil


Thank you
Sheringham Shoal offshore wind farm
Gapfiller concept solution
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Senior consultant scientist
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Statoil

Wind turbines and radars

Photo: Åke Krantz, Saabgroup

Yttre Stengrund

FMV

Agenda

1. Background
2. The challenge: co-existence between radars and wind turbines
3. Flight tests
4. Results and conclusions from flight tests
5. Summary

FMV

1. Background

Sweden

- Total electric consumption per year, ca 150 TWh.
- Government planning goal is 30 TWh produced by wind power in the year 2020
- Today: 2 TWh from wind power
- The number of turbines is about 1000.

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1. Background

- The Swedish Armed Forces take every wind power project under consideration and give their opinion about it (conflicts with radars, radio relay links, airfields, land-, sea- or air exercise areas, etc.)
- The Swedish Armed forces has a strong legal support in their opinion, and it is difficult to appeal against this type of military decision.

Conclusion: It can in some situations exist conflicts between different national goals

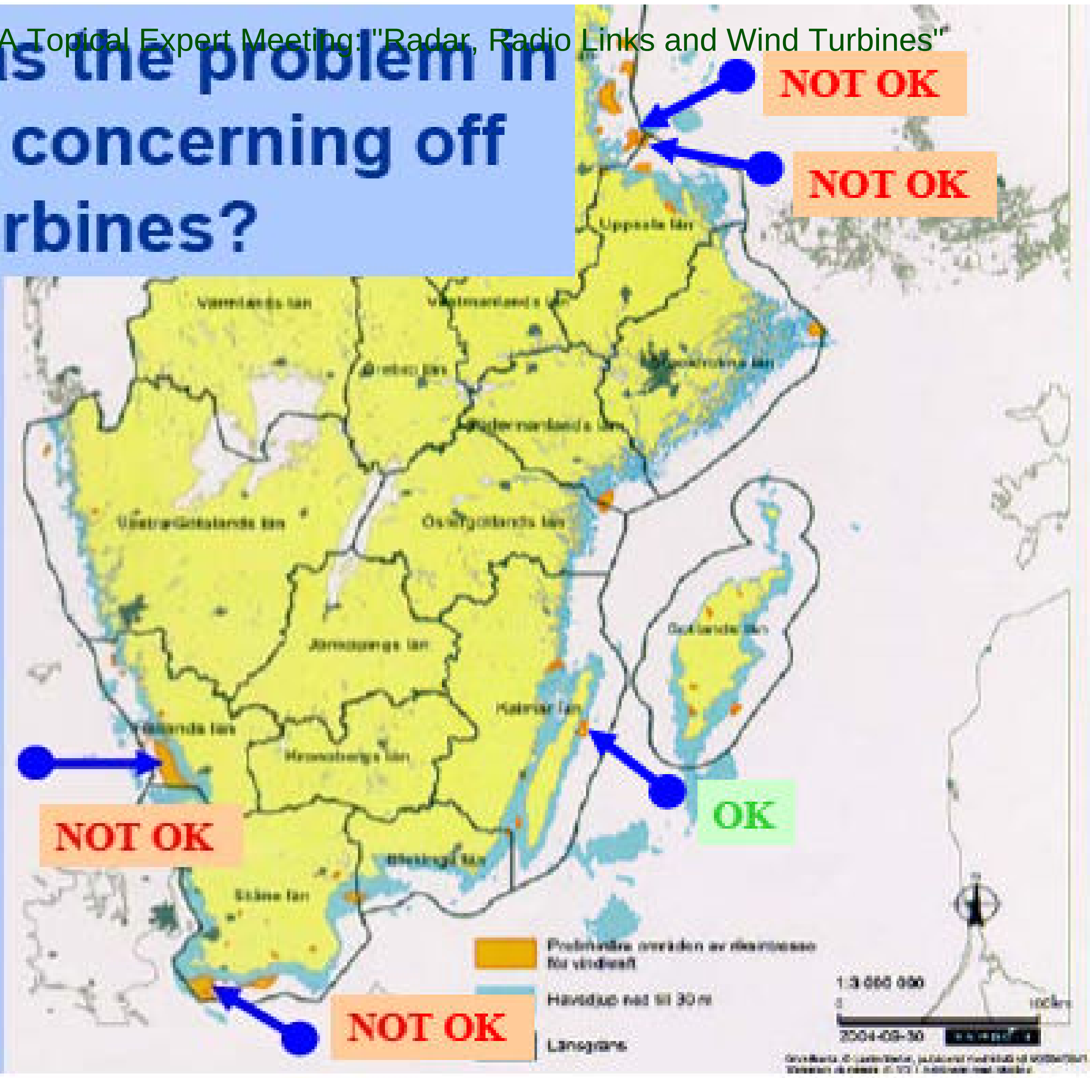
FMV

What was the problem in Sweden concerning off shore turbines?

WPS
1,5 MW

Tower 111,5 m
Base 5 m
Top 3 m

Rotor 77 m (3)
Blade 3 / 1,5 m



1. Background

Radar surveillance over the sea:

- National security
- The Schengen agreement

2. The challenge: co-existence between radars and wind turbines

Three identified fields of challenges:

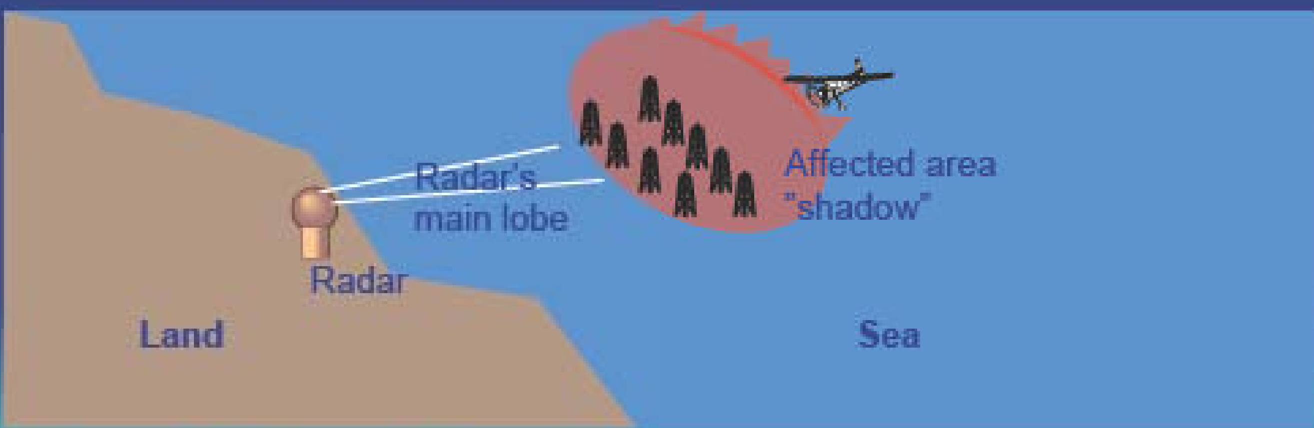
- Radar shadow behind the turbines/towers
- Doppler effects from rotating turbine blades
- Unwanted returns (”ghost targets”) due to reflections

FMV

2. The challenge: co-existence between radars and wind turbines

Radar shadow from off shore turbines:

Obstacles in front of the radar conceal the target that the radar is supposed to discover.



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2. The challenge: co-existence between radars and wind turbines

Why focus on the *radar shadow*?

Some arguments:

- It was (and is) the basis for the assessment that is used in the Swedish Armed Forces planning tool
- The purpose of radar surveillance: to discover real targets (the other problems are also important, but with limited resources a decision had to be made on the scope of studies)
- Limited knowledge of the spread of the radar shadow (width, length, compactness and so on).
- Despite what the phenomenon is called "shadow or something else…" it affects radar performance

3. Flight tests

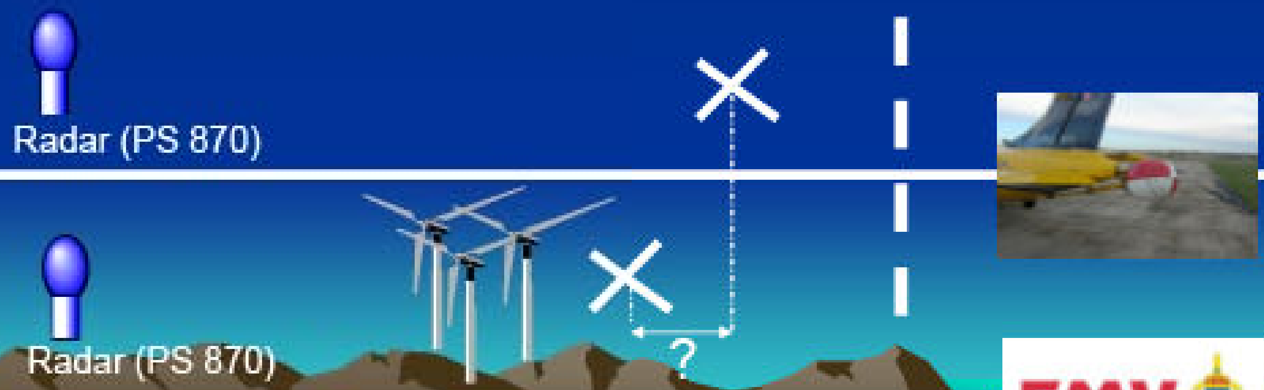
3. Flight tests

Main test

1. Get an understanding of the attenuation of the received signal behind the wind turbines

Complementary flight test

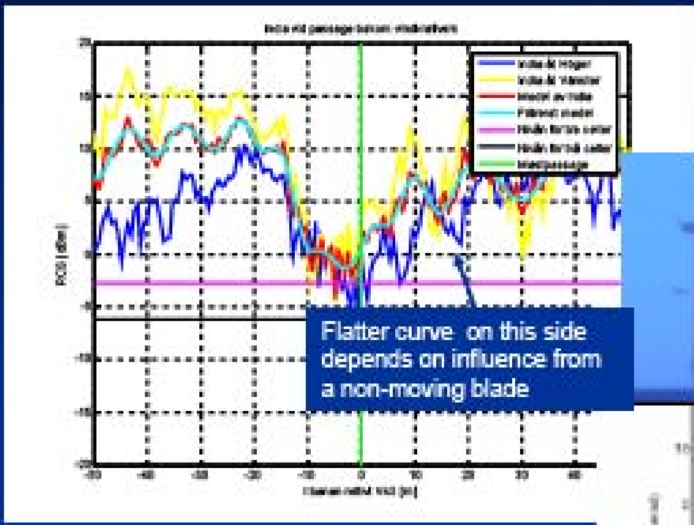
2. Which is the reduction in range for the radar for a target with known cross section area (in this case a sphere)
   - Flight tests with a sphere towed by the aircraft in a situation without turbines
   - Flight tests with a sphere towed by the aircraft in a situation with turbines



3.Flight tests

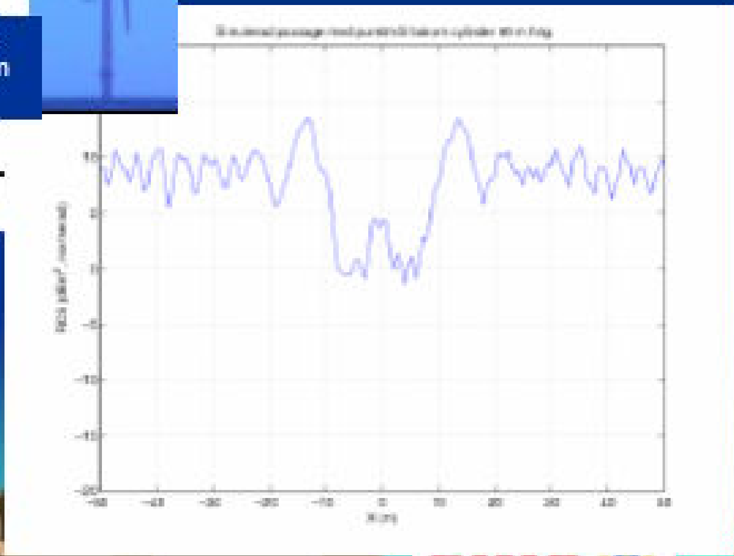
- Simulation (before the flight tests)

3.Flight tests



Measurement Relative changes in the radar cross section Area when the plane pass behind the turbines (6-10 dB)

Results from simulation:



4. Results and conclusions from the Flight tests

Assessment process

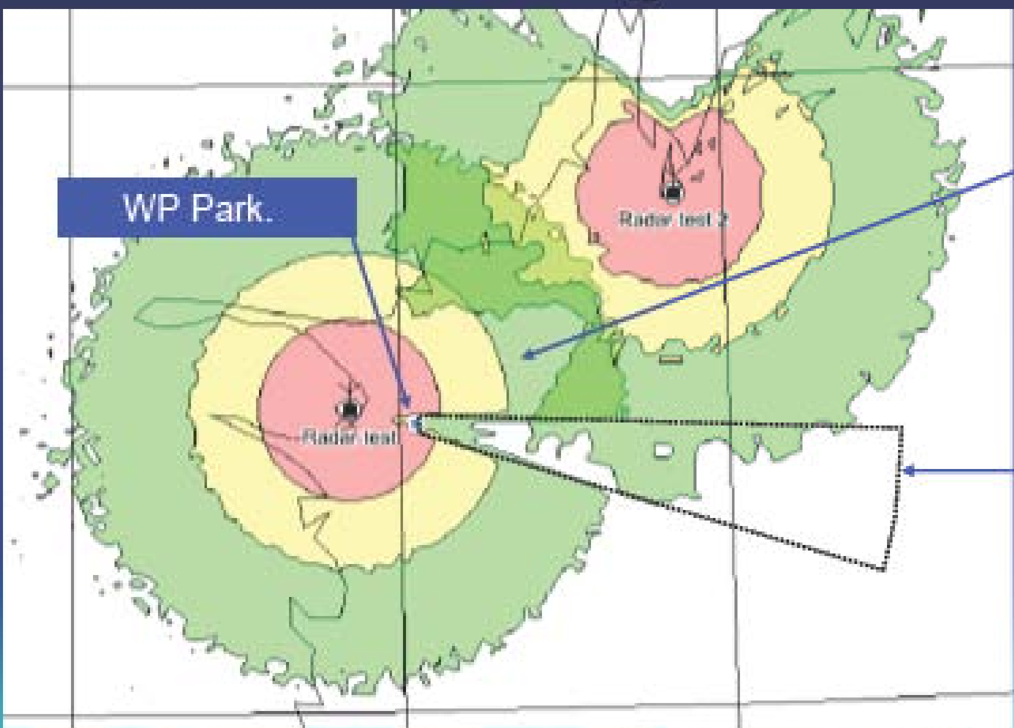
- Revise how to formulate the requirement (”approve” or ”reject”) for an acceptable disturbance on radars from turbines.
- Not SIR only (disadvantage: calculations ignore the actual size of the target)
- Combine technical and operational assessment

4. Results and conclusions from the Flight tests

Technical assessment; possible mitigations?

- Move a land based radar to another position
- Increase of radar's antenna height
- Complete with land based radars
- Complete with radars off shore (Schengen)

4. Results and conclusions from the Flight tests



"Radar test 2" has a terrain mask to WP Park. Little overlap of radar coverage.

Increase antenna height???

"Radar test" has shadowed sector behind wind turbines

4. Results and conclusions from the Flight tests

Operational assessments:

- Value different locations (more or less sensitive)
- Value different directions for a given location

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5. Summary

- Concerning radars and wind turbines

-Easy rule of thumb to assess for <u>on land turbines </u>and disturbances on radars

-More complicated to assess <u>off shore turbines </u>and their disturbances on coast based radars.

- Flight tests indicate that the reduction in a radar's range can be 14-25% in a situation due to turbines
- Other areas to focus on in the future: Doppler effects, unwanted returns (”ghost targets”), clutter etc

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5. Summary

- Big targets are normally no problem for the radar
- Targets however, have a tendency to get "smaller" due to stealth technology
- Perform a combined technical and operational assessment
- Continue studying doppler effects, ghost targets, clutter and so on

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Mobile: 46 70 5599833
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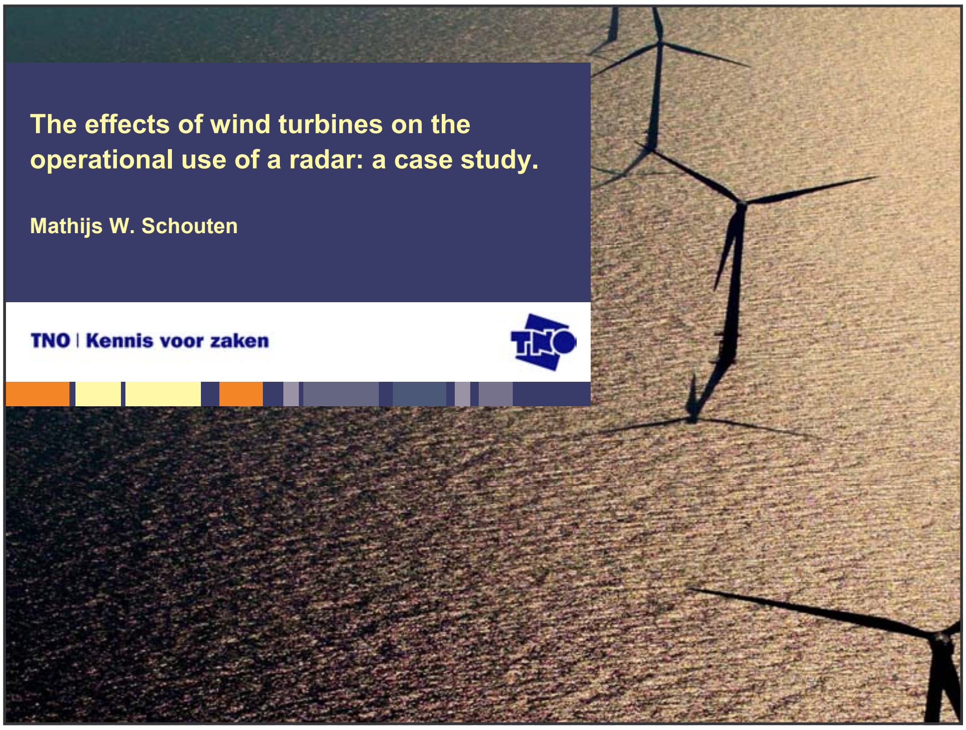


Contents

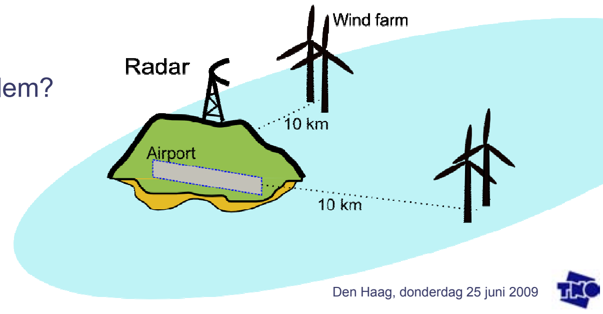
- Case and question
- Shadowing effect
  - what, where, and how much
  - operational impact
- Turbine clutter
  - what, where, and how much
  - operational impact
- Concluding remarks.

Case

- The case of an airport surveillance radar ..
- faced with plans for two wind farms within 10 nm,
- one of which is in the direction of the runway.

Question

- Will there be a problem?



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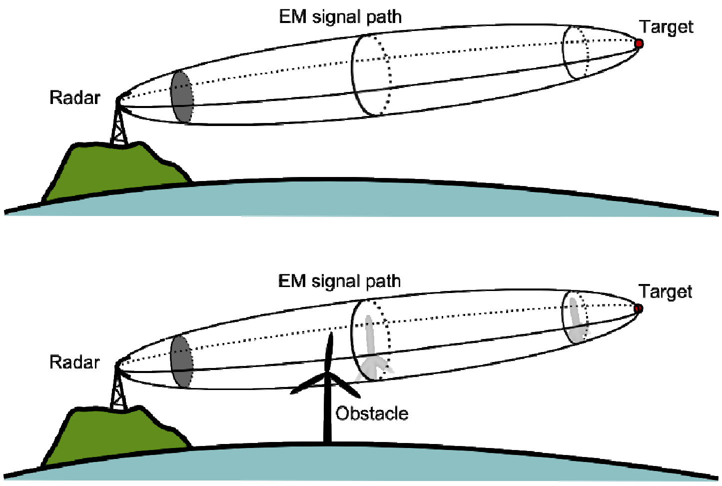
Shadowing effect



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What

- Reduced detection capability means that

  a) a target is visible only at shorter distances, or
  b) has to be larger to be seen at the same distance.

- We use 'relative detection distance', which indicates a change in detection for the same target.

- This relates to the definition of your required coverage.

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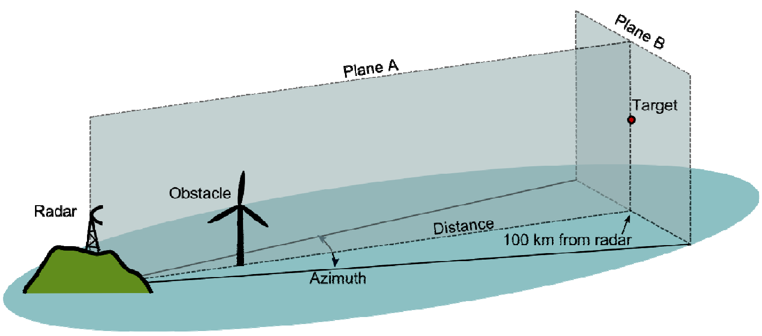
Where



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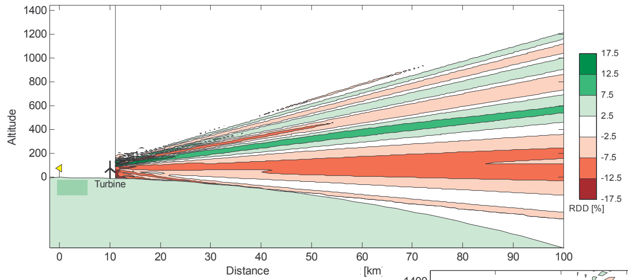
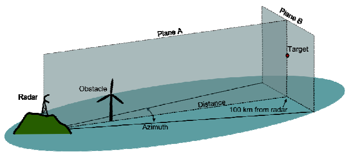
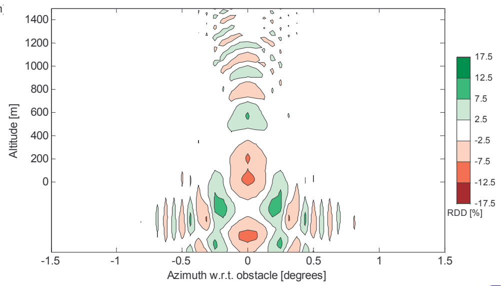
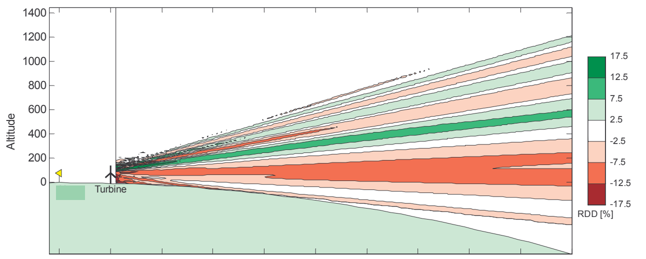
Reduced detection capability

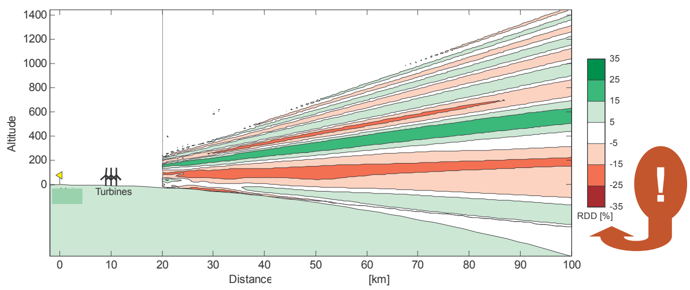




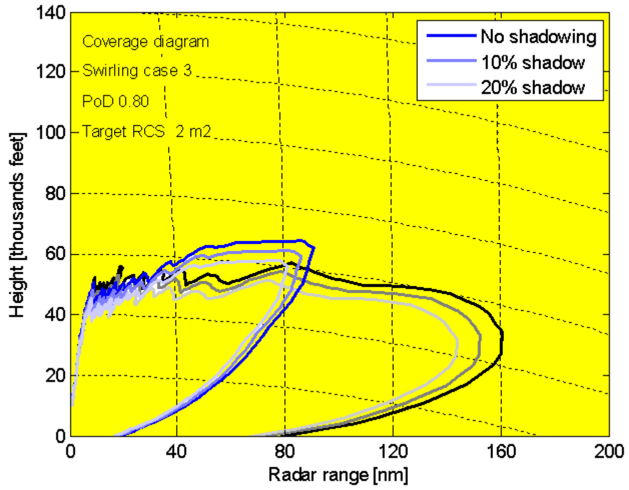


Multiple wind turbines





Impact



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Conclusions shadow effect

- noticeable effects, especially for multiple windturbines
- in small and unpredictable patches,
  - width *O*(100m)
  - height *O*(100m)
- both positive and negative impact.

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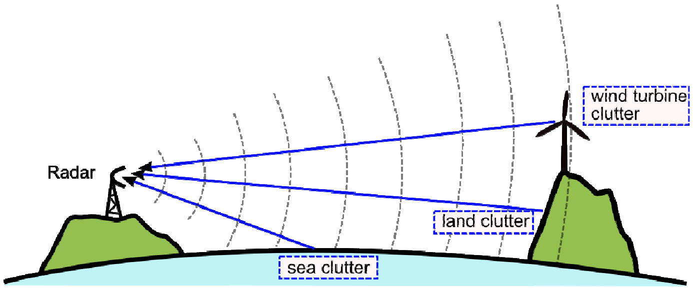
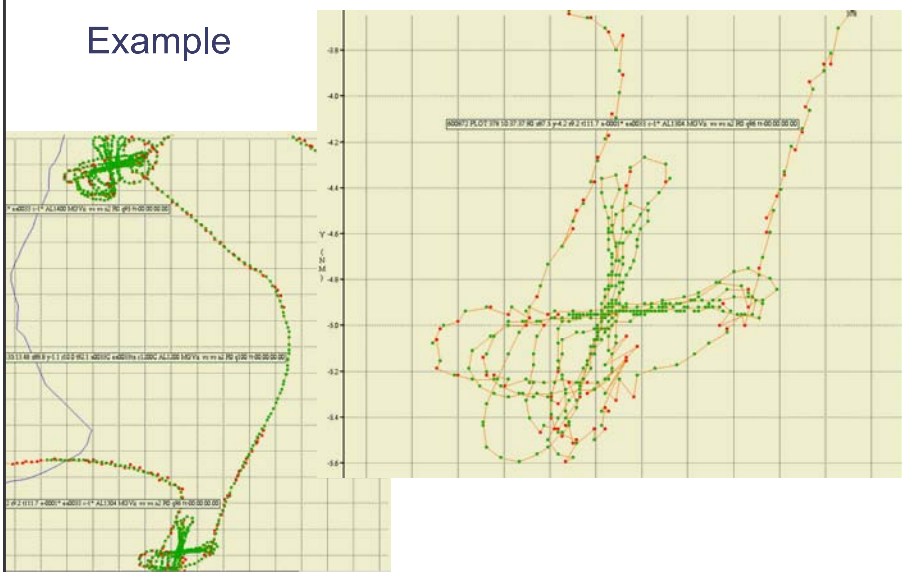
Effect two: clutter



Example

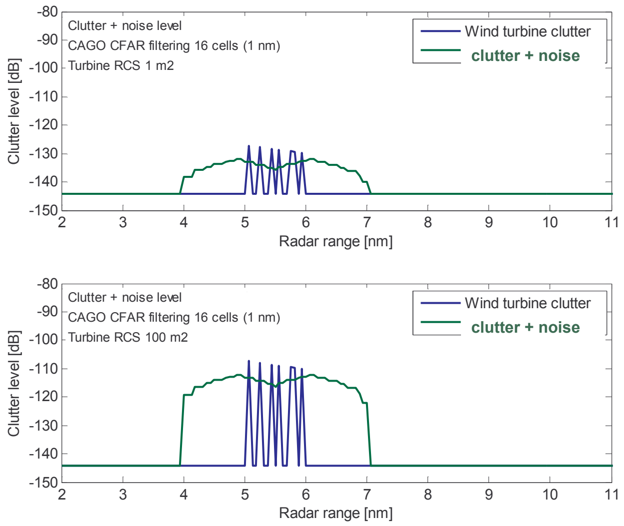


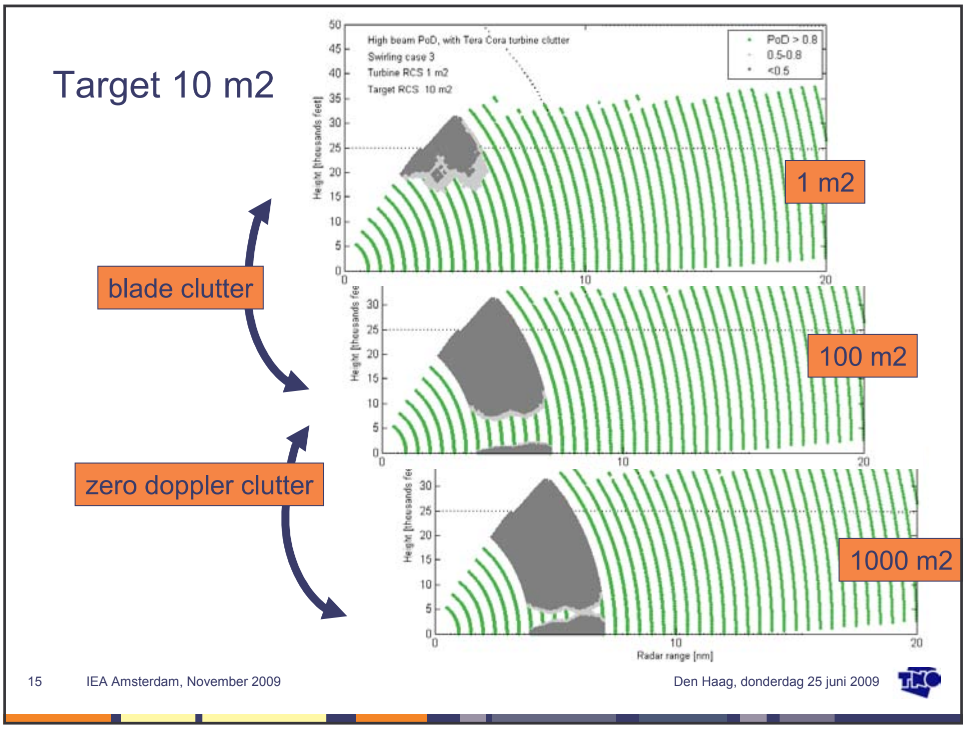
Doppler processing: three scenarios

rcs estimates based on published observations and modelling.

- Target in zero doppler bin:
  - Clutter from tower and nacell adds up to the already most clutter-contaminated doppler-cell.
  - Wind turbine RCS 100-1000 m2
- Target in a bin contaminated by turbine clutter
  - Combine statistics for occurrence of blade flashes
  - Blade flash: 10 - 100 m2
  - No blade flash 1 - 10 m2
- Target not in a doppler contaminated bin

CFAR processing spreads influence




Target 10 m2
High beam PoD, with Tera Cora turbine clutter
Swirling case 3
Turbine RCS 1 m2
Target RCS 10 m2
PoD > 0.8
0.5-0.8
<0.5
1 m2
100 m2
1000 m2
blade clutter
zero doppler clutter
Height [thousands feet]
Radar range [nm]
15
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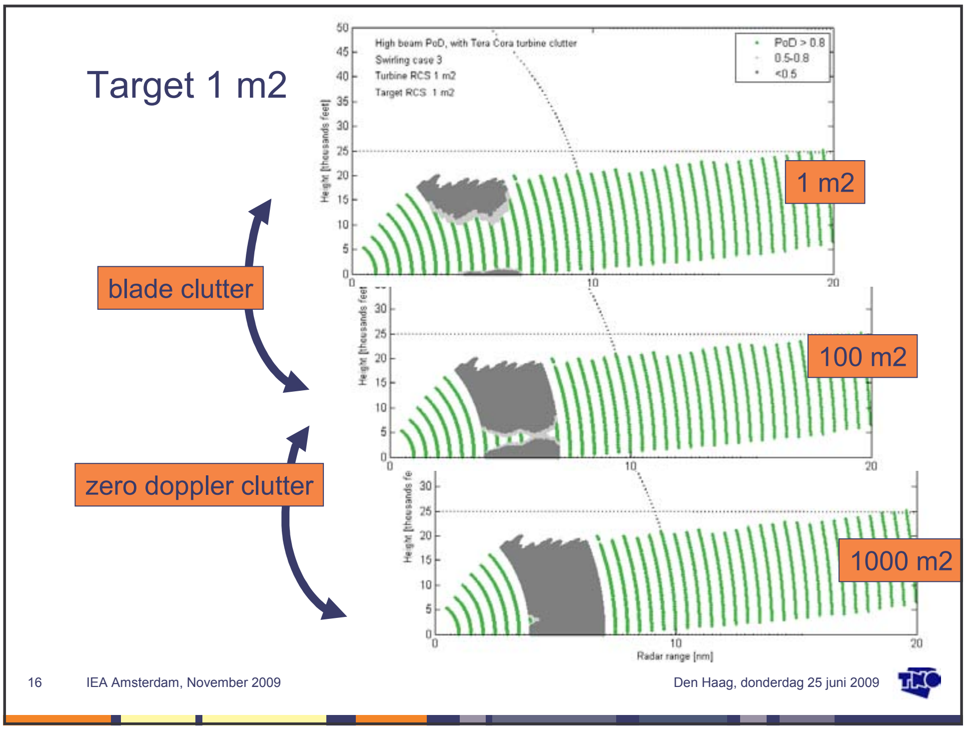
Target 1 m2
High beam PoD, with Tera Cora turbine clutter
Swirling case 3
Turbine RCS 1 m2
Target RCS 1 m2
PoD > 0.8
0.5-0.8
<0.5
1 m2
100 m2
1000 m2
blade clutter
zero doppler clutter
Height [thousands feet]
Radar range [nm]
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Conclusions turbine clutter

- Noticeable effects. Exact quantification not feasible due to many parameters of influence.
- In a part of the airspace above and around the windfarm detection may not be possible.
- For the case at hand, targets are still likely detected most of the time, due to their size, and height above the wind farm.
- With multiple wind turbines, clutter values may simply be added up.

Overall conclusions

- Shadowing is not often a likely source of operational problems.
- Turbine clutter is.
  - for certain scenarios (smaller targets)
  - and locations (where do you need detection capability)
  - Smarter CFAR processing can (and will soon) strongly reduce the impacted area.
- Shadow effects and their impact can be modelled adequately.
- Clutter effects and their impact can be roughly estimated.

Questions?

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Questions?

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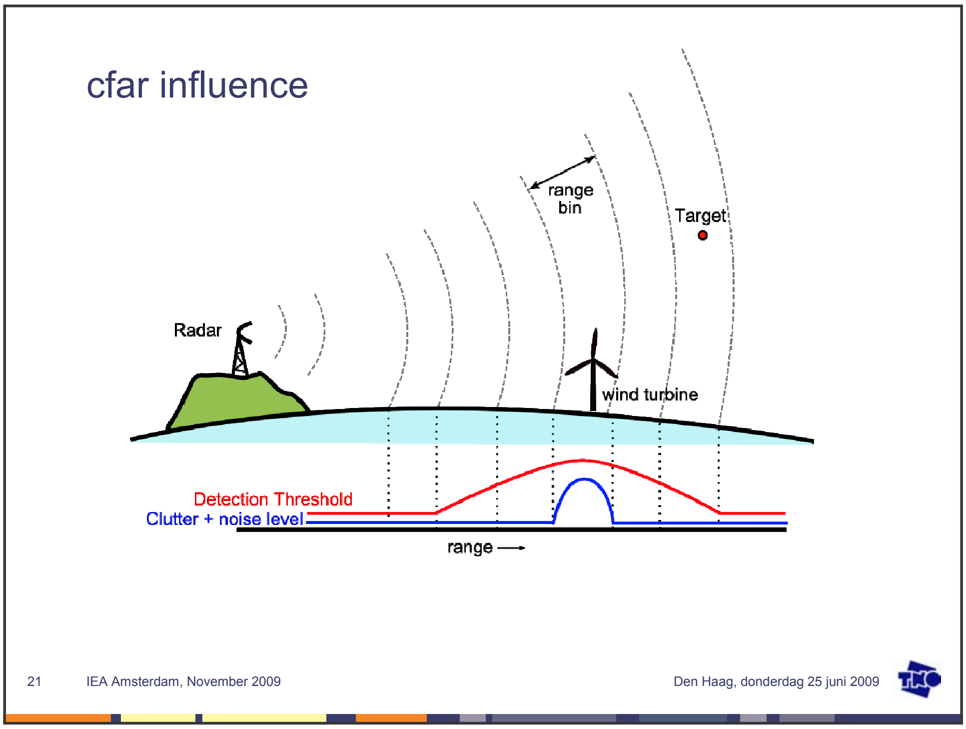

cfar influence
range
bin
Target
Radar
wind turbine
Detection Threshold
Clutter + noise level
range
21
IEA Amsterdam, November 2009
Den Haag, donderdag 25 juni 2009

THALES

IEA Wind TEM Amsterdam

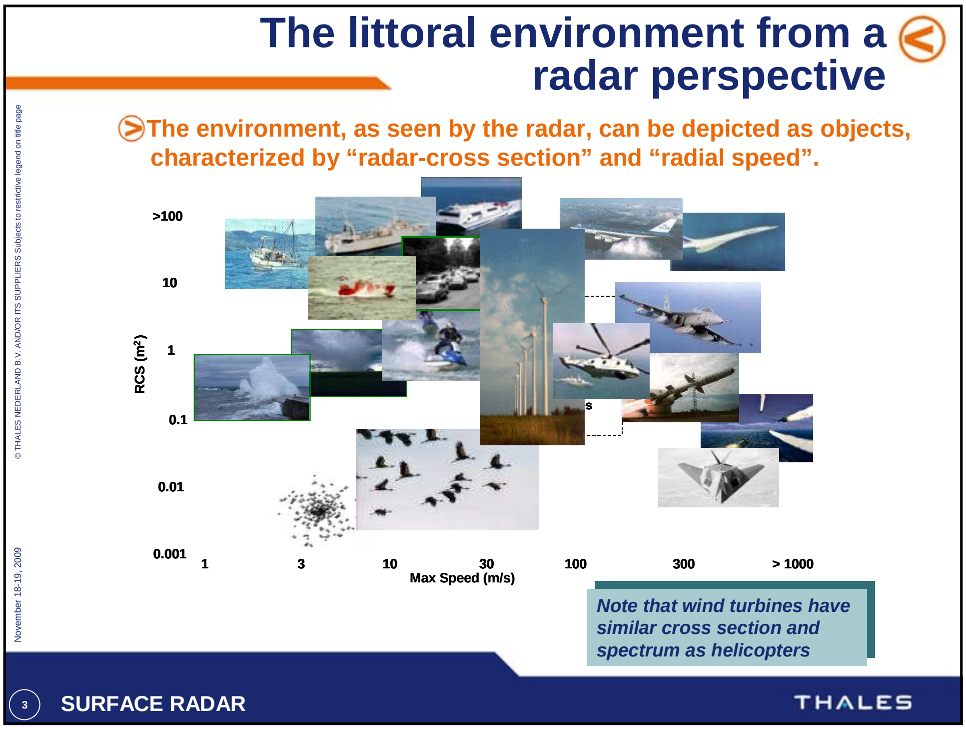
Radar and Wind Turbines

November 18-19, 2009

1 SURFACE RADAR

Content

2 SURFACE RADAR THALES


The littoral environment from a radar perspective
The environment, as seen by the radar, can be depicted as objects, characterized by "radar-cross section" and "radial speed".
>100
10
1
0.1
0.01
0.001
RCS (m²)
1
3
10
30
100
300
> 1000
Max Speed (m/s)
Note that wind turbines have similar cross section and spectrum as helicopters
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3
SURFACE RADAR
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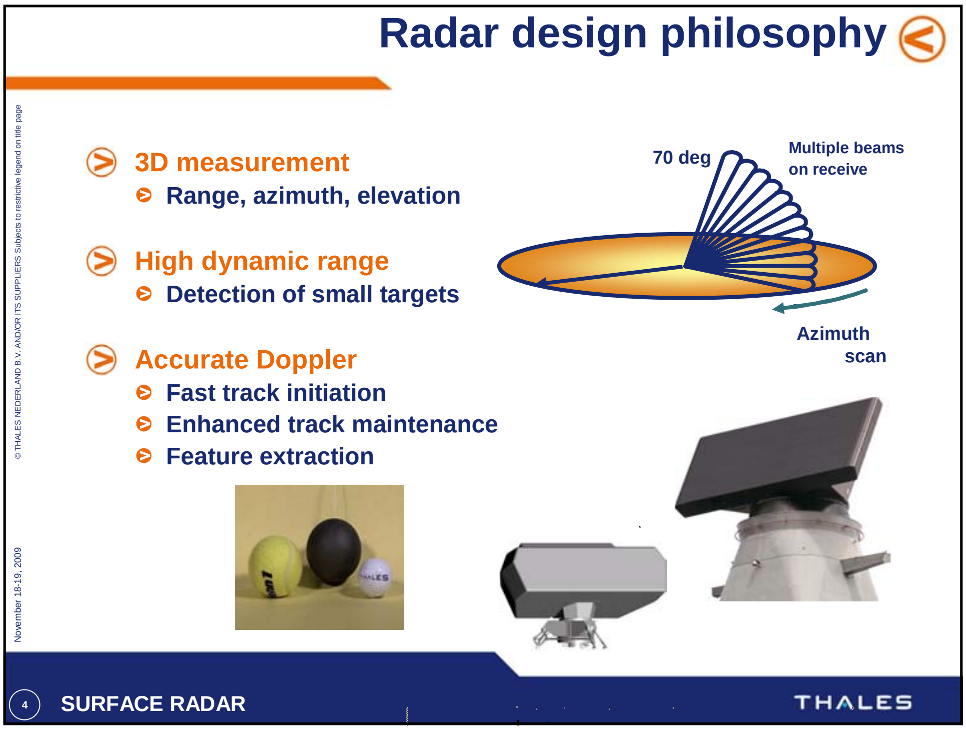
Radar design philosophy
3D measurement
Range, azimuth, elevation
High dynamic range
Detection of small targets
Accurate Doppler
Fast track initiation
Enhanced track maintenance
Feature extraction
70 deg
Multiple beams on receive
Azimuth scan
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SURFACE RADAR
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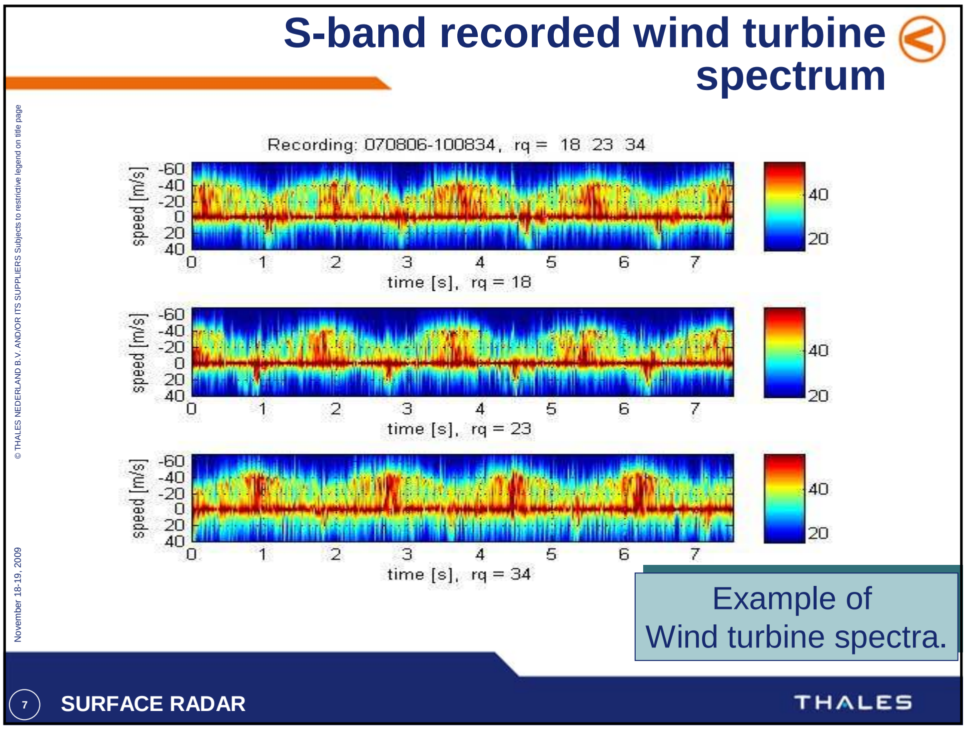
Wind turbines and radar

- **Wind turbines can cause:**
  - Obscuration,
  - False plots and
  - False tracks
- **Characteristics wind turbine detections by S-band radar**
  - Wind turbine RCS often larger than the moving and hovering helicopter RCS
  - Both, helicopters and wind turbines, show a wide Doppler spectrum due to the rotating blades
  - Wind turbine spectrum strongly depends on the aspect angle and Line of Sight

November 18-19, 2009

Experimental validation

November 18-19, 2009


S-band recorded wind turbine spectrum
Recording: 070806-100834, rq = 18 23 34
speed [m/s]
time [s], rq = 18
time [s], rq = 23
time [s], rq = 34
Example of Wind turbine spectra.
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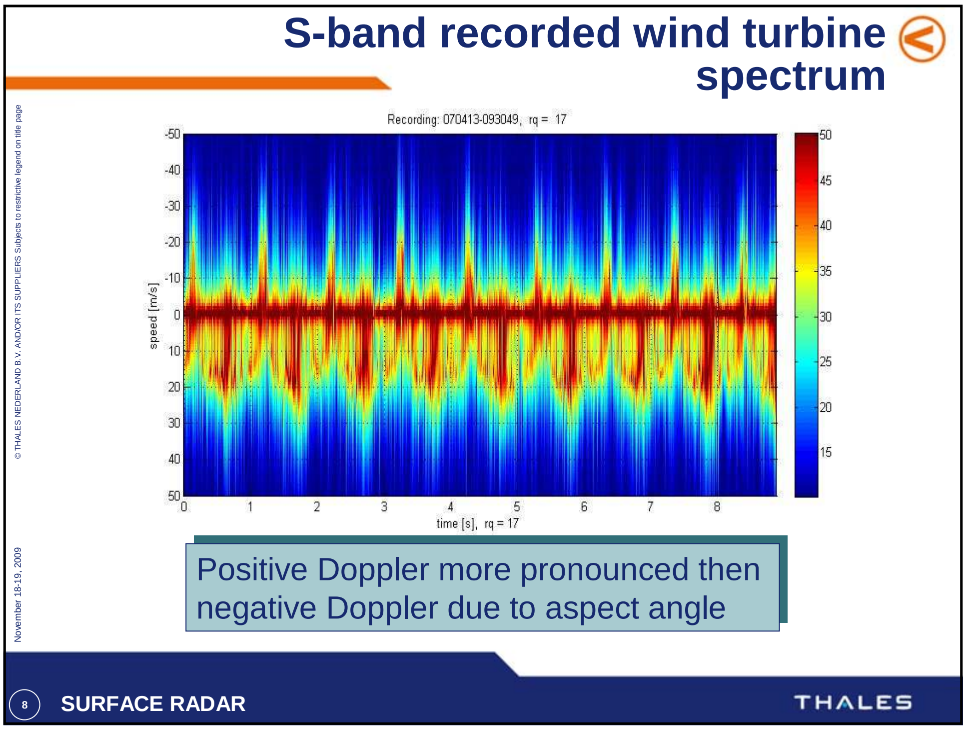
SURFACE RADAR
THALES


S-band recorded wind turbine spectrum
Recording: 070413-093049, rq = 17
speed [m/s]
time [s], rq = 17
Positive Doppler more pronounced then negative Doppler due to aspect angle
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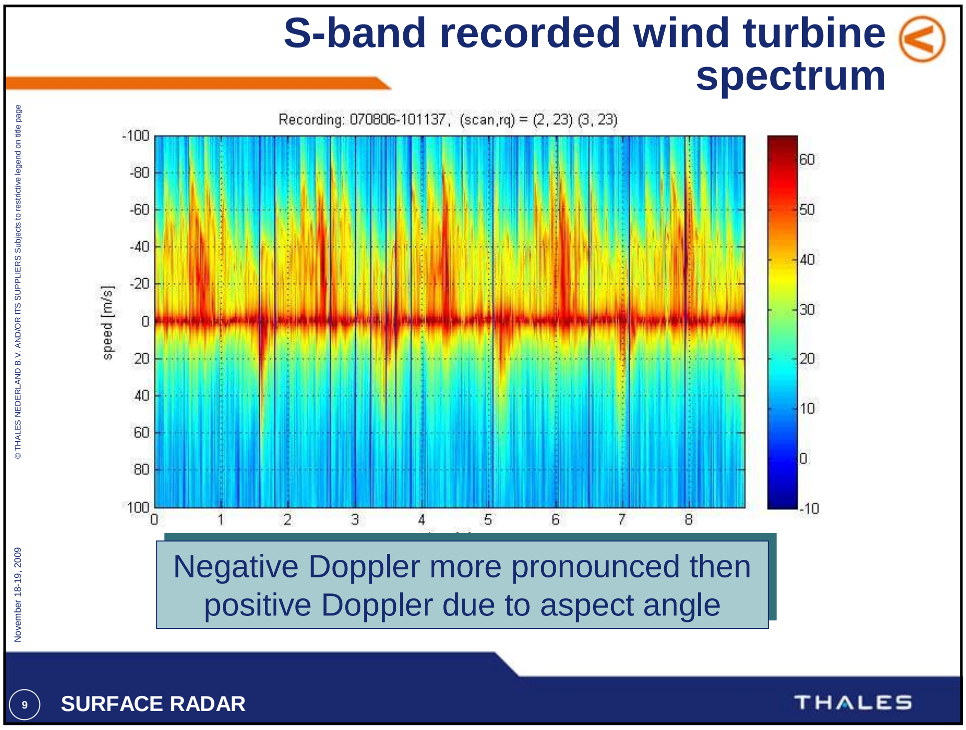
SURFACE RADAR
THALES


S-band recorded wind turbine spectrum
Recording: 070806-101137, (scan,rq) = (2, 23) (3, 23)
speed [m/s]
Negative Doppler more pronounced then positive Doppler due to aspect angle
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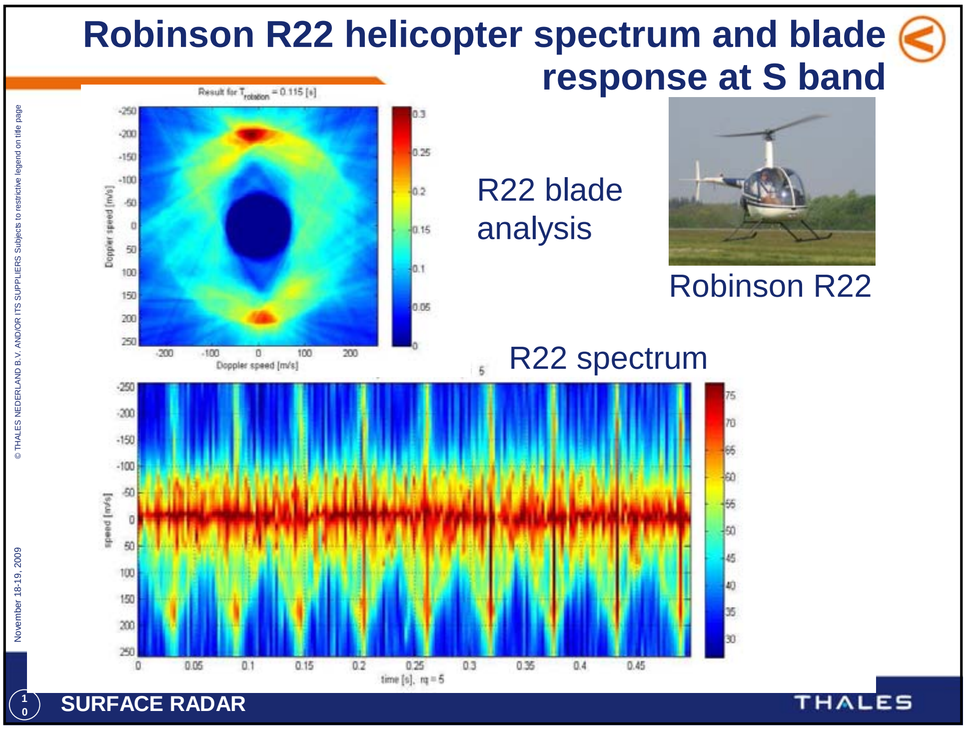
SURFACE RADAR
THALES


Robinson R22 helicopter spectrum and blade response at S band
Doppler speed [m/s]
R22 blade analysis
Robinson R22
R22 spectrum
speed [m/s]
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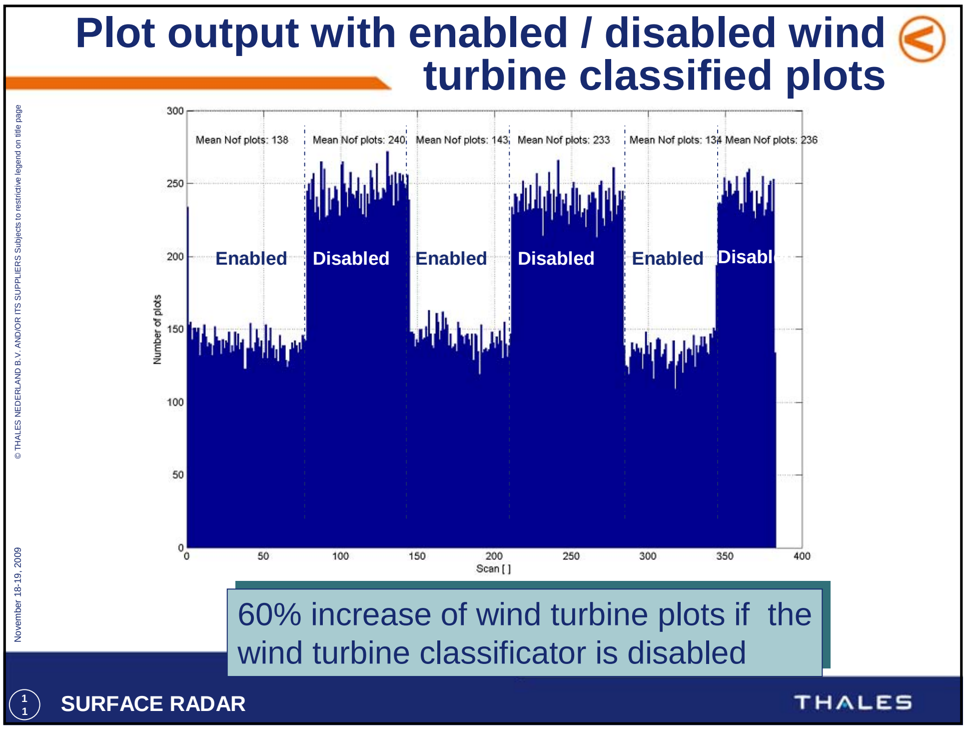
SURFACE RADAR
THALES


Plot output with enabled / disabled wind turbine classified plots
Mean Nof plots: 138
Mean Nof plots: 240
Mean Nof plots: 143
Mean Nof plots: 233
Mean Nof plots: 134
Mean Nof plots: 236
Enabled
Disabled
Enabled
Disabled
Enabled
Disabl
Number of plots
Scan [ ]
60% increase of wind turbine plots if the wind turbine classificator is disabled
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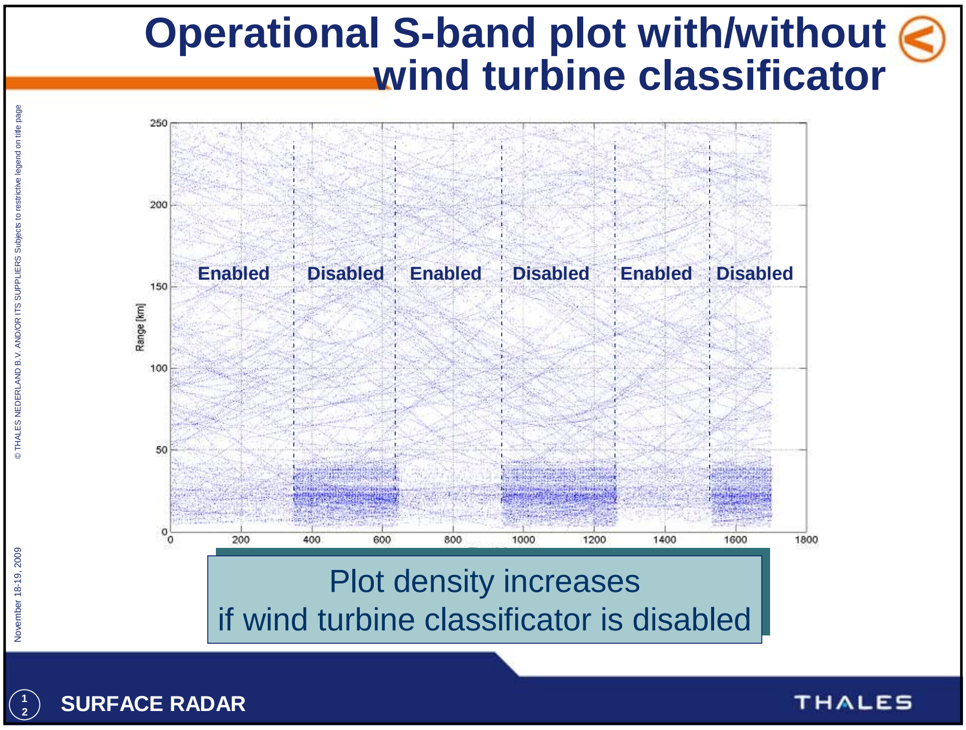
Operational S-band plot with/without wind turbine classificator
Enabled
Disabled
Enabled
Disabled
Enabled
Disabled
Range [km]
Plot density increases if wind turbine classificator is disabled
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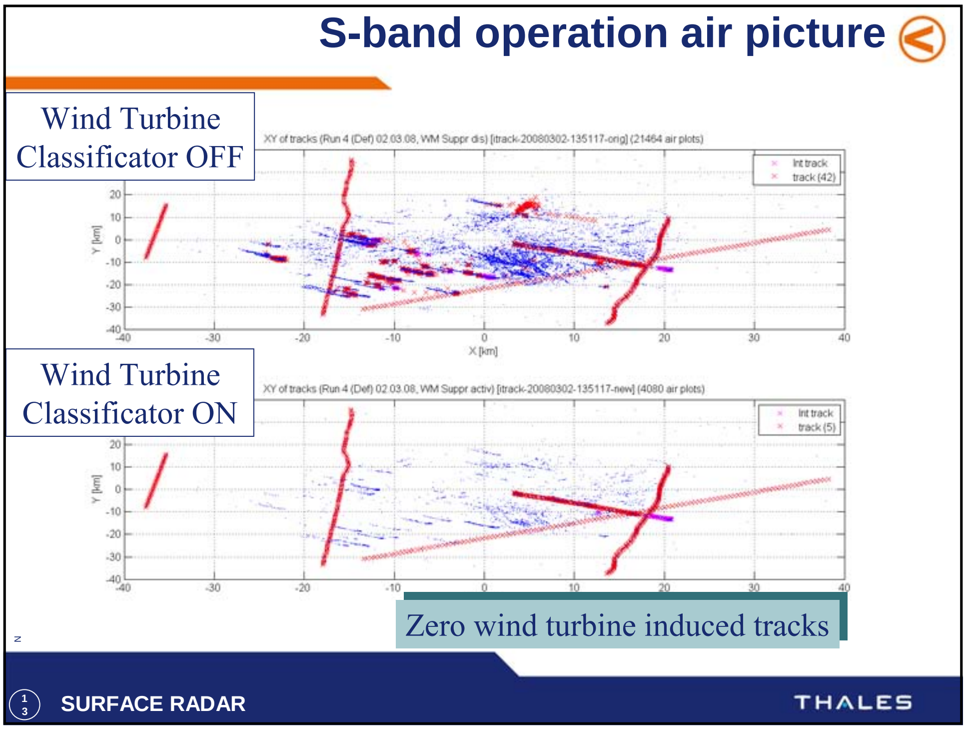
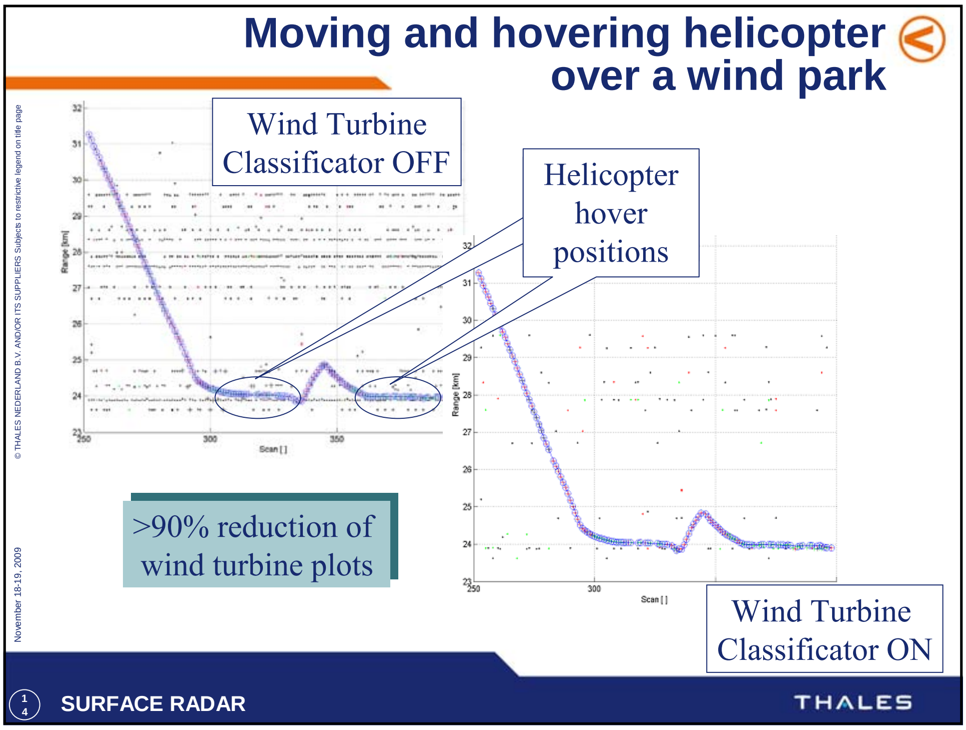


S-band operation air picture
Wind Turbine Classificator OFF
Wind Turbine Classificator ON
Zero wind turbine induced tracks
SURFACE RADAR
THALES



Moving and hovering helicopter over a wind park
Wind Turbine Classificator OFF
Helicopter hover positions
>90% reduction of wind turbine plots
Wind Turbine Classificator ON
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SURFACE RADAR
THALES

Conclusion

- **Effectiveness wind turbine classificator:**
  - Life trials at sea with regular air targets showed that no radar performance degradation
  - Life trials of helicopter over wind farm showed:
    - > No false track generation induced by wind turbines
    - > No track lost of a slow moving helicopter and hovering helicopter over a wind farm
    - > No track lost if the helicopter took cover behind the wind farm
    - > More than 90 % of the wind turbine detections are classified as wind turbine detections

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Summary

- **Classical MTI radars hardly can cope with wind turbine detections without operational performance degradation**
- **Thales successfully proved, implemented and made operational wind turbine classificator in the latest multibeam S-band radars**
  - Sensor sensitivity unchanged
  - No false tracks induced by wind turbines
  - No track lost of moving and hovering helicopters over wind parks
  - No helicopter track lost after helicopter took cover behind the wind turbine park

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THALES

Back-up slides

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17 SURFACE RADAR

Radar environment

- **The operational environment for radar changes continuously.**
  - **The spectrum of wanted and unwanted objects, natural and man-made clutter overlaps**
  - **Radar systems must be able to classify these detections accordingly to prevent false track initiation**
- **Thales latest S band multibeam radar systems are already enhanced with a wind turbine classification capability.**
- **Efficiency of the wind turbine classificator better than 90%**

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Offshore wind turbine parks booming industry

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The Dutch government has appointed 4 regions in the North Sea as spots for new offshore wind turbine parks.

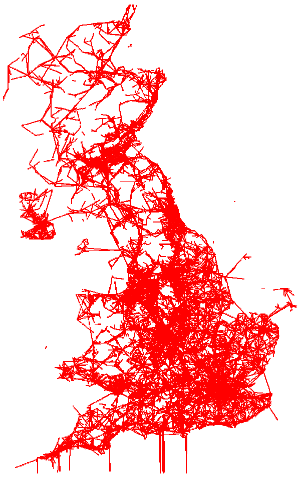
By 2020, the offshore wind turbine parks will have approx. 1500 to 2000 wind turbines which should produce 6000 megawatt (the equivalent of 6 big coal plants) of energy. Currently, the North Sea houses 2 parks with 96 wind turbines delivering 228 megawatt.

19 SURFACE RADAR

THALES

Understanding the Impact of Wind Turbines on Communications

Microwave Links and UHF Telemetry



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Understanding the Impact of Wind Turbines on Radar

- Microwave Communications and UHF Telemetry Links
- Interference Mechanisms and Clearance Calculations

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Microwave Links and UHF Telemetry

Microwave Communications Links

- Systems require Line of Sight to work correctly
- Used in communications between satellites and base stations e.g. Emergency Services
- ‘Backbone’ carriers for cellular systems

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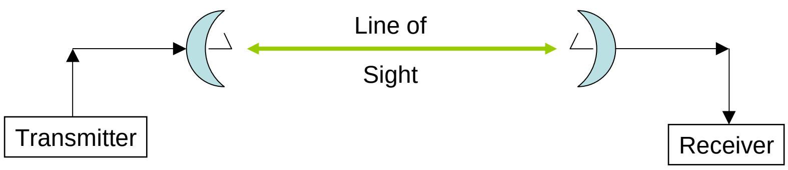
Microwave Links and UHF Telemetry

Microwave Communications Links

Bi-directional Communications Links have a Microwave Antenna at either end and require a clear ‘Line of Sight’:



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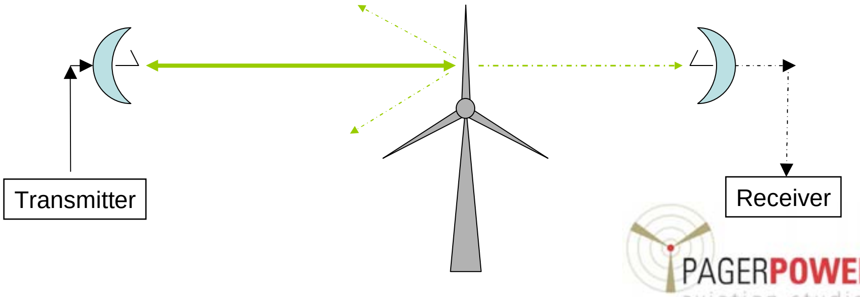
Interference Mechanisms

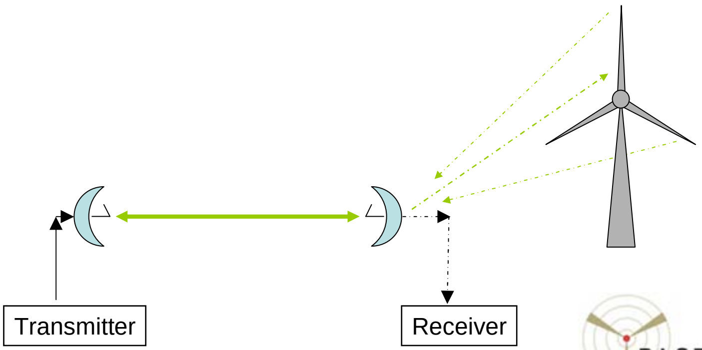
Although turbine blades are not of metallic construction, they can obstruct radio paths, and reflect and diffract radio waves.

Because of their large moving surfaces their effect is difficult to predict.

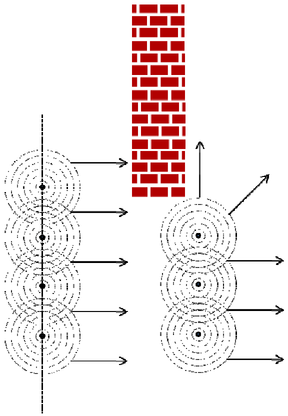


Interference Mechanisms

A turbine located in proximity to a mast end, whilst not directly interfering with the path, can still cause reflection issues.



Diffraction



Huygens' Principle

- Signals travel as waves rather than as rays.
- Signals tend to bend around obstructions, reducing the obstruction effect.
- Signals have associated zone around direct line between transmitter and receiver (Fresnel zones).

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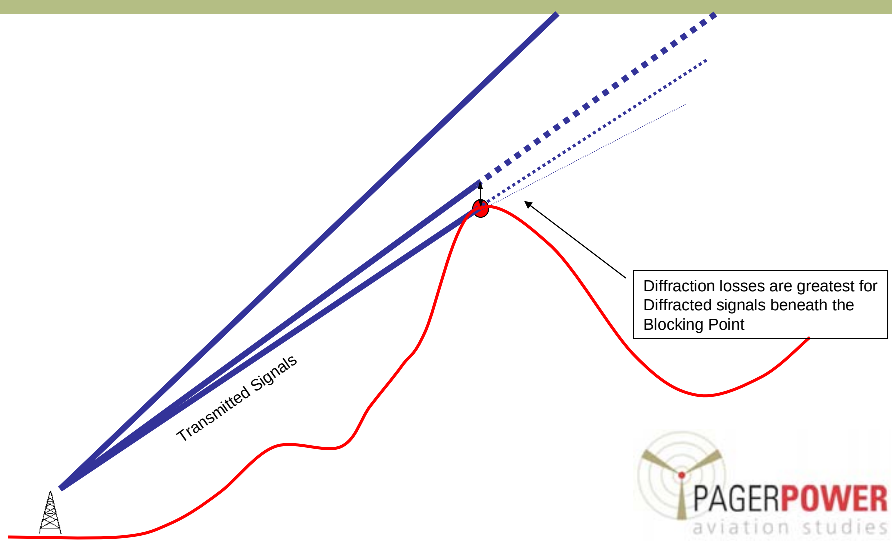
Diffraction



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Exclusion plotting and clearance calculation

Fresnel Zone Calculation

Using the correctly surveyed data, an exclusion zone around the link path can be calculated.

This exclusion zone is based on the second 'Fresnel Zone'

This method is the approach recommended by Ofcom in the UK, when the exact antenna locations are known

Pager Power also include an additional 25m 'buffer zone'

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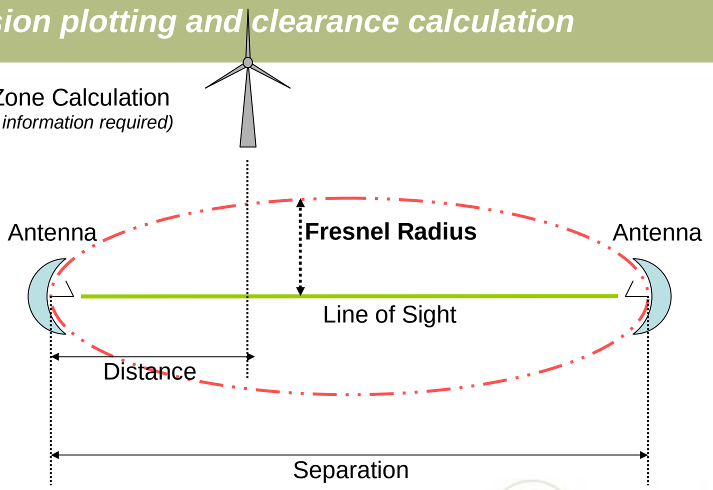
Exclusion plotting and clearance calculation

Fresnel Zone Calculation
(Frequency information required)



Conservative approach

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Microwave Links and UHF Telemetry

UHF Telemetry Links

- •Operate at a lower frequency (usually UHF)
- •Do not need full line of sight
- •Used by utilities
e.g. Gas, Water & Electricity companies

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Inaccuracies and Surveying

When link information is obtained it is very often inaccurate – the provided co-ordinates for mast ends are often only to the nearest100 metres.

The link operators will often request large exclusion zones around the link paths in order to protect their links.

Only by surveying the mast ends, can link ends be plotted accurately as constraints on a proposed development

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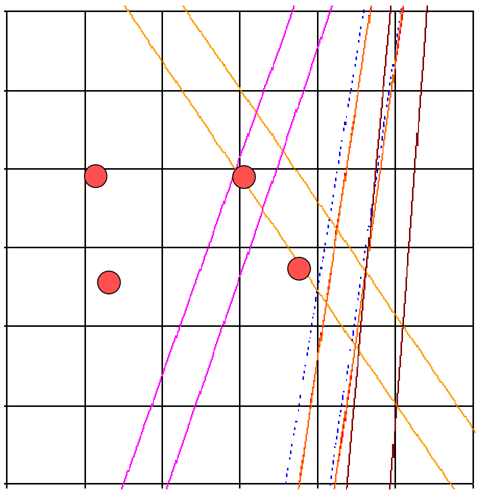
Exclusion plotting and clearance calculation



When correct data about link end co-ordinates has been obtained, Fresnel zones are calculated and links can be plotted as constraints against a site – to illustrate potential issues

Represent turbines

Represent link exclusion zones

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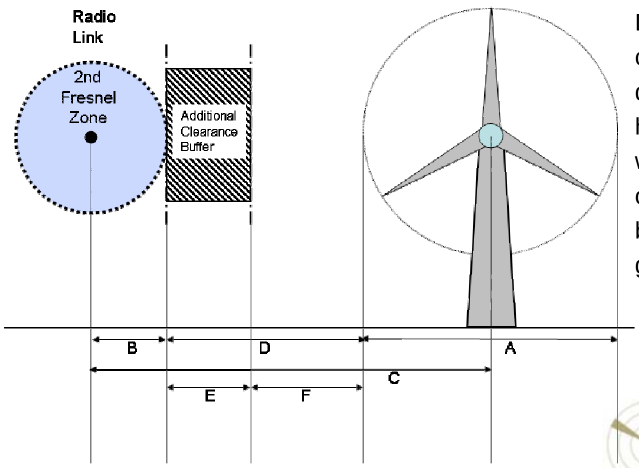
Exclusion plotting and clearance calculation



Detailed calculations can be undertaken to determine exactly how close a turbine would be to a link – or how far it needs to be moved in order to gain clearance.

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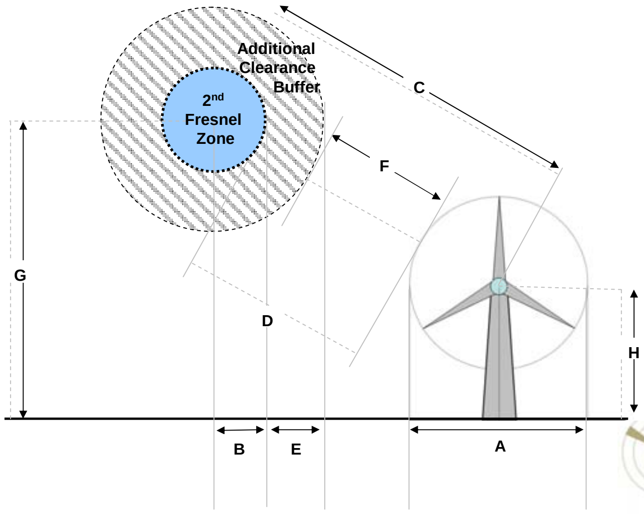
Exclusion plotting and clearance calculation



Sometimes it can be demonstrated that a link path will pass over or under the turbine blades, and clearance can be obtained by looking at the issue in 3D

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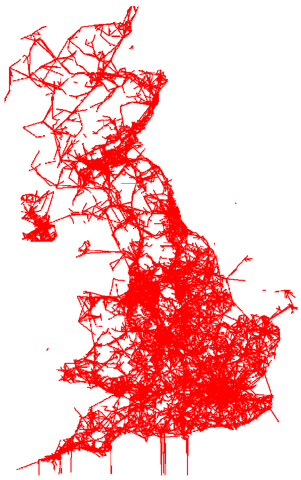
Microwave Links and UHF Telemetry



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