

Supergen



Offshore
Renewable
Energy

Andrew Garrad CBE
Founder – Garrad Hassan
Keynote Address

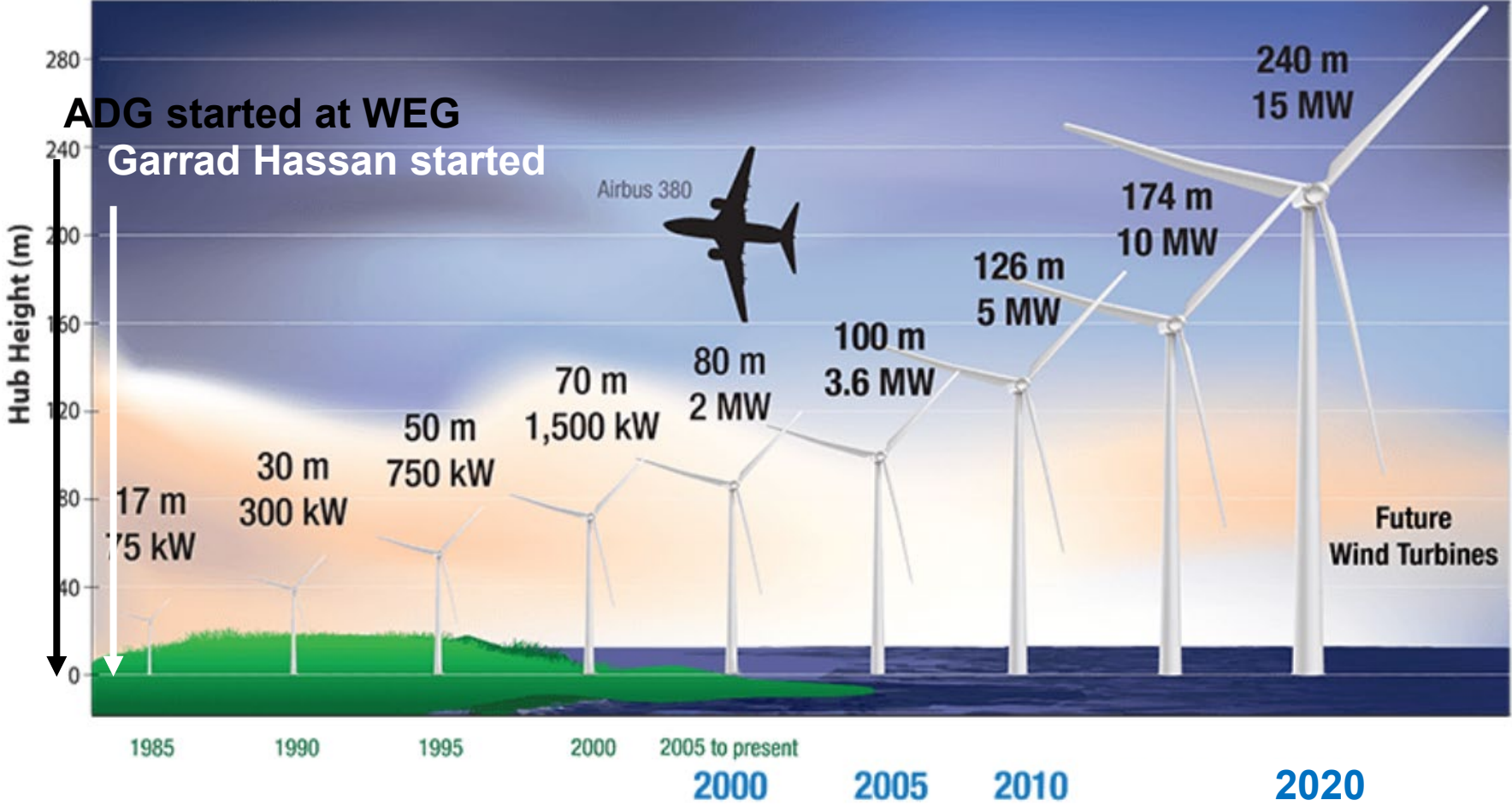
Some thoughts on large scale renewables How did we get here? What did we learn?

Supergen Plymouth

April 2024

Andrew Garrad

Wind turbine growth

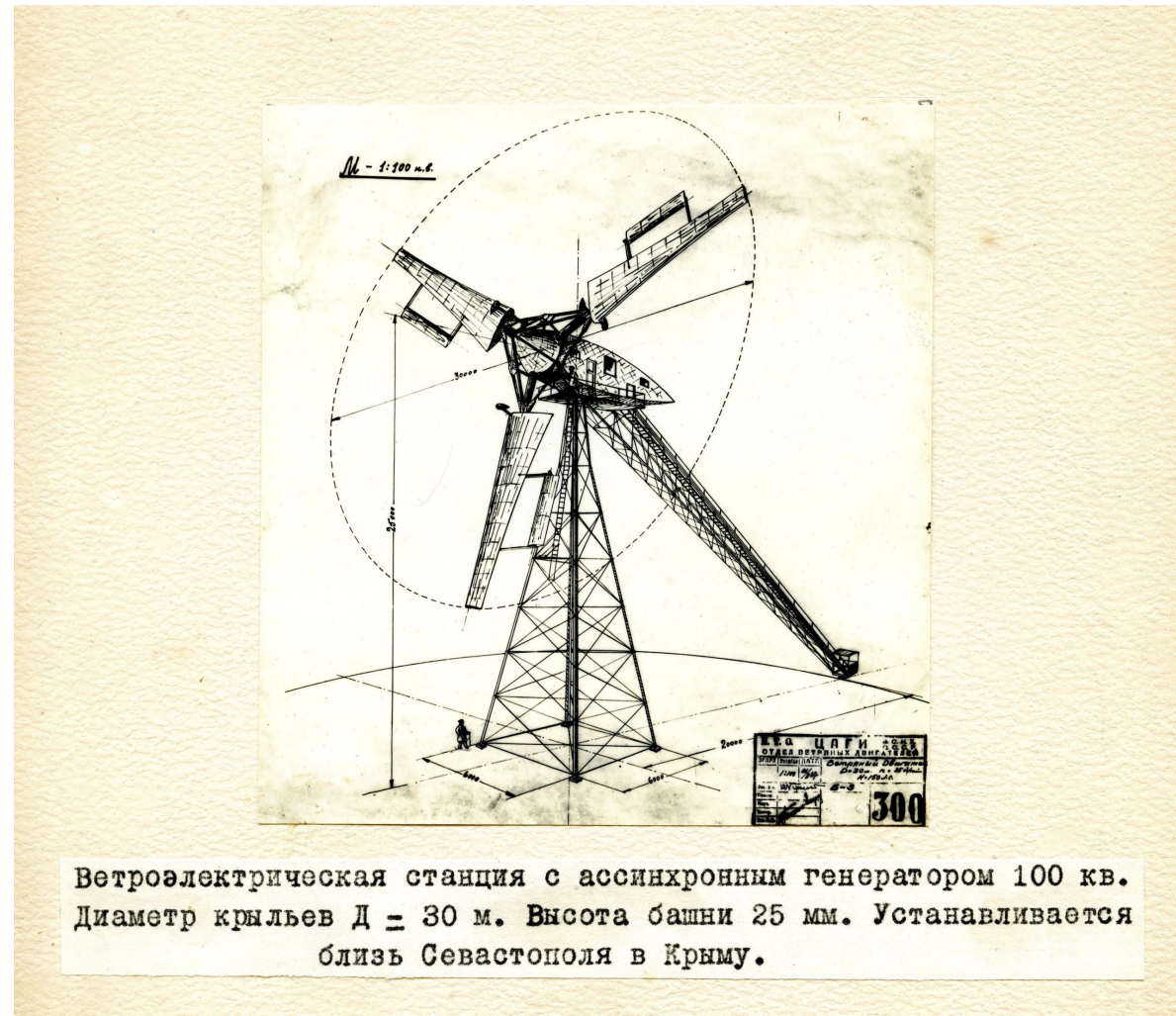


Some early history

Here are 1,000 years of innovation



Soviet 30m 100 kW 1930's



Joukowski was the boss of ЦАГИИ

Gedser, NASA, DK 1950's



Tvind 1975 54m 2 (1) MW

... a very Danish project!



Orkney - Wind Energy Group 1985 60m 3MW



Science from 1980s:

WEG

Lockheed

Boeing

Hamilton Standard

General Electric

Kaman Aerospace

MBB

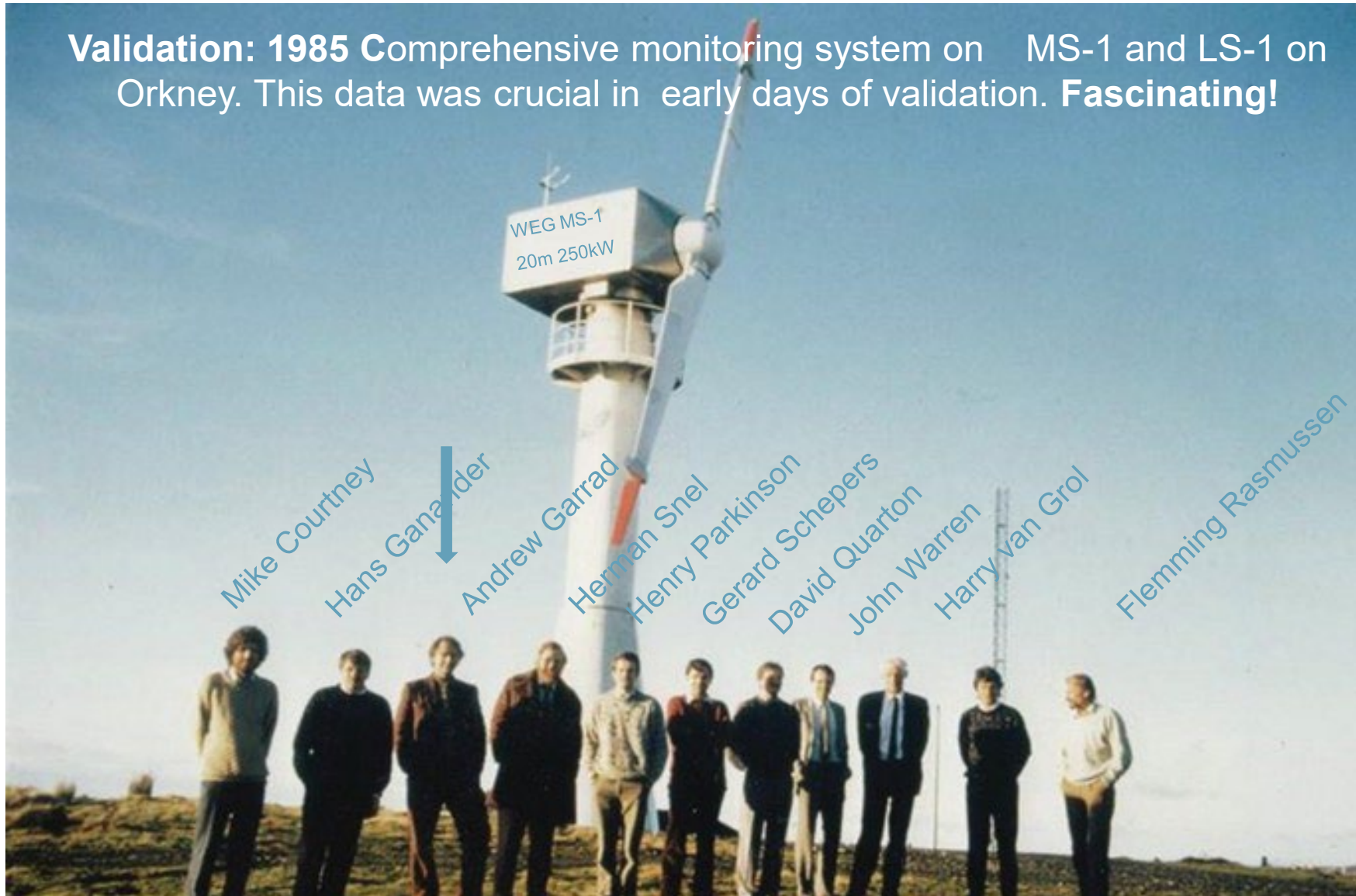
MAN

Fokker

KaMeWa



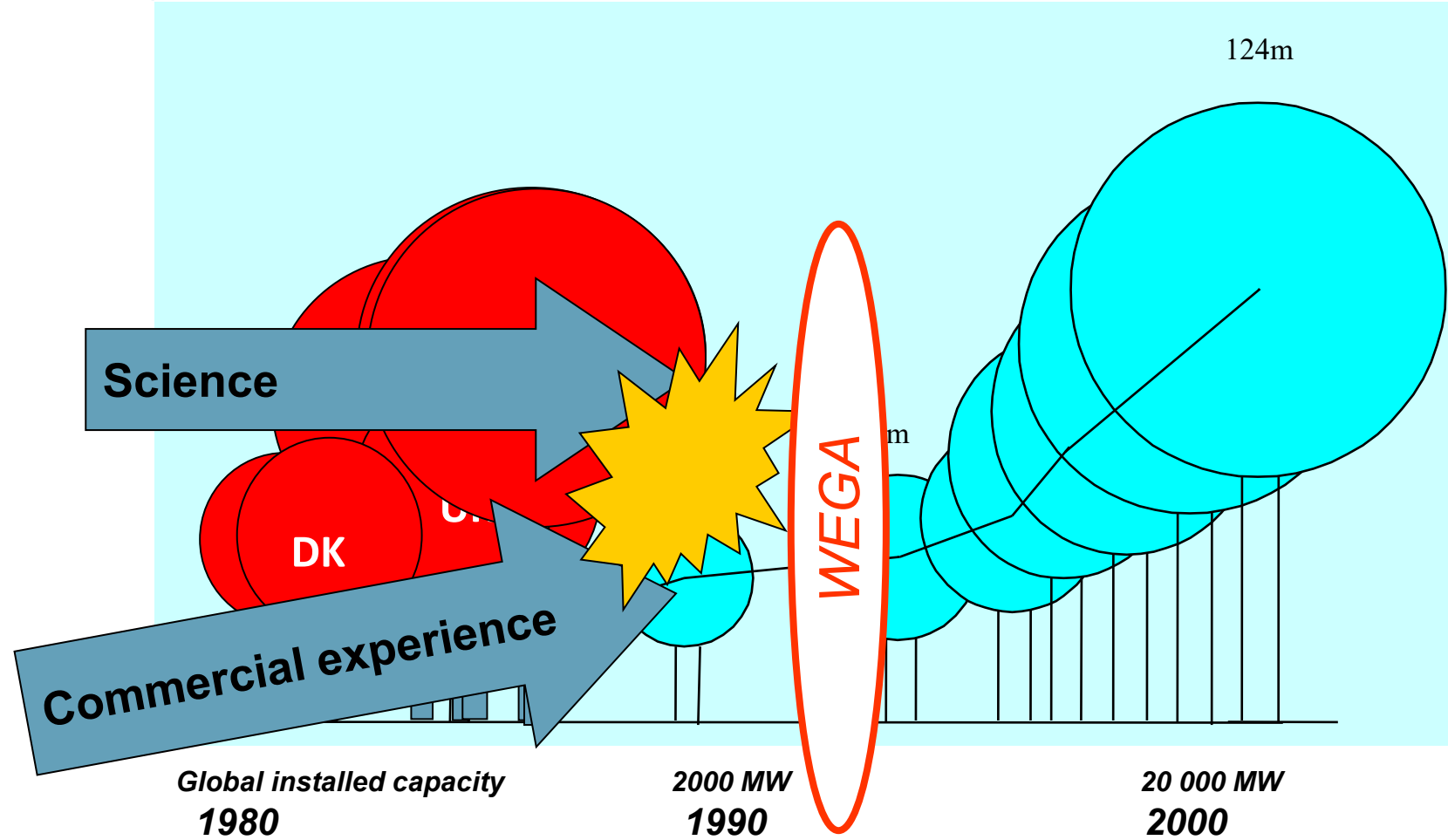
Validation: 1985 Comprehensive monitoring system on MS-1 and LS-1 on Orkney. This data was crucial in early days of validation. **Fascinating!**



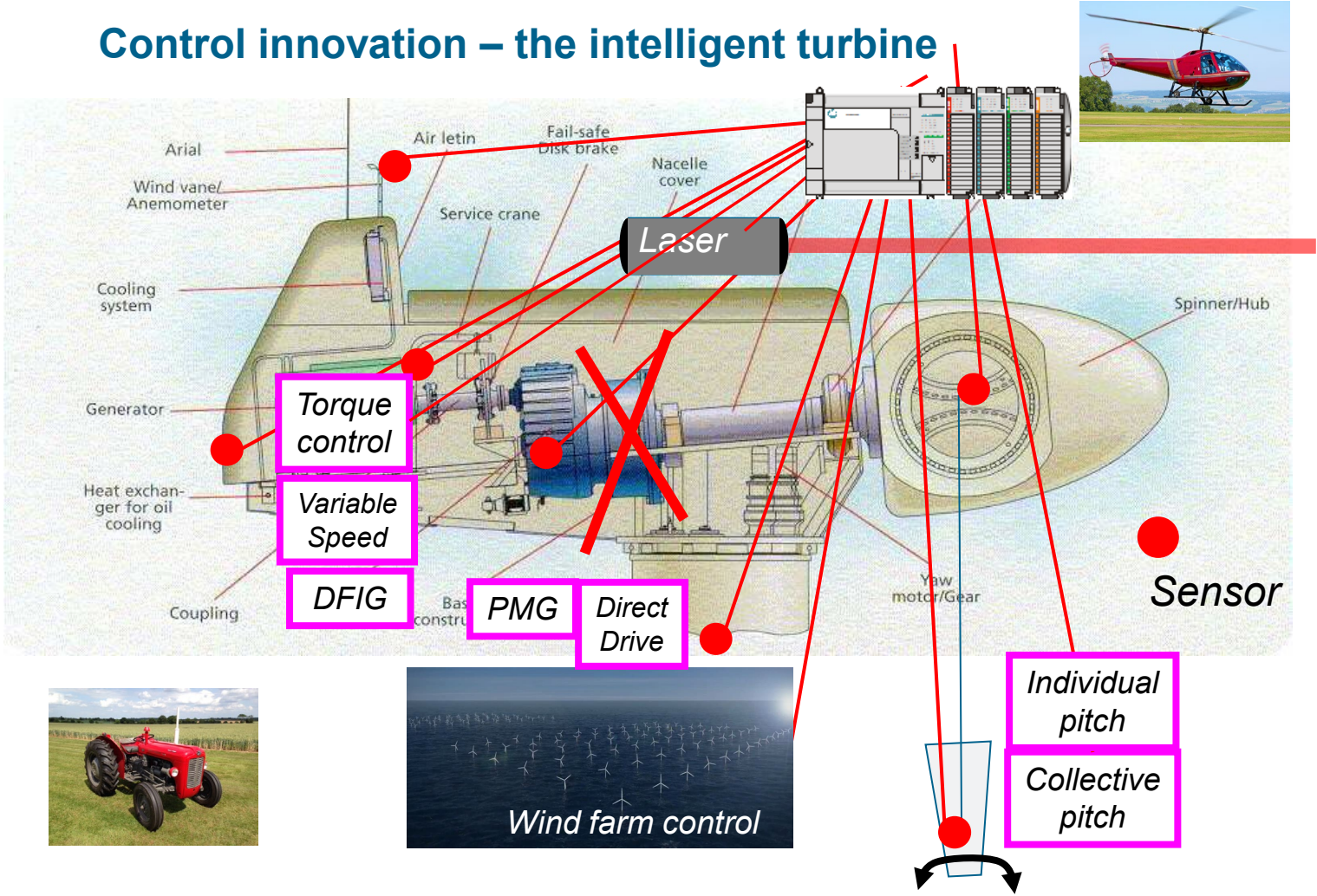
The Danish Concept of *“Powerful Simplicity”*...



The growth of commercial turbines.... and the macho machines



Control innovation – the intelligent turbine



Blade testing in the 1980's



LM blade testing today



Predictions and failures: How much do we know?

Blade damage – no lightning protection



Failure to re-torque yaw ring bolts



Initially no control then too much...



A good foundation!



Not such a good foundation!



Nature rules

Typhoons in Japan

85 m/s 1966

74 m/s 2003



14th Typhoon, Maemi, 2003

“Something is rotten in the state of Denmark”



The screenshot shows the top portion of a website. On the left, a vertical sidebar contains the text "THE ENERGY TO CHANGE THE WORLD" in yellow and green, and "RNOVA" in white. The main header is dark blue with "WINDPOWER" in large white letters and "MONTHLY" in smaller white letters below it. A navigation menu includes "Home", "News", "Analysis", "Intelligence", "Markets", and "More", each with a small downward arrow. To the right of the menu is a search bar with the text "Search" and a magnifying glass icon. The article title is "Owners must pay for gearbox failures -- Competing retrofits on offer" in a large, bold, black serif font. Below the title is a paragraph of text: "More than 130 Danish owners of 750 kW wind turbines gathered to discuss problems with gearboxes in their machines, all of which were bought from NEG Micon before its takeover by Vestas. Once the turbines are out of their warranty periods, the owners face bills of up to EUR 67,000 per machine for repairs or replacement. The purpose of the meeting was to provide information on the problems. Vestas was invited along to talk about its new offer for a solution to the problem." At the bottom left of the article content, the date "1 July 2005" is displayed in a small black font and is circled in red. To the right of the date are three circular social media icons: Twitter, Facebook, and LinkedIn.

WINDPOWER
MONTHLY

Home News Analysis Intelligence Markets More

Search

Owners must pay for gearbox failures -- Competing retrofits on offer

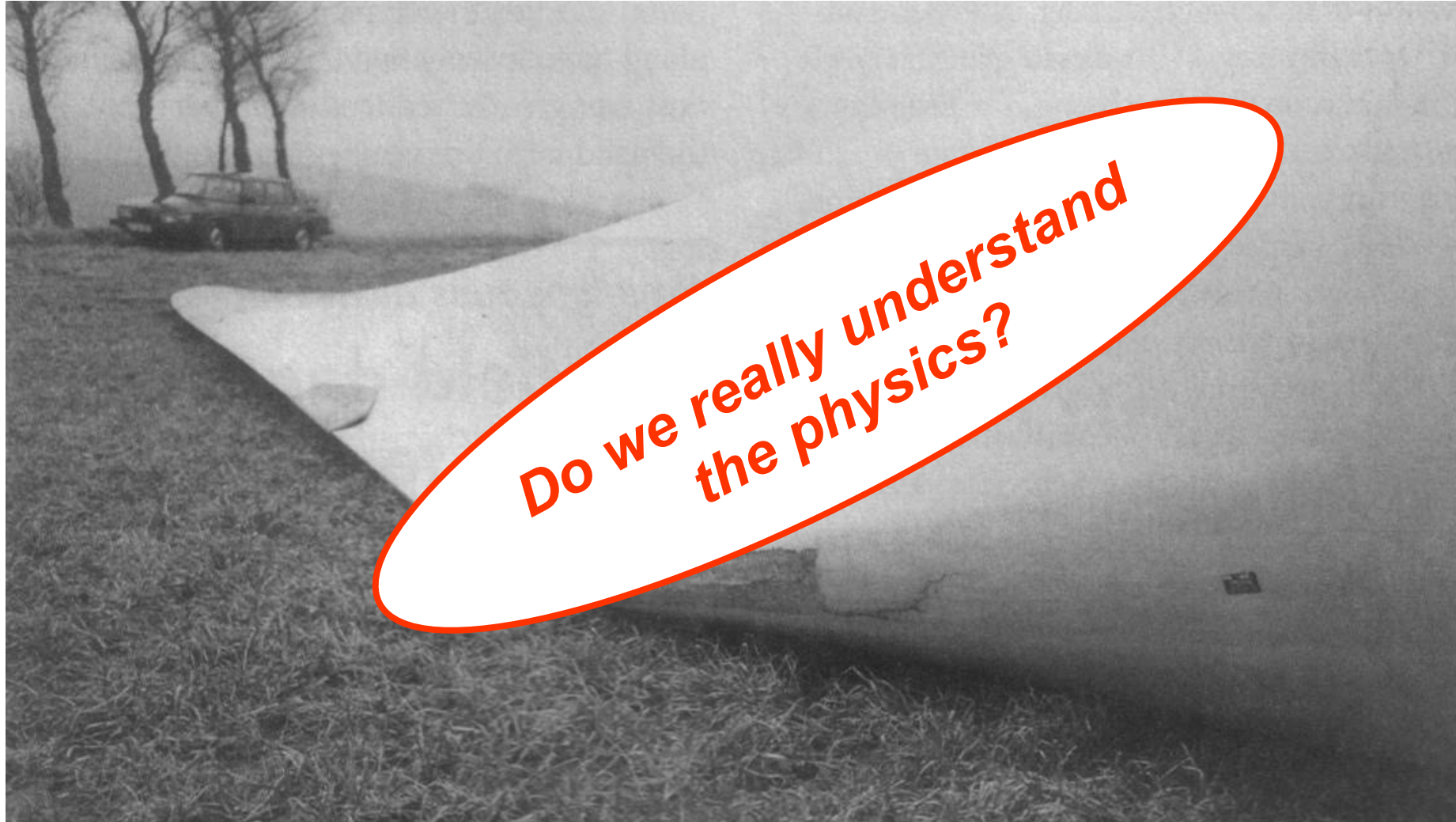
More than 130 Danish owners of 750 kW wind turbines gathered to discuss problems with gearboxes in their machines, all of which were bought from NEG Micon before its takeover by Vestas. Once the turbines are out of their warranty periods, the owners face bills of up to EUR 67,000 per machine for repairs or replacement. The purpose of the meeting was to provide information on the problems. Vestas was invited along to talk about its new offer for a solution to the problem.

1 July 2005

Catastrophic blade edgewise vibrations 1998

This was a shock!



Different types of failure

Nature is difficult to predict

Failure is understood but not predicted

Failure to observe good practice

Failure is understood and expected

Too adventurous a design

Failure is understood and should have been expected

The unknown in design

Failure is neither understood nor expected

Do we understand enough to continue?

Interview: Wind turbine 'arms race' must stop – Henrik Stiesdal and Andrew Garrad

The 'arms race' of ever-larger, more powerful wind turbines must stop, industry pioneers agreed – though Henrik Stiesdal and Andrew Garrad disagreed about who should make the move to limit sizes.

by Craig Richard



Our guilty secret



WIND ENERGY IN YOUR SNEAKERS

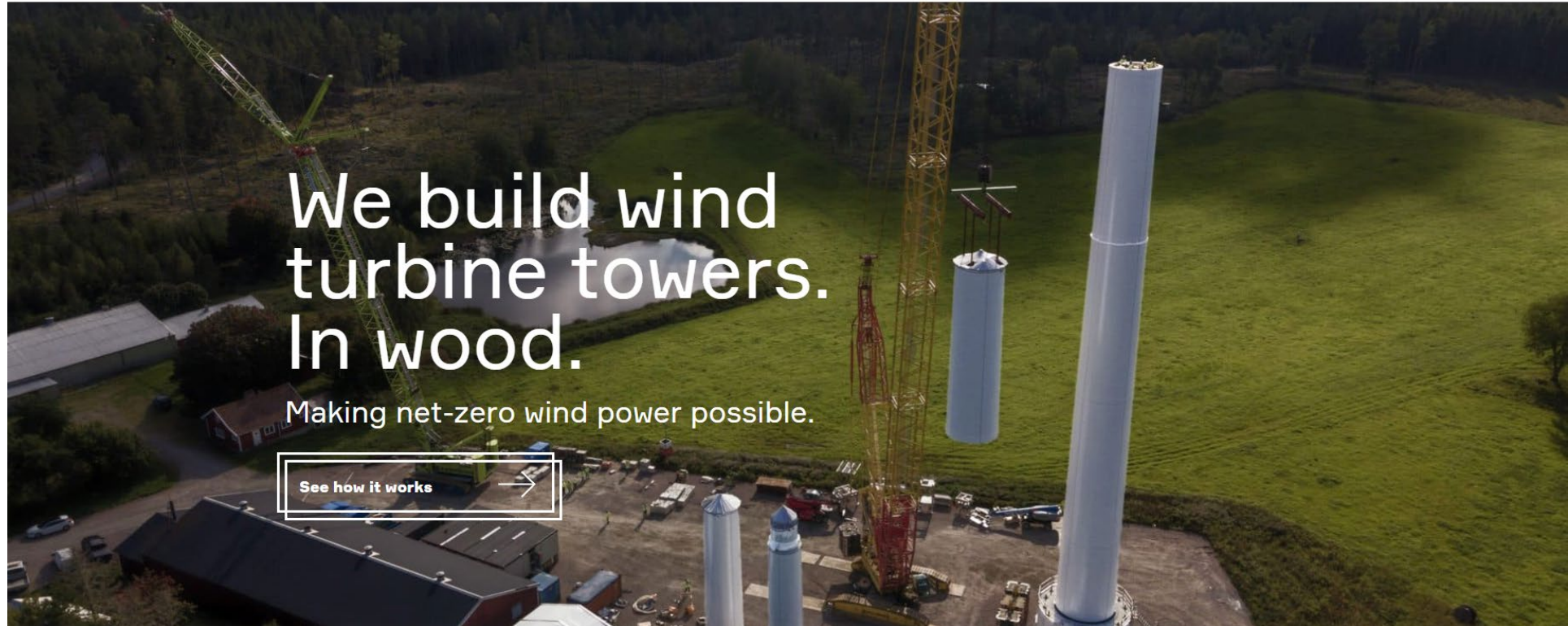
ACCIONA Energía and El Ganso create the first sneaker with recycled wind blade sole

Steel expensive? 100m wooden tower

modvion

[The future](#) [The product](#) [The company](#) [The projects](#)

[News & Press](#) | [Investors](#) | [Careers](#)

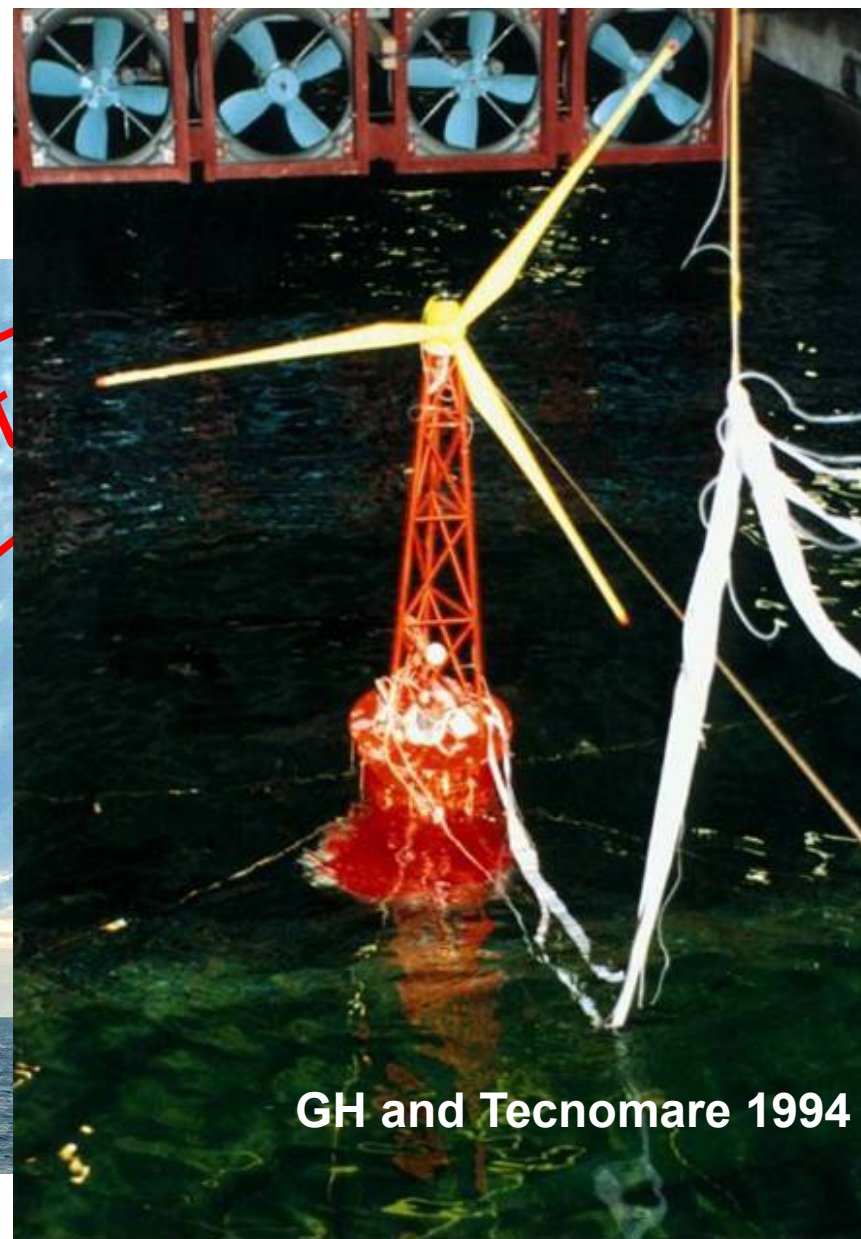


We build wind
turbine towers.
In wood.

Making net-zero wind power possible.

[See how it works](#) →

Floating offshore turbines





$36 \times 400\text{kW} = 14 \text{ MW}$
 $36 \times 1 \text{ MW} = 36 \text{ MW}$

Vestas multi-rotor 4 x V29 installed 2016



Wind Catching Systems (2024)



How mature is the wind industry?



Is consensus = maturity?

Consensus is boring!... But comfortable

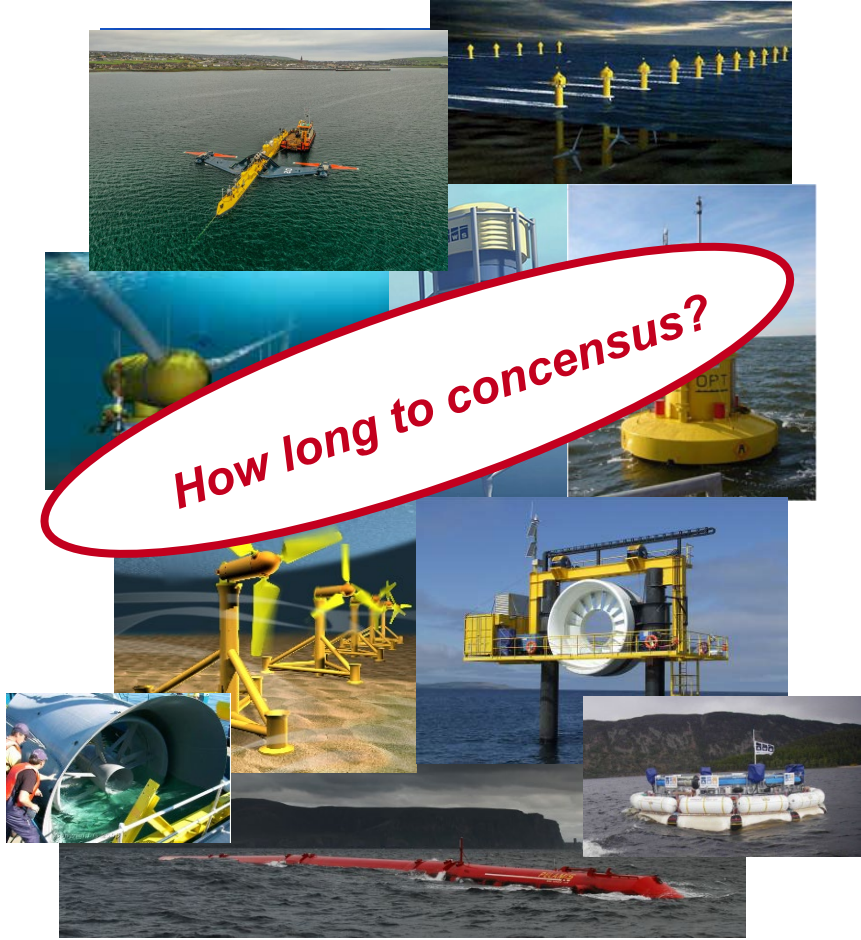
Consensus is an easy investment

Automotive is a mature industry



Marine technology now

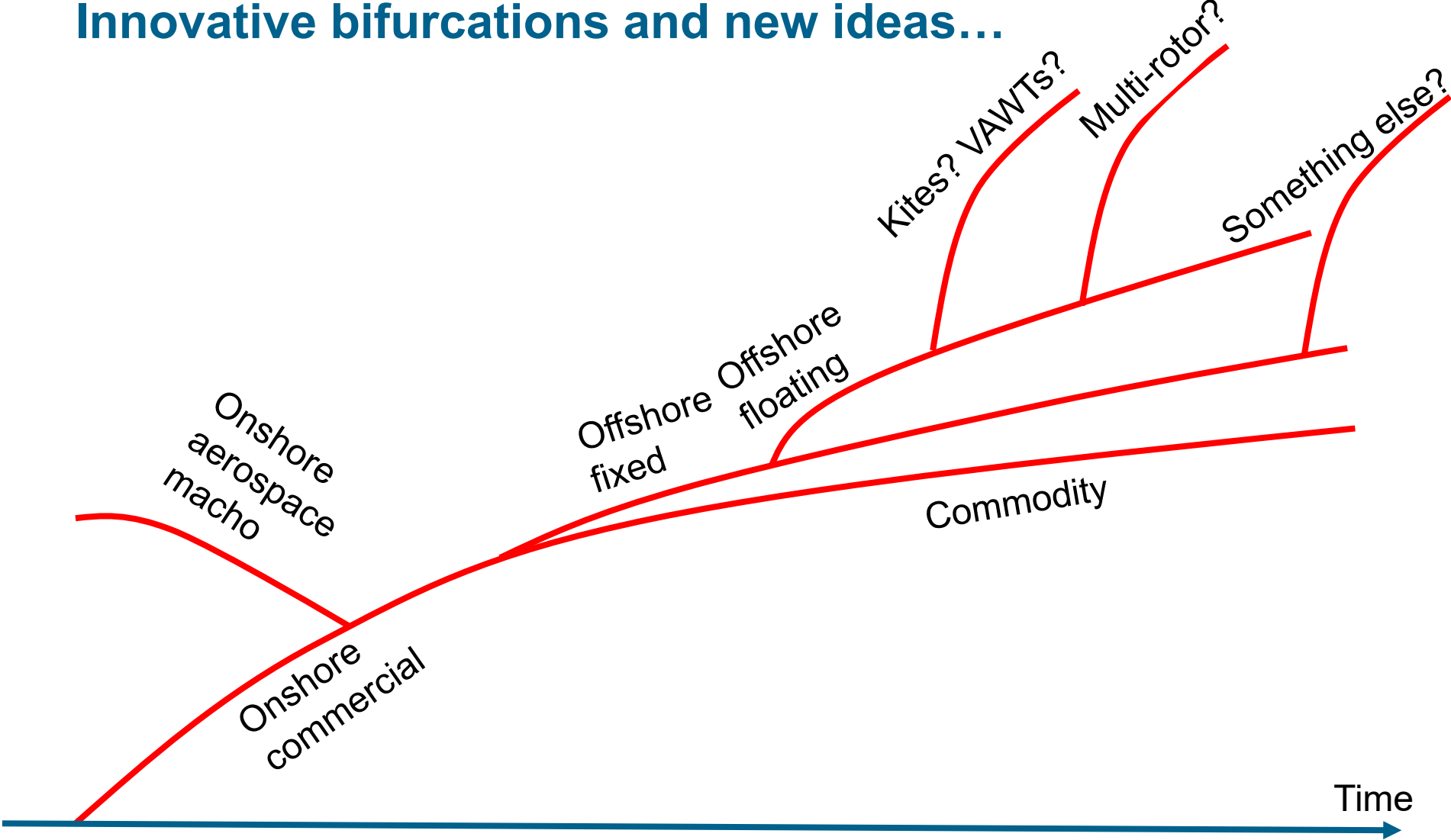
Wind turbines 35 years ago



How long to concensus?



Innovative bifurcations and new ideas...



China!





SYMBOLIC COMPUTING AS A TOOL IN WIND TURBINE DYNAMICS

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(Received 26 October 1984, and in revised form 25 September 1985)

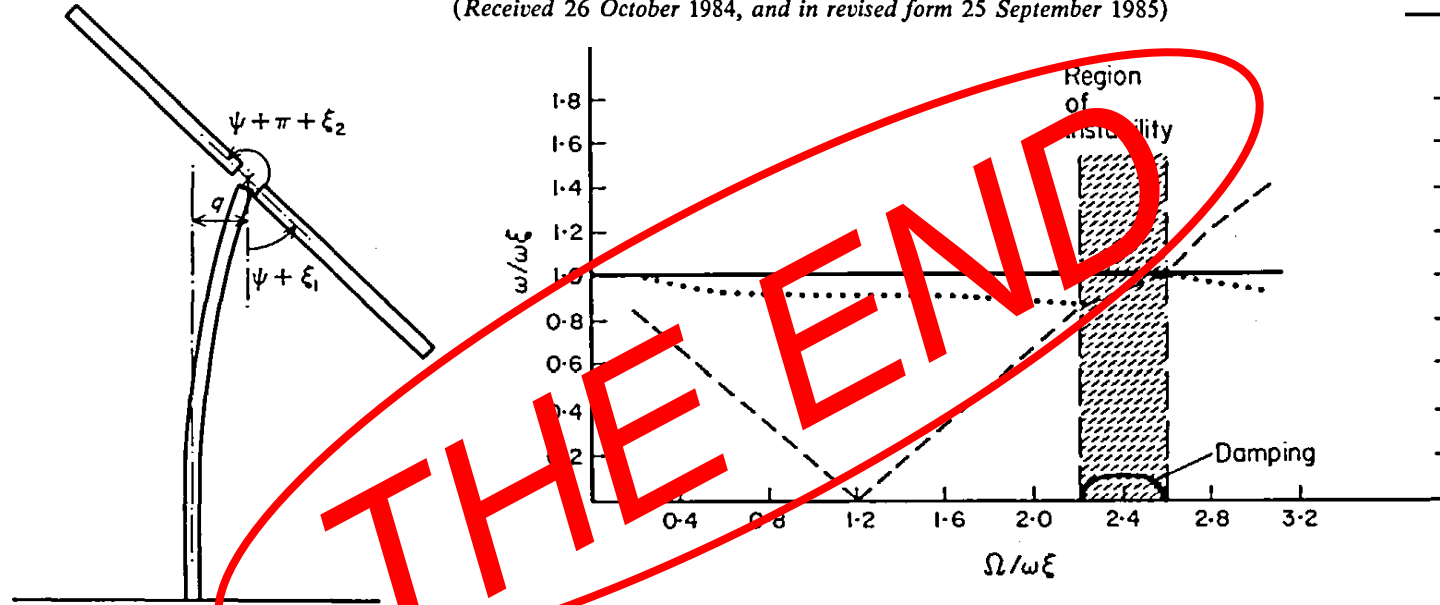


Figure 3. System frequencies of three degree of freedom model. —, Rotor collective mode; ---, rotor cyclic mode; ···, tower lateral mode.

After considerable manipulation the velocity of a point on the rotor can be expressed as

$$\begin{aligned}
 \mathbf{V}_6 = & [T_{\bar{\psi}}]^T [T_{\theta_z}]^T [T_{\theta_x}]^T [T_{\theta_y}]^T \dot{\mathbf{n}}_1 + [T_{\bar{\psi}}]^T [T_{\theta_z}]^T [T_{\theta_x}]^T (\dot{\theta}_y \times ([T_{\gamma}] \mathbf{R}_7 + [T_{\theta_x}] [T_{\theta_z}] \mathbf{n}_2)) \\
 & + [T_{\bar{\psi}}]^T [T_{\theta_z}]^T (\dot{\theta}_x \times ([T_{\gamma}] \mathbf{R}_7 + [T_{\theta_z}] \mathbf{n}_2)) + [T_{\bar{\psi}}]^T [\dot{\theta}_z \times ([T_{\gamma}] \mathbf{R}_7 + \mathbf{n}_2)) \\
 & + \dot{\bar{\psi}} \times [T_{\gamma}] \mathbf{R}_7 + [T_{\gamma}] (\dot{\mathbf{R}}_7 + \dot{\gamma} \times \mathbf{R}_7),
 \end{aligned} \tag{2}$$