

**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:

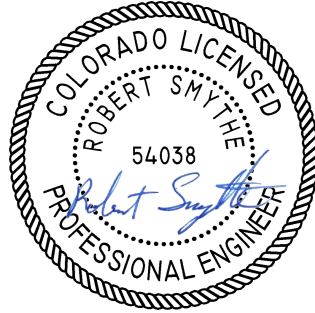
- Confirm that the existing structure matches the information provided in the structural survey, the approved installation plans and this certification.
- Identify discrepancies between this certification and the approved installation plans. If found, then this certification shall govern.
- Identify 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

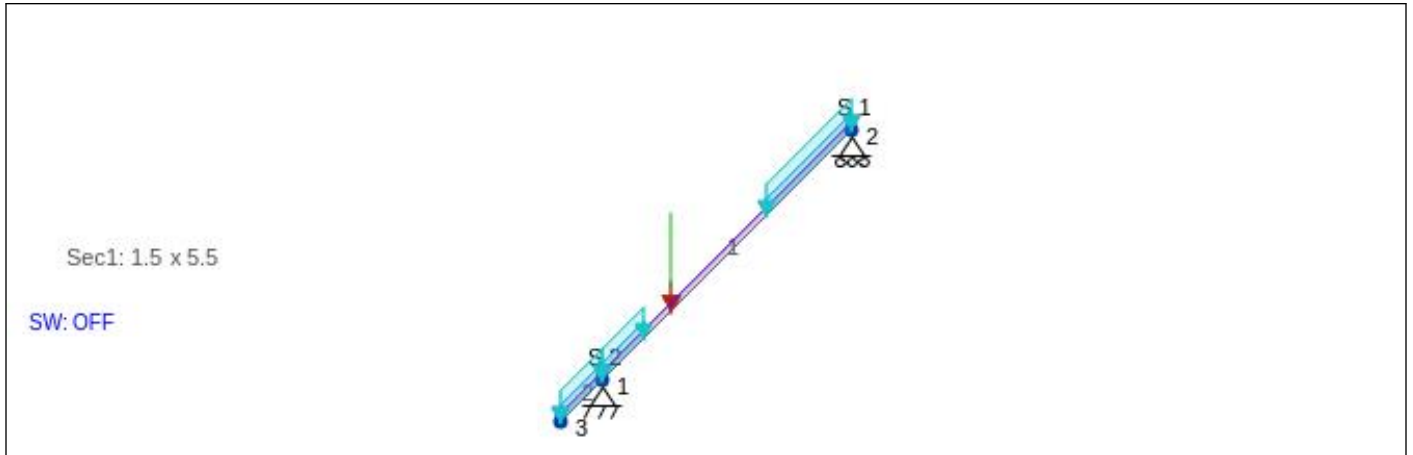
Robert D. Smythe, P.E.  
Right Angle Engineering

# Job Details

Roof Snow Load - ASCE 7-16		Design Criteria	
<b>Ground Snow Load (<math>p_g</math>)</b> <i>Section 7.2</i>	44.0 psf	<b>Wind Speed (<math>V_{ult}</math>)</b> <i>Local Design Criteria</i>	130.0mph
<b>Exposure Factor (<math>C_e</math>)</b> <i>Table 7.3-1</i>	0.9	<b>Exposure Category</b>	C
<b>Thermal Factor (<math>C_t</math>)</b> <i>Table 7.3-2</i>	1.1	<b>Risk Category</b>	2
<b>Importance Factor (<math>I_s</math>)</b> <i>Table 1.5-2</i>	1	<b>Mean Roof Height</b>	20 ft
<b>Flat Roof Snow Load (<math>p_f</math>)</b> <i>Equation 7.3-1</i>	30.49 psf	<b>Roof Type</b>	Gable Roof
<b>Slippery Surface Slope Factor (<math>C_s</math>)</b> <i>Figure 7.4-1</i>	0.6	<b>Building Type</b>	Enclosed
<b>Non-Slippery Surface Slope Factor (<math>C_s</math>)</b> <i>Figure 7.4-1</i>	1	<b>Roof Live Load</b>	
<b>Roof Snow Load</b> <i>Equation 7.4-1</i>	30.49 psf	<b>Existing Roof Live Load</b> <i>ASCE 7-16 Table 4.3-1</i>	20 psf
<b>Reduced Snow Load (Slippery Surface)</b> <i>Equation 7.4-1</i>	18.3 psf		
<sup>1</sup> Roof Dead Load			
<b>Asphalt Shingles</b>	2.0 psf	<b>No Drywall</b>	0.0 psf
<b>5/8" Plywood Sheathing</b>	2.0 psf	<b>Solar Panel Array</b>	2.74 psf
<b>Roof Framing</b>	2.36 psf	<b>Dead Load Without Panels</b>	7.56 psf
<b>Insulation</b>	1.2 psf		

<sup>1</sup>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 <i>DF No.2</i>
Spacing	16.0"
Beam Span	9.0'
Roof Pitch	45°
Panel Quantity	5
Panel Array Area	108.18 ft <sup>2</sup>
Panel Orientation	Portrait
Lag Screw Embedment	2.5"
Roof Attachment Type	FlashLoc Duo (2)-#12-14 wood screws
Shear Capacity <i>FlashLoc Duo Test Data</i>	190.0 lbs
Pullout Capacity <i>FlashLoc Duo Test Data</i>	495.0 lbs
Velocity Pressure <i>Equation 26.10-1 (K<sub>z</sub>=0.9, K<sub>ht</sub>=1, K<sub>d</sub>=0.85, K<sub>e</sub>=0.8)</i>	26.62 psf

GCP Zones	1/2e/ 2r	2n/3r	3e
<b>GC<sub>p</sub></b> <i>Figure 30.3-(2A-5B)</i>	-1.8	-2.0	-3.2
<b>Design Pressure Up [psf]</b> <i>Equation 29.4-7 γ<sub>a</sub>=0.78 γ<sub>E</sub>=1.0</i>	-37.2	-41.3	-66.1
<b>Exposed Design Pressure Up [psf]</b> <i>γ<sub>a</sub>=0.78 γ<sub>E</sub>=1.5</i>	-55.8	-62.0	-99.2
<b>Design Pressure Down [psf]</b>	16.5	16.5	16.5
<b>Tributary Area [ft<sup>2</sup>]</b>	12.8	12.8	12.8
<b>Maximum Connection Spacing [in]</b>	49	49	49
<b>Maximum Rail Span [in]</b>	48	48	48
<b>Maximum Rail Cantilever [in]</b>	16	16	16
<b>Design Connection Spacing [in]</b>	48	48	48
<b>Deign Connection Spacing (exposed) [in]</b>	48	48	32

## Design Ratio

Member ID	P	M <sub>z</sub>	V <sub>y</sub>	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 <sub>b</sub> <sup>t</sup> (ksi)	F <sub>t</sub> <sup>t</sup> (ksi)	F <sub>v</sub> <sup>t</sup> (ksi)	F <sub>c</sub> <sup>t</sup> (ksi)	F <sub>cp</sub> <sup>t</sup> (ksi)	E' (ksi)	E <sub>min</sub> <sup>t</sup> (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	FFFFFF

## 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 Mol	Z-Axis Mol	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

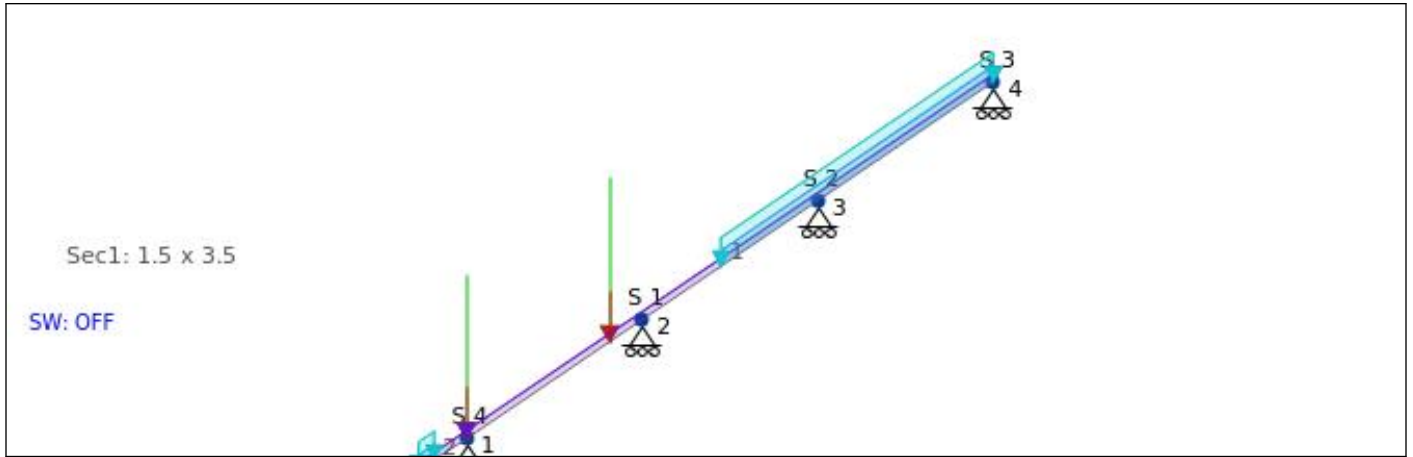
### Member Displacement Span Check

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 ft <sup>2</sup>
Panel Orientation	Portrait
Lag Screw Embedment	2.5"
Roof Attachment Type	FlashLoc Duo (2)-#12-14 wood screws
Shear Capacity <i>FlashLoc Duo Test Data</i>	190.0 lbs
Pullout Capacity <i>FlashLoc Duo Test Data</i>	495.0 lbs
Velocity Pressure <i>Equation 26.10-1 (K<sub>z</sub>=0.9, K<sub>ht</sub>=1, K<sub>d</sub>=0.85, K<sub>e</sub>=0.8)</i>	26.62 psf

GCP Zones	1/2e/ 2r	2n/3r	3e
GC <sub>p</sub> <i>Figure 30.3-(2A-5B)</i>	-1.8	-2.0	-3.2
Design Pressure Up [psf] <i>Equation 29.4-7 γ<sub>a</sub>=0.79 γ<sub>E</sub>=1.0</i>	-37.9	-42.1	-67.4
Exposed Design Pressure Up [psf] <i>γ<sub>a</sub>=0.79 γ<sub>E</sub>=1.5</i>	-56.8	-63.1	-101.0
Design Pressure Down [psf]	16.8	16.8	16.8
Tributary Area [ft <sup>2</sup> ]	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 <sub>z</sub>	V <sub>y</sub>	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 <sub>b</sub> <sup>t</sup> (ksi)	F <sub>t</sub> <sup>t</sup> (ksi)	F <sub>v</sub> <sup>t</sup> (ksi)	F <sub>c</sub> <sup>t</sup> (ksi)	F <sub>cp</sub> <sup>t</sup> (ksi)	E' (ksi)	E <sub>min</sub> <sup>t</sup> (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	FFFFFF

## 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 Mol	Z-Axis Mol	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