FY2005 DOE Wind Program Implementation Meeting

Small Wind Research Turbine (SWRT)

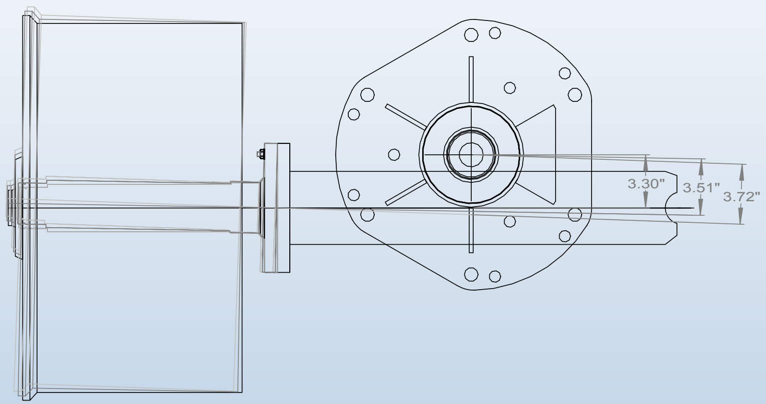
November 17, 2004 – Dave Corbus

Rationale for SWRT testing and furling model development

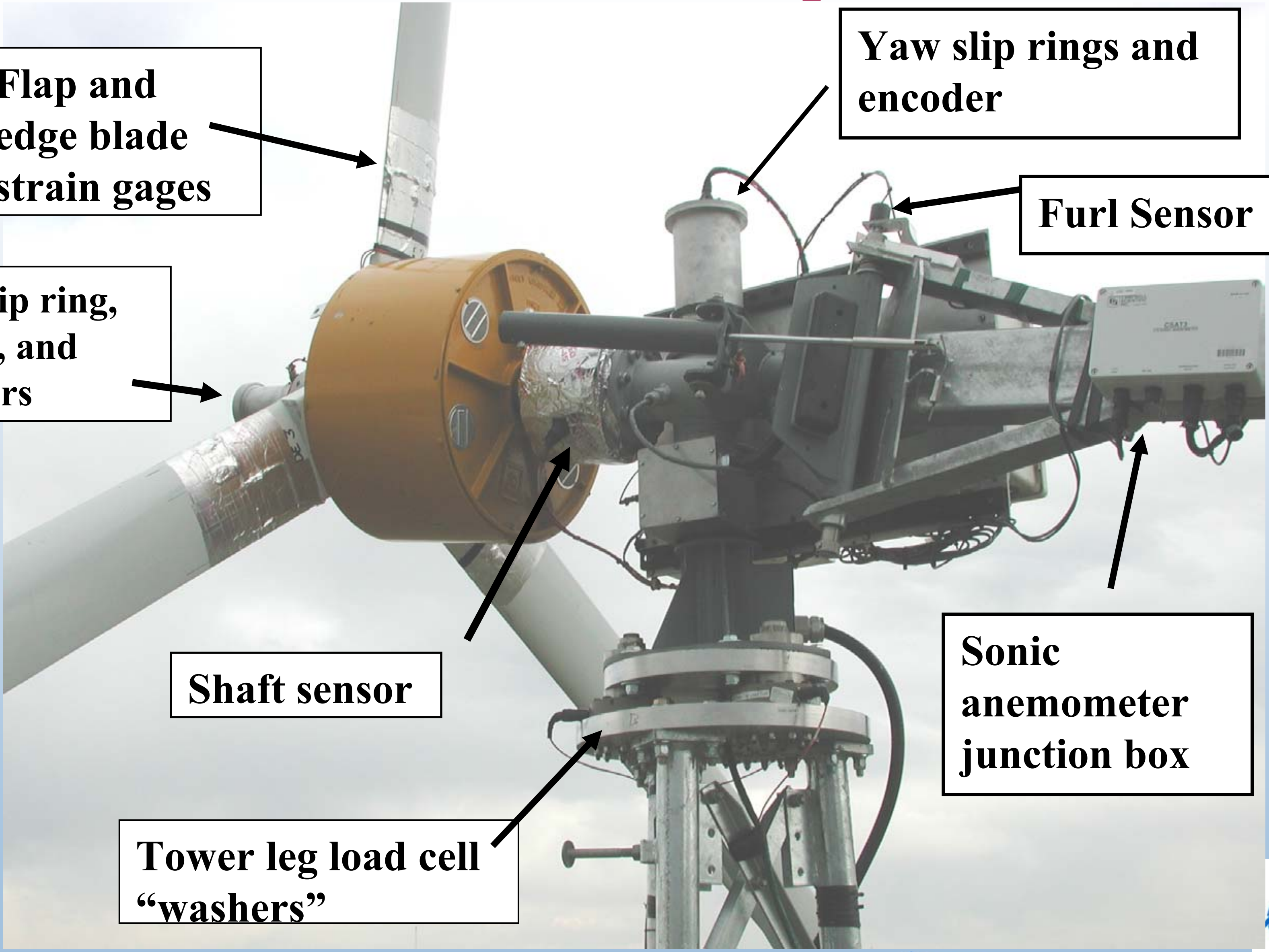
- **Poor understanding of small turbine loads and dynamic behavior especially furling**
- **Lack of high quality data sets for small turbine model development and validation**
- **Wind turbine aero-elastic models did not include furling**
- **Test procedures unique to small turbines need to be addressed**

SWRT testing and model development approach

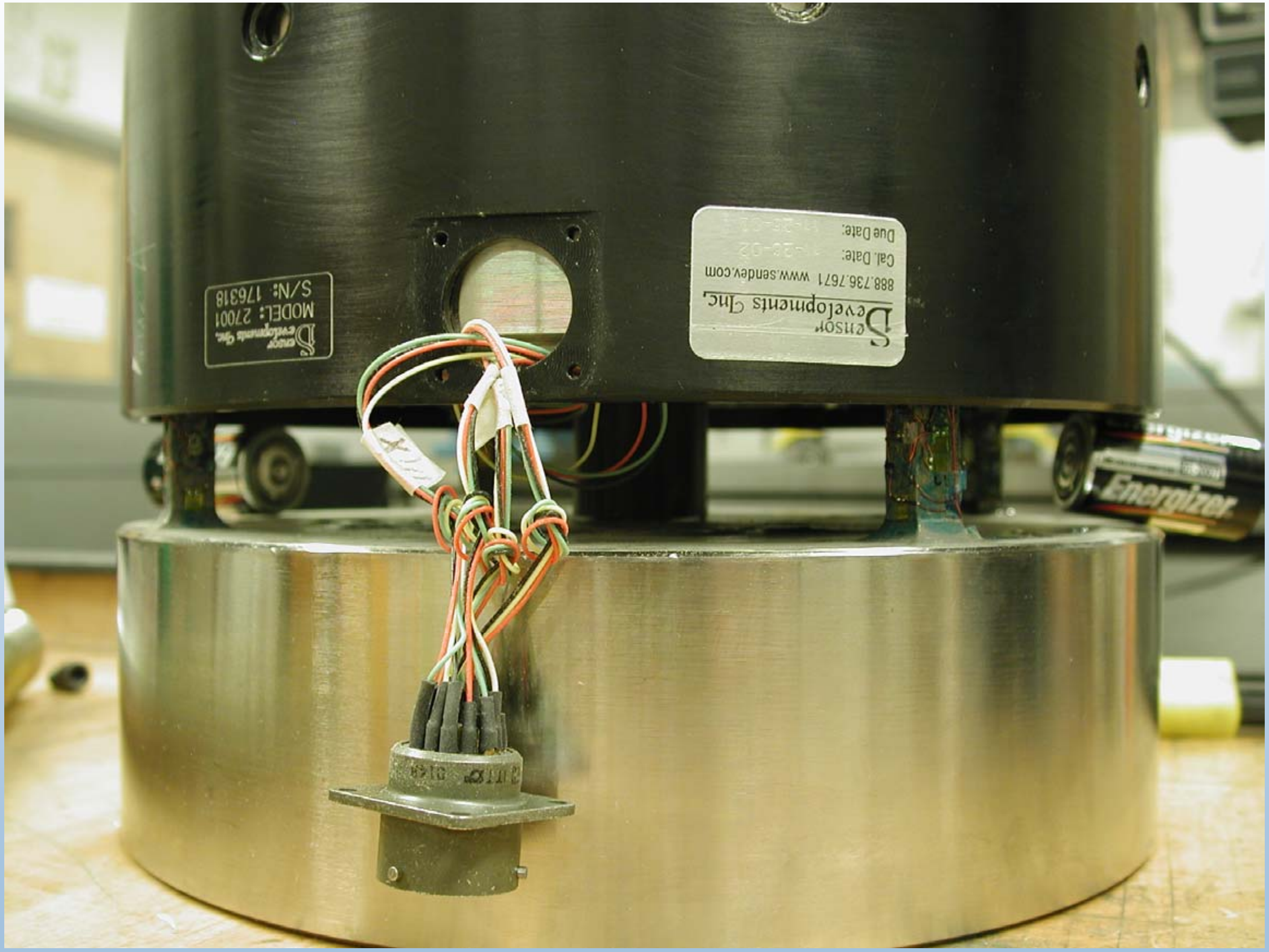
- ***SWRT Test***
  - ***Most comprehensive small turbine test***
  - ***Three different turbine configurations tested***
- ***Upgrade FAST model to include furling***
  - ***Perform model comparisons between FAST and ADAMS***
  - ***Perform model validation between FAST-SWRT model and SWRT data***



SWRT test description



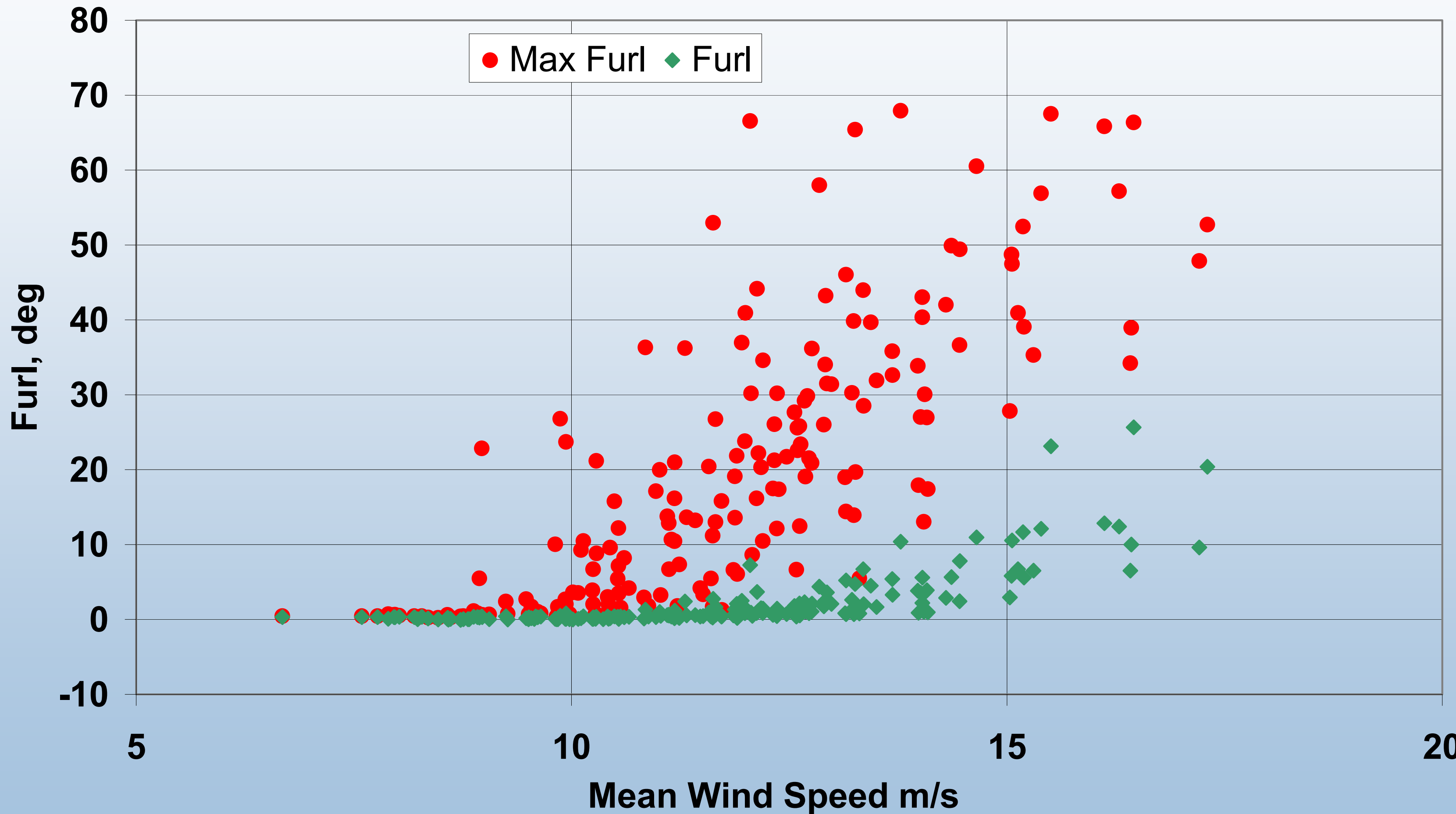
SWRT shaft sensor - first accurate small turbine thrust measurements



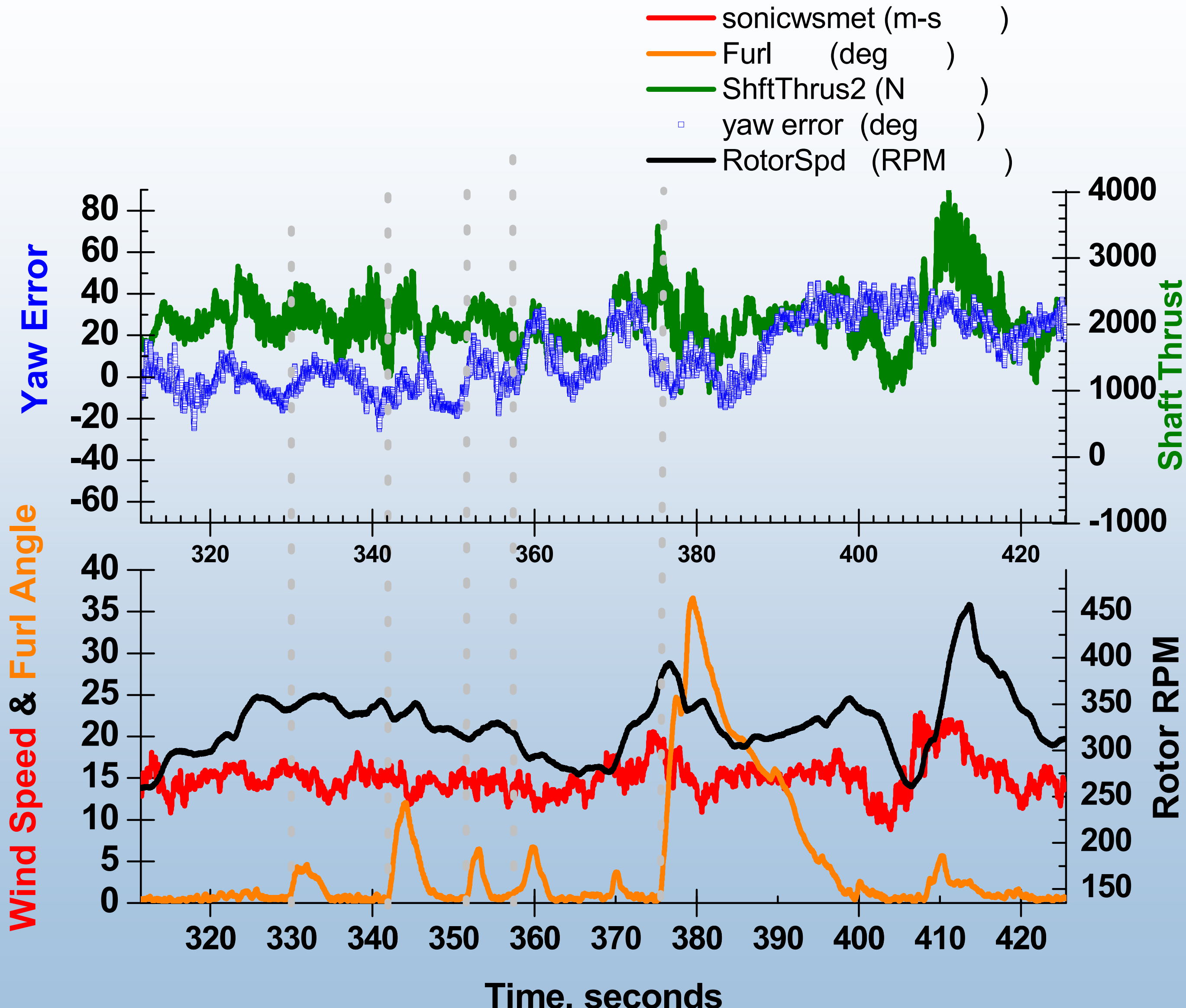
Pre-testing turbine characterization

- ***Data for modeling included:***
  - *Tail assembly and main frame:*
    - *– Weight, Cg, bi-filar, moment of inertia about yaw axis*
  - *Magnet can Cg and moment of inertia estimated in Solidworks*
  - *Tail damper properties*
  - *Exact turbine geometries*
  - *Blade modal test*

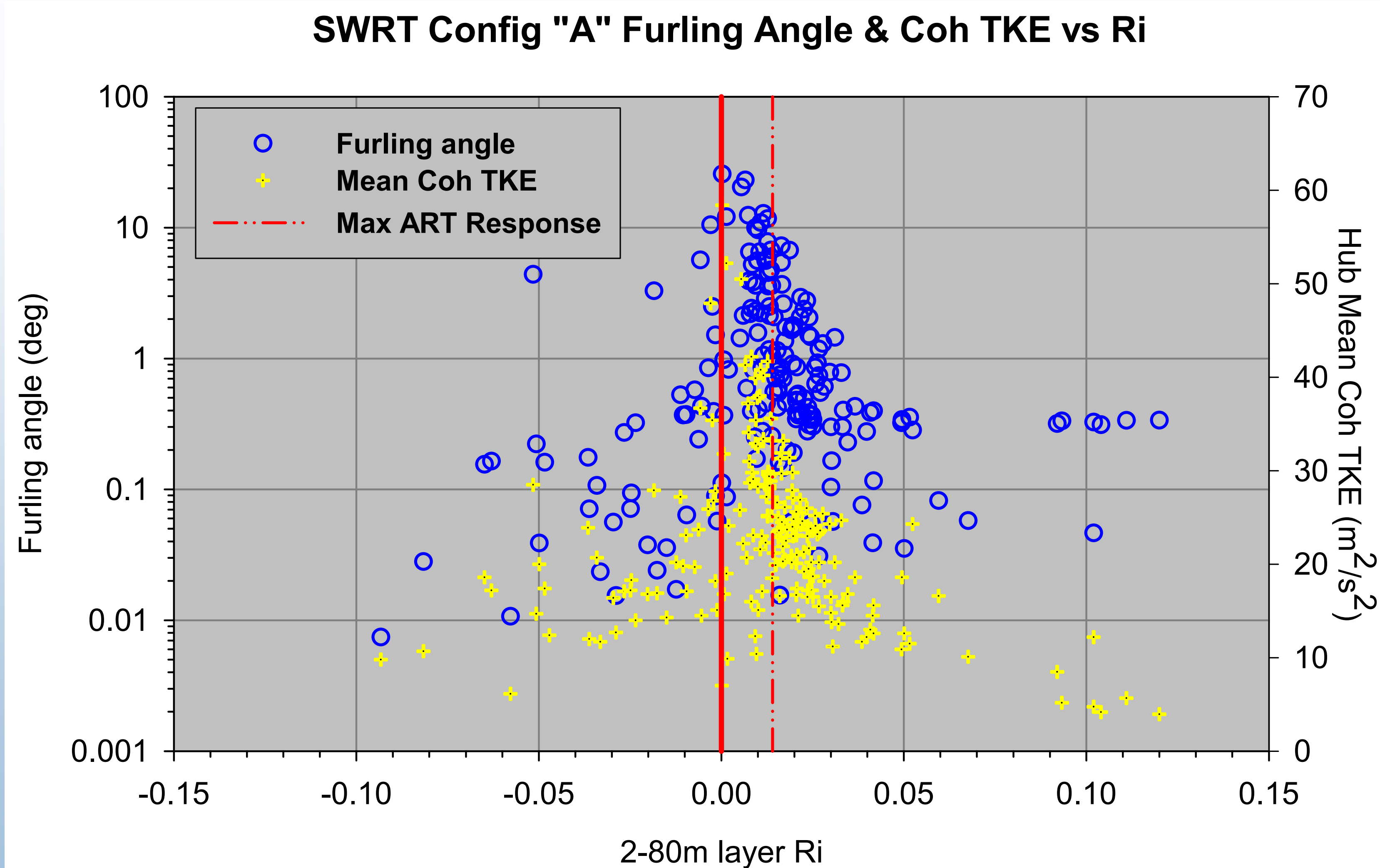
Max and Mean Furl vs. Mean Wind Speed 10-minute data files



SWRT furling event – time series plot



Furling and inflow



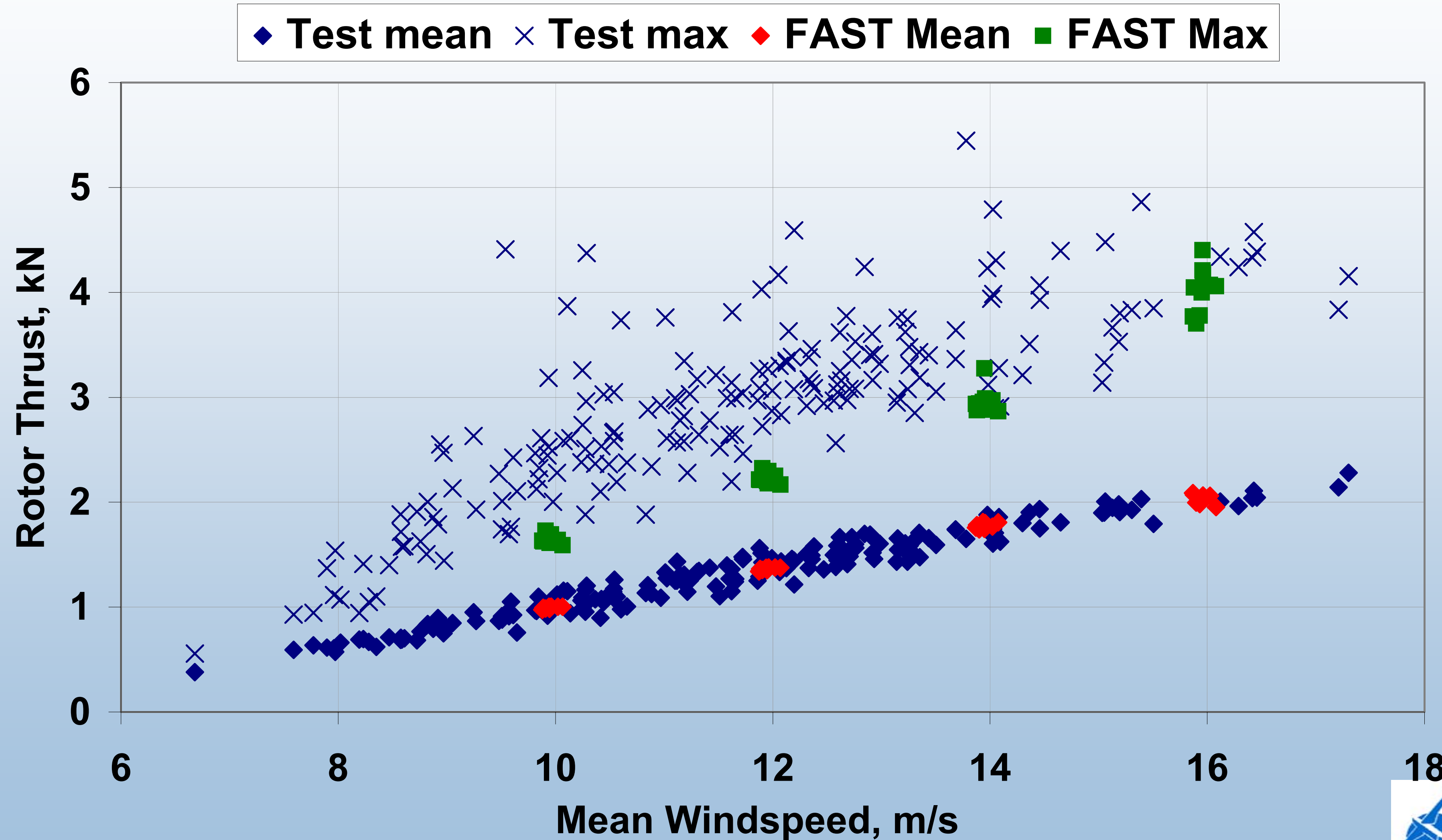
FASTmodel furling upgrades

What?
- ***New to** FAST **is the availability of a lateral offset and skew angle of the rotor-shaft, rotor-furling, tail-furling, and tail inertia and aerodynamics***

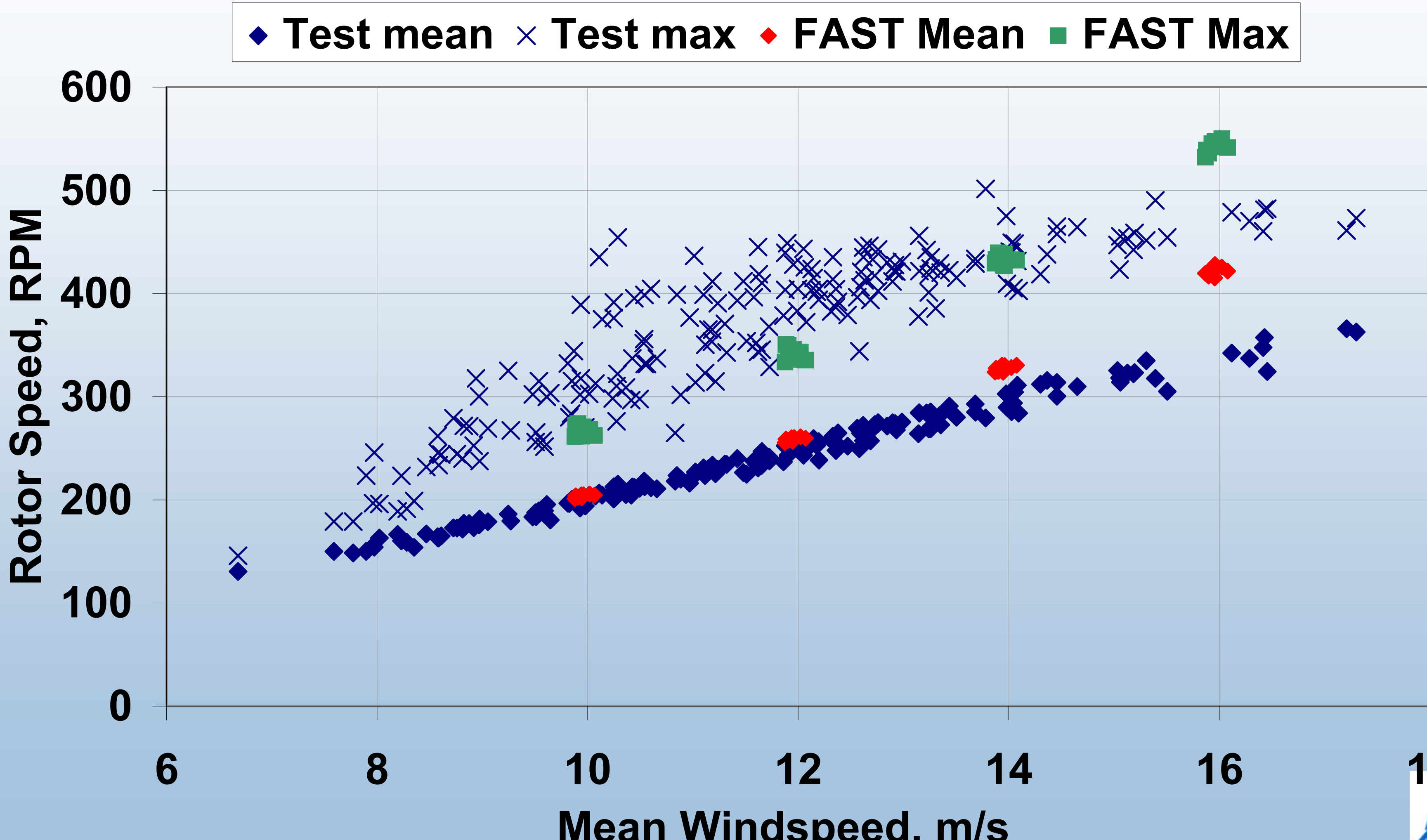
Why?
- ***Requested by SWT manufacturers.***
- ***Recommended action from the NWTC Furling Workshop, July, 2000.***

How?
- ***Polled users of FAST and SWT community for potential needs.***
- ***Redeveloped FAST's equations of motion to incorporate furling; then codified changes.***
- ***Dynamics verified via comparisons to ADAMS***

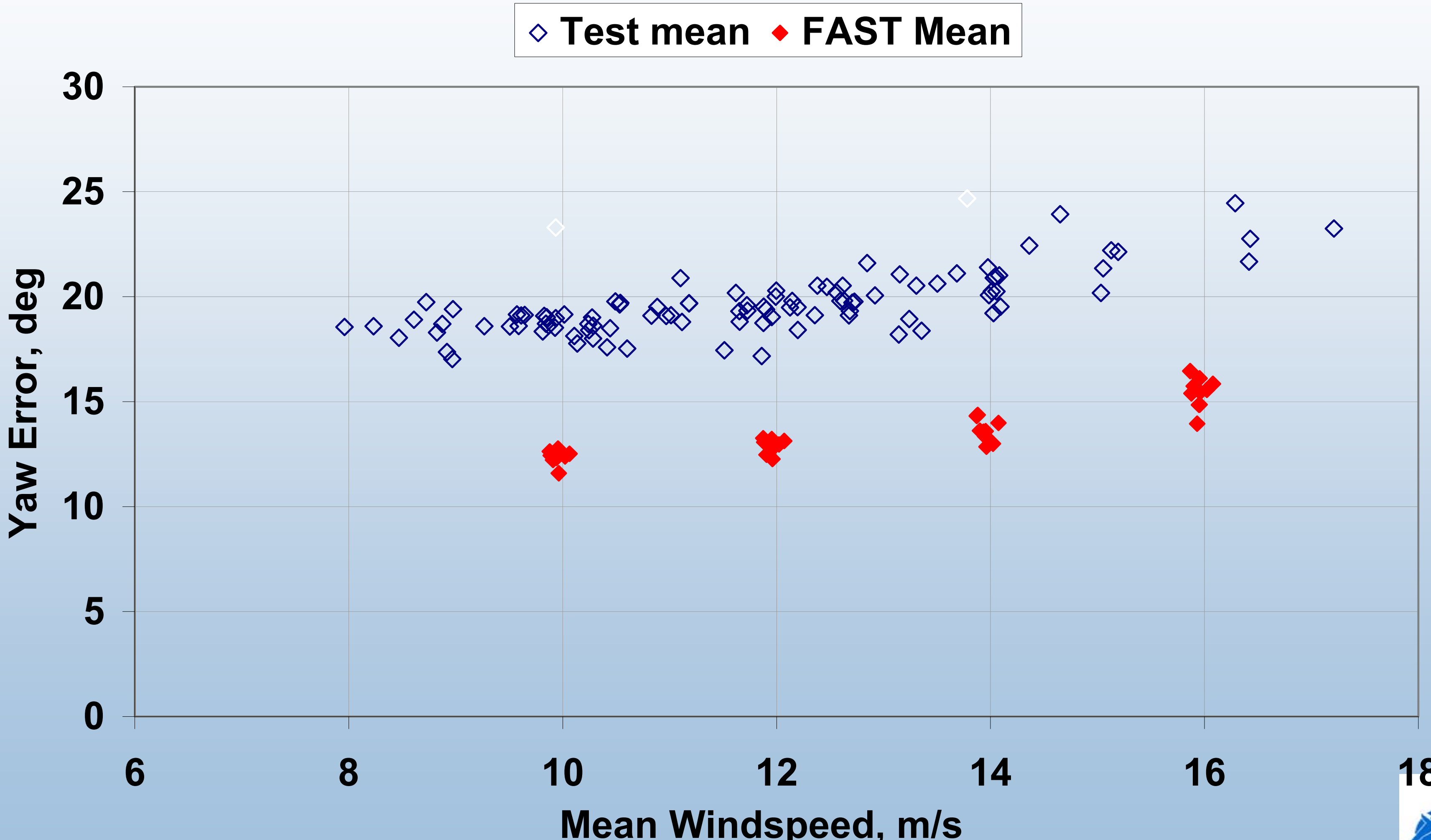
FAST vs. SWRT 10-minute mean/max rotor thrust force



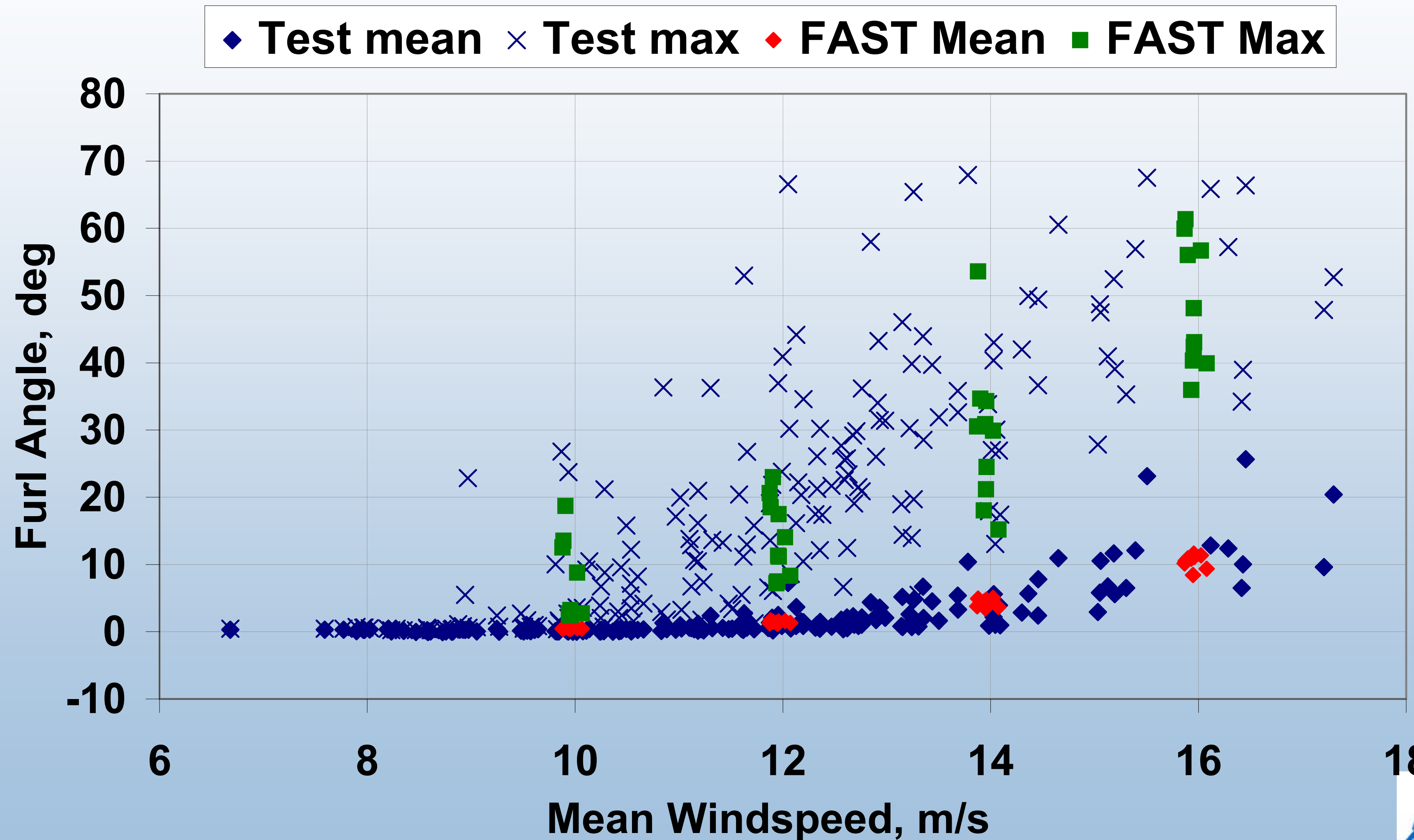
FAST vs. SWRT 10-minute mean/max rotor RPM



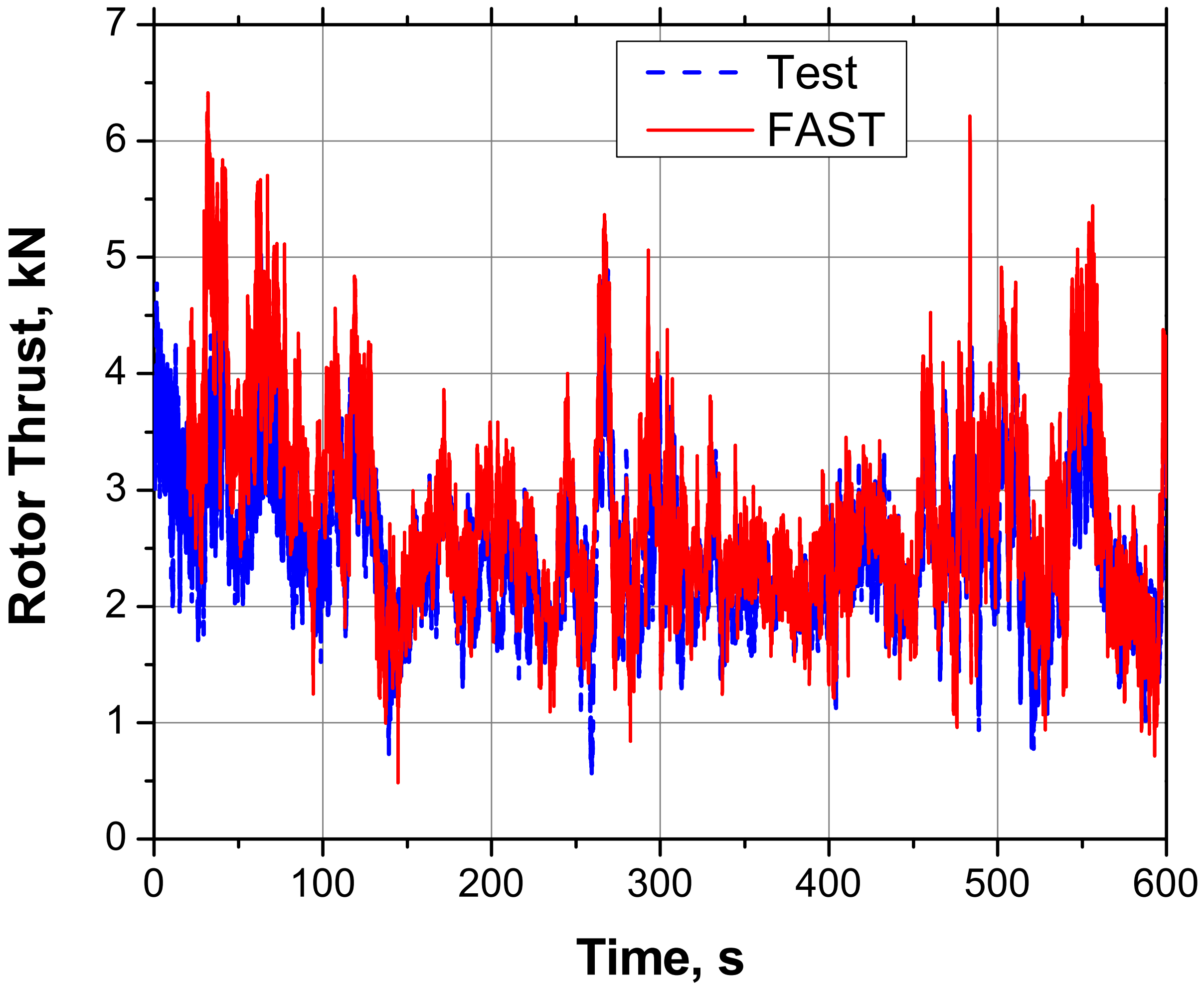
FAST vs. SWRT 10-minute mean yaw error



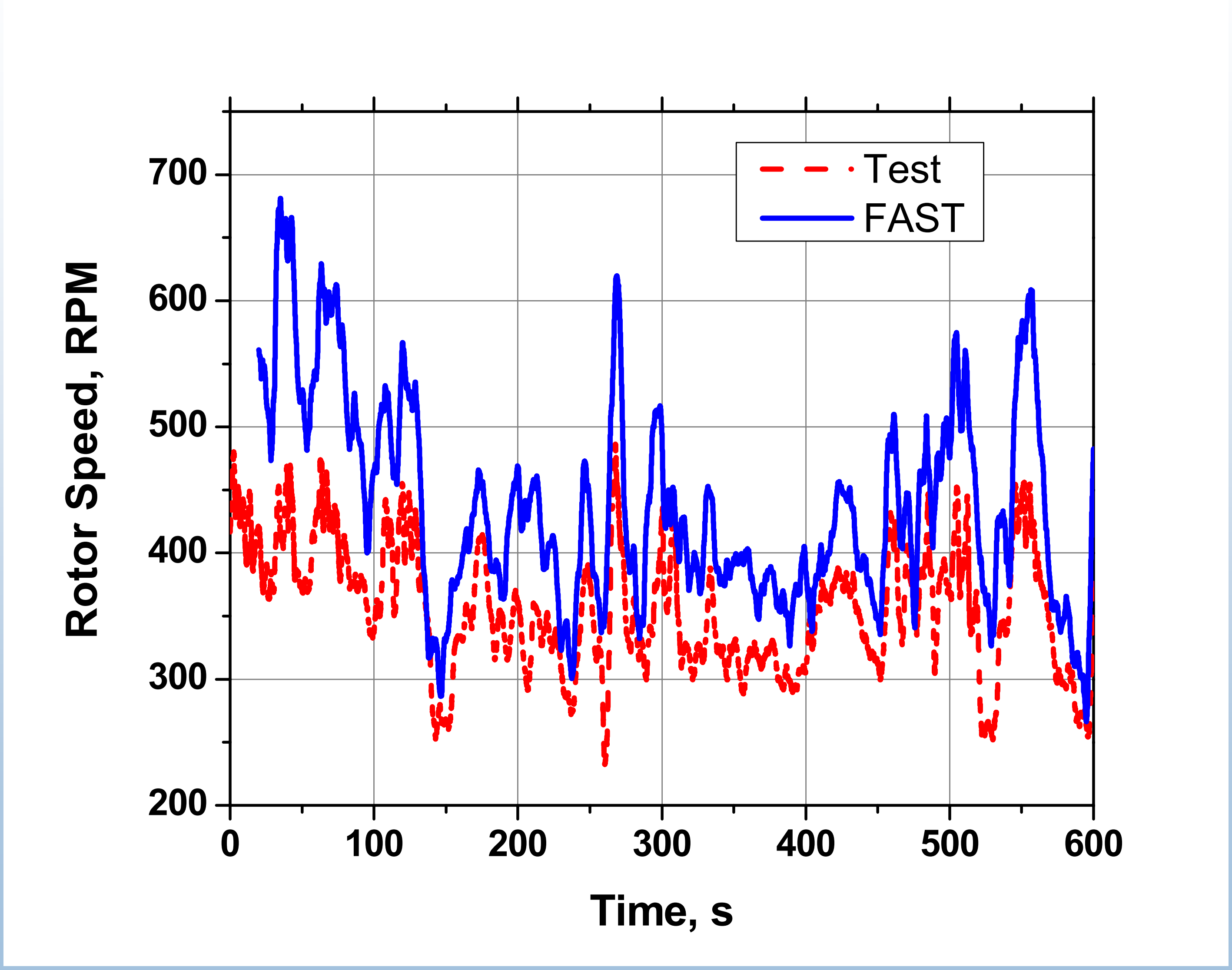
FAST vs. SWRT 10-minute mean/max furl angle



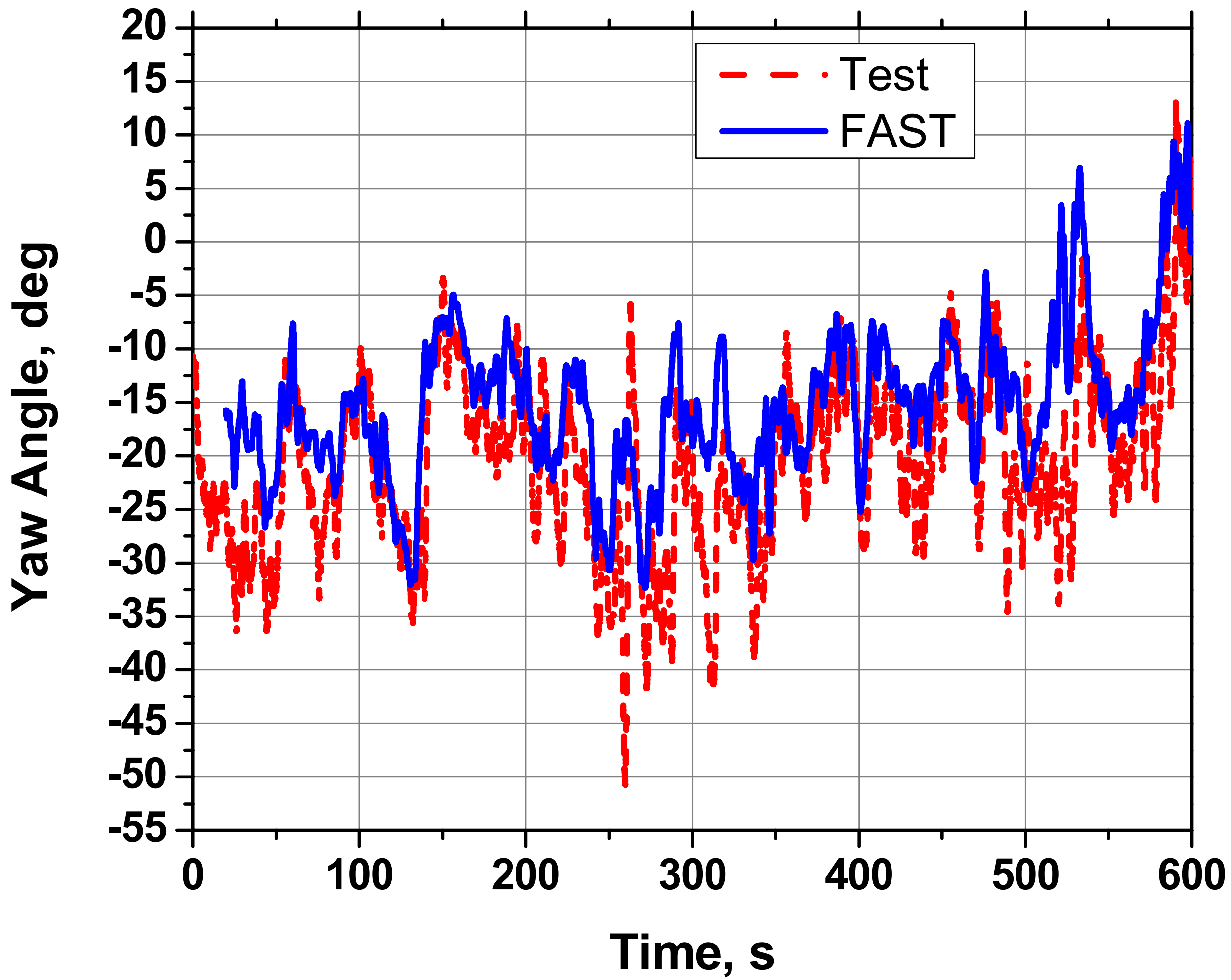
Rotor thrust for one 10-minute file of Configuration B with resistor load – 17.6 m/s average wind speed



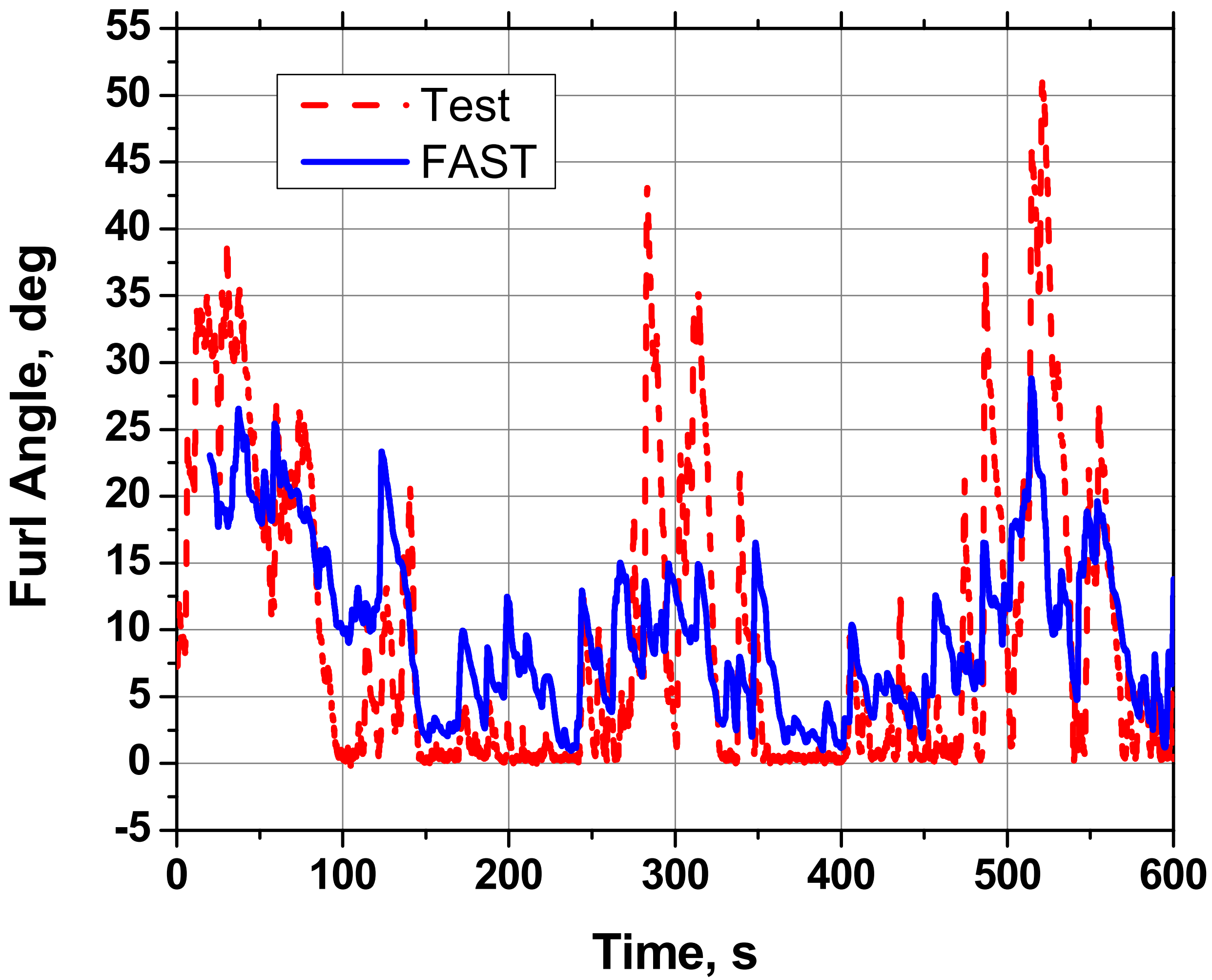
Rotor speed for same 10-minute time period



Rotor yaw angle for the same time period



Tail furl angle for the same time period



Outreach and industry participation examples

- ***SWRT test results and FAST model available on NWTC website***
- ***Windward Engineering***
  - ➢ *Use SWRT data analysis results and FAST model to provide modeling capabilities to industry*
- ***Bergey Windpower***
  - ➢ *Testing results used for turbine development*

Accomplishments

- *FAST furling model available*
- *2 ASME papers completed documenting SWRT test and FAST modeling results*
- *Better understanding of small wind turbine dynamic behavior, including thrust and furling*
- *Better test procedures for small turbine testing*
- *Questions still remain on FAST furling model validation and small wind turbine modeling in general*

Future Work

- ***SWRT testing completed***
  - *Further SWRT analysis*
    - *model comparison for final configuration C*
    - *Run FAST model with TurbSim to better quantify inflow effects*
  - *Final SWRT technical report*
  - *Windpower paper for 2005*
    - *will include some IEC 1400-2 comparisons*
- ***Other NWTC code developments will help both small and large wind turbine modeling efforts***
  - *Non-linear generalized dynamic wake model, TurbSim for turbulent inflow, future FAST modifications*
- ***Planning for future wind tunnel test to get more detailed data such as wake data?***