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Characteristics of The Wind Turbine Blades Industry

Jacques Nader & Peter Fuglsang - Siemens Wind Power

Outline

- Facts on Siemens Wind Power
- Company growth and Intro to the Boulder Center of Excellence
- Characteristics of The Wind Turbine Blades Industry
  - Growth in Rotor Size
  - Manufacturing Characteristics
  - Blade Design and Innovation
- Challenges and long term outlook

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Siemens Wind Power
Facts at a glance

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Siemens Wind Power facts

- One of the world's leading suppliers of wind power solutions
- Acquired Danish wind turbine manufacturer Bonus Energy A/S in 2004
- Total Installed Base: > 17,600 turbines with ~ 35 GW capacity
- 2016 Installed base : > 1,370 turbines with > 4 GW capacity
- ~14,500 employees globally incl. Wind Service

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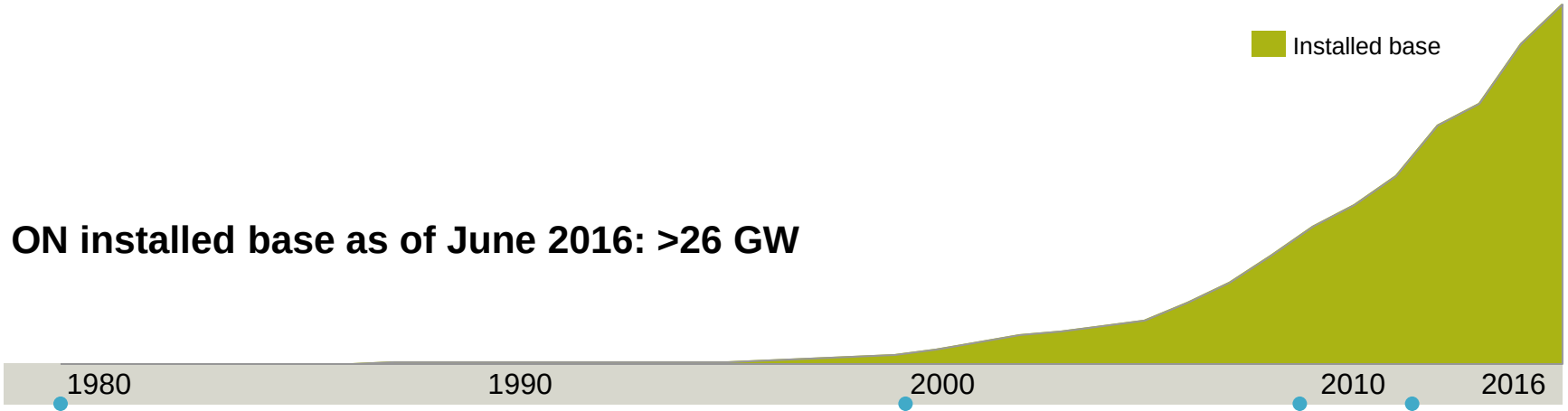
Onshore Wind – Siemens with considerable experience and track record of installed projects

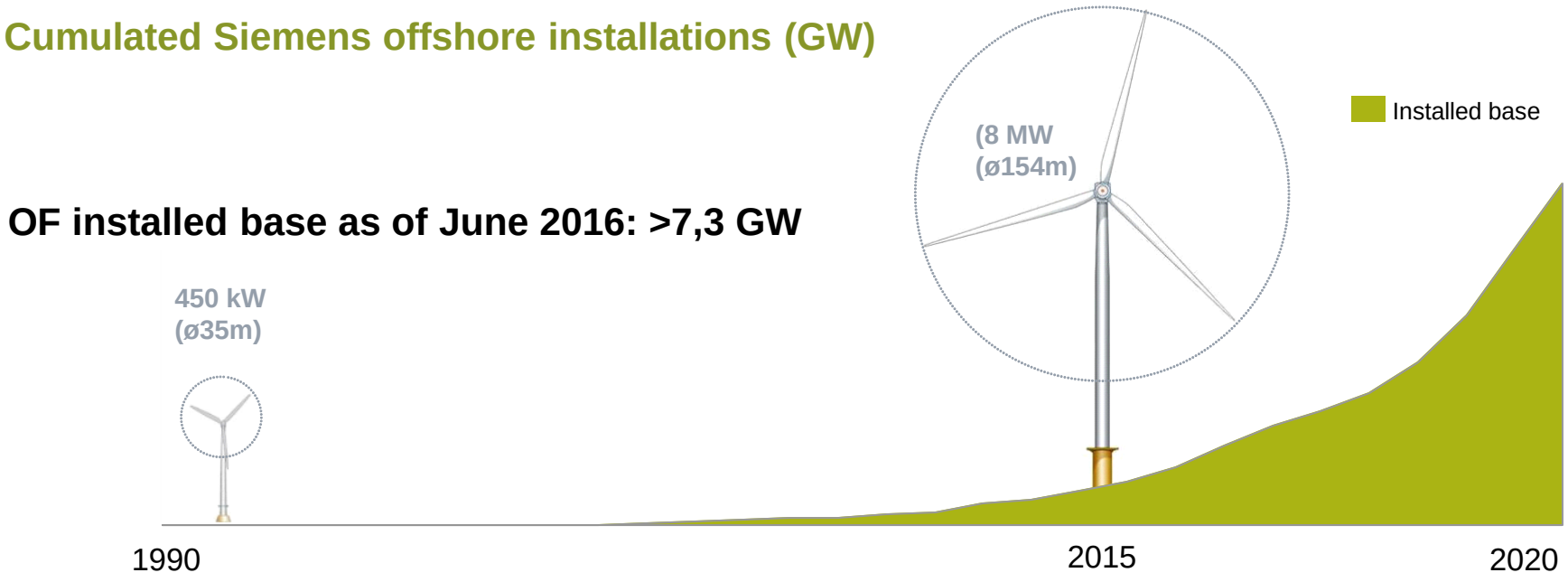
Cumulated Siemens onshore installations (GW)



ON installed base as of June 2016: >26 GW

Offshore Wind – Leading player with >7,3 GW installed base in strongest growing market

Cumulated Siemens offshore installations (GW)



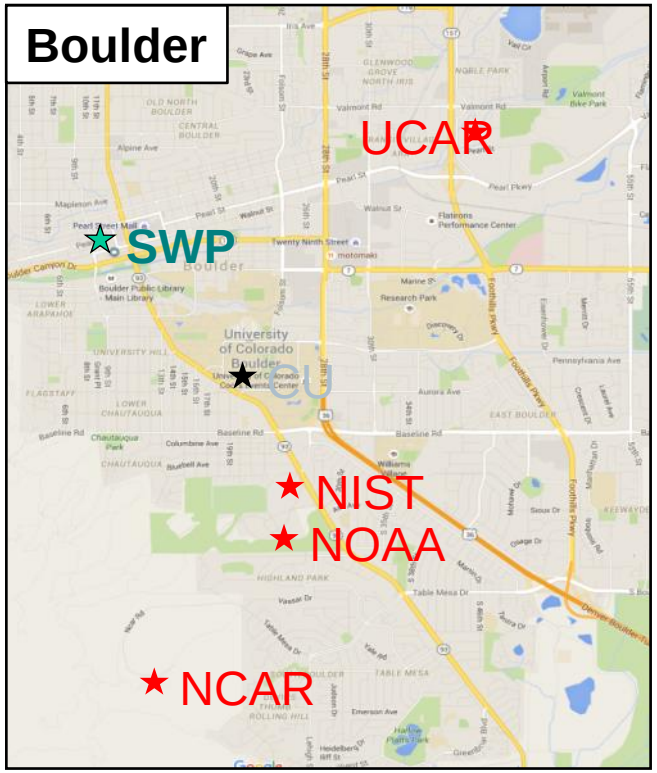
OF installed base as of June 2016: >7,3 GW

Wind Turbine Blade R&D Center of Excellence in Boulder, Colorado

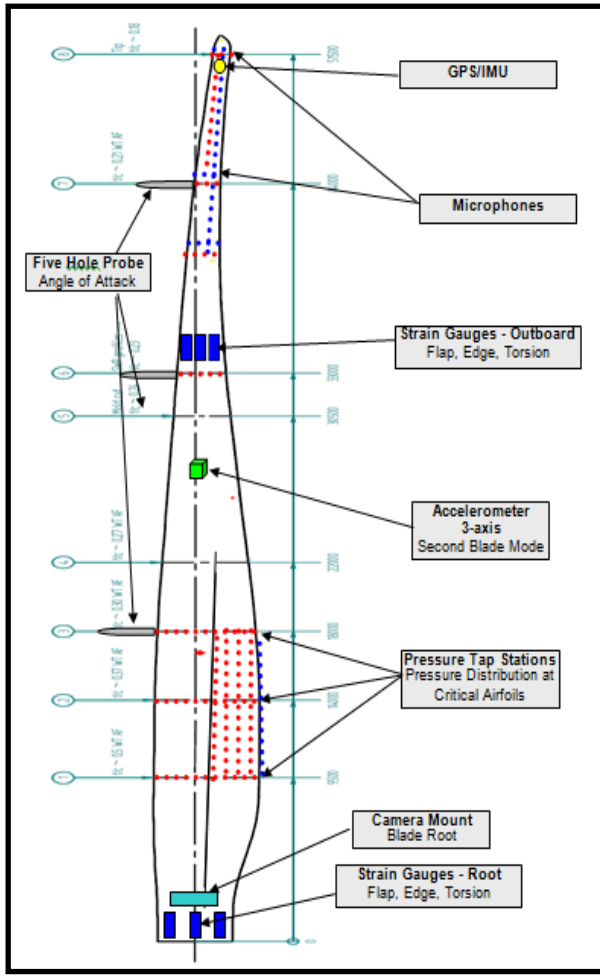
- Established in 2008
- 50 full-time engineers
- Rotor research, design and technology
- 30% PhD & 70% Masters
- Investing in American engineering
- Global footprint

Attractive Location for Top Talent:

- Forbes: “Boulder Tops List of America’s Smartest Cities”
- Money: “Louisville Best Places to Live”



NREL-SWP CRADA Test Turbine



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Characteristics of The Wind Turbine Blades Industry

GROWTH IN ROTOR SIZE

MANUFACTURING

DESIGN & INNOVATION

The most dramatic and overwhelming representation of innovation – the growth in size

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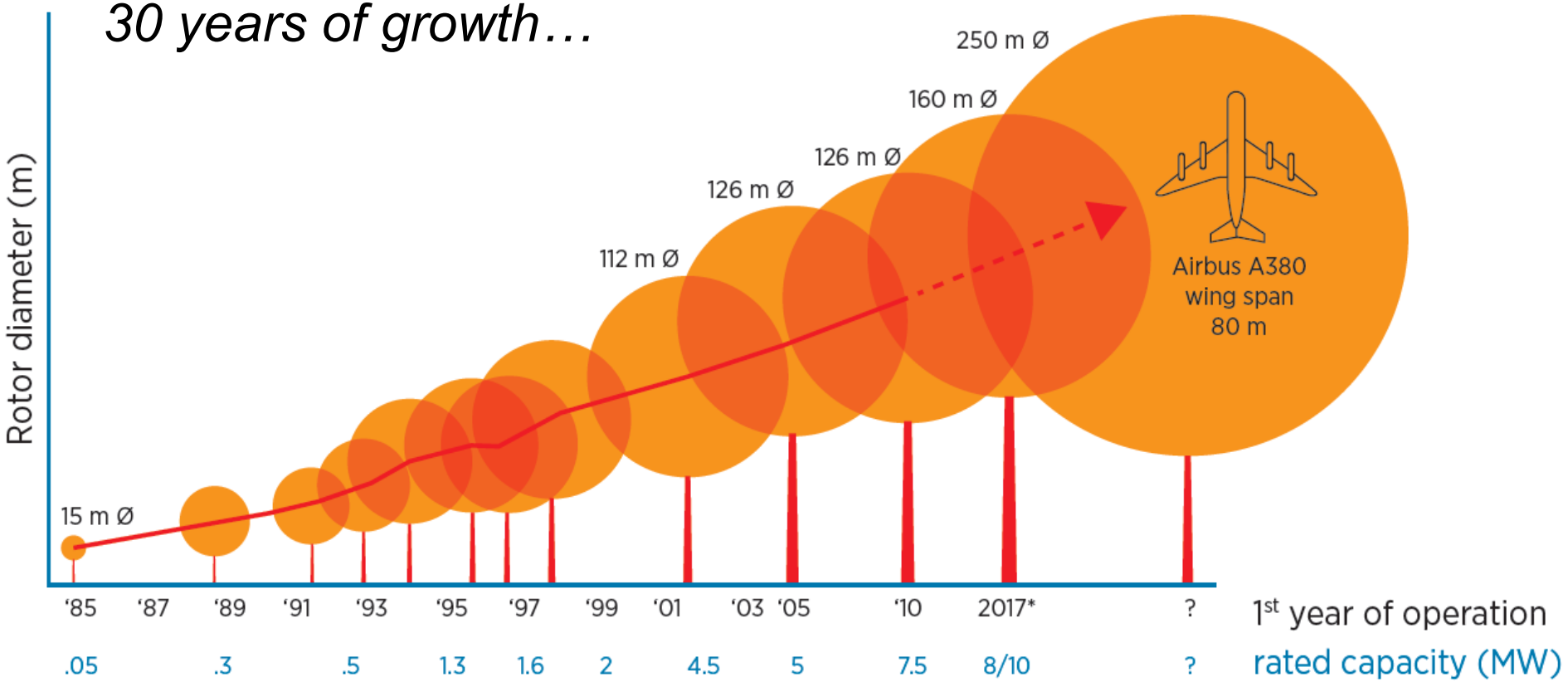
30 years of growth…



** Expected*

Source: IRENA, EWEA

Driven by strong market growth

Relatively short product market cycle time

Fundamental changes in shape and design

30 years of blade development scaled to the same size

75 m blade for SWT 8.0 MW

5 m blade from Bonus 27 kW

We have come a long way…

Fundamental changes in shape and design

30 years of blade development scaled to the same size

Two blades scaled to same size

Fundamental changes in shape and design

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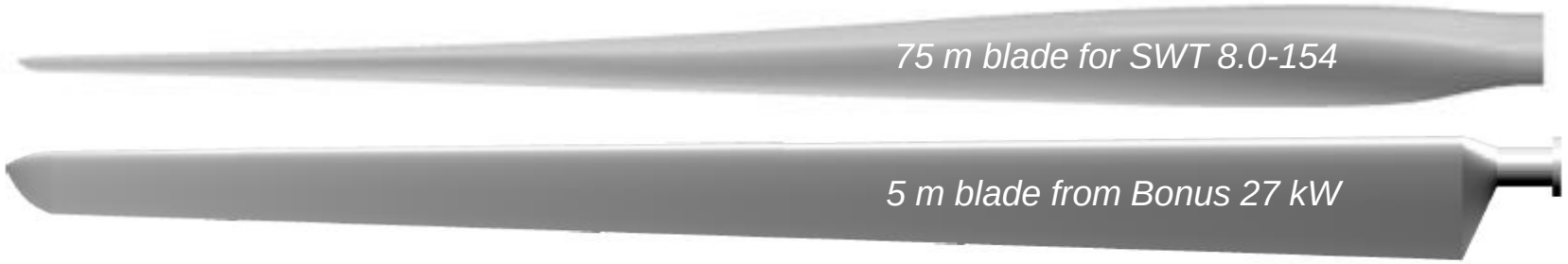
Two blades scaled to same size



Did You Know?

- Profiles changed from 1930s aircraft types to modern custom-made types
- Solidity changed from ~10% to much less than 5% (Blade area divided by swept area)
- A75 m scaled version of the 27KW blade would weight over 50 Tones (Approximately the weight of 30 mid size cars)

SWP 8.0-154 with 75 m blades

One of the world's largest fiberglass component cast in one piece

Did You Know?

- 75 m long blades and a rotor diameter of 154 m.
- Blade weight of 25 tons equal to 16 mid-sized cars.
- The rotors swept area is equivalent to 4½ football fields.

The 154 m rotor for the 8.0 MW is a large piece of equipment …Here with an Airbus A380

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Prototype installation ...

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75 meter blade mould …

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B75 blade, during transportation

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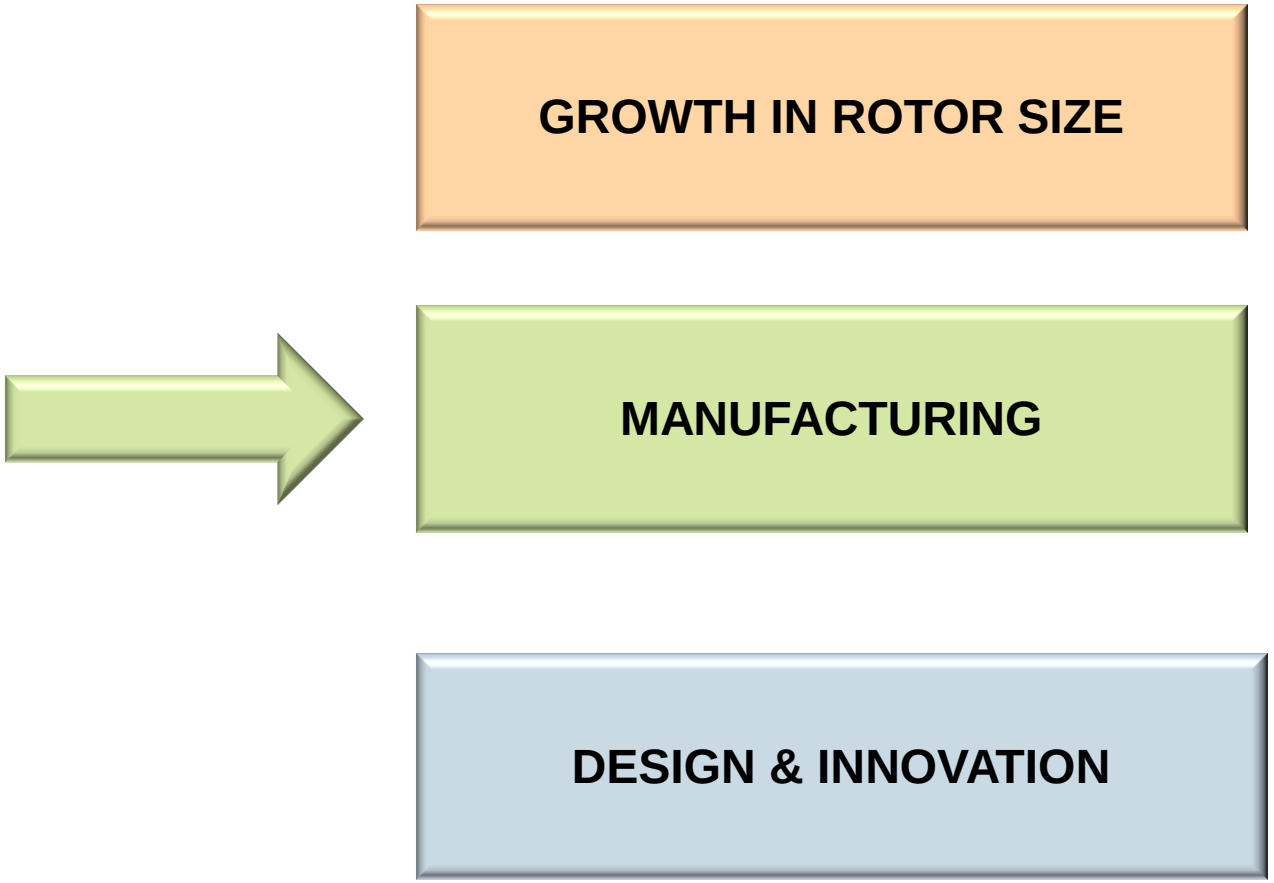
Preparing B75 flapwise blade load test …

Characteristics of The Wind Turbine Blades Industry



IntegralBlade®
Patented Manufacturing Method by Siemens

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Manufacturing: Still very manual…and relatively fast
Mold cycle time less than 24 hrs
Over 2300lb of glass per hour

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Some Facts

Blade Manufacturing

- We make the world's largest composite structures infused as one piece
- On average it takes 24 hours to make a blade
- Layup speed is over 2300 lbs per hour
- Less than $10 per KG

Characteristics of The Wind Turbine Blades Industry

GROWTH IN ROTOR SIZE

MANUFACTURING

DESIGN & INNOVATION

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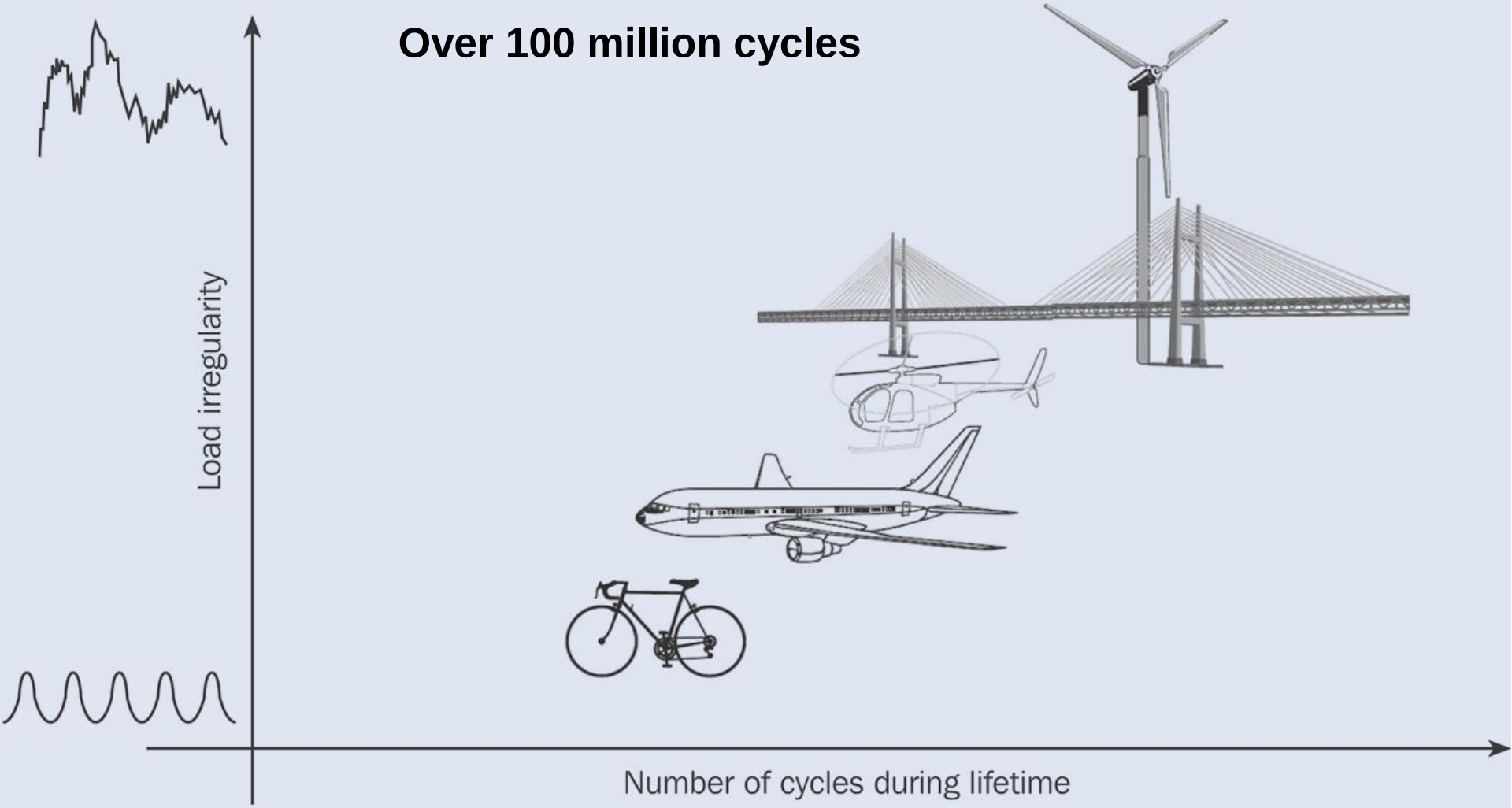
25 years of Fatigue loads



Source: WMC (TU Delft-ECN)

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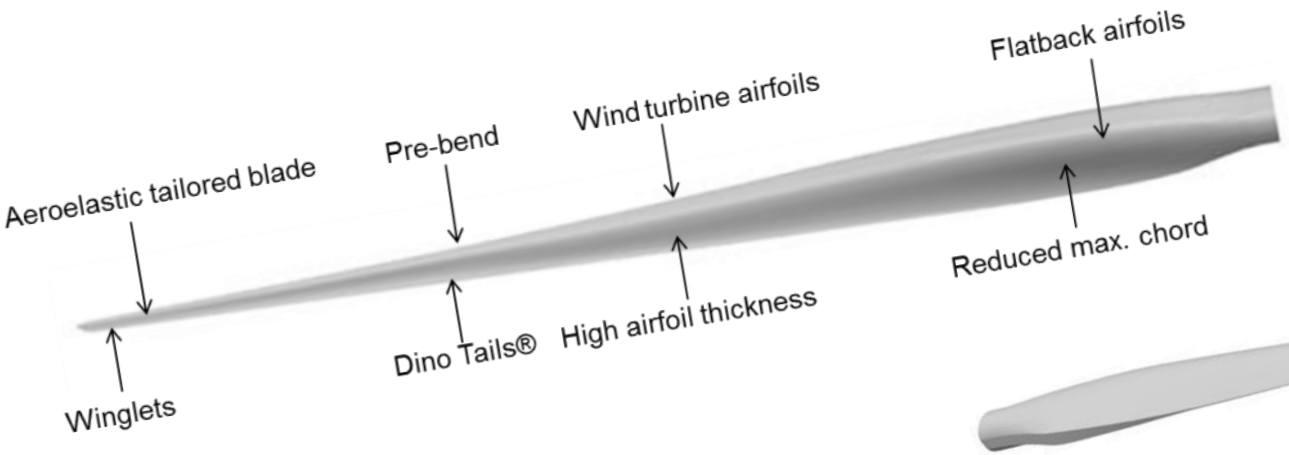
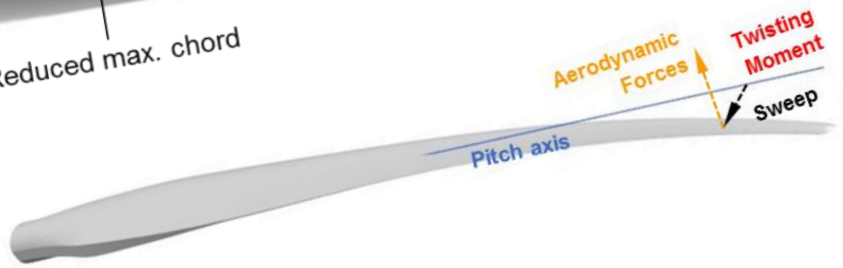
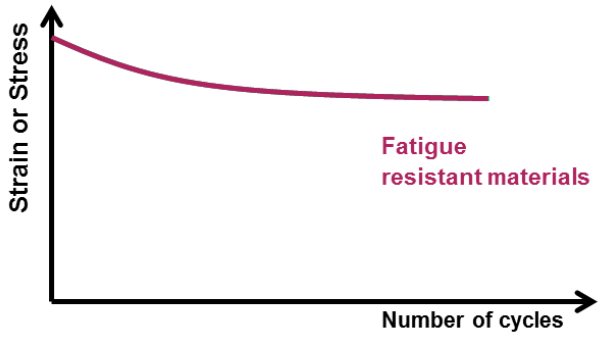
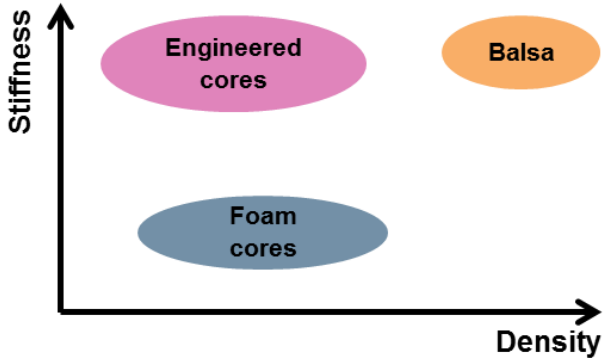
TIP deflection and Buckling challenge...

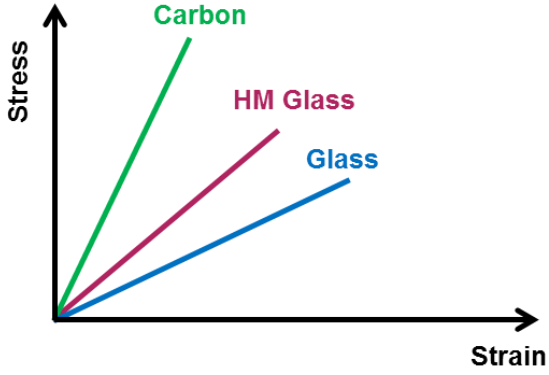
Innovation: Aerodynamics, Materials, Loads reduction











Some Facts

Blade Design

- Over 100 million fatigue cycle over a lifetime of 25 years
- The first 30% of the blade can weight over 50% of the total blade mass
- The 75 m blade has tip deflection of over 15 meters (~50 ft)
- Blade density in 2015 is 1/3 the blade density in 2004
- 30% of blade mass is from resin

To summarize some highlights…

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SIZE	Rapid Growth > 150 meters
Product Market Life Cycle	Short <3 years
Production Speed	< 24 hours >2300 lbs per hour
Manufacturing Method	Manual
Cost	<$10 /KG
Product Life Time	>25 years

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Future challenges

Leading edge erosion

Testing

Transportation

Maintenance

Manufacturing/automation

Size

Tip deflection

AEP

Generic long term outlook

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Cost efficient turbines

Smart wind turbines and farms

Competitive wind energy LCOE

Thank you for your attention

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