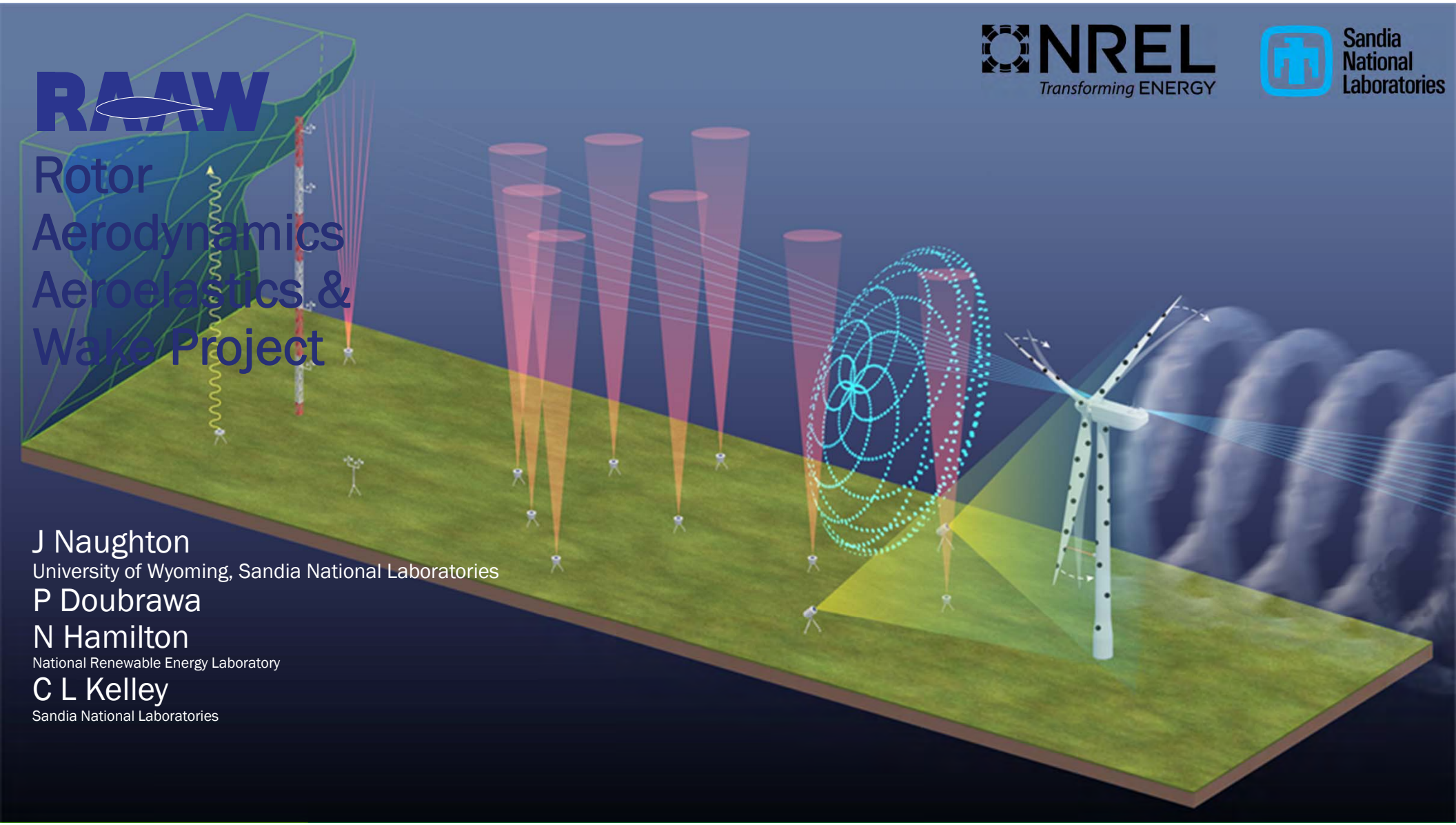
RAAW

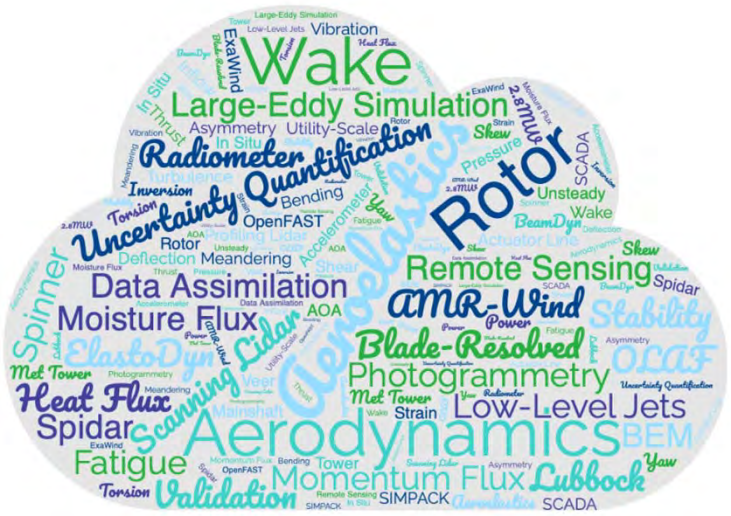
Rotor Aerodynamics Aeroelastics & Wake Project



J Naughton
University of Wyoming, Sandia National Laboratories
P Doubrawa
N Hamilton
National Renewable Energy Laboratory
C L Kelley
Sandia National Laboratories

What is RAAW ?

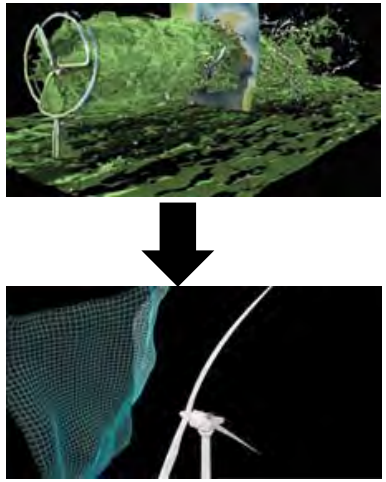
- A 3-year (2021-2024) project
- A partnership
  - **GE Renewable Energy**
  - United States Department of Energy (DOE)
  - National Renewable Energy Laboratory (**NREL**)
  - Sandia National Laboratories (**SNL**)
  - Others
    - Danish Technical University (DTU)



- A 1-year field campaign
  - Is performed using a 2.8-MW wind turbine
  - Collects detailed inflow, rotor and wake measurements
  - Includes extensive model validation activities
    - Design-level
    - Blade-resolved codes

Why RAAW?

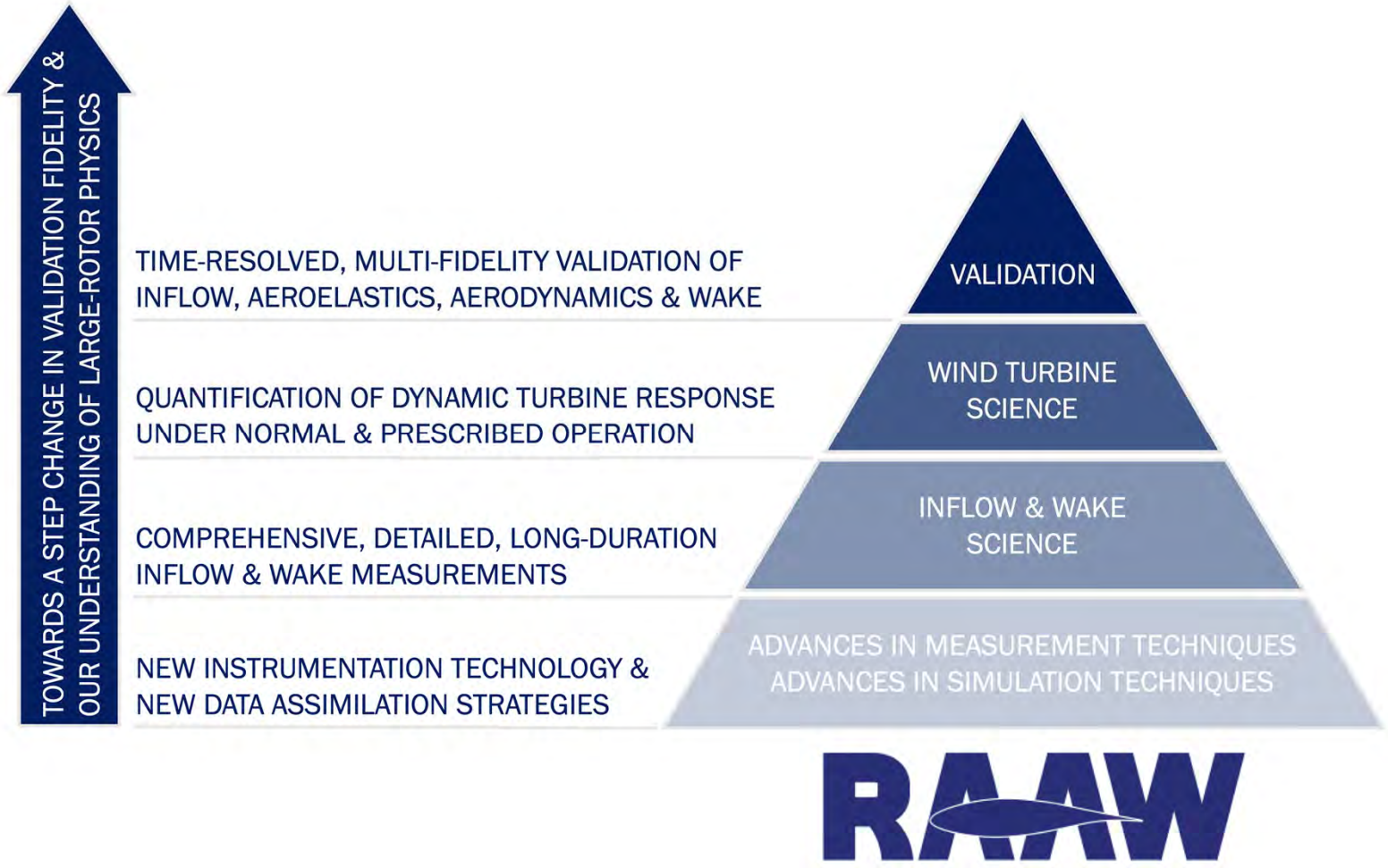
The model improvement cascade: highest fidelity simulations improve lower fidelity models used to design new technology



only works if highest fidelity codes are validated against relevant and accurate measurements

Shortcomings in available datasets	Solutions proposed by RAAW	
Turbine data available for input to models is often limited	Sufficient wind turbine information is available to build a detailed, high-fidelity model of the system	✓
Inflow data available for initial and boundary conditions to models is often limited	The inflow will be extensively measured covering a large area and supplying the quantities and resolutions required	✓
Data available for comparisons with model output is often limited	The wind turbine response and wake will be measured at high resolution	✓
Available datasets are primarily based on scaled-down and stiffer rotors	The wind turbine size and aerodynamic design are representative of modern land-based technology	✓

Why RAAW?


TOWARDS A STEP CHANGE IN VALIDATION FIDELITY & OUR UNDERSTANDING OF LARGE-ROTOR PHYSICS
TIME-RESOLVED, MULTI-FIDELITY VALIDATION OF INFLOW, AEROELASTICS, AERODYNAMICS & WAKE
QUANTIFICATION OF DYNAMIC TURBINE RESPONSE UNDER NORMAL & PRESCRIBED OPERATION
COMPREHENSIVE, DETAILED, LONG-DURATION INFLOW & WAKE MEASUREMENTS
NEW INSTRUMENTATION TECHNOLOGY & NEW DATA ASSIMILATION STRATEGIES
VALIDATION
WIND TURBINE SCIENCE
INFLOW & WAKE SCIENCE
ADVANCES IN MEASUREMENT TECHNIQUES
ADVANCES IN SIMULATION TECHNIQUES
RAAW

The Primary Objectives of RAAW

Model Validation
- Time series validation of inflow, wind turbine response and wake
- Statistical validation of inflow and wind turbine response
- Uncertainty quantification of measured signals

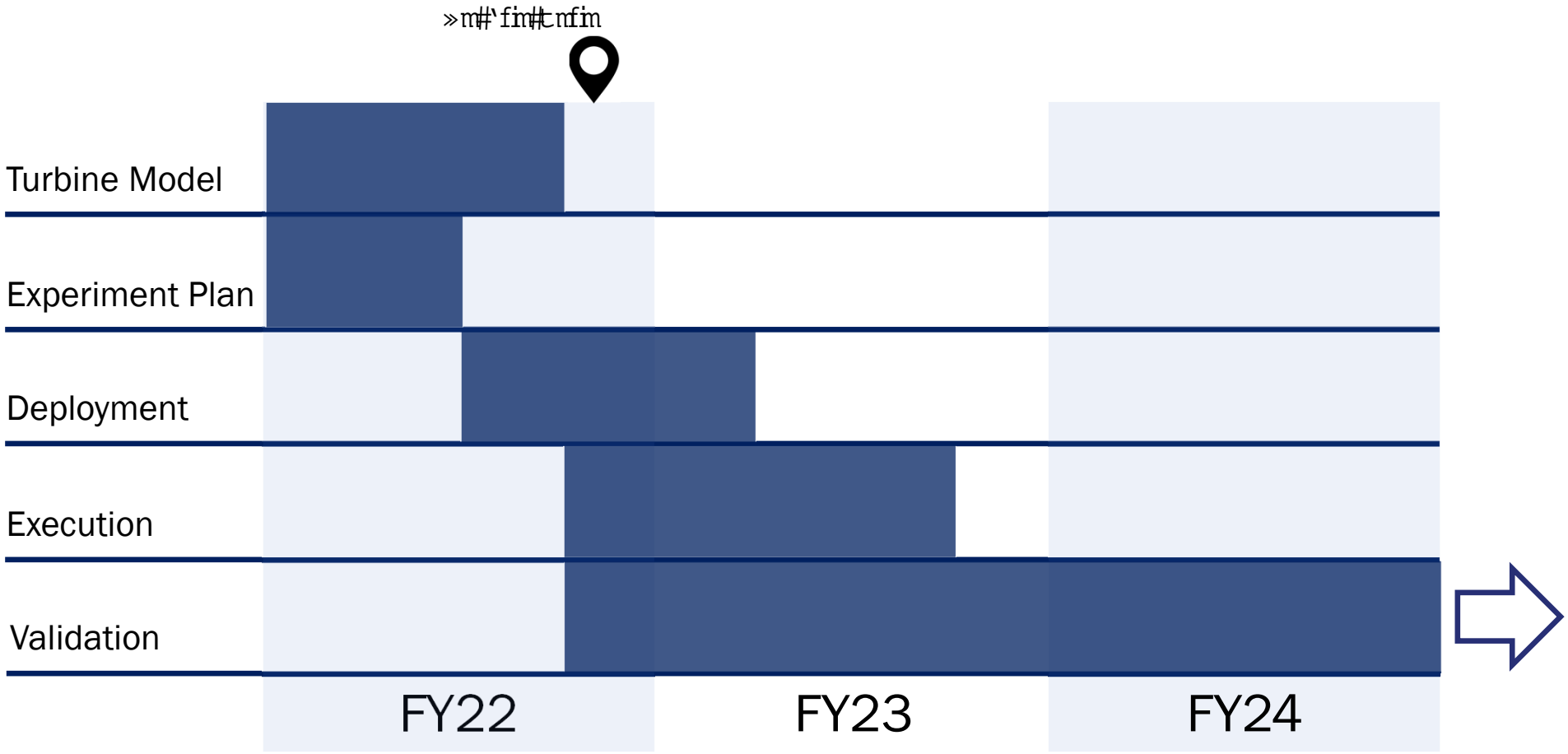
Model Development
- Inflow data assimilation in mid-fidelity simulations
- Inflow data assimilation in high-fidelity simulations

Wind Turbine Science
- Quantification of blade deflection
- Quantification of aerodynamic loads
- Characterization of wind turbine response under off-normal (wind/operational) conditions

Wind and Wake Science
- Comprehensive spatiotemporal characterization of inflow
- Characterization of mean and dynamic near-to-far wake

Advances in Instrumentation Techniques
- Large-scale photogrammetry for blade bending measurements
- Blade aerodynamic measurements for an operational wind turbine
- Spatially and temporally detailed inflow characterization

The RAAW timeline



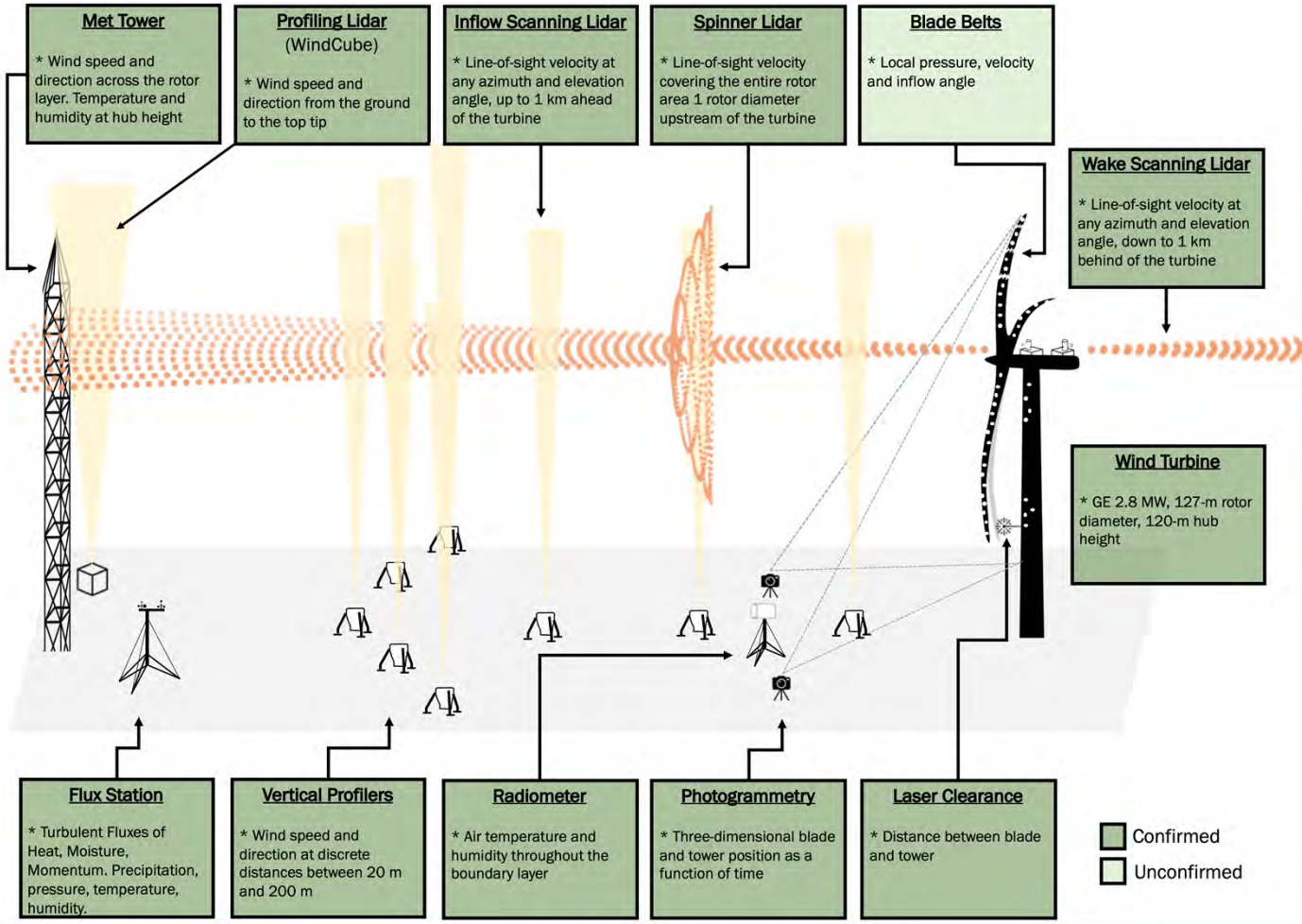
The RAAW field campaign

- Campaign Location
  - Lubbock, Texas
- Campaign Timing
  - June 2022 – June 2023
- Campaign Turbine
  - GE 2.8MW
    - 120-m hub height
    - 127-m rotor diameter
- Campaign Data Management
  - A2e Data Archive Portal

https://a2e.energy.gov/projects/raaw

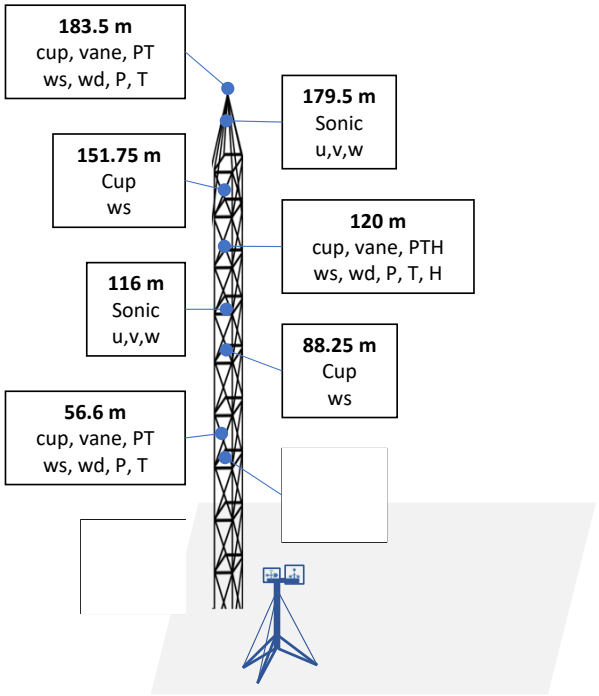
The RAAW field campaign

- Heavy focus on **inflow** for accurate atmospheric characterization and initia and boundary conditions validation simulations
- Detailed **structural respo** measurements with in-situ (strain gages, accelerome and remote (photogramm laser clearance) systems
- **Concurrent** inflow, turbine response, and wake measurements
- **Intentional** instrument placement and measurem strategies
- Normal and prescribed, **o design** for specific validat cases



The RAAW field campaign

Met tower and Surface Met Station



Met Tower

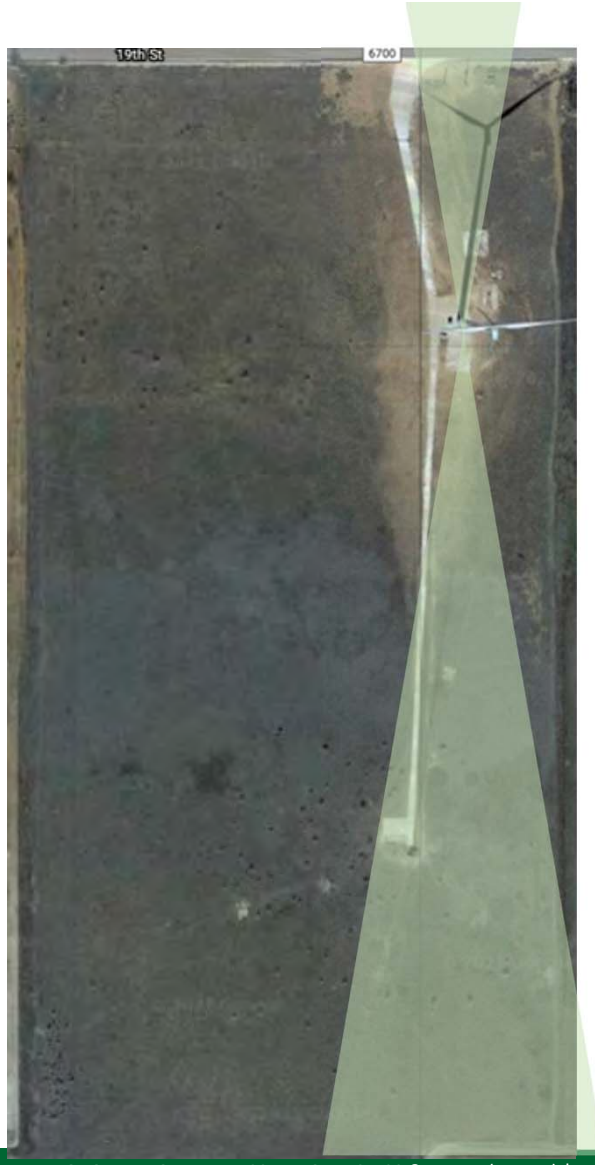
* Wind speed and direction across the rotor layer. Temperature and humidity at hub height

Flux Station

* Turbulent Fluxes of Heat, Moisture, Momentum. Precipitation, pressure, temperature, humidity.

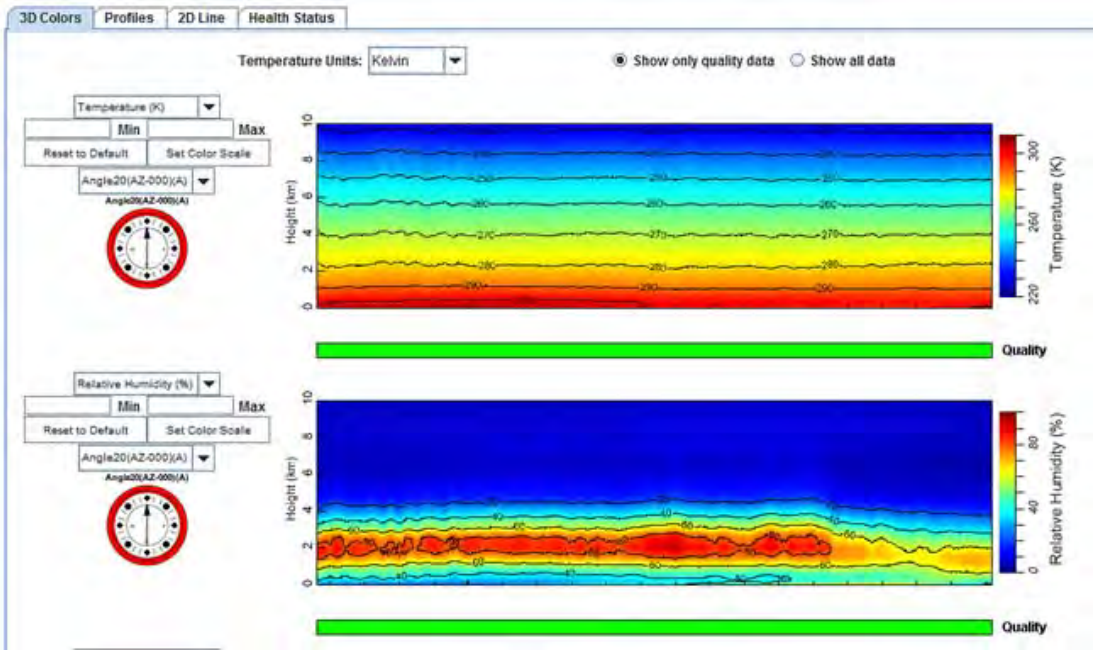
The RAAW field campaign

- Nacelle-Mounted Lidars
  - Halo Photonics Streamline XR
  - Forward-facing 200-216 for inflow measurements
  - Rearward-facing 200-217 for wake measurements
  - Range up to 1 km



The RAAW field campaign

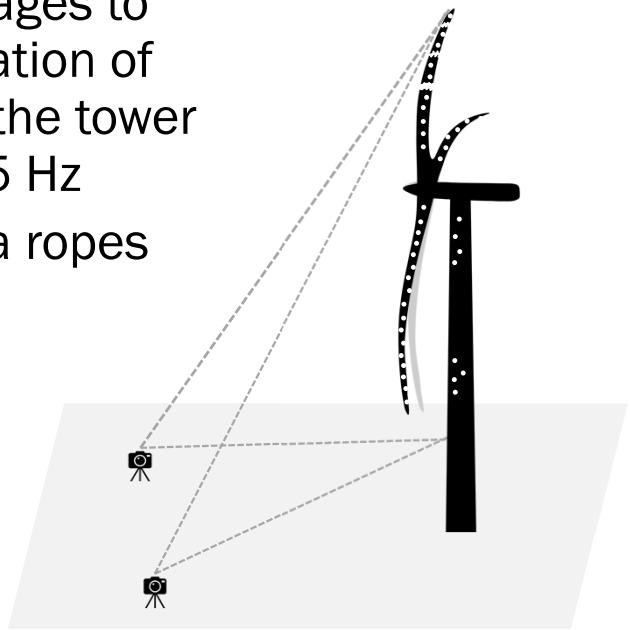
- Microwave Radiometer
  - Radiometrics MP3000A
  - Measures irradiance spectra/brightness temperatures



- Calculates profiles of temperature and humidity
- Integrated into the DAP

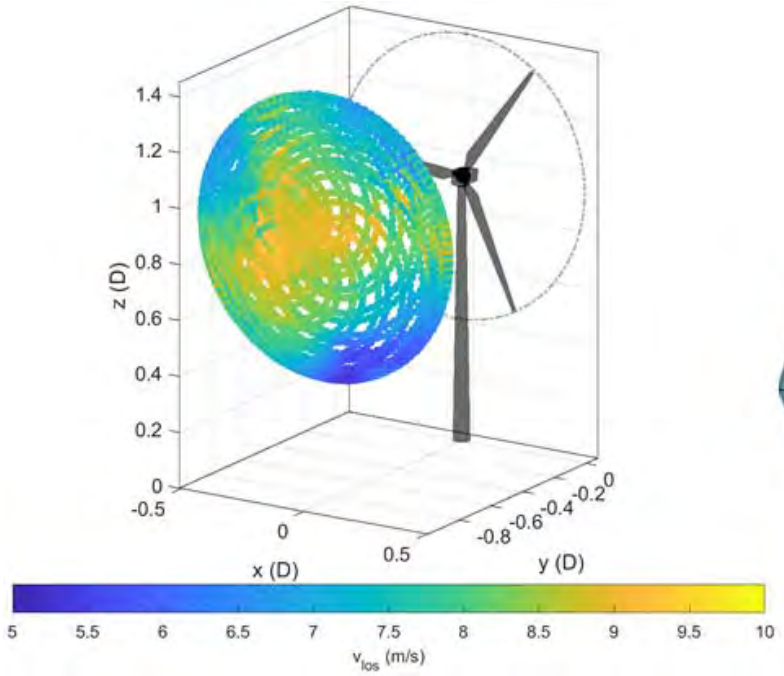
The RAAW field campaign

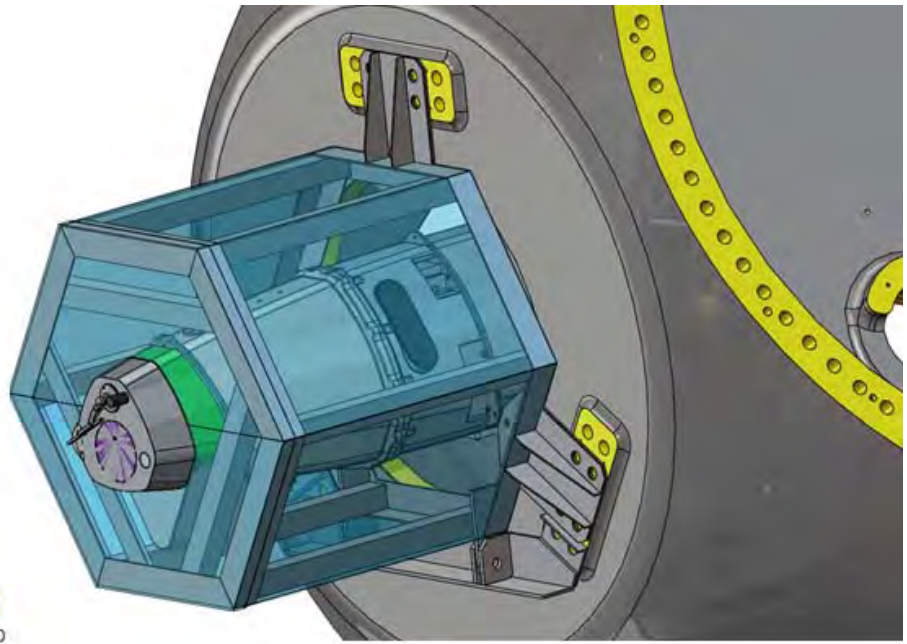
- Photogrammetry
  - Trilion Quality Systems LLC
  - Aramis 12 MP cameras
  - Stereoscopic images to measure 3D location of ~120 points on the tower and blades at 25 Hz
  - Decals hung by a ropes crew



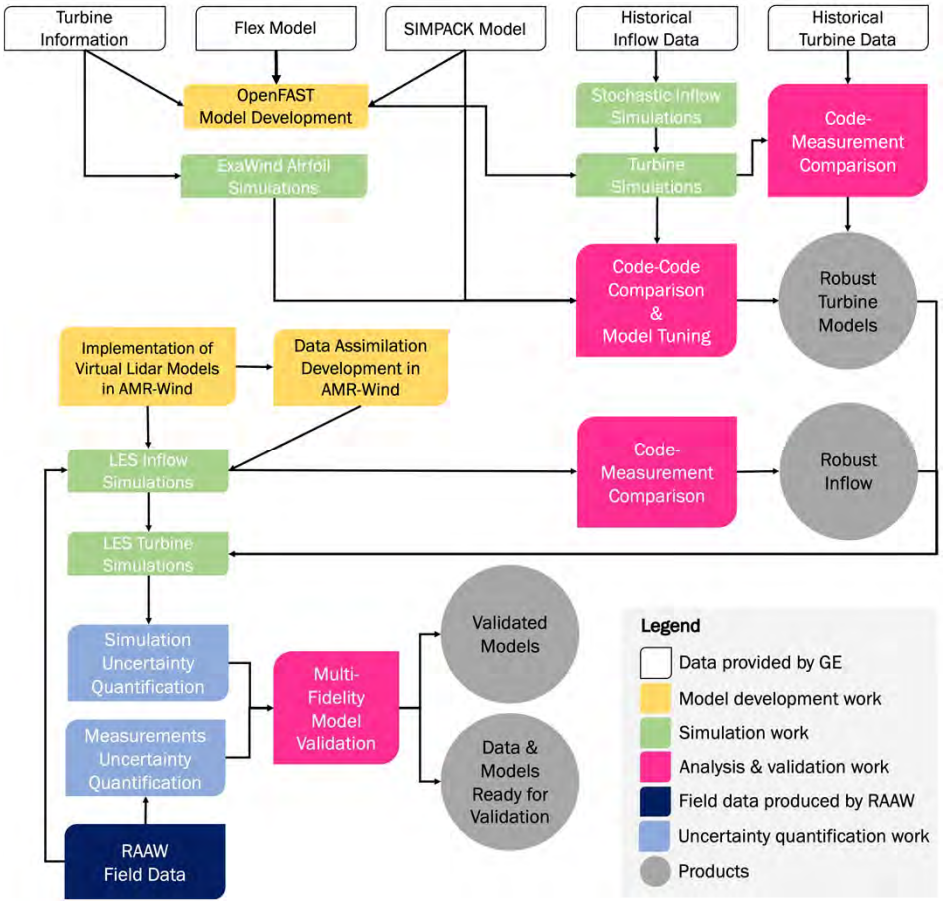
The RAAW field campaign

- Spinner Lidar
  - DTU system
    - Previously used at SWiFT
- Scans a region 1 D upstream of hub
  - Captures plane every 1-2 seconds



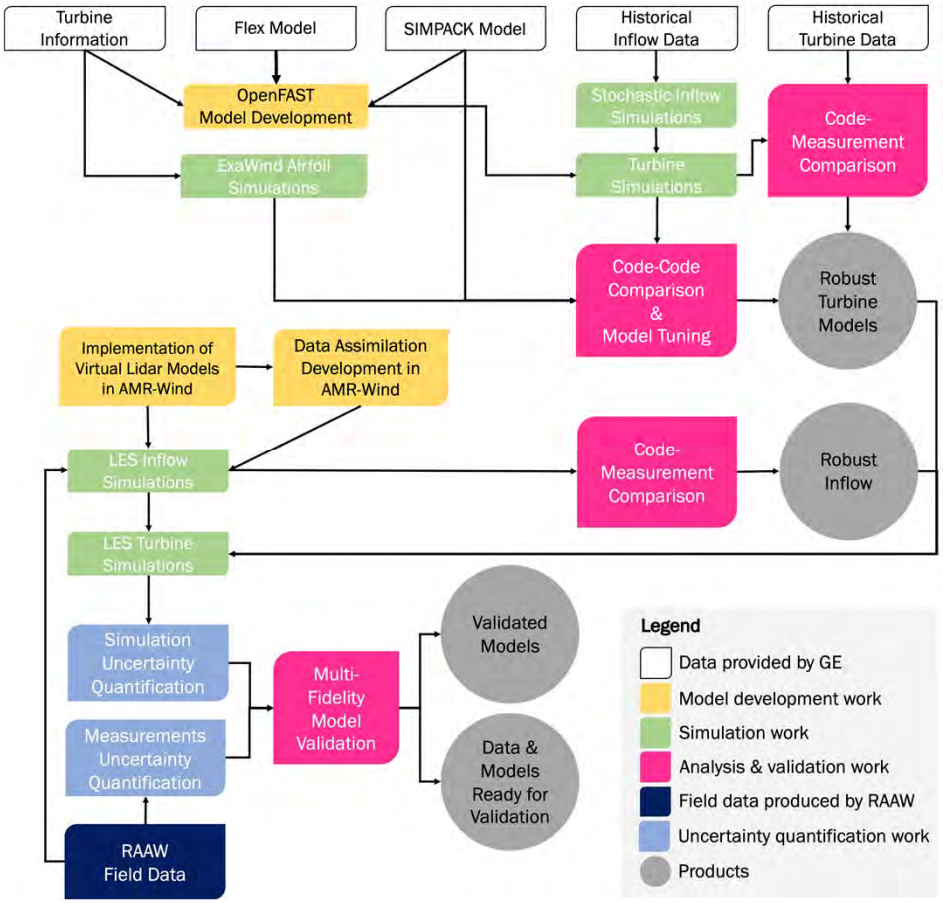


The RAAW research products



- **Open-source validated models** can be used by the international community
- Interaction between turbulent inflow, tall towers, flexible rotors, and wake generation provide a greater understanding of the **system dynamics**
- **Validation and science results** will be disseminated
- Validation **benchmarks** will be shared with the international community
- All released data will protect proprietary data

The RAAW simulation products



- Robust **wind turbine models**
  - Ready to use for validation
  - Well documented
  - Based on detailed wind turbine data
  - Validated against measurements
  - Validated against other simulation tools
- **Data assimilation** capabilities
  - Ready to use for time-resolved validation
  - Implemented into ExaWind
  - Validated
  - Well documented and portable
- Robust **inflow models**
  - Ready-to-use framework for inflow generation in mid-fidelity and high-fidelity codes
  - Applicable to statistical and time-resolved validation activities

Questions?