National Defense Center for Energy and Environment

DoD Executive Agent

Office of the
Assistant Secretary
of the Army
Installations, Energy and
Environment

Power System Implementation and Demonstration at Camp Katuu, Palau

Clark Boriack, NDCEE/*CTC*

E2S2, New Orleans
May 11, 2011

The NDCEE is operated by: CTC *Concurrent Technologies Corporation*

Technology Transition – Supporting DoD Readiness, Sustainability, and the Warfighter

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
11 MAY 2011		**00-00-2011 to 00-00-2011**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Power System Implementation and Demonstration at Camp Katuu, Palau	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **National Defense Center for Energy and Environment (NDCEE),Concurrent Technologies Corporation,100 CTC Drive,Johnstown,PA,15904**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Presented at the NDIA Environment, Energy Security & Sustainability (E2S2) Symposium & Exhibition held 9-12 May 2011 in New Orleans, LA. U.S. Government or Federal Rights License

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**30**	

Outline

- Demonstration Overview
  - Site review
  - Demonstration goals
- Development and Design Considerations
  - Layout
  - Electrical
  - Mechanical
- Critical Design Aspects
  - Safety
  - Component selection
  - Local electrical utility performance

Site Review

- Camp Katuu, located near Koror, Palau; latitude of 7° 30’ North
- NREL PVWatts™ did not have Palau in the historical database so Awassa, Ethiopia; 7° 3’ North latitude was used

Demonstration Goals

- Camp Katuu Installation
  - Increase civil outreach and nation building with Palau Government
  - Reduce environmental footprint at Camp Katuu
  - Increase use of alternative energy
  - Demonstrate the feasibility of using alternative energy in the region
  - Quantify PV system performance/capability
  - Train 249th Engineer Battalion to install Photovoltaic Systems
  - Validate camp electrical costs reduction
- Future Installations
  - Leverage design aspects for other remote installations (grid frequency and voltage regulation, corrosion, high electricity costs)
  - Next generation to include off-grid operation capability with energy storage

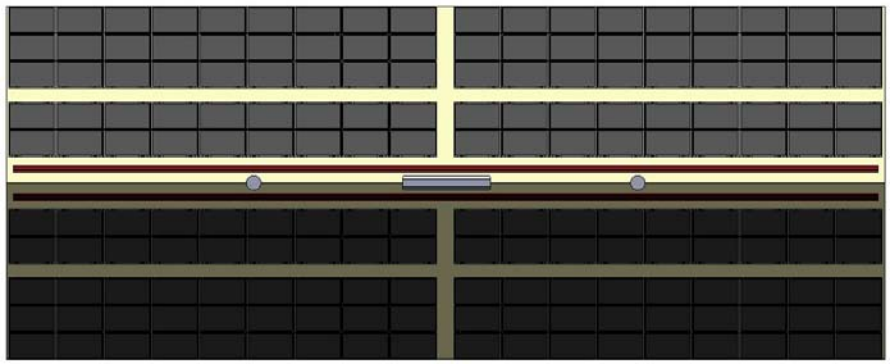
Development and Design Considerations

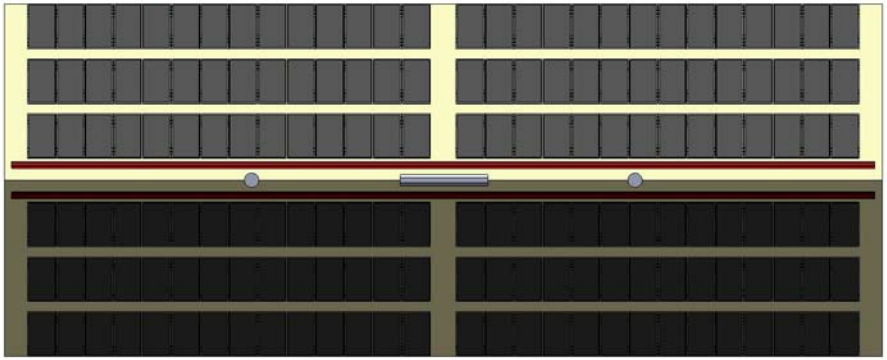
- PV System Layout Considerations
  - Access ways for installation, repair, maintenance
  - Ease of installation
  - Maximize system rating

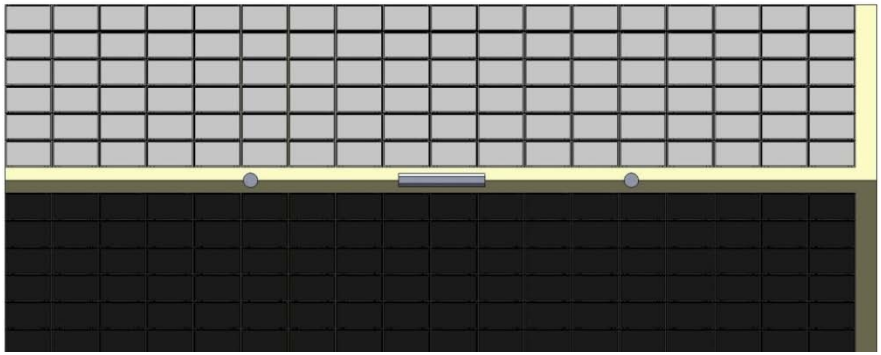
Camp Katuu Builder's Shop – PV Array Installation Location

Development and Design Considerations

- PV System Layout Options Considered







Development and Design Considerations

- PV System Layout Considerations

PV LAYOUT OPTION SUMMARY					
		Option 1	Option 2	Option 3	Option 4
No.	Consideration	5 Horizontal Rows	3 Vertical Rows	3 Vertical Rows with Center Walkway	6 Vertical Rows
1	Amount of rail mounting (lf)	1440'	1800'	1800'	1440'
2	Ease of rail installation	some rail cutting required to clear walkway	requires two level rail mounting system	requires two level rail mounting system	no rail cutting required
3	Ease of wiring	Intuitive circuit pattern	Very Intuitive circuit pattern	Very Intuitive circuit pattern	odd circuit pattern
4	Maintenance access	21" horizontal & vertical walkway, does not have direct access to all panels	Accessible with 15" walkways	Direct access to each panel and has a center walkway	No direct access to most panels
5	System DC Rating (kW DC) [1]	42.300	42.300	39.480	50.760
6	System AC rating (kW AC) [2]	32.571	32.571	30.400	39.085
7	Fall Protection System	accomodates rail system	accomodates rail system	accomodates rail system	does not accommodate rail system
8					

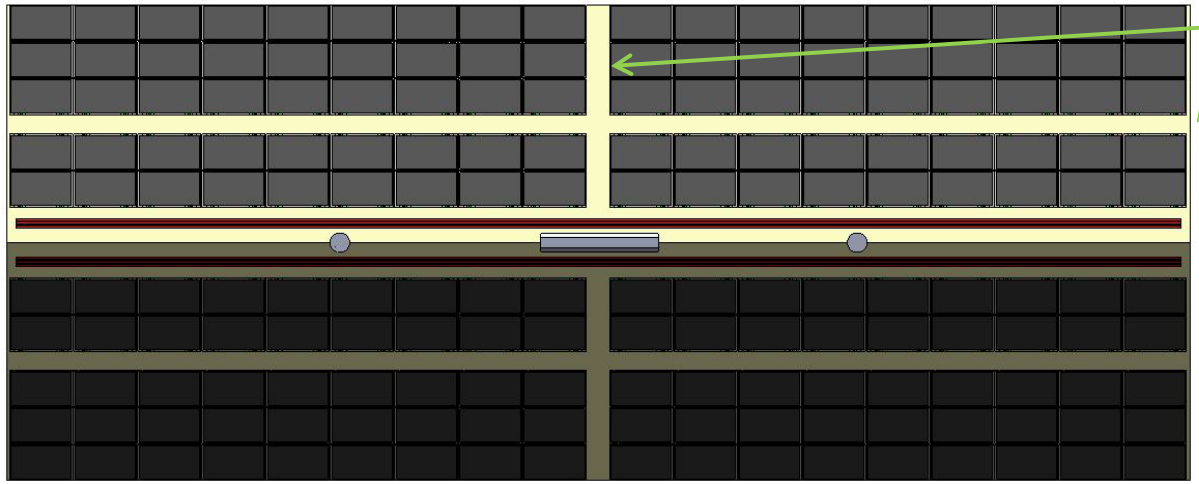
Color Legend	
	most favorable
	more favorable
	least favorable

Note [1] System DC Rating based upon use of 235W solar panels

Note [2] System AC Rating based upon typical .77 conversion factor from DC power to AC power

Development and Design Considerations

- PV System Layout Selected



No.	Consideration	Impact
1	Amount of rail mounting (lf)	1440'
2	Ease of rail installation	some rail cutting required to clear walkway
3	Ease of wiring	Intuitive circuit pattern
4	Maintenance access	21" horizontal & vertical walkway, does not have direct access to all panels
5	System DC Rating (kW DC) [1]	42.300
6	System AC rating (kW AC) [2]	32.571
7	Fall Protection System	accomodates rail system

Color Legend

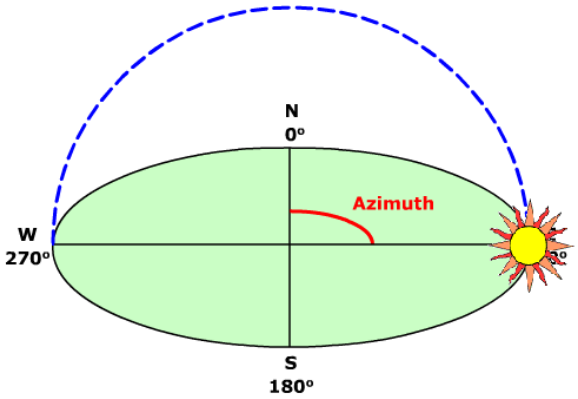
most favorable

more favorable

least favorable

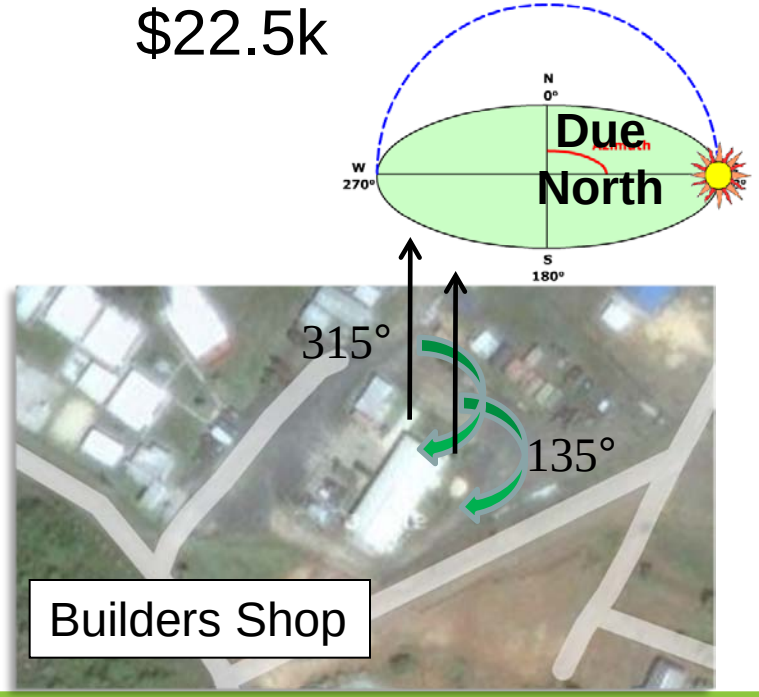
Economics
Array Azimuth Angle

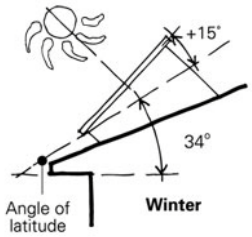
- The array azimuth angle is defined as the clockwise angle of the array face from true north

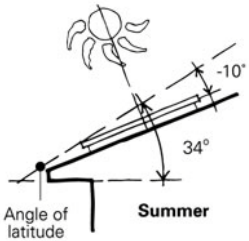


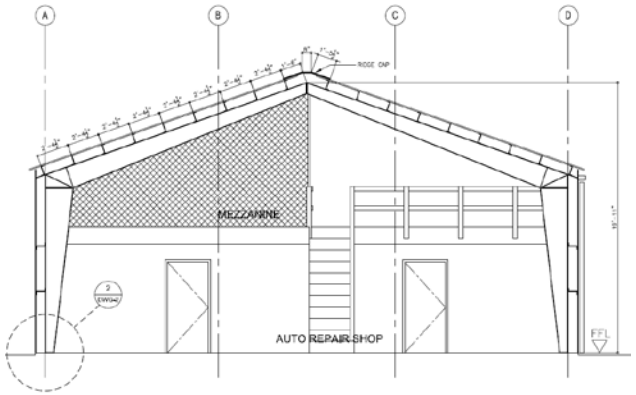
Economics
Array Tilt Angle

- The array tilt angle is the angle of the array face to the sun's rays
- 4:12 pitch of Builder's Shop roof provides a tilt angle of 18°
- Ideal 7° pitch improved annual savings from $21.8k to $22.5k

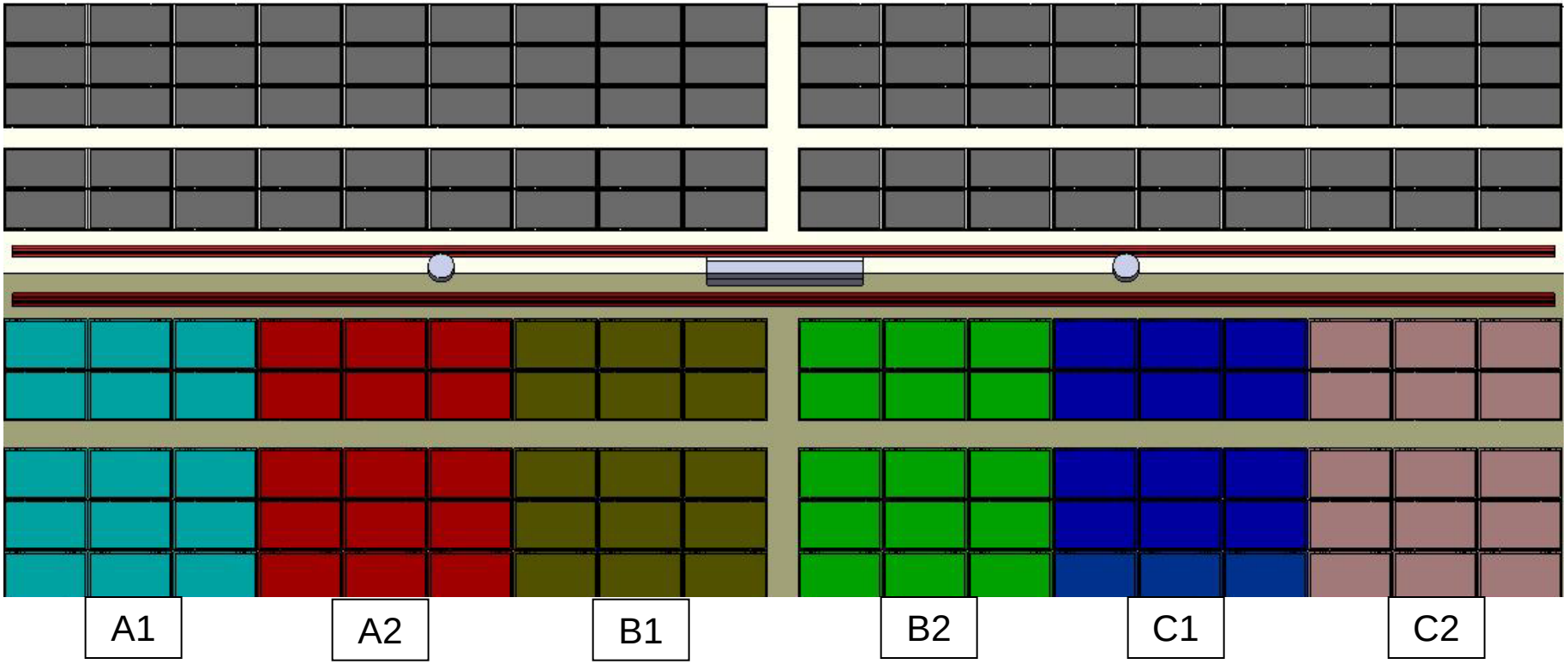








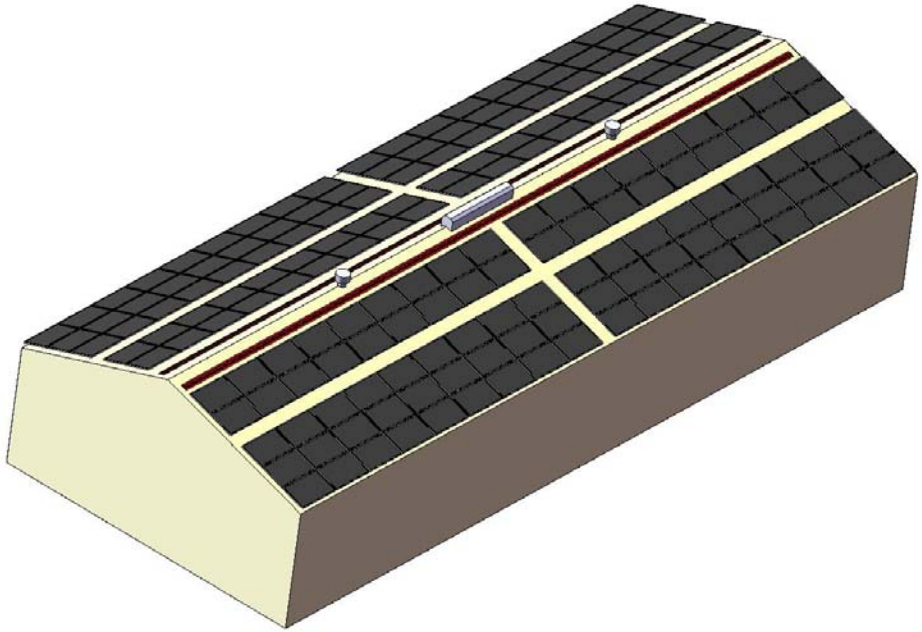
Development and Design Considerations



- Two Groups of 15 panels for each inverter for each side of roof
- Balanced 3 phase system
- Both circuits for each inverter on same side of roof
- Logical organization to support installation/sustainment

Critical Design Aspects
Safety

- Safety Railing
  - Maximizes Safety Considerations
  - Supports installation
  - Supports maintenance
- Access Ways
  - Supports installation
  - Supports maintenance
  - Beginning to be required



Safety Rail Systems

- Horizontal Cables
  - Pre-engineered but require installation and load testing by a certified vendor
  - Higher mounting height minimizes the possibility of rope catching on panels
- Single Point Anchors
  - Limited mobility and low ease of use
    - To move from anchor to anchor, must first tie off on second anchor, return to unhook, then move to work area
  - Inexpensive equipment and installation
  - Requires heavy gage material for attachment
- Horizontal Rails
  - Pre-engineered so installation and design costs are minimal
  - Does not require installation and/or inspection by a certified vendor
  - Mounts very close to roof – rope may catch on edges of panels

Cost Benefit Comparison

System Type	Equipment Cost	Design Fee	Vendor Installation Fee	Personnel Training Costs	Total Cost	Ease of Use (1-10, 10 being best)
Horizontal Rail	$5.5k	$0	$0	$5k (vendor travel cost)	***$10.5k***	8
Single Point Anchors	$4k	$2k	$0	$5k (vendor travel cost)	***$11k***	2
Horizontal Cable	$10K	$2k	$14k	$0 (included in installation)	***$26k***	10

- The horizontal rail system is the most cost effective solution and is easy to use, therefore it is recommended for this application
- Although the single point anchors are also cost effective, they limit mobility and are not easy to use
- Horizontal cable systems require vendor installation and certification, making them the most costly - Once installed, they are the easiest to use

Fall Protection
Roof Rail Systems

Figure 7: Rail Type Fall Protection System

- Systems are pre-engineered and can be installed by others
- Fosters safe, efficient travel across roof
- Product support is available for installation and training
- Estimated Material Costs
  - ~$20k FLEXRIDGE™ System
  - ~$6k Uniline™ System

Mounting System
UNIRAC™ Method

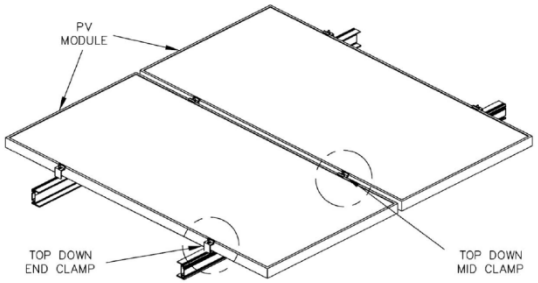


Figure 4: Roof Top Flush Mounting System

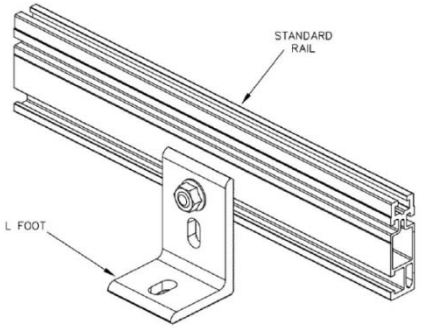


Figure 5: UNIRAC Standard Rail and L Mounting Bracket

Corrosion Contributing Factors:

- Humid, Salty climate
- Galvanic cell between dissimilar metals

Steps to Mitigate Corrosion Risks:

- Barrier material installation
- ASTM B117 corrosion testing to confirm compatibility (500hr test during April 2011)
- PV module has been tested, verified to withstand corrosion by manufacturer; 25 year warranty

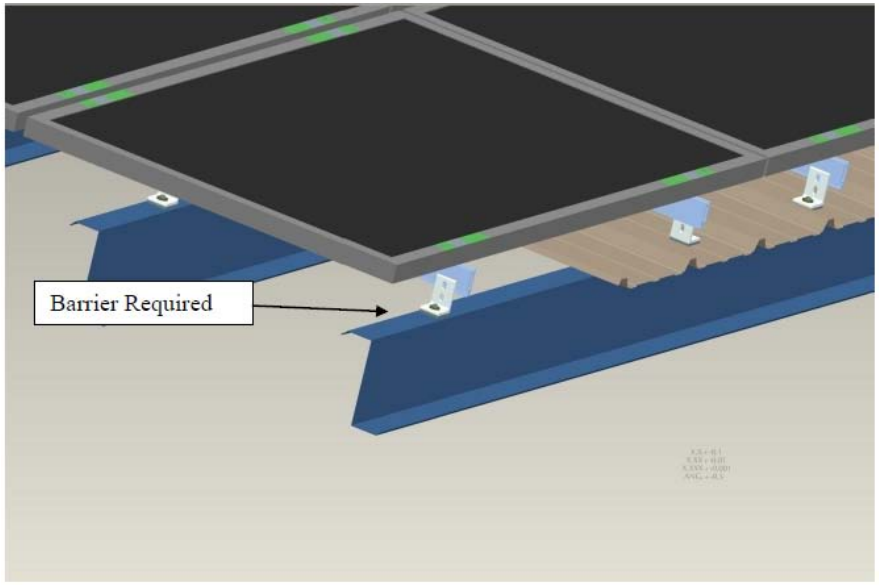
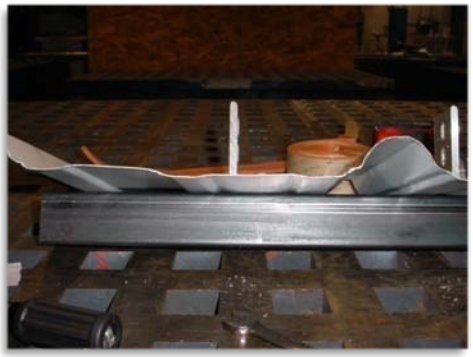


Figure 6: Rail Mounting Bracket Interface

Shop Prototype Application Corrosion Testing

Predrill



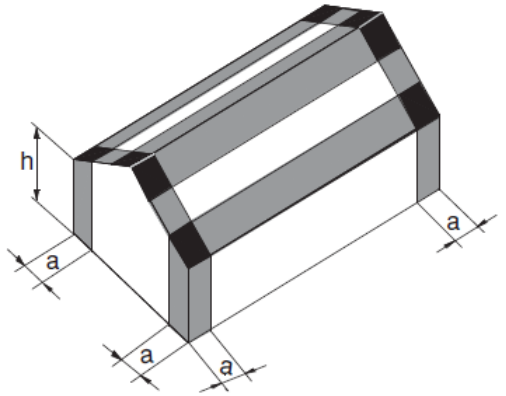
Steel Tubing

Insert Riv-nut

Final Assembly

Wind Load Distribution

- Wind load distribution for enclosed gable roof buildings is as shown
- Dimension “a” is calculated as the lesser of either:
  - 10% of the least horizontal dimension (w) 0.10 * 40′-0″ = 4′-0″
  - 0.4h
  - 0.4 * 13′-3″ = 5′-4″
- Dimension “a” is taken as 4′-0″

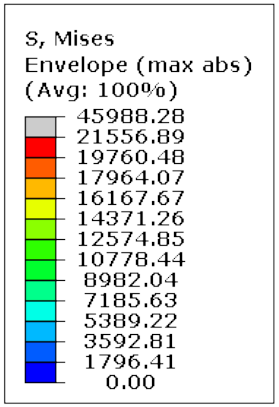


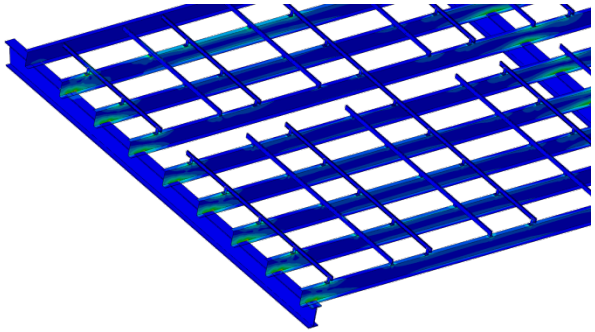
Gable Roof ($7° < \theta \leq 45°$)

Interior Zones
Roofs - Zone 1/Walls - Zone 4

End Zones
Roofs - Zone 2/Walls - Zone 5

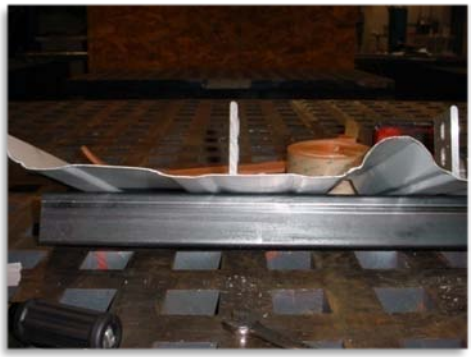
Corner Zones
Roofs - Zone 3





Shop Prototype Application Fastener Testing

Predrill



Steel Tubing

Insert Riv-nut

Final Assembly

Mounting System Original Fastener

BIN-FLEX™ 300 Series Stainless Steel Self-Locking Fasteners

Selection Guide

	ECP Catalog No.†	Size	L Length	Drive System	Point Size	Max. Drilling Cap.	B Maximum Load-bearing Length*	Pieces per 1/4 Keg†	Job Pack: Pieces per Box†
Hex Washer Head									
	EAJ110	10-16	3/4"	5/16" hex	2	.110"	0.320"	6000	250
	EAJ185	12-14	1"		2	.140"	0.500"	4000	150
	EAJ215		1-1/2"				1.00"	2500	125
	EAJ240		2"				1.500"	2000	75
	EAJ190	12-14	1"		3	.210"	0.500"	4000	150
	EAJ220		1-1/2"				1.00"	2500	125
	EAJ260		2-1/2"				2.00"	1500	50
	EAJ340	12-24	2"		5	.500"	1.100"	2000	75
	EAJ415	1/4-14	1"	3/8" hex	2	.175"	0.500"	3000	125
	EAJ430		1-1/2"				1.00"	2000	75
	EAJ445		2"				1.500"	1500	50
	EAJ540	1/4-20	1"		3	.312"	0.500"	2500	125
	EAJ580		1-1/2"				1.00"	2000	75
	EAJ610		2"				1.500"	1500	50
	EAJ640		2-1/2"				2.00"	1000	50
	EAJ615	1/4-20	2"		5	.500"	1.100"	1500	50
Flat Head Reamers w/wings									
	EBN140	10-16	1-1/2"	#2 phillips	3	.140"	0.800"	3500	125
	EBN345	12-24	2-13/16"	#3 phillips	5	.500"	1.710"	1500	50
	EBN645	1/4-20	2-13/16"				1.710"	1000	50
Flat Head Undercut									
	EBN200	12-14	1"	#3 phillips	2	.140"	0.500"	4000	150
	EBN240		1-1/2"				1.00"	2500	125

Identification

The head marking consists of the number "3" above the Elco® logo as shown below.

flat head — hex washer head

* The load-bearing length is the length of 300 series stainless under the hex head or including the flat head. Hardened steel length (lead threads and point) should be through the connection and not in the load bearing section of the connection.

† **Standard packaging:** ¼ keg quantities as shown.

Job Pack: Pieces per box as shown/ six boxes per shipper. Available upon request. Indicate Job Pack by placing a "P" at the end of the ECP Catalog No.

NOTE: All performance data shown is based on tests performed under laboratory conditions at independent construction testing facilities. The appropriate safety factor should be applied and code requirements factored into specification and use of these fasteners. A safety factor of 4:1 or 25% of the ultimate average values shown is generally accepted as an appropriate working load. Final determination of the appropriate safety factor and use of these fasteners is the sole responsibility of the user, specifying Engineer, Architect or other responsible person designing the connection. Due to a wide variety of application conditions or intervening factors not under our control, we assume no liability for the use of the information provided in this document. For additional product information and technical assistance, please contact Elco directly at 1-800-435-7213.

Performance Data

Pull-Out Values

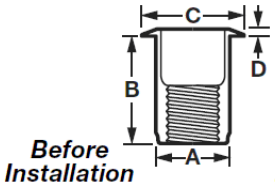
Screw Size	Drill Point Type	Drill Cap (In.)	Pull-Out (Lbs) Steel RB60-75 50 – 66KSI 18 ga.	16 ga.	14 ga.	12 ga.	1/8"	3/16"	1/4"	Aluminum 6063-T5 22KSI 1/8"	1/4"
10-16	2	0.150	455	677	793	1394	1906	–	–	994	–
10-16	3	0.187	–	616	684	1242	1605	1527	–	961	–
12-14	2	0.187	528	750	892	1536	2602	2514	–	1132	–
12-14	3	0.210	417	679	802	1371	2028	2499	–	974	–
12-24	5	0.500	–	–	–	–	–	2110	2781	538	1995
1/4-14	2	0.210	619	885	1082	1830	2943	3535	–	1310	–
1/4-20	3	0.375	–	680	780	1442	2623	3684	4069	1037	2786
1/4-20	5	0.500	–	–	–	–	–	–	2622	–	1724

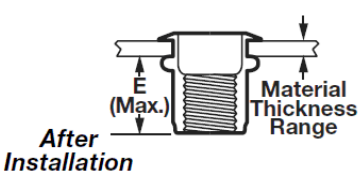
Ultimate Strengths**

Size	Tensile (Lbs)	Shear Average Lbs Ultimate
10-16	1847	1282
12-14	2628	1950
12-24	2734	2284
1/4-14	3459	2676
1/4-20	4124	2860

** Values are for 300 series stainless fastener threaded shank

- Sufficient Pull Out Rating for load
- Insufficient for Pull Out for installation
- Select rivet-nut instead of self-drilling fastener





PV Module Comparison Results

Mechanical Characteristics	Canadian Solar PVCS6P-235P	Kyocera KD215GX-LPU	Sharp PVSH ND-224 UC1	Evergreen PVES-A-210-FA3	BP PVBP3215B	BP PVBP3230T
length(in)	64.5	59.1	64.6	65.0	65.6	65.6
width (in)	38.7	39	39.1	37.5	39.4	39.4
thickness (in)	1.57	1.8	1.8	1.8	2	2
weight (lbs)	44.1	39.7	44.1	41.0	42.8	42.8
Electrical Characteristics						
power output (dc w)	235	215	224	215	215	230
panel open circuit voltage rating (volts)	36.9	33.2	36.6	23.1	36.5	36.7
panel maximum power voltage rating (volts)	29.8	26.6	29.3	18.7	29.1	29.1
panel current rating (amps)	7.90	8.09	7.66	11.23	7.40	7.90
Other Characteristics						
cost/panel	$ 479.36		$ 479.57	$ 456.66	$ 456.66	$ 490.45
cost/watt	$ 2.04	$ -	$ 2.14	$ 2.12	$ 2.12	$ 2.13
power output warranty (years)	25	20	25	25	25	25
delivery (weeks)	STOCK	12	STOCK	STOCK	STOCK	STOCK

PV Module
Recommended Product

- Highest Power Output
- Tested for Corrosion
- Best Value
- Stock Item

PV Module Specifications	Canadian Solar
Mechanical Attributes	**CS6P-235P**
Length(in)	64.5
Width (in)	38.7
Thickness (in)	1.57
Weight (lbs)	44.1
Electrical Attributes [1]	
Nominal Maximum Power Output at STC (Pmax)	235 Watts
Voltage at Pmax (Vmp)	29.8 Volts
Current at Pmax (Imp)	7.9 Amps
Open Circuit Voltage (Voc)	36.9 Volts
Short Circuit Current (Isc)	8.09 Amps
[1] Standard Test Conditions for panel ratings: 1,000 Watts/M^2, AM 1.5, 25 C	

Figure 9: PV Module Specifications

Inverter System
SMA 7000US

- Six SMA 7000US Inverters for system
- Reliable Product
- Rated for Outdoors Use
- Simple interface
- Integral DC Disconnect
- Several Options
- Stock Item

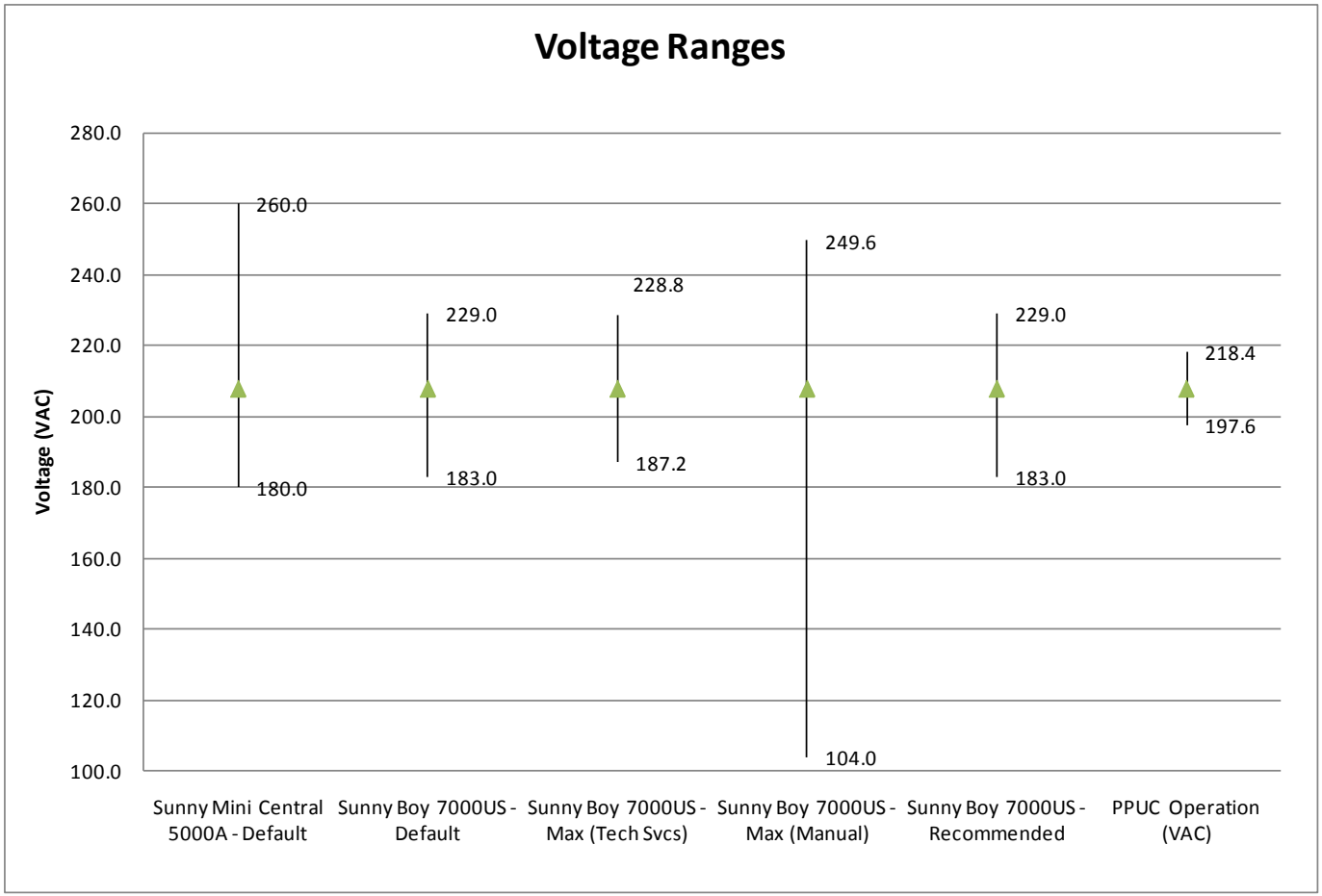
Critical Design Aspects

- Local Electrical Utility Performance

Nominal frequency	Trip limit	Trip frequencies	Trip times
60 HZ	> 60.5 Hz	60.45 Hz ... 60.55 Hz	max. 0.1602 s
	< 57.0 Hz ... 59.8 Hz (default 59.3 Hz)	56.95 Hz ... 59.85 Hz (default 59.25 Hz ... 59.35 Hz)	adjustable 0.16 s ... 300 s (default max. 0.1602 s)
	< 57.0 Hz	56.95 Hz ... 57.05 Hz	max. 0.1602 s

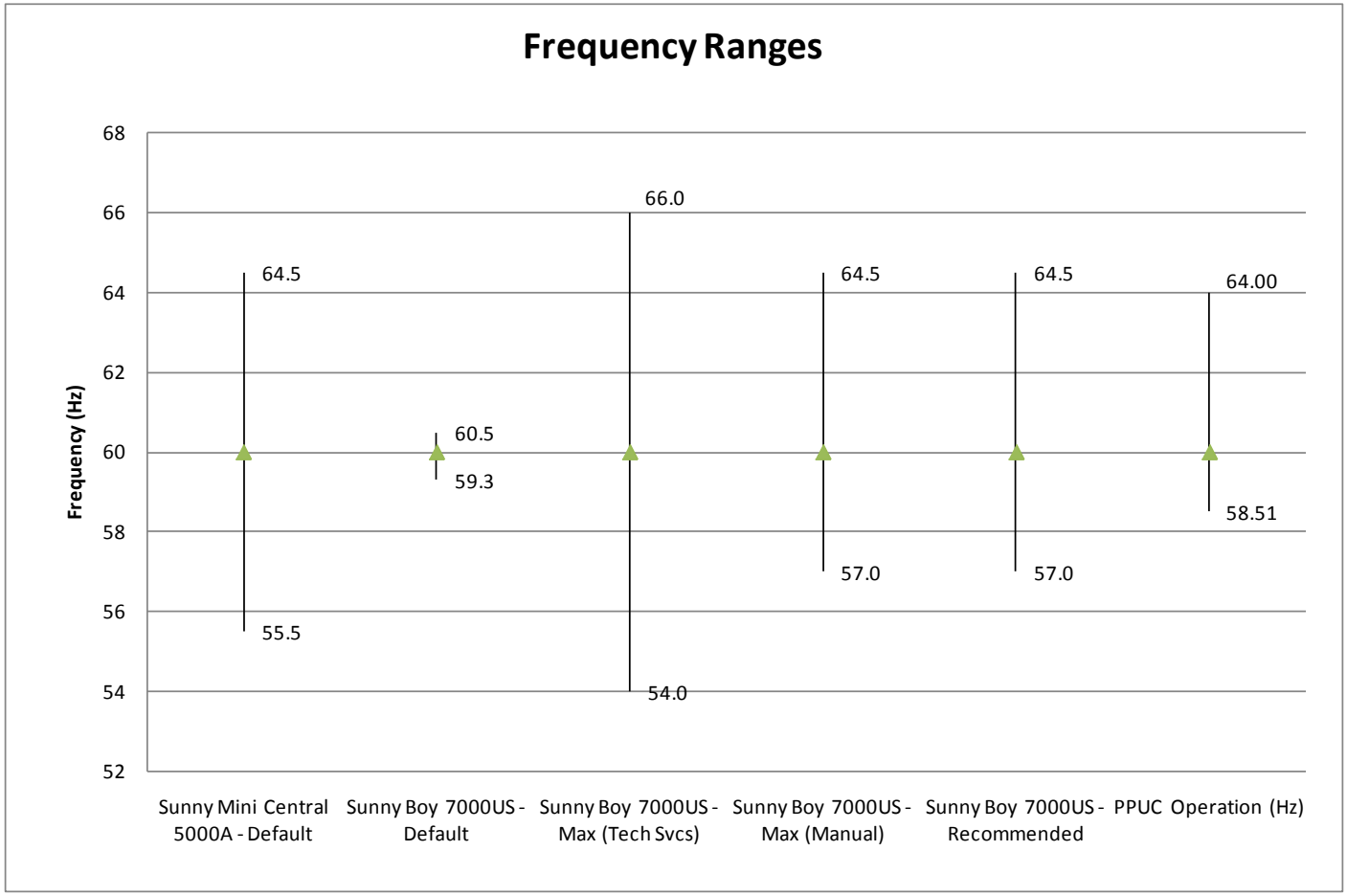
Nominal voltage	Trip limit	Trip voltages line-to-neutral*	Trip voltages line-to-line*	Trip times
208 V	50 %	57.6 V ... 62.4 V	99.8 V ... 108.2 V	max. 0.1602 s
	88 %	103.2 V ... 108.0 V	178.9 V ...187.2 V	max. 2.002 s
	110 %	129.6 V ... 134.4 V	224.6 V ... 233.0 V	max. 1.001 s
	120 %	141.6 V ... 146.4 V	245.4 V ... 253.8 V	max. 0.1602 s

Critical Design Aspects



Default Voltage Operating Range is acceptable

Critical Design Aspects



Available Frequency Operating Range is acceptable

Maintenance Features

- Safety Railing
  - Maximizes Safety Considerations
  - Supports installation and maintenance
- Access Ways
  - Supports installation and maintenance
  - Beginning to be required
- Metering
  - Automatic Data Collection to quantify system performance
  - Scheduled data reports to minimize communications system impact
- Component Support
  - Global Manufacturer Technical Support (phone and online)
  - Commercial-off-the-Shelf (COTS) components
  - 10 year inverter warranty, 25 year module warranty
  - Critical spares provided to mitigate failure downtime

Maintenance
Requirements

- Module Cleaning - Remove dirt, dust and debris may collect on the modules. Power washing of modules in Palau is recommended every 6 months.
- Inverter Fan Cleaning – Remove dirt, dust collected on inverter intake fans and exhaust fins every 3 months.
- System Performance – Measure and compare string voltages to identify connection or module issues every 3 months.

Simple, easy system to maintain

SUMMARY

- Training and transfer of design applications and methods to 249th EN BN
- Remaining Camp Katuu PV System Schedule (commissioning to end of monitoring and turn over to PACOM)
- System monitoring and metrics
- Estimated Camp Cost savings per year

National Defense Center for Energy and Environment

DoD Executive Agent

Office of the Assistant Secretary of the Army Installations, Energy and Environment

www.ndcee.ctc.com

Points of Contact

- **NDCEE Technical Monitor**
  John Horstmann
  ARCENT
  Phone: (404) 464-2352
  Email: john.horstmann@arcent.army.mil

- ***CTC* Project Manager**
  John Forte
  Phone: 814-269-6821
  Email: forte@ctc.com

This work was funded through the Office of the Assistant Secretary of the Army Installations, Energy and Environment and conducted under contract W91ZLK-10-D-0005 *Task 0720. The views, opinions, and/or findings contained in this paper are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision unless so designated by other official documentation.*