“Solar and Wind Power System for the ARIANNA Array”

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http://arianna.ps.uci.edu
ARIANNA = Antarctic Ross Ice shelf ANtenna Neutrino Array

Deployed 2012
Planned 2013

7 stations funded by NSF
900 stations envisioned
Communications

**AFAR** Communications, Santa Barbara, CA
radio model number AR24027E 2.4GHz WLAN

Each station to USAP Mt. Discovery relay point
then direct to McMurdo

**IRIDIUM** SBD module, NAL Research
model A3LA-XM 1.6GHz Satellite

Each station through DoD network
then to ARIANNA gmail and UCI server
Ultra-high Energy Neutrino Detection

Radio Cherenkov pulse
Detection band 100-1000MHz

Need LOW NOISE environment!
ARIANNA Station Components

Tower(s) for: Communications antennas
Solar panels for austral Summer operation
Wind generator for potential Winter operation
Batteries (large ice chest; Temp +20 to -40°C)
DAQ electronics: custom 2GHz, threshold triggering, 65dB gain amps
4 LPDA antennas

Net power usage:
2009 deployment = n/a, test system
2010 deployment = 30W
2011 deployment = 20W
2012 deployment = 10W
2013 deployment = 10W expected
2010 deployment
Barwick, Hanson

USAP provided AFAR link

2009 wind generator
Forgen1000

Aero6gen wind generator
1.7" OD x 14' Al pole

Tower with four 50W solar panels,
Iridium, GPS, DAQ electronics
and 4 LPDA antennas
(deployed 2009 and refurbished 2010)

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Aero6gen wind generator
2” OD x 12’ Al pole

2011 deployment
Berg, Tatar, Hanson

Lead-acid batteries
LPDA antennas: f > 180MHz

four 30W solar panels, Iridium, GPS, AFAR, anemometer

DAQ electronics to be positioned at flag
2012 deployment

Li-ion batteries

Air40 wind generator
16foot prefab tower

One 100W and two 30W solar panels

4 buried LPDA antennas at flags

AFAR & Iridium mast

buried DAQ electronics

Kleinfelder, Fan, Brooks (USAP staff), Tatar, and Reed
Power Schematics

2011 station
monitor voltages at:

2012 stations
(7W for DAQ + comms + losses)

Wind
Solar

30+30+30+30W

20W

212Ahr
Pb-acid

1Ω divert

charge controller
set to 16V

0.1Ω each
on negative leads

Wind
Solar

10W

224Ahr
Li-ion

100+30+30W
Battery System

Lithium Ion (Li FePO₄) Braille Batteries:
- two sealed 112Ahr 12V batteries (34lbs each)
- cold charging (tests up to 7A) ~80Ahr
- cold discharging (tests up to 2A) ~60Ahr

Internal microcontroller disconnects when
- drained (>10.5V) or full (<16.8V) to prevent damage

# 647, -30C, charge, +7A
# 647, -30C, discharge, -1A

Lead Acid typically only discharge 30-50% rated Ahr
and <0.1A limited charging
Air-40 Wind Generator Tests

(Southwest Windpower, Flagstaff, AZ)
13lbs, 46”OD, 6-50mph (110mph max), 12V system

Onboard microcontroller:
draws small current to operate
regulates load with proprietary smart algorithm
protection mode (brakes applied) if
over ~50mph or
over voltage (adjustable 13.6 - 17V)

Tested with a hand drill (Amps vs rpm)
Rooftop and driving tests (Amps vs mph)
(Duffin, Griskevitch)
Air-40 Wind Generator Tests

61 rpm/Amp, above ~550rpm

~13.39V so at 15mph we see 0.87A/mph
Air-40 Wind Generator Tests

61 rpm/Amp, above ~550rpm

\[ y = -6.4874 + 0.016384x \quad R^2 = 0.99921 \]

~13.39V so at 15mph we see 0.87A/mph

UC Irvine Air40. YLW>GRN>BLU>VIO over 1hr
Anemometry on the Ross Ice Shelf

Highest wind measured these time periods (and 52mph last week)

Mean usable 2012-13 season = 4.14mph
Wind Power on the Ross Ice Shelf

4.14mph season mean useable
*0.87A/mph UCI test = 3.60A
*1.33A/mph deployed Air40 = 5.51A
(mostly into 1 Ohm divert load)
*0.65A/mph deployed Aero6gen

3.36A mean generator current
Wind Issues

Multiple internal charge controllers: wind generator, Li-ion batteries
thresholds at 15.6V (wind, adjustable) and 16.8V (battery, fixed)
so charging stops if batteries are charged
PRIOR to battery controller overvoltage disconnect
need solar to activate wind generator to start charging depleted batteries

RF Noise: Air40 contains a controller which produces impulsive RF noise
shielded cabling and RF filter-pins to suppress
at 100ft distance, noise at 100-300MHz, if full battery and high wind

Wind generator destruction:
2009-2010 deployment: Forgen1000, OK
2010-2011 deployment: Aero6gen blades broke and Aluminum mount broke
2011-2012 deployment: Aero6gen blades broke, hitting pole mount
2012-2013 deployment: Air40, so far so good
Live Time and Power Source

Solar Position

Altitude Angle (degrees)

Solar only
Solar and Wind
Windpower only
Solar and Wind
Solar only

2009
2010
2011
2012
2013

2013 DATES (others ±1 day)

Deployment

Jan 1
Feb 23
d54
Apr 21
d11
Aug 22
d234
Oct 20
d293
Dec 31
D365
Solar Charging Model

Model:
- astronomical solar position (Mathematica)
- realistic horizon features (mountains)
- 2011 solar array geometry
- one parameter “fit” = overall panel rating

Hottel (1976) clear sky model with 5km visibility

\[ \frac{I}{I_0} = a_0 + a_1 e^{(-\kappa/\cos \theta)} \]

\( a_0, a_1, \kappa = \) altitude dependant constants

Model improvements needed:
- new atmospheric model
- add atmospheric refraction
  - *add snow reflection
- fit \( a_0, a_1, \kappa \) to data
Solar Charging Data and Model

2012-2013 season

Solar Amps
- daily mean
- daily max
- underestimate

Solar Amps
- daily min
- diurnal

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Solar Model and Live Time

(Pb-acid) battery empty on 3/4/12
station shutdown 4/4/12

Model: battery empty 3/17
Panel Rating Dependence

Live time is insensitive to panel rating above ~30W
30W -> 40W 2011 to 2012
1W stations can operate year-round with batteries alone
1kW stations can operate year-round with an indoor generator

How does one power a 10W station year-round with green technology?

1) We have tested and are in the process of demonstrating the effectiveness of a Li-ion battery system in the cold environment

2) We have site wind data and have tested a number of wind generators, and are in the process of demonstrating effectiveness over winter

3) We have a viable solar model for predicting summer solar-only operation and panel rating dependence
ARIANNA
UCI Physics and Engineering Contingent

Steve Barwick, principal investigator
Stuart Kleinfelder, professor
*Corey Reed and *Eric Berg, project scientists
*Joulien Tatar, Liang Zou, Mahshid Roumi Ph.D. Candidates
Jordan Hanson, Ph.D. graduate (-> Kansas University)
Kelly Margaritis, James Walker, Zongnan Fan graduate students
*Thorin Duffin, B.S. graduate

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* pictured, testing at UCI

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Extra slides
Ultra-high Energy Neutrinos

![Graph showing energy distribution of neutrinos with different datasets and sensitivities.](image)

Fig. adapted from Kampert & Unger

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Neutrino Resolution

Detection efficiency: expect 0-50 events/year with 900 stations operating year-round.

Neutrino flavor resolution
flavor = e, μ, or τ

Neutrino energy resolution

angular resolution

log(Eν) eV

log(E_ν_measured/E_ν_true) eV

σ_θ ≈ 2.8°
Anemometry on the Ross Ice Shelf

Automated Weather Station (AWS), by U. Wisconsin
“Linda” station E. of Mina Bluff (measured/10min)

Windspeed (mph)

Day of the year 2008 and 2009

14.4 mph annual mean

12 -> 16 mph summer to winter

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