Current Plans for the ARA Autonomous Renewable Power (AARP) Station
27 May, 2010

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* Goals
* Turbine Selection
* Sites
* APS Block Diagram
* Modeling
* Siting Plans
* Monitoring Comms
* System Health Monitor
* Static

Component documentation is gathered at
http://www.idl.ku.edu/ARA/AARPS/Documents

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ARA AARPS Goals

1. 300W dc power (total) to be provided to 3 ARA clusters, communications, and monitoring systems.
2. Live time >97%.
3. Deployment by 2 persons.
4. Serviceable by 2 persons.
5. Extensible by incremental addition of components.
6. Service interval >= 1year.
7. Replacement interval >= 10 years.

2011 ARA AARPS Goals

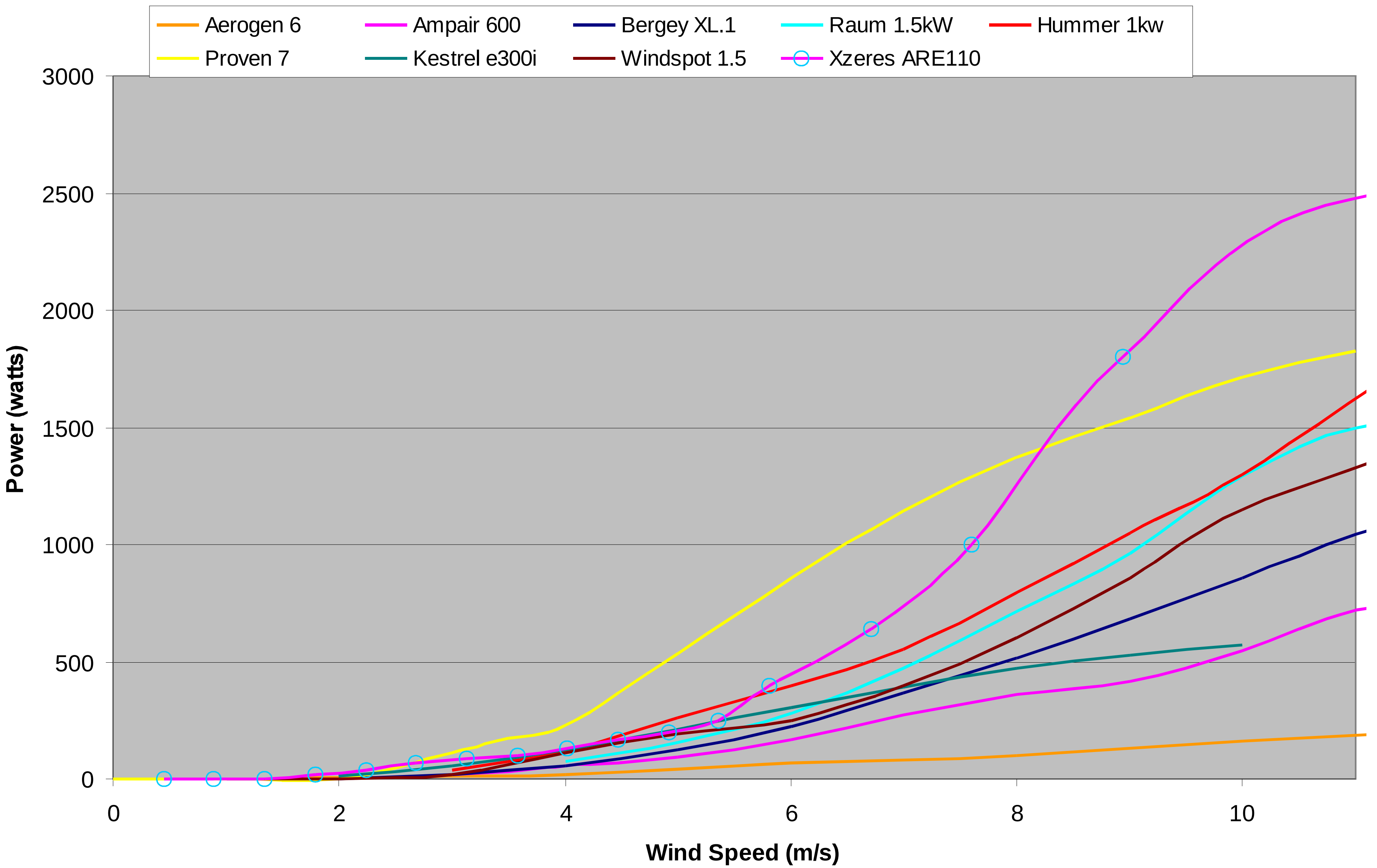
1. Test performance of 3 different turbines at Pole: robustness, power curve, deployment.
2. Determine wind profile (alpha) in order to optimize tower height.
3. Test performance of a Photovoltaic (PV) panel.
4. Attempt to quantify parameters related to performance: heat losses, temperatures, wind speeds and directions, etc.
5. Develop better sensing techniques for monitoring power inputs and outputs.
6. Compare ultrasonic anemometers with the standard RM Young propeller anemometer.
7. Develop an equipment box with adequate thermal insulation and emi shielding.
8. Improve understanding of the effects and possible mitigation of static buildup.
9. Develop deployment procedures.

Comparative figures – we will test 3

Turbine	Cut-in (m/s)	Power (@8m/s) Manufacturer's data	Weight (kg)	Diam (m)	Turbine Cost	Comments
Aerogen 6 (UK)		100	12.6	1.2	$1950	* Successful on plateau but too small.
Ampair 600 (UK)	3.0	360	16	1.7	$2900	* Successful on margin; probably too small.
Bergey XL.1 (US --Norman, OK)		515	37	2.5	$2790	* Used successfully on the margin.
Raum 1.5 (Canada – Sask)	3.3	713	39	2.9	$3600	* Manufacturer reports successful Arctic deployments
Kestrel e300i (South Africa)	2.5	471	75	3		* Recommended for robustness; many in U.S.
Windspot 1.5 (Spain)		650	135	3.3		* Looks impressive, but heavy. Many in Europe.
Hummer 1kw (China)	3	760	15	3.1		* Looks robust; many in China.
Xzeres 2.5kw (US)	2.5	1400	143	3.6		* Based on AWP; under test by NREL at Pole in 2010.
Proven 7 (UK)	2.5	1600	190	3.5	$25,000	* Recommended, but too big?

Manufacturers' Power Curves

Notes:
1) Probably all at sea level.
2) Large "grain of salt" required,



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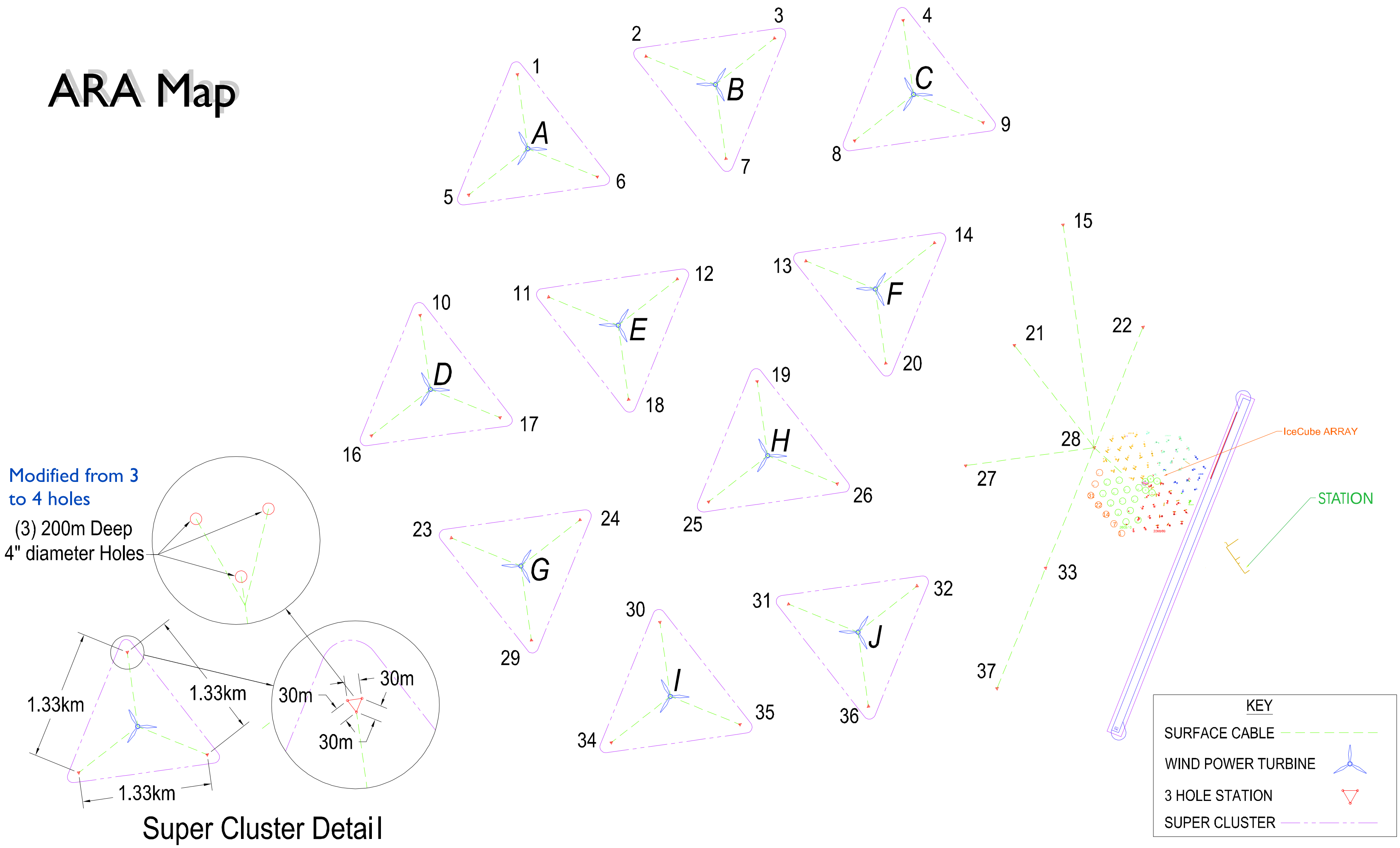
ARA Map



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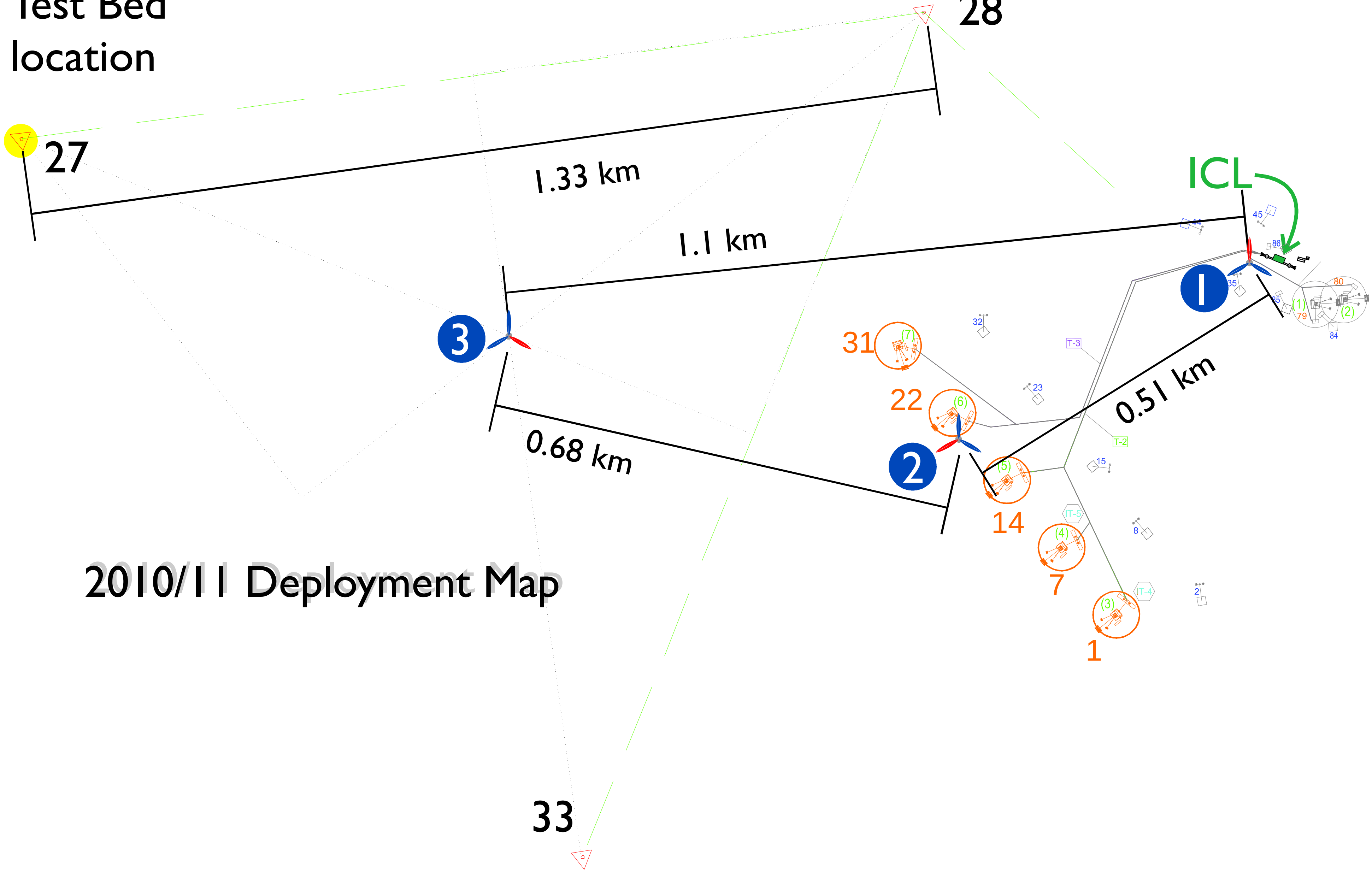
Test Bed location



2010/11 Deployment Map

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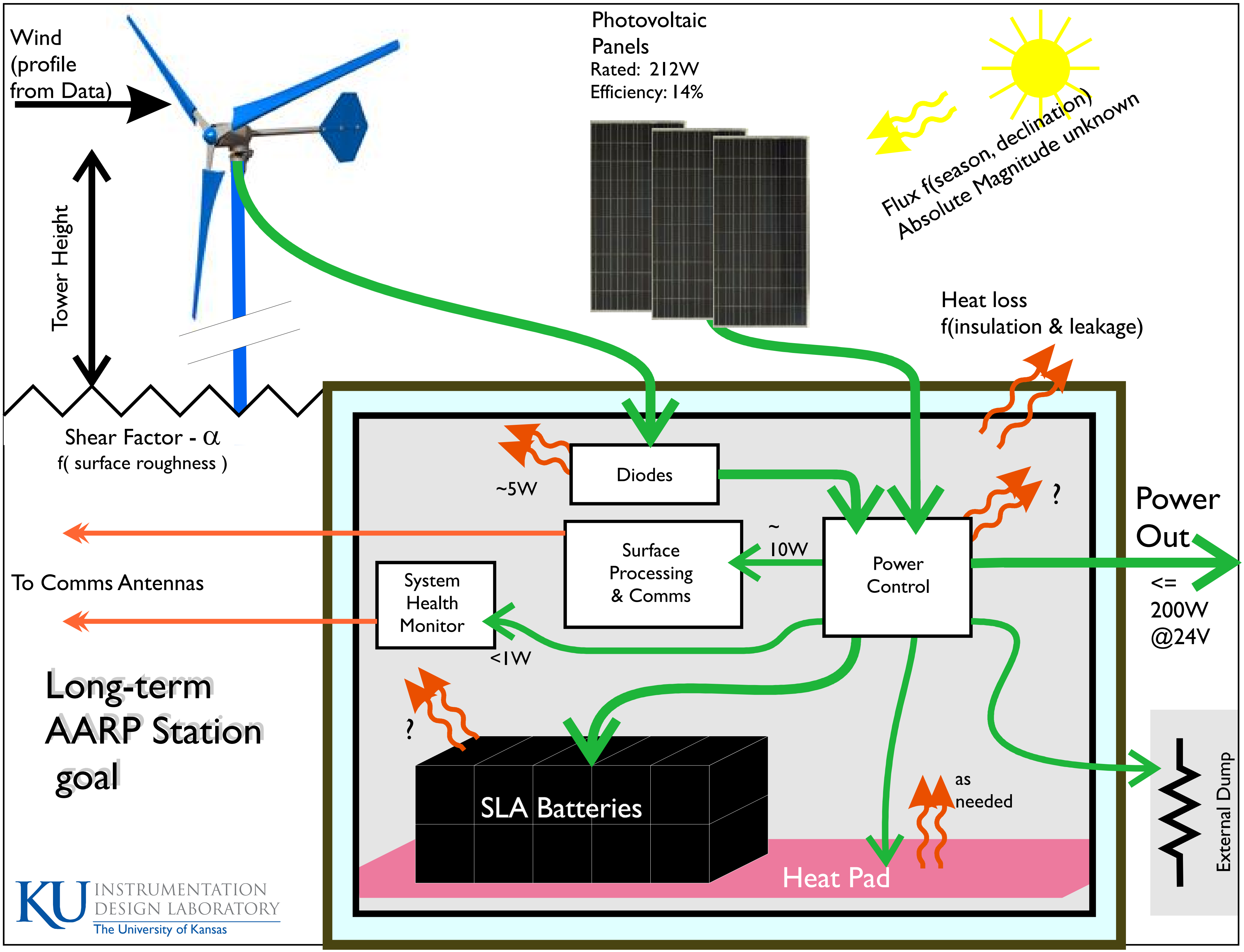
Wind
(profile
from Data)
Tower Height
Shear Factor - α
f(surface roughness)
Photovoltaic
Panels
Rated: 212W
Efficiency: 14%
Flux f(season, declination)
Absolute Magnitude unknown
Heat loss
f(insulation & leakage)
Diodes
~5W
Surface
Processing
& Comms
~
10W
Power
Control
?
Power
Out
<=
200W
@24V
System
Health
Monitor
<1W
To Comms Antennas
?
SLA Batteries
as
needed
Heat Pad
External Dump
Long-term
AARP Station
goal
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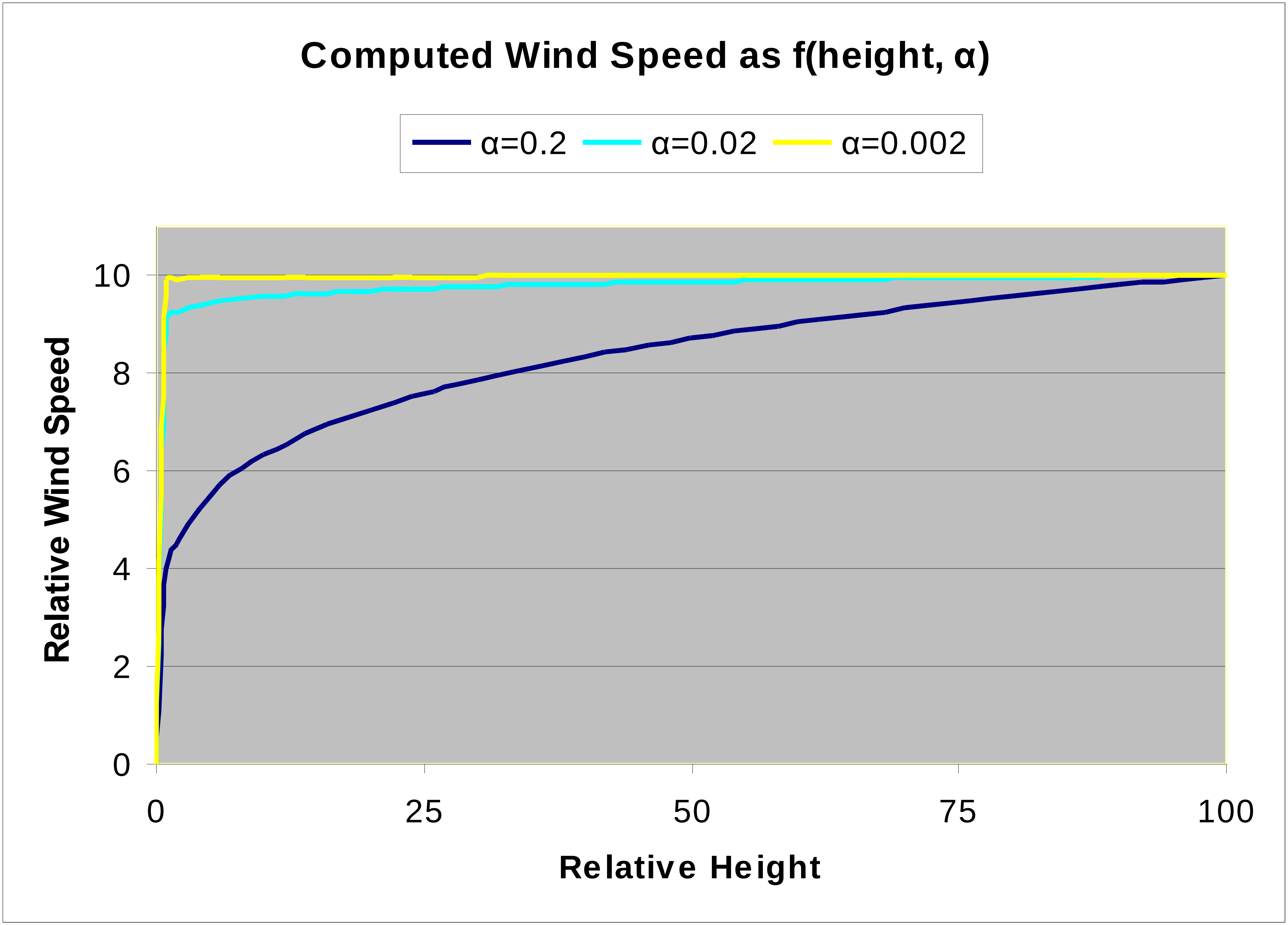
Inputs for System Model to determine Live Time / Battery Requirements

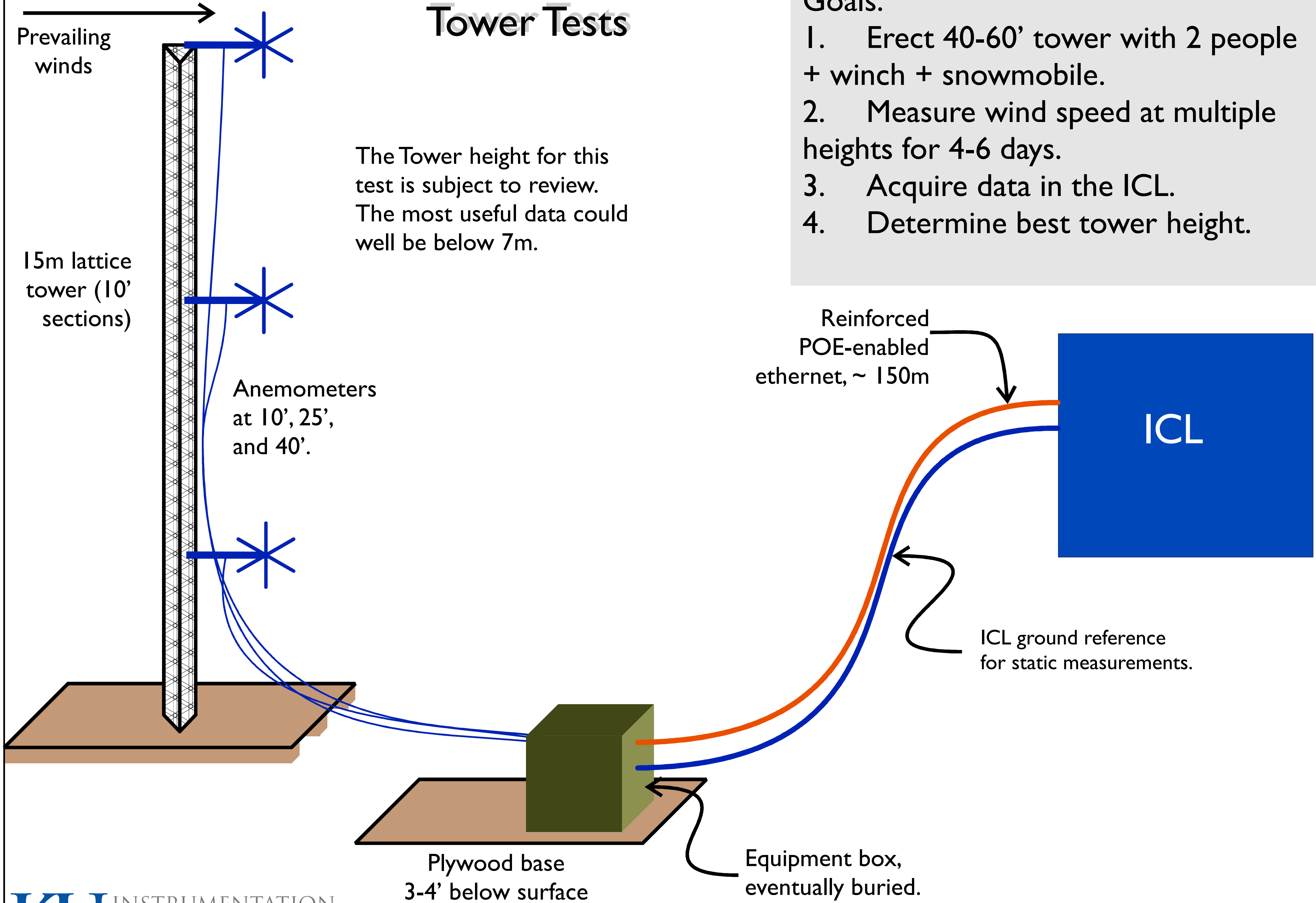
Power Curves	Taken from manufacturers; must be verified.
Wind profiles	Acquired from AWS, Met office; will be measured in coming season.
Tower Height	$S/S_0 = (H/H_0)^\alpha$ – α estimated at 0.002; will measure 01/2011.
Photovoltaic output	Depends on solar flux. Output to be measured during coming season.
Power Requirements: ARA	Now estimated at 200W.
Power Requirements: SHM & Comms	Estimated at 10W. To be measured.
Power losses in the enclosure (as heat)	TBD
Number of batteries per APS	TBD from this season's testing
Heat losses from the equipment box.	To model from R value and determine from coming season's measurements.


Computed Wind Speed as f(height, α)
α=0.2
α=0.02
α=0.002
Relative Wind Speed
0
2
4
6
8
10
0
25
50
75
100
Relative Height

2010-11 Site 1 Tower Tests

Goals:

1. Erect 40-60' tower with 2 people + winch + snowmobile.
2. Measure wind speed at multiple heights for 4-6 days.
3. Acquire data in the ICL.
4. Determine best tower height.



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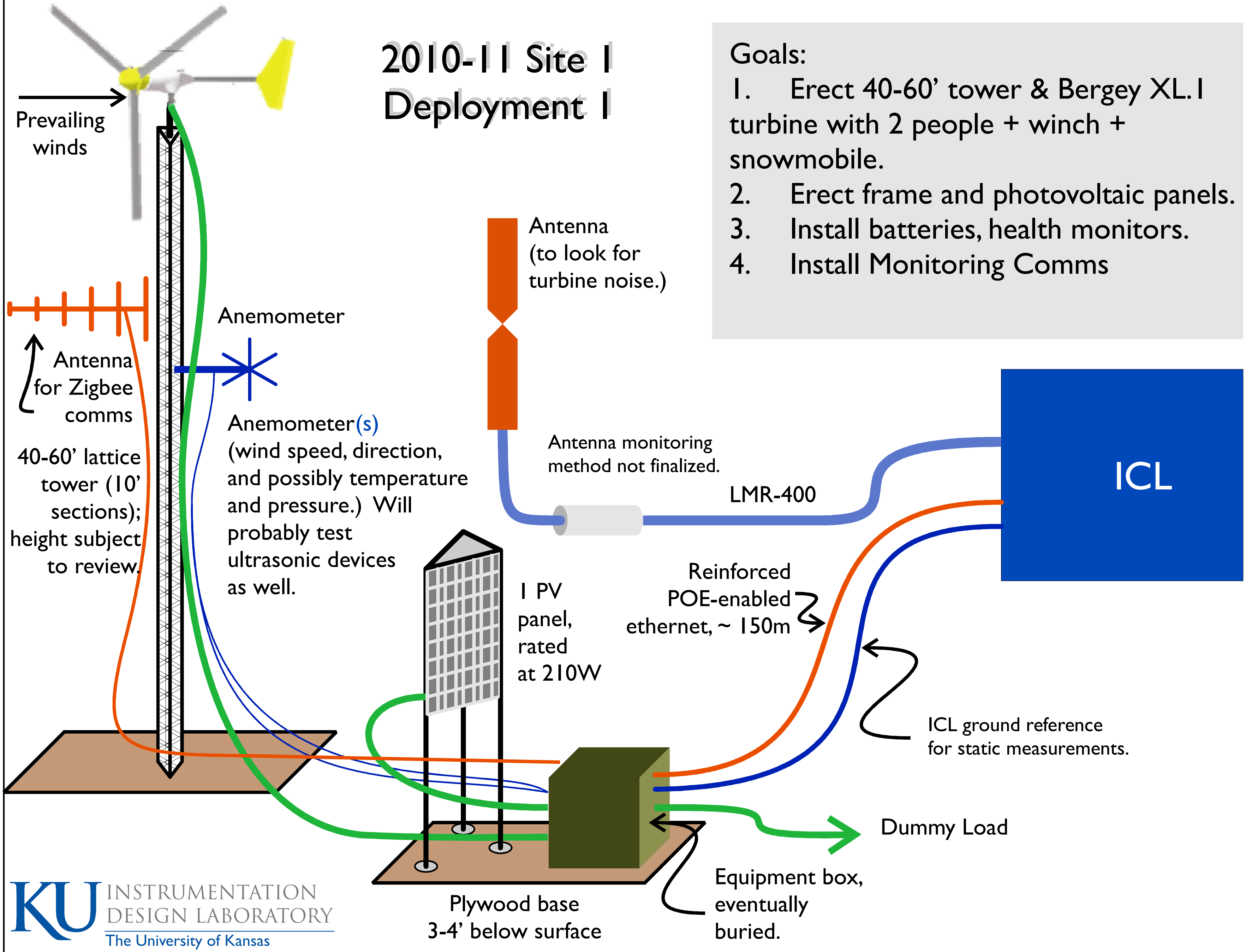
2010-11 Site 1 Deployment 1

Goals:

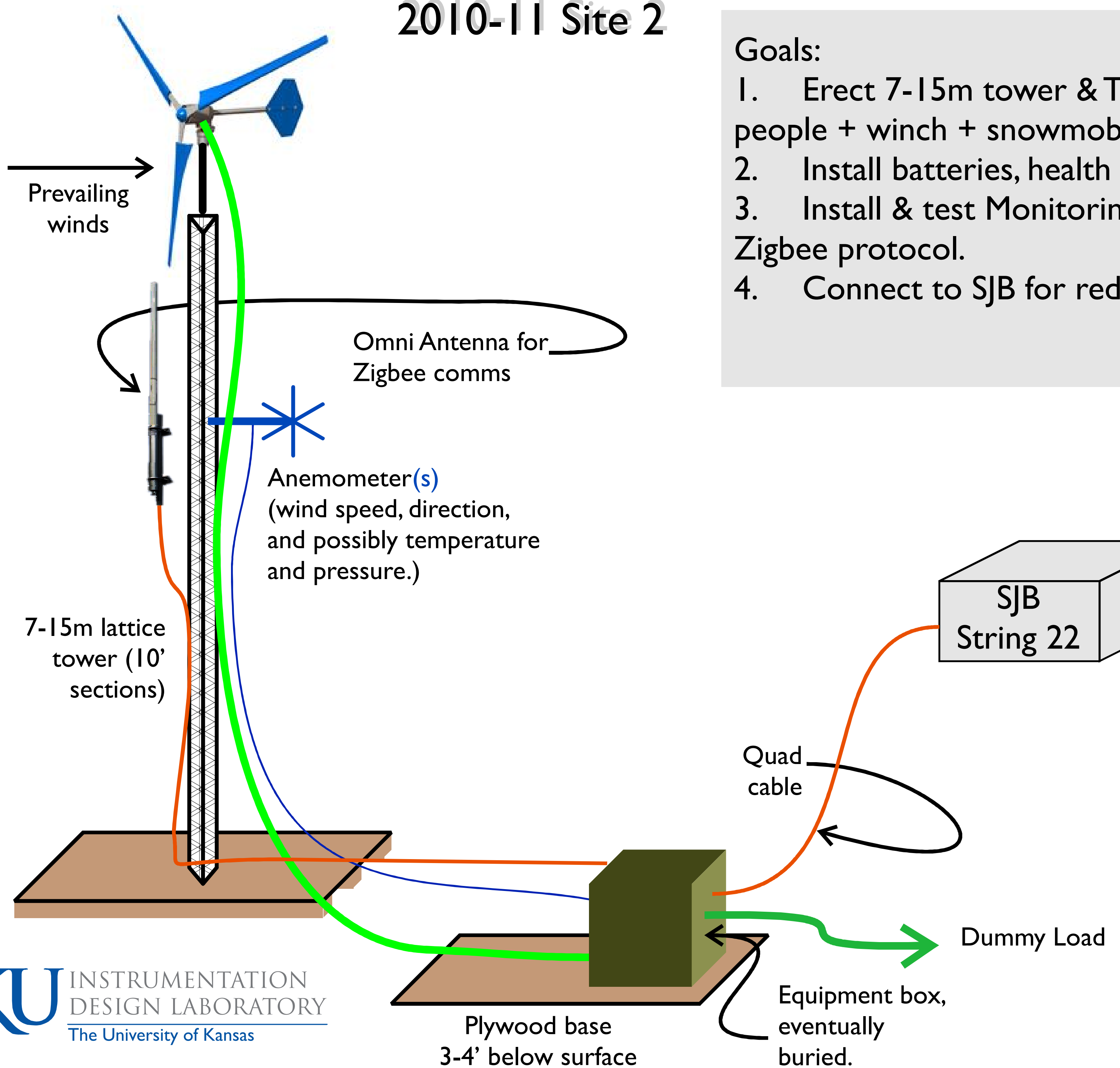
1. Erect 40-60’ tower & Bergey XL.1 turbine with 2 people + winch + snowmobile.
2. Erect frame and photovoltaic panels.
3. Install batteries, health monitors.
4. Install Monitoring Comms



2010-11 Site 2

Goals:

1. Erect 7-15m tower & Turbine 2 with 2 people + winch + snowmobile.
2. Install batteries, health monitors.
3. Install & test Monitoring Comms via Zigbee protocol.
4. Connect to SJB for redundant comms.



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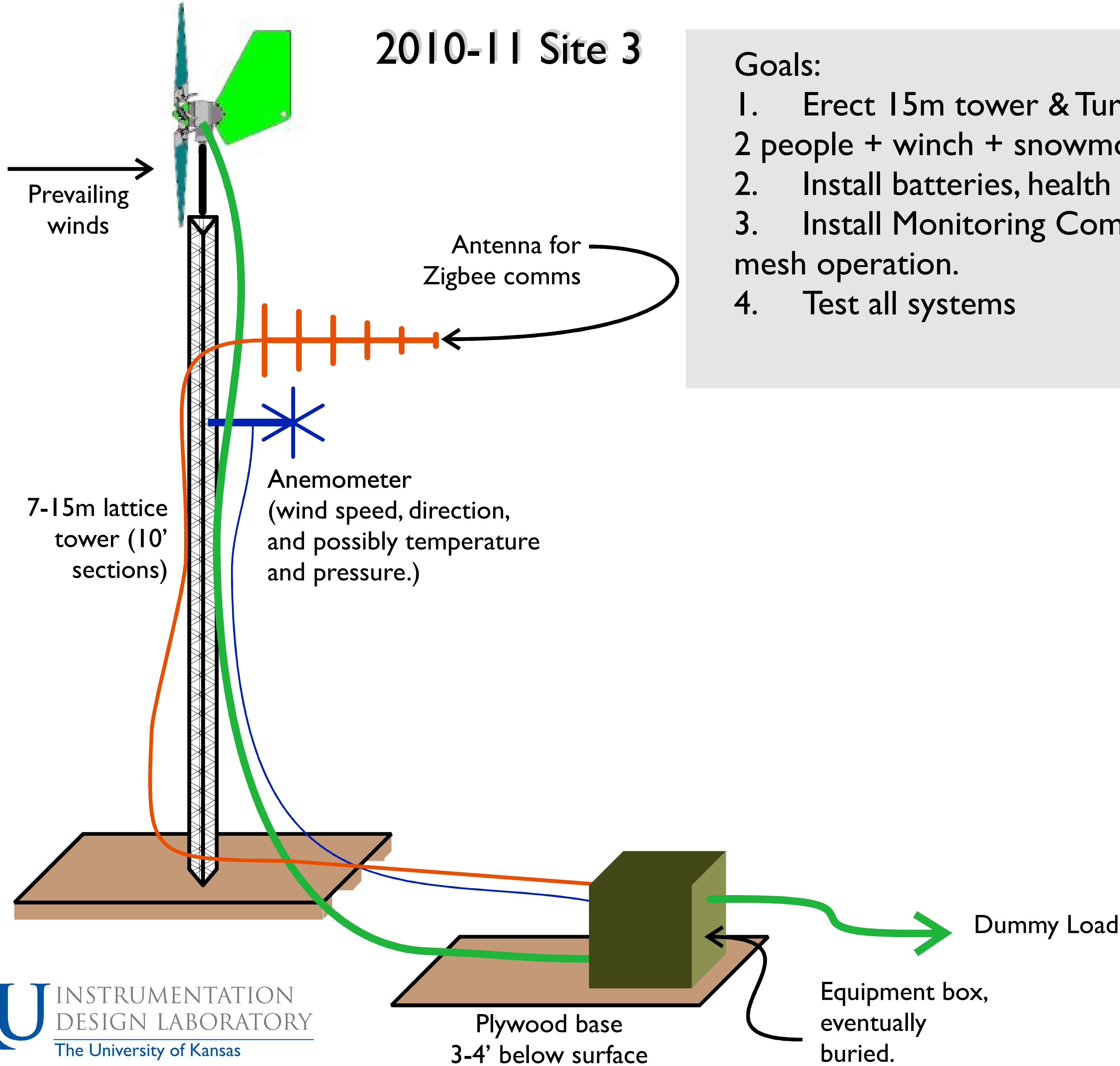
2010-11 Site 3

Goals:

1. Erect 15m tower & Turbine 3 with 2 people + winch + snowmobile.
2. Install batteries, health monitor.
3. Install Monitoring Comms; test mesh operation.
4. Test all systems



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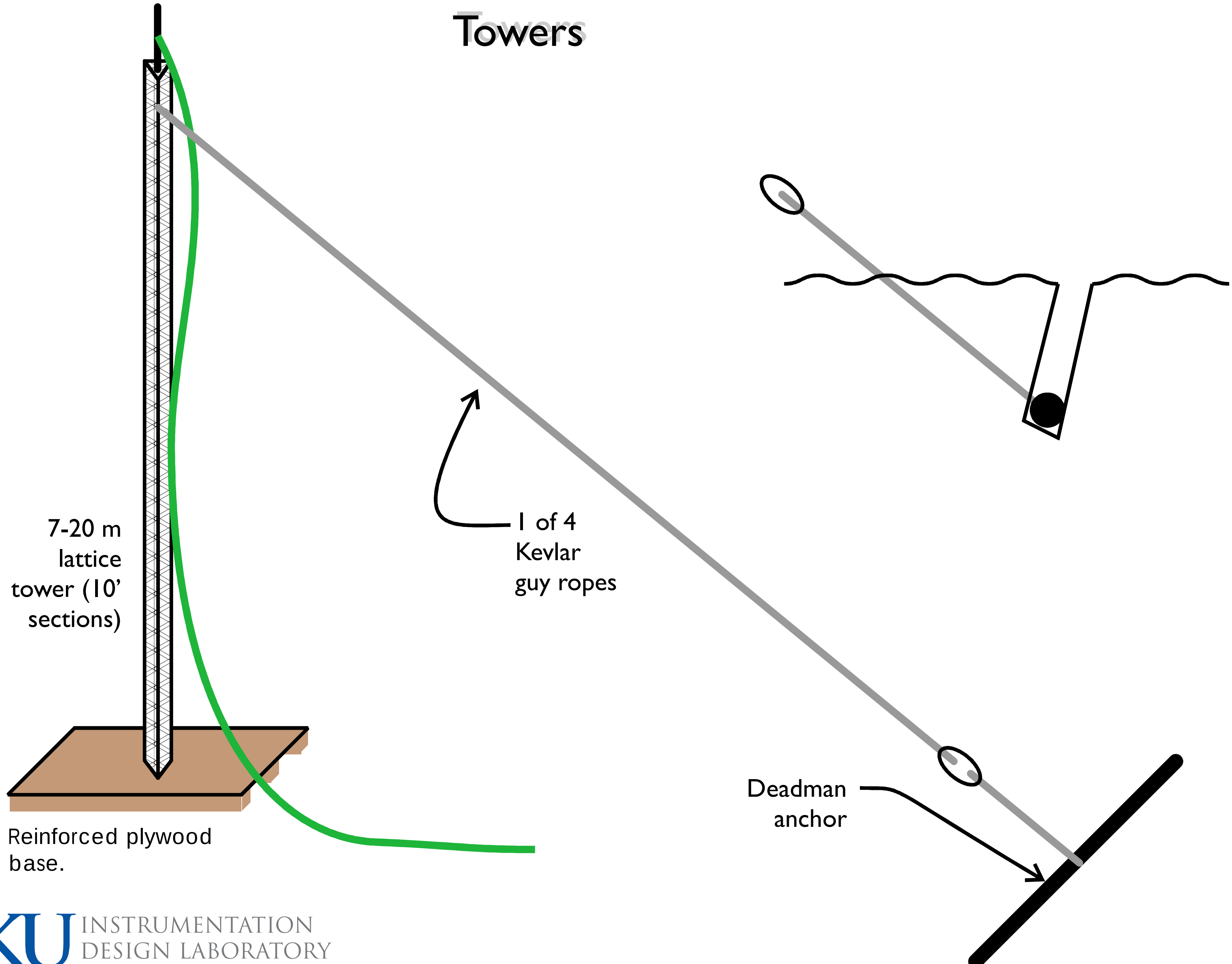
Towers



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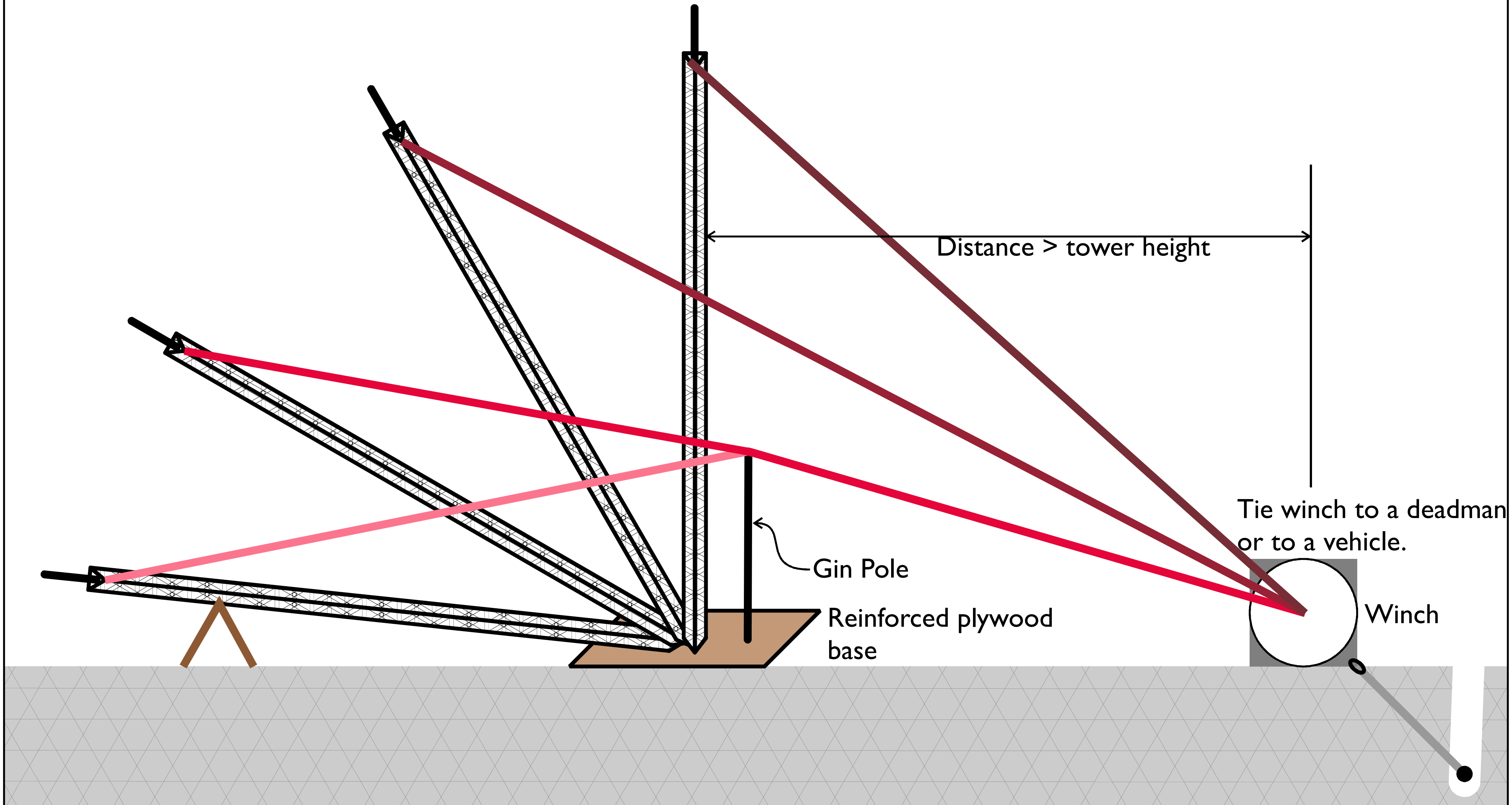
Tower installation

Depth and size of deadman anchor TBD
Anchor for base TBD
Hinged tower mount supplied with tower (includes Gin Pole)



Procedures for Raum lattice tower install:
http://www.idl.ku.edu/ara/APS/Documents/WindGen/Raum/Raum_1.4kW_Installation_Manual.pdf
For Raum monopole:
http://www.idl.ku.edu/ara/APS/Documents/WindGen/Raum/Raum_15m_Tower_Installation_Manual_2009.pdf
Procedures for a Bergey tower:
http://www.idl.ku.edu/ara/APS/Documents/WindGen/Bergey/XL1.Tilt.IM.4.pdf

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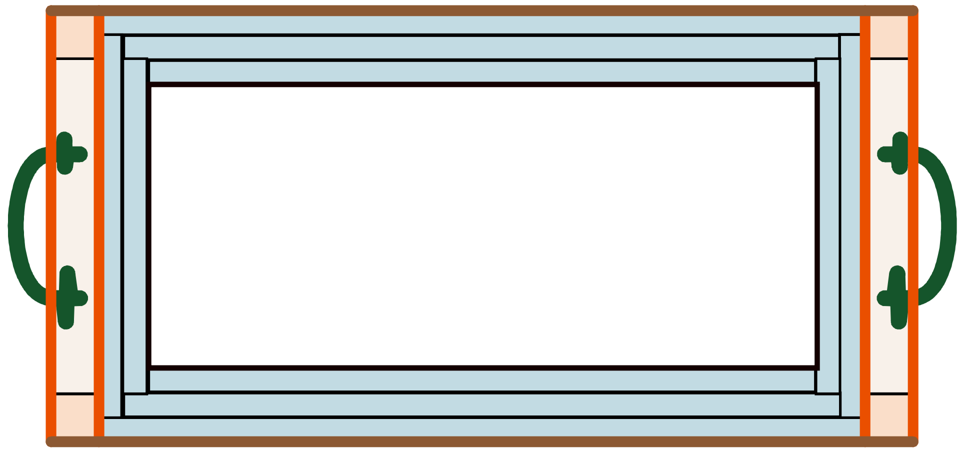
Equipment Box

Hardigg Mobile Master 24

OR

Plywood box, sized according to needs.



For either option, the box will be carefully insulated, with Nanopore Vacuum Insulation Panels (R=8) or Dow Blue Board (R=6.5) or Polyisocyanurate (R=7-8).

(R is specified for 1")

All corners sealed, inside and outside of the insulation.
Masonite inside the insulation.
Full insulation all 6 side with a gasket on the lid and multiple clips. All penetrations in the same area. Penetrations use gaskets.
EMI sealed.

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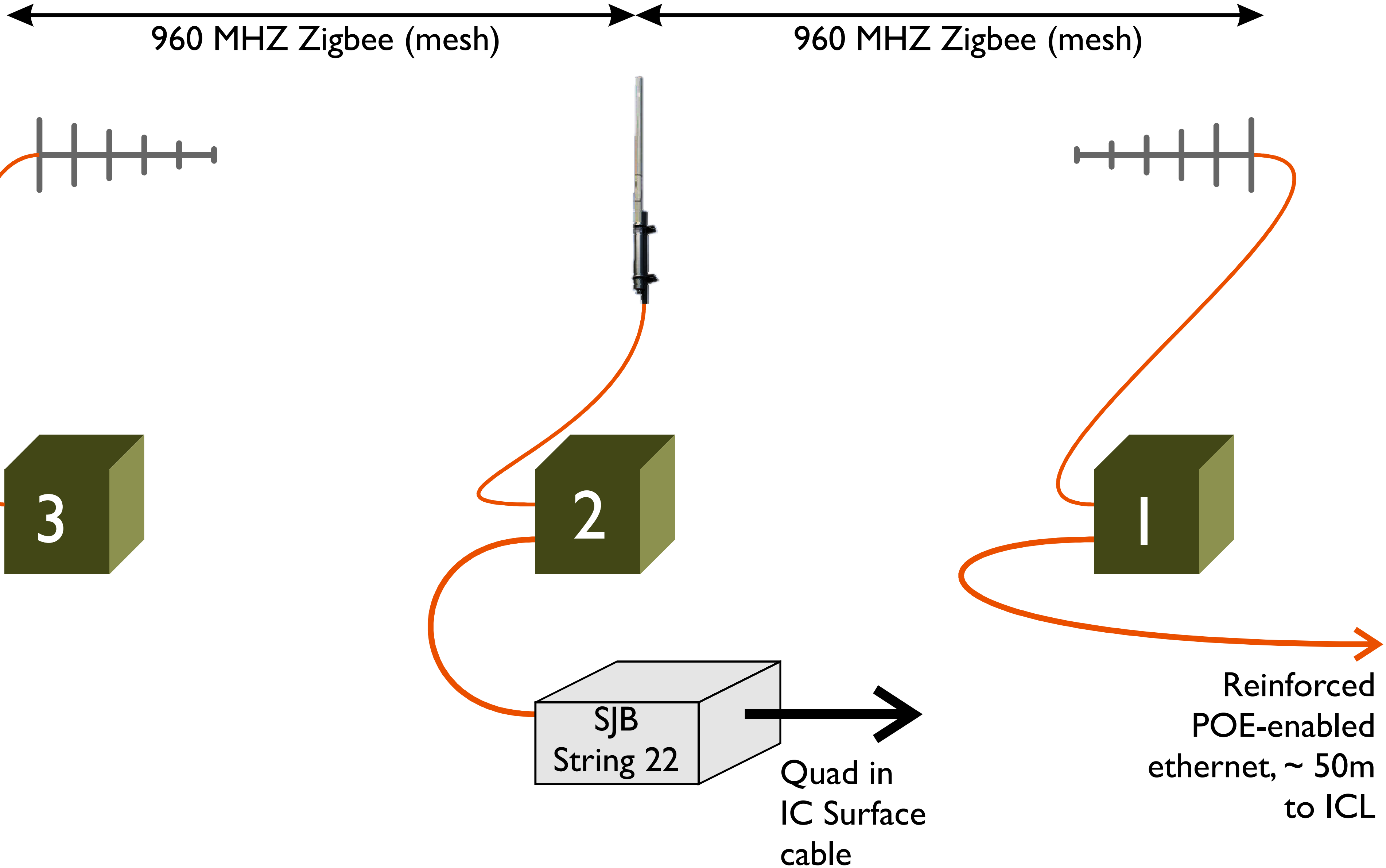
Comms Summary



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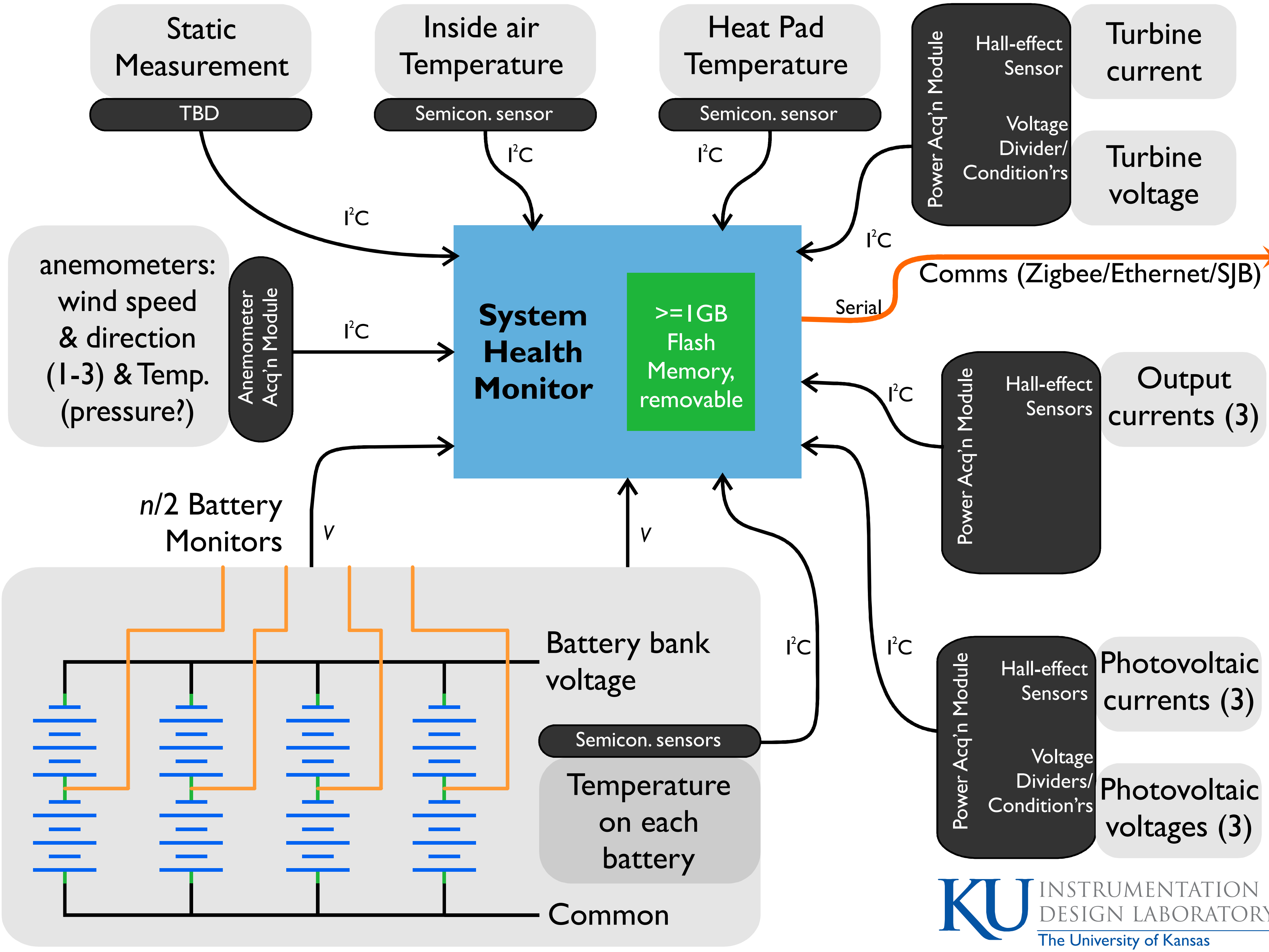
System Health Monitor



Static

Information about static (much is obvious).

Note that nearly every reference opens by saying that the phenomena are not well understood.

* Wind-related noise is observed at AURA DRMs at *both* 250m and 1400m. The source remains unknown.

* *Many* anecdotal Polar stories are told about static and arcing; most installations avoid damage and interference by maintaining a robust *common*.

* A source of static build-up on structures is likely the triboelectric effect of snow/ice particles impacting other materials. This is observed in:

aircraft: http://www.smartcockpit.com/data/pdfs/flightops/meteorology/Precipitation_Static.pdf https://acc.dau.mil/CommunityBrowser.aspx?id=148961

skis: http://www.dominatorwax.com/snowfriction.html

and electronic communication in snowstorms.

* There is also sizable electrostatic buildup in blowing snow. This could be the source of the observed noise. See http://www.idl.ku.edu/ara/APS/Documents/ESD/snow-electrostatic.pdf

* *If* the noise arises from ESD, it would probably come from structures. Normal methods of mitigation revolve around good grounding (unavailable at Pole.) It would also be reasonable to expect that changing the contact material would help (see the triboelectric series: http://amasci.com/emotor/tribo.html). A coating could help.

* Aircraft mitigate by making sure all conductive structural components share a robust common and then bleed off static through pointed structures on the wings. Their biggest concern is ESD between different components of the plane.

* Conclusions:

1) We have not found a way to measure or reduce static on structures in the absence of a ground reference. Static on structures *might* be mitigated with a coating. However, we are not set up to apply coatings or to run control experiments.

2) We expect that the noise experienced currently arises from the surface (blowing snow) and is unrelated to a turbine, but we want to see if the turbines add to that.

3) Work is underway at Nebraska to devise a way to measure static buildup.

Status

* We are nearly prepared to order turbines. The visit to the AWEA (American Wind Energy Association) exposition 24.05.10 added a few things to check.

* Tower selection is not complete. The heights are likely to be modified downward. Some interesting alternatives have been provided

* We are consulting about the base for the tower and securing the guy wires. Jeff Cherwinka has provided some insight from IC experience. Advice will be welcome.

* See previous page about ESD. We do not have a plan to mitigate possible ESD this season.

* The Sensor boards for measuring voltage and currents from turbines and PVs are in design, and the sensor board for transmitting wind speed and direction are beginning to be designed.

* Some testing has been done with the low-power/low-speed comms. We have equipment in house Some of the monitoring equipment is complete.

* By the end of the month, we will have ordered most components.

* After receiving the turbines we will need to change out most bearings and grease. (Raum will do theirs for us.)

* By mid July, anechoic chamber tests will be completed on the turbines, and we will have tested the erection of a tower.