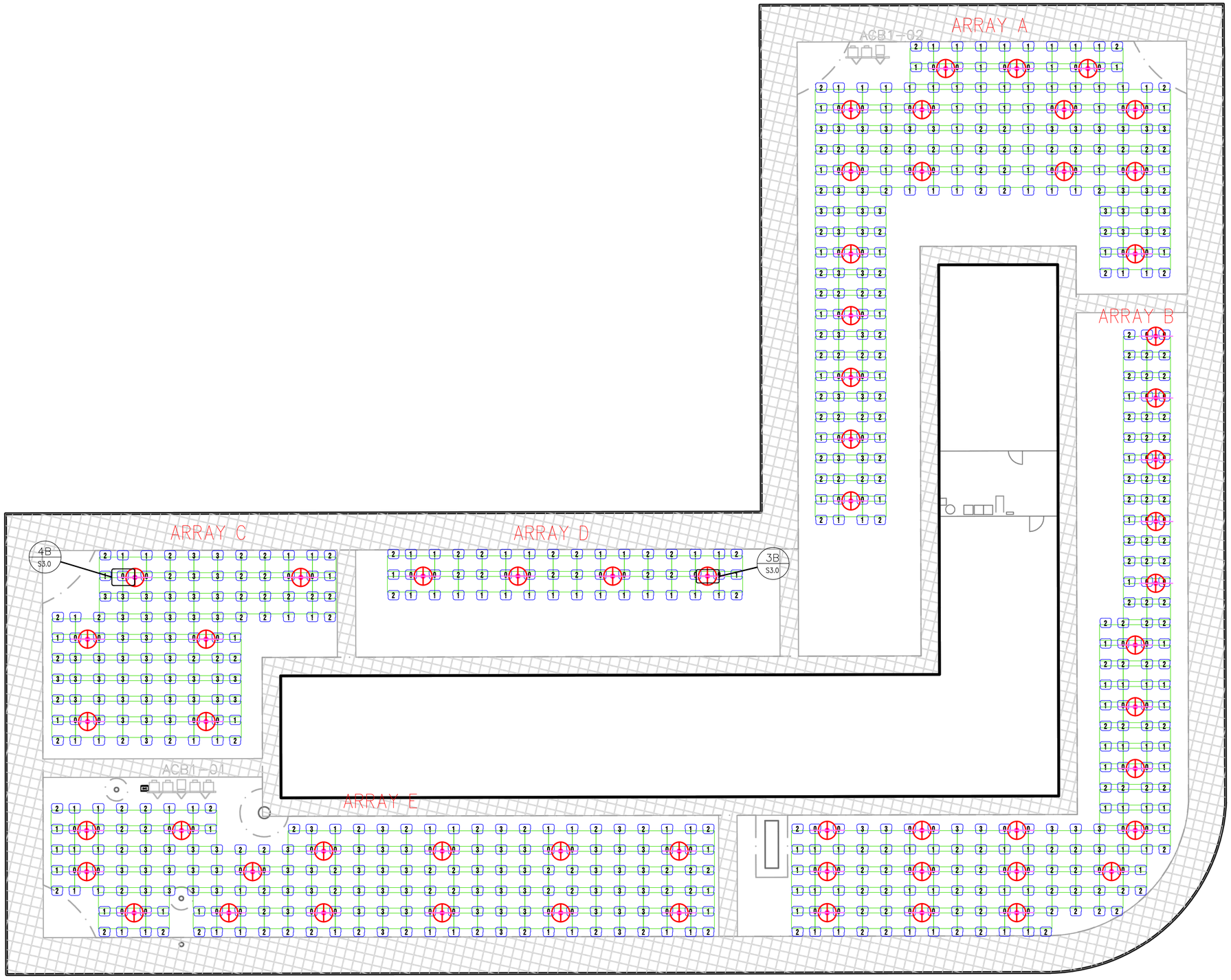
Sollega Sample Engineering - Oracle
10/23/18

Racking Layout - Campus 1



0 16 32

SCALE: 3/32" = 1'-0"

SEE S2.0 AND S3.0 FOR SOLLEGA ANCHOR, PANEL, AND CORNER SUPPORT ATTACHMENT DETAILS

SITE

PROJECT SPECIFICATIONS	
PROJECT ID	**For Construction**
Roof Height (ft)	**65**
Wind Speed ASCE 7-10 (MPH)	**110**
Exposure Factor	**C**
Azimuth (deg.)	**212**
Module Brand	**SunPower**
Module Count (#)	**528**
Module Wattage (W)	**327**
Module Length (in)	**61.30**
Module Width (in)	**41.20**
Module Thickness (in)	**1.81**
Module Weight (lbs)	**41.00**
System Size (kW-DC)	**172.66**
Total FastRacks (#)	**695**
Wind Screens (#)	**0**
Roof Anchors (#)	**60**
Row Spacing (in)	**53.60**
Tilt Angle (DEG)	**10**
Total CMU Blocks (#)	**1108**
Total Non-ballast Weight (lbs)	**25445**
Total Ballast Weight (lbs)	**33240**
Total System Weight (lbs)	**58685**
Total Load / Array Area (psf)	**4.51**

PROJECT INFO.

NOTES

2.7 S2.0 — Roof Anchor

1-4 S3.0 — 8' Rail

Ballast Required (#CMU blocks)

FASTRACK 510

= Ballast Per FastRack

CMU: 30 lb , 4"x8"x16"

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2480 Mission St, Ste 107B, San Francisco, CA 94110
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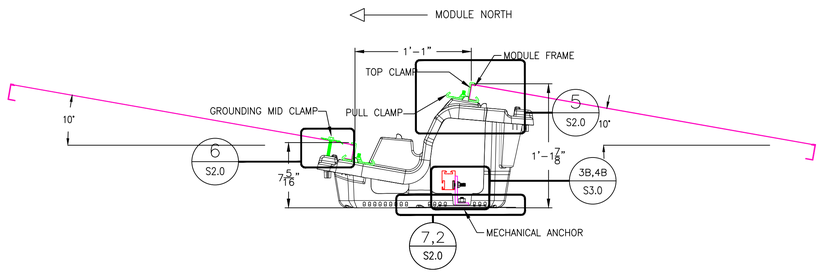
DRAWING INFO.

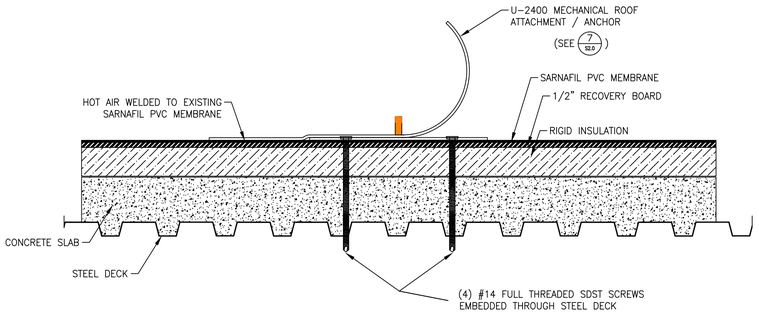
REV #	Description	Drawn	Approved	M/D/Y
0	Preliminary	JC	LR	11/30/17
1	Engineered Design	JC	LR	12/11/17

Date & Time	12/11/2017 4:50 PM
Sheet Name	**S1.0**

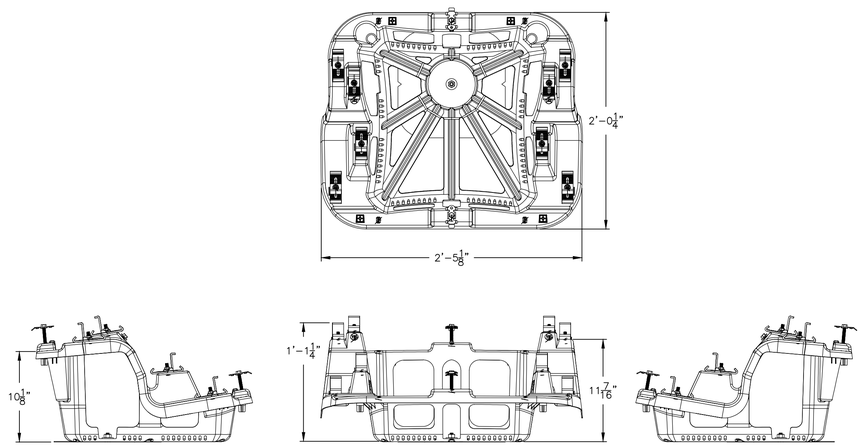
FORMATTED FOR 24" x 36"



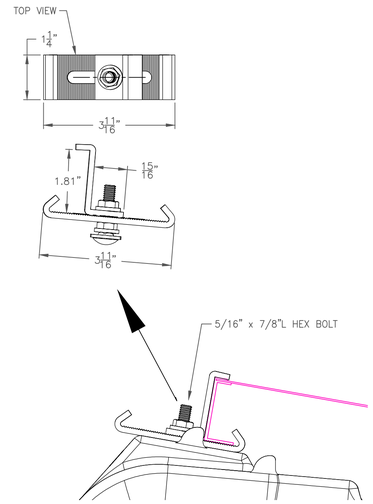
1 S2.0 MODULE ATTACHMENT DETAIL
SCALE: 1-1/2" = 1'-0"



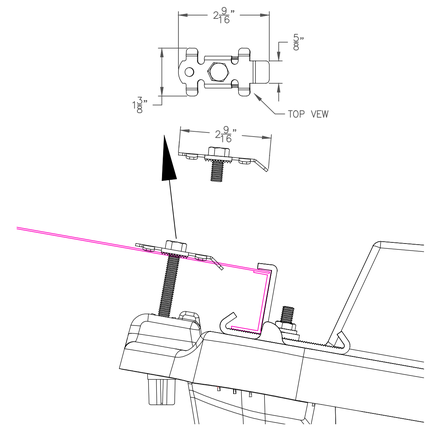
2 S2.0 ROOF ANCHOR ATTACHMENT DETAIL – SIDE
SCALE: 1-1/2" = 1'-0"



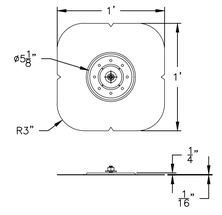
4 S2.0 SOLLEGA FAST RACK 510 (FR510)
SCALE: 1-1/2" = 1'-0"



5 S2.0 CLAMP DETAIL
SCALE: 6" = 1'-0"



6 S2.0 MID CLAMP DETAIL
SCALE: 6" = 1'-0"



SEE 2 S2.0 FOR FASTENER DETAILS AND ROOF DECK ELEVATION

7 S2.0 MECHANICAL ANCHOR DETAIL
SCALE: 1-1/2" = 1'-0"

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NOTES

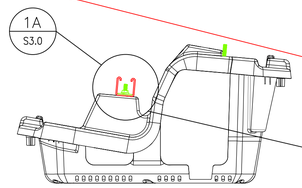
PROJECT INFO

DRAWING INFO.		
Date & Time	10/18/2017 4:50 PM	
Prepared/Approved by	JC	LR
Sheet Name	S2.0	

1 S3.0 EXTERNAL CORNER SUPPORT DETAILS
NTS

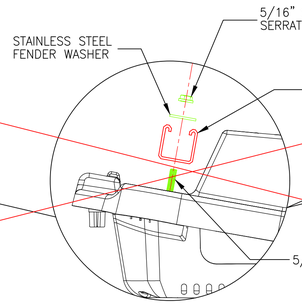
EXTERNAL CORNER SUPPORT RUNNING EAST–WEST SIDE VIEWS

FASTRACK AT 5°

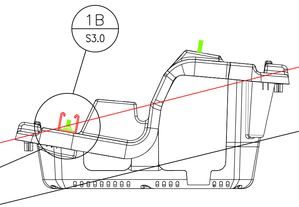


EXTERNAL STRUT CONNECTION – NORTH END OF ARRAY

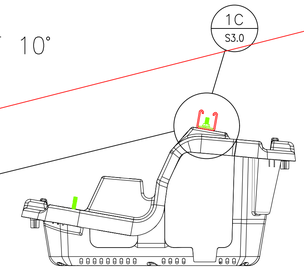
*NOTE: EXTERNAL STRUT ON SOUTH END OF ARRAY FOR FASTRACK AT 5° ASSEMBLY, BOLTS MUST BE MOVED TO THE 10° MOUNTS (HIGH SIDE OF FASTRACK) FOR CLEARANCE OF THE STRUT CONNECTION (SEE FASTRACK AT 10° SOUTH END OF ARRAY)



FASTRACK AT 10°

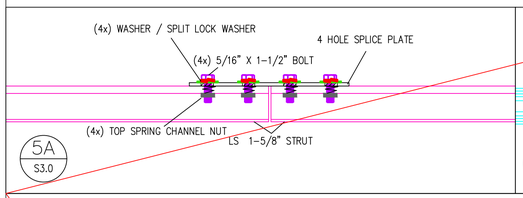


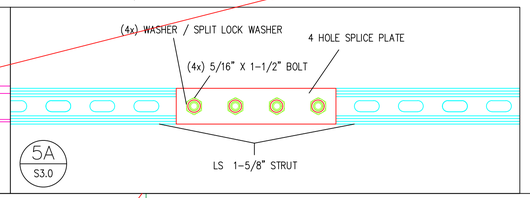
EXTERNAL STRUT CONNECTION – NORTH END OF ARRAY



*EXTERNAL STRUT CONNECTION – SOUTH END OF ARRAY

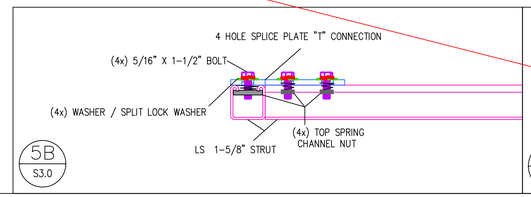
LINEAR SPLICE PLATE CONNECTION SIDE / TOP

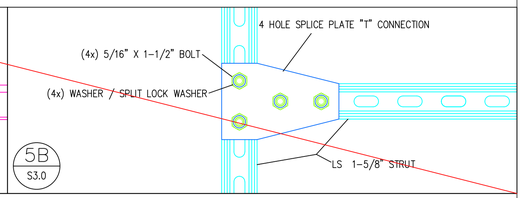




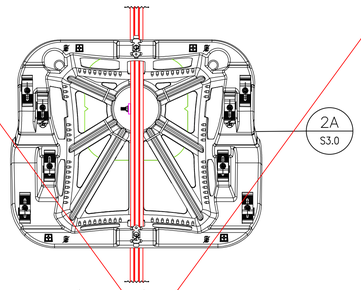
5 S3.0 CORNER SUPPORT SPLICE DETAILS
NTS

"T" SPLICE PLATE CONNECTION SIDE / TOP

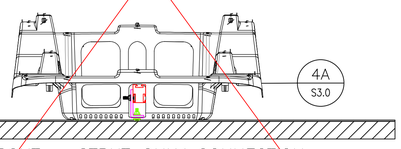




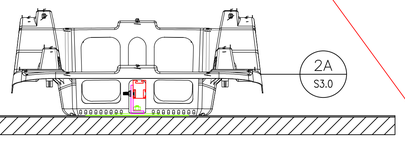
INTERNAL CORNER SUPPORT RUNNING NORTH–SOUTH ALTERNATE VIEWS



TOP – ANCHOR/STRUT/FASTRACK CONNECTION

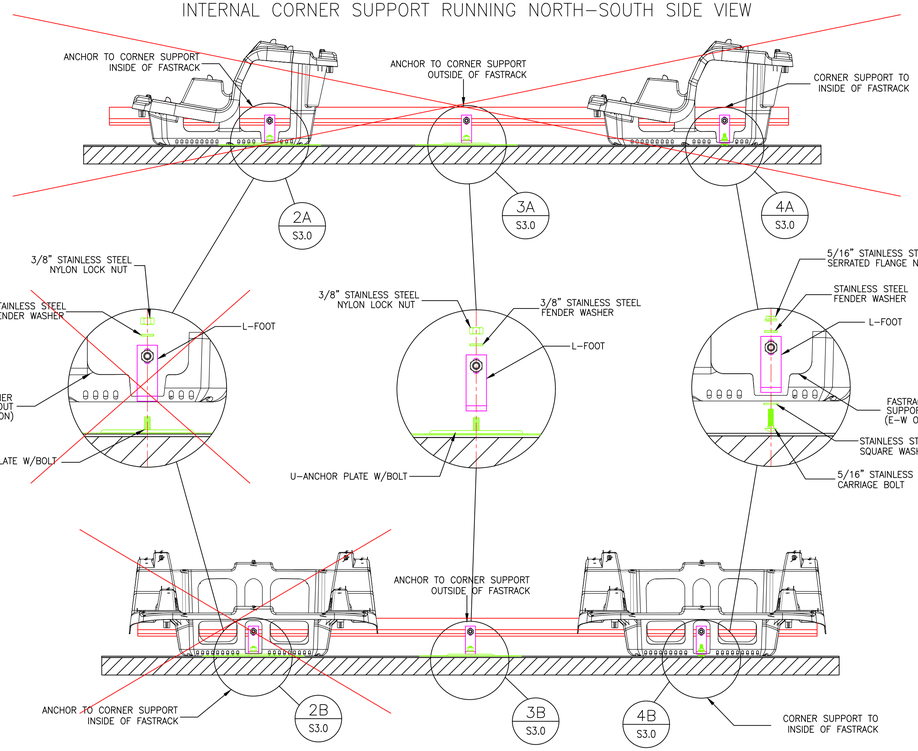


FRONT – STRUT ONLY CONNECTION



FRONT – ANCHOR/STRUT/FASTRACK CONNECTION

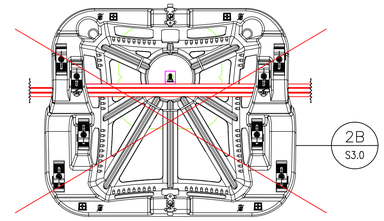
INTERNAL CORNER SUPPORT RUNNING NORTH–SOUTH SIDE VIEW



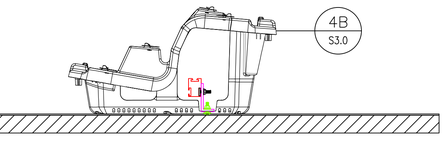
INTERNAL CORNER SUPPORT RUNNING EAST–WEST FRONT VIEW

2,3,4 S3.0 INTERNAL CORNER SUPPORT DETAILS
NTS

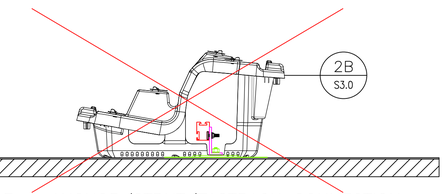
INTERNAL CORNER SUPPORT RUNNING EAST–WEST ALTERNATE VIEWS



TOP – ANCHOR/STRUT/FASTRACK CONNECTION



SIDE – STRUT ONLY CONNECTION



SIDE – ANCHOR/STRUT/FASTRACK CONNECTION

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NOTES

PROJECT INFO
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P

DRAWING INFO.

Date & Time	10/18/2017 4:50 PM	
Prepared/Approved by	JC	LR
Sheet Name	S3.0	

Racking Layout - Campus 2

0 16 32

SCALE: 3/32" = 1'-0"

SEE S2.0 AND S3.0 FOR SOLLEGA ANCHOR, PANEL, AND CORNER SUPPORT ATTACHMENT DETAILS

SITE

PROJECT SPECIFICATIONS	
PROJECT ID	**For Construction**
Roof Height (ft)	65
Wind Speed ASCE 7-10 (MPH)	110
Exposure Factor	C
Azimuth (deg.)	190
Module Brand	SunPower
Module Count (#)	498
Module Wattage (W)	327
Module Length (in)	61.30
Module Width (in)	41.20
Module Thickness (in)	1.81
Module Weight (lbs)	41.00
System Size (kW-DC)	162.85
Total FastRacks (#)	648
Wind Screens (#)	0
Roof Anchors (#)	56
Row Spacing (in)	53.60
Tilt Angle (DEG)	10
Total CMU Blocks (#)	844
Total Non-ballast Weight (lbs)	23958
Total Ballast Weight (lbs)	25320
Total System Weight (lbs)	49278
Total Load / Array Area (psf)	4.02

PROJECT INFO.

NOTES

2,7 S2.0 — Roof Anchor

1-4 S3.0 — 8' Rail

Ballast Required (#CMU blocks)

FASTRACK 510

= Ballast Per FastRack

CMU: 30 lb , 4"x8"x16"

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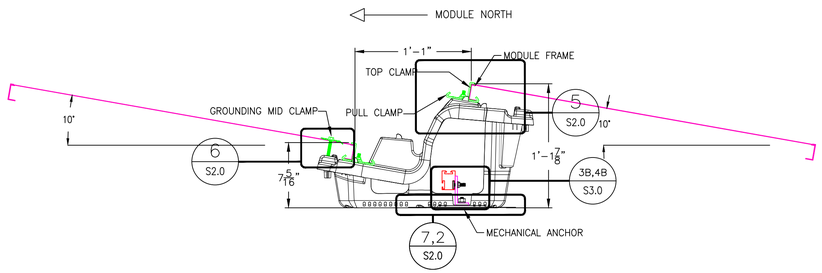
DRAWING INFO.

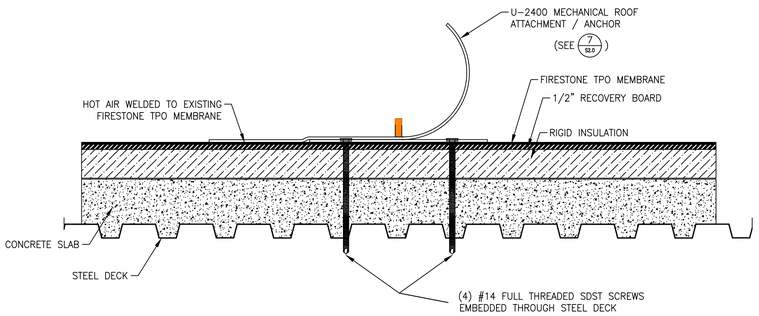
REV #	Description	Drawn	Approved	M/D/Y
0	Preliminary	JC	LR	11/30/17
1	Engineered Design	JC	LR	12/11/17

Date & Time	12/11/2017 4:08 PM
Sheet Name	S1.0

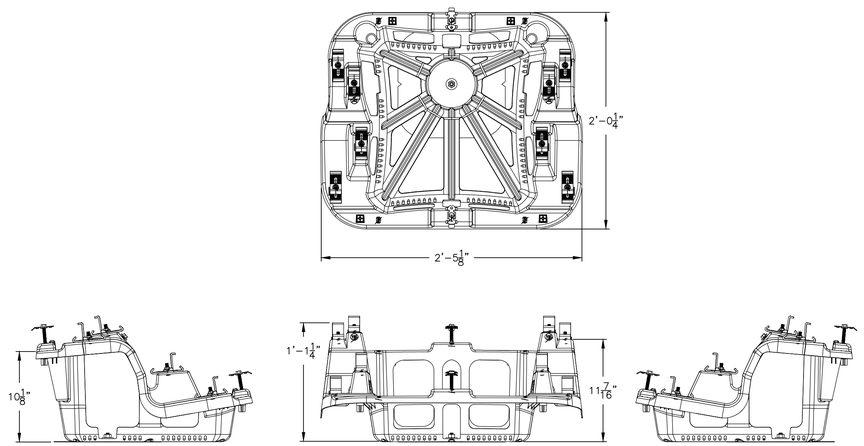
FORMATTED FOR 24" x 36"



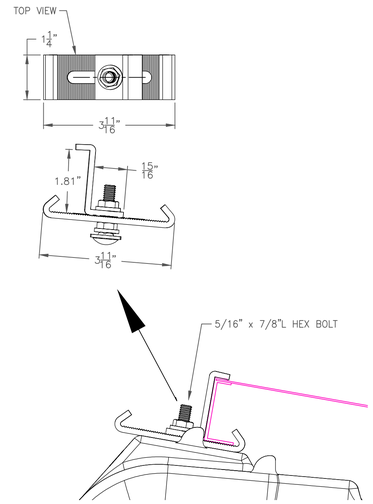
1 S2.0 MODULE ATTACHMENT DETAIL
SCALE: 1-1/2" = 1'-0"



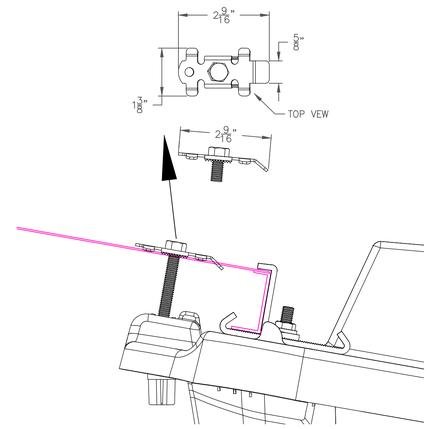
2 S2.0 ROOF ANCHOR ATTACHMENT DETAIL – SIDE
SCALE: 1-1/2" = 1'-0"



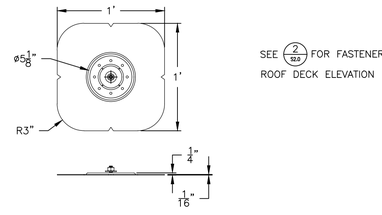
4 S2.0 SOLLEGA FAST RACK 510 (FR510)
SCALE: 1-1/2" = 1'-0"



5 S2.0 CLAMP DETAIL
SCALE: 6" = 1'-0"



6 S2.0 MID CLAMP DETAIL
SCALE: 6" = 1'-0"



SEE 2 S2.0 FOR FASTENER DETAILS AND ROOF DECK ELEVATION

7 S2.0 MECHANICAL ANCHOR DETAIL
SCALE: 1-1/2" = 1'-0"

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NOTES

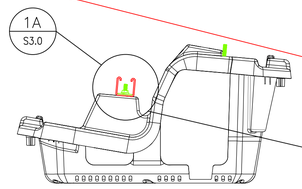
PROJECT INFO
Phone 415.517.7602

DRAWING INFO.		
Date & Time	12/12/2017 11:37 AM	
Prepared/Approved by	JC	LR
Sheet Name	S2.0	

EXTERNAL CORNER SUPPORT RUNNING EAST–WEST SIDE VIEWS

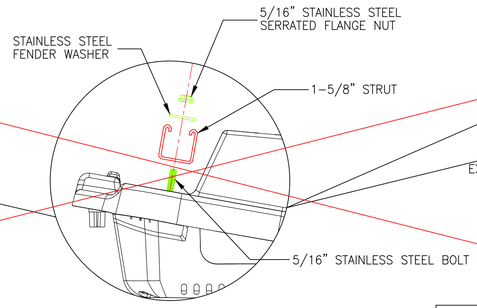
1 S3.0 EXTERNAL CORNER SUPPORT DETAILS
NTS

FASTRACK AT 5°

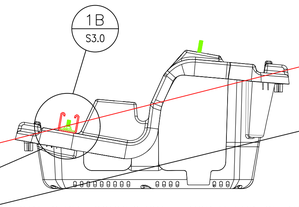


EXTERNAL STRUT CONNECTION – NORTH END OF ARRAY

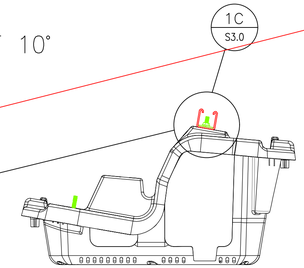
*NOTE: EXTERNAL STRUT ON SOUTH END OF ARRAY FOR FASTRACK AT 5° ASSEMBLY, BOLTS MUST BE MOVED TO THE 10° MOUNTS (HIGH SIDE OF FASTRACK) FOR CLEARANCE OF THE STRUT CONNECTION (SEE FASTRACK AT 10° SOUTH END OF ARRAY)



FASTRACK AT 10°

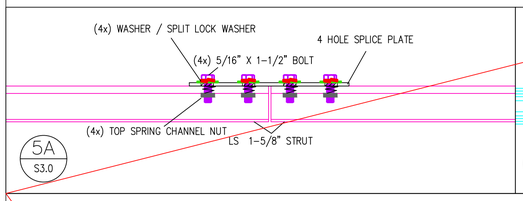


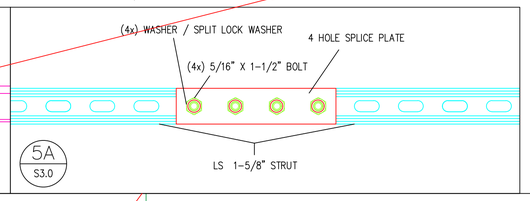
EXTERNAL STRUT CONNECTION – NORTH END OF ARRAY



*EXTERNAL STRUT CONNECTION – SOUTH END OF ARRAY

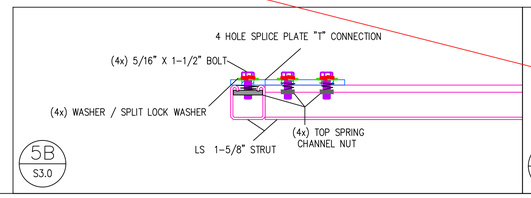
LINEAR SPLICE PLATE CONNECTION SIDE / TOP

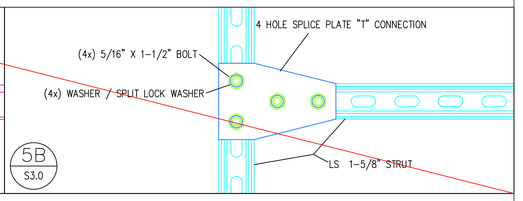




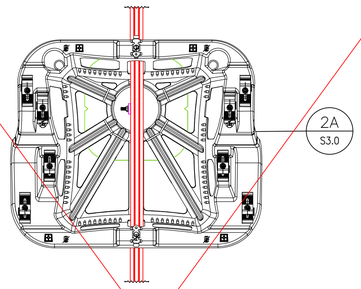
5 S3.0 CORNER SUPPORT SPLICE DETAILS
NTS

"T" SPLICE PLATE CONNECTION SIDE / TOP

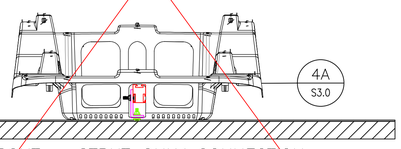




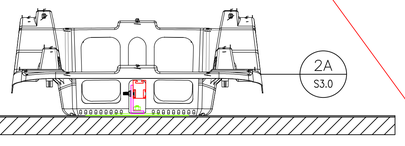
INTERNAL CORNER SUPPORT RUNNING NORTH–SOUTH ALTERNATE VIEWS



TOP – ANCHOR/STRUT/FASTRACK CONNECTION

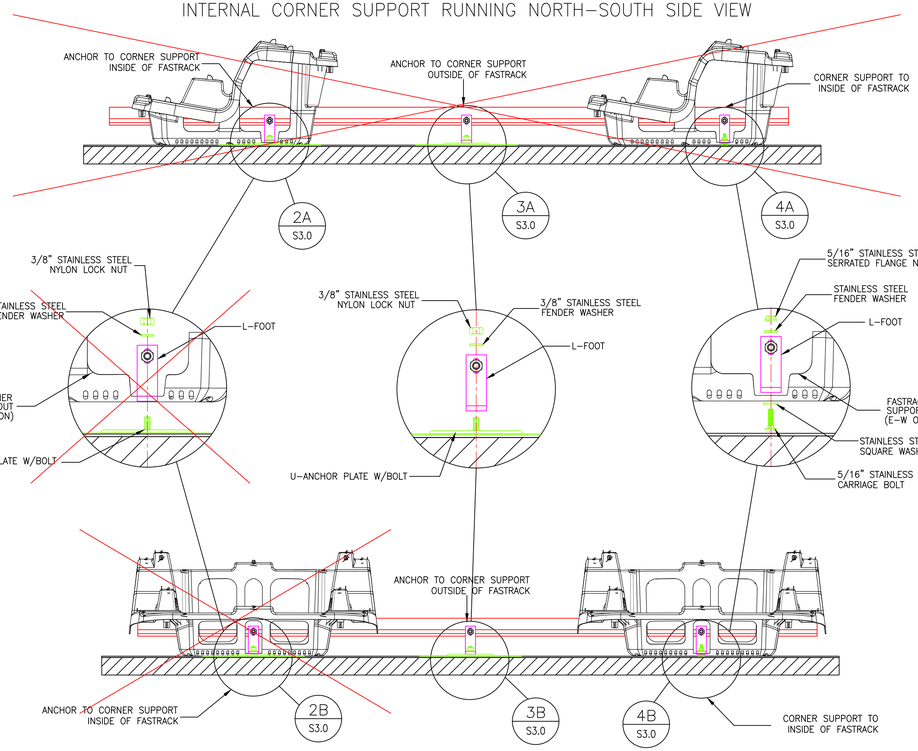


FRONT – STRUT ONLY CONNECTION



FRONT – ANCHOR/STRUT/FASTRACK CONNECTION

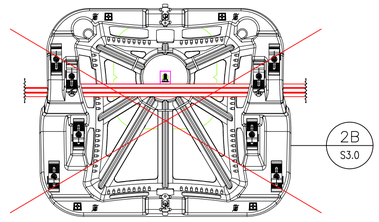
INTERNAL CORNER SUPPORT RUNNING NORTH–SOUTH SIDE VIEW



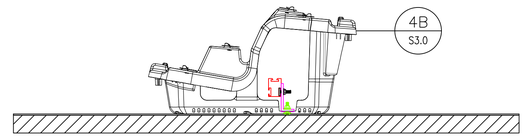
INTERNAL CORNER SUPPORT RUNNING EAST–WEST FRONT VIEW

2,3,4 S3.0 INTERNAL CORNER SUPPORT DETAILS
NTS

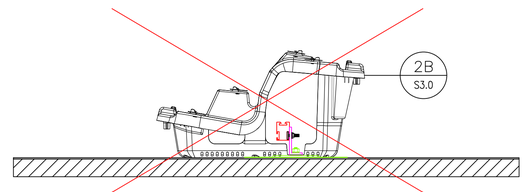
INTERNAL CORNER SUPPORT RUNNING EAST–WEST ALTERNATE VIEWS



TOP – ANCHOR/STRUT/FASTRACK CONNECTION



SIDE – STRUT ONLY CONNECTION



SIDE – ANCHOR/STRUT/FASTRACK CONNECTION

Sollega™

Sollega: 415-648-1299
2480 Mission Street, Ste. 107B, San Francisco, CA 94110
www.Sollega.com

NOTES

PROJECT INFO

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DRAWING INFO.

Date & Time	12/12/2017 11:37 AM	
Prepared/Approved by	JC	LR
Sheet Name	S3.0	

Ballast Configuration	Project ID: Roof / Module 1, PRELIMINARY DESIGN	Project Status:	For Construction

General Project Information

Customer
Building Owner
Installation Location

Site & Building Information

The following values are provided to Sollega by the Customer. It remains the responsibility of the Customer to verify with the Engineer of Record and with the Building Official that these values are appropriate for this project, and to notify Sollega immediately if these parameters require adjustment.

ASCE Perimeters	Unit	Equation	Value
Wind Speed ASCE 7-10 (3s gust)	mph	V	110
Ground Snow Load	psf		0
Exposure Category			C
Site Topographic Effects			None
Building Risk Category			II
Building Roof Height	ft	z	65

All pressure coefficients obtained using the methodologies and recommendations found in I.F.I Institut's Report # SOF01-1, based on results of Boundary Layer Wind Tunnel testing of the FastRack510 Mounting System.

Basic Velocity Pressures	Unit	Equation	Values	Notes
Velocity Pressure Exp. Coefficient		K_z	1.159	ASCE Table 30.3-1
Topographic Factor		K_{zt}	1.00	ASCE Fig. 26.8-1
Directionality Factor		K_D	0.85	ASCE Table 26.6-1
Basic Velocity Pressure	psf	q_z	30.51	ASCE 30.3.2 equation 30.3-1

Array Configuration & Weights	Unit	Equation	Value	Notes
Number of Sub-arrays			5	Distinctly disconnected systems
Module Manufacturer			SunPower	Per Customer
Module Wattage			327	
Module Dimensions	in		61.3x41.2x1.81	L x W x D
Module Weight	lbs		41	
Module Tilt Angle	deg		10	
Row Spacing	in		53.60	Distance from the edge of one module to the edge of the module in the next row
Number of Modules	#		528	
Number of FastRacks	#		695	
Ratio of FastRacks to Modules			1.32	The number of FastRacks divided by the number of Modules
Array Platform Area	sq ft		13,021	Area covered by Array
Total Roof Area	sq ft		37,180	Area of the entire roof

ITEM	Units	Equation	Per Module	Total	Notes
Module Area	sq ft	A_A	17.54	9,260	Per Manufacturer & Model above
Module Weight	lb		41.00	21,648	Per Manufacturer & Model above
FastRack Weight	lb		5.00	3,475	
Racking System Weight	lb	D	47.58	25,123	
Ballast Weight	lb	B_T	62.95	33,240	
Total Weight	lb	W_T	111.15	58,685	

ITEM	Units	Equation	Value	Notes
Ballast Block Weight	lb	W_{CMU}	30.0	Ballast used should be 16" x 8" x 4" nominal blocks (CMUs)
Are Roof Anchors Used?			Y	
ASD (Allowable) Anchor Strength Uplift	lb	S_R	600	Installer's engineer must verify that anchor connections used meet or exceed the assumed capacity.
ASD (Allowable) Anchor Strength Lateral	lb	S_L	900	Installer's engineer must verify that anchor connections used meet or exceed the assumed capacity.

Wind Load Factors from ASCE 7-10

All pressure coefficients obtained using the methodologies and recommendations in I.F.I Institut's Report # SOF01-1, based on results of Boundary Layer Wind Tunnel testing of the FastRack510 Mounting System.

ITEM	Units	Equation	Sub-Array												Total	Notes
Sub Array			**A**	**B**	**C**	**D**	**E**									
Min. Coefficient of Friction (Static)		COF														*+
Modules	#		153	129	78	30	138								**528**	
Array Area	sq ft	A_A	3,669	3,129	1,916	846	3,461								**13,021**	
Racking System Weight	lb	D_{Sys}	7,371	6,240	3,744	1,449	6,641								**25,445**	**
Module Area	sq ft	A_M	2,683	2,262	1,368	526	2,420								**9,260**	
FastRack Count	#		196	175	100	48	176								**695**	
Total Lift (After Load Combination)	lb	F_L	-16,867	-14,901	-8,192	-2,659	-15,200								**-57,818**	ASCE 7-10 Basic Load Combination 2.4.1
Total Net Lift	lb	$F_{LN} = F_L - (0.6 * D_{Sys})$	-12,444	-11,157	-5,946	-1,789	-11,215								**-42,551**	
Total Drag	lb	F_D	-2,278	-1,992	-1,075	-321	-2,127								**-7,793**	ASCE 7-10 Basic Load Combination 2.4.1
Roof Anchor Count	#	$RA_T = \Sigma RA$	17	19	6	4	14								**60**	
Total Roof Anchor Strength (Uplift)	lb	$S_{RT} = RA_T * S_R$	10,200	11,400	3,600	2,400	8,400								**36,000**	
Total Roof Anchor Strength (Lateral)	lb	$S_{LT} = RA_T * S_L$	15,300	17,100	5,400	3,600	12,600								**54,000**	
Total Net Lift After Anchors ++	lb	$F_{NA} = F_{LN} - RA_{ML} * RA_T$	-3,873	-3,071	-3,305	-372	-4,451									
Total Net Drag After Anchors	lb	$F_{ND} = F_D + RA_{MD} * RA_T$	0	0	0	0	0									States 0 for 0 or greater
Ballast Required	lb	$B_L = (F_{NA} + F_{ND}/COF) / .6$	6,454	5,118	5,508	621	7,418									
CMUs on FastRacks	#	CMU	294	234	203	56	321								**1,108**	CMU weight is 30 lbs
Designed Ballast Weight	lb	$B_T = \Sigma CMU * W_{CMU}$	8,820	7,020	6,090	1,680	9,630								**33,240**	
Avg Anchor Load (Lift)	lb	$RA_{ML} = (F_{LN} + (0.6*B_T)) / RA_T$	421	366	382	195	388									++
Avg Anchor Load (Drag)	lb	$RA_{MD} = F_D / RA_T$	134	105	179	80	152									
Overturning Resistance?	Y / N	$-F_{LN} < (0.6*B_T) + S_{RT}$	Y	Y	Y	Y	Y									
Sliding Resistance?	Y / N	$-F_D < S_{LT}$ OR $B_T > B_L$	Y	Y	Y	Y	Y									
Total Weight	lb	$W_T = B_T + D$	16,191	13,260	9,834	3,129	16,271								**58,685**	
Distributed Weight ***	psf	$W_{SA} = W_T / A_A$	4.41	4.24	5.13	3.70	4.70								**4.51**	
AVG global load on Roof	psf	$W_{GA} = W_T / A_A$													**1.58**	

Notes

* Customer to notify Sollega if different COF should be used. COF increases with larger arrays.
** Racking System Weight includes all components excluding ballast
*** Total distributed weight over the Array Area only.
\+ A blank coefficient of friction indicates that all lateral loads are resisted through anchorage.
++ Anchors are only effective for modules directly local to the attachment so design load is analyzed on a per module basis. This implies that anchors are not necesarrily loaded to total allowable strength .Value listed is a sum of remaining lift after

Seismic Calculations	Project ID: Roof / Module 1, PRELIMINARY DESIGN	Project Status:	For Construction

General Project Information

Customer
Building Owner
Installation Location

Seismic Configuration: Anchored Design Without Friction

Seismic Design Category		D	Class D "Stiff Soil" is default
Component Amplification Factor	a_p	1	component amplification factor that varies from 1.00 to 2.50 (select appropriate value from Table 13.5-1 or 13.6-1)
Spectral Acceleration Short Period *	S_{DS}	**1.266**	spectral acceleration, short period, as determined from Section 11.4.4
Component Response Modification Factor	R_P	1.5	component response modification factor that varies from 1.00 to 12 (select appropriate value from Table 13.5-1 or 13.6-1)
Seismic Importance Factor	I_e	1	Seismic importance factor that varies from 1.00 to 1.50 (see Section 1.5.1, Table 1.5-2)
Total System Weight	W_P	58,685	Total Deadload
Height of full structure	z	65.00	height in structure of point of attachment of component with respect to the base. For items at or below the base, z shall be taken as 0. The value of z/h need not exceed 1.0
Building Height	h	65.00	average roof height of structure with respect to the base
Roof Anchor Lateral Strength	lbs	900	Lateral Eccentric Moment strength. See Anchor Products testing Report.
Seismic Load	**F_P**	**59,436**	ASCE Equation 13.3-1, A
Applied Seismic Load	**$F_{Applied}$**	**41,605**	.7 of F_P as Prescribed by Basic Load Combinations in ASCE 2.4.1
Max Seismic Load	F_{pmax}	118,872	MAX
Min Seismic Load	F_{pmin}	22,288	MIN

13.3 SEISMIC DEMANDS ON NONSTRUCTURAL COMPONENTS

13.3.1 Seismic Design Force. The horizontal seismic design force (F_p) shall be applied at the component's center of gravity and distributed relative to the component's mass distribution and shall be determined in accordance with Eq. 13.3-1:

$$F_P = \frac{0.4 a_p S_{DS} W_P}{\left(\frac{R_P}{I_P}\right)} \left(1 + 2\frac{z}{h}\right) \quad (13.3\text{-}1)$$

F_P is not required to be taken as greater than

$$F_P = 1.6 S_{DS} I_P W_P \quad (13.3\text{-}2)$$

and F_P shall not be taken as less than

$$F_P = 0.3 S_{DS} I_P W_P \quad (13.3\text{-}3)$$

where

F_P = seismic design force
S_{DS} = spectral acceleration, short period, as determined from Section 11.4.4
a_P = component amplification factor that varies from 1.00 to 2.50 (select appropriate value from Table 13.5-1 or 13.6-1)
I_P = component importance factor that varies from 1.00 to 1.50 (see Section 13.1.3)
W_P = component operating weight
R_P = component response modification factor that varies from 1.00 to 12 (select appropriate value from Table 13.5-1 or 13.6-1)

			Sub Array											
			A	B	C	D	E							
Total Ballasted Weight	lbs.	58,685	16,164	13,286	9,820	3,171	16,243	0	0	0	0	0	0	0
Applied Seismic load per Array	$F_{Applied}$	41,605	11,460	9,419	6,962	2,248	11,516	0	0	0	0	0	0	0
Roof Anchors Needed	**#**	**48**	**13**	**11**	**8**	**3**	**13**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Seismic Configuration: Anchored Design WITH Friction**

Roofing Material type		TPO / PVC / EPDM / Foam	Non-Manufacturer Specific
Coefficient of Friction (Kinetic)	μ_k	0.59	

Contribution of Friction (SEAOC PV1 - 2012)
$(0.6\text{-}0.14S_{DS})(0.7\mu)W_{pf}$

			Sub Array											
			A	B	C	D	E							
Total Ballasted Weight, W_{pf}	lbs.	58,685	16,164	13,286	9,820	3,171	16,243	0	0	0	0	0	0	0
Applied Seismic load per Array	lbs.	41,605	11,460	9,419	6,962	2,248	11,516	0	0	0	0	0	0	0
Allowable Frictional Resistence	lbs.	10,246	2,822	2,320	1,715	554	2,836	0	0	0	0	0	0	0
Remaining Seismic Load	lbs.	31,359	8,637	7,099	5,248	1,695	8,680	0	0	0	0	0	0	0
25% of Applied Seismic Load	lbs.	10,401	2,865	2,355	1,741	562	2,879	0	0	0	0	0	0	0
Roof Anchors Needed^	**#**	**36**	**10**	**8**	**6**	**2**	**10**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Seismic Configuration: Un-Anchored Using Prescriptive Design Displacement**

Prescriptive Design Seismic Displacement***	SEAOC PV1-2012, Displacement (in)	
Distance Between Arrays	$0.5*(I_p)*\Delta_{MPV}$	22.5
Distance Between Arrays and Roof Objects	$(I_p)*\Delta_{MPV}$	45.0
Distance Between Arrays and Roof Edge With Parapet	$(I_e)*\Delta_{MPV}$	45.0
Distance Between Araays and Roof Edge Without Parapet	$1.5*(I_e)*\Delta_{MPV}$	67.5

Seismic Design Category	Δ_{MPV} (in)
A,B,C	6
D,E,F	$[(S_{DS}\text{-}.4)^2]*60$

Notes

For designs using prescriptive displacement (no anchors) or anchored with consideration for friction, displacement values must be listed on plan set documents. Each separate array shall be interconnected as an integral unit such that for any vetical section throught the array, the members and connections shall have design strength to resist a total horizontal force across the section, in both tension and compression, equal to the larger of $0.133*S_{DS}*W_1$ and $0.1*W_1$. Where, W_1 = the weight of the portion of the array, including ballast, on the side of the section that has smaller weight.

http://geohazards.usgs.gov/designmaps/us/

^ Design anchor strength used, is the greater of 25% of the applied seismic load and the remaining seismic load after consideration for allowable friction.
* S_{DS} is determined by the U.S. Seismic Design Maps Web Application. See link here: http://geohazards.usgs.gov/designmaps/us/
** See Sollega Friction Report for Specific Roof Material
*** See SEAOC PV1 STRUCTURAL AND SEISMIC REQUIREMENTS AND COMMENTARY FOR ROOFTOP SOLAR PHOTOVOLTAIC ARRAYS FINAL REPORT 2012

Sollega FastRack 510 Complies with the SEAOC PV2 requirements for both attached and un-attached system design. All friction values were determined by NRTL testing in compliance with the SEAOC recommendations as well as ASTMG115.

Ballast Configuration	Project ID: Roof / Module 1, PRELIMINARY DESIGN	Project Status:	For Construction

General Project Information

Customer	
Building Owner	Oracle - Campus 2
Installation Location	5805 Owens Dr, Pleasanton, CA 94588

Site & Building Information

The following values are provided to Sollega by the Customer. It remains the responsibility of the Customer to verify with the Engineer of Record and with the Building Official that these values are appropriate for this project, and to notify Sollega immediately if these parameters require adjustment.

ASCE Perimeters	Unit	Equation	Value
Wind Speed ASCE 7-10 (3s gust)	mph	V	110
Ground Snow Load	psf		0
Exposure Category			C
Site Topographic Effects			None
Building Risk Category			II
Building Roof Height	ft	z	65

All pressure coefficients obtained using the methodologies and recommendations found in I.F.I Institut's Report # SOF01-1, based on results of Boundary Layer Wind Tunnel testing of the FastRack510 Mounting System.

Basic Velocity Pressures	Unit	Equation	Values	Notes
Velocity Pressure Exp. Coefficient		K_z	1.159	ASCE Table 30.3-1
Topographic Factor		K_{ZT}	1.00	ASCE Fig. 26.8-1
Directionality Factor		K_D	0.85	ASCE Table 26.6-1
Basic Velocity Pressure	psf	q_z	30.51	ASCE 30.3.2 equation 30.3-1

Array Configuration & Weights	Unit	Equation	Value	Notes
Number of Sub-arrays			5	Distinctly disconnected systems
Module Manufacturer			SunPower	Per Customer
Module Wattage			327	
Module Dimensions	in		61.3x41.2x1.81	L x W x D
Module Weight	lbs		41	
Module Tilt Angle	deg		10	
Row Spacing	in		53.60	Distance from the edge of one module to the edge of the module in the next row
Number of Modules	#		498	
Number of FastRacks	#		648	
Ratio of FastRacks to Modules			1.30	The number of FastRacks divided by the number of Modules
Array Platform Area	sq ft		12,259	Area covered by Array
Total Roof Area	sq ft		38,060	Area of the entire roof

ITEM	Units	Equation	Per Module	Total	Notes
Module Area	sq ft	A_A	17.54	8,734	Per Manufacturer & Model above
Module Weight	lb		41.00	20,418	Per Manufacturer & Model above
FastRack Weight	lb		5.00	3,240	
Racking System Weight	lb	D	47.51	23,658	
Ballast Weight	lb	B_T	50.84	25,320	
Total Weight	lb	W_T	98.95	49,278	

ITEM	Units	Equation	Value	Notes
Ballast Block Weight	lb	W_{CMU}	30.0	Ballast used should be 16" x 8" x 4" nominal blocks (CMUs)
Are Roof Anchors Used?			Y	
ASD (Allowable) Anchor Strength Uplift	lb	S_R	600	Installer's engineer must verify that anchor connections used meet or exceed the assumed capacity.
ASD (Allowable) Anchor Strength Lateral	lb	S_L	900	Installer's engineer must verify that anchor connections used meet or exceed the assumed capacity.

Wind Load Factors from ASCE 7-10

All pressure coefficients obtained using the methodologies and recommendations in I.F.I Institut's Report # SOF01-1, based on results of Boundary Layer Wind Tunnel testing of the FastRack510 Mounting System.

ITEM	Units	Equation	Sub-Array												Total	Notes
Sub Array			**A**	**B**	**C**	**D**	**E**									
Min. Coefficient of Friction (Static)		COF														*+
Modules	#		79	105	54	65	195								**498**	
Array Area	sq ft	A_A	1,960	2,662	1,365	1,628	4,644								**12,259**	
Racking System Weight	lb	D_{Sys}	3,801	5,042	2,603	3,120	9,392								**23,958**	**
Module Area	sq ft	A_M	1,386	1,842	947	1,140	3,420								**8,734**	
FastRack Count	#		104	149	72	84	239								**648**	
Total Lift (After Load Combination)	lb	F_L	-8,438	-7,392	-7,524	-5,526	-17,048								**-45,929**	ASCE 7-10 Basic Load Combination 2.4.1
Total Net Lift	lb	$F_{LN} = F_L - (0.6 * D_{Sys})$	-6,157	-4,367	-5,962	-3,654	-11,413								**-31,554**	
Total Drag	lb	F_D	-1,091	-1,001	-1,035	-805	-2,230								**-6,163**	ASCE 7-10 Basic Load Combination 2.4.1
Roof Anchor Count	#	$RA_T = \Sigma RA$	9	10	7	6	24								**56**	
Total Roof Anchor Strength (Uplift)	lb	$S_{RT} = RA_T * S_R$	5,400	6,000	4,200	3,600	14,400								**33,600**	
Total Roof Anchor Strength (Lateral)	lb	$S_{LT} = RA_T * S_L$	8,100	9,000	6,300	5,400	21,600								**50,400**	
Total Net Lift After Anchors ++	lb	$F_{NA} = F_{LN} - RA_{ML} * RA_T$	-2,191	-1,432	-2,239	-1,538	-2,450									
Total Net Drag After Anchors	lb	$F_{ND} = F_D + RA_{MD} * RA_T$	0	0	0	0	0									States 0 for 0 or greater
Ballast Required	lb	$B_L = (F_{NA} + F_{ND}/COF) / .6$	3,652	2,387	3,732	2,564	4,084									
CMUs on FastRacks	#	CMU	173	170	130	117	254								**844**	CMU weight is 30 lbs
Designed Ballast Weight	lb	$B_T = \Sigma CMU * W_{CMU}$	5,190	5,100	3,900	3,510	7,620								**25,320**	
Avg Anchor Load (Lift)	lb	$RA_{ML} = (F_{LN} + (0.6*B_T)) / RA_T$	338	131	517	258	285									++
Avg Anchor Load (Drag)	lb	$RA_{MD} = F_D / RA_T$	121	100	148	134	93									
Overturning Resistance?	Y / N	$-F_{LN} < (0.6*B_T) + S_{RT}$	Y	Y	Y	Y	Y									
Sliding Resistance?	Y / N	$-F_D < S_{LT}$ OR $B_T > B_L$	Y	Y	Y	Y	Y									
Total Weight	lb	$W_T = B_T + D$	8,991	10,142	6,503	6,630	17,012								**49,278**	
Distributed Weight ***	psf	$W_{SA} = W_T / A_A$	4.59	3.81	4.76	4.07	3.66								**4.02**	
AVG global load on Roof	psf	$W_{GA} = W_T / A_A$													**1.29**	

Notes

* Customer to notify Sollega if different COF should be used. COF increases with larger arrays.
** Racking System Weight includes all components excluding ballast
*** Total distributed weight over the Array Area only.
\+ A blank coefficient of friction indicates that all lateral loads are resisted through anchorage.
++ Anchors are only effective for modules directly local to the attachment so design load is analyzed on a per module basis. This implies that anchors are not necesarrily loaded to total allowable strength .Value listed is a sum of remaining lift after

Seismic Calculations	Project ID: Roof / Module 1, PRELIMINARY DESIGN	Project Status:	For Construction

General Project Information

Customer	
Building Owner	Oracle - Campus 2
Installation Location	5805 Owens Dr, Pleasanton, CA 94588

Seismic Configuration: Anchored Design Without Friction

Seismic Design Category		D	Class D "Stiff Soil" is default
Component Amplification Factor	a_p	1	component amplification factor that varies from 1.00 to 2.50 (select appropriate value from Table 13.5-1 or 13.6-1)
Spectral Acceleration Short Period *	S_{DS}	**1.266**	spectral acceleration, short period, as determined from Section 11.4.4
Component Response Modification Factor	R_P	1.5	component response modification factor that varies from 1.00 to 12 (select appropriate value from Table 13.5-1 or 13.6-1)
Seismic Importance Factor	I_e	1	Seismic importance factor that varies from 1.00 to 1.50 (see Section 1.5.1, Table 1.5-2)
Total System Weight	W_P	49,278	Total Deadload
Height of full structure	z	65.00	height in structure of point of attachment of component with respect to the base. For items at or below the base, z shall be taken as 0. The value of z/h need not exceed 1.0
Building Height	h	65.00	average roof height of structure with respect to the base
Roof Anchor Lateral Strength	lbs	900	Lateral Eccentric Moment strength. See Anchor Products testing Report.
Seismic Load	**F_P**	**49,909**	ASCE Equation 13.3-1, A
Applied Seismic Load	**$F_{Applied}$**	**34,936**	.7 of F_P as Prescribed by Basic Load Combinations in ASCE 2.4.1
Max Seismic Load	F_{pmax}	99,818	MAX
Min Seismic Load	F_{pmin}	18,716	MIN

13.3 SEISMIC DEMANDS ON NONSTRUCTURAL COMPONENTS

13.3.1 Seismic Design Force. The horizontal seismic design force (F_p) shall be applied at the component's center of gravity and distributed relative to the component's mass distribution and shall be determined in accordance with Eq. 13.3-1:

$$F_P = \frac{0.4 a_p S_{DS} W_P}{\left(\frac{R_P}{I_P}\right)} \left(1 + 2\frac{z}{h}\right) \quad (13.3\text{-}1)$$

F_P is not required to be taken as greater than

$$F_P = 1.6 S_{DS} I_P W_P \quad (13.3\text{-}2)$$

and F_P shall not be taken as less than

$$F_P = 0.3 S_{DS} I_P W_P \quad (13.3\text{-}3)$$

where

F_P = seismic design force
S_{DS} = spectral acceleration, short period, as determined from Section 11.4.4
a_P = component amplification factor that varies from 1.00 to 2.50 (select appropriate value from Table 13.5-1 or 13.6-1)
I_P = component importance factor that varies from 1.00 to 1.50 (see Section 13.1.3)
W_P = component operating weight
R_P = component response modification factor that varies from 1.00 to 12 (select appropriate value from Table 13.5-1 or 13.6-1)

			Sub Array											
			A	B	C	D	E							
Total Ballasted Weight	lbs.	49,278	8,997	10,204	6,512	6,627	16,939	0	0	0	0	0	0	0
Applied Seismic load per Array	$F_{Applied}$	34,936	6,379	7,234	4,616	4,698	12,009	0	0	0	0	0	0	0
Roof Anchors Needed	**#**	**43**	**8**	**9**	**6**	**6**	**14**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Seismic Configuration: Anchored Design WITH Friction**

Roofing Material type		TPO / PVC / EPDM / Foam	Non-Manufacturer Specific
Coefficient of Friction (Kinetic)	μ_k	0.59	

Contribution of Friction (SEAOC PV1 - 2012)
$(0.6\text{-}0.14S_{DS})(0.7\mu)W_{pf}$

			Sub Array											
			A	B	C	D	E							
Total Ballasted Weight, W_{pf}	lbs.	49,278	8,997	10,204	6,512	6,627	16,939	0	0	0	0	0	0	0
Applied Seismic load per Array	lbs.	34,936	6,379	7,234	4,616	4,698	12,009	0	0	0	0	0	0	0
Allowable Frictional Resistence	lbs.	8,604	1,571	1,782	1,137	1,157	2,957	0	0	0	0	0	0	0
Remaining Seismic Load	lbs.	26,332	4,808	5,452	3,479	3,541	9,051	0	0	0	0	0	0	0
25% of Applied Seismic Load	lbs.	8,734	1,595	1,808	1,154	1,175	3,002	0	0	0	0	0	0	0
Roof Anchors Needed^	**#**	**32**	**6**	**7**	**4**	**4**	**11**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Seismic Configuration: Un-Anchored Using Prescriptive Design Displacement**

Prescriptive Design Seismic Displacement***	SEAOC PV1-2012, Displacement (in)	
Distance Between Arrays	$0.5*(I_p)*\Delta_{MPV}$	22.5
Distance Between Arrays and Roof Objects	$(I_p)*\Delta_{MPV}$	45.0
Distance Between Arrays and Roof Edge With Parapet	$(I_e)*\Delta_{MPV}$	45.0
Distance Between Araays and Roof Edge Without Parapet	$1.5*(I_e)*\Delta_{MPV}$	67.5

Seismic Design Category	Δ_{MPV} (in)
A,B,C	6
D,E,F	$[(S_{DS}\text{-}.4)^2]*60$

Notes

For designs using prescriptive displacement (no anchors) or anchored with consideration for friction, displacement values must be listed on plan set documents. Each separate array shall be interconnected as an integral unit such that for any vetical section throught the array, the members and connections shall have design strength to resist a total horizontal force across the section, in both tension and compression, equal to the larger of $0.133*S_{DS}*W_1$ and $0.1*W_1$. Where, W_1 = the weight of the portion of the array, including ballast, on the side of the section that has smaller weight.

http://geohazards.usgs.gov/designmaps/us/

^ Design anchor strength used, is the greater of 25% of the applied seismic load and the remaining seismic load after consideration for allowable friction.
* S_{DS} is determined by the U.S. Seismic Design Maps Web Application. See link here: http://geohazards.usgs.gov/designmaps/us/
** See Sollega Friction Report for Specific Roof Material
*** See SEAOC PV1 STRUCTURAL AND SEISMIC REQUIREMENTS AND COMMENTARY FOR ROOFTOP SOLAR PHOTOVOLTAIC ARRAYS FINAL REPORT 2012

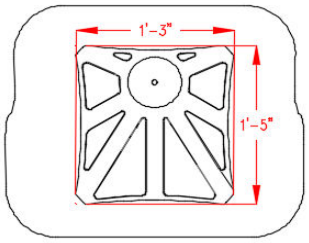
Sollega FastRack 510 Complies with the SEAOC PV2 requirements for both attached and un-attached system design. All friction values were determined by NRTL testing in compliance with the SEAOC recommendations as well as ASTMG115.

Sollega™

Solar Mounting System
Array Weight and Wind Load Advisory
Point Loading Report Details

Structural Support		Project Status: **Final Design**

E-W on Center Spacing for FastRacks	61.68 in
N-W on Center Spacing for FastRacks	53.61 in
First / Last column on center spacing of FastRacks (E-W)	45.68 in



FastRack Reactions

Deadload - 4 CMU's

Maximum Deadload / FastRack	lb	166.00	Includes one module, one FastRack and four ballast blocks (30 lbs per piece)
FastRack Bearing Area	sq ft	1.77	Assuming uniform bearing under FastRack. Includes only the bottom surface that is touching the roof.
Bearing Pressure on Roof	psf	93.79	
	psi	0.65	

Deadload - 3 CMU's

Maximum Deadload / FastRack	lb	136.00	Includes one module, one FastRack and three ballast blocks (30 lbs per piece)
FastRack Bearing Area	sq ft	1.77	Assuming uniform bearing under FastRack. Includes only the bottom surface that is touching the roof.
Bearing Pressure on Roof	psf	76.84	
	psi	0.53	

Deadload - 2 CMU's

Maximum Deadload / FastRack	lb	106.00	Includes one module, one FastRack and two ballast blocks (30 lbs per piece)
FastRack Bearing Area	sq ft	1.77	Assuming uniform bearing under FastRack. Includes only the bottom surface that is touching the roof.
Bearing Pressure on Roof	psf	59.89	
	psi	0.42	

Deadload - 1 CMU's

Maximum Deadload / FastRack	lb	76.00	Includes one module, one FastRack and one ballast block (30 lbs per piece)
FastRack Bearing Area	sq ft	1.77	Assuming uniform bearing under FastRack. Includes only the bottom surface that is touching the roof.
Bearing Pressure on Roof	psf	42.94	
	psi	0.30	

*Column Spacing on ends of rows is smaller because FastRacks are pushed in towards modules 16 in

Sample Coefficient Calculation

The following is a sample calculation of wind loading coefficients for fixed tilt (5°) 72-cell solar panels in landscape on a flat roofed commercial building using the results of the boundary layer wind tunnel test report produced by I.F.I (The Institute at Aachen University of Applied Sciences) [1] for the Sollega FR510 (FastRack 510) Ballasted/Anchored hybrid racking system.

This calculation shows the process and flow of how to utilize the wind tunnel test report to develop the negative pressure coefficients (negative indicating that the pressure is normal and away from the panel's surface) that are to be used in conjunction with ASCE 7-05, 7-10 and 7-16 load combinations and velocity pressures to determine ballast and anchoring requirements and distribution.

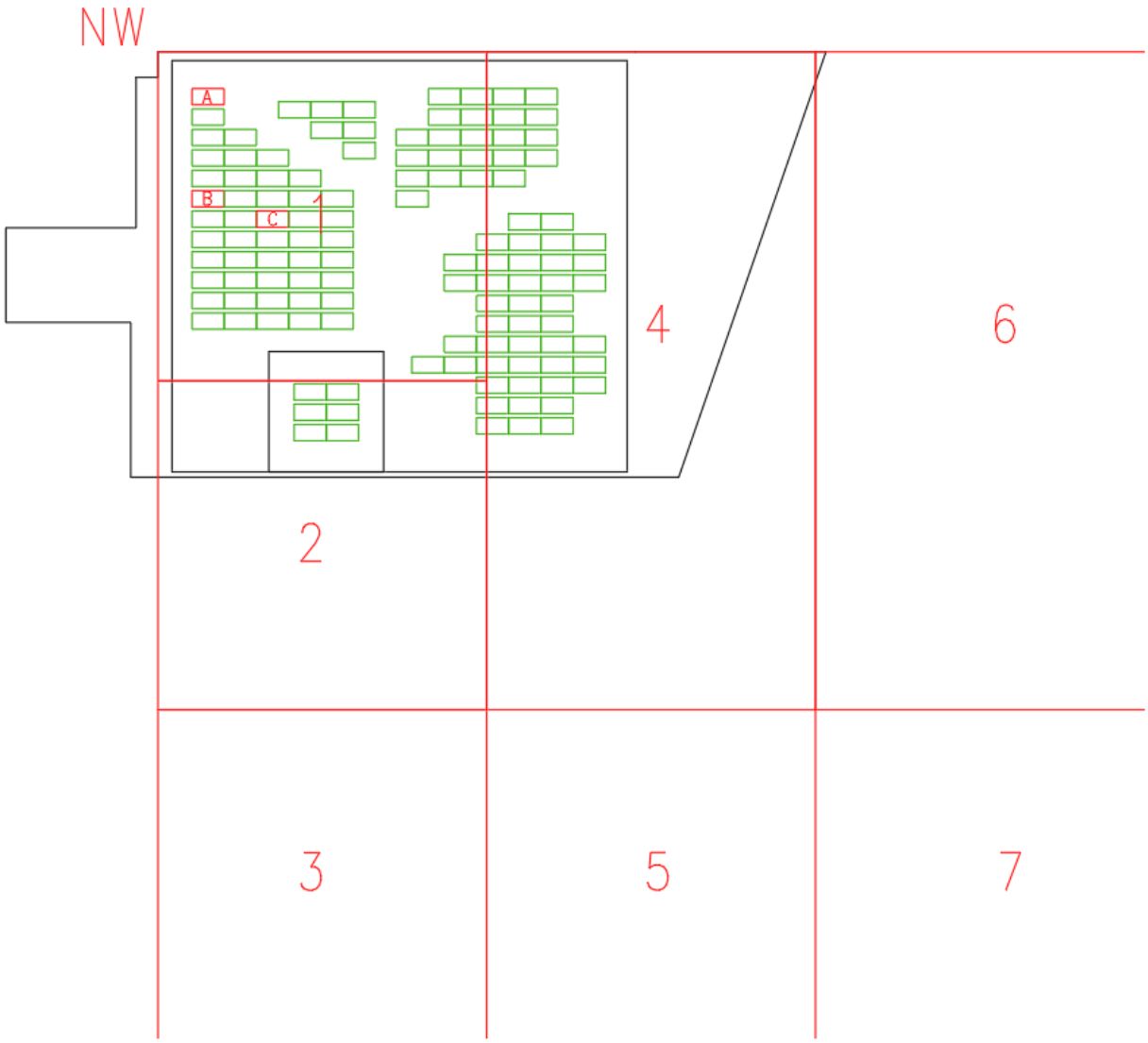
In this example we will determine the coefficients for 3 different modules from just one cornering wind direction, the Northwest, and only for the uplift mode of failure. In practice we determine coefficients for each solar panel from all four directions and both uplift and sliding modes of failure and use the worst case value for the final design. The process of determining these coefficients from all different directions and modes of failure are identical.

Project location, design parameters, building and module dimensions.

Project Name	Mike's Auto Body					
Installation Location	2288 N Main St., Walnut Creek, CA 94596					
Project ID	Roof / Module 1, PRELIMINARY DESIGN					
ASCE CODE-SET	ASCE 7-10					
Item	**Unit**	**Value**	PSF	**Item**	**Unit**	**Value**
Wind Speed Zone	mph	110	*18.45*	Status of Project		For Construction
Ground Snow Load	lbs	0		Number of Sub Arrays	#	5
Exposure Factor		B		Module Count	#	124
Topographic Effects		None		Total FastRack Count	#	187
Occupancy Category		II		Wind screens	#	
Building Height	ft	16.0		Corner Supports	#	
Building Azimuth	degree	177		Roof Anchors	#	14
Total Roof Area	sq ft	10,930		Roof Anchors Max Load (Tension)	lbs	600
Primary bldg length E-W	ft	164		Roof Anchors Max Load (Lateral)	lbs	900
Primary bldg length N-S	ft	85		Module Manufacturer	Manuf. Name	JA Solar
Parapet Height	ft	3.00				
				Module Wattage	W	350
Min Coefficient of Friction (COF)	Static	0.64		Module Length (E-W)	in	77.00
Min Coefficient of Friction (COF)	Kinetic	0.59		Module Width (N-S)	in	39.00
				Module Thickness	in	1.77
				Module Weight	lbs	58.4
				Roof Paver Minimum Weight	lbs	30.0
				Tilt Angle	degree	5
				Row Spacing	in	48.84

Roof Material	TPO / PVC / EPDM / Foam	
Seismic Value S_{DS}	Unitless	1.203

Simplified Array layout showing panel location on the building and the wind zones from the NW as defined in the wind tunnel test report from IFI [1].



The modules in question are labeled above as A,B and C. Their individual coefficients are derived from their relative position on the roof (roof zone 1 thru 7), their windward exposure in the North-south direction (North rows, interior rows, south rows) and their windward exposure in the East-West direction (1st – 4th module column and interior columns).

Module	Position
A	Zone 1 / North Row / 1st - 4th Column
B	Zone 1 / Inner Row / 1st - 4th Column
C	Zone 1 / Inner Row / 1st - 4th Column

These positions can be used to determine each panel's γ value based on the following table from [1].

Table D.1: Values for the power law exponent, γ, depending on roof position and row category

		Roof position 1	Roof position 2	Roof position 3	Roof position 4	Roof position 5	Roof position 6	Roof position 7
		γ [-]	γ [-]	γ [-]	γ [-]	γ [-]	γ [-]	γ [-]
North row, wind from north, 0°-90°	1st-4th module	-0.75	-1.25	-1.50	-1.50	-1.00	-2.00	-1.75
	Interior modules	-0.75	-1.25	-1.50	-1.50	-1.00	-2.00	-1.75
Inner rows, wind from north, 0°-90°	1st-4th module	-0.75	-1.25	-1.50	-1.50	-1.00	-2.00	-1.75
	Interior modules	-0.75	-1.25	-1.50	-1.50	-1.00	-2.00	-1.75
Inner rows, wind from south, 90°-180°	1st-4th module	-1.25	-1.50	-1.00	-1.00	-1.00	-1.00	-1.00
	Interior modules	-1.25	-1.50	-1.00	-1.00	-1.00	-1.00	-1.00
South row, wind from south, 90°-180°	1st-4th module	-1.25	-1.50	-1.00	-1.00	-1.00	-1.00	-1.00
	Interior modules	-1.25	-1.50	-1.00	-1.00	-1.00	-1.00	-1.00

This value is used to determine which equation that will be used to determine the value for A_n, or the "Normalized wind area". The values for modules A,B and C are

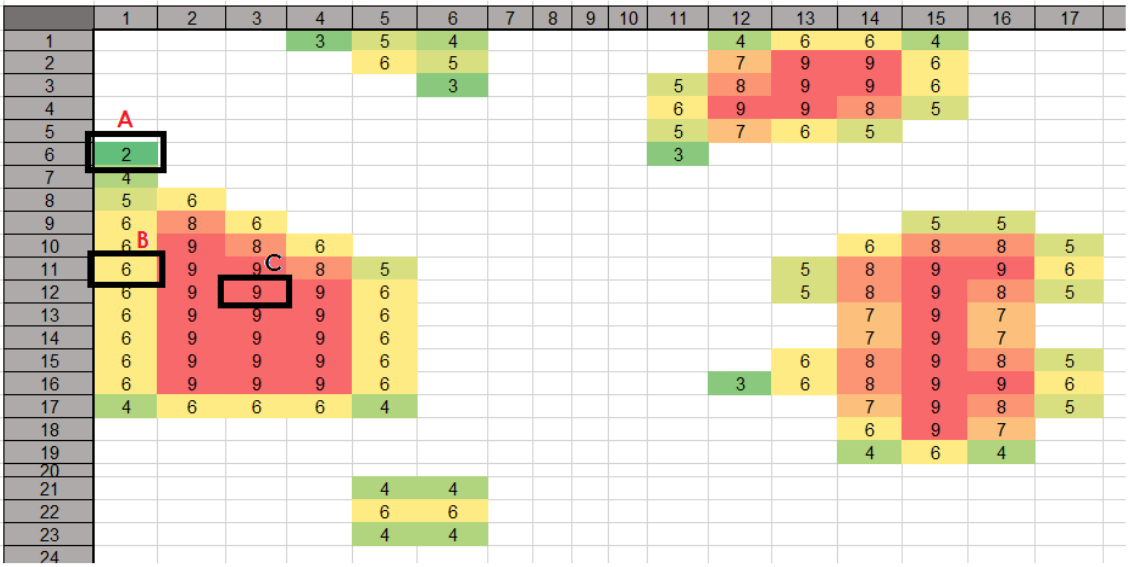
Module	γ Value
A	-0.75
B	-0.75
C	-0.75

Which results in the use of the following equation:

$$A_{n1} = \frac{1000 \cdot A}{\max\left[150;\min\left(h \cdot W_L;4 \cdot h^2;4 \cdot W_s^2\right)\right] \cdot \left(\frac{\max(6.12\text{m};h)}{12.5\text{m}}\right)^{\gamma}} \quad \text{,valid for } \gamma > -2 \text{ (D1)}$$

Where A is equal to the area of the panel times the number, n, of modules rigidly connected together. A conservative approach to calculating 'n' for each module is to consider the number of units directly adjacent to the module in question. The 'n' for each module is illustrated below in a screen shot of the load sharing assumption for each panel in the array.

# of Modules Considered Rigid or to be sharing loads. "n" in the calculation of A_n (The effective wind area).



With this assumption in place, the Normalized wind area for each module is

Module	Normalized Area (Unitless)
A	**15.12**
B	**45.36**
C	**68.04**

These values, used in conjunction with the appropriate table from [1] (see below) for modules in roof zone 1 in the uplift failure mode and the following equations for linearly interpolating between plotted data points are used to determine the C_{pM} for uplift for each panel.

1st - 4th Module				Interior Modules			
North Row	0°-90°	An [-]	cP MS [-]	North Row	0°-90°	An [-]	cP MS [-]
	i=a	1	-0.80		i=a	1	-0.38
	i=b	6	-0.44		i=b	1	-0.38
	i=c	28	-0.34		i=c	6	-0.28
	i=d	170	-0.18		i=d	60	-0.18
	i=e	10000	-0.18		i=e	10000	-0.18
Inner Rows	0°-90°	An [-]	cP MS [-]	Inner Rows	0°-90°	An [-]	cP MS [-]
	i=a	1	-1.24		i=a	1	-1.04
	i=b	6	-1.07		i=b	6	-0.44
	i=c	12	-0.61		i=c	12	-0.34
	i=d	170	-0.18		i=d	50	-0.18
	i=e	10000	-0.18		i=e	10000	-0.18

$$c_{pM,ab}(A_n) = c_{pM,a} + \frac{c_{pM,b} - c_{pM,a}}{\log(A_{n,b}) - \log(A_{n,a})} \cdot \left[\log(A_n) - \log(A_{n,a})\right]$$

for $A_{n,a} \le A_n \le A_{n,b}$

$$c_{pM,bc}(A_n) = c_{pM,b} + \frac{c_{pM,c} - c_{pM,b}}{\log(A_{n,c}) - \log(A_{n,b})} \cdot \left[\log(A_n) - \log(A_{n,b})\right]$$

for $A_{n,b} \le A_n \le A_{n,c}$

$$c_{pM,cd}(A_n) = c_{pM,c} + \frac{c_{pM,d} - c_{pM,c}}{\log(A_{n,d}) - \log(A_{n,c})} \cdot \left[\log(A_n) - \log(A_{n,c})\right]$$

for $A_{n,c} \le A_n \le A_{n,d}$

$$c_{pM,de}(A_n) = c_{pM,d} + \frac{c_{pM,e} - c_{pM,d}}{\log(A_{n,e}) - \log(A_{n,d})} \cdot \left[\log(A_n) - \log(A_{n,d})\right]$$

for $A_{n,d} \le A_n \le A_{n,e}$

The results for each module being

Module	C_{PM} for Uplift
A	**-0.38**
B	**-0.39**
C	**-0.33**

Along with this value, a parapet factor must similarly be determined for each module using the following table and equations

Data points for Parapet factors for Zone 1 for North to South winds in uplift

Uplift				
000-090	hp = 0.75 m		hp = 1.50 m	
	A [m²]	kp MU [-]	A [m²]	kp MU [-]
i = a	1	0,86	1	0,92
i = b	18	1,00	18	0,92
i = c	50	1,00	50	0,83
i = d	10000	1,00	10000	0,83

And

$$k_{p\,ab}(A) = k_{p\,a} + \frac{k_{p\,b} - k_{p\,a}}{\log(A_b) - \log(A_a)} \cdot \left[\log(A) - \log(A_a)\right]$$

for $A_a \le A \le A_b$

$$k_{p\,bc}(A) = k_{p\,b} + \frac{k_{p\,c} - k_{p\,b}}{\log(A_c) - \log(A_b)} \cdot \left[\log(A) - \log(A_b)\right]$$

for $A_b \le A \le A_c$

$$k_{p\,cd}(A) = k_{p\,c} + \frac{k_{p\,d} - k_{p\,c}}{\log(A_d) - \log(A_c)} \cdot \left[\log(A) - \log(A_c)\right]$$

for $A_c \le A \le A_d$

These values for winds from the north in zone 1 assuming uplift as the mode of failure are

Module	K_p Parapet factor
A	**.92**
B	**.97**
C	**.98**

Lastly we combine these values to get

Module	Final Coefficient for Uplift (C_{PM} x K_P)
A	**-0.35**
B	**-0.38**
C	**-0.32**

These are the final coefficients that will be compared to the similarly calculated values from the other wind directions and the sliding failure mode. The worst case of which is used in conjunction with the load combinations and velocity pressure as determined in ASCE 7 to calculate the ballast and/or anchoring requirements.

The image below is a screen shot from the ballast calculation tool built in Microsoft Excel showing all the coefficients determined for this layout for uplift and winds from the NW.

Final Uplift Coefficients for Winds from the NW.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1				0.33	0.30	0.32						0.32	0.29	0.38	0.48		
2					0.38	0.41						0.36	0.32	0.23	0.26		
3						0.48					0.30	0.34	0.32	0.23	0.18		
4	A										0.38	0.32	0.32	0.24	0.18		
5											0.41	0.36	0.38	0.28			
6	0.35										0.48						
7	0.44																
8	0.41	0.29															
9	0.38	0.34	0.29												0.42	0.42	
10	0.38 B	0.32	0.34	0.29										0.38	0.24	0.24	0.42
11	0.38	0.32	0.32 C	0.34	0.19								0.30	0.24	0.23	0.23	0.18
12	0.38	0.32	0.32	0.32	0.18								0.41	0.24	0.23	0.24	0.18
13	0.38	0.32	0.32	0.32	0.18									0.25	0.23	0.25	
14	0.38	0.32	0.32	0.32	0.18									0.25	0.23	0.25	
15	0.38	0.32	0.32	0.32	0.18								0.29	0.24	0.23	0.24	0.35
16	0.38	0.32	0.32	0.32	0.18							0.33	0.38	0.24	0.23	0.18	0.18
17	0.44	0.38	0.38	0.38	0.22									0.25	0.23	0.24	0.28
18														0.26	0.23	0.25	
19														0.30	0.26	0.30	
20																	
21					0.82	0.82											
22					0.34	0.34											
23					0.39	0.39											

To calculate the amount of ballast blocks needed per panel, the process above must be completed for all 4 directions and for the sliding mode of failure. For this example, at this point in the calculation, a reduction factor is included as per [1, pg. 28, section 4.12] to adjust the values for a 5° tilted rack system. (The values above are for the 10° tilted system).

The final coefficients used for the modules in the example above are:

Module	Final Design Coefficient
A	-.32 (for n=2, the value is reduced by 8%)
B	-.33 (for n=6, the value is reduced by 13%)
C	-.28 (for n=9, the value is reduced by 13%)

Next we must calculate the amount of uplift on each module, this is:

Module Surface Area (A)	X	Velocity Pressure @ Z (qz)	X	COS(5°)	X	Final Design Coefficient C_{PM}	X	Load Combination Factor For Wind
20.85 sq. ft.	X	18.45 PSF	X	COS(5°)	X	{-.32,-.33,-.28}	X	.6W

Module	Lift (in Lbs.) Per Module. Rounded to nearest lb.
A	74 lbs.
B	76 lbs.
C	64 lbs.

Next we find the net lift on each panel by subtracting the modified dead load of each module from the lift we calculated above. Since the appropriate load combination using ASD in ASCE 7-10 boils down to .6W + .6D (Combination 7 [2, pg. 51, 2.4.1]) we modify the modules' weight by .6. The Calculator also includes the dead load from the racking itself. Each racking unit is 5 lbs. and the ratio of racking units (FASTRACK 510) to modules is 1.51, so we add 5*1.51 = 7.6 lbs. to the weight of the module.

Module	NET Lift (in Lbs.) Per Module. Rounded to nearest lb.
A	74 lbs. - .6*(58.4 lbs. + 7.6 lbs.) = 34 lbs.
B	76 lbs. - .6*(58.4 lbs. + 7.6 lbs.) = 36 lbs.
C	64 lbs. - .6*(58.4 lbs. + 7.6 lbs.) = 24 lbs.

Dividing this value by the load combination of .6 for dead load, gives us the amount of ballast required to fully resist the calculated wind load.

Module	Ballast required in lbs.	# of 30 lbs. blocks (rounded to nearest whole block)
A	34 lbs. / .6 = 57 lbs.	57 lbs / 30 lbs = ~2x (30 lbs 4x8x16 in blocks)
B	36 lbs. / .6 = 60 lbs.	60 lbs / 30 lbs = ~2x (30 lbs 4x8x16 in blocks)
C	24 lbs. / .6 = 40 lbs.	40 lbs / 30 lbs = ~2x (30 lbs 4x8x16 in blocks)

Since ballast is shared between neighboring modules, the designer/engineer must consider how many ballast trays (FASTRACK 510's) are attributed to the module in question and distribute the required ballast appropriately. For example, module A shares 2 trays with the module directly South of it and also has 2 trays devoted solely to itself on its North end, so it has a total of 3 trays devoted to it, making it only necessary to have a min of 1 block per tray. This same strategy is employed throughout the entire system design along with consideration for uplift that is being resisted by the anchors within the arrays.

For further clarification or questions please contact Sollega at info@sollega.com or call 415.648.1299

[1] Wind loads on the solar ballasted roof mount system "FastRack 510" of Sollega, Inc., Thorsten Kray, 02/28/2017, I.F.I. Institut fur Industriearodynamik GmbH Institute at Aachen University of Applied Sciences.

[2] ASCE 7-10, Minimum Design Loads for Buildings and Other Structures, Copyright 2010, The American Society of Civil Engineers.