Toward an Autonomously Powered Neutrino Observatory at the South Pole

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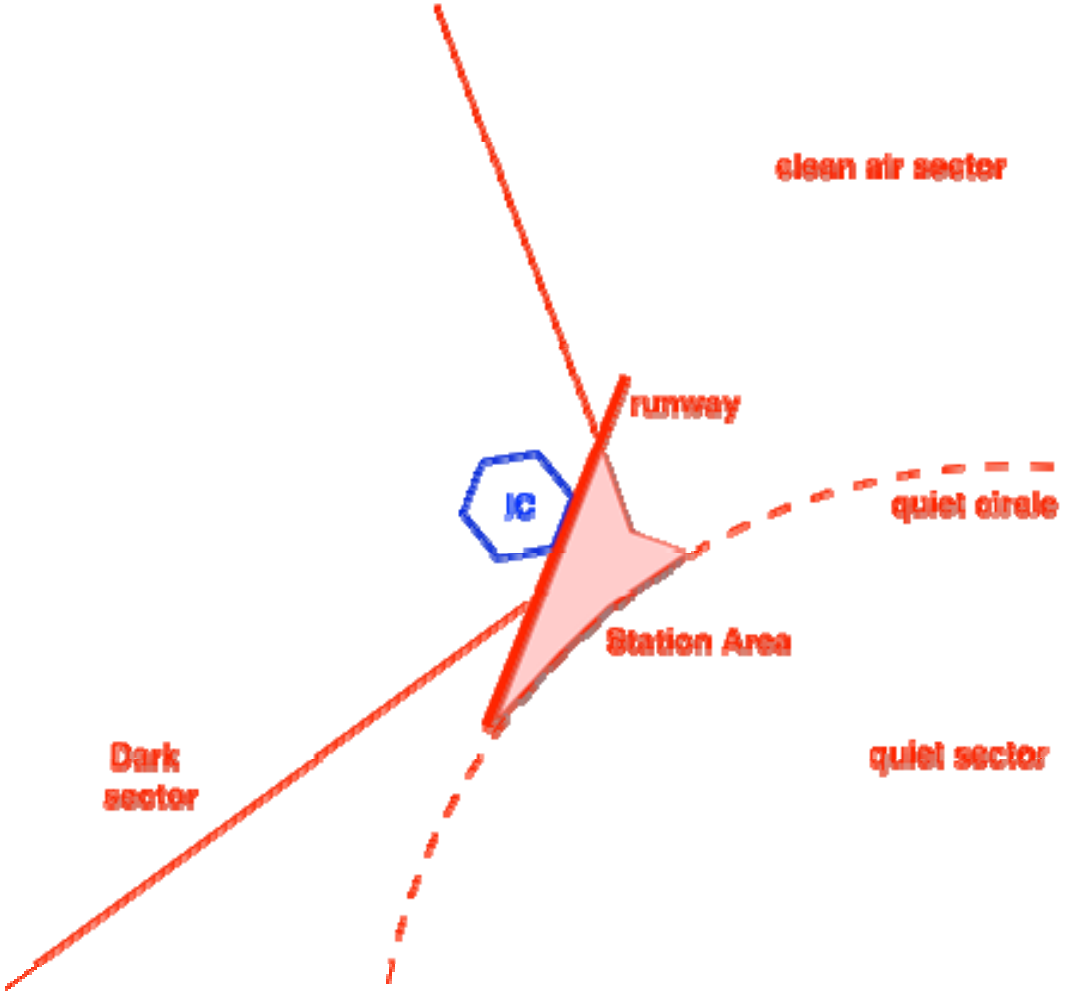
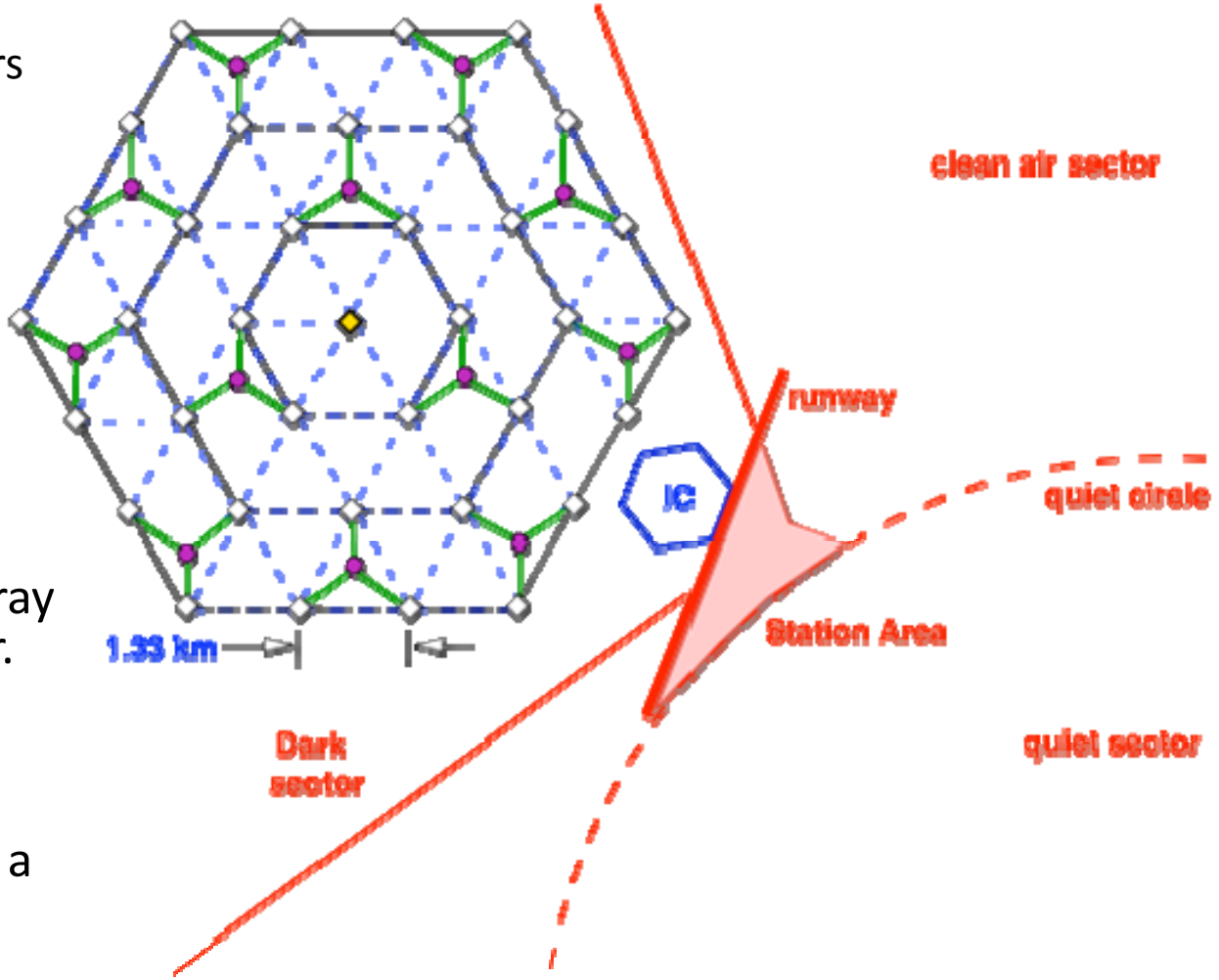
Moving out from station



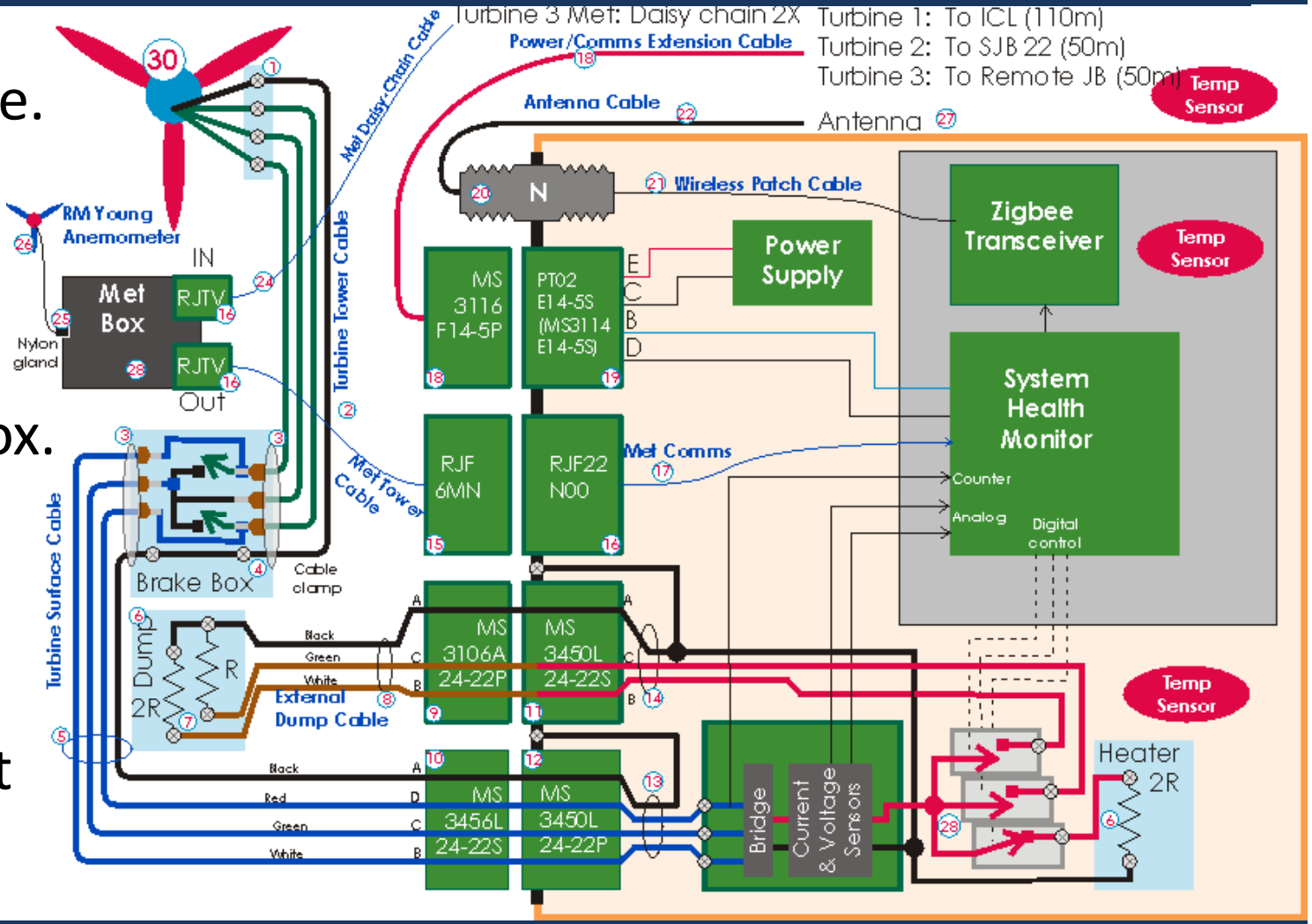
Moving out from station

- **Askaryan Radio Array:**
  - 37 radio receiver clusters spaced at 1.33 km.
- Assigned design specs:
  - 100w per cluster.
  - 3 per power station.
  - "near 24-7" service.
  - "no" *rf* emissions!
- Autonomous power very desirable. Long term, array will possibly be 10x larger.
- Need AARPs: The ARA Autonomous Renewable Power systems. Turbines a possible component.



AARPs for 2010 *Testing*

- Turbine performance.
- 900 MHz Zigbee.
- Insulated box.
- System monitor.
- Deployment procedures.

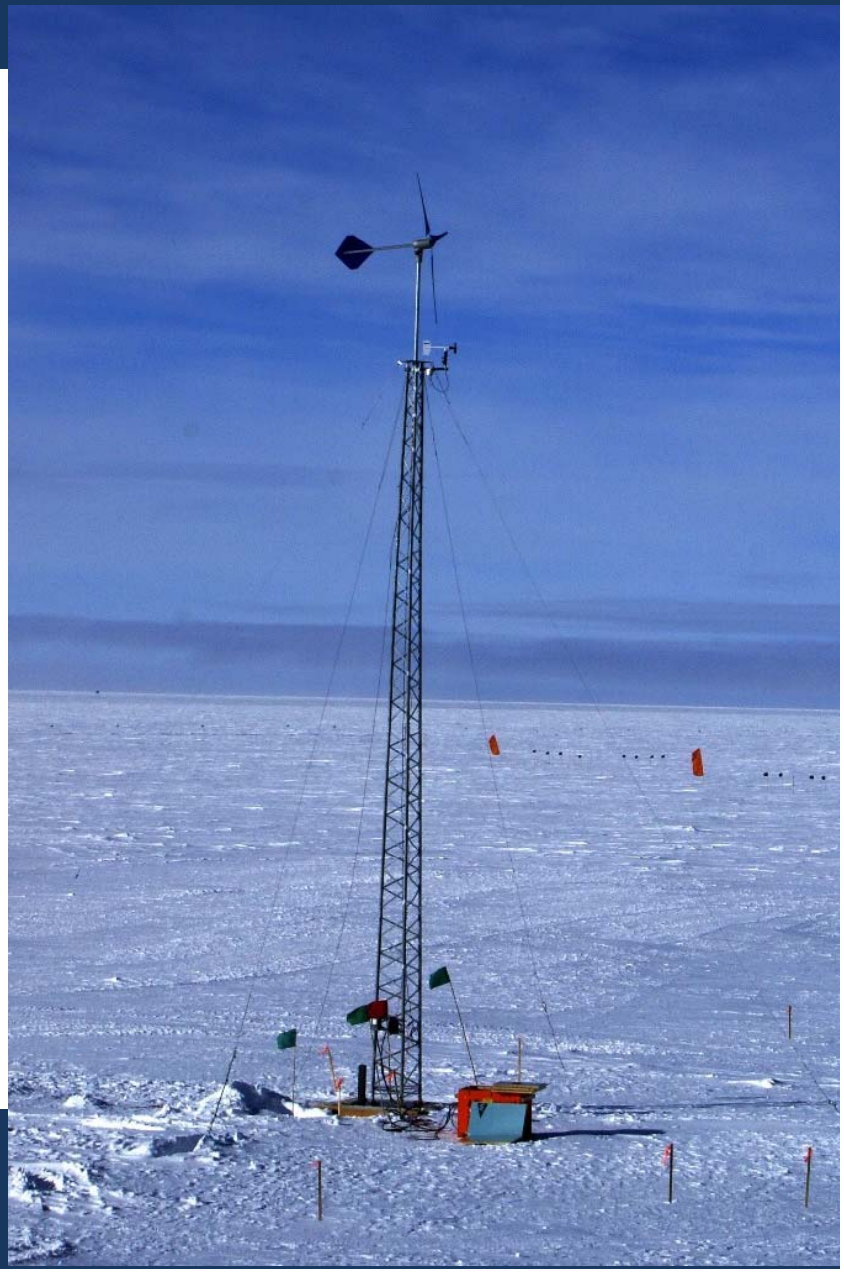


Turbines

- 1-1.5 kw range. May need 2 per site, but this physical size is manageable.
- Selected for apparent ruggedness, availability, manufacturer's data, word-of-mouth.
- Prefer turbines without air flow-through (diamond dust).
- No slip rings (source of rf emissions). If present, they must be removed.
- Turbines to be supplied with tilt-towers.
- No batteries, no charge controller this year.
- Need access to bearings.
- Everything must operate to -80C.

Turbine 1: Raum

- Deployed on 50’ lattice tilt-tower.
- Base: 1” plywood on horizontal timbers.
- “Hinge” built into base. One set of guys added.
- 6”x6”x4’ timbers used as deadmen.
- Sask. manufacturer fitted turbine for cold.
- Native design: no slip rings.



Deployment straight-forward

- Tilt-up easy with gin pole & Pisten Bully (after a case of erectile dysfunction.)
- Tower shipping a problem.
- Raum is a “slow starter” but rugged.

Turbine 2: Hummer

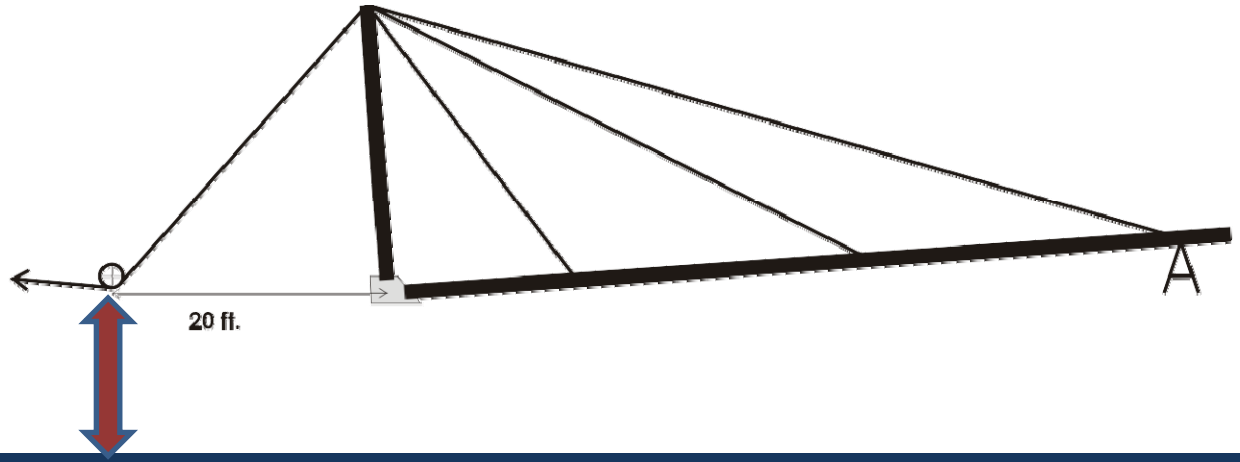
- Rugged Chinese turbine. Internals well-protected.
- Removed slip rings, changed bearings. (Not built to be opened.)
- Bad tower/tilt procedure; shortened to 50’ for tilt-up.
- Tedious guy adjustments.
- Single-phase output; 3-phase preferred.
- Good power output until failure. Turned easily. (Not fully diagnosed.)

Turbine 3 – Bergey XL.1

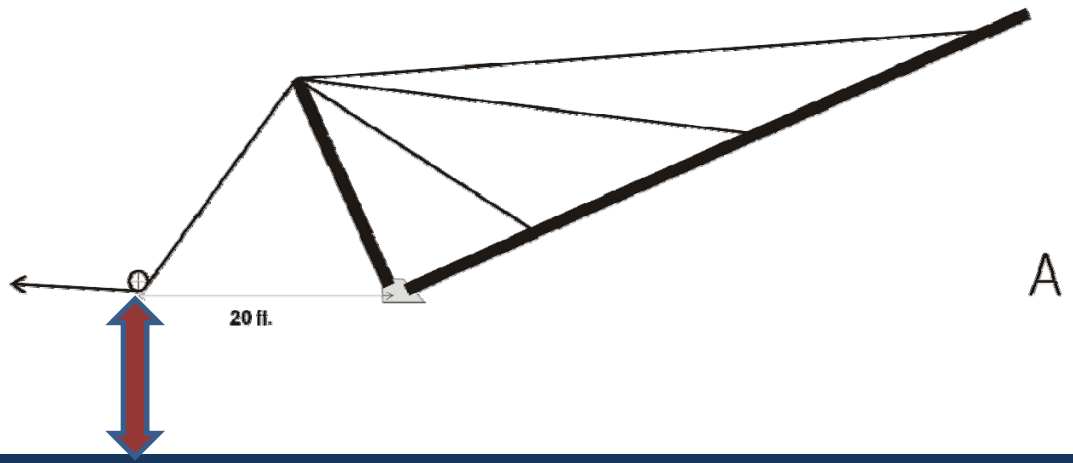
- Rugged; well-protected internals.
- Slip-rings removed (failed cold-test anyway.)
- Uses tapered bearings – easy removal.
- We replaced steel guys with Kevlar.
- Note 3 anemometers & Yagi.

Tower Deployment

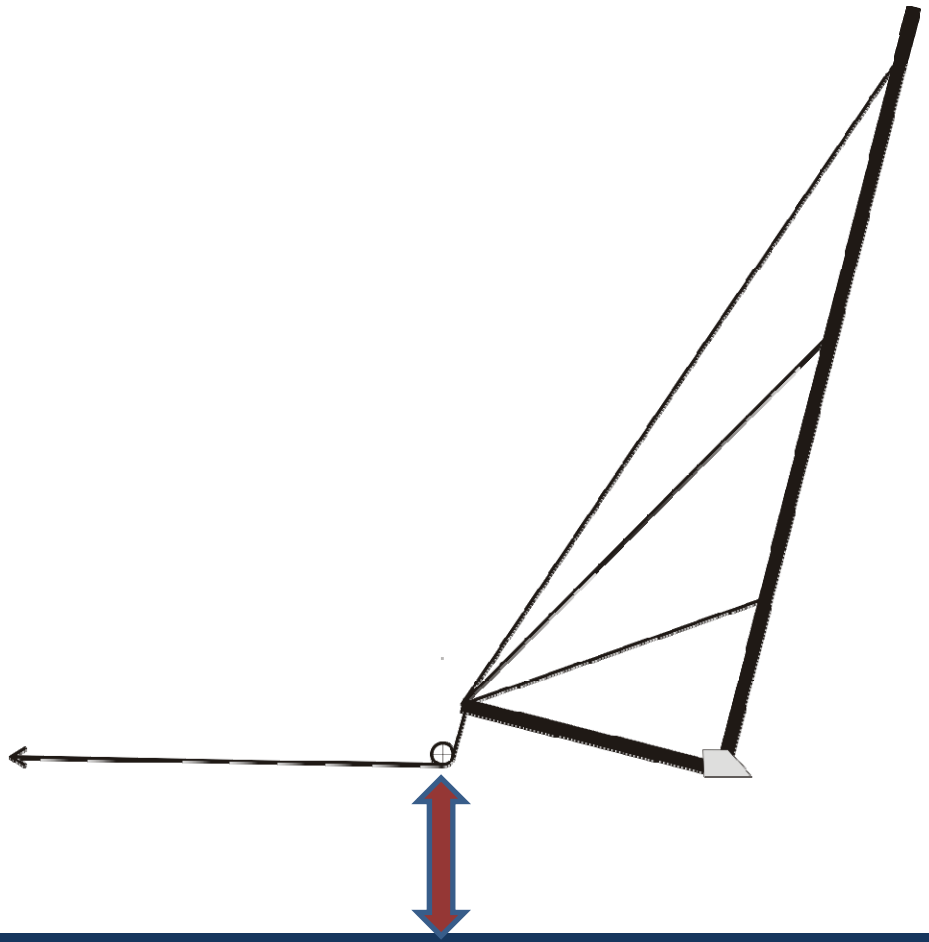
- 60’ tower.
- Uses gin pole and pulley.



Tower Deployment



Tower Deployment

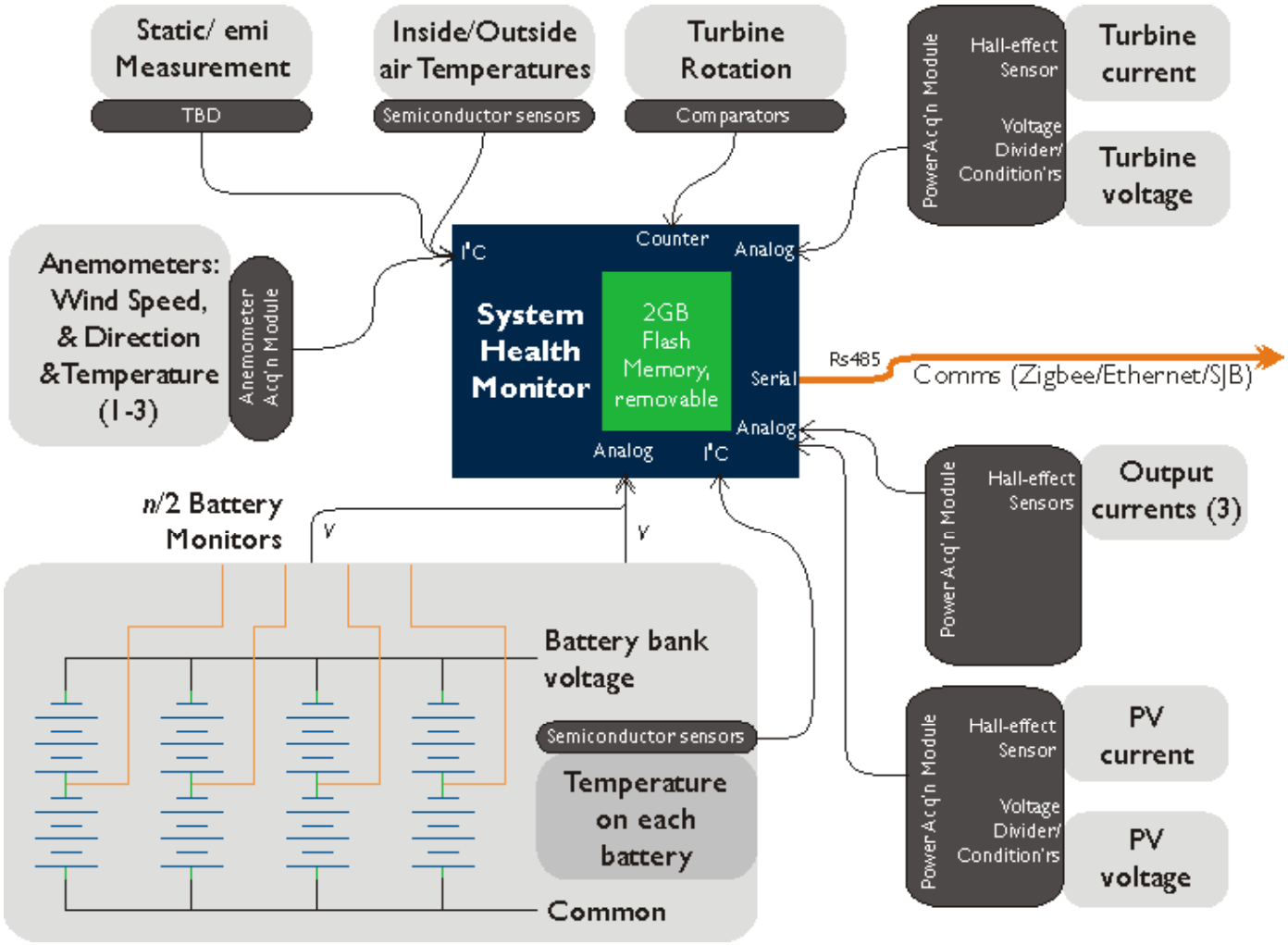


Tower Deployment

- Tower goes up smoothly.
- Guy cable adjustments are v. tedious; better procedure in process.
- Turbine turns easily.

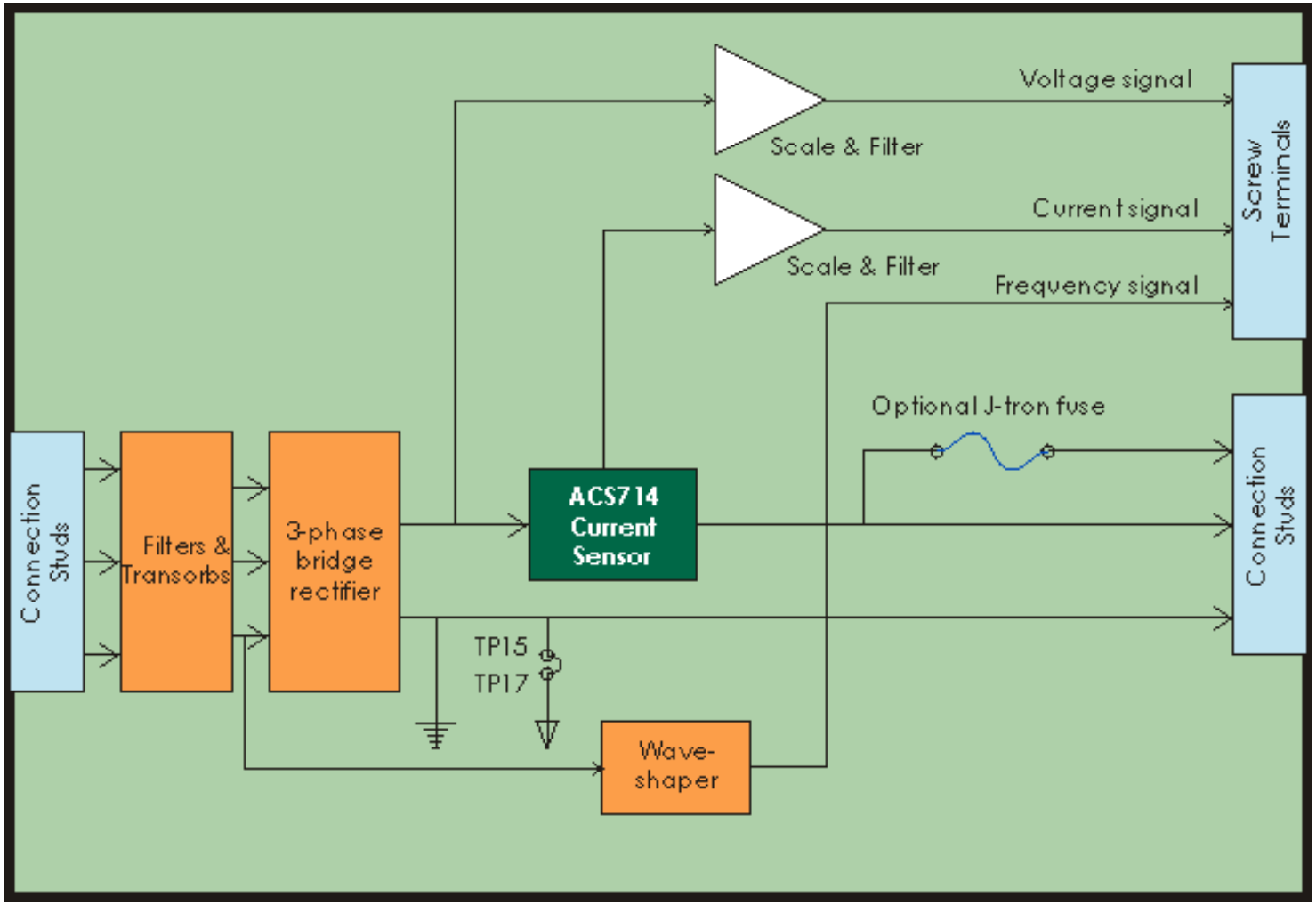
System Health Monitor

- Monitors multiple parameters. Sends data w. variances to ICL at 10s intervals.
- Currently consumes 2W; (line drivers are the killers.)
- One power acq'n module may have experienced a failure.
- Susceptible to wind interference when exposed?



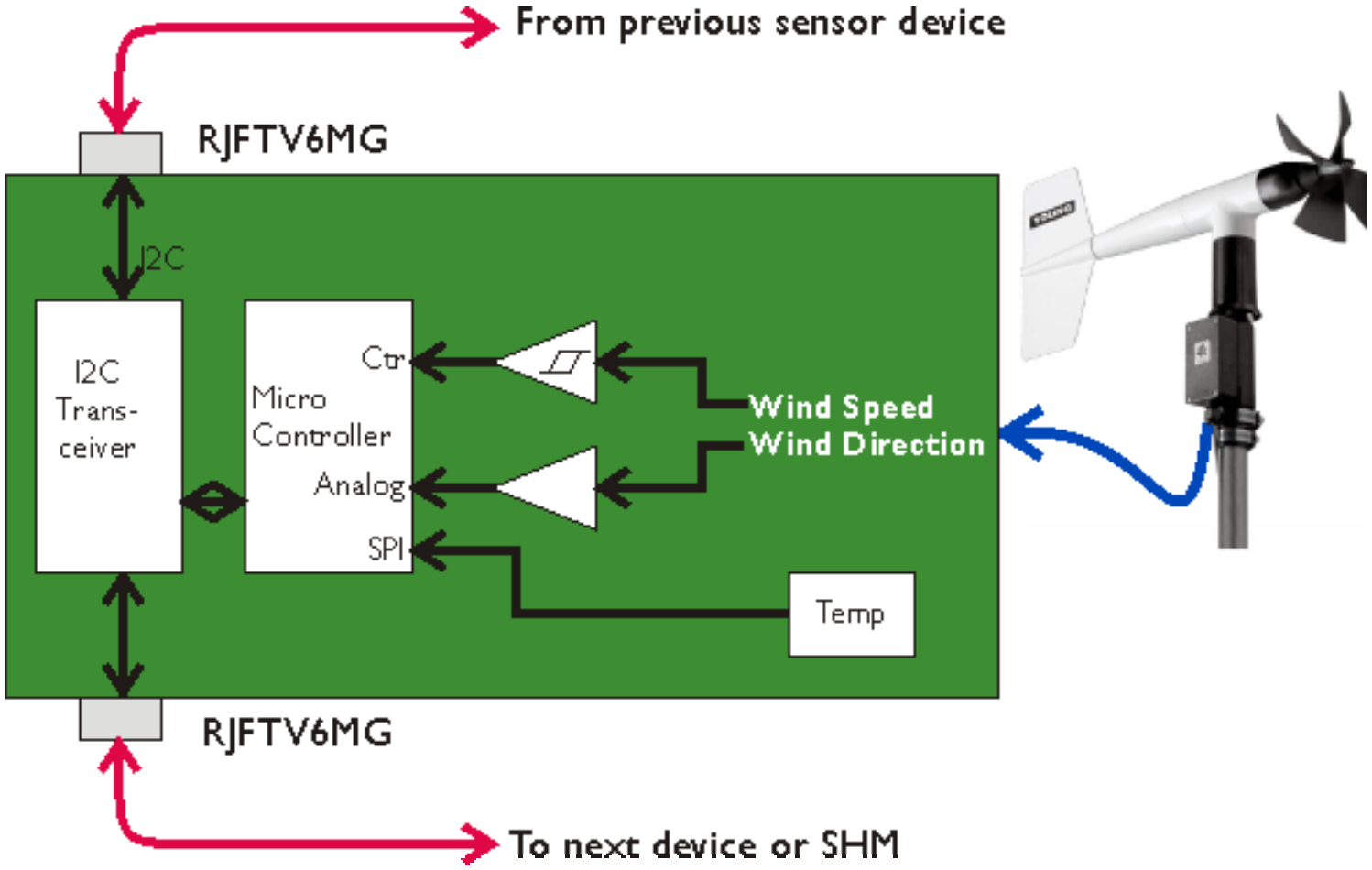
Power Measurement Module

- Hall-effect current sensor – isolated; no voltage drop.
- Rectifier requires large heat sink (0.6V drop).
- Careful attention to studs and crimps.



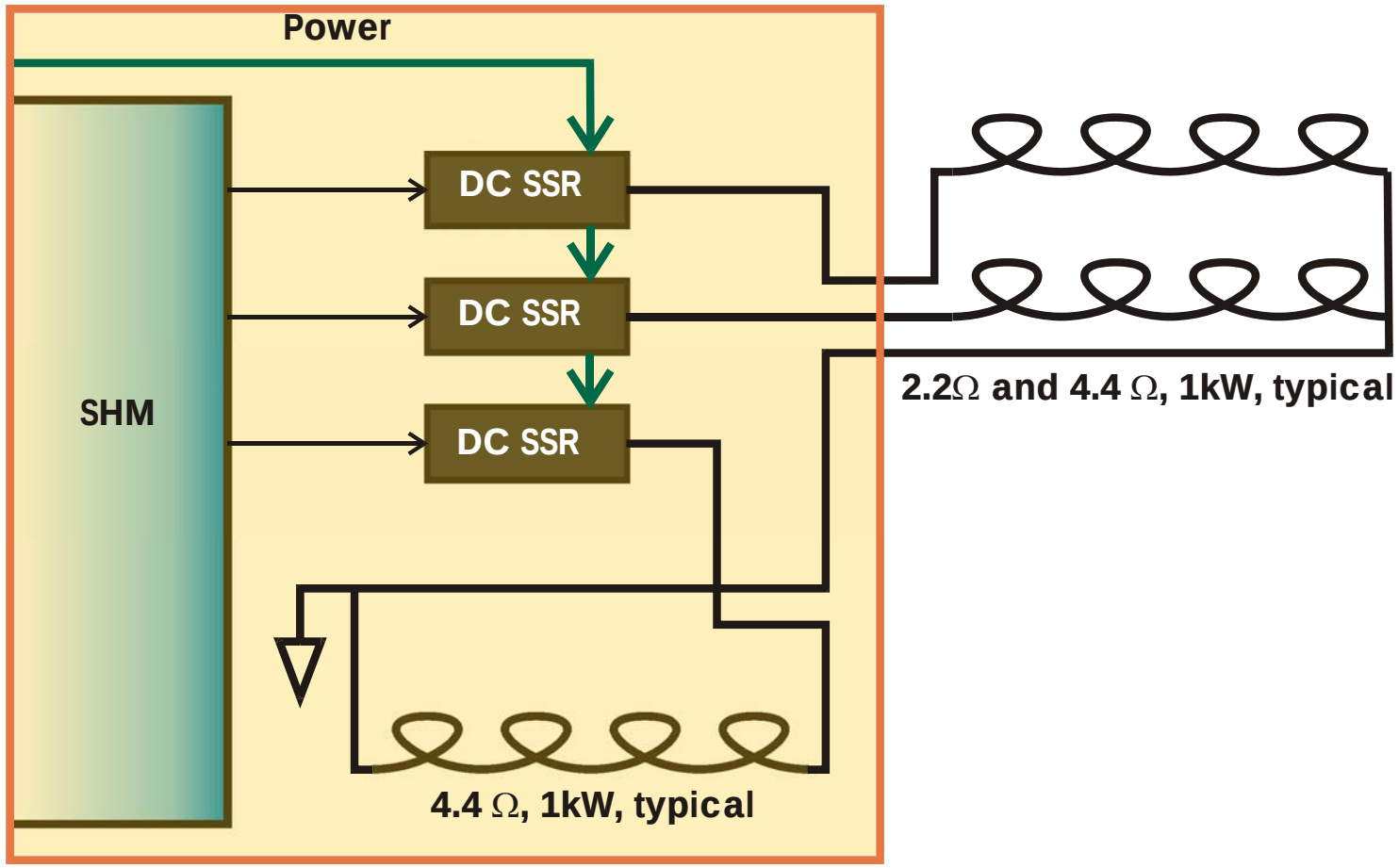
Anemometer acquisition

- Delivers *averaged* speed, direction, temperature every 10 seconds.
- Cable must be shielded.



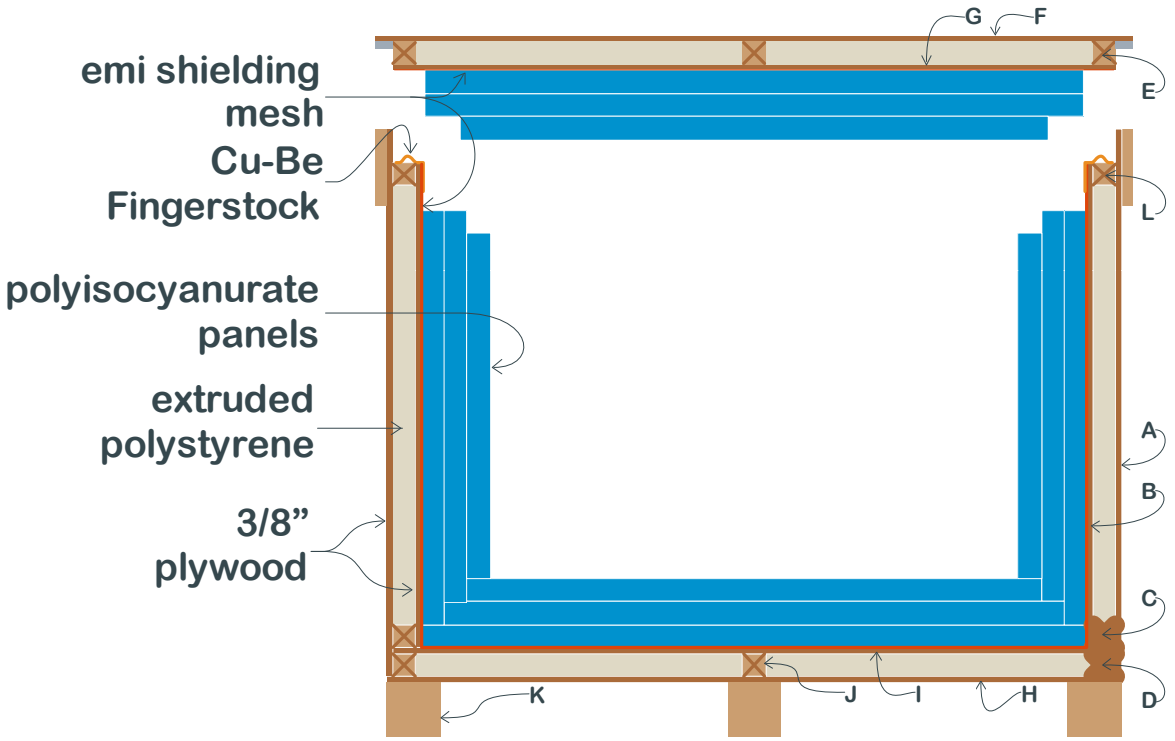
Power Dump

- Switched loads instead of batteries in 2011.
- Thresholds to enable easy startup and optimize voltage drop for MPP.



Power Instrumentation Box

- Insulation: Polyisocyanurate panels.
- Cu/polyester fabric (Flectron) for up to 50 dB.
- Cu-Be Fingerstock to emi-seal opening.
- Silicone gaskets.

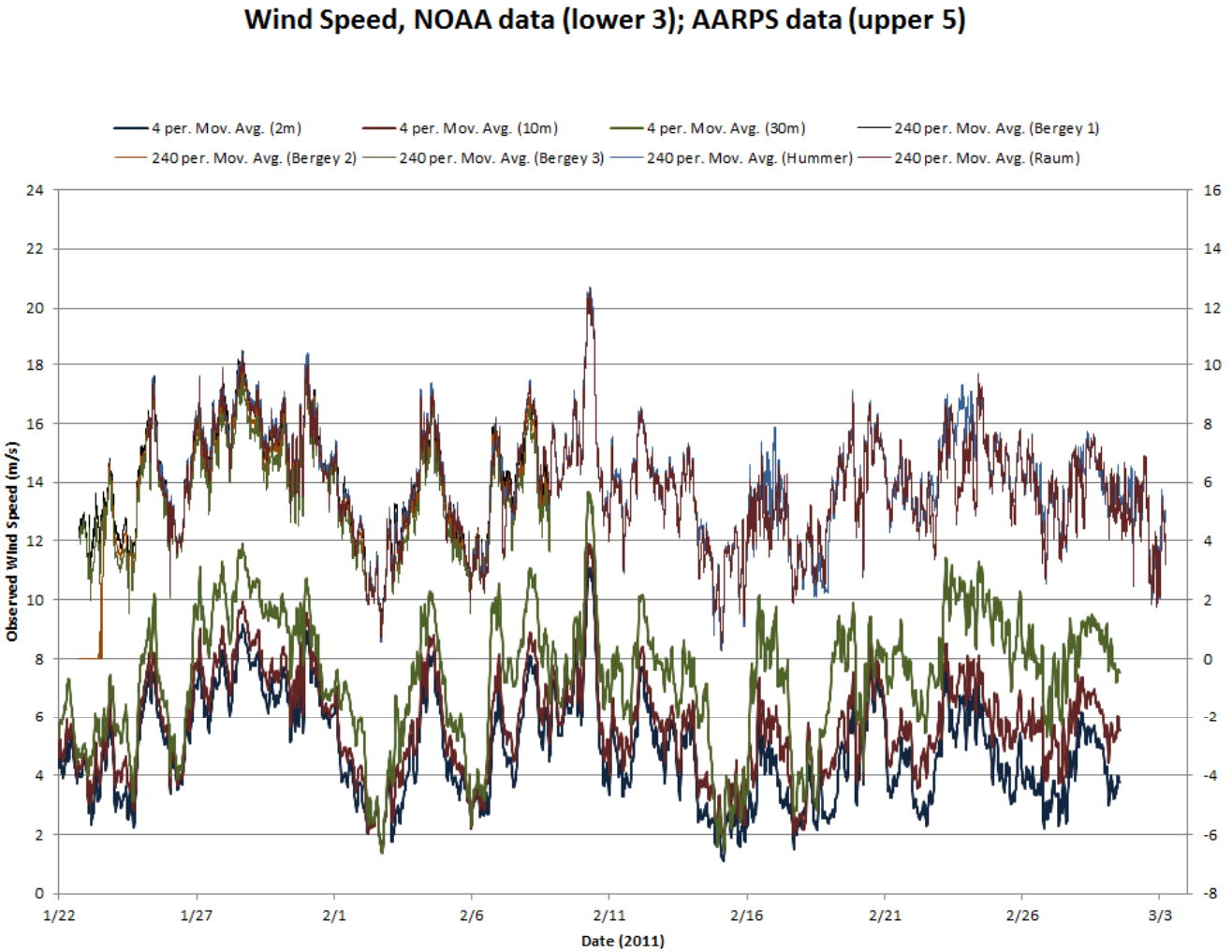


Results from 2011 deployment

- We are comfortable with deployment procedures for 50' to 60' towers with Pisten Bully. RPSC support in the field was excellent. Deadmen worked well, even for vertical pull.
- System Health Monitor worked well -- forms basis for reducing consumption to << 1W. Sensors all work well – probably. (Strange but innocuous behavior in wind.)
- Power Instrumentation Box successful. ~ R30 insulation. Can be shielded to at least 40db, 100-800 MHz.
- Hummer is out – too difficult to prep, erect, examine. (But works v. well at low speed.)
- Zigbee worked well at low power over several km. (Now turned off – don't know how to get authorization.)
- Uncertain about Seoprene (Arctic Flex) cable (8awg). We "love" our pneumatic crimper for 6-12 awg cable.
- The ARA "Test bed" has detected no rf emissions from our turbines!

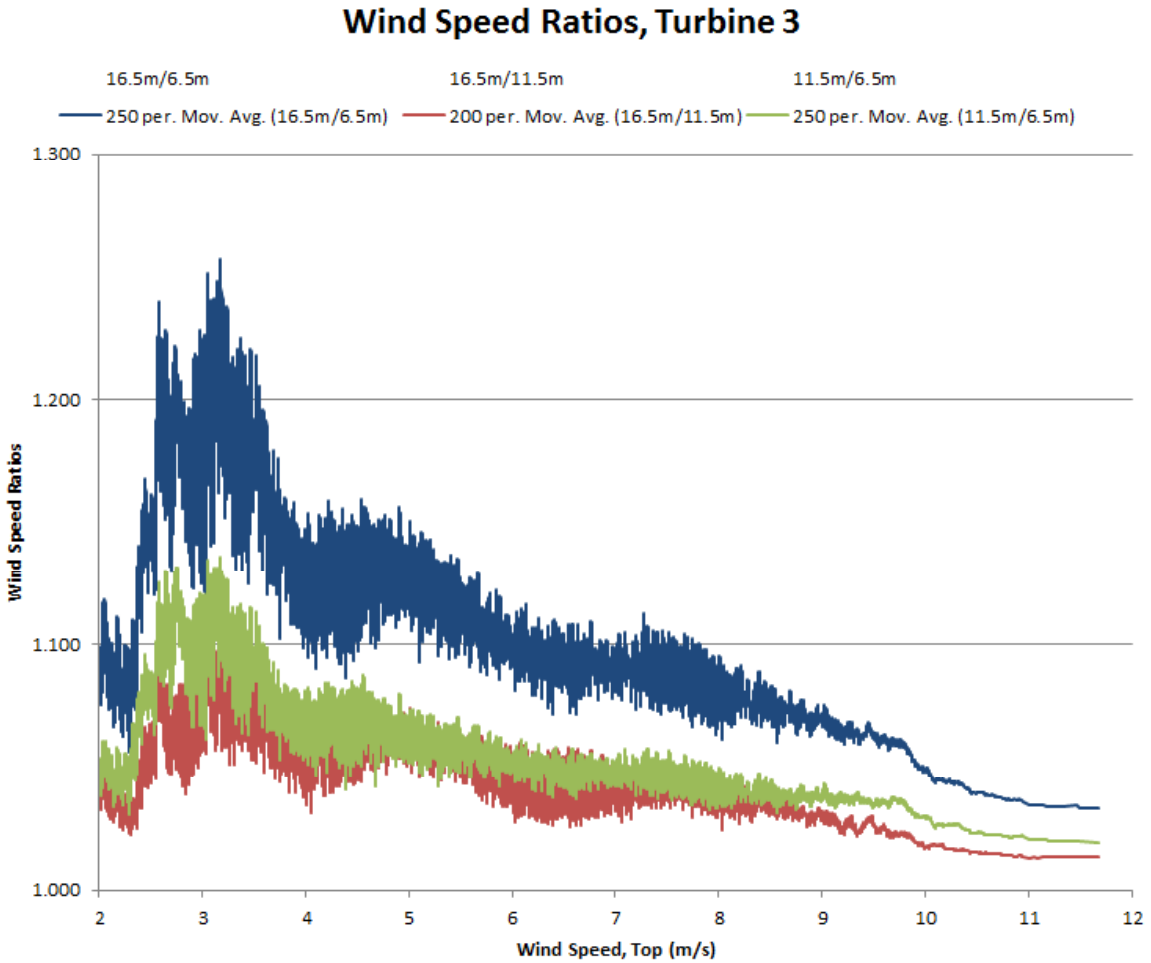
Some Wind Profile Results

- ARO data and AARP data track (offset in the chart.)



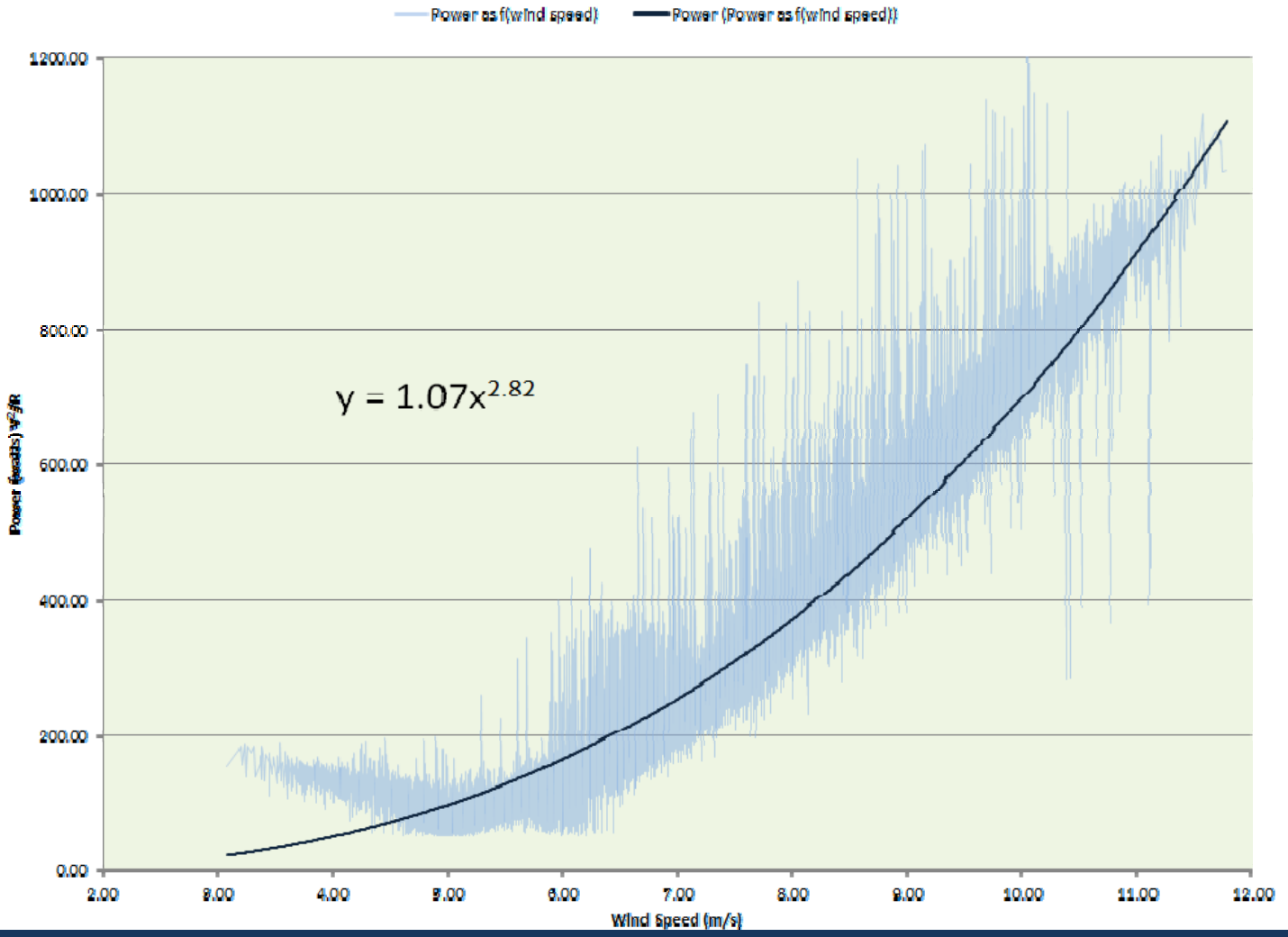
Height Ratio Data

- Consistent with ARO data.
- Will be used for surface roughness estimates.



Power Profile Measurement

- Example Power profile from Hummer on a 50’ tower.

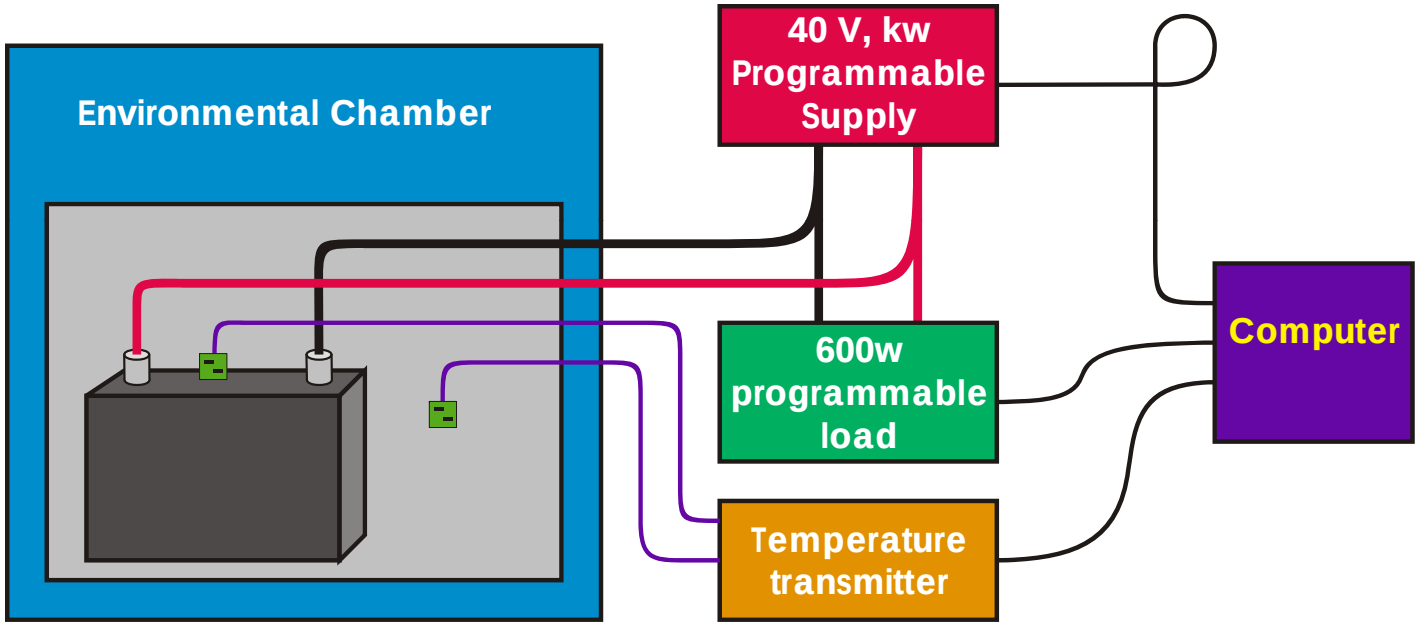


Major Disappointments

- Optical Fiber from Turbine 3 damaged – no real-time data. Data will not be available until spring.
- Turbine 2 produced loud resonance sounds and in a couple weeks, tail fell off. (Needed more deployment time/people, mechanism for locking blind threads in the field.)
- Turbines 1 and 3 needed optimization of thresholds for switching to get good power data. (Ran out of time.)
- Infrastructure problems
  - Communication glitches with RPSC
  - Unavailability of connection to #3
  - Security of IceCube security.

SLA Battery Studies

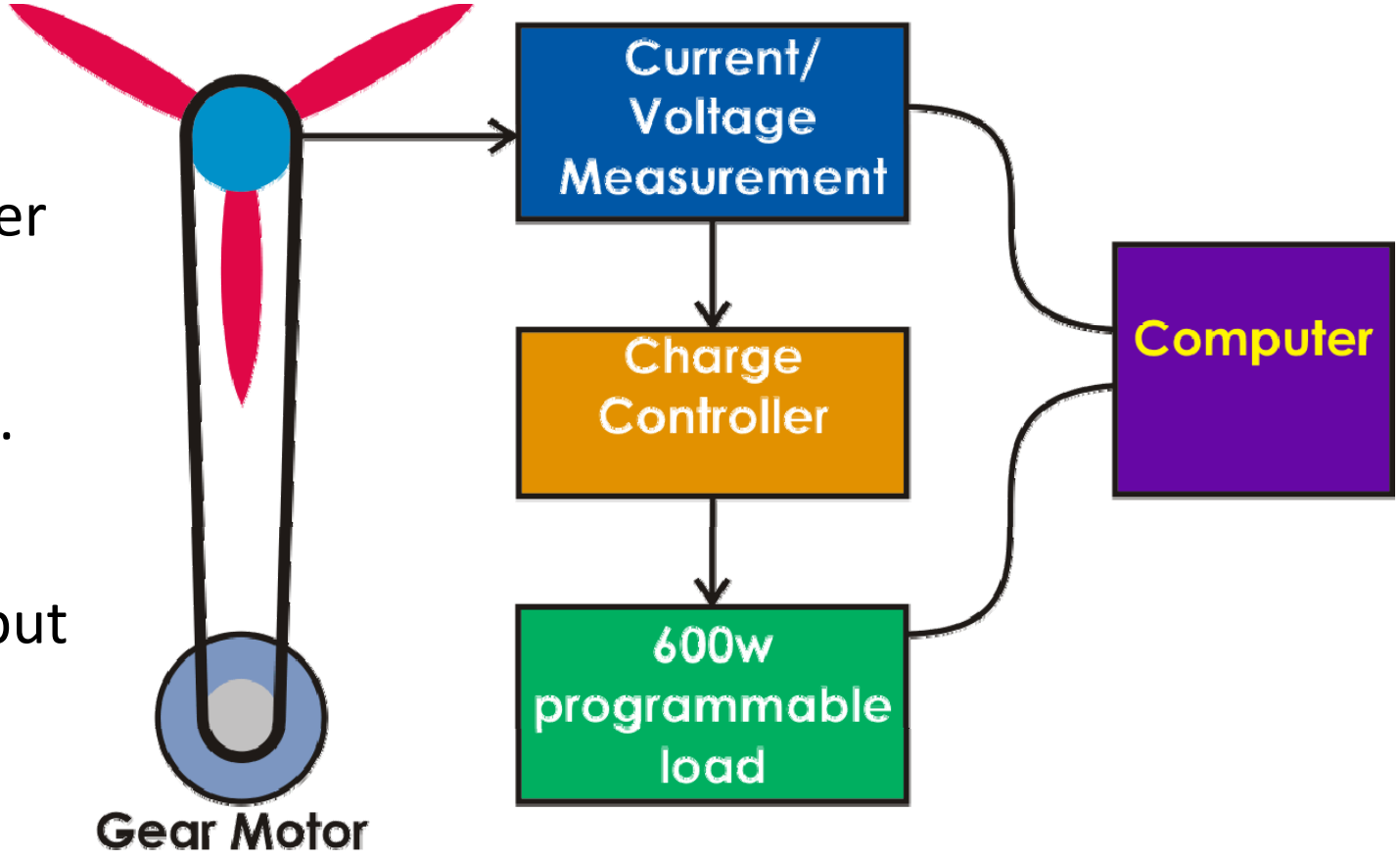
- Get a better handle on battery performance at cold.



- Determine how much power must be devoted to warming the box.

Turbine and Charge Controller Studies

- Turbine studies.
- Charge controller studies.
- Some rf studies.
- Need to test methods for input power measurement.
- Test PV integration.



Zigbee mesh studies

- Set up mesh in an isolated area.
- Test self-healing network capabilities.
- Determine lowest power for normal operation.
- Find the “USAP Frequency Manager” to decide if we can use 900 MHz or 2.4GHz.

AARP System Personnel

- Rob Young, Design Engineer, Instrumentation Design Lab, University of Kansas
- Andrew Wendorff, KU student
- Dan Kennedy, KU student
- Alan Hase, machinist, KU Physics
- Dave Besson, University of Kansas Physics