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38TH INTERNATIONAL SYSTEM SAFETY CONFERENCE

SAND2020-11098C

Evolution of Safety Management Within the Scaled Wind Farm Technology (SWiFT) Facility Program

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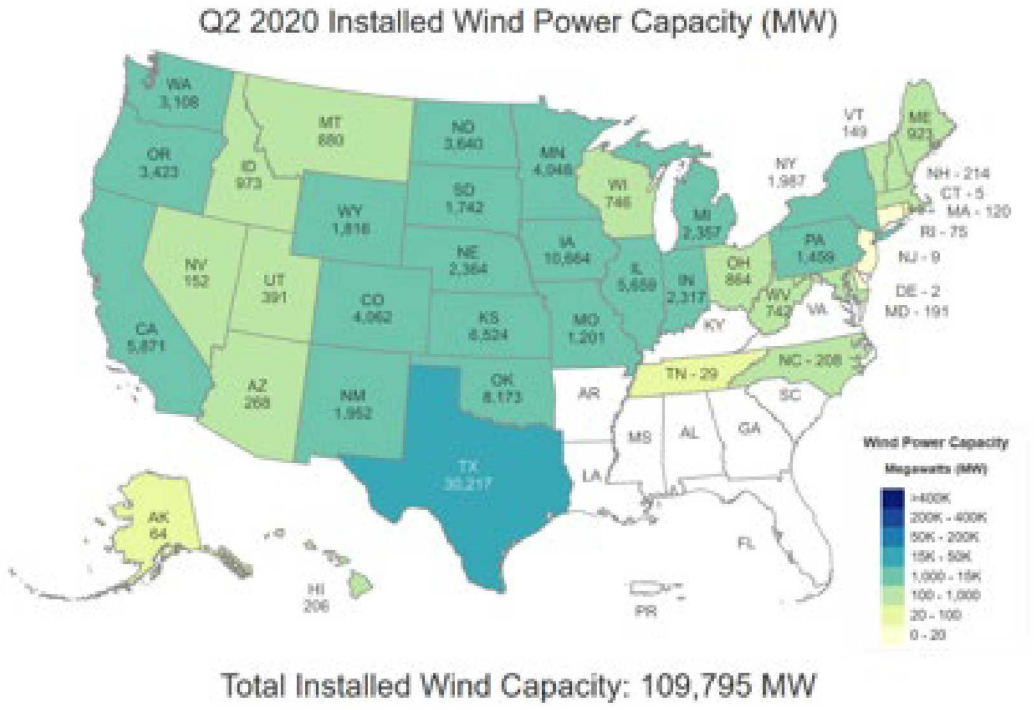
Growing footprint of wind energy

- More than 60,000 wind turbines presently in use in 41 states, Guam, and Puerto Rico
- Another 10,000 forecast to be installed by 2030



DOE WETO (2020). https://windexchange.energy.gov/maps-data/321

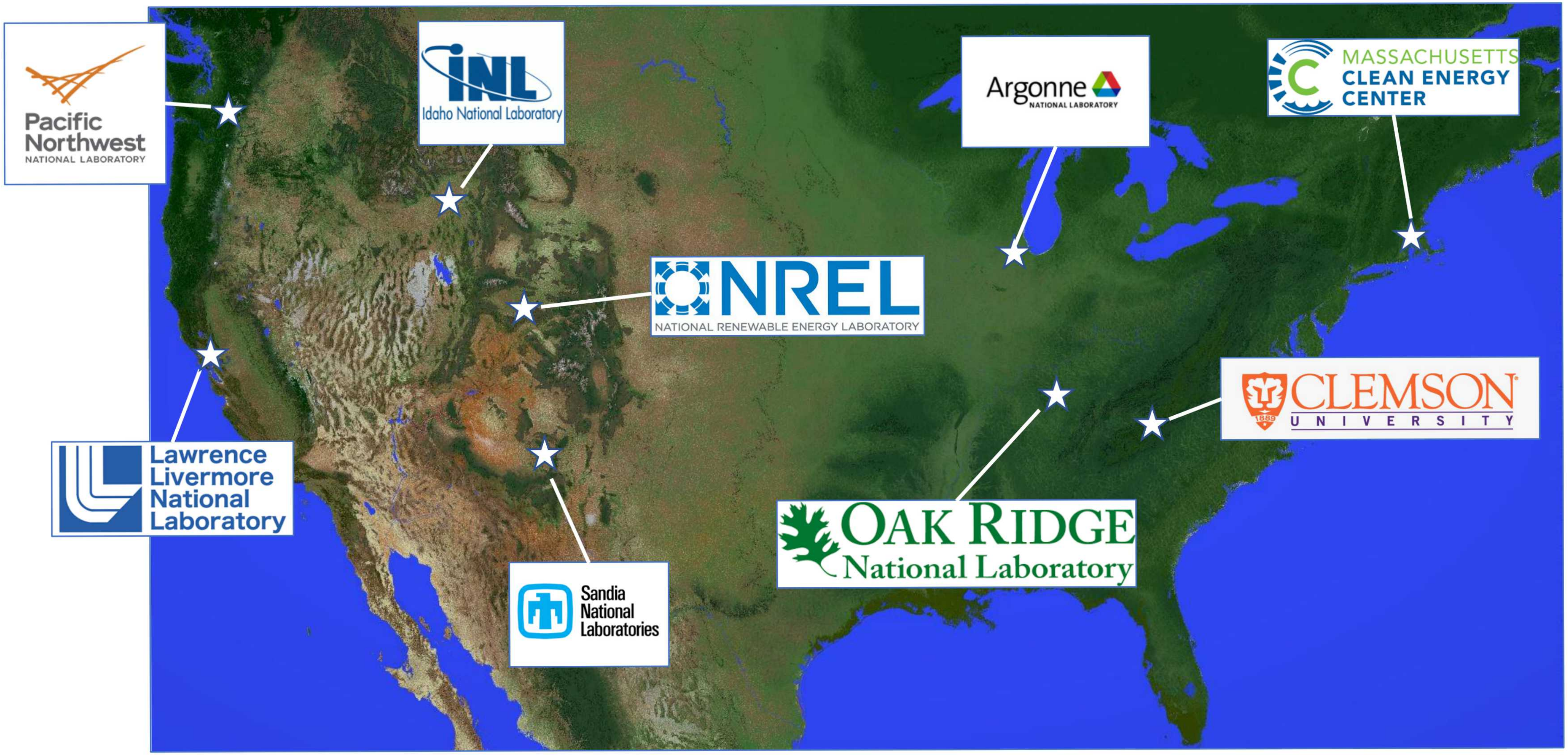
- Average age of installed wind turbines in 2018 was seven years
- Average will increase to 14 years in 2030
- Operations and maintenance (O&M) costs average between $42,000 and $48,000 per megawatt during the first 10 years of a turbine's operations
- $40 billion in O&M costs over the next 10 years
- Performance optimization is key to wind plant sustainability and reduced cost of operation

Impact of wind energy research

- Government-sponsored, industry-focused research into wind plant performance can help to dramatically lower the O&M costs of current and future wind plants
- The U.S. Department of Energy national laboratories lead efforts to accelerate the deployment of wind power technologies, improve performance, and lower costs:
  - Research leading to increased reliability levels of wind turbines reduces commercial risks and financing costs
  - Development of analytical modeling, engineering databases, test protocols, and test facilities allow turbine designers to move away from trial-and-error methods and large safety factors intended to avoid frequent turbine failures

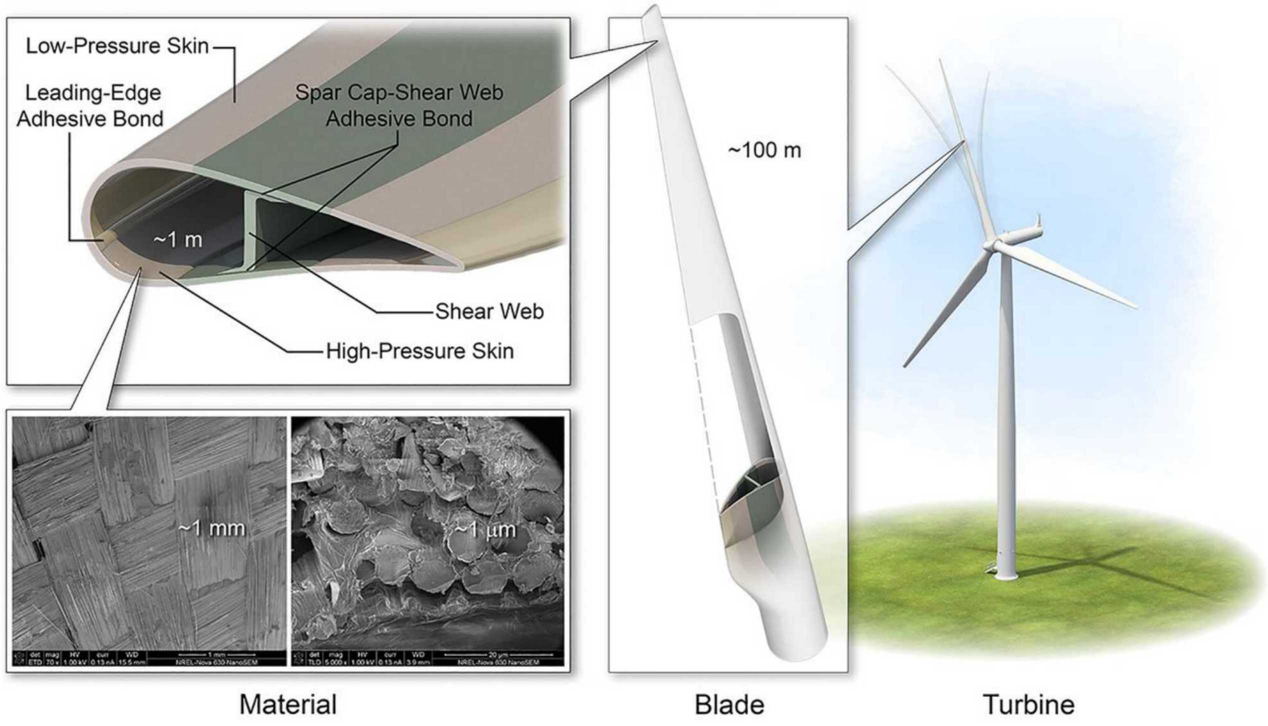
Herges, T., Berg, J., Bryant, J., White, J., Paquette, J. & Naughton, B. (2018). *Detailed analysis of a waked turbine using a high-resolution scanning lidar*. Report No. SAND2018-6590 C. Albuquerque, NM: Sandia National Labs.

National research presence



Research capabilities

- Advanced manufacturing
- High-performance computing
- Resource characterization
- Grid integration
- Field testing
- Drivetrain testing
- Blade testing

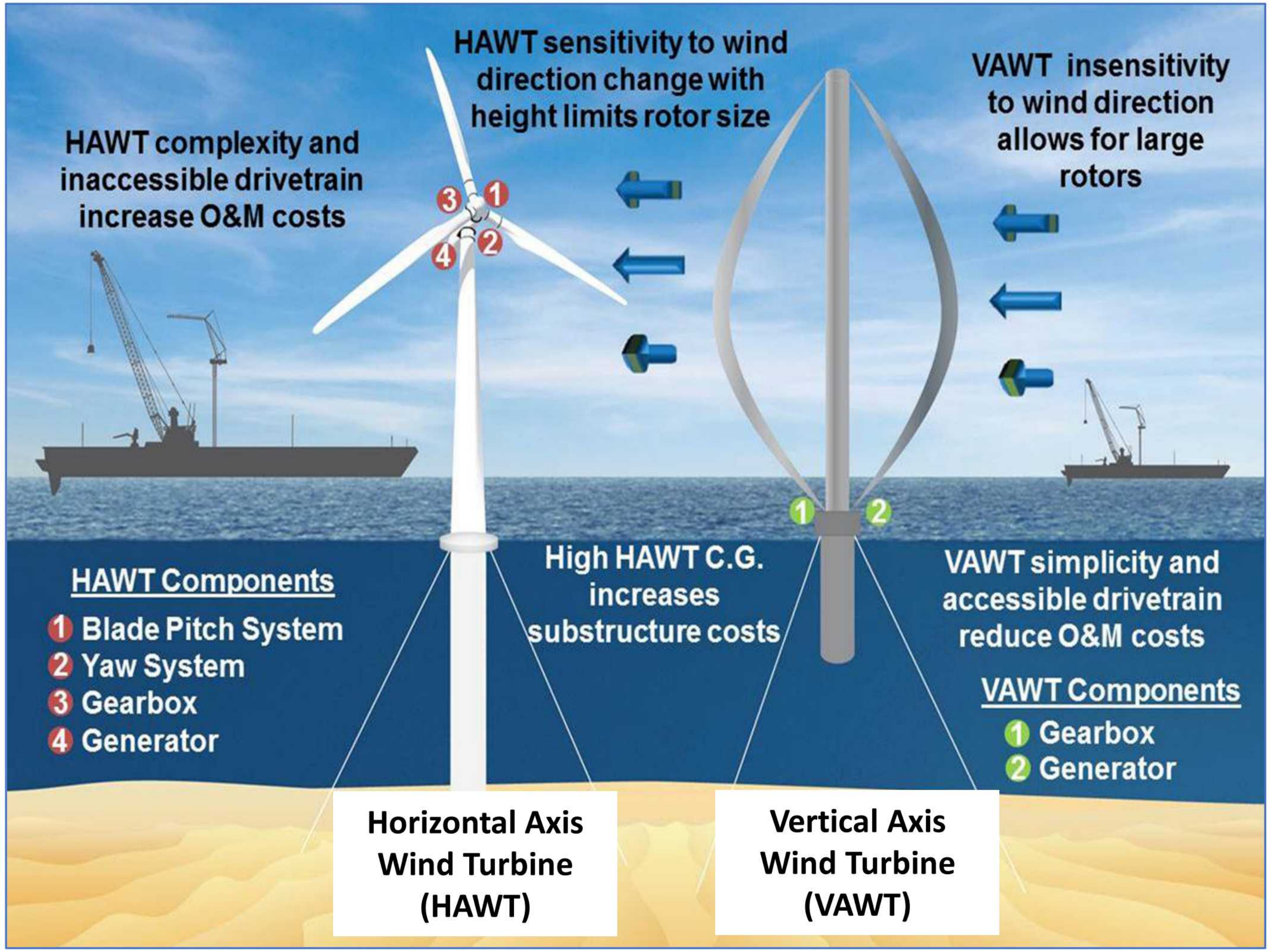


Veers, P., Dykes, K., Lantz, Barth, S., Bottasso, C., Carlson, O., Clifton, A., Green, J., Green, P., Holttinen, H., Laird, D., Lehtomäki, V., Lundquist, J., Manwell, J., Marquis, M., Meneveau, C., Moriarty, P., Munduate, X., Muskulus, M., Naughton, J., Pao, L., Paquette, J., Peinke, J., Robertson, A., Rodrigo, J., Sempreviva, A., Smith, J., Tuohy, A., & Wiser, R. (2019). *Grand challenges in the science of wind energy*. Science, 336(6464), doi: 10.1126/science.aau2027.

Diversity of research institutions

- Specific areas of expertise and capabilities
- Significant reductions in the cost of wind energy through improved understanding of the complex physics governing electricity generation by wind plants
- Collaboration of scientists from the laboratories, industry, and academia conduct systems-level research and advanced high-fidelity modeling to gain an understanding of wind plant operating environments

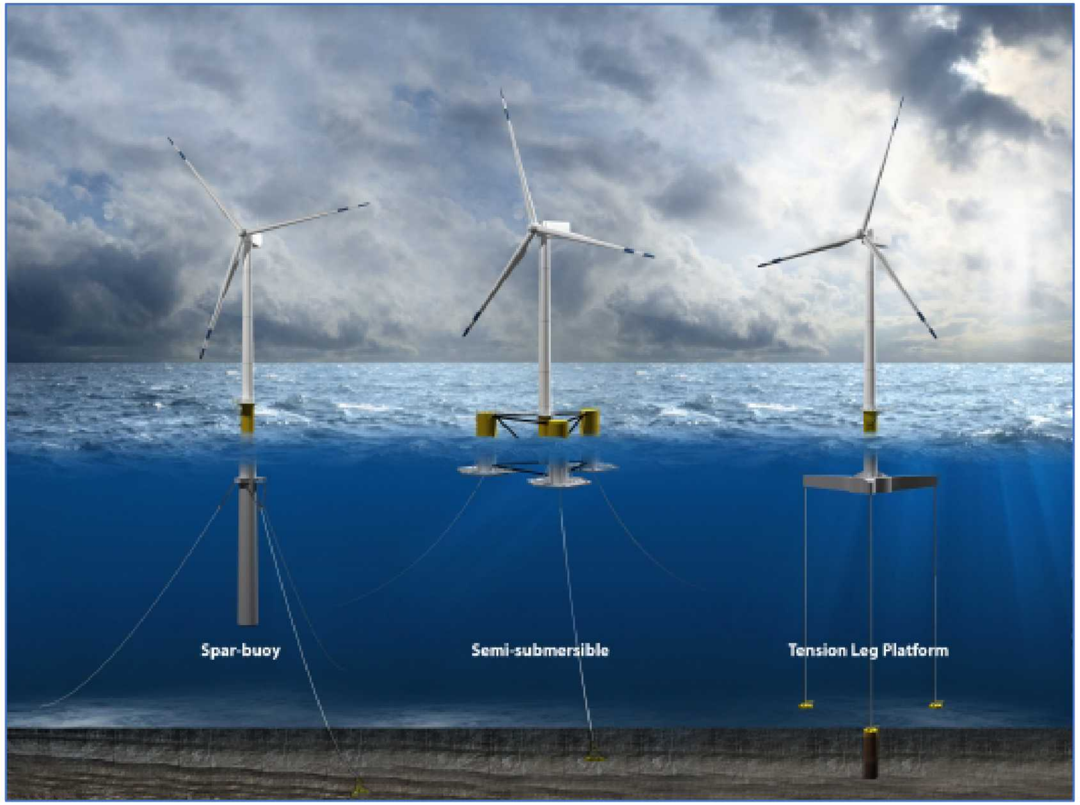
HAWTs and VAWTs



Sandia National Laboratories (2018). https://www.energy.gov/eere/wind/articles/vertical-axis-wind-turbines-could-reduce-offshore-wind-energy-costs

Onshore & offshore wind turbines

Winchell, J. (2018). https://www.fws.gov/ecological-services/energy-development/wind.html

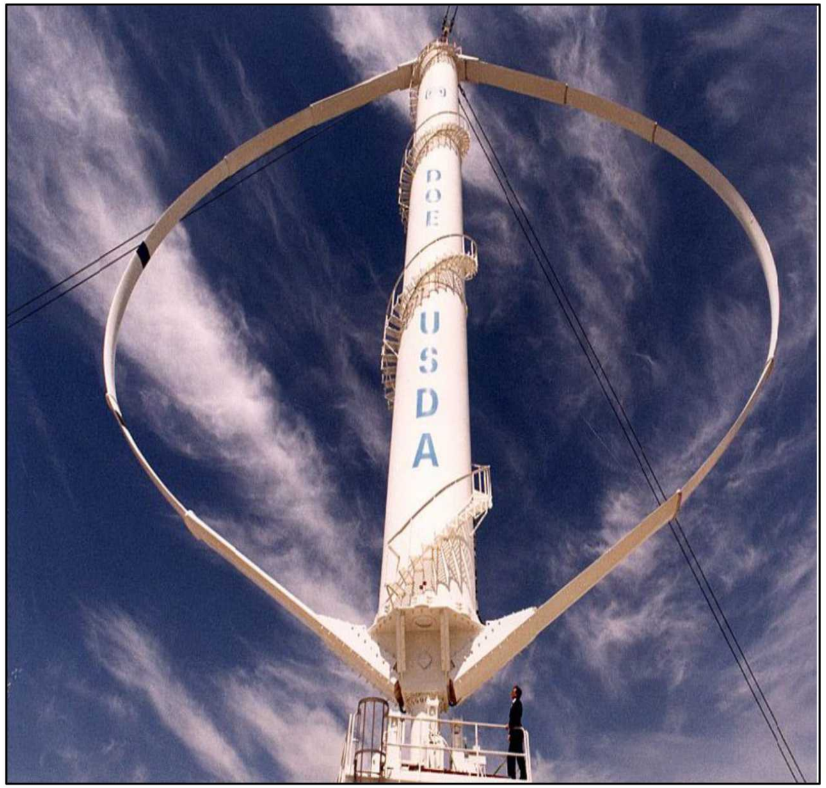


Bauer, J. (2020). https://www.energy.gov/eere/wind/articles/top-10-things-you-didn-t-know-about-offshore-wind-energy

Early Sandia National Labs wind energy research

Sandia National Laboratories NM

USDA Site Bushland, Texas



Berg, D. (2016). *The Sandia legacy VAWT Research Program: Scientific and technological challenges in offshore VAWTs*. Albuquerque, NM: Sandia National Labs.

Sandia wind research moves to Lubbock, TX

Scaled Wind Farm Technology (SWiFT) Facility

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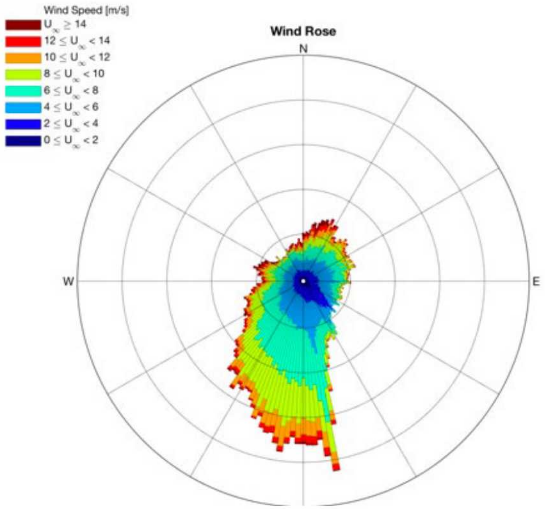
Google Earth (2020)

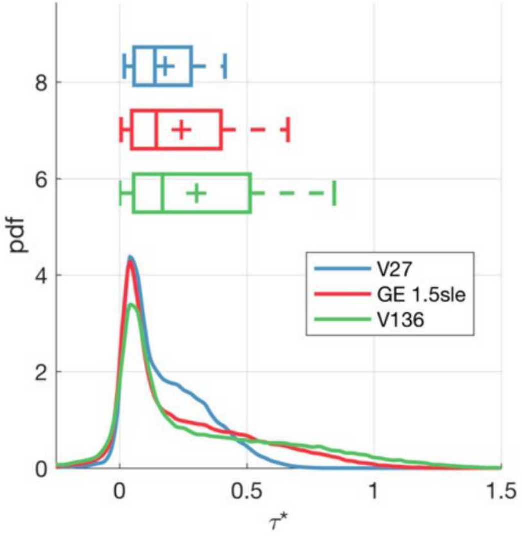
Scaled Wind Farm Technology (SWiFT) Facility

TEXAS TECH UNIVERSITY
National Wind Institute™

Atmospheric conditions at the SWiFT Facility

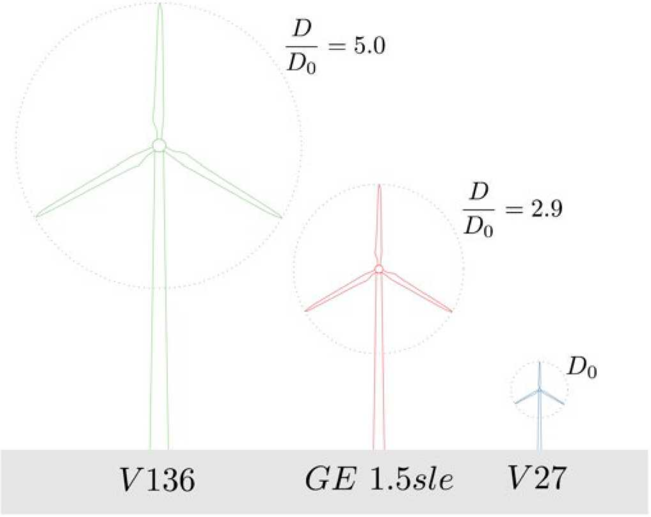
- Strong and consistent wind resource allow frequent and predictable experimentation in the real atmosphere
- The small scale emulates all important parameters seen in full-scale wind turbines; At SWiFT it happens with different frequency
- The exceptional instrumentation at SWiFT allows very detailed classification at literally every rotation of the rotors
- Just as strong and great as offshore winds





Wind shear example

$Pr(\tau^* > 0.75) = 4.6\%$ for GE 1.5sle
$Pr(\tau^* > 0.75) = 11.4\%$ for V136

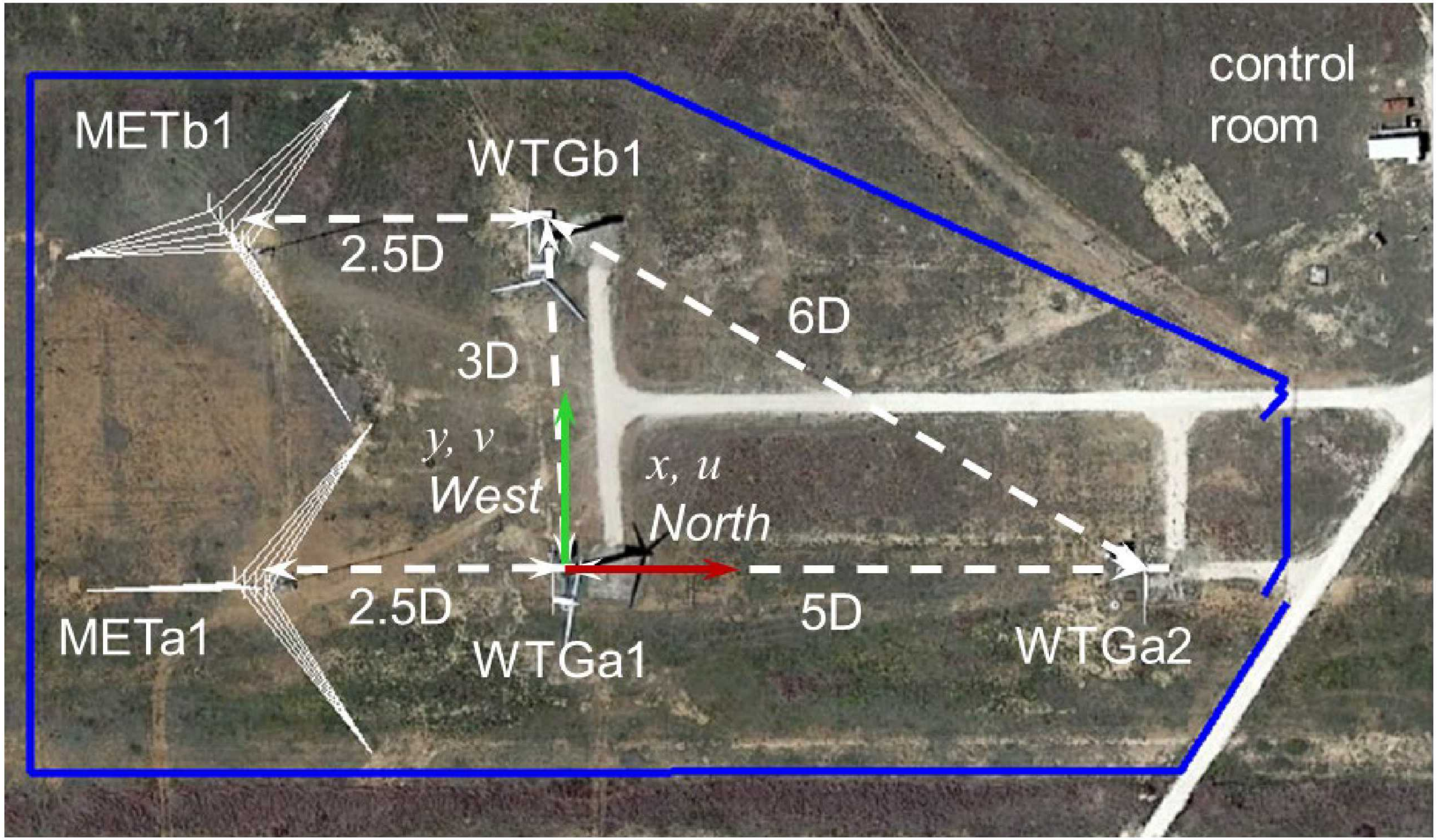


Detailed study published in SAND–2016-0216

Outreach

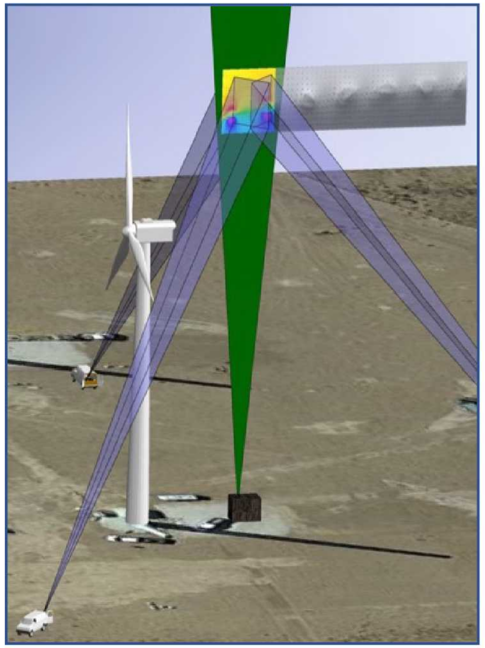
- Reduce turbine-to-turbine interaction and wind plant underperformance
- Develop advanced wind turbine rotors
- Improve the validity of advanced simulation models

Scaled Wind Farm Technology (SWiFT) Facility



SWiFT's uniqieness

- Designed up front to be as open-source as possible to maximize the value and access to the data and knowledge generated at the site.
- SWiFT is at a scale that is both relevant to modern utility systems, and most cost effective in terms of time and resources to conduct field research with sufficient precision.



National Renewable Energy Laboratory (NREL)

Key regional research partner with Sandia and the SWiFT Facility

- Design review and analysis
- Software development, modeling, and analysis
- Advanced controls development and testing
- Certification and design evaluation testing
- Highly Accelerated Life Testing
- Transmission and grid integration
- Wind resource assessment

Schroeder, D. (2016). https://images.nrel.gov/MX/Profiles/en/default/#/main/gallery/5252bff9-0745-467a-a028-705c06736abd

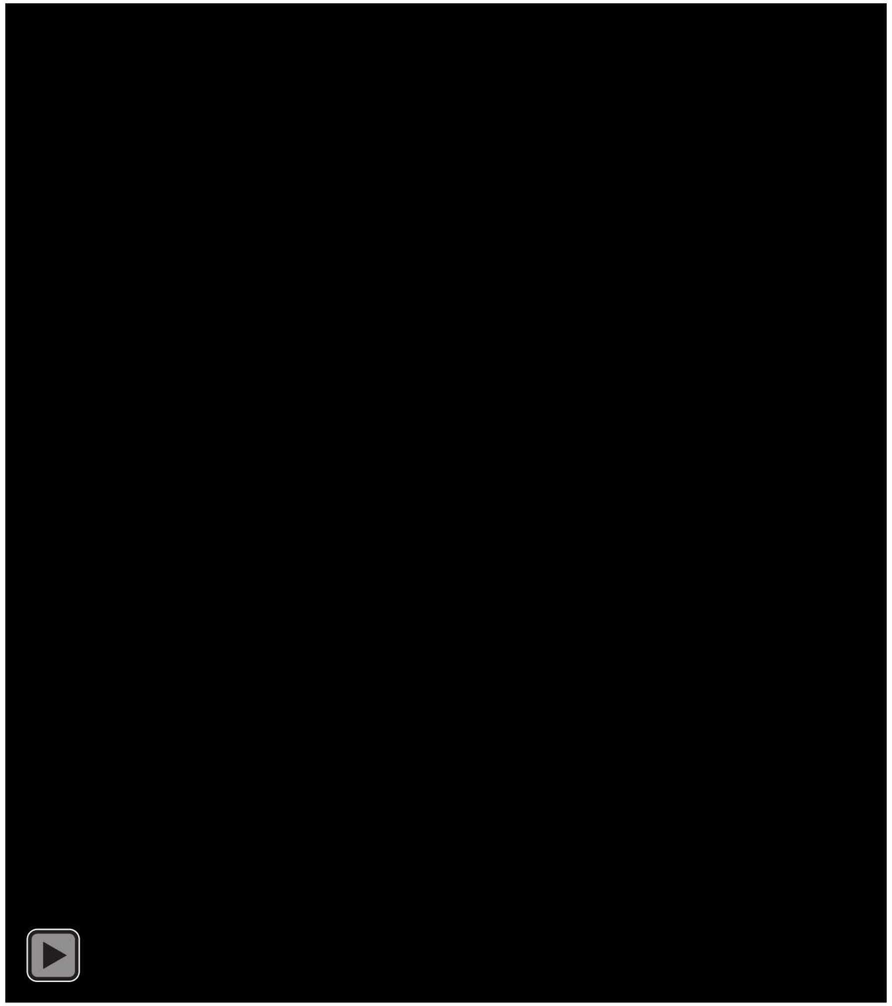
A new research facility

2014 event

- Rotor overspeed
- Numerous corrective actions following a root cause analysis
- Led to moderate-hazard facility designation

Corrective actions

- Management self-assessment (MSA)
- Independent Readiness Review (IRR)
- Granted approval to resume normal operations in 2017

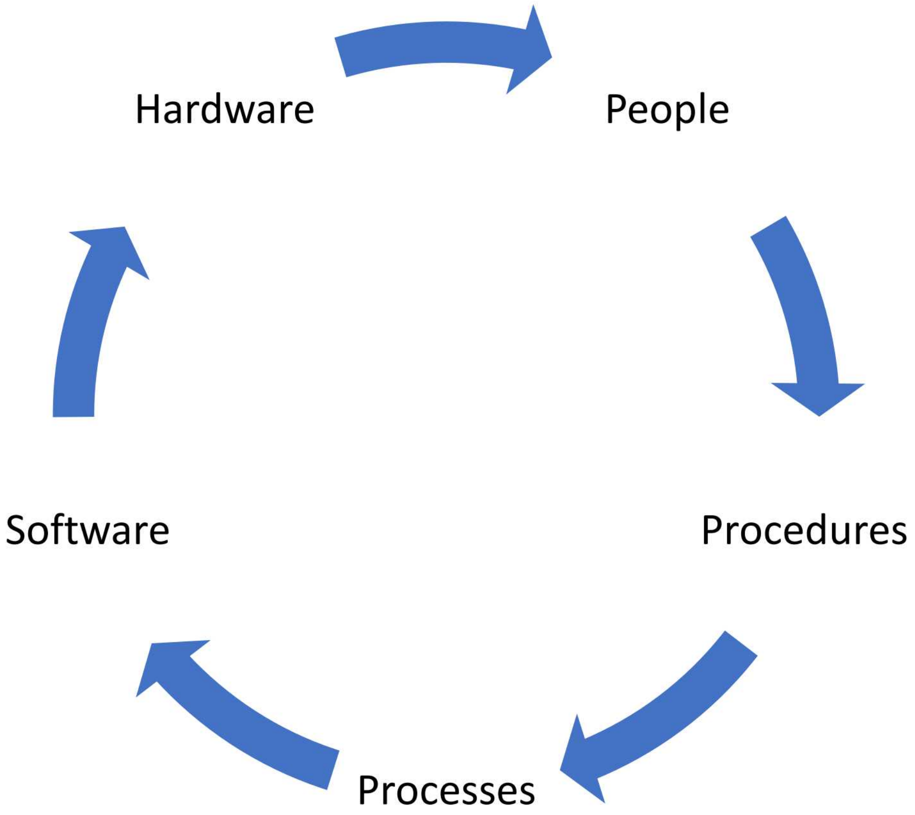


2018 event

- While troubleshooting a turbine system, an employee experienced a mild electrical shock
- RCA revealed several areas associated with the turbine safety systems, along with implementation of work planning and controls
  - the process of identifying, planning, approving, controlling and executing work at a DOE facility
- RCA recommendations:
  - strengthening training
  - additional rigor on work documentation
  - continuing efforts to improve software parameter changes
  - intrateam communications
  - turbine electrical system design for operability (user-centered design)

Holistic approach

- Frequent and concise communication
- Conservative decisions / verify assumptions
- Anticipate problems and mitigate
- Be on the lookout for conditions that can lead to human error and eliminate them
- Reinforce defense strategies that mitigate error consequences
- Focus on the task at hand to reduce the likelihood of error
  - self-check
  - peer checking (two-person verification)
  - mentoring/coaching to
- Follow procedures and technical work documents, correct procedural deficiencies before starting or continuing the task
- Integrate and practice team skills to improve performance



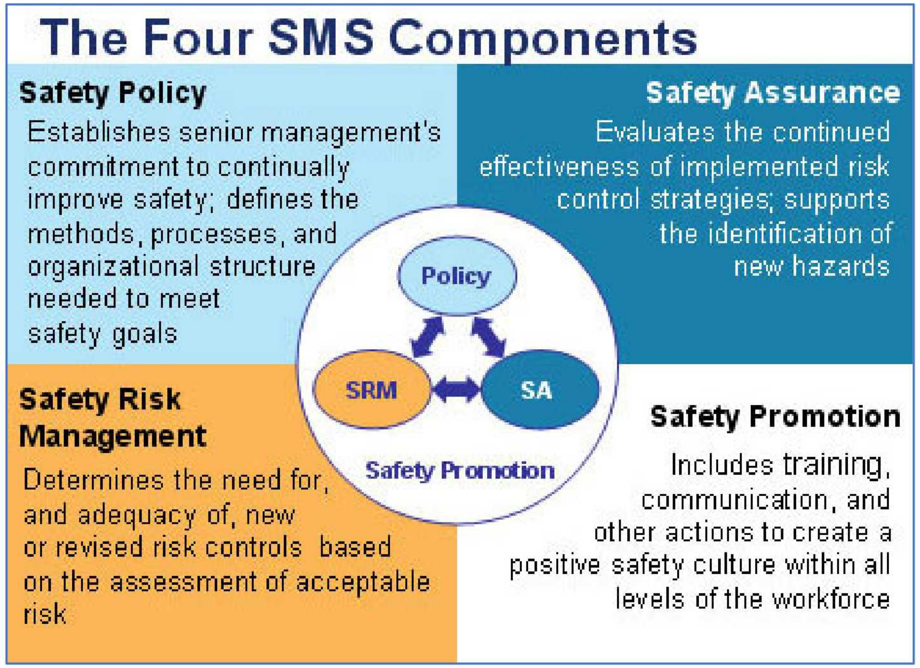
Drive out risks

- Latency
- Risk ID & management
- Continuous improvement
- Measure performance
- Analyze processes
- Safety as an integral part of a facility's operational management and site culture

https://www.forbes.com/sites/steveculp/2020/06/29/covid-19-highlights-need-for-new-approaches-to-risk-management/#5440a48766b8

Safety Management System (SMS)

- Control of safety risks
- Acceptable level of safety
- Besides helping to better understand current level of safety, a safety management system (SMS) communicates that level of safety to all stakeholders
- Prevents incidents and accidents
- Improves overall communication, morale, and productivity

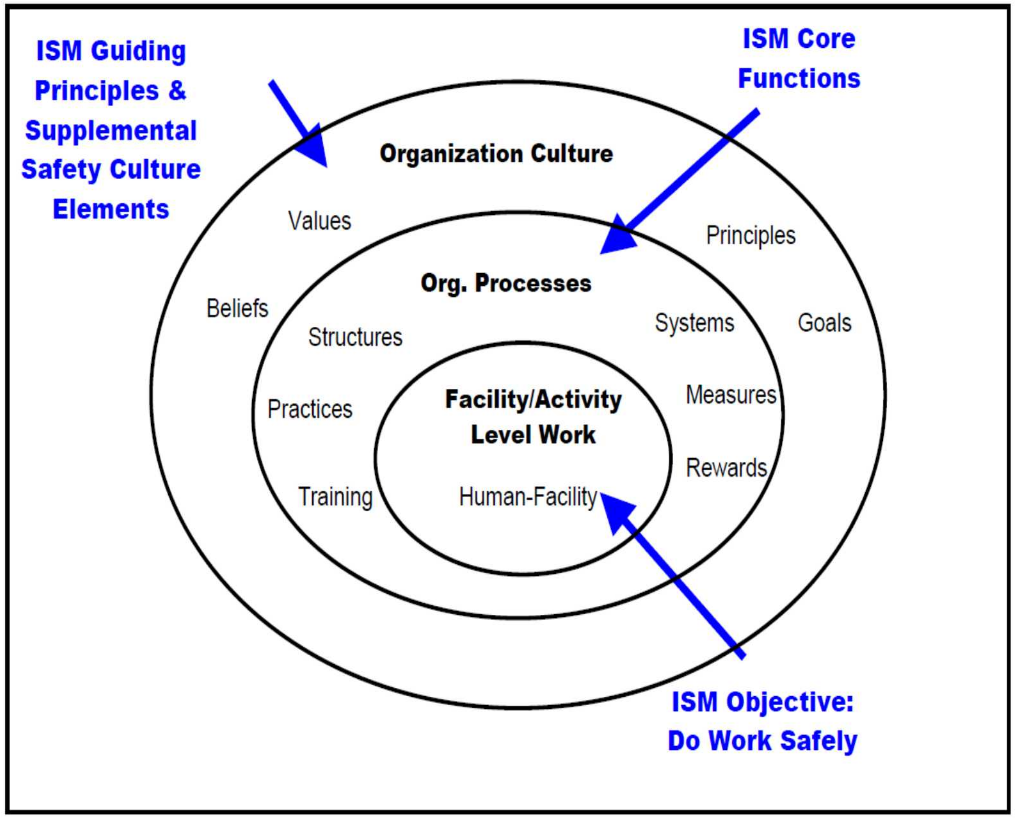


Federal Aviation Administration (2020).
https://www.faa.gov/about/initiatives/sms/explained/components/

Integrated Safety Management (ISM)

DOE system safety:

"a facility structure, system, or component of which the preventative or mitigative function is a major contributor to defense in depth or worker safety as determined from hazard analysis



ISM benefits

- Considers site-specific factors, conditions, analyses, and processes to include:
  - Types of potentially hazardous work at the site
  - Results of design studies, safety analyses, hazard reduction analyses, and risk analyses
  - Types of hazards at the site (chemical, physical, ergonomic, environmental, transportation)

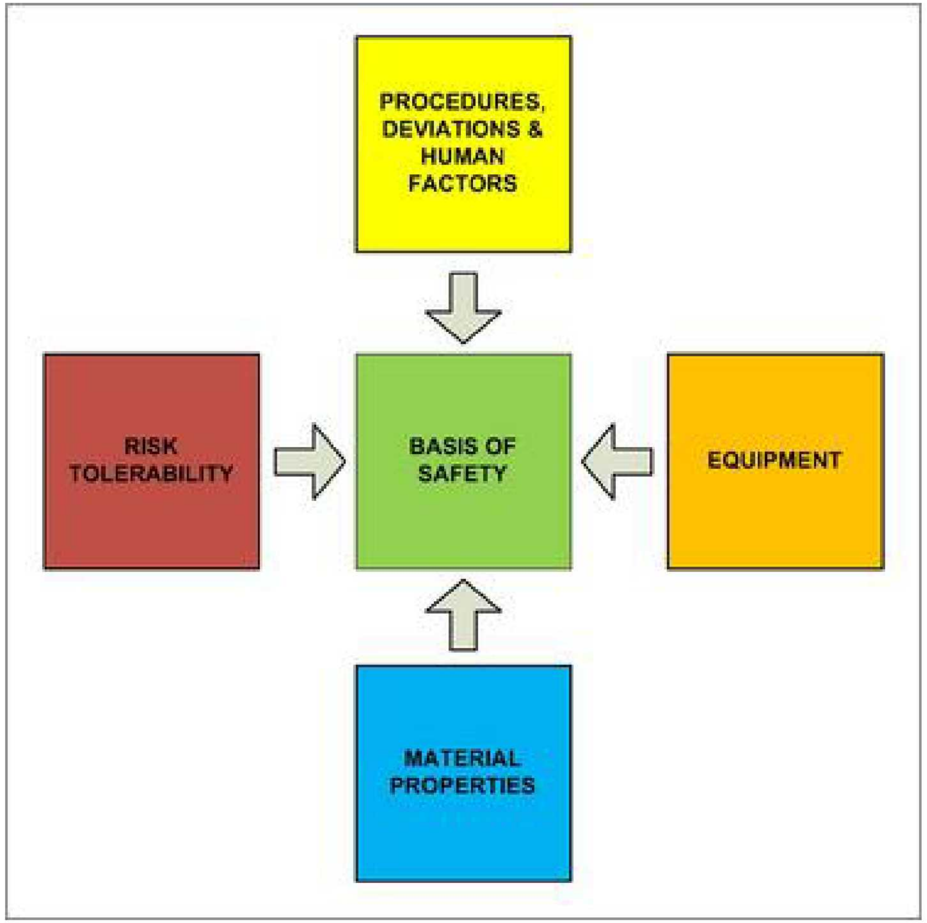
Hazard analysis

Safety basis process

- Systematic identification of both natural and man-made hazards
- Evaluate normal, abnormal, and accident conditions
- Enabled team to derive and update the hazard controls
    - protection of workers
    - protection of the public
    - protection of the environment
    - demonstrate adequacy of controls
- It defines the characteristics of the safety management programs necessary to ensure the safe operation of the facility

Project team diversity

- Must first identify the possible hazards of a new system through collaborative hazard analyses
- Identify those states that can lead to an accident or incident
- Qualified experts representing all systems and specialties relevant to the new facility
- Safety case is prepared that assures the system is as safe as reasonably possible



http://www.hazardous-area-consultants.com/basis-of-safety.html

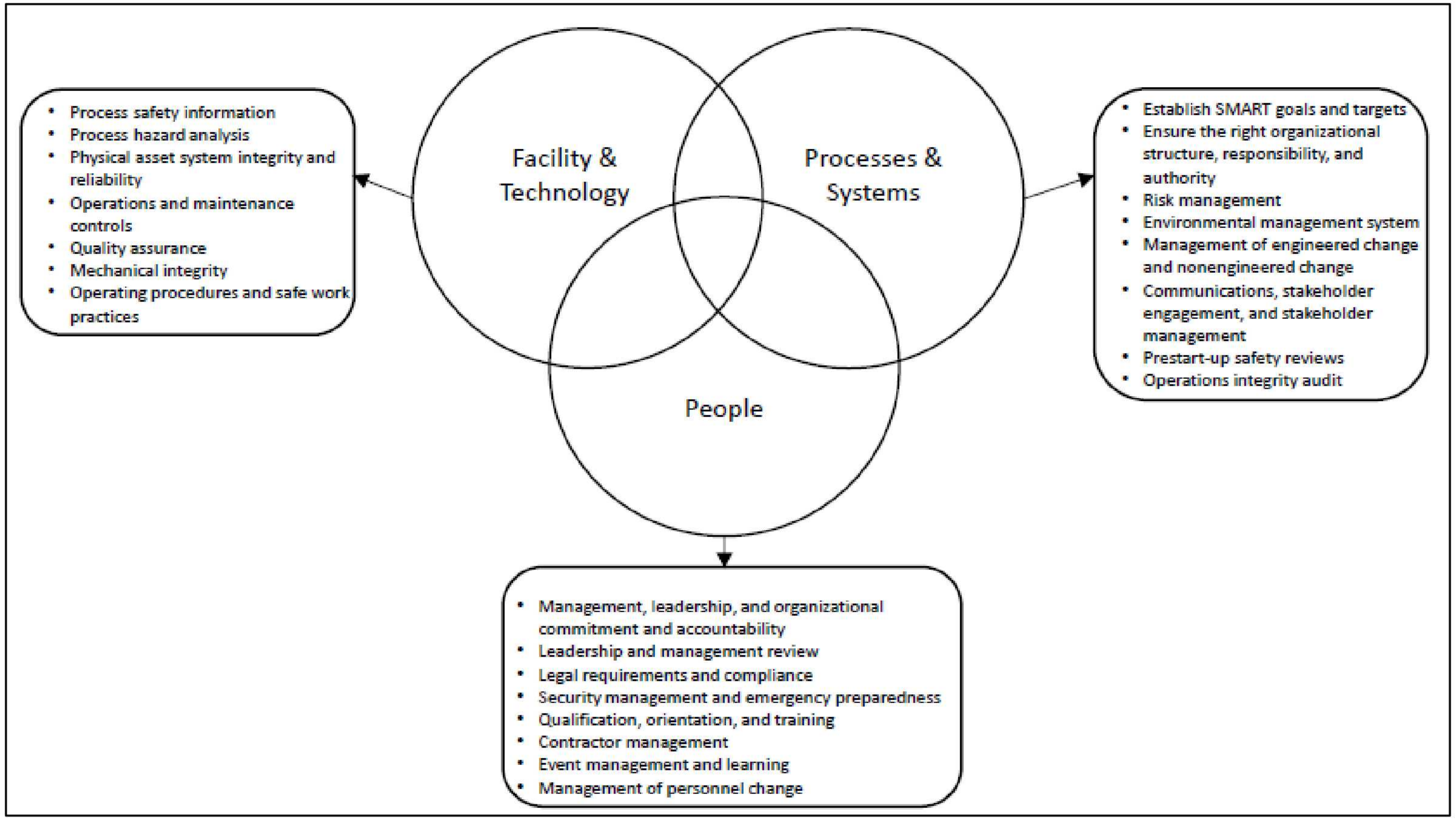
Control framework

Early project development

- Comprehensive SMS throughout the system life cycle
- Implement robust and deliberate system safety early on in a project
- Conduct initial hazard analysis in the early conceptual stage of a new research facility
- Have the necessary knowledge and safety expertise available as leverage to influence design, and to help manage stakeholder and customer expectations.

Operational Excellence Management System

- Manage corrective actions
- Engage the team
- Drive ownership in the vision for the facility and research program
- Add structure to overall project and safety management systems
- Keep a well-defined set of tasks in progress, rather than implement a total site stand-down



Lutchum, C., Evans, D., Maharaj, R., Al Hashemi, W., & Al Hashemi, W. (2015). *7 fundamentals of an operationally excellent management system*. Boca Raton, FL: CRC Press.

Engagement and improvement

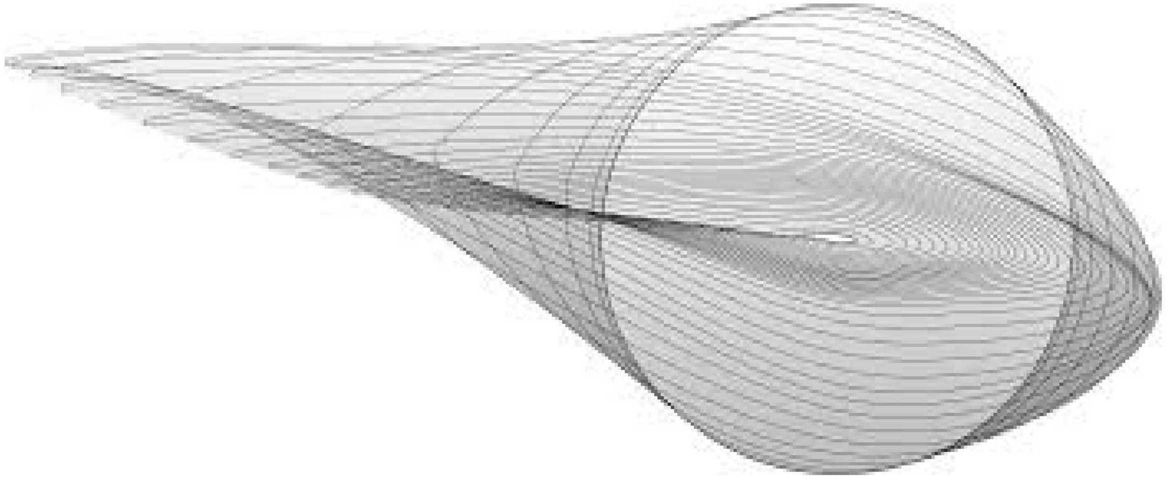
- Multidisciplinary team of ES&H professionals and systems safety SMEs travelled to the site in 2018 & 2019
- Emergency management, facilities electrical safety, LOTO, industrial hygiene, and fall prevention and protection disciplines
- Confined space, dedicated circuits and suggested modifications to better implement LOTO, tower rescue (incapacitated worker/climber – need for emergency response drills)
- Procedures, policies, and technical work documents
- New procedures developed for turbine safety systems and software
- Dedicated hardware-in-the-loop (HIL) system to test software deployments offline before deploying in the field on the turbines
- Configuration management procedure with an engineering change notice (ECN) process
- New procedures are reviewed holistically to ensure that they are not introducing new, unintended hazards, such as the requirement to climb the tower multiple times to accomplish a task

Sustainable safety

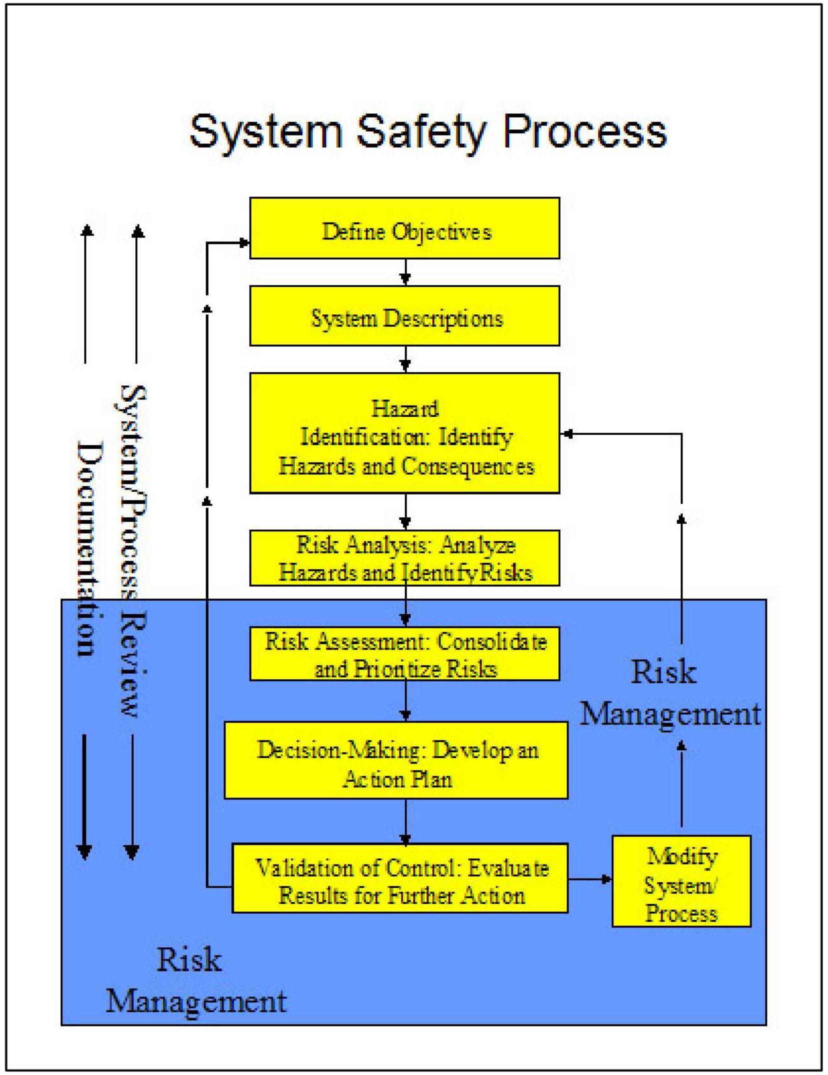
- Start every meeting with safety
- Wind industry expertise
- Collaborative engagement with safety engineering and safety basis organizations

https://nawindpower.com/wp-content/uploads/2017/05/turbine-technician.jpg

Where we’re at now

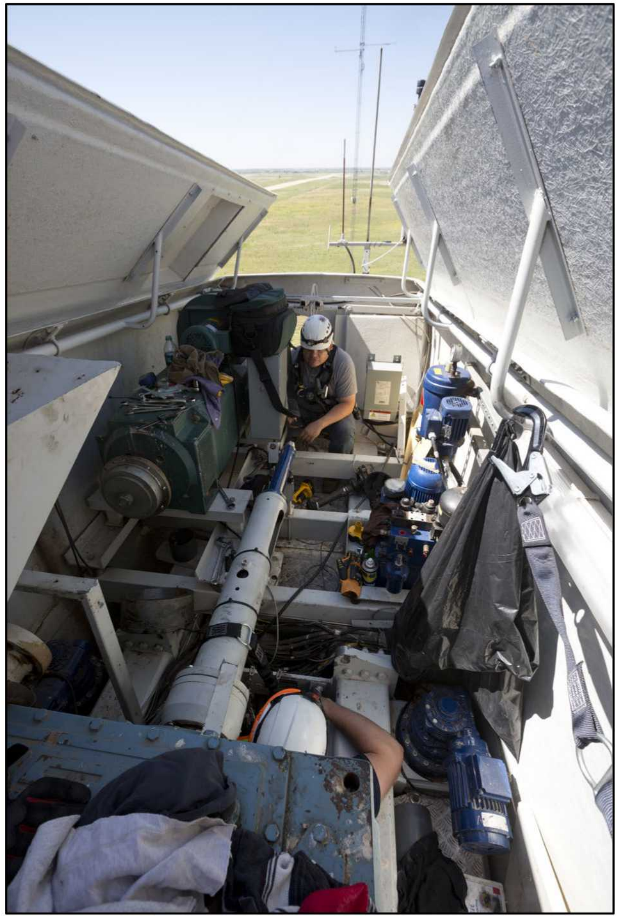


System safety



https://www.faasafety.gov/gslac/alc/libview_normal.aspx?id=6877

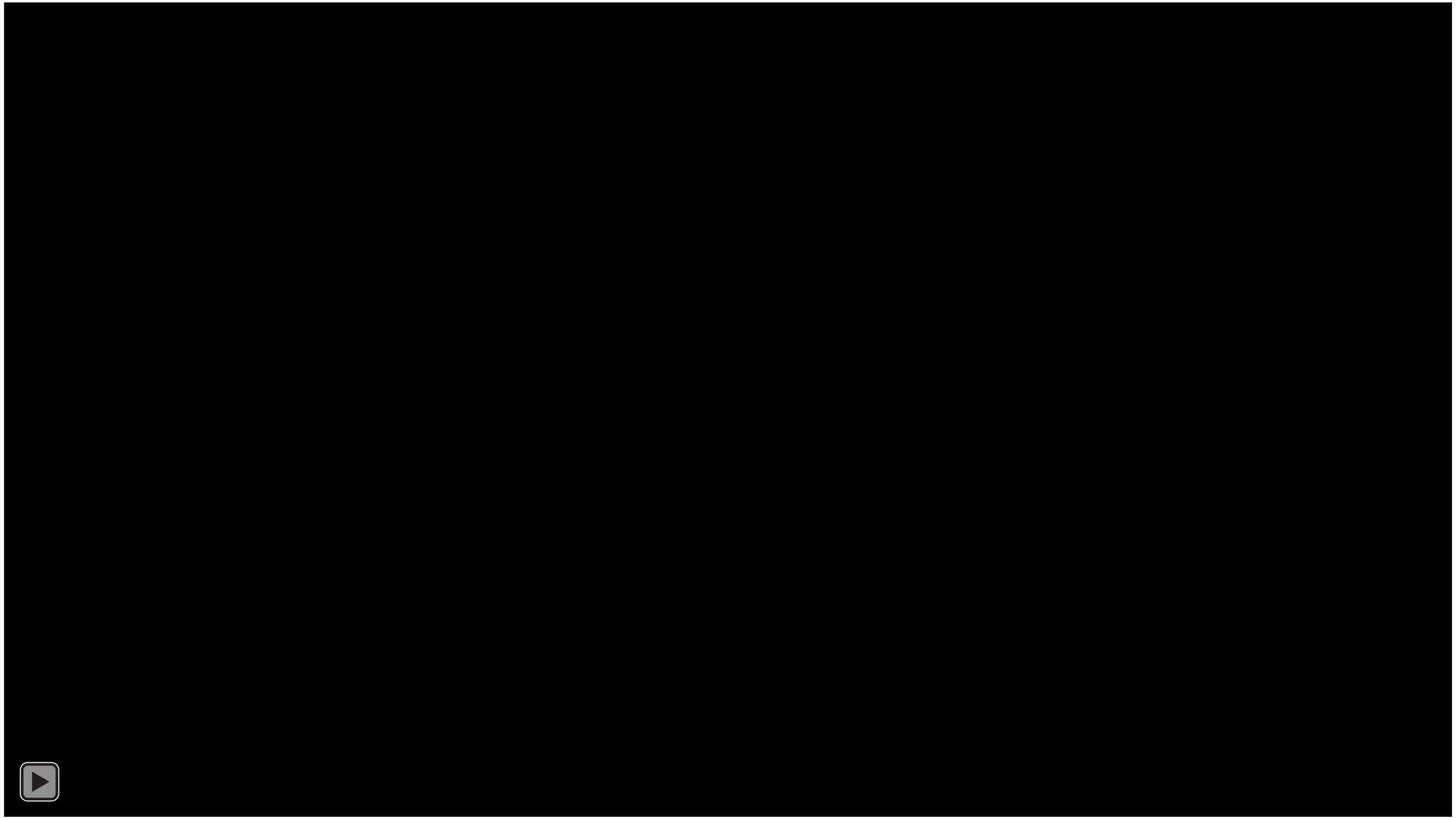
Resiliency



Cross-cutting approach to safety

https://medium.com/@solar.dao/risk-management-in-renewable-energy-projects-129eb976fde5

Research center-of-excellence



Thank you!