



# Windtell

Wind Farm  
Analytics and  
Performance  
Management

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## Project Impetus

### **GROWING BUT MATURING WIND INDUSTRY**

- Wild West pioneering days of onshore development are transitioning to challenges of innovative operations and maintenance.
- In many cases, commercial farms are ageing differently and more rapidly than anticipated.
- Still much to be understood in the dynamic interaction of full scale turbine groups (turbine to turbine, farm to farm).

### **PROJECT ORIGINS**

- Culmination of extensive field research program working exclusively with full scale commercial wind farms since 2008.
- Working Partnerships with various Canadian Wind Farms and the Wind Energy Institute of Canada (WEICan) have made the project possible.



## Project Objectives



### 1. DEVELOP AN INTELLIGENT, SEMI-AUTONOMOUS OPERATIONS MANAGEMENT TOOL TO IMPROVE THE LIFE-TIME PROFITABILITY OF COMMERCIAL WIND FARMS.

- Maximum Profit  $\sim f(\text{optimize}(\text{performance management}))$
- Higher order, comprehensive monitoring, near-real-time analyses to enable adaptive operations.
- The challenge is to maximize profit for the life of the asset – how long is that? Do you run ‘hard and short’ or ‘easy and long’?, etc.

### 2. DEVELOP A RESEARCH TOOL CAPABLE OF EXPLORING ANTICIPATED AND PREVIOUSLY UNKNOWN RELATIONSHIPS BETWEEN WIND FARM OPERATIONAL VARIABLES.

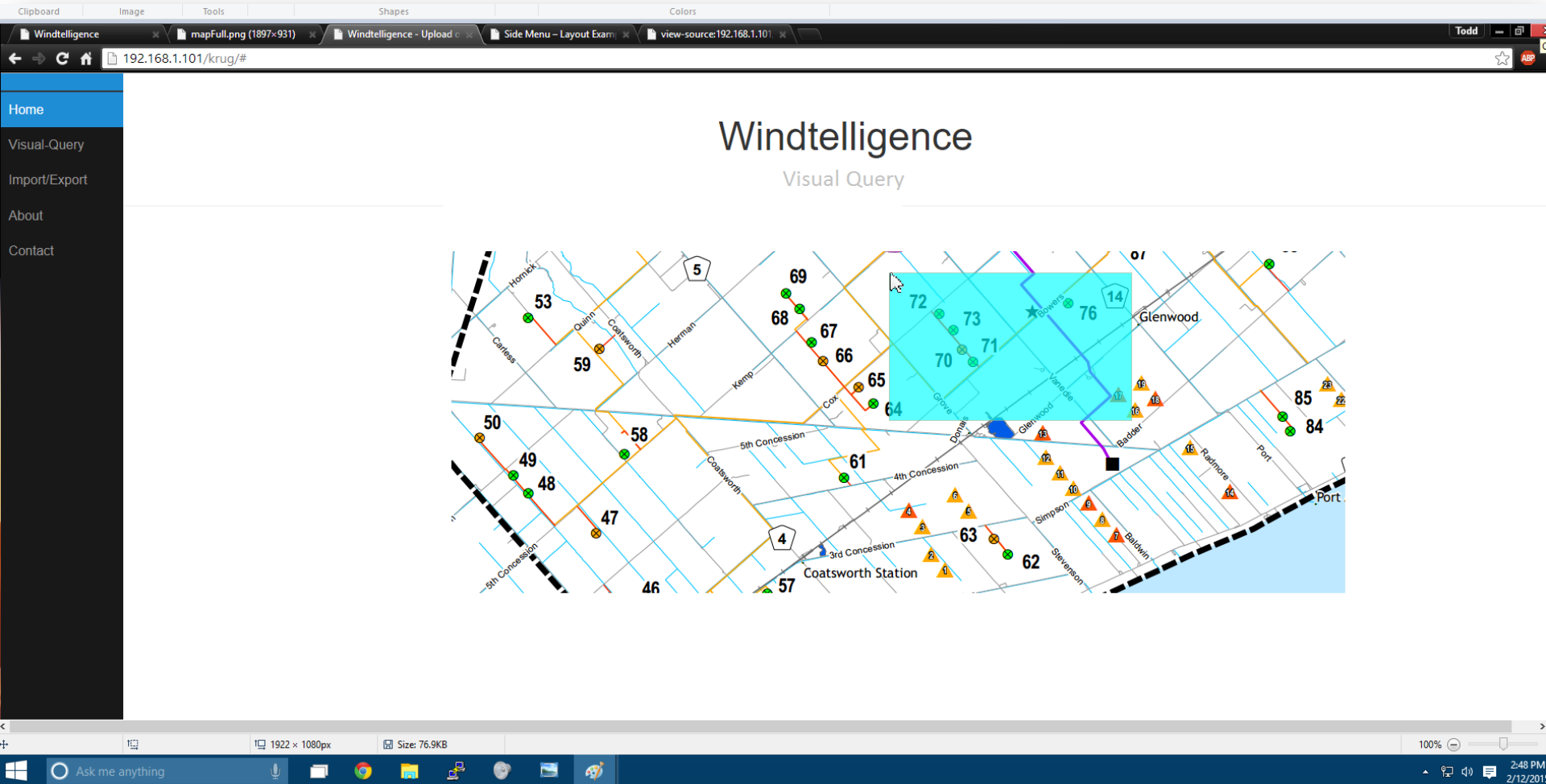
- Powerful querying capability of broad, high resolution database.
- Semi-autonomous agent, “Mr. Smith” tears through data seeking correlations, outliers, and anomalies.

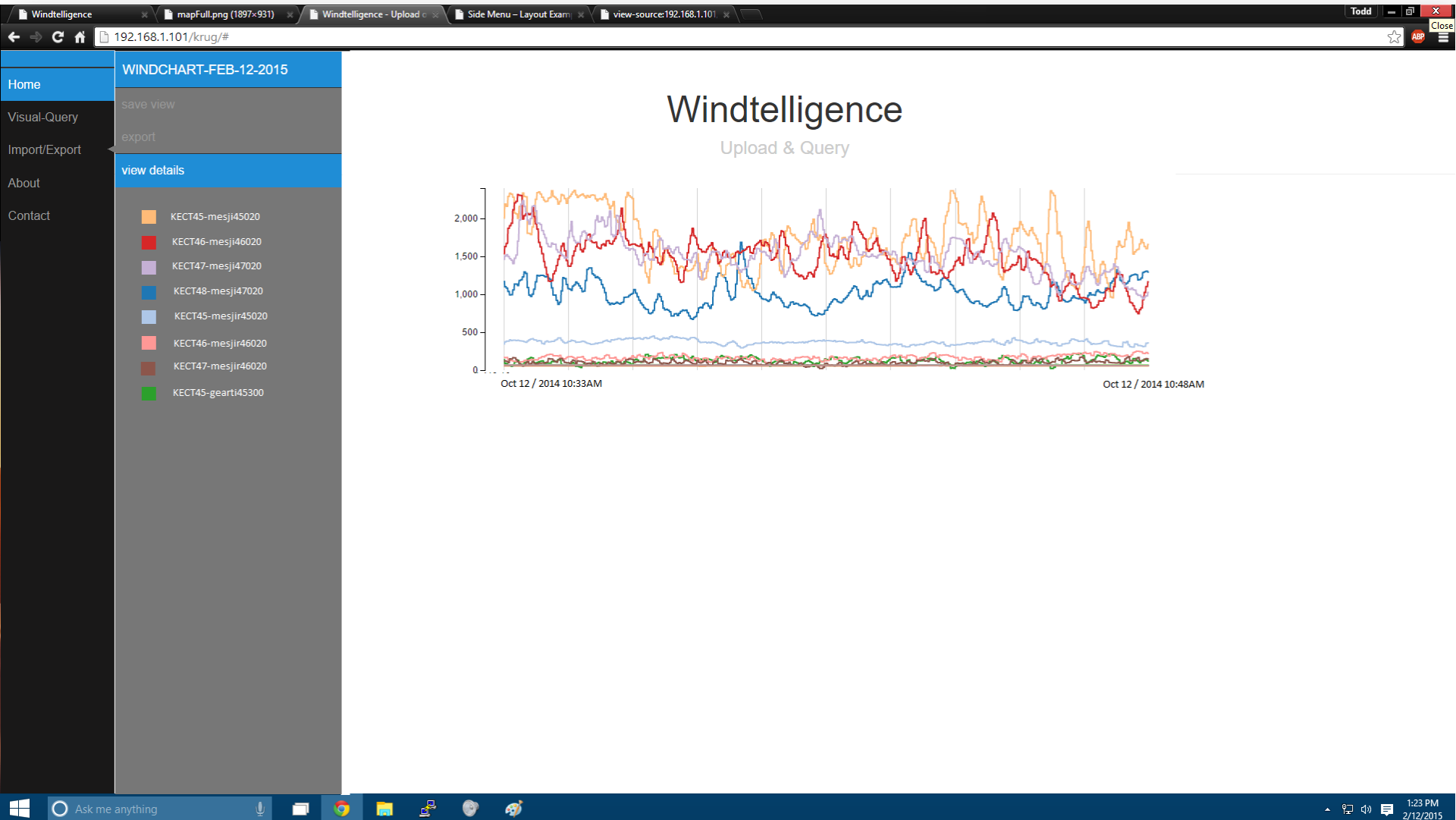
## The Analytical Database Tool

### HOW DOES IT WORK?

- Built on open source MySQL DBMS.
- Custom queries are built through graphic selection or scripts.
- Post processing outputs are rendered graphically by interactive javascript charting and visualization libraries (d3.js).
- Populated with highest resolution Farm SCADA data.
- Expands to include custom user inputs (manual maintenance logs, etc.), and/or additional sensors (structural health monitoring, temperature, icing, LIDAR, etc.).







## Sample Potential Outputs

### OUTPUT TESTS

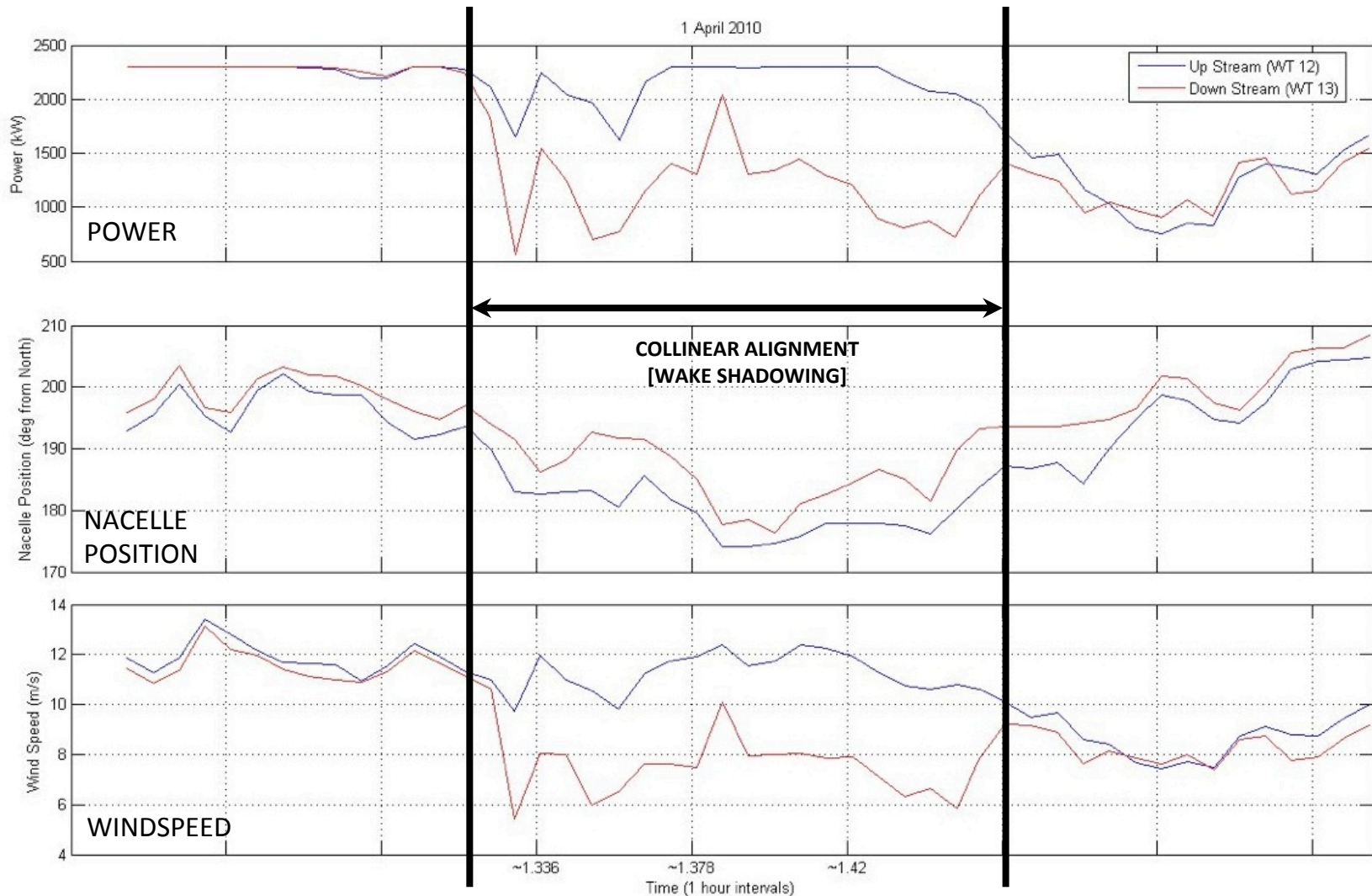
- Borrowing from previous “hand assembled” analyses **Ref[1-3]**, we attempted to recreate them using the Windtell tool – validating database functionality, illustrating significant time savings, and introducing the potential for real time monitoring and control.
- We have also generated new “sample” outputs currently being analyzed.
- Demonstration outputs include:
  - Common wake-effected loss tracking.
  - Structural loading observations.
  - 2 year high and low power performer analysis.
  - Anomaly tracking.

## Wake Effect Losses [1]



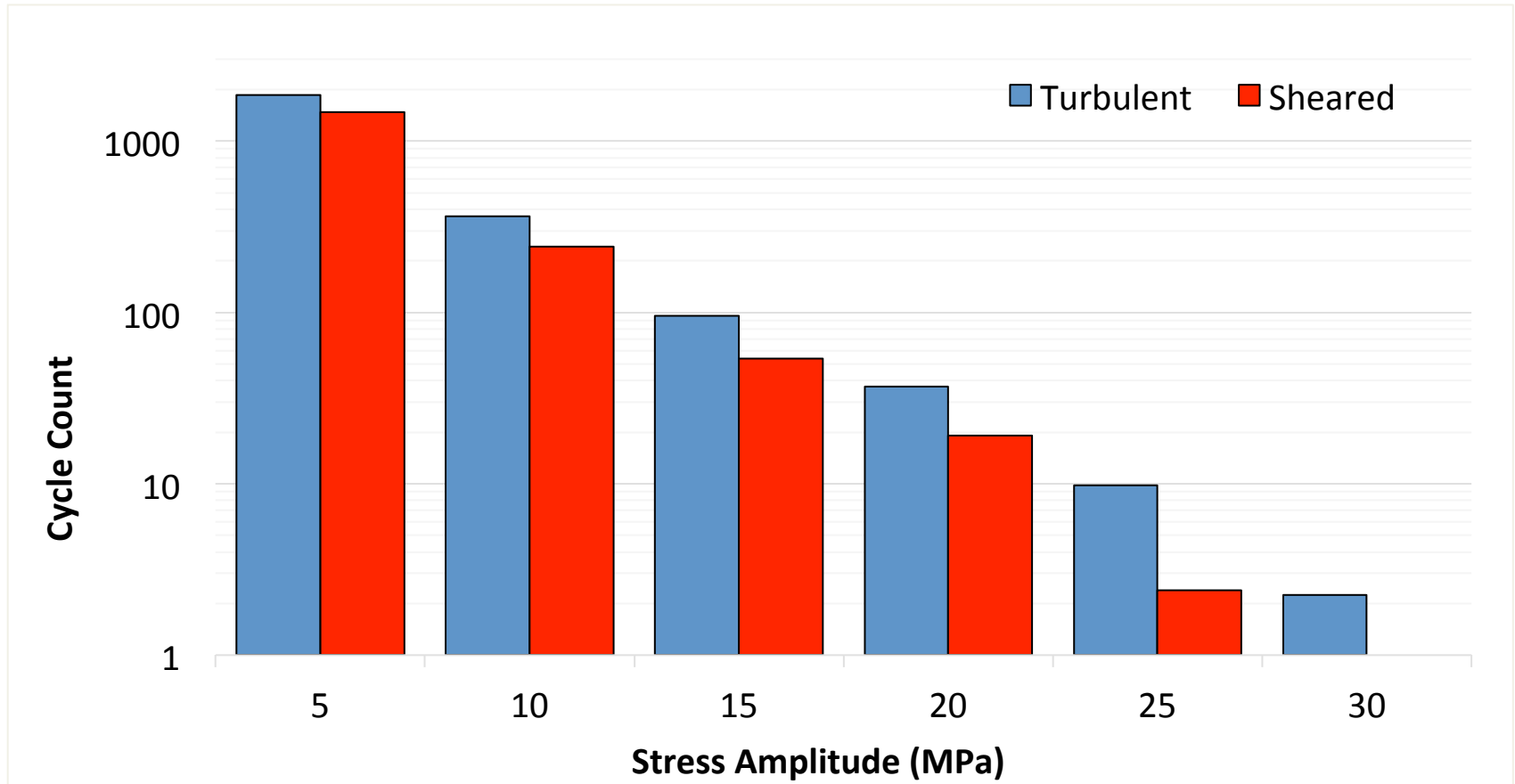


## Wake Effectuated Losses [1]



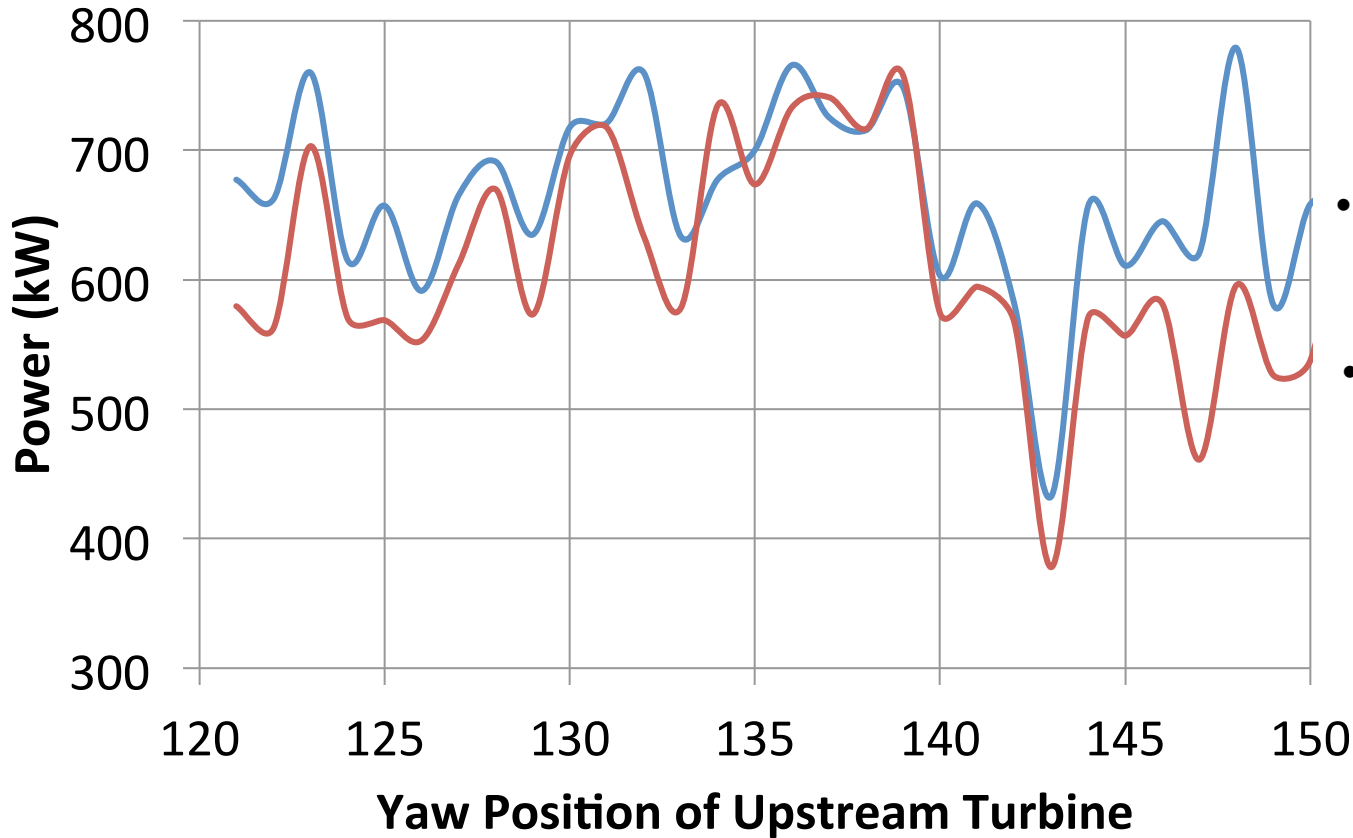
## Structural Loading Insights [2,3]

WT4 Turbine Tower Cyclic Loading Comparing Turbulent and Sheared Winds |  $U = 17 \text{ m/s} \pm 0.5 \text{ m/s}$  [2,3]



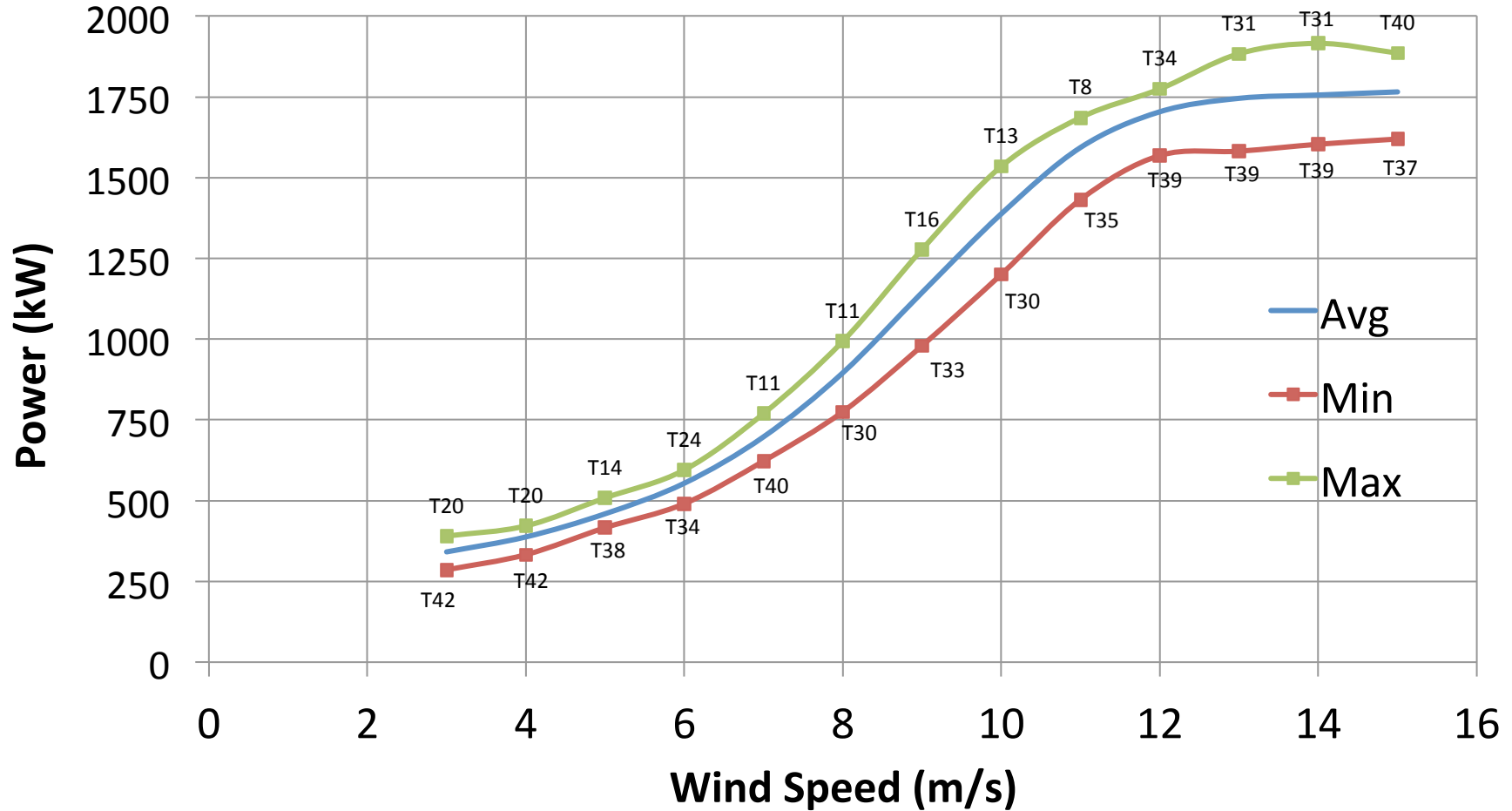
## Wake Effectuated Losses

### Wake-Affected Power Deficit for WT8 2012-2014

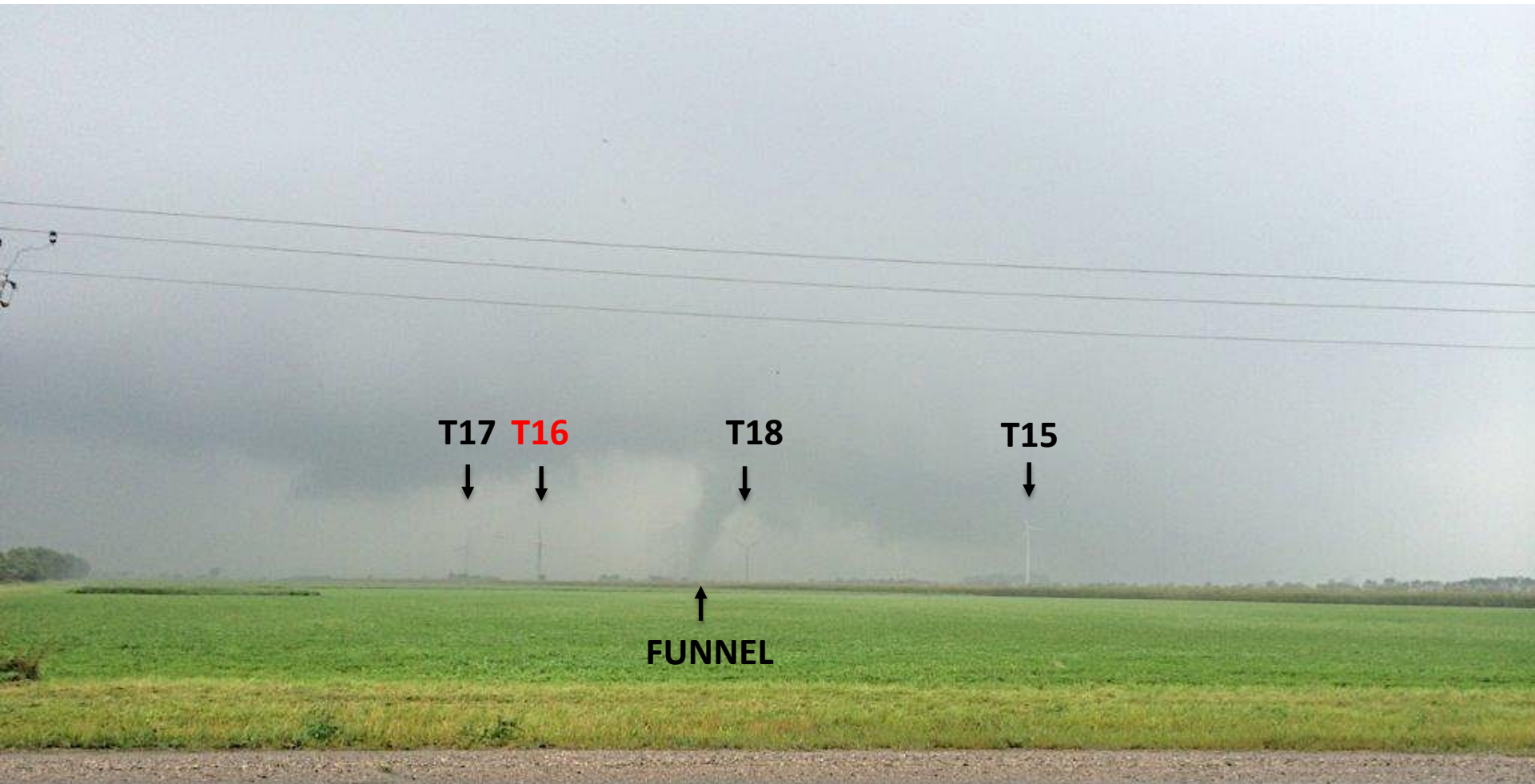


- Waking alignments occurred 20% of time.
- Cumulative power deficit over period between WT7 and WT8 is 8%.

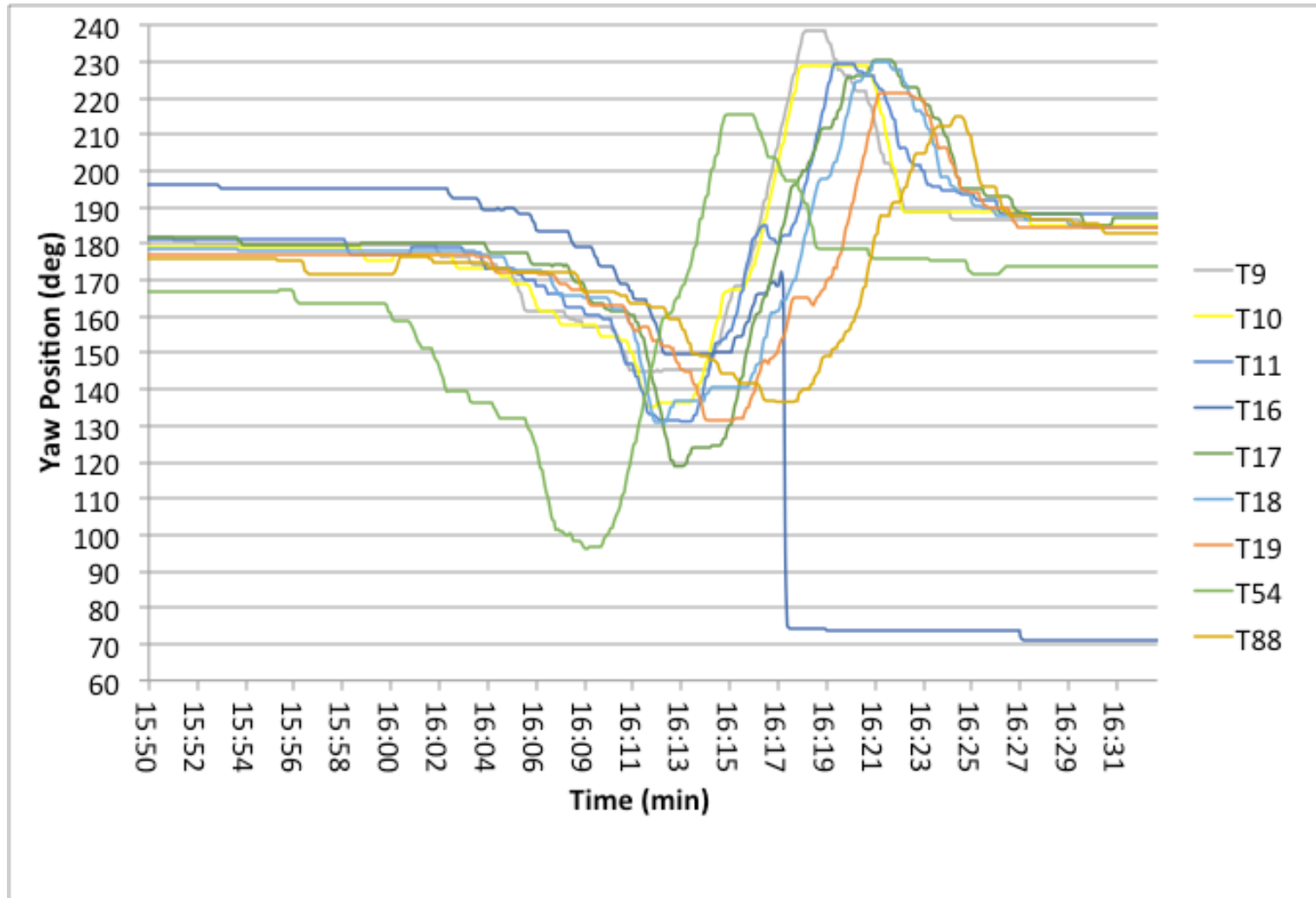
## 2 Year Power Performance Observations 2012-2014



## Testing Mr. Smith With a Tornado



## Testing Mr. Smith With a Tornado





Foundations may not be “fixed” boundary conditions as most models would have you believe.

## Conclusions and Next Steps

### CONCLUSIONS

- The Windtell Performance Management Tool has shown promise as a potential enabler for users to make conventional and less conventional historical data analyses through its ability to incorporate previously incongruent data streams.

### NEXT STEPS

- Improve user interface and robustness.
- Implement “real time” analysis.
- Consider operation tuning control opportunities.
- Report on most valuable analyses – feed back into Sandia and IEC-like efforts.
- Consider recommendations to OEMs for strategic sensor embeddings, smart components that map their own service life expectancy, etc.
- Map service life estimation to depreciation.





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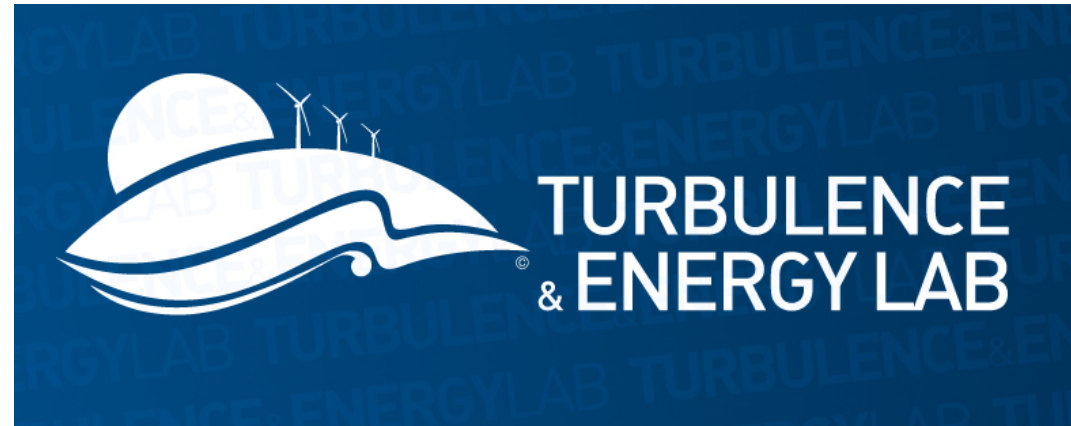
Todd Baert

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- [1] McKay, P.; Carriveau, R.; S-K Ting, D. **Wake Impacts on Downstream Wind Turbine Performance and Yaw Alignment.** *Wind Energy*, 16(2), 221-234, 2013.
- [2] Smith, J.; Carriveau, R.; S-K Ting, D. **Turbine Power Production Sensitivity to Coastal Sheared and Turbulent Inflows.** *Wind Engineering*, 39(2), 183-192, 2015.
- [3] Smith, J.; Carriveau, R.; S-K Ting, D. **Inflow Parameter Effects on Wind Turbine Tower Cyclic Loading.** *Wind Engineering*, 38(5), 477-488, 2014.

**Thanks for Your Time and Attention.**



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## Structural Loading Insights [2]

Mean Base Bending Moment Comparing Turbulent and Sheared Winds [2]

