Research Options for Wind/Radar Challenges

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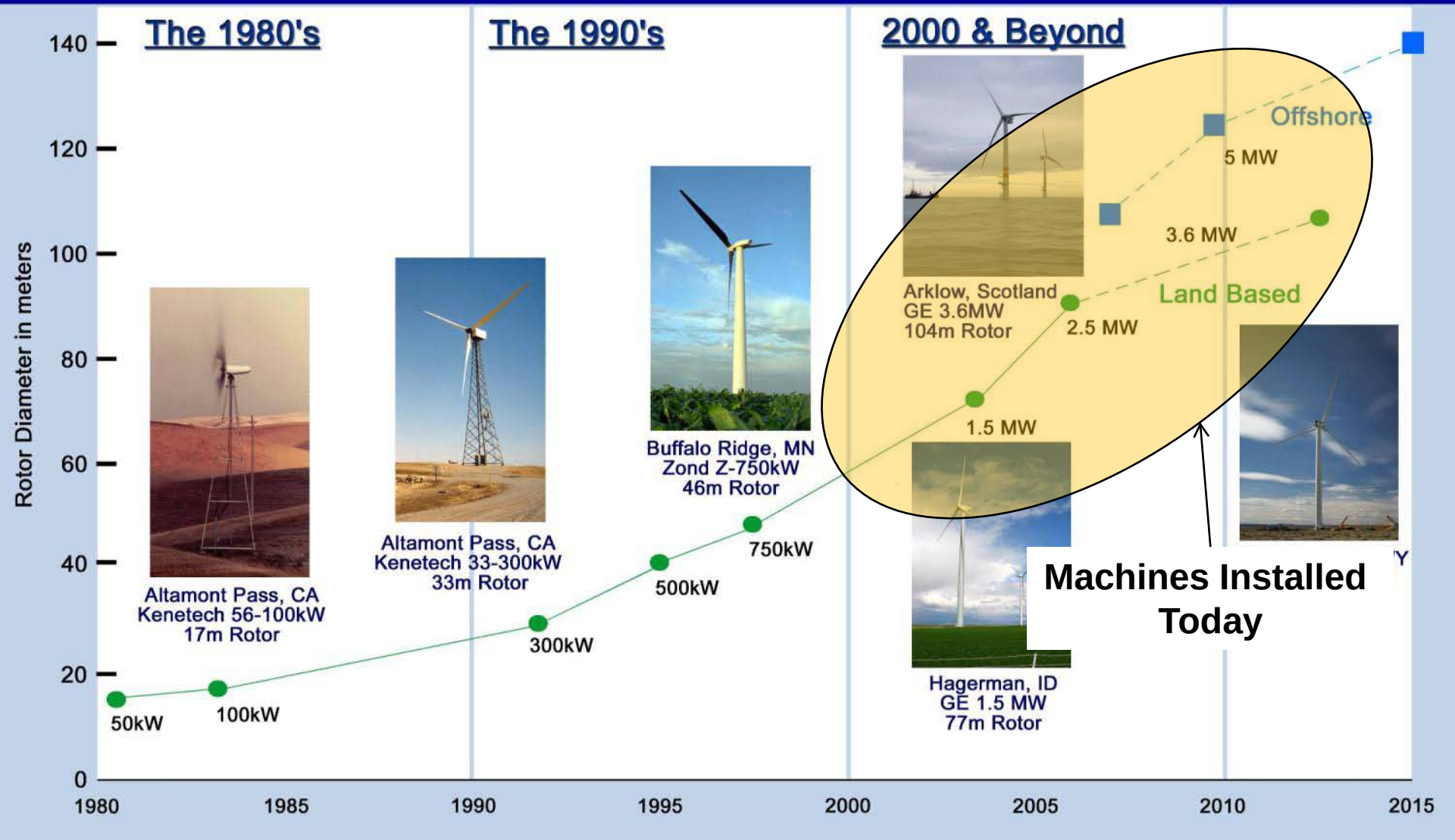
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Evolution of U.S. Commercial Wind Technology

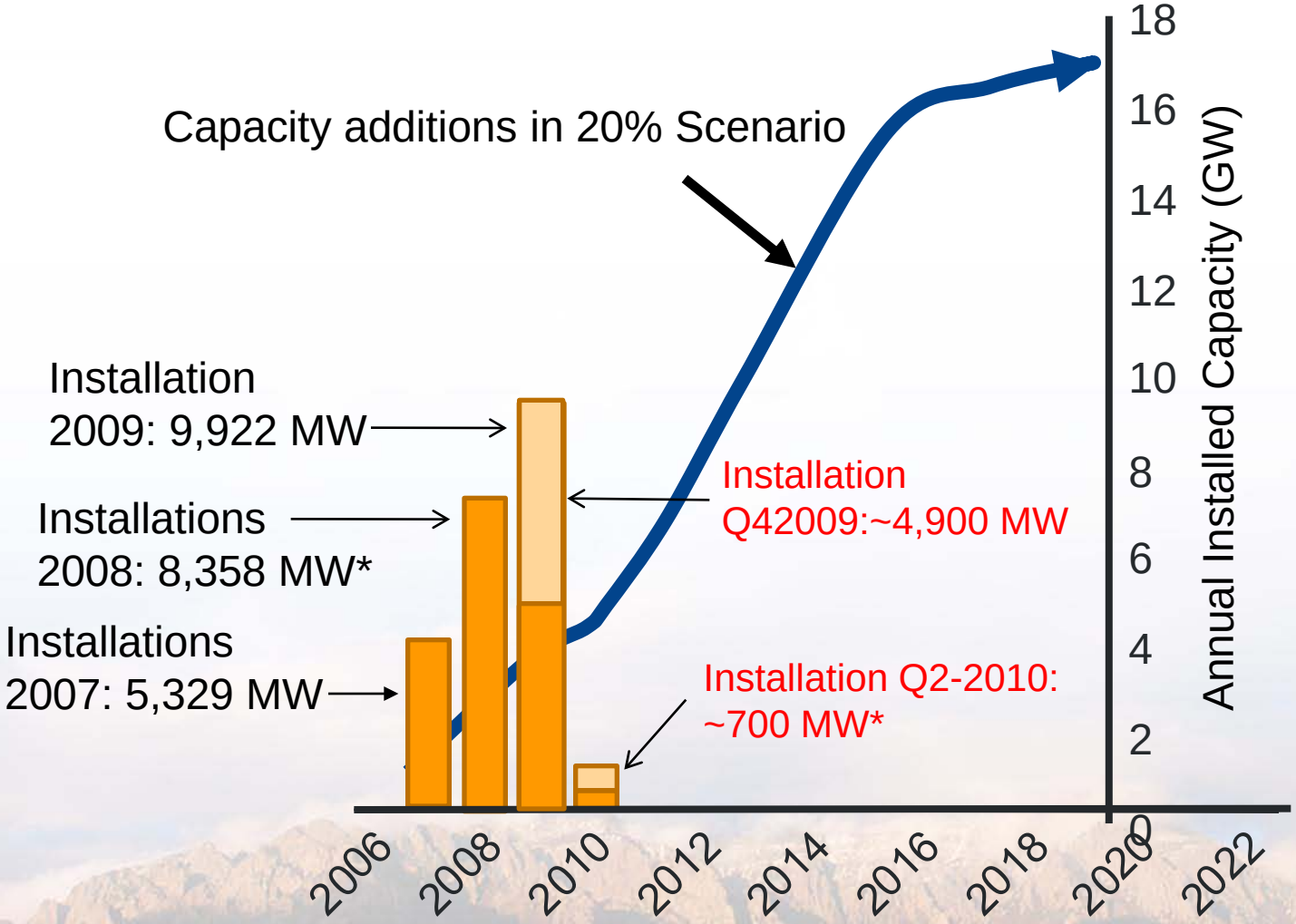


Administration's National Green Goals

- **Double renewable energy capacity by 2012**
- **10% renewable energy by 2012**
- **25% renewable energy by 2025**
- **Create 5 million new green jobs**
- **80% GhG reduction (from 1990 levels) by 2050**
- **Informed by "20% Wind Energy by 2030" report issued by DOE in May 2008**

Renewables have Strong Policy Support
from Administration & Congress

Scenario Installed Capacity vs. Current Installed Capacity



Source*: AWEA, 2010

Annual GW Installed

Wind/Radar:
Statement of Problem

- **Wind turbines are large EMI reflectors/Potential Obstructions**
  - Radar systems can not easily discriminate between turbine blade movement and aviation movement (Clutter & Doppler Shift)
  - Wind turbines can pose obstruction to aviation safety and federal agency operations (Clutter)

- **Creates significant barriers in siting and permitting**
  - Interference and impacts on operation is not well defined
  - Perceived and real effects can cause permitting impacts
  - There is no single entity responsible for approval
  - Mitigations are not readily available
  - No single entity is responsible to develop mitigations

2009 Radar Impact

Delayed .....2,100 MW
Deferred.....5,100 MW
Abandoned.....2,100 MW
TOTAL.....9,100 MW

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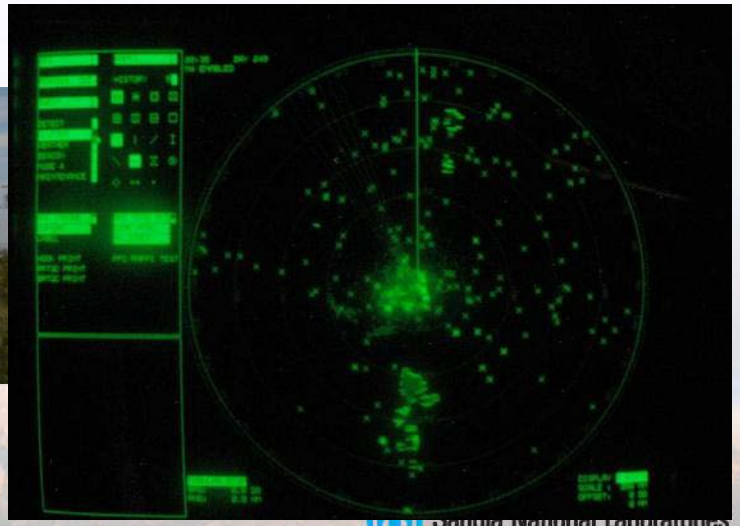
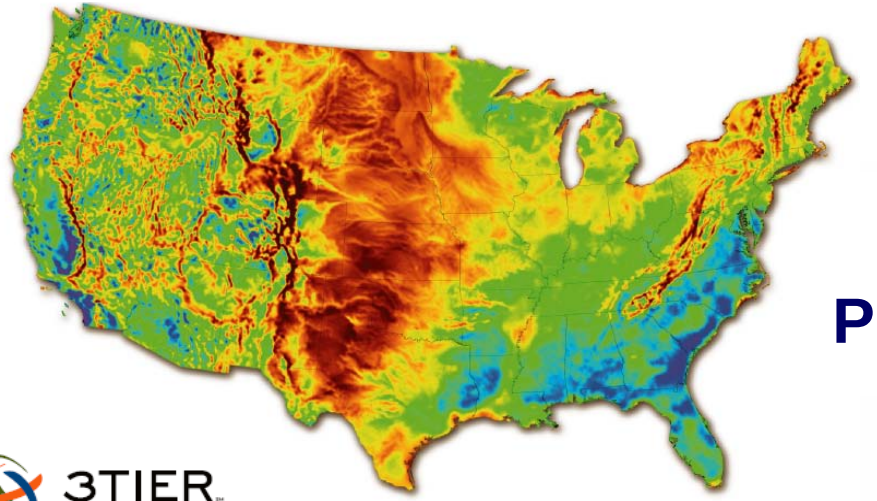
Wind-Radar – Challenges

- Software under control of radar manufacturers
- Balancing of multiple agency priorities (DOE, DOD, DHS, DOT, …)
- No single solution for process or mitigation technologies
- Mitigation needs to be developed and validated
- Impacts expected to increase as more turbines are installed
- Commercial stealth technologies not yet developed and validated
- Performance parameters and field data is limited, and privately held



Siting Impacts could be Significant

Situation Today!



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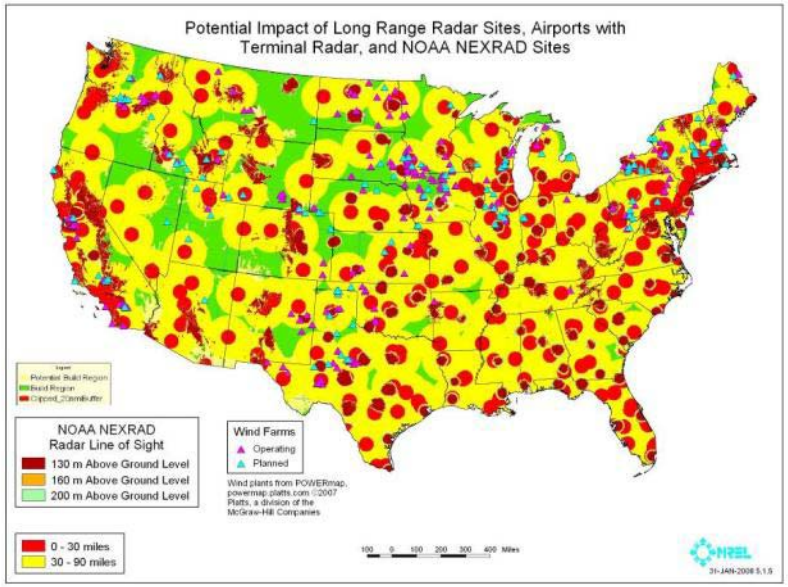
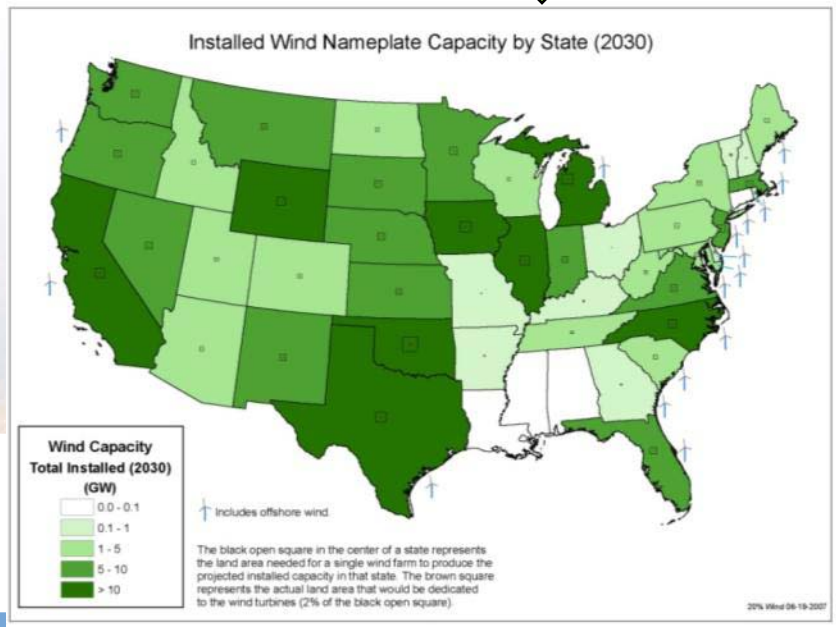
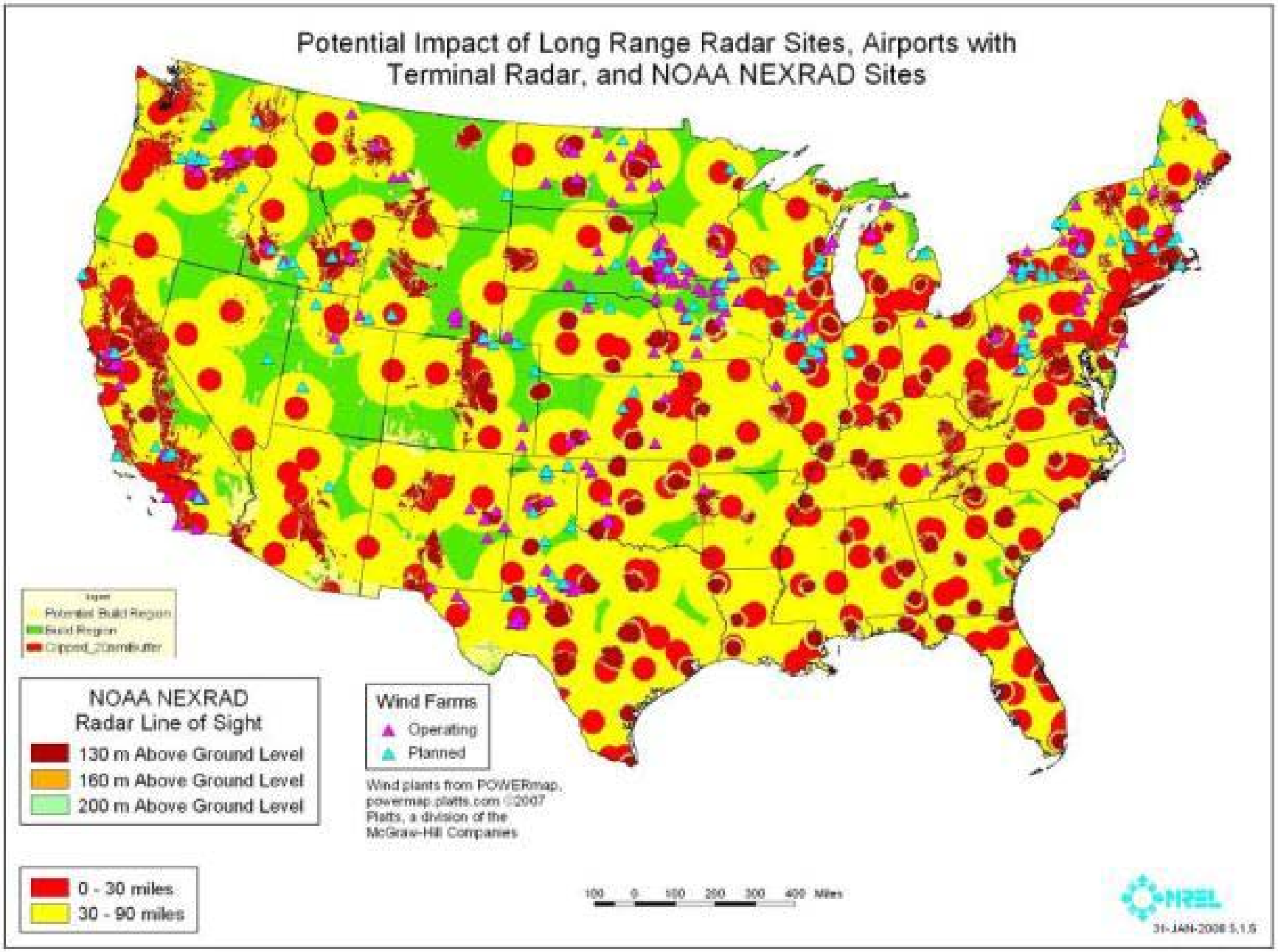
2030 Potential Impact?






Potential Impact of Long Range Radar Sites, Airports with Terminal Radar, and NOAA NEXRAD Sites
Legend
Potential Build Region
Build Region
Clipped_20miBuffer
NOAA NEXRAD Radar Line of Sight
130 m Above Ground Level
160 m Above Ground Level
200 m Above Ground Level
Wind Farms
Operating
Planned
Wind plants from POWERmap, powermap.platts.com ©2007 Platts, a division of the McGraw-Hill Companies
0 - 30 miles
30 - 90 miles
100 0 100 200 300 400 Miles
NREL
31-JAN-2008 5.1.5

Wind/Radar Program

Mitigation Strategy

Goal: Develop technology mitigation options to reduce the reflectivity of wind turbines

Challenges:

- Economics (Blades < $10/lb)
- Potential impacts to O&M strategy and cost
- Complex field experiments
- Multidisciplinary objectives and stakeholders
- Complex Radar network (mission & age)

Program Focus (Rotors):

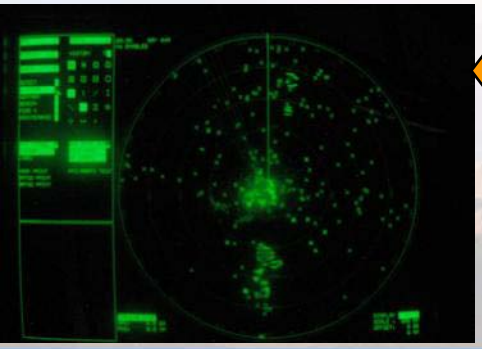
- Identify mitigation options for pre and post manufactured blades (Materials & Coatings)
- Leverage stealth technology options from other applications
- Evaluate mitigation options and identify viable options for multiple objectives (Radar cross-sectional measurement campaign)

Industry Impact:

- Mitigation options to facilitate a clear, timely, predictable Federal agency decision-making on wind siting processes

Blade Manufacturing
(Courtesy TPI Composites)

Radar Replacement and/or Software Modifications



Complexity & Cost | **Complexity & Cost**

Radar | **Wind Turbine**

•No Modifications!
•Future Impacts ?

Complex/Expensive Stealth Options

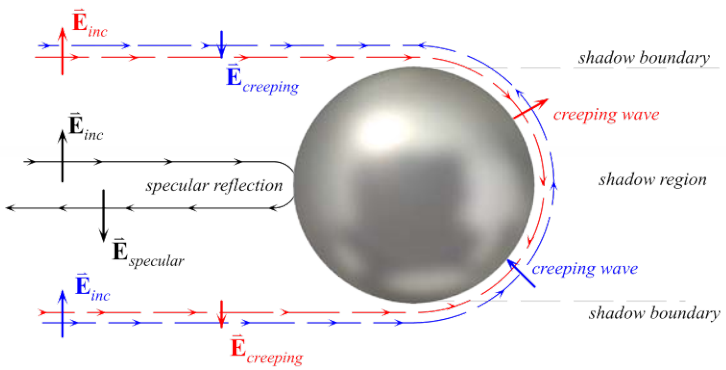
Concepts for Radar Cross Section

What is radar cross section (RCS)?

$$P_{Rx} = \underbrace{\underbrace{P_{Tx}\frac{G_{Tx}}{4\pi r^2}}_{\text{power density at target}}\ \frac{\sigma}{4\pi r^2}}_{\text{power density at the receiver, from scattering by the target}}\ \underbrace{\frac{G_{Rx}\lambda^2}{4\pi}}_{\text{effective area of receiving antenna}}$$

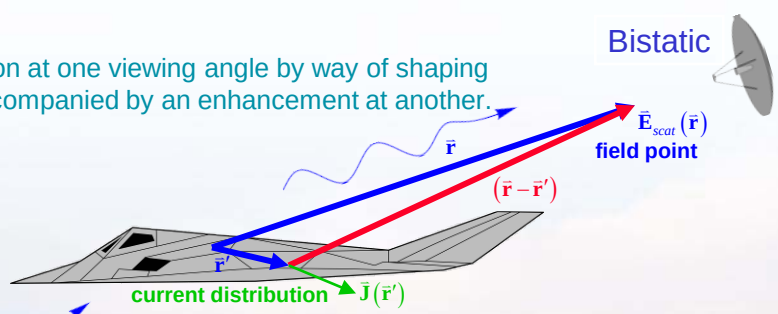
P_{Tx} = transmitted power (watt)
P_{Rx} = received power (watt)
G_{Tx} = transmitter antenna gain
G_{Rx} = receiver antenna gain
r = range to target (m)
σ = radar cross section (m^2)
λ = wavelength of signal (m)

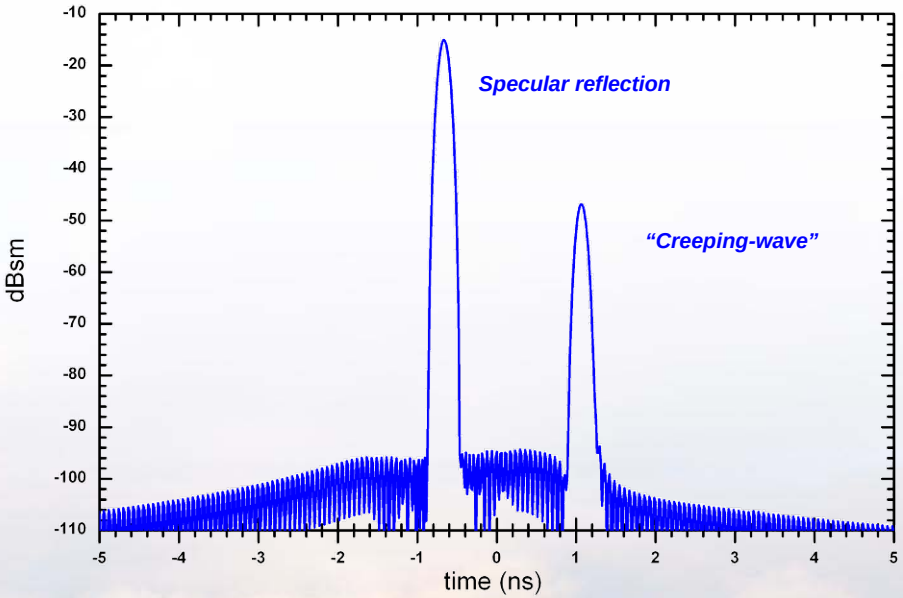
RCS is the projected area of an *isotropic* scatterer that would scatter the same power in a given direction as the *actual* target.

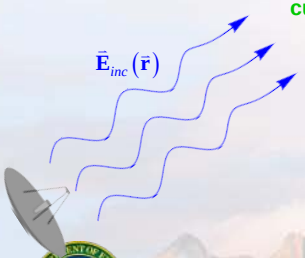


$$\sigma_{tgt} = \lim_{r\to\infty} 4\pi r^2 \frac{\vec{\mathbf{E}}_{scat}(\vec{\mathbf{r}})\cdot\vec{\mathbf{E}}^*_{scat}(\vec{\mathbf{r}})}{\vec{\mathbf{E}}_{inc}\cdot\vec{\mathbf{E}}^*_{inc}} = \vec{\gamma}(\theta,\phi)\cdot\vec{\gamma}^*(\theta,\phi)$$

RCS reduction at one viewing angle by way of shaping is usually accompanied by an enhancement at another.







Incident field induces currents on surface of target
These currents are the source of the scattered field

Monostatic

RCS depends on:
frequency, polarization, material, size, shape, orientation & observation angle!

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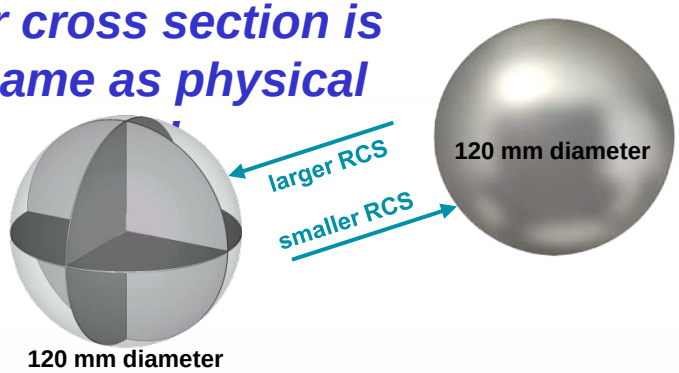
Some Myths About Radar Cross Section

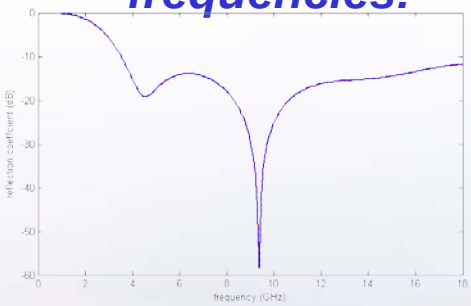
If it's not metal, the radar won't see it!

Radar cross section is the same as physical

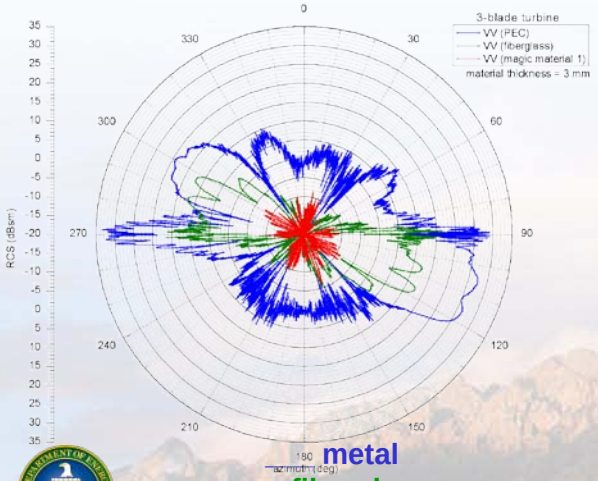


Just buy some "absorbing" paint; that will fix it!

A simple fix works for all frequencies!

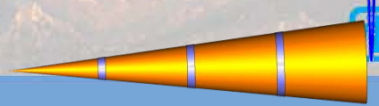


How about a cloaking device!



___ metal
___ fiberglass
___ Weston's magic material; $\varepsilon_r = \mu_r$
(this material doesn't exist, yet)

The radar won't see a few bumps and seams!



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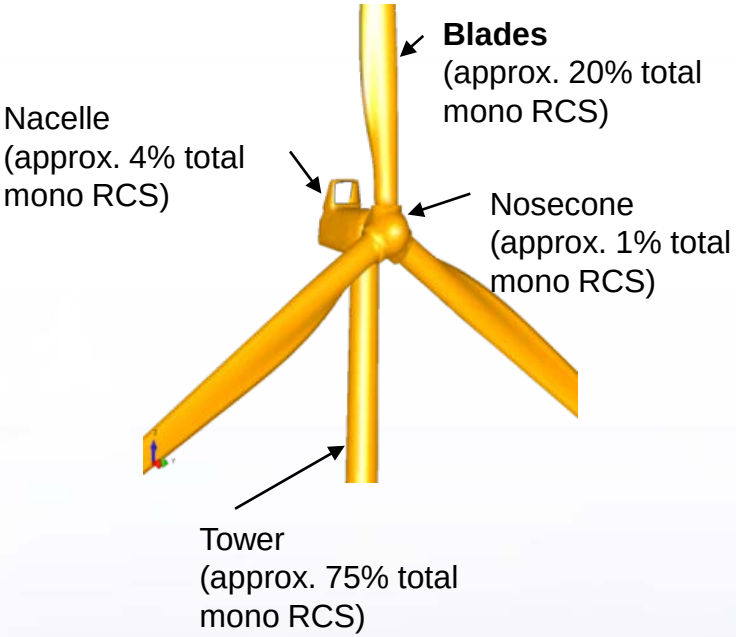
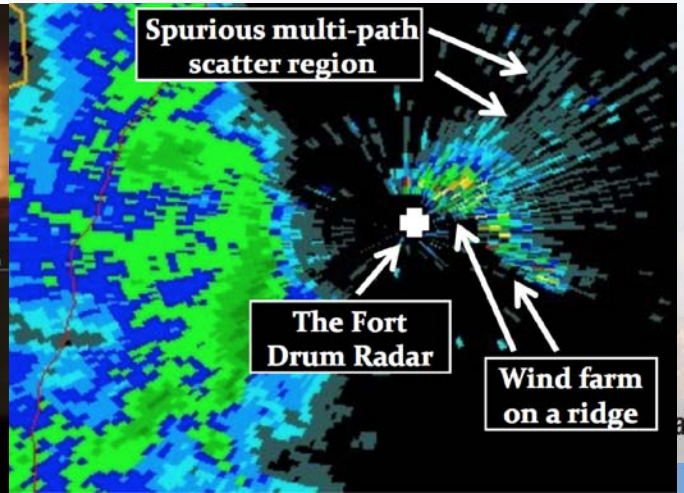
DOE/SNL's Targeted Research

Technology Approach

- Focus on wind rotor (20 dB red.)
  - Dynamic Radar cross section
    - **Yaw and Pitch**
  - Doppler effect
    - **Variable speed**
- Technology solutions transferred to other key components (tower, nacelle, etc.)



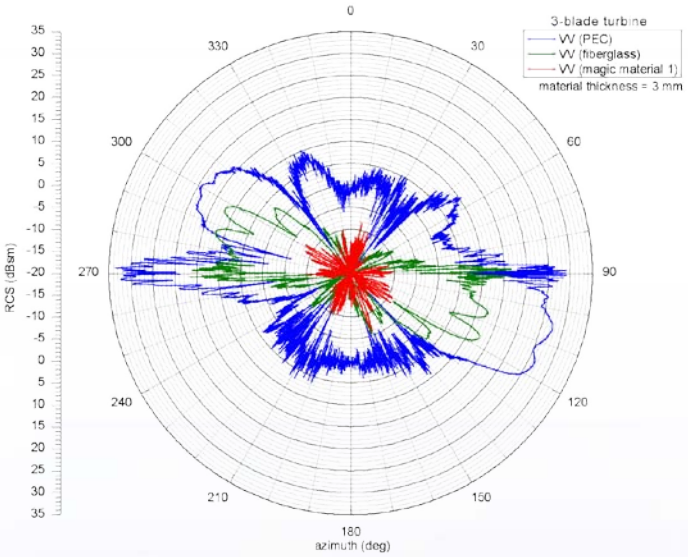
http://www.roc.noaa.gov/WSR88D/Publicdocs/WRPerspectiveonWF.pdf



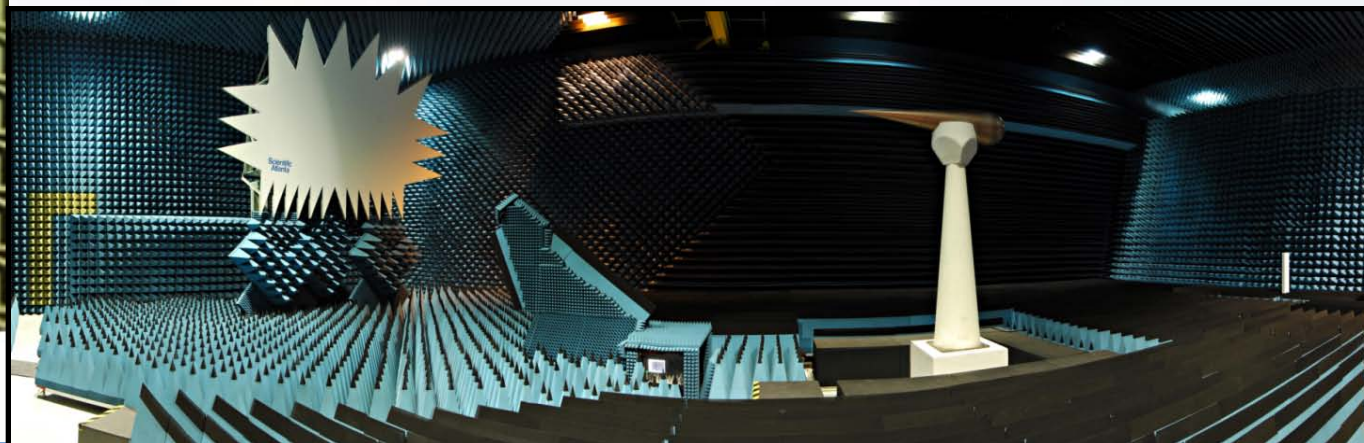
Evaluating Technology Options

Examples of radar absorbing powders, foams, CAAs, and honeycomb RASs (clockwise from top).

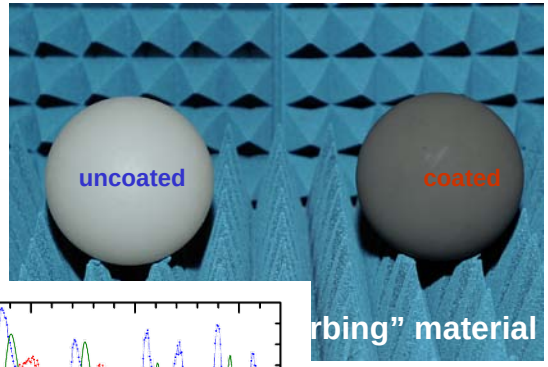
- **Options**
  - Radar absorbing materials, foams, resins, and coatings
  - Circuit analogue
- **Analysis**
  - Computational
  - Testing (SNL/FARM)
    - Facility for Antenna and Radar-cross-section Measurement



SNL FARM Facility

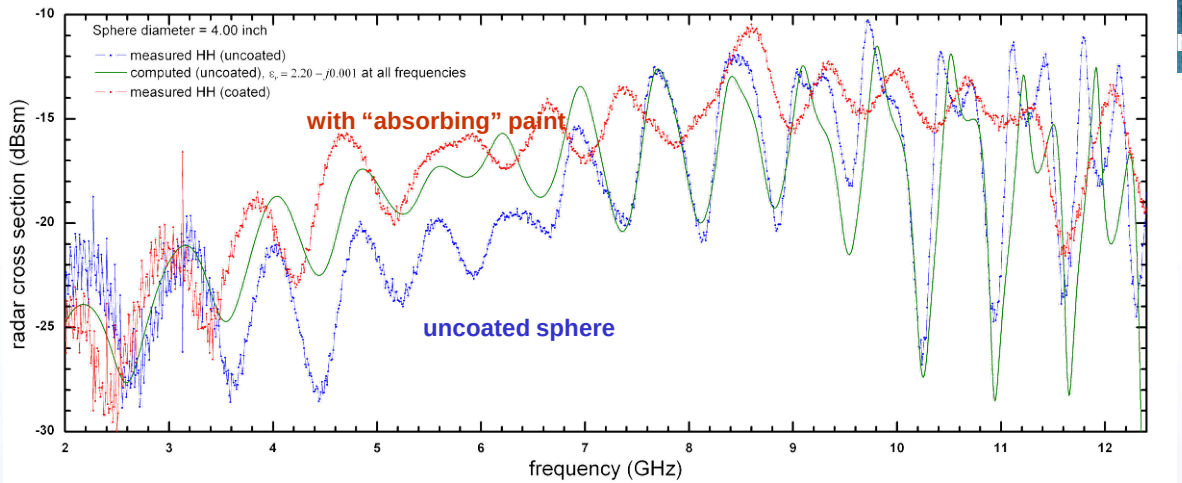


Considerations for Low Radar Cross Section



What will Not Work for Wind Technologies

- Modification of blade geometry
- Ferrite/iron-loaded elastomer–based sheet material applied by bonding
- Thin coat of "absorbing" material applied like a paint



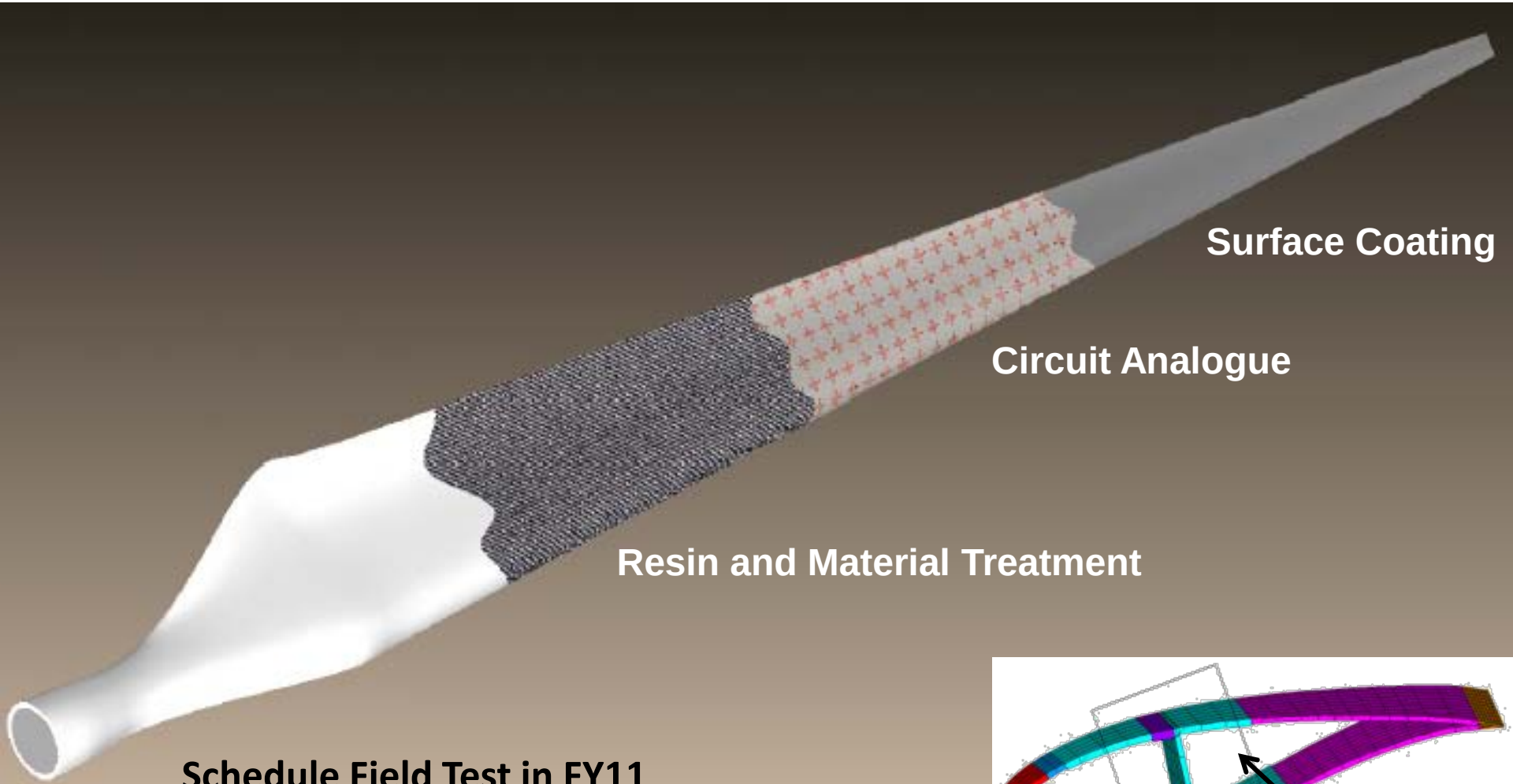
Useful technologies

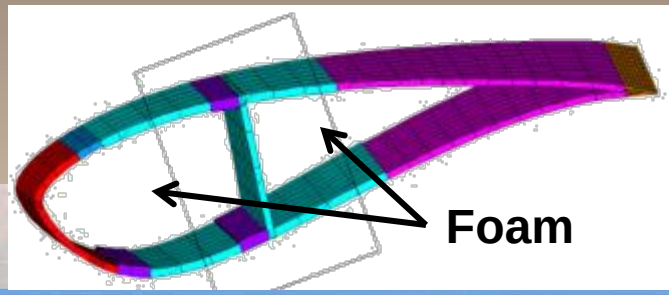
- Tailoring microwave properties of laminates integrated into lay-up (with or without metal backing)
- Thin, engineered materials
  - Frequency-selective absorber
  - Metamaterial structures (two- and three-dimensional)
  - Metal-backed or bare dielectric substrates

Challenges

- Maintain the mechanical integrity of the turbine blade
- Minimizing effects of abrasion and weathering at surface
- Maintaining tolerances on dimensions and microwave properties during manufacture
- Providing ultraviolet-exposure protection

Applying Technology Options





Schedule Field Test in FY11

Coordinated Strategy is Key

- **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
- **DOE is committed to supporting mitigation options**

Summary

- Involve all concerned parties
- Approach all issues openly and fairly
- Articulate and quantify Impact
- Address mitigation
- Research and mitigations needed
- Technology improvements are being evaluated
- **There is a critical need to balance the security and safety mission with the energy security mission**

Wind and Radar can co-exist!

Questions?

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