

# P1.7 A Comparison of Wind Speed Data from Mechanical and Ultrasonic Anemometers

## Overview

### ■ Motivation

- Mechanical wind sensors being replaced by Ultrasonic wind sensors
  - At Kennedy Space Center/Cape Canaveral AFS (“Eastern Range,” ER)
  - and Vandenberg Air Force Base (“Western Range,” WR)
    - ✓ Under the Range Standardization and Automation (RSA) Program

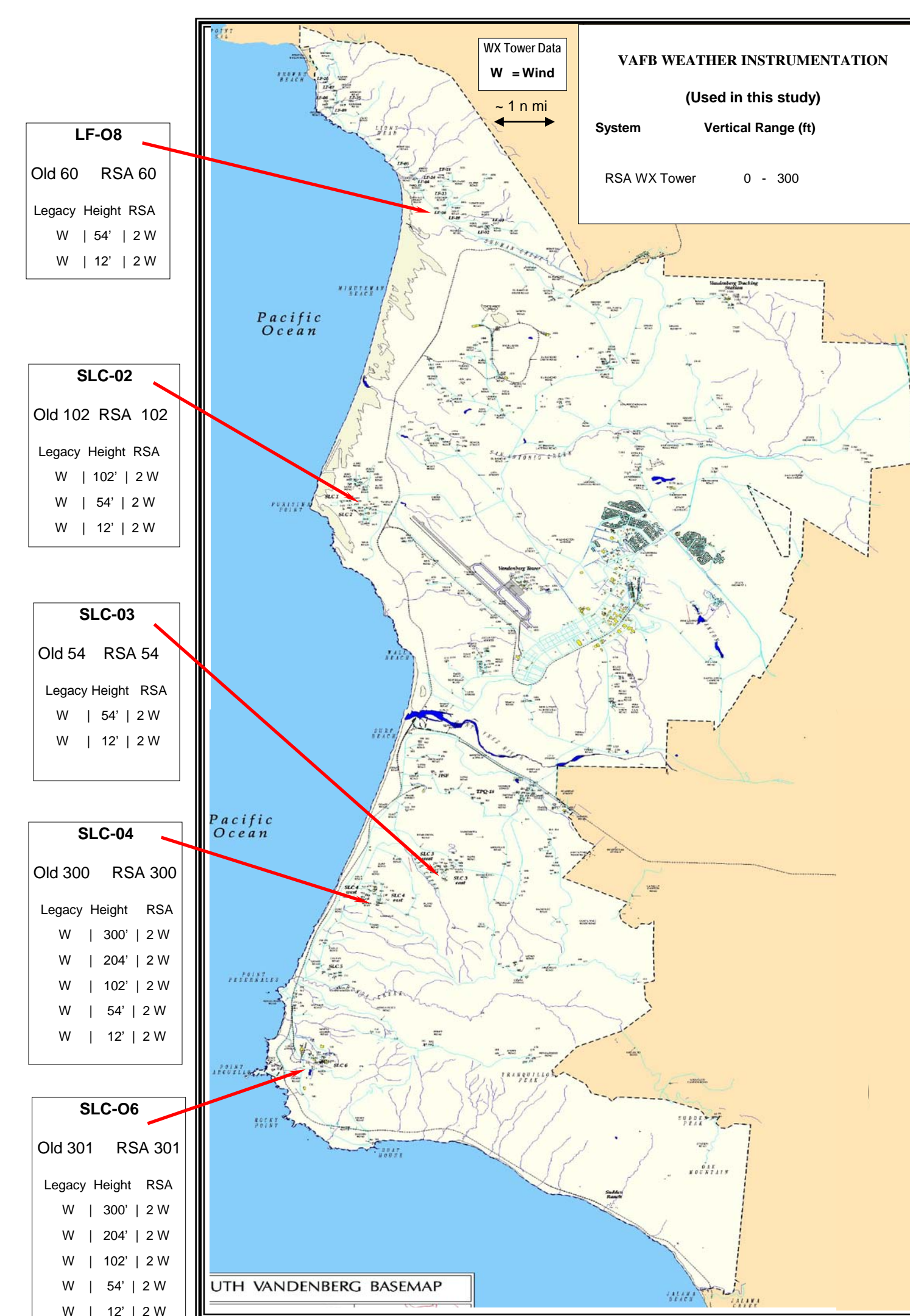
### ■ Goal

- Determine effect of instrumentation change on wind speed statistics
  - Effects on Operational decision making for Space Launch and Landing
    - ✓ Average Wind Speed and Peak Wind Speed (Wind Gusts)

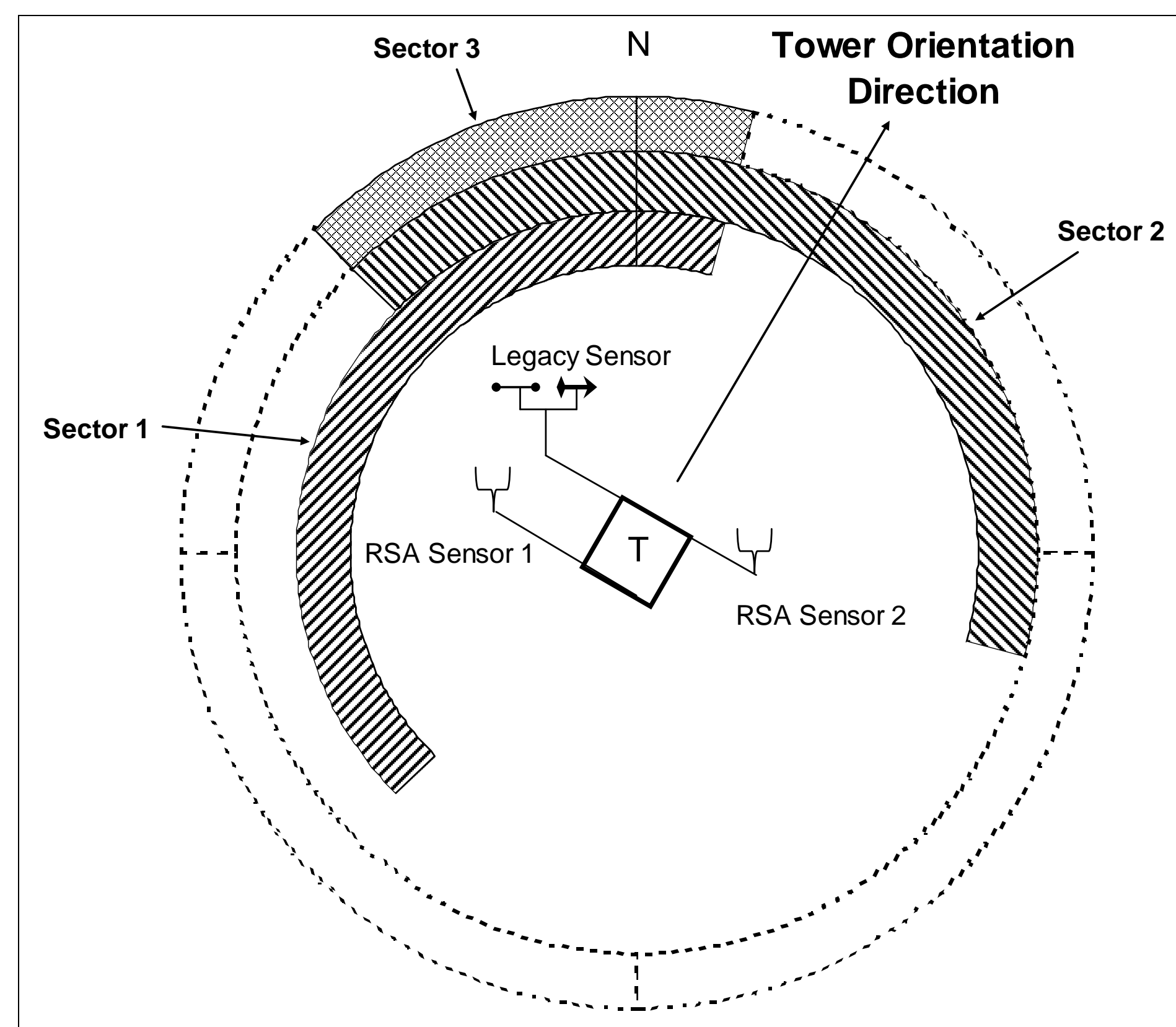
### ■ Data and Analysis method

- Collocated Mechanical (“Legacy”) and Ultrasonic (“RSA”) sensors
- Average and Peak Wind Speed from RSA Ultrasonic sensors

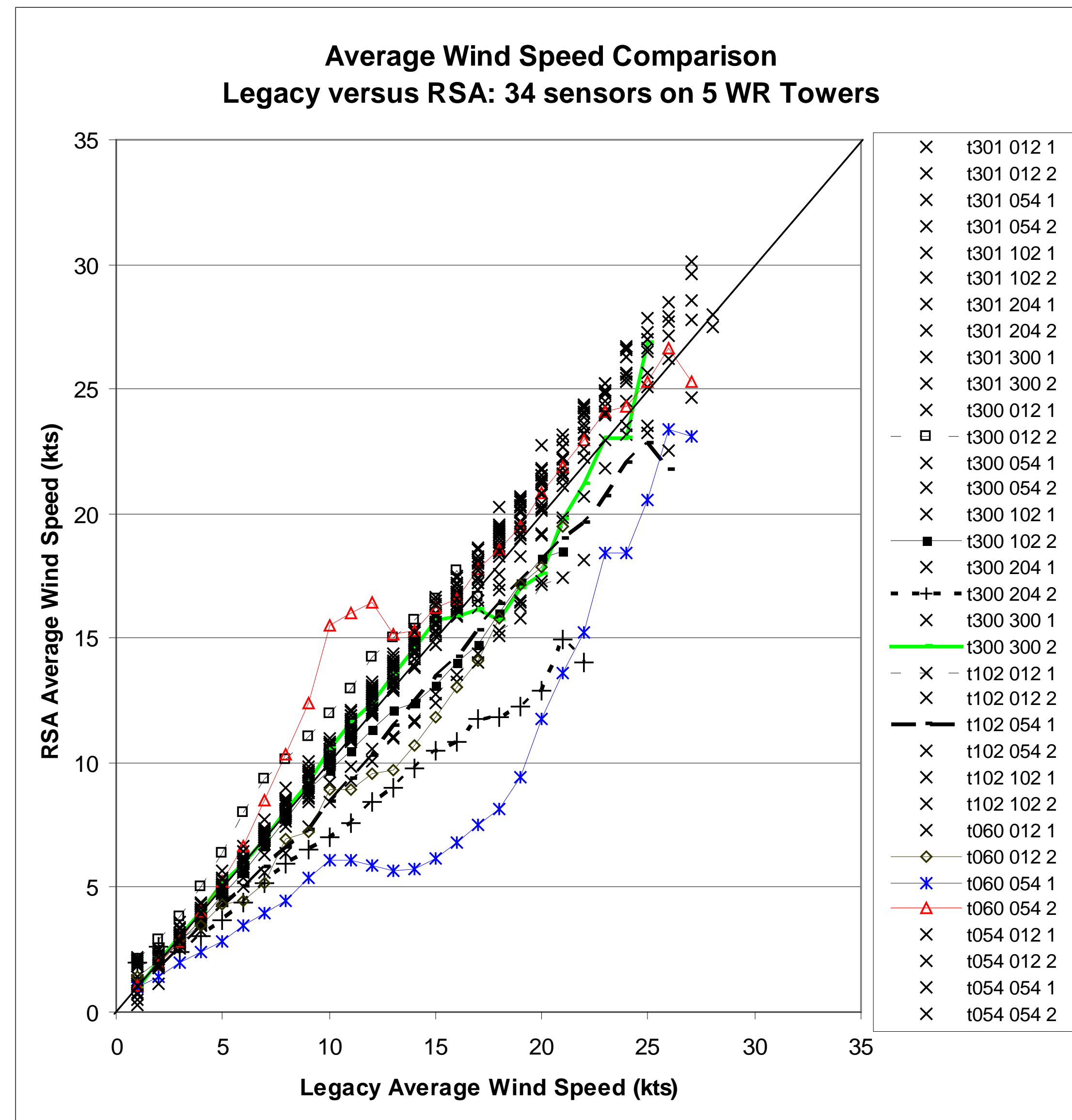
compared to Average and Peak Wind Speed from Legacy Mechanical sensors



Legacy and RSA wind sensors at the 12 ft level on Tower 102 at VAFB. Legacy cups can be seen in the middle-right. The Legacy wind vane is obscured by the electronics box. The RSA1 ultrasonic sensor can be seen in upper-center, inside the dashed black circle.

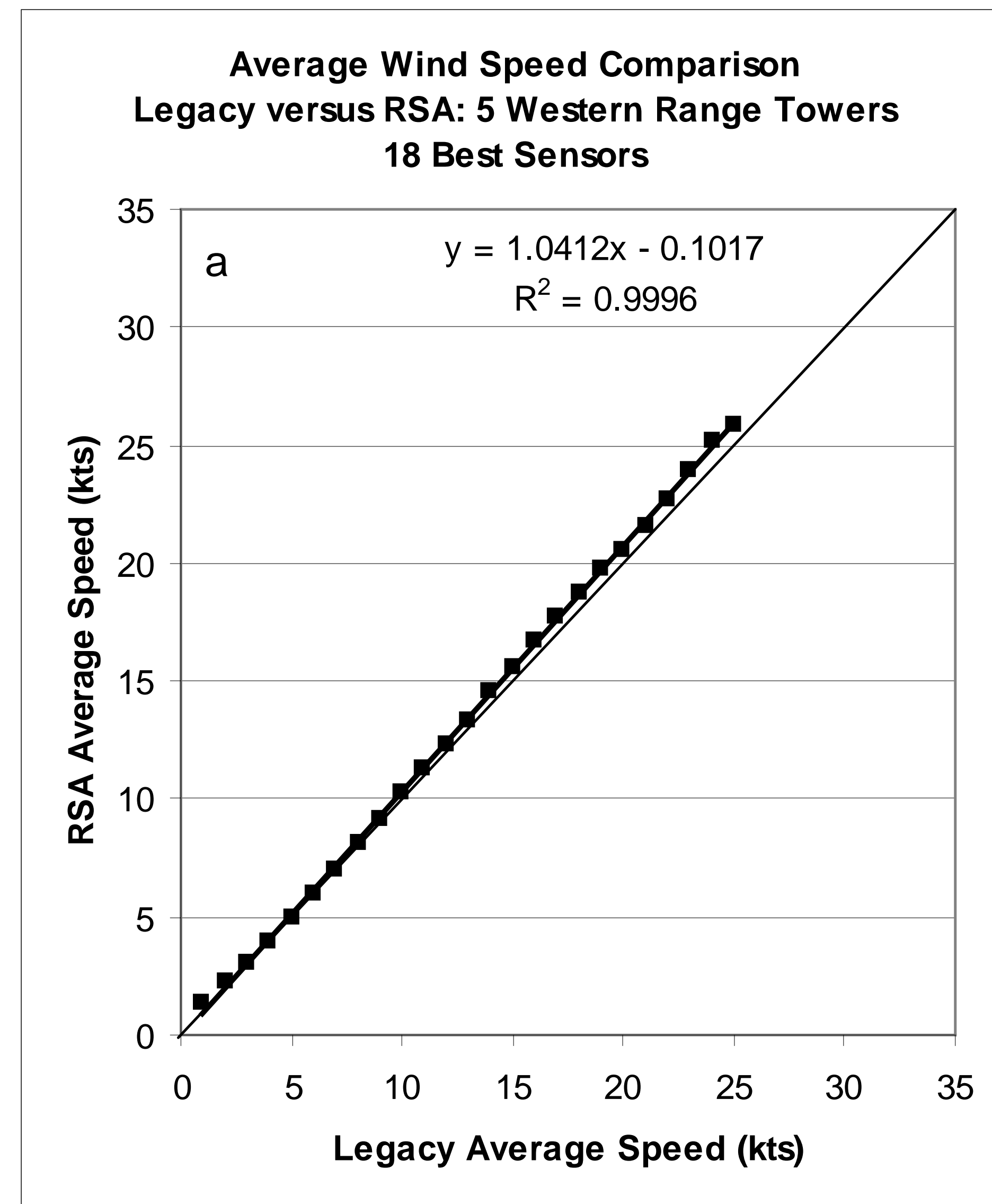


- Legacy and RSA instrument configuration used for wind speed comparisons.
  - Sector 1 was used to compare the Legacy and RSA 1 sensors.
  - Sector 2 was used to compare the Legacy and RSA 2 sensors.
    - Wind direction from the Legacy sensor was used as the reference.
- Sector 3 was used to compare the RSA 1 and RSA 2 sensors.

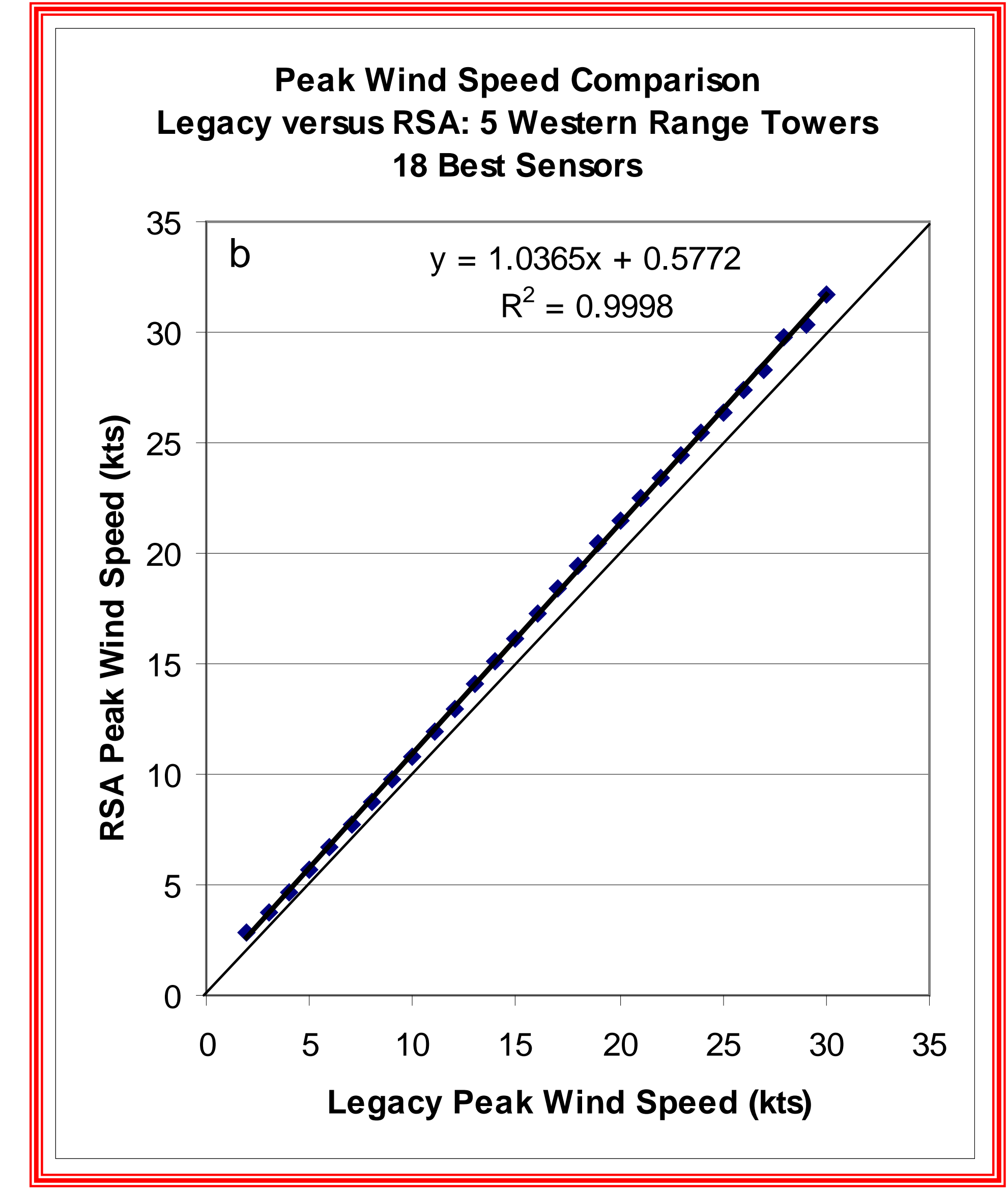


- Average wind speed comparisons for each of the 34 Legacy/RSA sensors pairs on 5 VAFB towers.
  - Period-of-record is 29 May – 23 June 2005.
- The legend indicates tower, level and RSA sensor number.
  - Nine RSA sensors are marked as outliers by dashed and solid lines.
- At ~ 25 kts the number of samples becomes small (< 30) for each sensor and the comparisons become noisy.
  - The 1:1 diagonal line is solid, extending from the point 0,0 to the point 35,35, indicating an unbiased agreement between sensor readings for data points falling along the line.

Tower numbers and sensor levels for Legacy and RSA wind data from 5 WR towers					
Level (ft)	Tower 301	Tower 300	Tower 102	Tower 060	Tower 054
300	L, RSA1, RSA2	L, RSA1, RSA2	-	-	-
204	L, RSA1, RSA2	L, RSA1, RSA2	-	-	-
102	L, RSA1, RSA2	L, RSA1, RSA2	L, RSA1, RSA2	-	-
054	L, RSA1, RSA2	L, RSA1, RSA2	L, RSA1, RSA2	L, RSA1, RSA2	L, RSA1, RSA2
012	L, RSA1, RSA2	L, RSA1, RSA2	L, RSA1, RSA2	L, RSA1, RSA2	L, RSA1, RSA2



(a) Average wind speed comparisons for the best 18 RSA sensors on 5 WR towers. Period-of-record is 29 May – 23 June 2005. Total sample size is 87,894. Each data point plotted had at least 30 one-minute samples.



(b) Peak wind speed comparisons for the best 18 RSA sensors on 5 WR towers. Total sample size is 87,894. Each data point plotted had at least 30 samples.

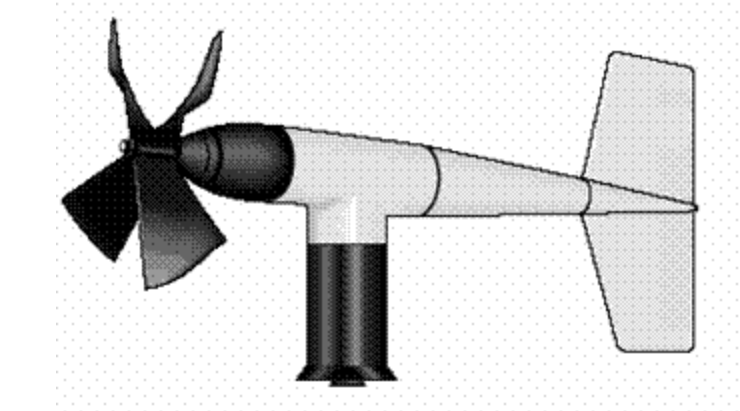
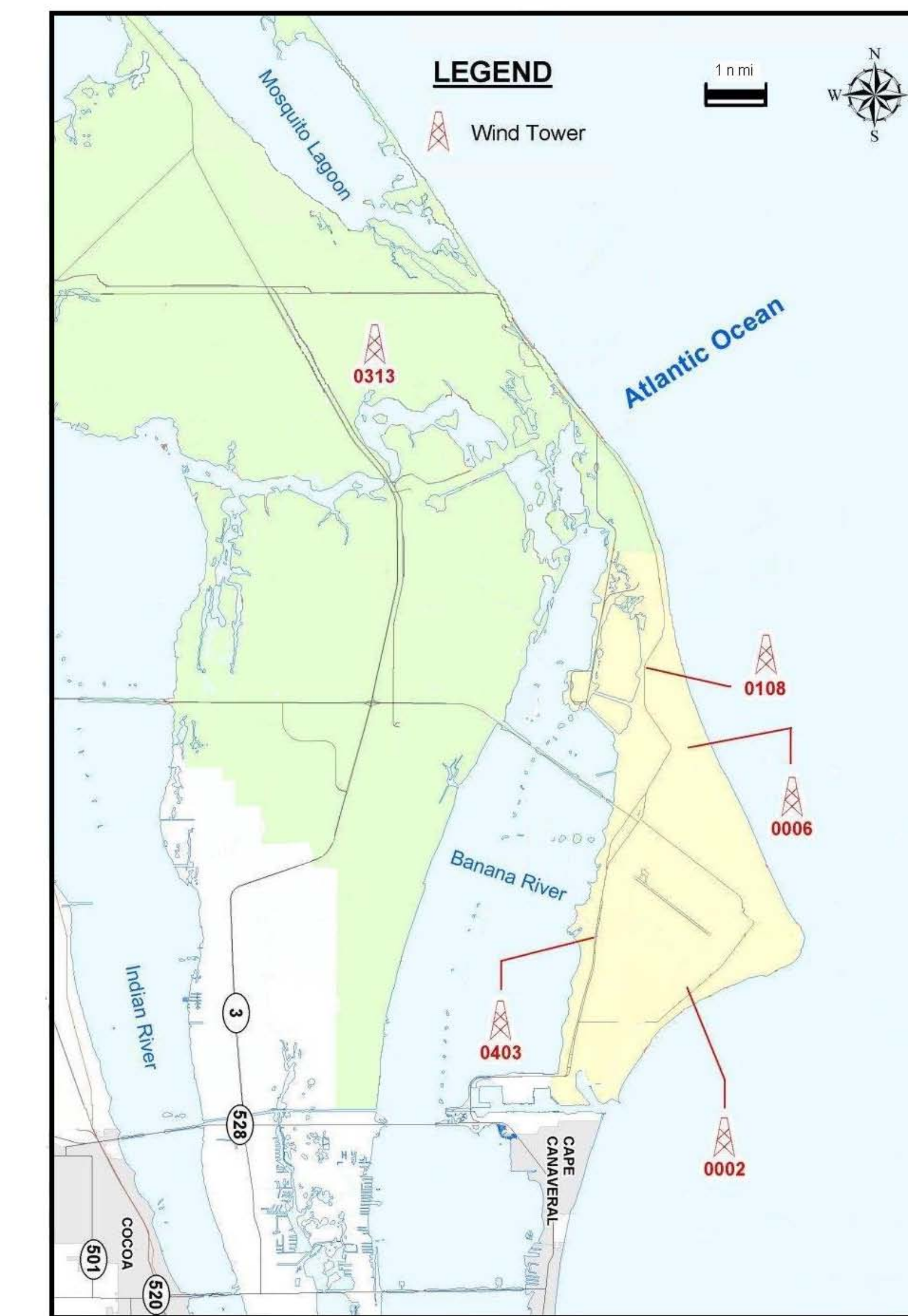
- ### Discussion
- One-minute average and peak wind speed data derived from 1-second sampling
    - Legacy is sampled instantaneously; system has moving cups
    - RSA sample is integrated over 0.2 sec; the system has no moving parts
  - RSA sensor mounting scheme allowed comparisons between each RSA sensor and the Legacy sensor and between the two RSA sensors, while avoiding wind blockage by the tower. RSA-to-RSA comparison allowed consistency check.
    - Bias and RMS of one-minute average wind speed and direction used to identify most consistent sensor pairs
    - Data confined to 1600L – 2200L; Avg. Speed 10.25 kt; Avg. Peak 13.68 kt

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## Major Findings

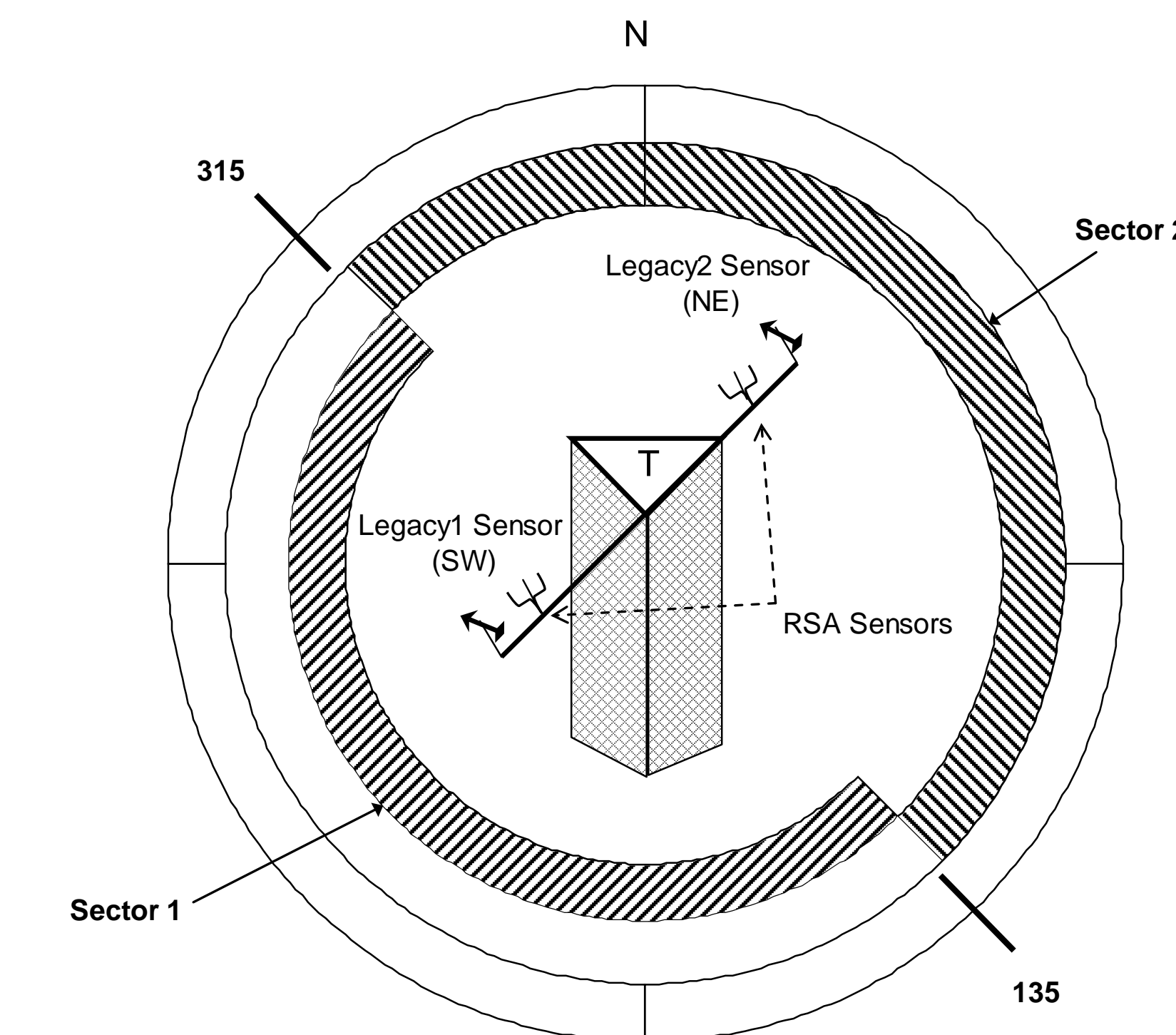
- Ultrasonic Average wind speed ~ 4 % higher than Mechanical Average wind speed
  - By ~ 0.5 kt @ 15 kt
  - By ~ 1.0 kt @ 25 kt
- Ultrasonic Peak wind speed ~ 7 % higher than Mechanical Peak wind speed
  - By ~ 1.0 kt @ 15 kt
  - By ~ 2.0 kt @ 30 kt
- Based on 511,587 one-minute samples from 53 Ultrasonic Sensors
  - Collocated with 36 Mechanical Sensors on 10 Operational Towers
- Potential Impact on Space Launch and Landing Operations:
  - Assuming a 20 kt Peak Wind Constraint
    - Legacy Mechanical Sensors indicate 95.2% availability
    - RSA Ultrasonic Sensors indicate 92.3% availability



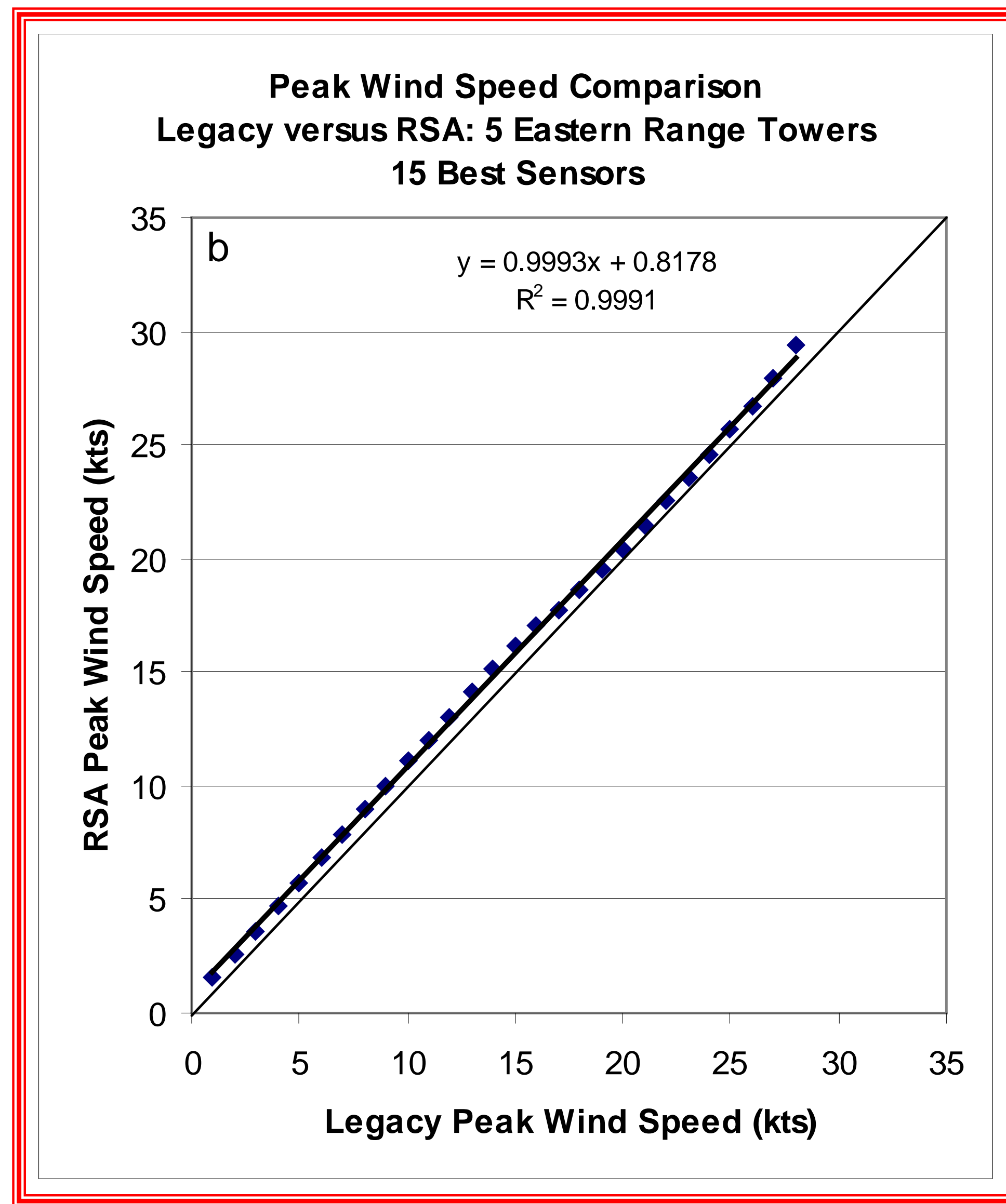
Schematic image of the propeller-and-vane type wind sensor used on the 5 KSC/CCAFS towers used in this study. Wind speed accuracy is +/- 0.58 kts.



Ultrasonic RSA wind sensor used in this study (adapted from the Vaisala Model WS425 Ultrasonic Wind Sensor).

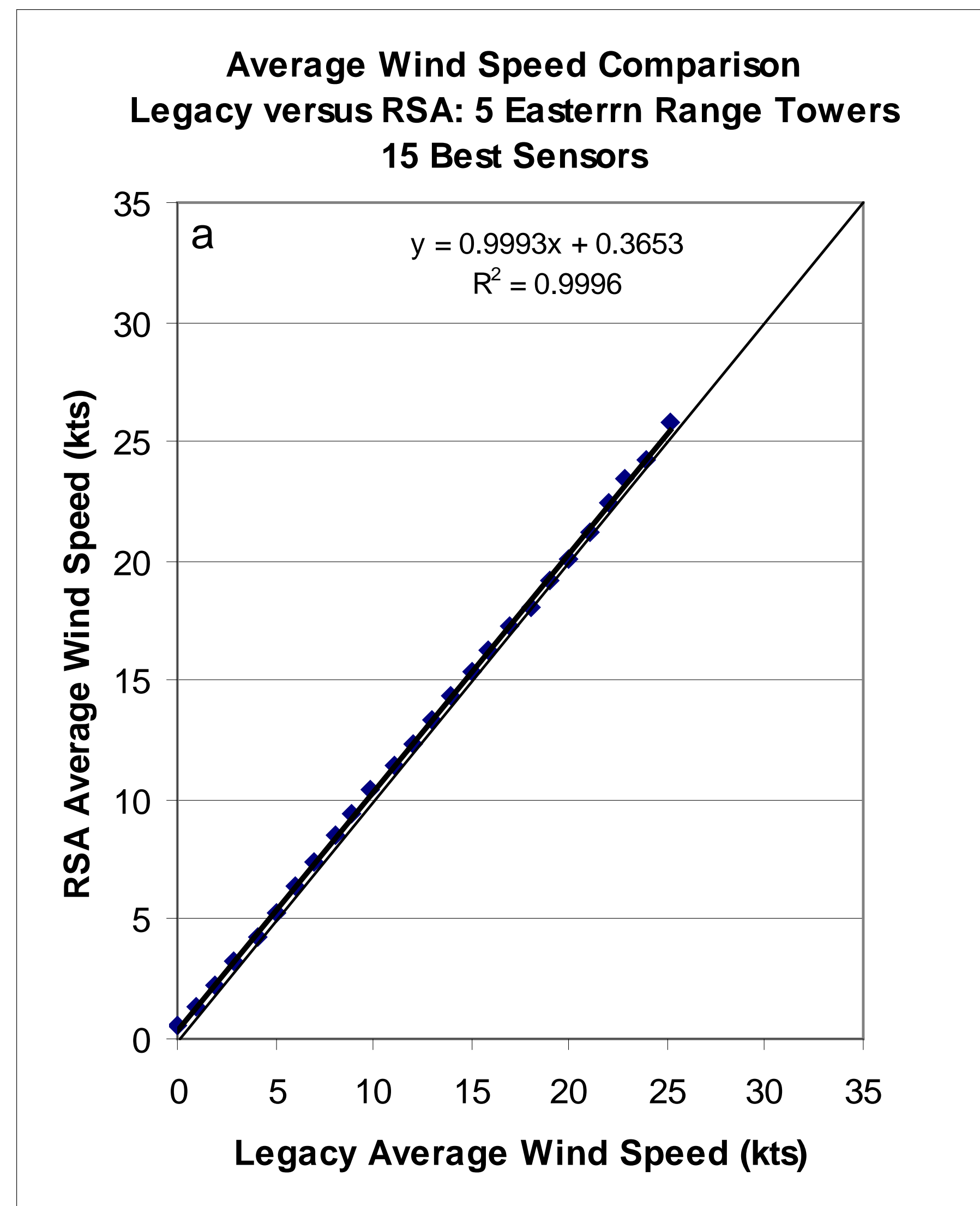


- Schematic of Legacy and RSA instruments used on Tower 0313.
- Sector 1 was used for comparing the Legacy1 and the SW RSA sensor.
- Sector 2 was used for comparing the Legacy2 and the SW RSA sensor.
  - Data from only one RSA sensor was available at each level
- Wind direction from the Legacy1 sensor was used as the reference.

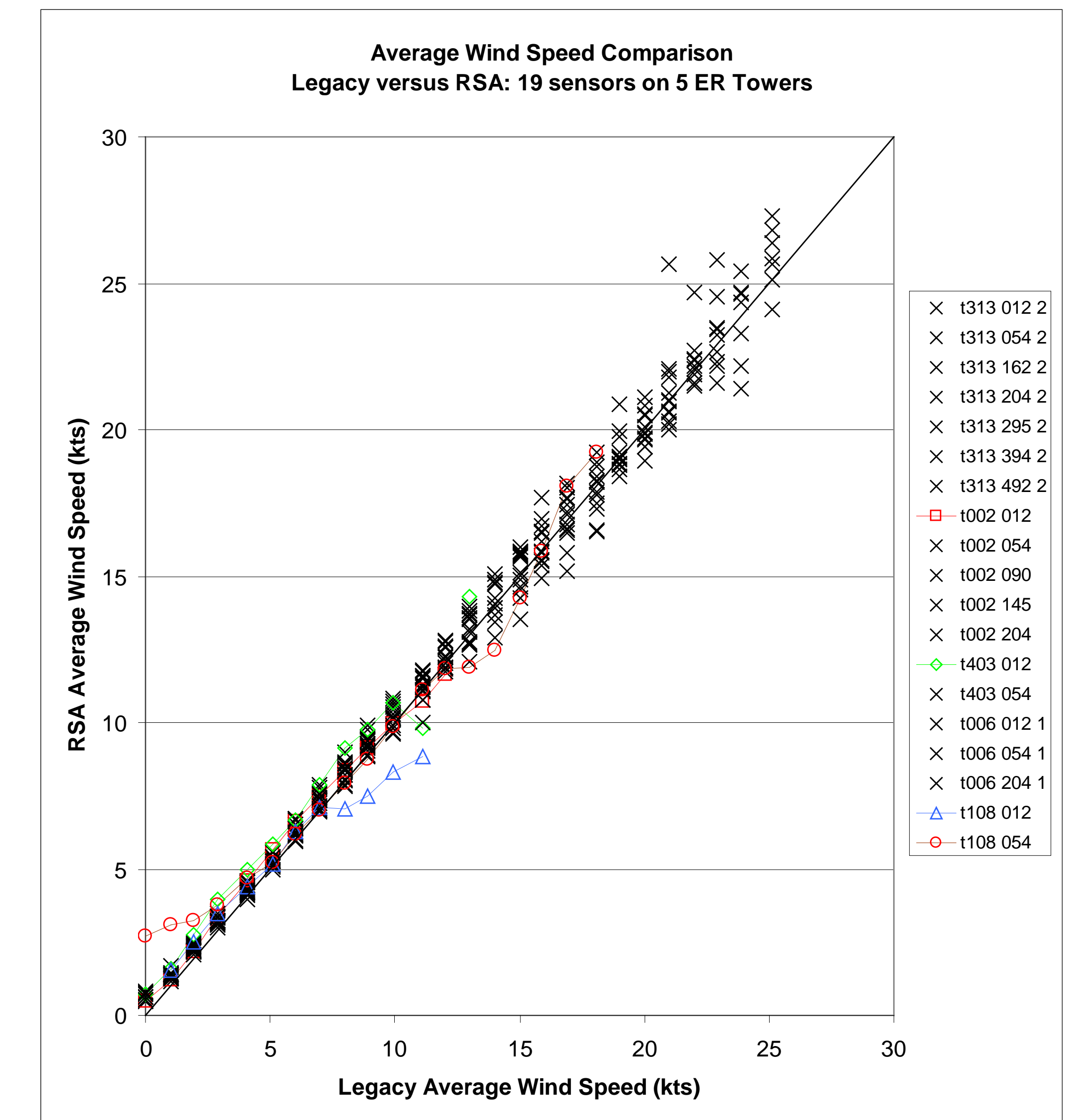


(b) Peak wind speed comparisons for the best 15 RSA sensors on 5 ER towers. Total sample size is 171,726. Each data point plotted had at least 30 one-minute samples.

Tower numbers and sensor levels for Legacy and RSA wind data from 5 ER towers					
Level (ft)	Tower 0002	Tower 0006	Tower 0108	Tower 0313	Tower 0403
492				L1, L2, RSA	-
394				L1, L2, RSA	-
295				L1, L2, RSA	-
204	L, RSA	L1, L2, RSA		L1, L2, RSA	-
162				L1, L2, RSA	-
145	L, RSA				-
090	L, RSA				
054	L, RSA	L1, L2, RSA	L, RSA	L1, L2, RSA	L, RSA
012	L, RSA	L1, L2, RSA	L, RSA	L1, L2, RSA	L, RSA



(a) Average wind speed comparisons for the best 15 RSA sensors on 5 ER towers. Total sample size is 171,726. Each data point plotted had at least 30 one-minute samples.



- Average wind speed comparisons for each of the 19 Legacy/RSA sensors pairs on 5 ER towers.
  - Period-of-record is 13 May – 30 May 2005.
- The legend indicates Legacy Tower ID, level (in ft) and Legacy sensor number, when applicable.
  - Four outliers are marked by solid lines.
- Above ~15 kts the number of samples becomes small (< 30) for each sensor and the comparisons become noisy.
  - The 1:1 solid diagonal line extends from the point 0,0 to the point 30,30, and represents the no-difference line.

### Discussion

- one-minute average and peak wind speed data derived from 1-second sampling
  - Legacy is sampled instantaneously; system has moving propeller
  - RSA sample is integrated over 0.2 sec; the system has no moving parts
- Data from one RSA sensor at each level was compared to the Legacy sensor on the same side of the tower. Bias and RMS of one-minute average wind speed and direction was used to identify most consistent sensor pairs.
- Data spanned the full diurnal cycle: Avg. Speed 8.00 kts; Avg. Peak 10.13 kts
  - One RSA sensor showed anomalously high wind speeds during the late night and early morning hours. See Short and Wheeler (2006b) for details.

### References

- Short, D. A, and Mark M. Wheeler, 2006a. RSA/Legacy Wind Sensor Comparison. Part I: Western Range. NASA Contractor report CR-2006-214200, Kennedy Space Center, FL, 26 pp.
- Short, D. A, and Mark M. Wheeler, 2006b. RSA/Legacy Wind Sensor Comparison. Part II: Eastern Range. NASA Contractor report CR-2006-214205, Kennedy Space Center, FL, 26 pp.

See Reports online at <http://science.ksc.nasa.gov/amu>