# Update on Sandia Active-Aero Rotor Field Test

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Wind Energy Technologies Department
Sandia National Laboratories

## 2012 Wind Turbine Blade Workshop

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Albuquerque, NM

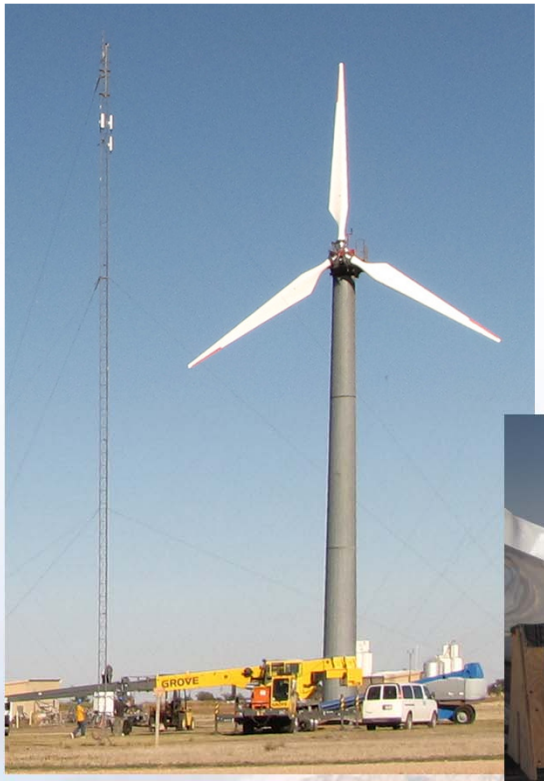
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

# *Presentation Outline*

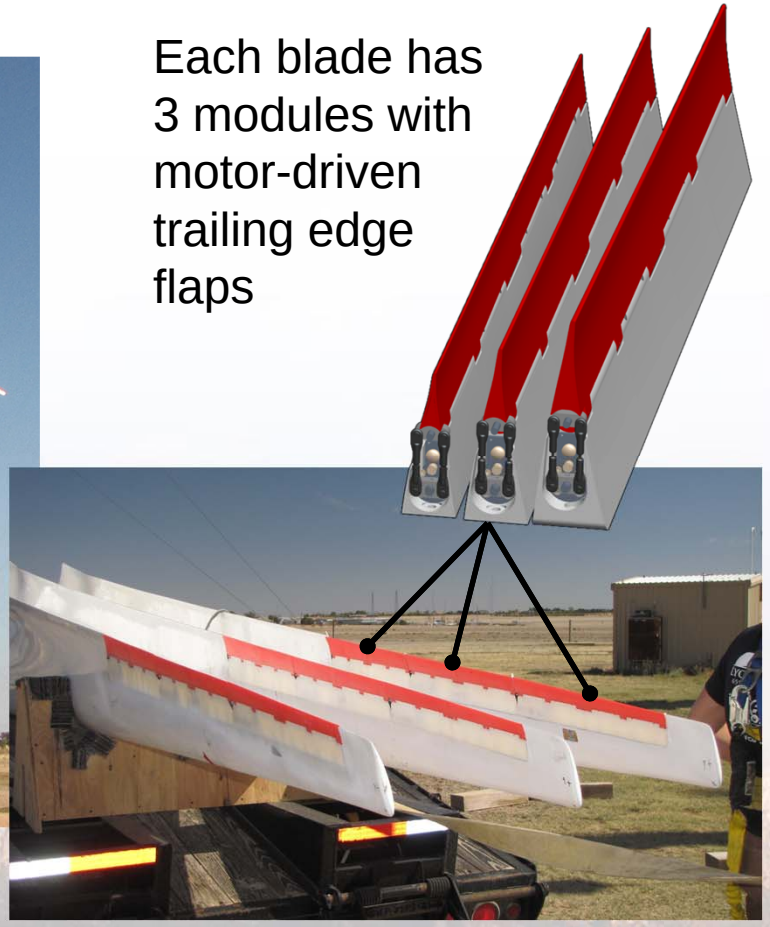
- **Project Overview and Videos**
- **Why did Sandia build an active-aero rotor?**
- **How did we design & build the blade set?**
- **What are the analysis results to date?**

# Project Overview

At our test site near Amarillo, TX, Sandia has been testing an active-aerodynamic rotor.




Each blade has 3 modules with motor-driven trailing edge flaps



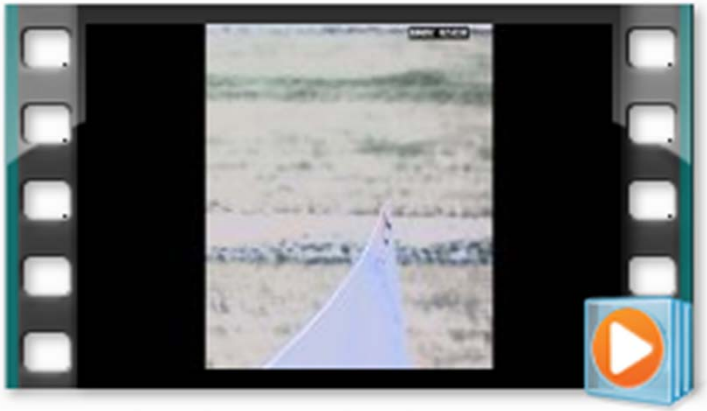
During the last few months, we have acquired operational sensor data and video

# *The Test Turbine*

- **Micon 65/13M (modified)**
- **Hub height: 23m (75ft)**
- **Generator rated at 115kW**
- **Nominal rotor speed: 55 rpm**
- **Fixed pitch**

- **Trailing edge flaps**
  - 20% chord rigid flaps
  - Outer 6 feet (20%) of blade span

# *Video Results Preview (Let's cut to the chase!)*



NonRotating_SineSweep.wmv

Operational_SineSweep.wmv

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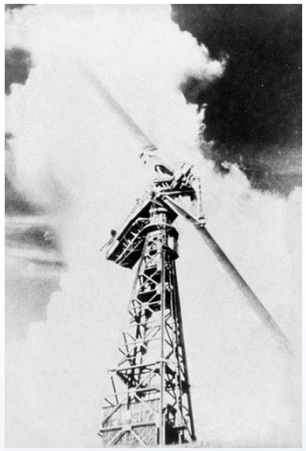
# Motivation

- **Fast-acting, distributed aerodynamic control along the wind blade may be the next step forward in wind turbine control.**
- **Consider the history of pitch regulated turbines**
  - Full-span pitch control was devised as early as 1941[1]
  - Yet the stall-regulated rotor was common for a number of years due to simplicity
  - However, pitch regulation in modern designs has enabled lighter blades and smaller drivetrains
- **Distributed aerodynamic control offers:**
  - Load control & rotor balancing
  - Aerodynamics tailored to inflow conditions

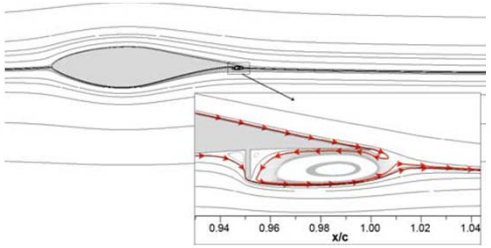


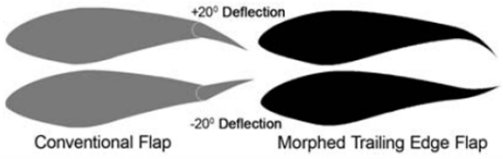
1250kW Smith-Putnam wind turbine (1941)
Courtesy of DOE/NREL

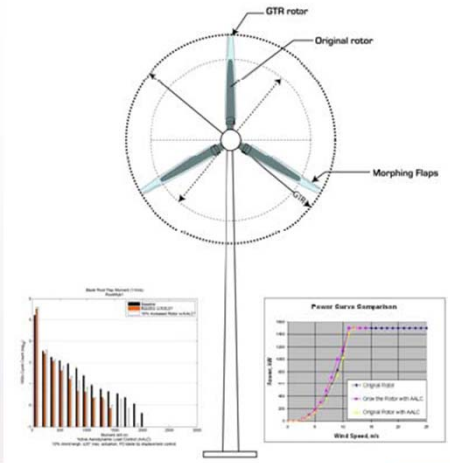
1. Burton, et al. "Wind Energy Handbook". Discussion of 1250kW Smith-Putnam wind turbine, p. 1

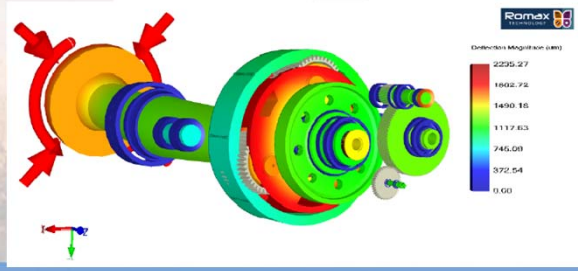
# History at Sandia

- **Devices: microtabs, both rigid and morphing trailing edge flaps, air jets**
- **Subcontract with UC Davis to perform wind tunnel tests and high-fidelity simulation**
- **Simulation of Active Aero Load Control (AALC)**
  - Showed reduction of peak and fatigue structural loads
  - Demonstrated 5-8% reduced COE by growing rotor
  - Demonstrated benefits for drivetrain stresses
- **Decided to build active-aero rotor to answer lingering questions:**
  - How well do our aero-elastic simulation tools represent reality?
  - What are the implementation challenges?



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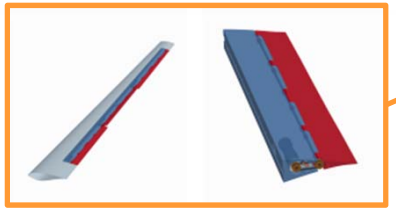
# Design-build-test Plan

- **Design**
  - Leveraged existing SNL CX-100 blade design
  - Modular active device construction (blade set can be used for future device concepts)
  - Conventional rigid flaps chosen, not for aerodynamic efficiency but rather for relative simplicity of integration
- **Build**
  - TPI Composites fabricated skins using standard techniques
  - Installed internal sensors before closing blades
  - Utilized expertise of SNL's composites group to modify blades for integration of flap modules
  - Used rapid prototyping for modules to focus on function rather than development of manufacturing techniques
- **Test**
  - Full system structural and aerodynamic response is being characterized through incremental learning steps

# Instrumentation

Sensors are critical for active-aero device characterization & control!

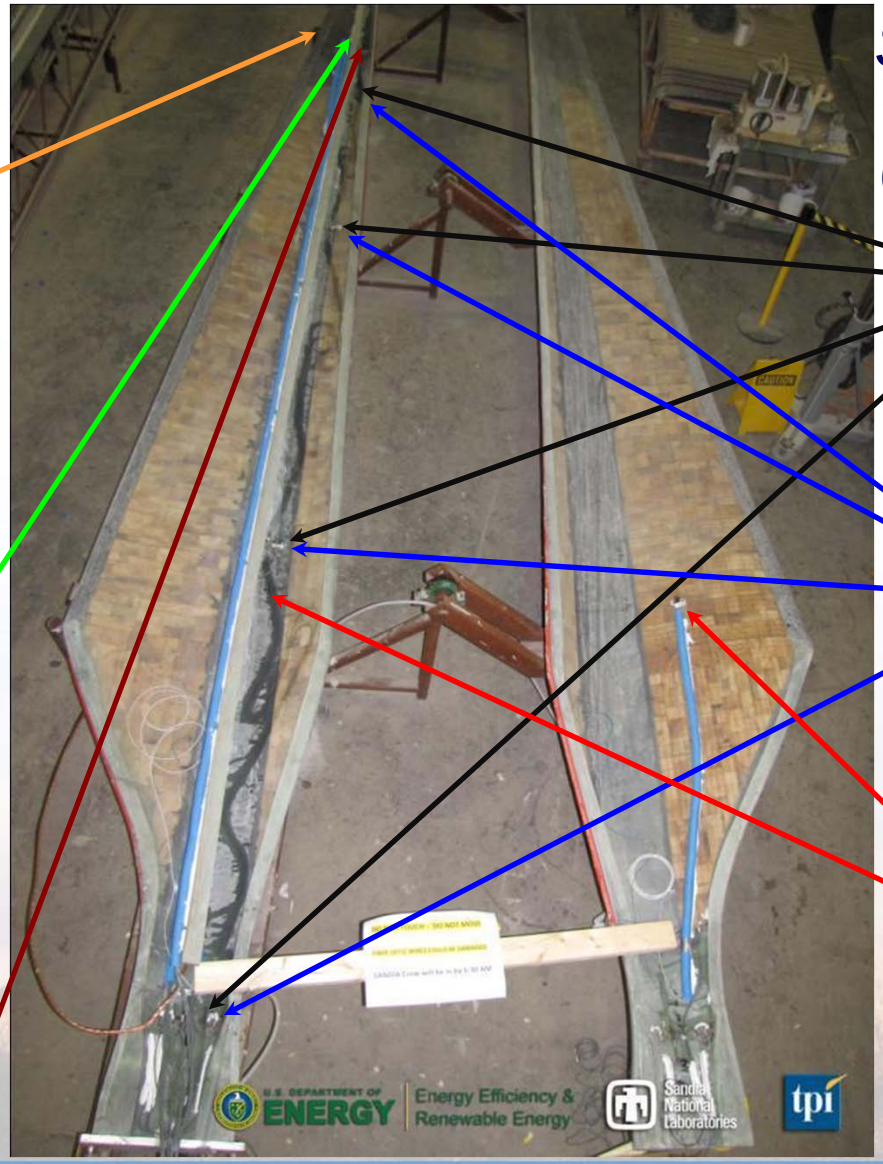
## Aero Actuator



## Aero Sensors

*Pressure Taps*
*(surface pressure)*

*5-Hole Pitot Tube*
*(AOA and Velocity)*

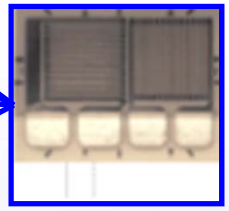



## Structural Sensors

*Fiber Optic*
*(strain and temperature)*

*Strain Gage*
*(strain)*

S



*Accelerometer*
*(acceleration)*

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U

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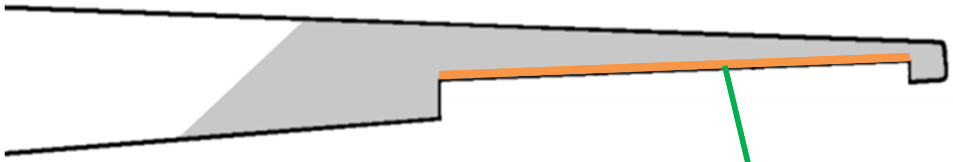
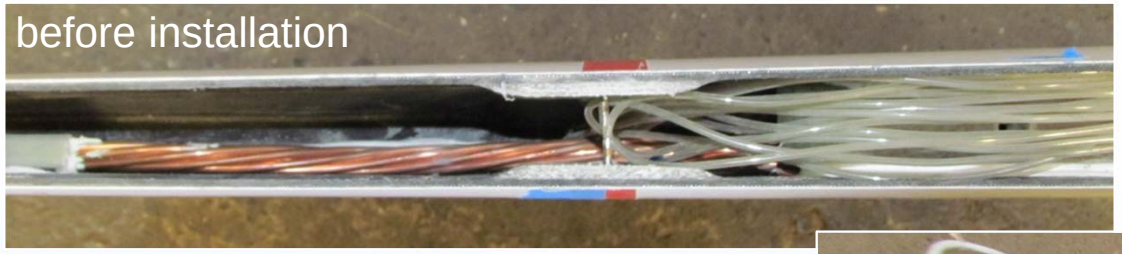
# Blade Modifications

- **Custom-built web**
  - Regain lost stiffness
  - Provide flat surface for attaching modules



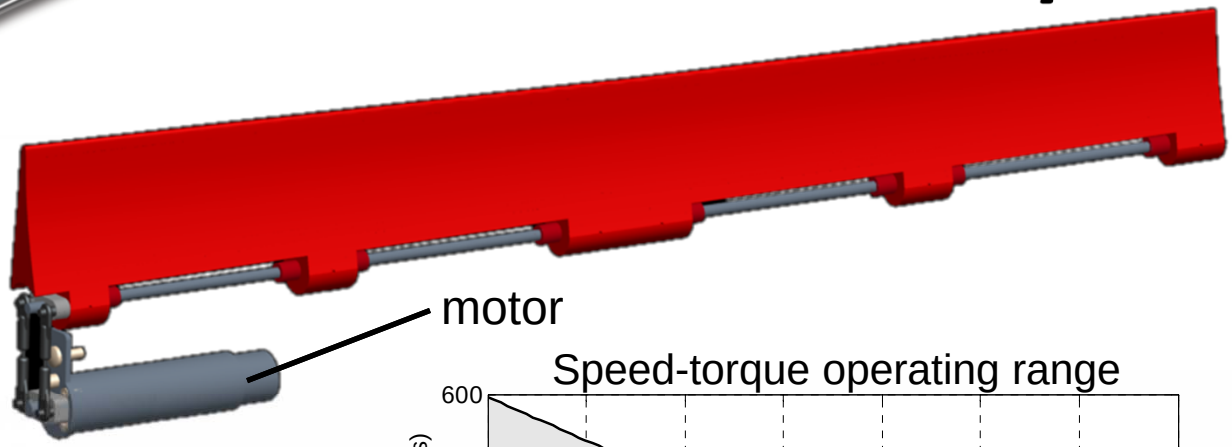
web



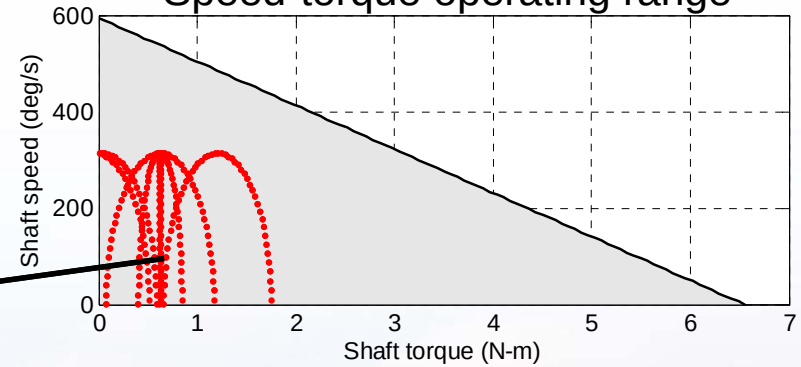

module control
cable feed-thru

Threaded nut-plates
provide attachment points

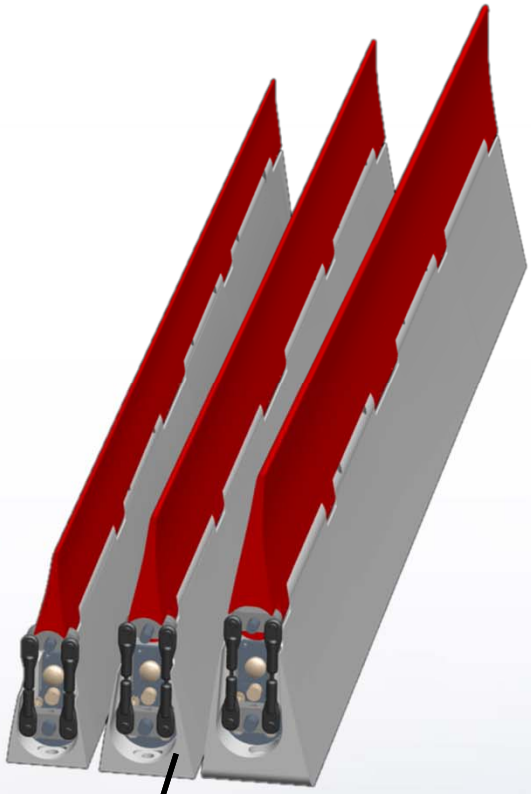
# Flap Module Design




Speed-torque operating range

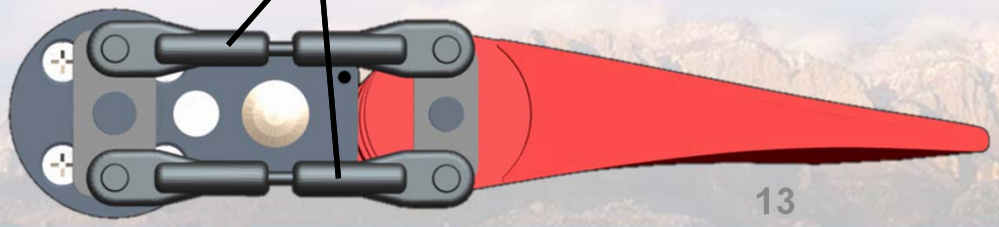



Expected operating curves



Fabricated using rapid-prototyping technology

Linkages transfer motion from motor to flap



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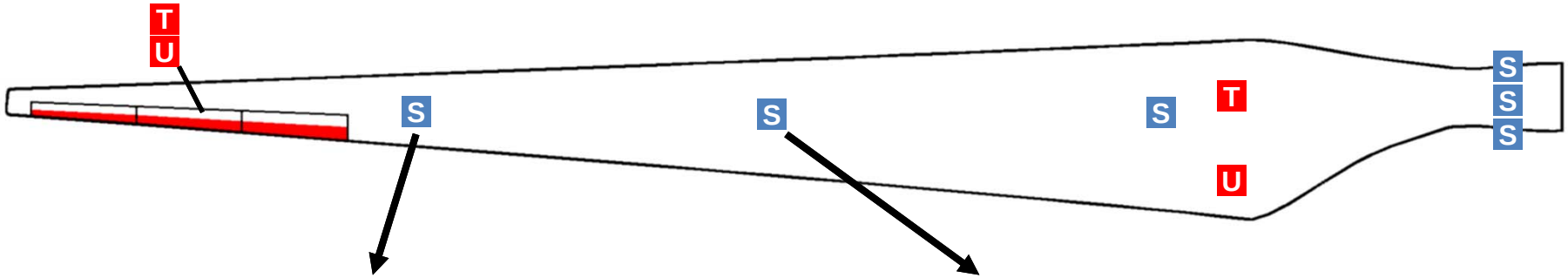
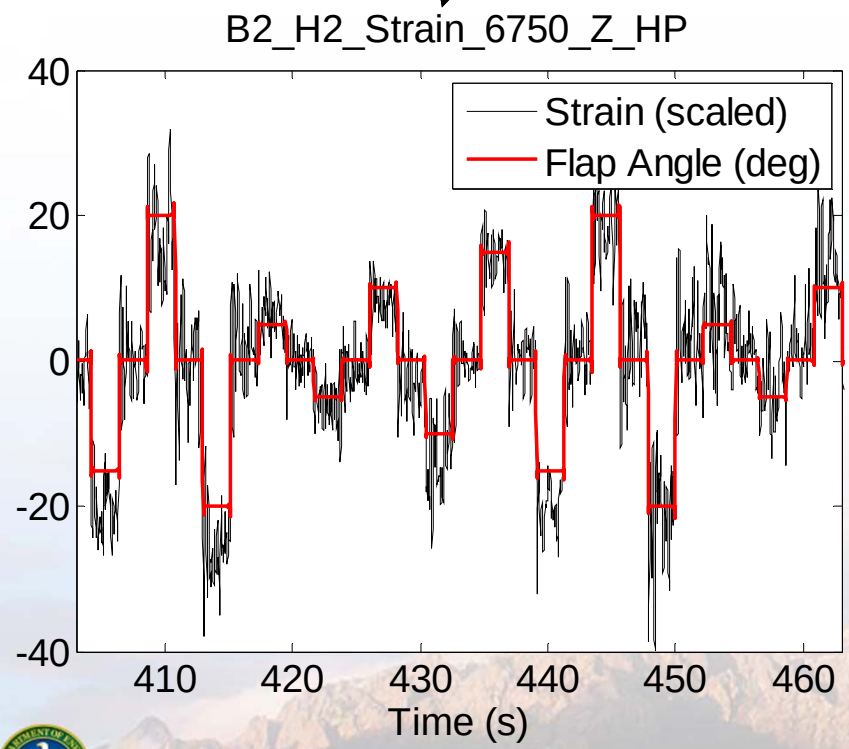
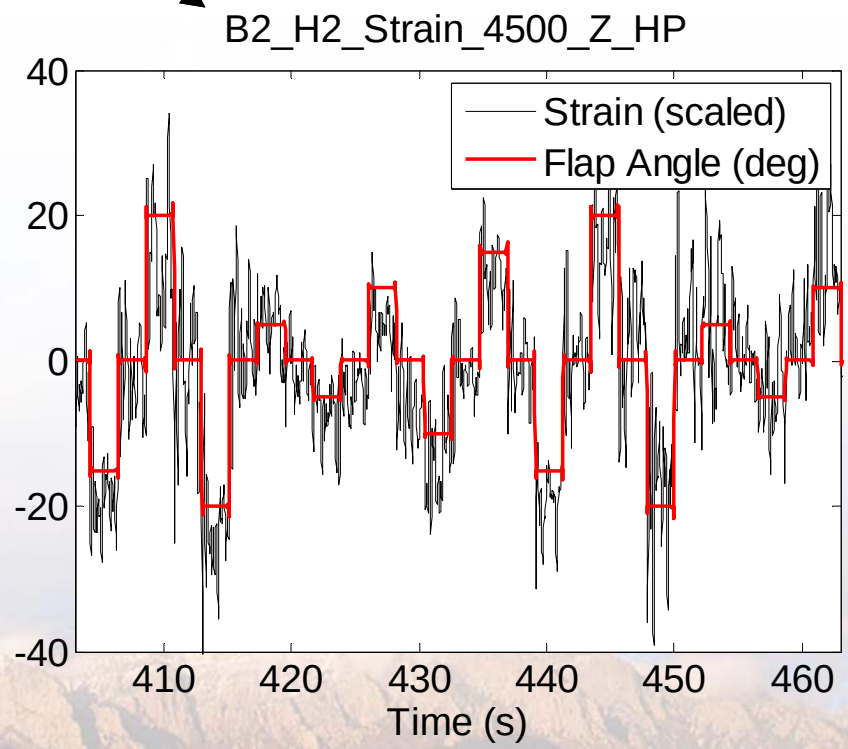
# Raw Strain Response

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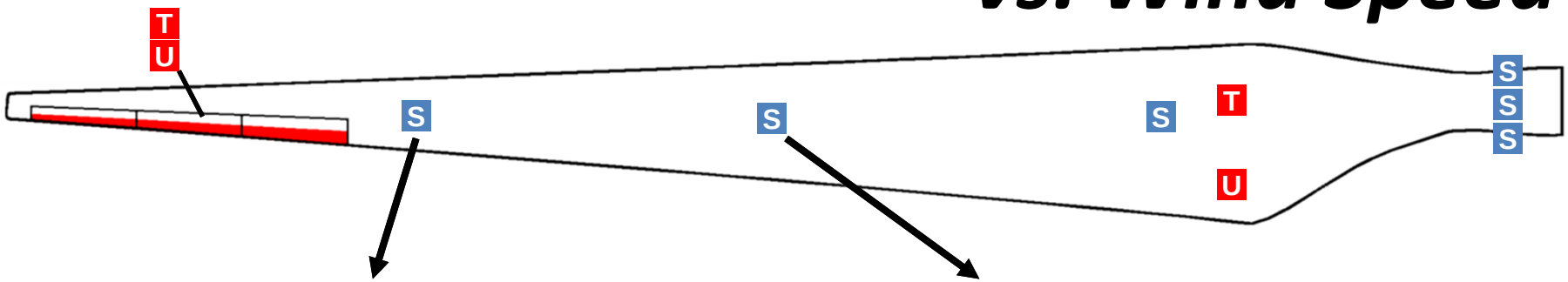
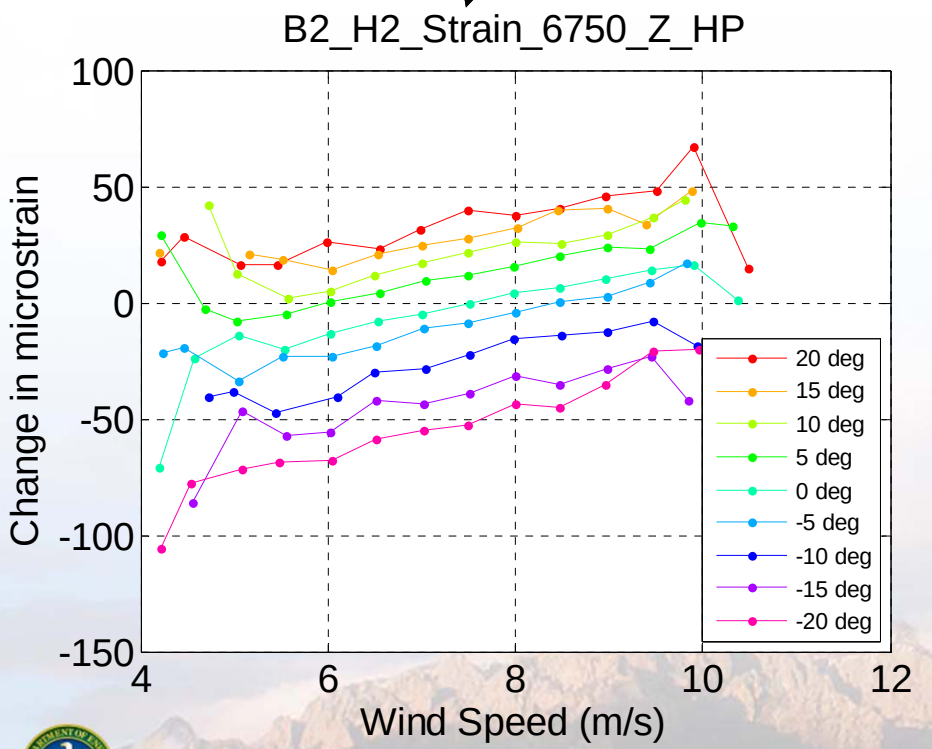
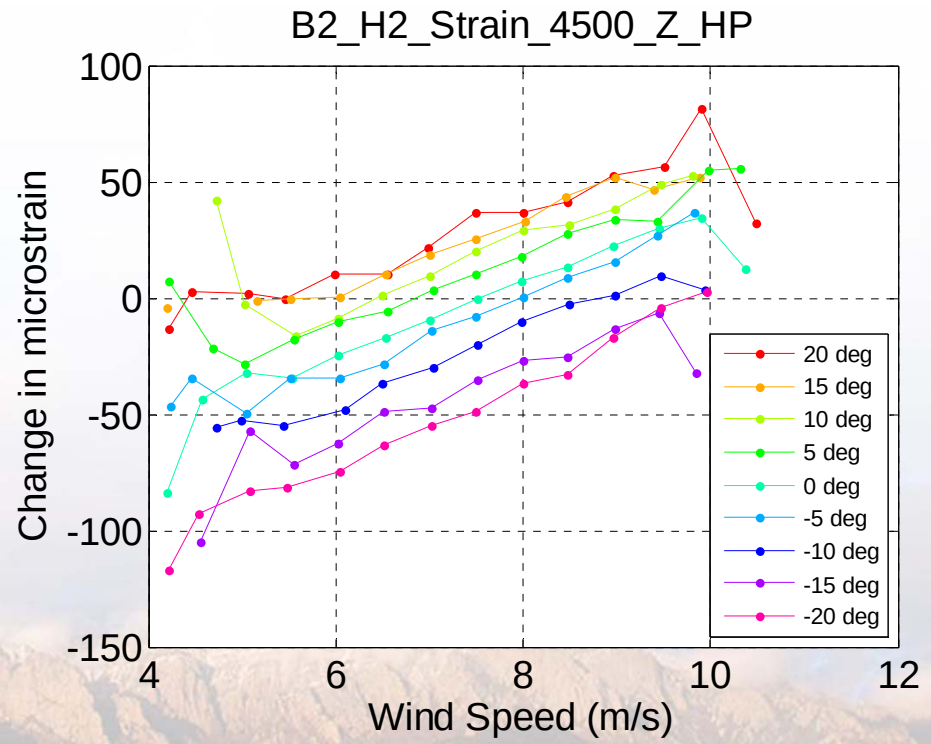
# Mean Strain Response vs. Wind Speed

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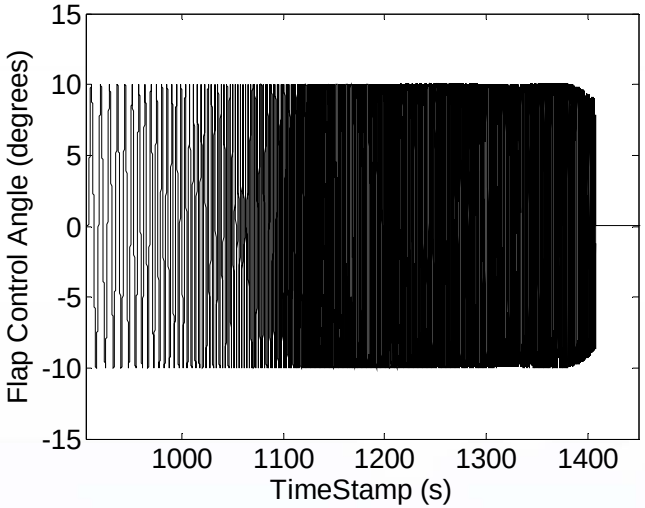
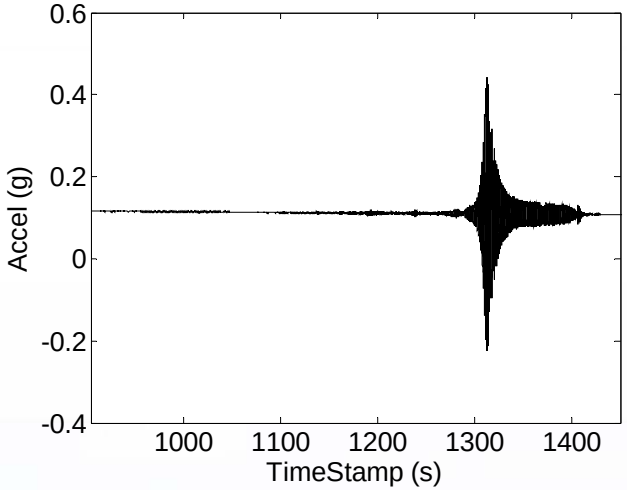
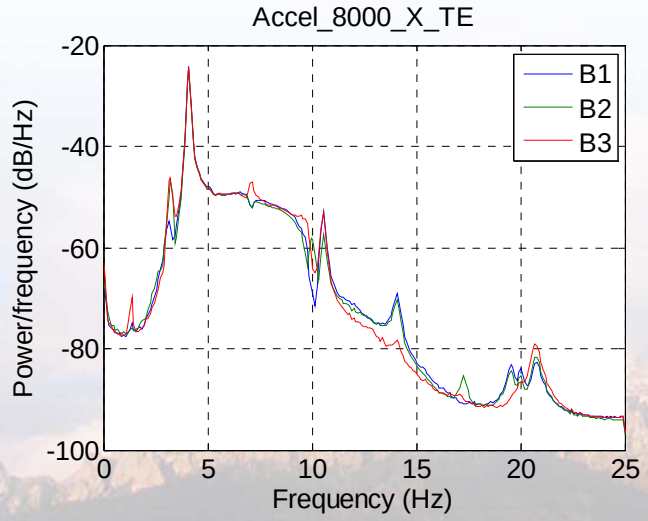
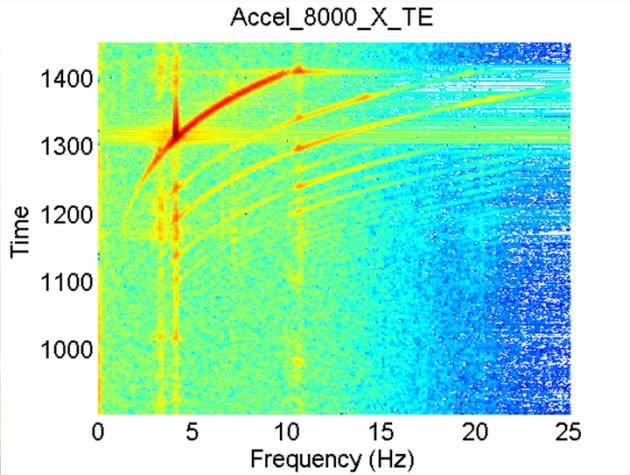
# System ID – Parked Rotor Sine Sweep

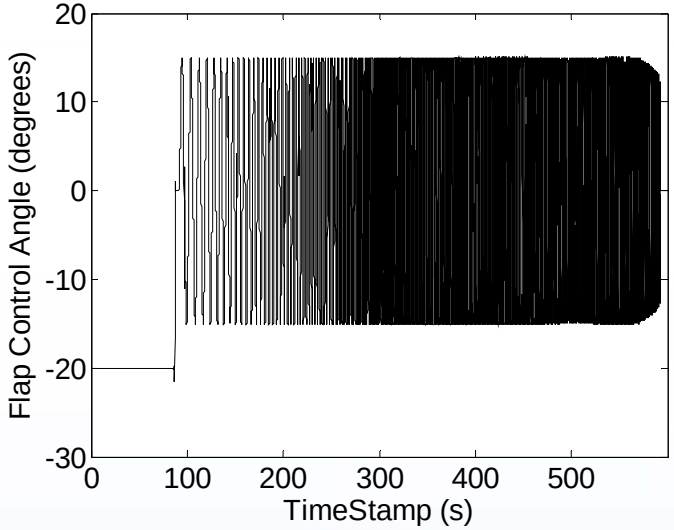


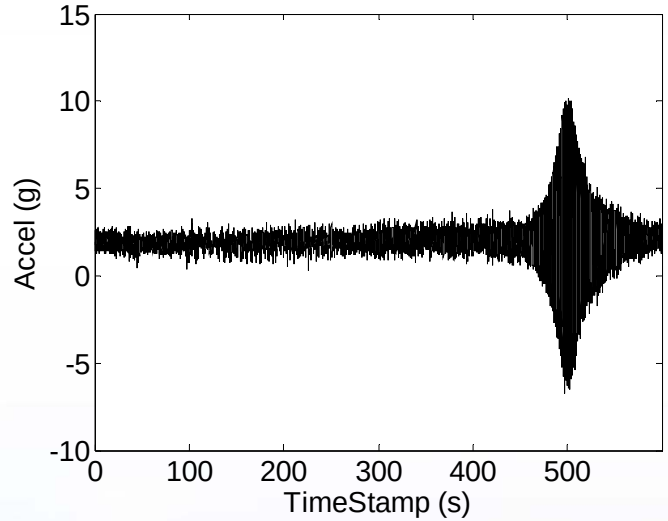



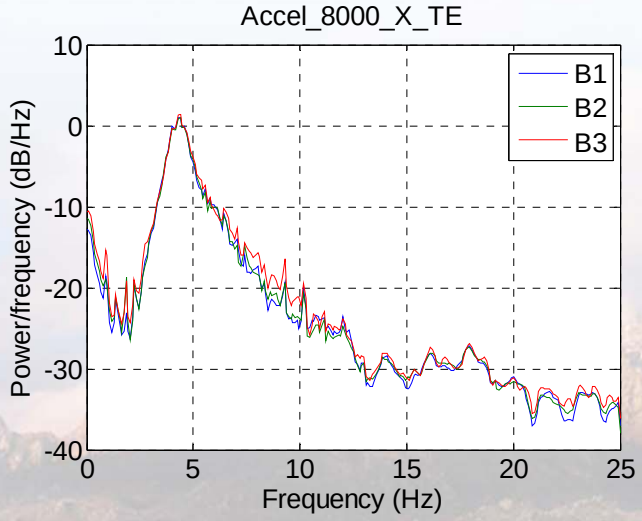



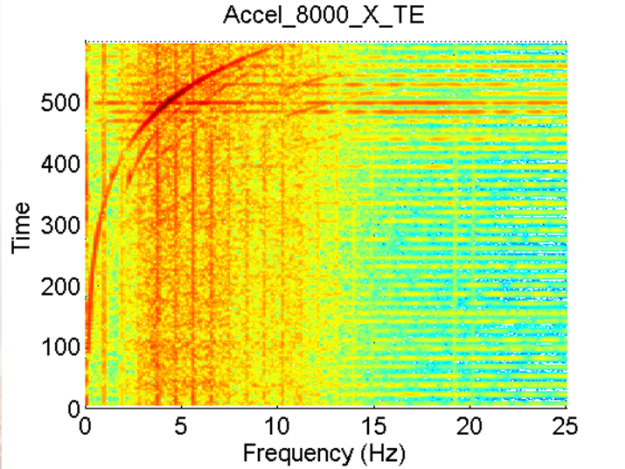



# System ID – Operational Sine Sweep



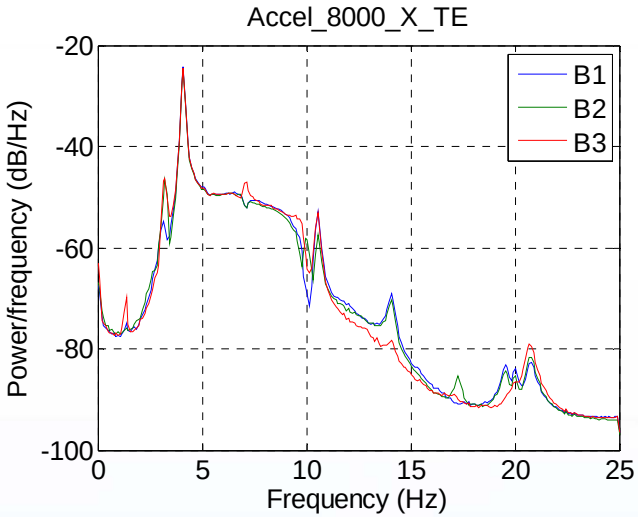



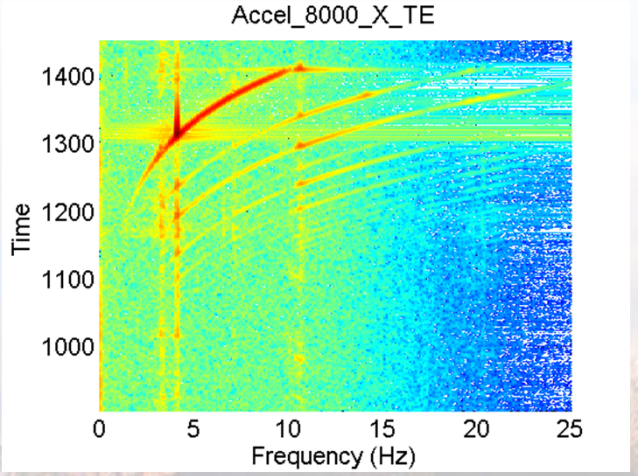



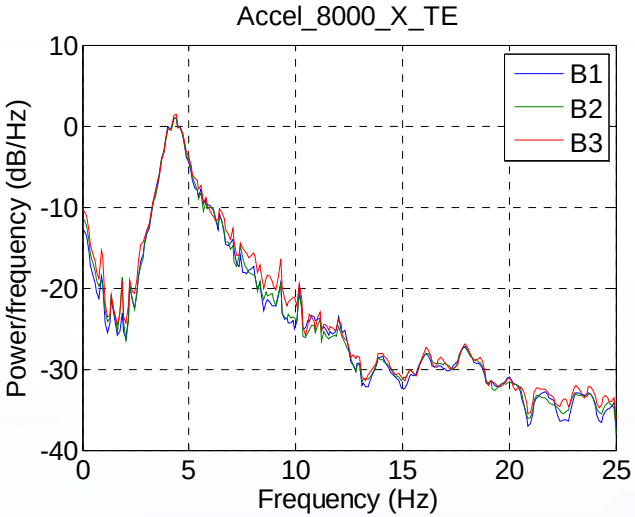
# System ID - Comparison

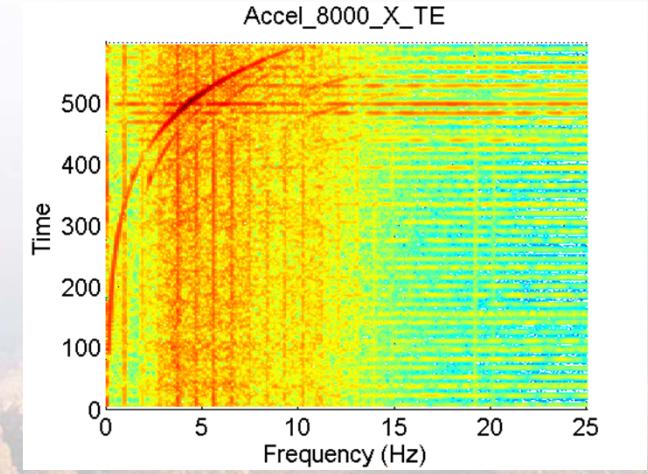
Parked rotor




Operating



# *Future Work*

- **Compare to simulation**
  - Control authority
  - Aerodynamic damping
  - Time lag between actuation and response
- **Work towards closed-loop control**
  - Refine system ID techniques
  - Controller design

# *Thank You*

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