Power Options
&
Alternatives

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Wind Turbine Performance Modeling

It works! Modeled results are within **1.2%** of the output of the output of a turbine at the South Pole.

Raytheon Wind Turbine: ARE110-HV (2.5kW turbine) on a twelve meter tower.

April only month with no turbine problems

Logs from UT.. April 241.5 kWh

Model Predictions 244.19 kWh

Note difference explainable as we don't know what time the UT's made their rounds.

How Does The Model Work?

RPSC Weather Data

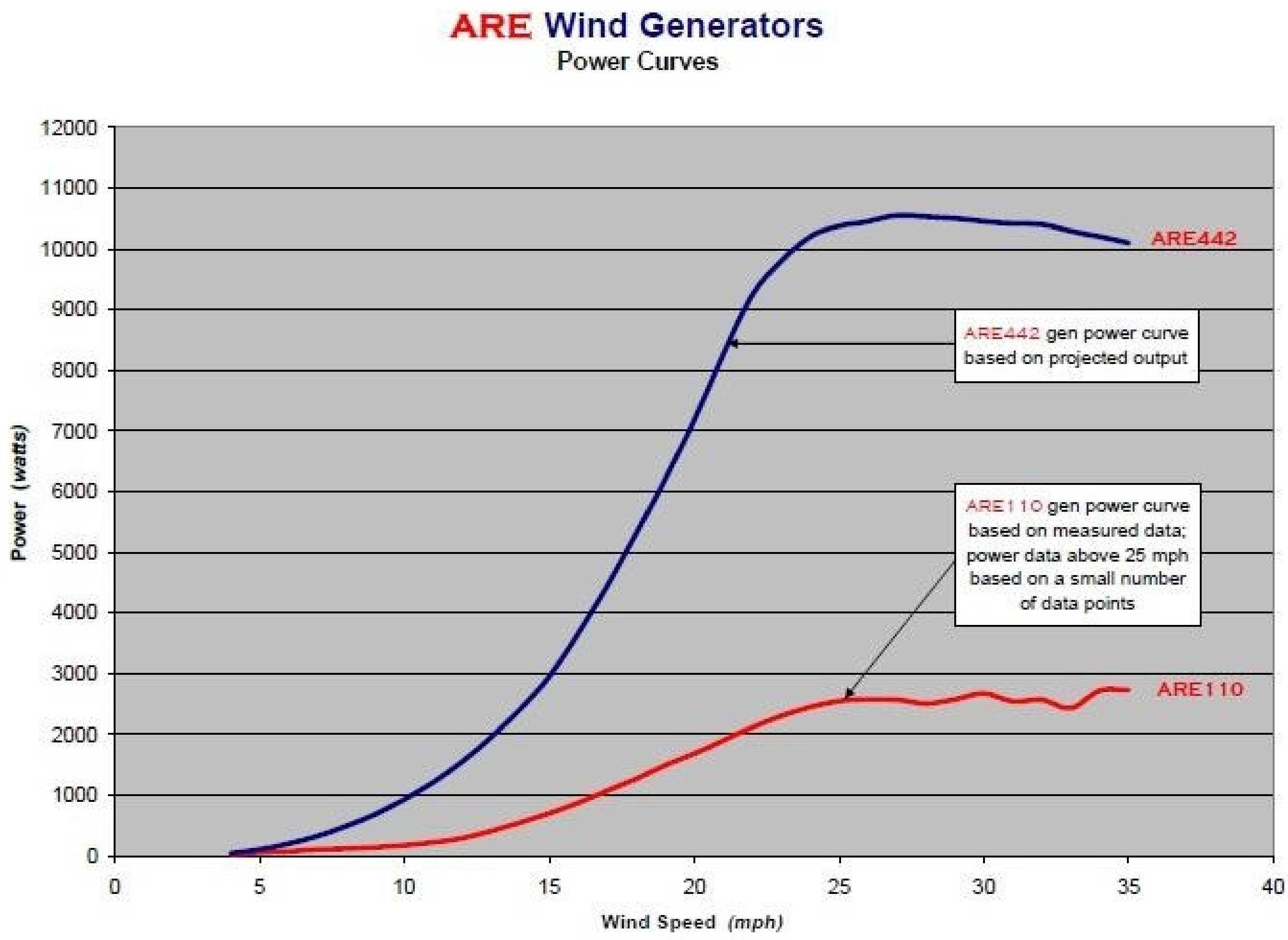
Raytheon provides weather data with one minute samples of wind speed, direction, temperature and pressure. All wind speed and direction measurements where taken at 10 meters.

Poor Quality

One must correct for poor data quality. Over the course of April of this year they are actually missing 3 days worth of samples. Luckily these samples are spread very uniformly over the month so missing samples are assumed to be identical to the sample before them.

How does the model work?

Power Curves:



Is defined for pressure at MSL with standard pressure and temperature.
A curve was fit to this power curve.

How does the model work?

Derating for altitude:

Wind turbines: fundamentals, technologies, application, economics
Page 509, section 14.4.2 - Air Density

p = absolute pressure - > kPa
R = specific gas constant for dry air (287.05 J/(kg*K))
T = absolute temp (deg K)
NIST standard temperature and pressure:
20 deg C, 101.325 kPa
Rho = 101325. / (287.05 * (20+273.15)) = 1.2041183

wattsAtAltitude = wattsAtSeaLevel * (densityAtAltitude / densityAtSealevel)

How does the model work?

Modeling For Tower Height:

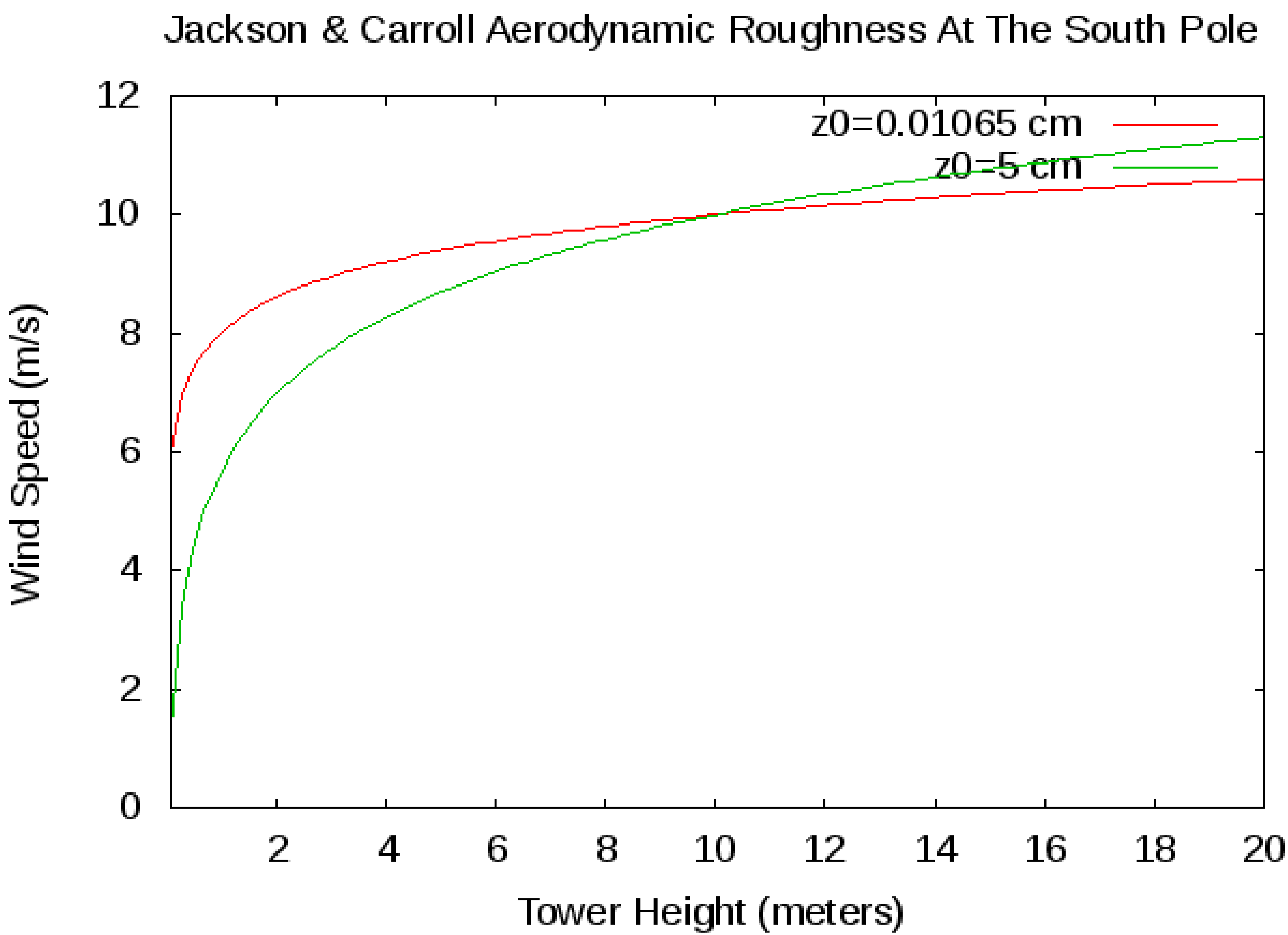
Raytheon's wind turbine is on a twelve meter tower. The Meteorological Office only measures wind speed and direction at ten meters off the surface.

Aerodynamic roughness as a function of wind direction over asymmetric surface elements
Boundary-layer Meteorology, B.S. Jackson, J.J. Carroll 1978
Available at: http://www.idl.ku.edu/ara/AARPS/Documents/Structural/Jackson&Carroll.pdf

The above reference measured the aerodynamic roughness as a function of wind direction at the South Pole during the winter of 1975. Wind direction matters because of sastrugi structure!

Does Wind Direction Really Matter?

The extremes: z0=0.1065cm (10-15 degrees) z0=5cm (60-100 degrees)
Remember, power in wind goes by the cube of the wind speed.



How does the model work?

Summary of results:

April only month with no turbine problems

Logs from UT.. April 241.5 kWh

Model Predictions 244.19 kWh

The difference is explainable as we don't know what time the UT's made their rounds.

Model source code and associated data is available at
http://www.icecube.wisc.edu/~mnewcomb/hawaii

NOTE: Current power budget calls for a draw of 365 watts for 24 hours for 30 days = 262.8 kWh, 2.5kW turbine will not produce enough power for 100% uptime for this month.

Applying the model to a new turbine:

Bergey XL1 (kWh per month per year) on a 20 meter tower

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
2005	57.8	195.1	233.2	**299.4**	268.8	**284.4**	180.5	**317.3**	**324.9**	**283.3**	183.5	201.8
2006		94.0		**306.4**	**364.9**	248.0	223.1	233.8	216.6	186.5	188.2	77.7
2007	131.8	108.4	186.8	196.3	**316.0**	**437.1**	**299.1**	236.4	218.6	270.6	110.8	
2008	79.5	128.2	211.0	198.0	91.8	66.5	186.8	**382.3**	249.0	187.8		
2009	78.2	**259.2**		211.9		**325.2**	224.6	233.4	**303.3**	**271.3**	213.9	71.8

Results:

Bold – sufficient power for 100% uptime

The model estimates at BEST that 40% of April's and 20% of July's would have enough power for 100% uptime. This is is assuming a LARGE 20 meter tower!

Another Option:

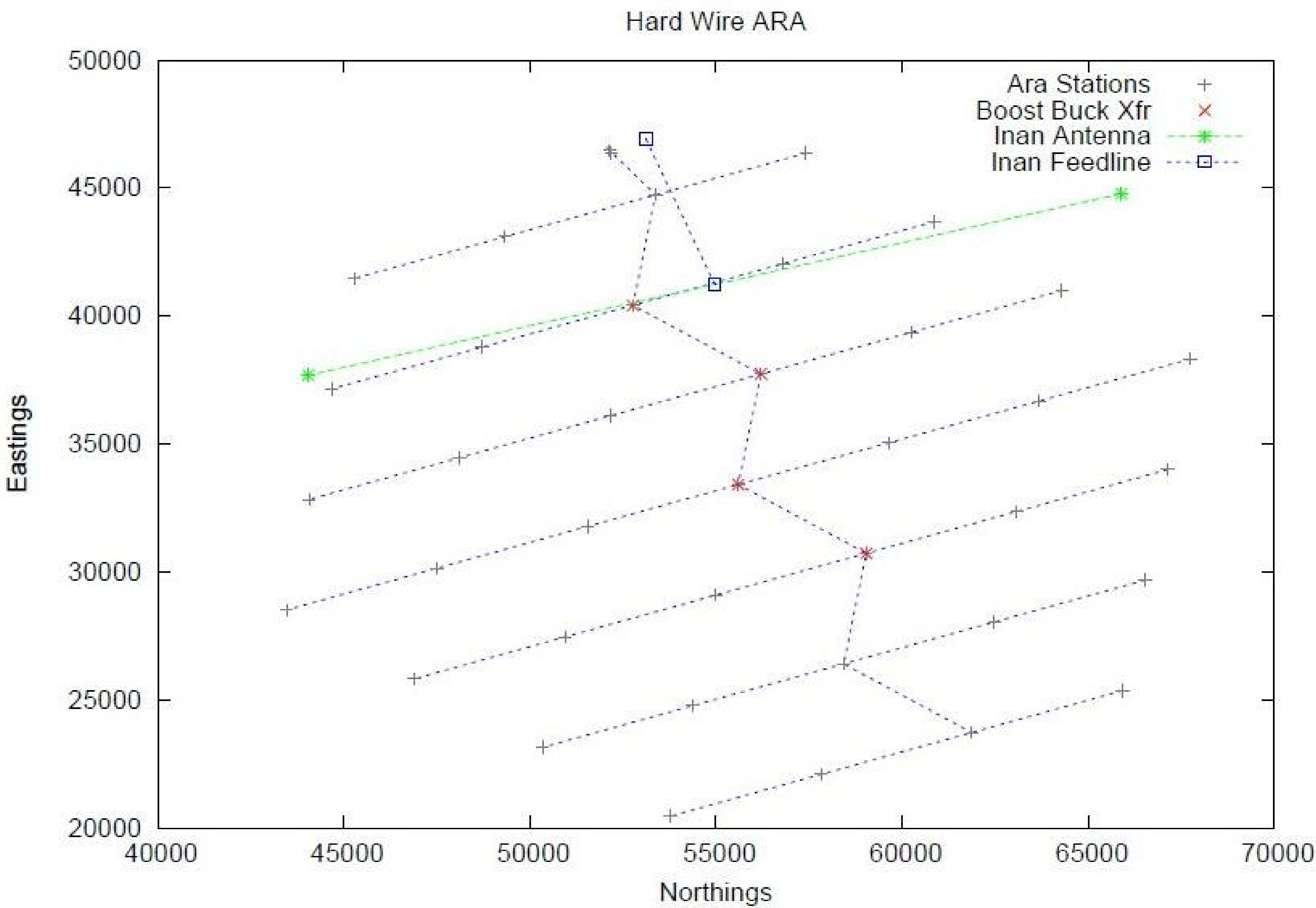
Run power cables to every station!

Mark Thoma's initial design calls for 600 VAC to be sent to each station with a step down transformer to bring the voltage down to 120VAC. Design assumes a 134 watt draw at each station. All cabling to be unshielded direct burial cable. The main feed line will require four buck boost transformers.

Cable installation to NSF required depth (~2 feet as per op-s-346-1) done by furrow plow attached to the back of a Caterpillar tractor. Mark Thoma and Dennis Dueling estimate a 1 to 3 mph trenching speed.

Note: EMI considerations need to be taken into account. What are the requirements?

Estimated material cost: $256K

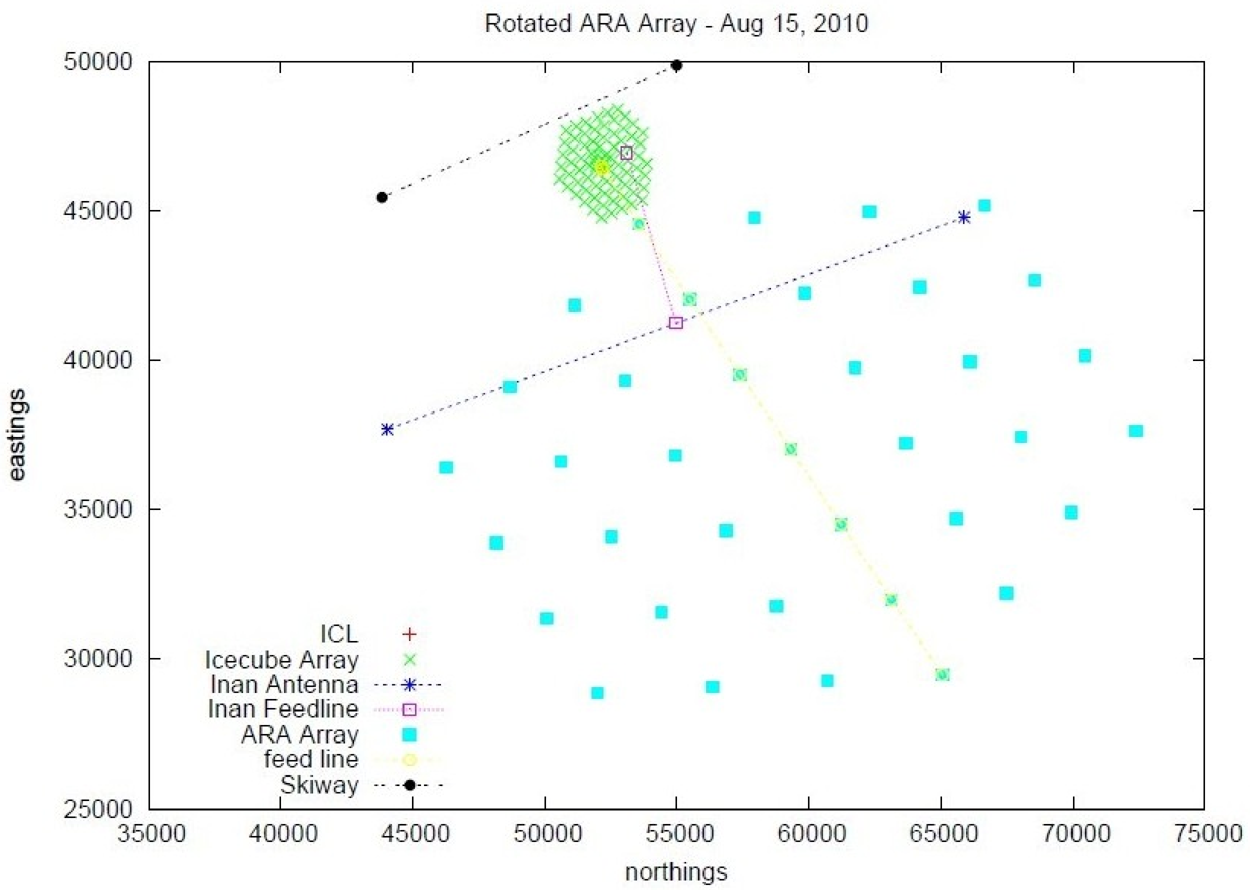


Hard Wire ARA
Ara Stations
Boost Buck Xfr
Inan Antenna
Inan Feedline
Eastings
Northings
50000
45000
40000
35000
30000
25000
20000
40000
45000
50000
55000
60000
65000
70000

A Rotated ARA Array

A slight rotation and translation of the current ARA geometry cuts 3.23 KM of cable from the requirements (reducing costs to $244K) AND moves stations farther away from the INAN antenna.

According to the 2004-2005 NSF as builts we will not have any station interference.



Estimated Tuned Geometry Costs:

					Voltage				End to end drop						
Row	1.33 Km X	Super Clusters	Watts/row	Watts progressive	600 Wire size		Resistance	L of Branch	Voltage drop	% drop	Number of Xfrm * cost	Cost of xfrm	Cost of run	Disconnect	
1	3	3	402	402	0.67	14	5.06	13092.00	44.38	7.40	484	121	13092	500	
1a	3	3	402	402	0.67	14	5.06	13092.00	44.38	7.40	363	121	13092	500	
2	3	3	402	402	0.67	14	5.06	13092.00	44.38	7.40	484	121	13092	500	
2a	3	3	402	402	0.67	14	5.06	13092.00	44.38	7.40	363	121	13092	500	
3	3	3	402	402	0.67	14	5.06	13092.00	44.38	7.40	484	121	13092	500	
3a	3	3	402	402	0.67	14	5.06	13092.00	44.38	7.40	363	121	13092	500	
4	3	3	402	402	0.67	14	5.06	13092.00	44.38	7.40	484	121	13092	500	
4a	3	3	402	402	0.67	14	5.06	13092.00	44.38	7.40	363	121	13092	500	
5	2	2	268	268	0.45	14	5.06	8728.00	19.73	3.29	363	121	8728	500	
5a	2	2	268	268	0.45	14	5.06	8728.00	19.73	3.29	242	121	8728	500	
6	1	1	134	134	0.22	14	5.06	4364.00	4.93	0.82	242	121	4364	500	
6a	1	1	134	134	0.22	14	5.06	4364.00	4.93	0.82	121	121	4364	500	
7	1	1	134	134	0.22	14	5.06	4364.00	4.93	0.82	121	121	4364	500	
							Total length	135284.00			4477		135284	6500	146261

	Home Run KM			ohms/K feet								
	7.98	600 Wire size		Resistance	L to Xfr	Voltage drop	% drop	# of Xfrs	Cost of xfrm	Cost of run	Disconnect	
7	134	0.22	14	5.06	4364	4.93	0.82			4364		
6	536	0.89	14	5.06	4364	19.73	3.29			4364		
5	1206	2.01	14	5.06	4364	44.38	7.40	1	3300	4364	500	
4	2144	3.57	12	3.18	4364	49.59	8.26	1	3300	5629.56	500	
3	3082	5.14	10	2	4364	44.83	7.47	1	3300	7069.68	500	
2	4020	6.70	10	2	4364	58.48	9.75	1	3300	7069.68	500	
1	4958	8.26	6	0.81	4364	29.14	4.86			25223.92		
0	4958	8.26	6	0.81	4364	29.13	4.85			25223.92		
				Total length	34912				13200	83308.76	2000	98508.76
											Total cost	244769.76

AWG	R/K	Cost/foot
14	5.06	1
12	3.18	1.29
10	2	1.62
8	1.26	4.47
6	0.81	5.78
4	0.51	7.62

Hard Wired Communications

Fiber Along Main Feed Line:

OCC Fiber – Arctic Fox
Used successfully at the south pole. Flexible to -70C
6 Fibers - $1.05/ft +/- 5% with 3280 ft minimum

Length: 20580 ft
Cost: $21609.00

Westermo Lynx 1400 Series Switch Rated to -40C
Used for redundant ring feature – reduces required fiber count

«« PROPRIETARY INFORMATION OF OPTICAL CABLE CORPORATION »»

DETAIL DRAWING

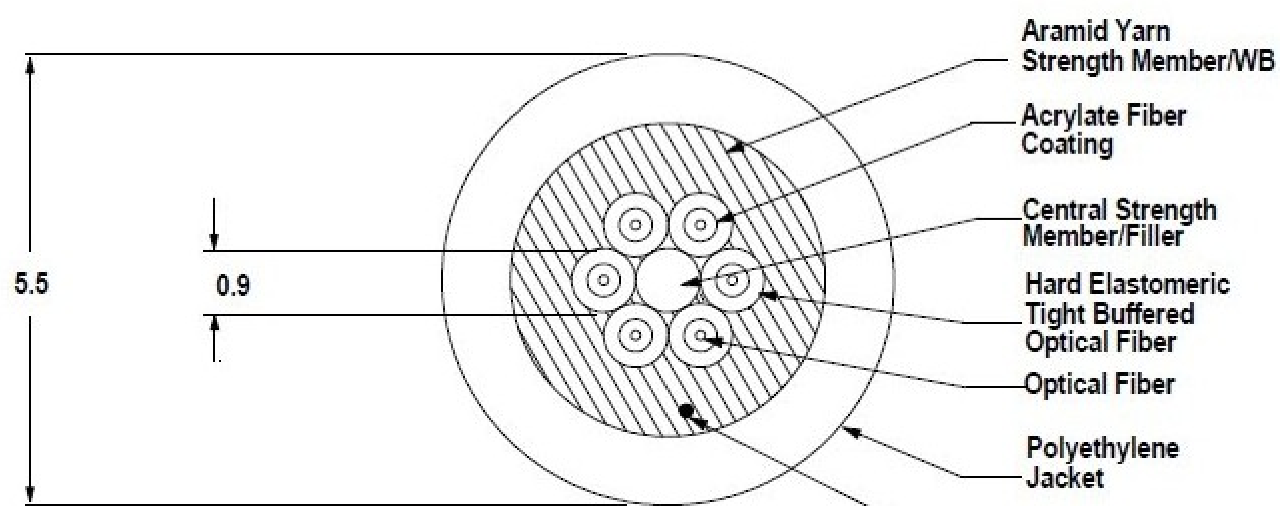
6-CHANNEL

TIGHT BUFFERED DISTRIBUTION FIBER OPTIC CABLE

OPTICAL CABLE CORPORATION P/N:

D-006ASLS5KAAF *

ARCTIC FOX PLUS™



(All dimensions in mm., drawing not to scale)

Hard Wired Communications

4 Conductor 20 AWG cable run from feed line run from fiber connected station to non fiber connected stations

Westermo DDW-220

Daisychain-able Ethernet Extender

Good to -40C

Scaling To Larger Arrays:

PLATO – Plateau Observatory

What is Plato?

Stand alone 1 KW diesel generator module
One year service interval (dome A – running for 580 days unattended)
Developed by the University of New South Wales.
UNSW has over a decade worth of remote power system experience in Antarctica (Plato – AASTINO - AASTO)

Scaling power production up with the UNSW system can be done by adding a larger fuel tank. Scaling up a few more watts with a wind/solar hybrid system has the potential to require a new tower/generator.

Costs:

Estimated costs for a ~300 watt version of PLATO is $88K with an estimated fuel consumption of 150 gallons of diesel for one year

Recurring costs include refueling, oil changes, and replacing diesel engines.

The current design is a diesel / solar hybrid system. It may be possible to further reduce fuel consumption by adding wind turbines to this system to reduce engine hours during the winter.