RIGHT ANGLE *ENGINEERING*

STRUCTURAL CERTIFICATION REPORT

Roof-mounted Solar Panels

October 04, 2023

To: Solarise
2936 Janitell Rd.
Colorado Springs, CO 80906

Re: Timothy & Marcie Murphy
1320 N Nevada Ave
Colorado Springs, CO 80903
AHJ: **Pikes Peak (Region)**, CO

Solarise proposes to install new roof-mounted solar panels at this residence and asked *Right Angle Engineering* to review the existing structure for suitability. This letter summarizes the methods that were used to survey, evaluate, and certify the existing roof framing and the attachment of the new solar panels to it.

STRUCTURAL DESIGN

Building Code:	Pikes Peak Regional Building Code 2023
Design Standards:	ASCE 7-16
Snow:	Ground: p_g= 44.0 psf | Flat Roof: p_f= 30.49 psf | Sloped Roof: p_s= 18.3 psf
Wind:	Ultimate Wind Speed = 130.0 mph | Exposure = C
Seismic:	Risk Category = 2 | Seismic Design Category = A | Site Class = D

STRUCTURE

Field Technicians from *Solarise* visited the site and observed the existing structure :

Array Name	Panel Quantity	Roof Framing	Material	Pitch
Array 1	5	2x6 Rafter | 16" o.c.	Asphalt Shingles	45°
Array 2	6	2x4 Truss | 16" o.c.	Asphalt Shingles	34°

ANCHORAGE

The solar panel anchorage shall be installed according to the manufacturer's most current installation manual. Anchorage shall be staggered to distribute the load evenly to adjacent roof members. The solar panels should be mounted parallel (max 10 inches) to the roof surface.

Array Name	Connection Type	Fastener	Max Anchorage Spacing
Array 1	FlashLoc Duo	(2)-#12-14 wood screws (2.5" embedment) into roof substructure	48"
Array 2	FlashLoc Duo	(2)-#12-14 wood screws (2.5" embedment) into roof substructure	48"

Installation Instructions

Solar panels and the equipment shall be installed per the manufacturer's installation specifications. Improper installation will void this certification. Deviations from the approved structural plans (including equipment substitutions) are not allowed without written approval from Right Angle Engineering. Prior to installation, the installer should:

- Confirm that the existing structure matches the information provided in the structural survey, the approved installation plans and this certification.
- Identify discrepancies between this certification and the approved installation plans. If found, then this certification shall govern.
- Identify structural elements that are dangerous (cracked, broken, excessive sag, signs of overstress, rot,decay, fire, water). If found, installation shall cease until those elements are adequately abated and made to comply with the referenced building code.
- Verify that both the existing structure and the solar addition has been permitted through the AHJ.

STRUCTURAL CERTIFICATION

I certify the addition of solar panels on the roof of this structure does not cause the structure to become unsafe or make it generally less compliant with the life-safety requirements of the referenced building code. Based on the evaluation methods described below, for the loads that exist at this site, the existing framing will safely support the new solar panels if they are installed and attached correctly. Electrical design is not included in this certification.

Array Name	Certification Method	Retrofits
Array 1	Stress analysis Pikes Peak Regional Building code 324.4.1	None required
Array 2	Stress analysis Pikes Peak Regional Building code 324.4.1	None required

Regards,

10/04/2023

Robert D. Smythe, P.E.
Right Angle Engineering

Job Details

Roof Snow Load - ASCE 7-16	
Ground Snow Load (p_g) *Section 7.2*	44.0 psf
Exposure Factor (C_e) *Table 7.3-1*	0.9
Thermal Factor (C_t) *Table 7.3-2*	1.1
Importance Factor (I_s) *Table 1.5-2*	1
Flat Roof Snow Load (p_f) *Equation 7.3-1*	30.49 psf
Slippery Surface Slope Factor (C_s) *Figure 7.4-1*	0.6
Non-Slippery Surface Slope Factor (C_s) *Figure 7.4-1*	1
Roof Snow Load *Equation 7.4-1*	30.49 psf
Reduced Snow Load (Slippery Surface) *Equation 7.4-1*	18.3 psf

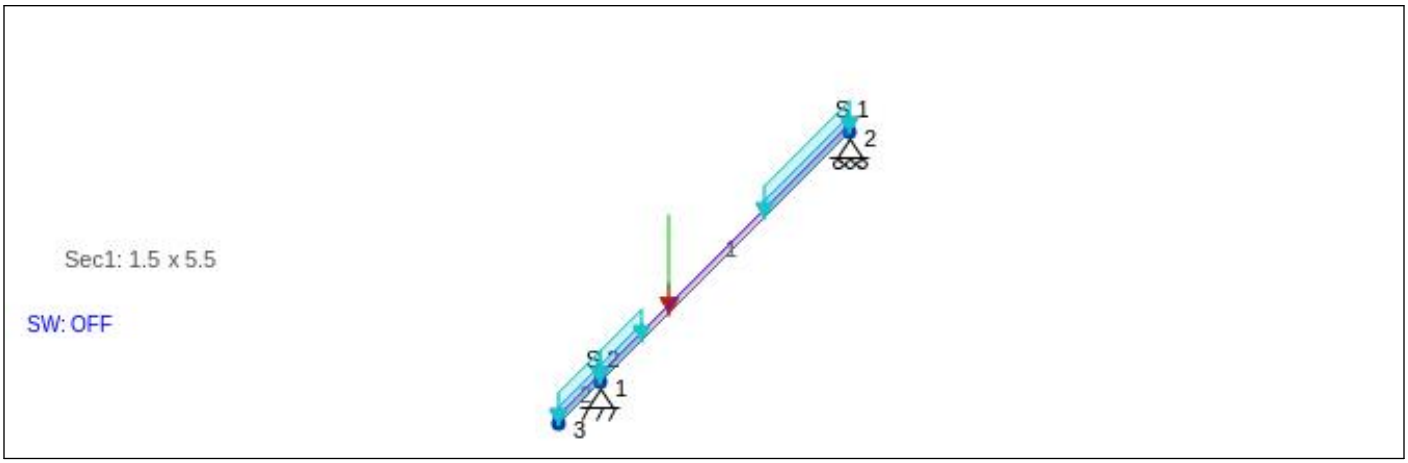
Design Criteria	
Wind Speed (V_{ult}) *Local Design Criteria*	130.0mph
Exposure Category	C
Risk Category	2
Mean Roof Height	20 ft
Roof Type	Gable Roof
Building Type	Enclosed

Roof Live Load	
Existing Roof Live Load *ASCE 7-16 Table 4.3-1*	20 psf

[1]Roof Dead Load			
Asphalt Shingles	2.0 psf	**No Drywall**	0.0 psf
5/8" Plywood Sheathing	2.0 psf	**Solar Panel Array**	2.74 psf
Roof Framing	2.36 psf	**Dead Load Without Panels**	7.56 psf
Insulation	1.2 psf		

[1]Roof Dead Load is taken from the worst case scenario dead load from all arrays of the job in order to provide a more conservative evaluation.

Array 1



Array Details	
Roof Framing	2x6 Rafter *DF No.2*
Spacing	16.0"
Beam Span	9.0'
Roof Pitch	45°
Panel Quantity	5
Panel Array Area	108.18 ft²
Panel Orientation	Portrait
Lag Screw Embedment	2.5"
Roof Attachment Type	FlashLoc Duo (2)-#12-14 wood screws
Shear Capacity *FlashLoc Duo Test Data*	190.0 lbs
Pullout Capacity *FlashLoc Duo Test Data*	495.0 lbs
Velocity Pressure *Equation 26.10-1 (K_z=0.9, K_{ht}=1, K_d=0.85, K_e=0.8)*	26.62 psf

GCP Zones	1/2e/ 2r	2n/3r	3e
GC_p *Figure 30.3-(2A-5B)*	-1.8	-2.0	-3.2
Design Pressure Up [psf] *Equation 29.4-7 γ_a=0.78 γ_E=1.0*	-37.2	-41.3	-66.1
Exposed Design Pressure Up [psf] *γ_a=0.78 γ_E=1.5*	-55.8	-62.0	-99.2
Design Pressure Down [psf]	16.5	16.5	16.5
Tributary Area [ft^2]	12.8	12.8	12.8
Maximum Connection Spacing [in]	49	49	49
Maximum Rail Span [in]	48	48	48
Maximum Rail Cantilever [in]	16	16	16
Design Connection Spacing [in]	48	48	48
Deign Connection Spacing (exposed) [in]	48	48	32

Design Ratio

Member ID	P	M_z	V_y	C	SR	D	Status
1	0.013	0.386	0.164	0.35	0.044	0.256	Pass
2	0.01	0.07	0.062	0.08	0.044	0.391	Pass

Member Design Capacity (LRFD)

Member ID	F'_b(ksi)	F'_t(ksi)	F'_v(ksi)	F'_c(ksi)	F'_{cp}(ksi)	E'(ksi)	E'_{min}(ksi)
1	2.324	1.292	0.311	2.566	0.939	1600.0	1041.216
2	2.324	1.292	0.311	2.566	0.939	1600.0	1041.216

Node Coordinates

ID	X Coordinate	Y Coordinate
1	0.000	0.000
2	9.000	9.000
3	-1.500	-1.500

Members

ID	Node A	Node B	Section	Node A Fixity	Node B Fixity	Length
1	1	2	1	FFFFFF	FFFFFF	12.728
2	3	1	1	FFFFFF	FFFFFF	2.121

Supports

ID	Node ID	Restraint Code
1	2	RFFRRR
2	1	FFFFFR

Materials

ID	Name	Young's Modulus	Density	Poisson's Ratio
1	NDS - Table 4A - DOUGLAS FIR-LARCH - No.2- 2in & wider	1600.000	33.308	0.400

Sections

ID	Name	Depth	Width	Shear Area Z	Shear Area Y	Torsion Radius
1	1.5 x 5.5	6.000	1.500	7.502	7.500	1.495

ID	Centroid Y	Centroid Z	Area	Y-Axis MoI	Z-Axis MoI	Torsion Constant
1	0.750	3.000	9.000	1.688	27.000	5.687

Point Loads

ID	Load Group	Member	Position %	Y Magnitude
1	Solar-Snow	1	27.778%	-0.127
2	Solar	1	27.778%	-0.022

Member Distributed Loads

ID	Load Group	Start Position	End Position	Member	Y Magnitude
1	Dead Load	0.000%	100.000%	2	-0.010
2	Dead Load	0.000%	100.000%	1	-0.010
3	Roof Live Load	0.000%	100.000%	2	-0.021
4	Roof Live Load	0.000%	16.667%	1	-0.021
5	Roof Live Load	65.823%	100.000%	1	-0.021
6	Snow Load	0.000%	100.000%	2	-0.041
7	Snow Load	0.000%	16.667%	1	-0.041
8	Snow Load	65.823%	100.000%	1	-0.041

Load Combinations

ID	Name	Dead Load Factor	Snow Load Factor	Solar Factor	Solar-Snow Factor	Roof Live Load Factor
1	1. 1.4D	1.4	0	1.4	0	0
2	3. 1.2D + 1.6Lr	1.2	0	1.2	0	1.6

3	3. 1.2D + 1.6S	1.2	1.6	1.2	1.6	0
4	4. service loads A	0	1	0	1	0
5	5. service loads B	0	0	0	0	1

Internal Member Forces and Moments

Member	Axial Force (Min/Max)	Shear Force Y (Min/Max)	Shear Force Z (Min/Max)	Torsion (Min/Max)	Bending Moment Y (Min/Max)	Bending Moment Z (Min/Max)
1	-0.264 / 0.305	-0.264 / 0.305	0.000 / 0.000	0.000 / 0.000	0.000 / 0.000	-0.123 / 0.673
2	-0.116 / 0.000	-0.116 / 0.000	0.000 / 0.000	0.000 / 0.000	0.000 / 0.000	-0.123 / 0.000

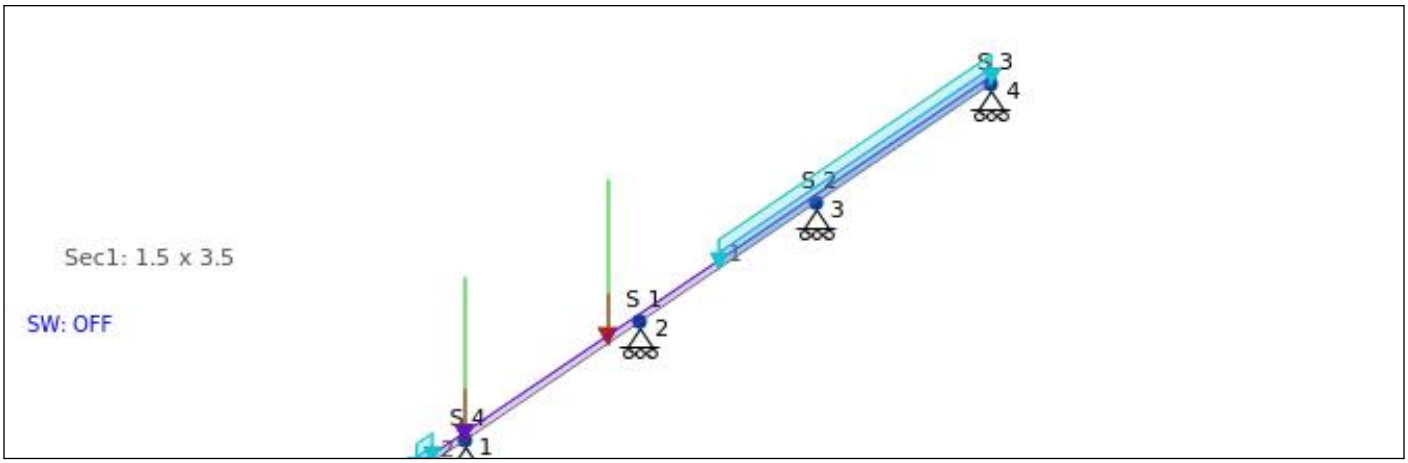
Member Displacement Span Check

Member	Length	Max Relative Displacement	Span Method 1
1	12.728	0.217	L/704
2	2.121	0.111	L/230

Member Stresses

Member	Axial Stress (Min/Max)	Torsion Stress (Min/Max)	Shear Stress Y (Min/Max)	Shear Stress Z (Min/Max)	Top Bending Moment Z (Min/Max)	Bottom Bending Moment Z (Min/Max)
1	-0.029 / 0.034	0.000 / 0.000	-0.044 / 0.051	-0.000 / -0.000	-0.164 / 0.897	-0.897 / 0.164
2	-0.013 / 0.000	0.000 / 0.000	-0.019 / 0.000	0.000 / 0.000	-0.164 / 0.000	0.000 / 0.164

Array 2



Array Details	
Roof Framing	2x4 Non Standard *DF No.2*
Spacing	16.0"
Beam Span	5.5', 5.5', 5.5'
Roof Pitch	34°
Panel Quantity	6
Panel Array Area	129.81 ft²
Panel Orientation	Portrait
Lag Screw Embedment	2.5"
Roof Attachment Type	FlashLoc Duo (2)-#12-14 wood screws
Shear Capacity *FlashLoc Duo Test Data*	190.0 lbs
Pullout Capacity *FlashLoc Duo Test Data*	495.0 lbs
Velocity Pressure *Equation 26.10-1 (K_z=0.9, K_{ht}=1, K_d=0.85, K_e=0.8)*	26.62 psf

GCP Zones	1/2e/ 2r	2n/3r	3e
GC_p *Figure 30.3-(2A-5B)*	-1.8	-2.0	-3.2
Design Pressure Up [psf] *Equation 29.4-7 γ_a=0.79 γ_E=1.0*	-37.9	-42.1	-67.4
Exposed Design Pressure Up [psf] *γ_a=0.79 γ_E=1.5*	-56.8	-63.1	-101.0
Design Pressure Down [psf]	16.8	16.8	16.8
Tributary Area [ft^2]	16.2	16.2	12.7
Maximum Connection Spacing [in]	62	62	49
Maximum Rail Span [in]	48	48	48
Maximum Rail Cantilever [in]	16	16	16
Design Connection Spacing [in]	48	48	48
Deign Connection Spacing (exposed) [in]	48	48	32

Design Ratio

Member ID	P	M_z	V_y	C	SR	D	Status
1	0.025	0.275	0.272	0.3	0.035	0.141	Pass
2	0.004	0.073	0.041	0.077	0.035	0.127	Pass

Member Design Capacity (LRFD)

Member ID	F^l_b(ksi)	F^l_t(ksi)	F^l_v(ksi)	F^l_c(ksi)	F^l_{cp}(ksi)	E^l(ksi)	$E_{min}{}^l$(ksi)
1	2.681	1.49	0.311	2.683	0.939	1600.0	1041.216
2	2.681	1.49	0.311	2.683	0.939	1600.0	1041.216

Node Coordinates

ID	X Coordinate	Y Coordinate
1	0.000	0.000
2	5.500	3.710
3	11.000	7.420
4	16.500	11.129
5	-1.500	-1.012

Members

ID	Node A	Node B	Section	Node A Fixity	Node B Fixity	Length
1	1	4	1	FFFFFF	FFFFFF	19.903
2	5	1	1	FFFFFF	FFFFFF	1.809

Supports

ID	Node ID	Restraint Code
1	2	RFFRRR
2	3	RFFRRR
3	4	RFFRRR
4	1	FFFFFR

Materials

ID	Name	Young's Modulus	Density	Poisson's Ratio
1	NDS - Table 4A - DOUGLAS FIR-LARCH - No.2- 2in & wider	1600.000	33.308	0.400

Sections

ID	Name	Depth	Width	Shear Area Z	Shear Area Y	Torsion Radius
1	1.5 x 3.5	4.000	1.500	5.000	5.000	1.463

ID	Centroid Y	Centroid Z	Area	Y-Axis MoI	Z-Axis MoI	Torsion Constant
1	0.750	2.000	6.000	1.125	8.000	3.437

Point Loads

ID	Load Group	Member	Position %	Y Magnitude
1	Solar-Snow	1	0.000%	-0.233
2	Solar	1	0.000%	-0.037
3	Solar-Snow	1	27.182%	-0.233
4	Solar	1	27.182%	-0.037

Member Distributed Loads

ID	Load Group	Start Position	End Position	Member	Y Magnitude
1	Dead Load	0.000%	100.000%	2	-0.010
2	Dead Load	0.000%	100.000%	1	-0.010
3	Roof Live Load	0.000%	33.333%	2	-0.021
4	Roof Live Load	48.304%	100.000%	1	-0.021
5	Snow Load	0.000%	33.333%	2	-0.041
6	Snow Load	48.304%	100.000%	1	-0.041

Load Combinations

ID	Name	Dead Load Factor	Snow Load Factor	Solar Factor	Solar-Snow Factor	Roof Live Load Factor
1	1. 1.4D	1.4	0	1.4	0	0
2	3. 1.2D + 1.6Lr	1.2	0	1.2	0	1.6
3	3. 1.2D + 1.6S	1.2	1.6	1.2	1.6	0
4	4. service loads A	0	1	0	1	0
5	5. service loads B	0	0	0	0	1

Internal Member Forces and Moments

Member	Axial Force (Min/Max)	Shear Force Y (Min/Max)	Shear Force Z (Min/Max)	Torsion (Min/Max)	Bending Moment Y (Min/Max)	Bending Moment Z (Min/Max)
1	-0.228 / 0.168	-0.337 / 0.249	0.000 / 0.000	0.000 / 0.000	0.000 / 0.000	-0.245 / 0.231
2	-0.034 / 0.000	-0.051 / 0.000	0.000 / 0.000	0.000 / 0.000	0.000 / 0.000	-0.065 / 0.000

Member Displacement Span Check

Member	Length	Max Relative Displacement	Span Method 1
1	19.903	0.062	L/1279
2	1.809	0.015	L/1420

Member Stresses

Member	Axial Stress (Min/Max)	Torsion Stress (Min/Max)	Shear Stress Y (Min/Max)	Shear Stress Z (Min/Max)	Top Bending Moment Z (Min/Max)	Bottom Bending Moment Z (Min/Max)
1	-0.038 / 0.028	0.000 / 0.000	-0.084 / 0.062	-0.000 / -0.000	-0.736 / 0.693	-0.693 / 0.736
2	-0.006 / 0.000	0.000 / 0.000	-0.013 / 0.000	-0.000 / -0.000	-0.196 / 0.000	0.000 / 0.196