WIND TURBINE ENGINEERING

Simulation for Sustainable Energy Sources

DASSAULT SYSTEMES

USING THE POWER OF THE WIND

The air around us is full of energy. There are terawatts of power to be extracted from the wind, forever and without carbon emissions. Wind power is essential for reaching climate goals—not just replacing existing fossil fuel power stations, but also for electrifying sectors such as transportation and heavy industry.

The price per kilowatt of wind power has declined rapidly in recent years, to the point where electricity from wind is substantially cheaper than from fossil fuels or most other sources. This has come from the development of larger, more efficient wind turbines, optimization and mass production.

The development of onshore and offshore turbine technology continues to lower the cost of energy and accelerate the transition to net zero emissions. However, the extreme loading and coupled engineering disciplines make wind turbine design a challenge. **Simulation is vital for engineers who want to understand system dynamics and minimize loading**.

VIRTUAL TWIN

Different aspects of the turbine—aerodynamics, noise, loading, lightning strike, icing and more—can all be predicted and optimized using a virtual model before the first prototype is built. These models can be used in combination with real components, in real-time, for realistic testing. **Using a virtual twin not only reduces expensive testing, but unlocks entirely new avenues for innovation by giving every engineer a full understanding of the entire system**.

This e-book covers the fundamentals of wind turbine simulation and demonstrates how our solutions help companies meet aggressive targets in an ever increasing competitive market.

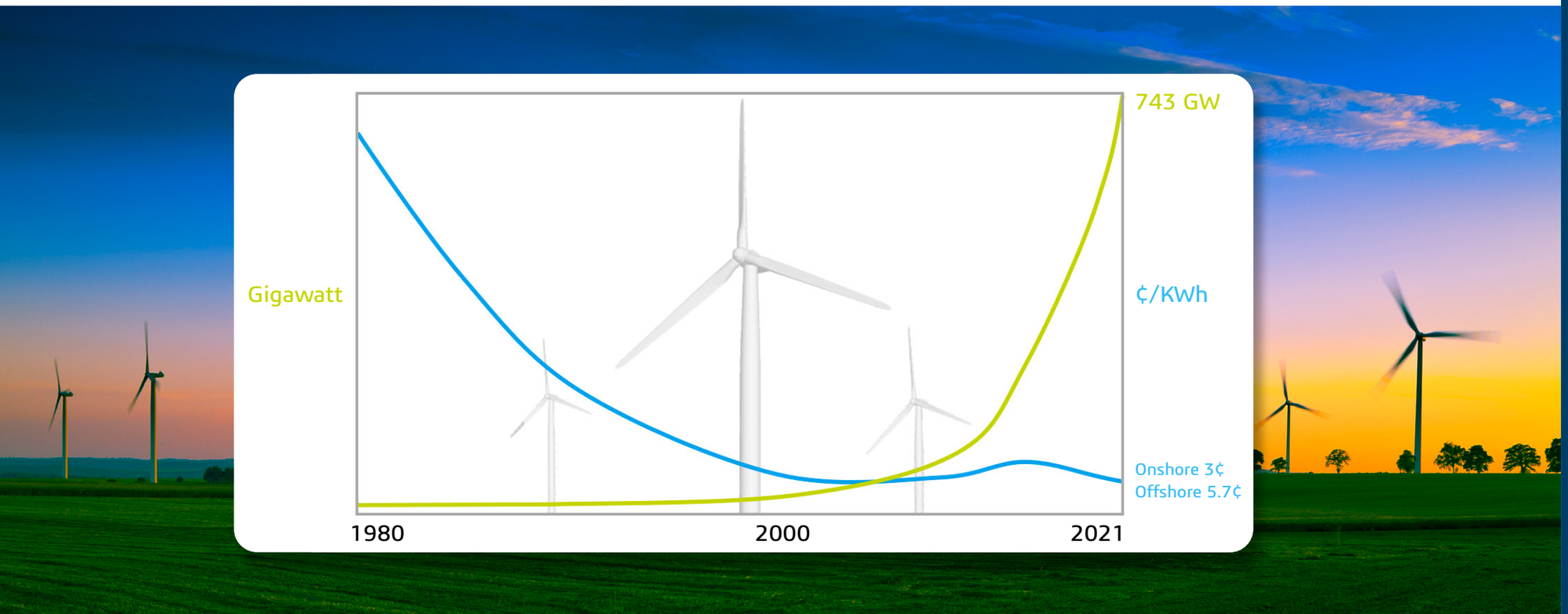
INDUSTRY TRENDS

The last decade in the wind power industry has been dominated by several trends—decreasing price for energy, increased turbine size, stricter regulations and the growing offshore wind market.

The industry will see additional disruption as improved design and energy storage technology offer the potential for tremendous cost reduction. Manufacturers will be able to stay ahead of competition by being able to offer complete solutions.

Addressing conflicts between wind farms and other stakeholders has been another key focus of the industry. One of the most important of these has been noise reduction, which has become a priority due to stricter local regulations. Another issue is radar reflection and possible interference with nearby air traffic control.

The rapid fall in the wind energy prices means that OEMs and suppliers have to constantly optimize and innovate to remain competitive. All manufacturers want to be first to bring better designs to the market, while also **reducing risk and ensuring compliance with diverse local regulations**.



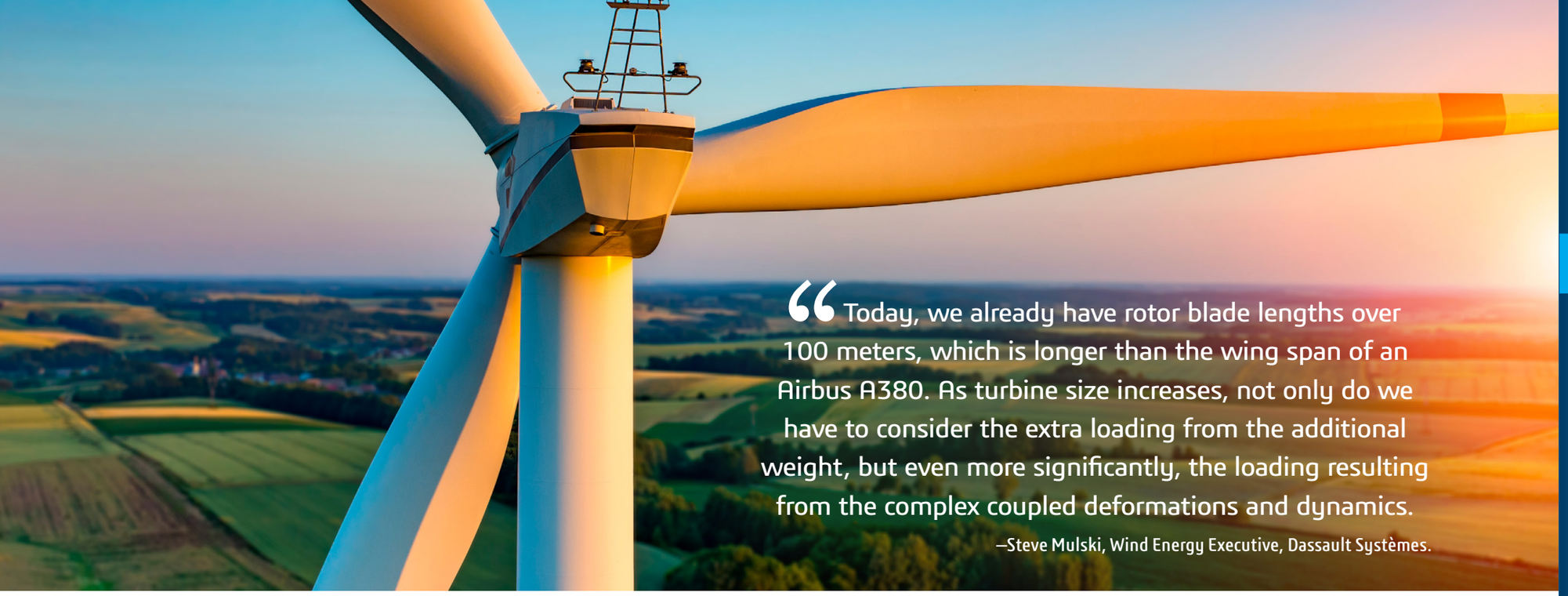
BIGGER TURBINES, BIGGER CHALLENGES

Larger wind turbines capture more energy and are more cost effective. They are also especially well suited for offshore installation, where space is almost unlimited and winds are better. But the sheer size introduces new challenges for designers.

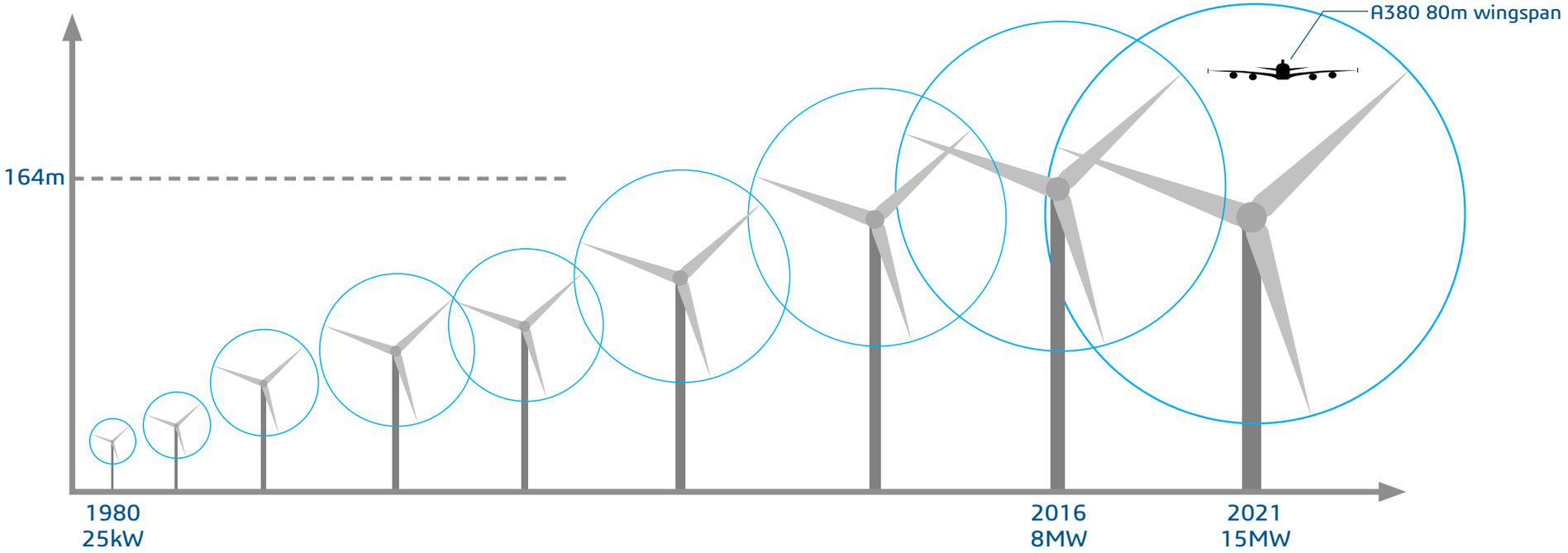
TESTING WITH VIRTUAL TWINS REPLACES PHYSICAL PROTOTYPES

Extreme events such as wind gusts or emergency stops are major concerns for large turbine sizes. The virtual twin approach can replicate these real world scenarios accurately through simulation. This reduces the need for physical tests. It allows engineers to explore innovative designs and carry out optimizations on every parameter of every component.

With simulation, engineers can easily predict natural frequencies and understand excitation mechanisms which may lead to critical resonances and even catastrophic failure. Counter measures can be made at an early design stage when changes are still inexpensive.



> “Today, we already have rotor blade lengths over 100 meters, which is longer than the wing span of an Airbus A380. As turbine size increases, not only do we have to consider the extra loading from the additional weight, but even more significantly, the loading resulting from the complex coupled deformations and dynamics.
>
> —Steve Mulski, Wind Energy Executive, Dassault Systèmes.



OFFSHORE CHALLENGES

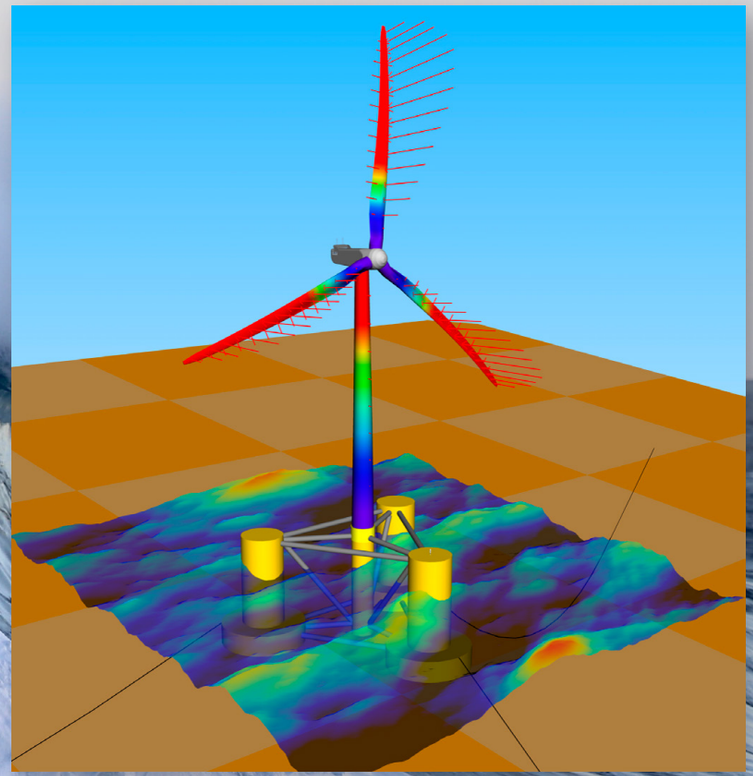
Installing wind turbines offshore adds a whole extra level of difficulty and challenges. Not only are the turbines much larger, but the conditions at sea are intense, with extreme wind forces pushing against the rotor and tower, and waves battering the foundation even more. There is even the risk of collisions with shipping vessels and other floating objects.

Marine growth, salt corrosion, and rogue waves all pose additional complications compared to onshore turbines. Sea bed characteristics have to be accurately measured and modeled as this will have a significant influence on potential critical resonances. Additional dynamics from floating platforms and mooring lines further increase required investigations and planning.

However, the potential rewards due to stronger consistent winds and almost limitless open space make the challenges worth it.

LIMIT OPERATING COSTS

Because of the remoteness, and limited accessibility due to changing sea conditions, installation and operation costs for offshore are significantly higher. As a result, durability and maintenance have a higher prioritization in the planning phase. **Optimized conditioning monitoring and maintenance scheduling are key to reducing long-term costs**.



LOWERING THE COST OF ENERGY

Even though wind energy already offers one of the cheapest forms of energy available, manufacturers and operators are preparing themselves for even lower returns, between 2¢ and 3¢ per kWh. Subsequently market competition is continually increasing, **requiring every aspect and every component of the design to be reviewed and optimized**.

With high fidelity modeling, significant capital expenditure (CAPEX) savings can be achieved. Optimizing control strategies and the application of vibration absorbers reduces maximum loads acting on the turbine's components. Engineers can then choose smaller and lighter components, resulting in further reduced loads. This cycle of optimization can significantly reduce the cost of components (see table). Planning maintenance operations and **reducing component failure**, at an early stage of the design, can significantly reduce later operating expenses (OPEX).

Reducing noise can increase the number of turbines allowed on a site. Even with a small decrease of noise per turbine, a substantial increase in the maximum allowable turbines for a specific park, and thus in the overall energy output, can be achieved. Additionally, lower noise levels can result in better nighttime operations, when stricter regulations apply, and therefore further increase output.

EXPLORE RADICAL INNOVATIVE IDEAS

With today's workflow automation and cloud computing, every single parameter can now be used within optimization loops to further reduce costs. SkyWind successfully used simulation to develop and validate an innovative, cost-saving hoisting system (see image).

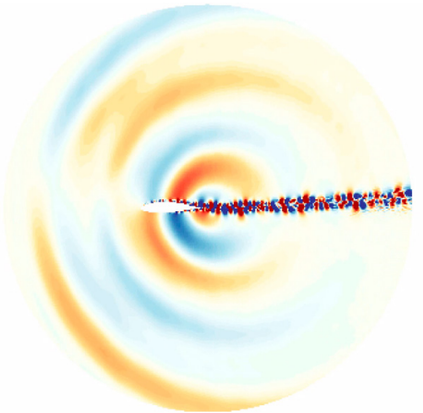
Significant cost savings are achieved by optimizing not only the design, but by optimizing every single aspect of the wind turbine and park, from certification to recommissioning and decommissioning.

Component	Cost Reduction
Tower	12%
Rotor	10%
Nacelle	13%
Drivetrain	9%
Total Savings	7.6%

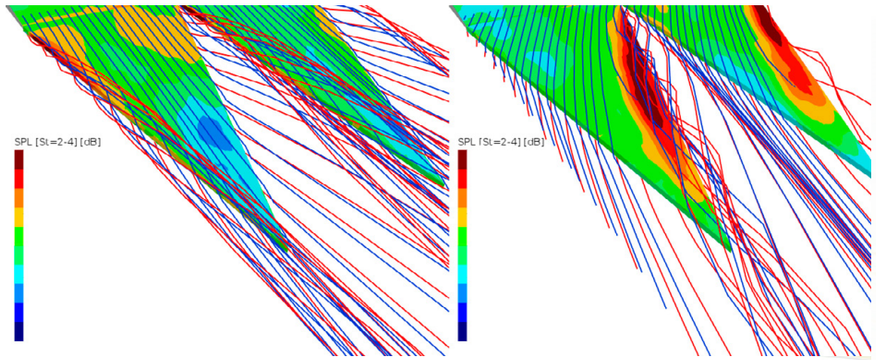
Courtesy of SkyWind GmbH

SILENCING THE NOISE

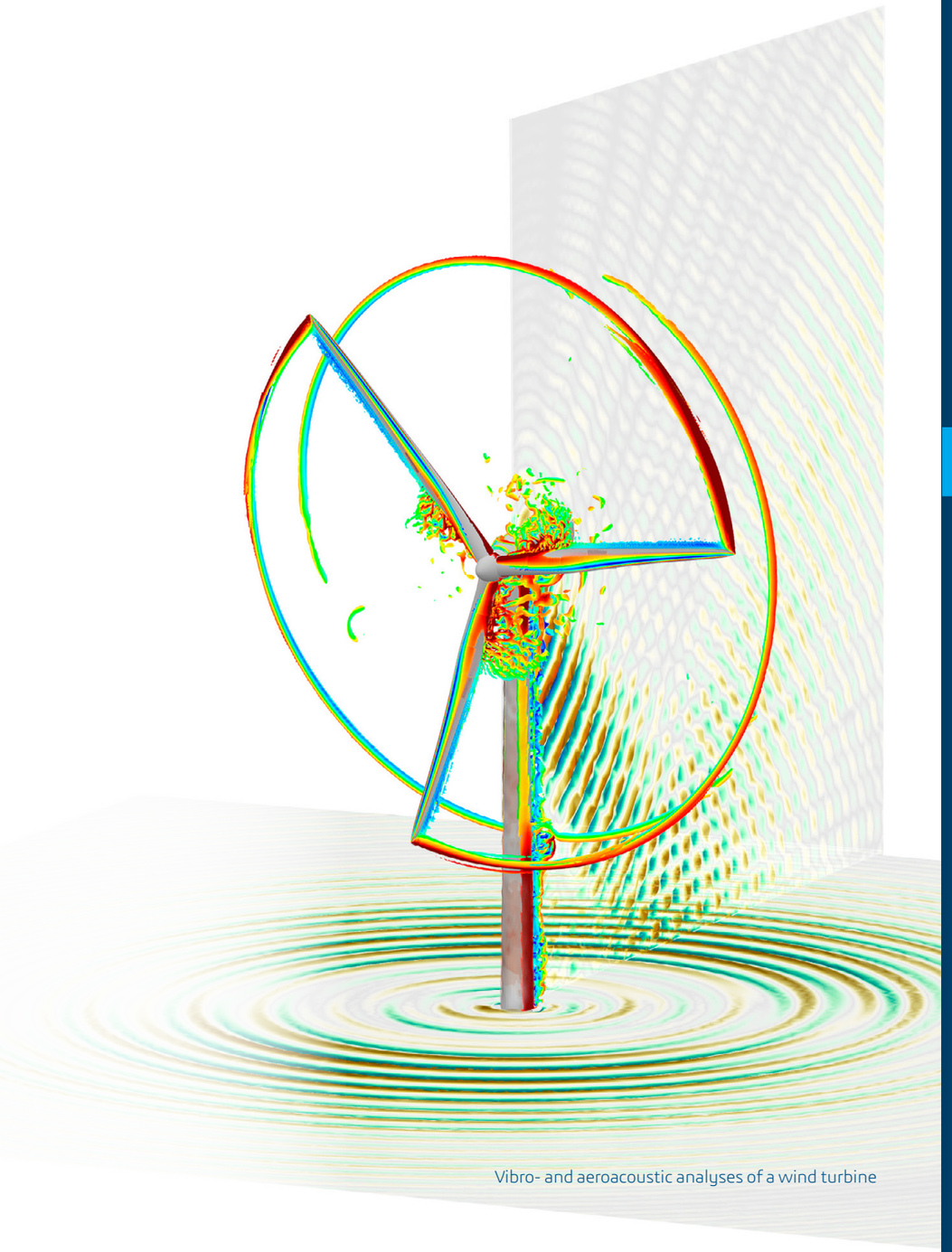
Noise is a primary limiting factor for a turbine's energy output. Quieter turbines make better neighbors and are more likely to be accepted by the community. Wind turbine tonalities mainly originate from the gearbox and radiate from the tower and blades, so **multibody dynamics** and **vibro-acoustics** are extremely important in their design. Using simulation to visualize noise sources and propagation gives engineers the insight needed to create new innovative noise suppression add-ons.



Acoustic waves from the trailing edge of a wind turbine blade



Blade trailing edge—variations of wind affecting the noise-suppression add-on's performance



Vibro- and aeroacoustic analyses of a wind turbine

SIMULATION ON THE 3DEXPERIENCE PLATFORM

Why use the **3D**EXPERIENCE® platform for Wind Turbine Engineering?

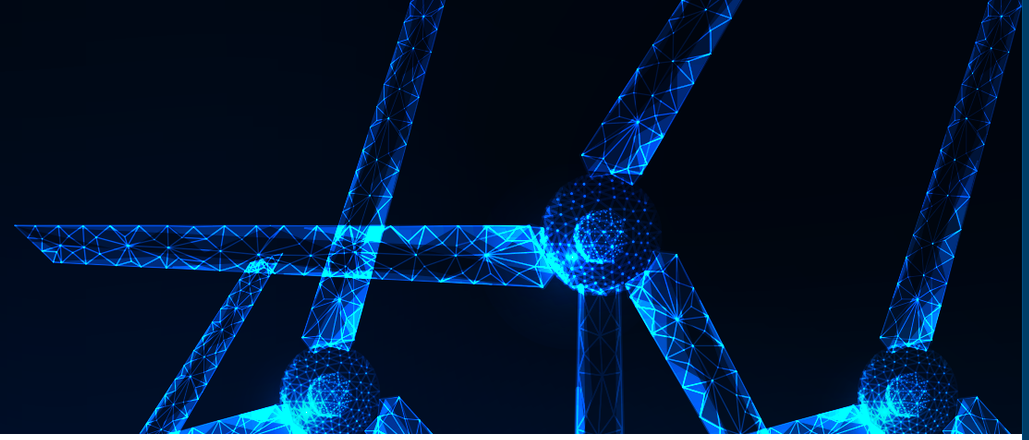
Dassault Sytèmes **3D**EXPERIENCE platform offers a full Digital Thread with continuity from design to simulation to manufacturing. The platform ensures that everyone collaborates with up-to-date data. If problems occur, traceability enables the source to be quickly identified and solutions found.

HOLISTIC VIEW

A wind turbine is an extremely complex multi-physical system, from the grid and power electronics, through the generator and control systems, all the way to the huge flexible structural components. Not to mention the aerodynamic and hydrodynamic loading. The **3D**EXPERIENCE platform allows a system-level view of all these components, enabling data-driven design decisions. The intelligence from requirements, testing and deployment is brought together to accelerate communication and collaboration between teams, improving productivity and time to market.

WHY SIMULATE?

Inexpensive, efficient and durable wind turbines will enable a sustainable future. The simulation tools from Dassault Systèmes empower engineers to design, understand, optimize and validate every aspect of wind turbines, from concept to decommissioning.



$€¥ Cost Savings

Cut costs and development times using virtual twins.

First to Market

Use virtual twins to reduce or even eliminate the need for physical prototypes. Get design feedback and identify risks in hours, not weeks, for a faster turnaround.

Collaboration

Ensure all stakeholders collaborate with up-to-date data for continuity from design to simulation to manufacturing.

Avoid Risk

Simulate to test and validate the performance of turbines in a wider range of real world conditions than possible with field testing. Be confident that designs will achieve the 20-year lifespan and fulfill regulations.

Optimize Products

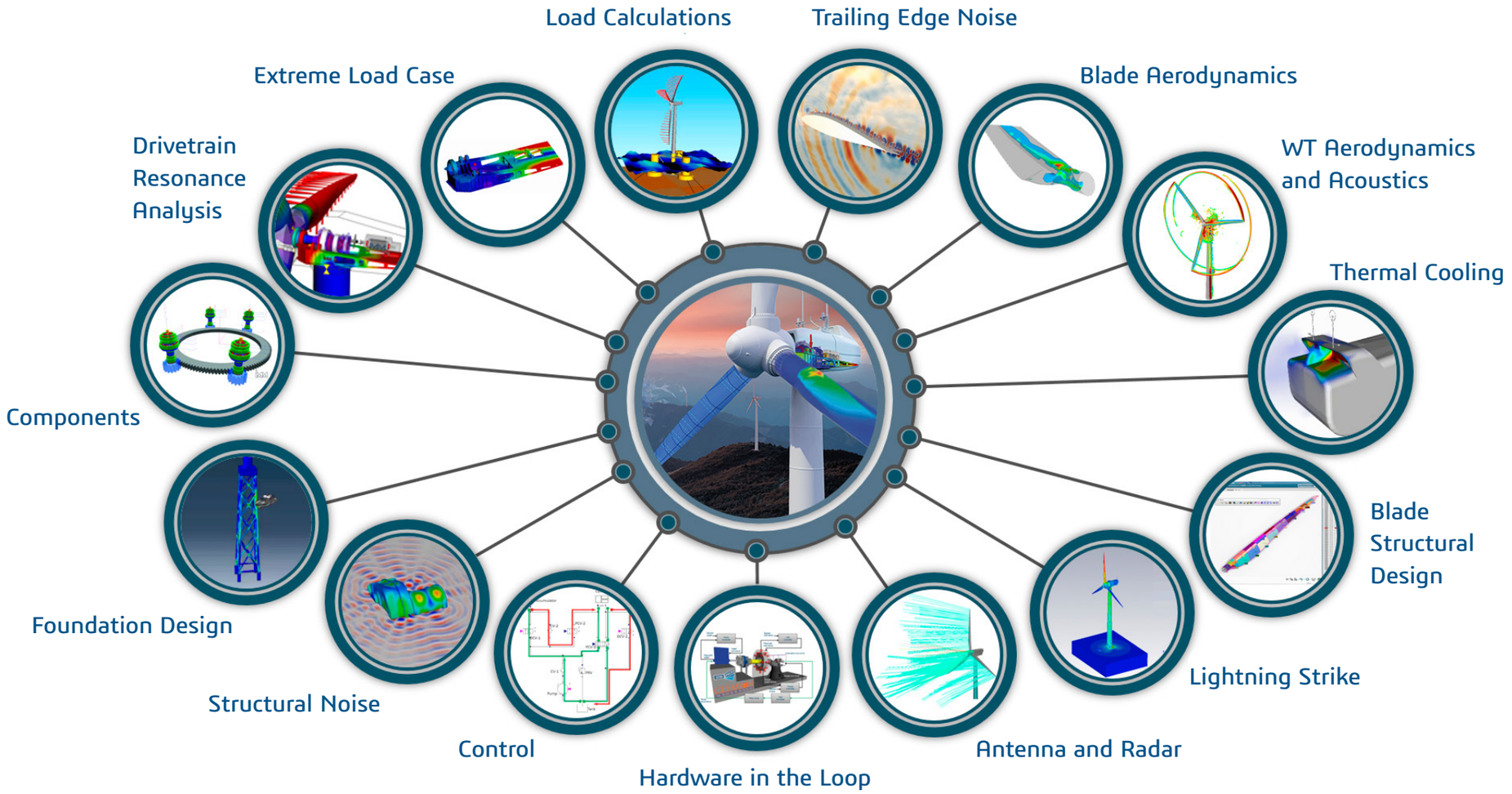
Optimize every component within the fully coupled holistic system.

Power Increase

Engineer larger wind turbines that are more efficient and have significantly higher output, using simulation to meet the associated challenges.

FULL TURBINE WORKFLOW

Customers in the wind energy sector are using simulation solutions from Dassault Systèmes to advance the **design**, **development**, and **optimization** of wind turbines and drivetrains.

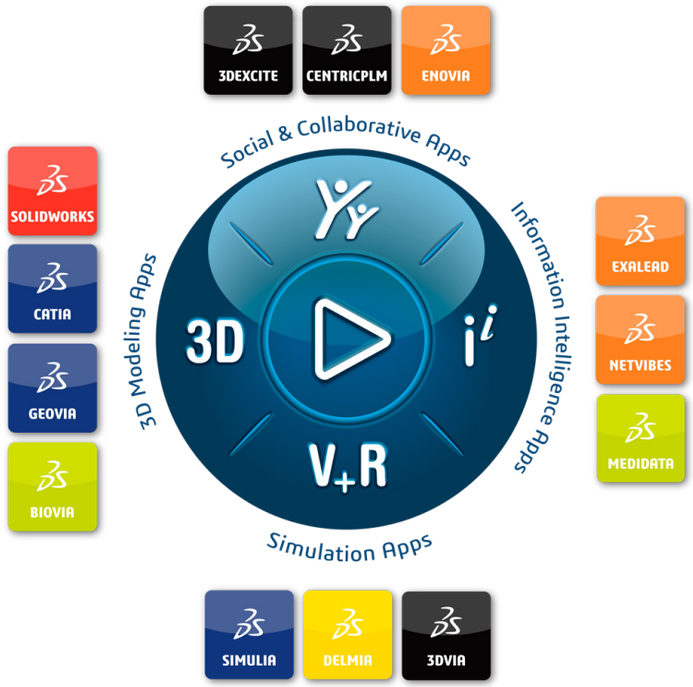


Discover more about Wind Turbine Engineering.

Our **3D**EXPERIENCE® platform powers our brand applications, serving 11 industries, and provides a rich portfolio of industry solution experiences.

Dassault Systèmes, the **3D**EXPERIENCE Company, is a catalyst for human progress. We provide business and people with collaborative virtual environments to imagine sustainable innovations. By creating 'virtual experience twins' of the real world with our **3D**EXPERIENCE platform and applications, our customers push the boundaries of innovation, learning and production.

Dassault Systèmes' 20,000 employees are bringing value to more than 270,000 customers of all sizes, in all industries, in more than 140 countries. For more information, visit **www.3ds.com**.



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