Performance of a Low-cost, Low-concentration Photovoltaic System

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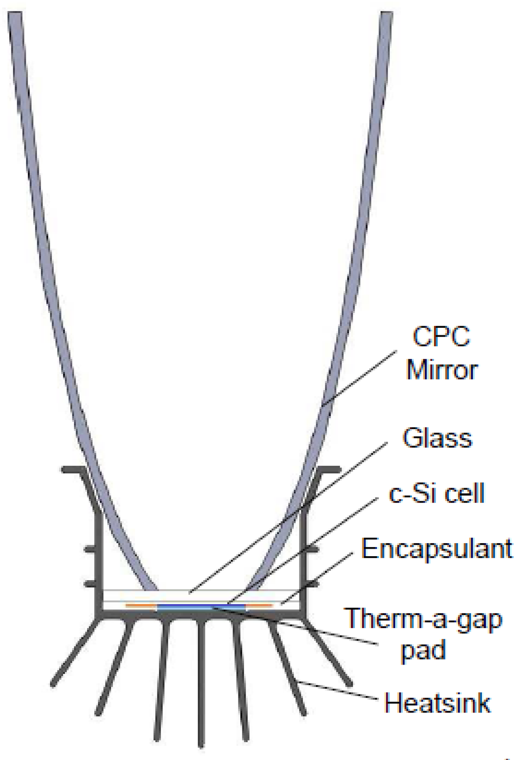
Introduction: LC2PV

Low-cost, Low-concentration PV
- 10x Geometric Concentration
- Asymmetric Dual-axis compound parabolic concentrating reflector

Benefits of low-concentration:
- Wide acceptance angles collect larger portion of circumsolar radiatio
- Reduce tracking accuracy requirements, lowering Balance of System costs
- Less risk for material degradation caused by concentrated UV exposure
- Can use more standard materials and manufacturing methods



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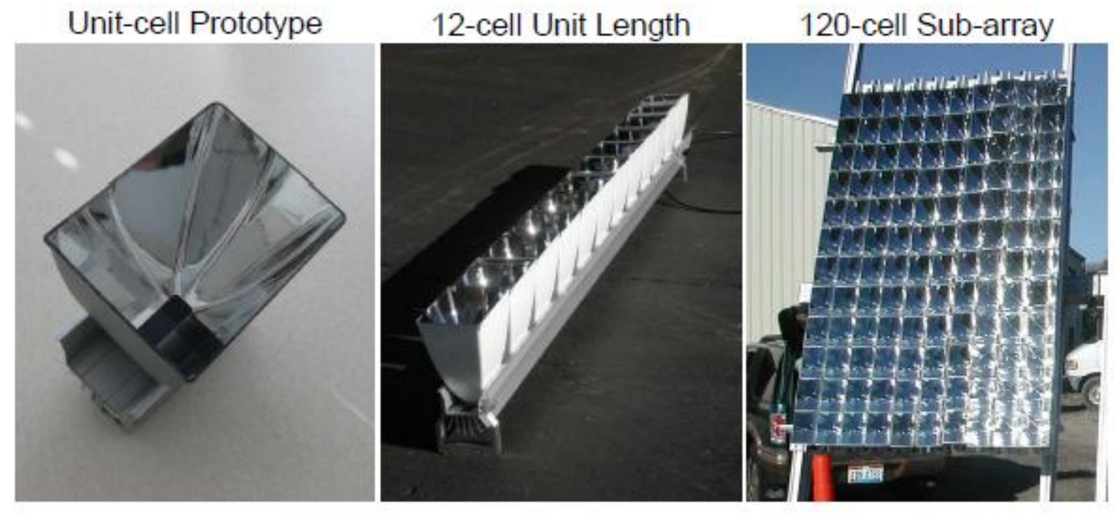
Prototypes



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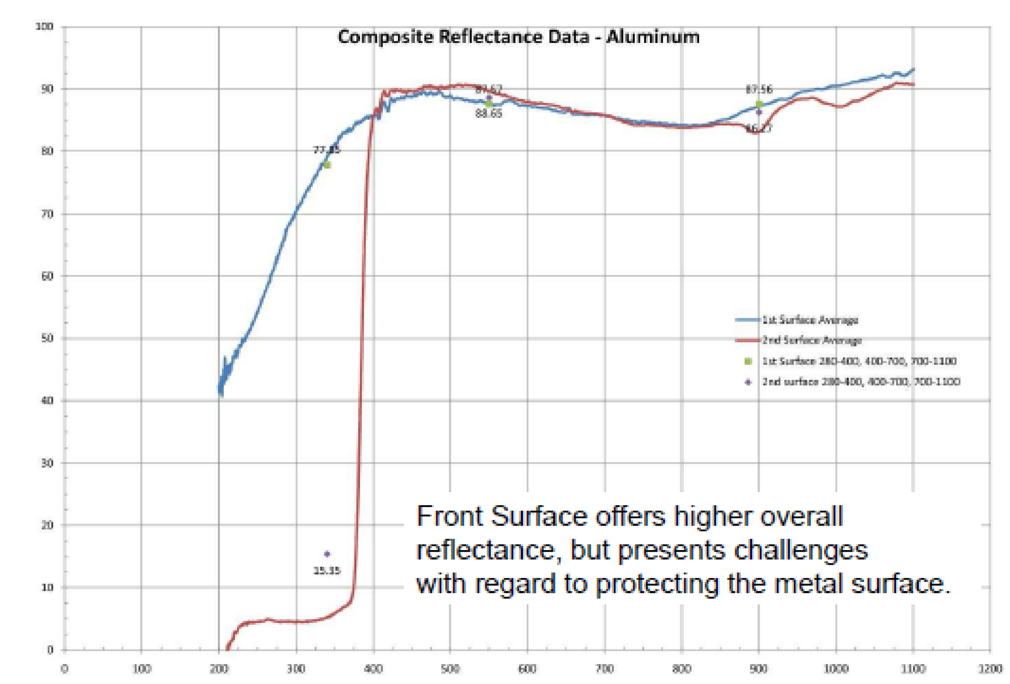
Optical Efficiency: Back vs. Front Surface



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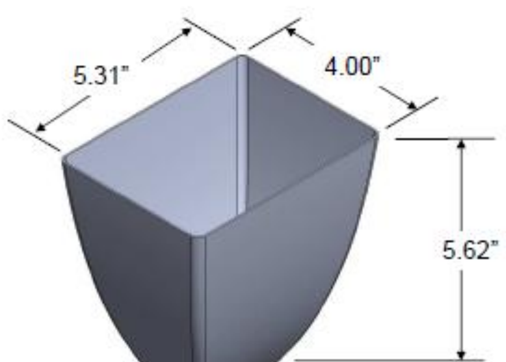
Optical Design

- Acrylic CPC
- Second surface mirror
- Designed for 1-axis inclined tracking
  - Non-tracking direction
    - θ_{ha} = 23.5°
    - Allows for seasonal variation in the angle of the sun
  - Tracking direction
    - θ_{ha} = 12.1 °
    - Allows for inaccuracies in tracking
- Geometric Concentration = 10.3



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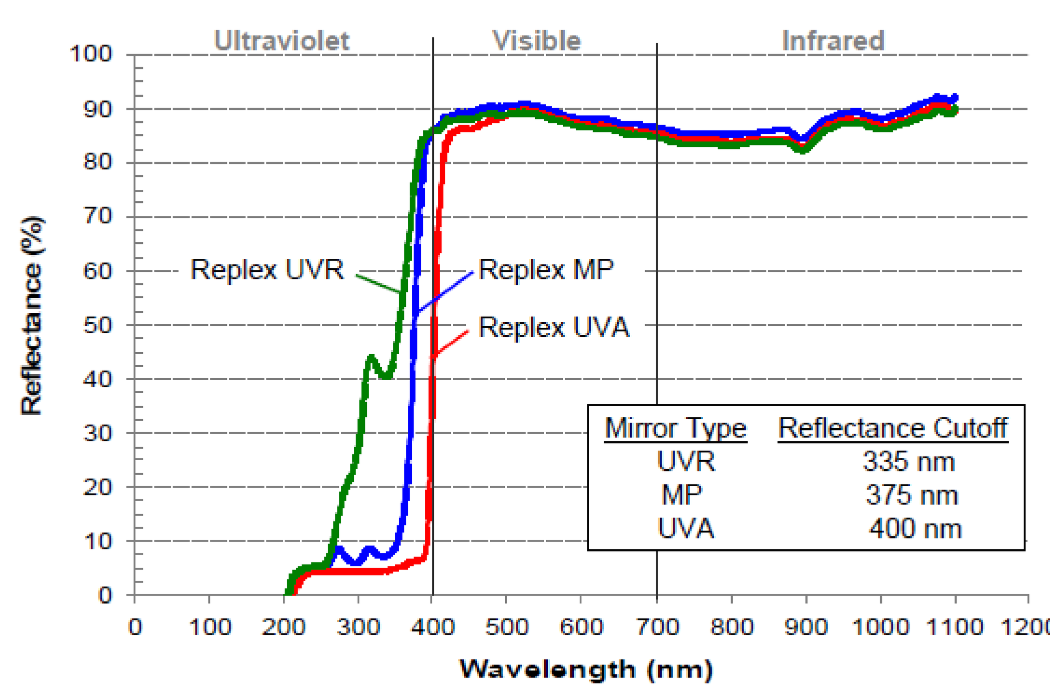
Replex UV Selective Mirrors



Mirror Type	Reflectance Cutoff
UVR	335 nm
MP	375 nm
UVA	400 nm

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Manufacturability

- Front Surface Mirror:
  - Higher overall spectral response.
    - Depending on cell technology, may not be relevant. ie: III-V vs c-Si
  - Higher accuracy (no refractive effects).
  - Substrate flexibility.
  - Lower durability, higher cost (coatings, tie layers).
- Back Surface Mirror (chosen for Gen 1 design):
  - Similar reflectance in visible.
  - Refractive effects must be accounted for.
  - Proper substrate selection important.
  - Good durability, low cost.
  - Able to reduce UV exposure to receiver through Replex' UV selective mirror.

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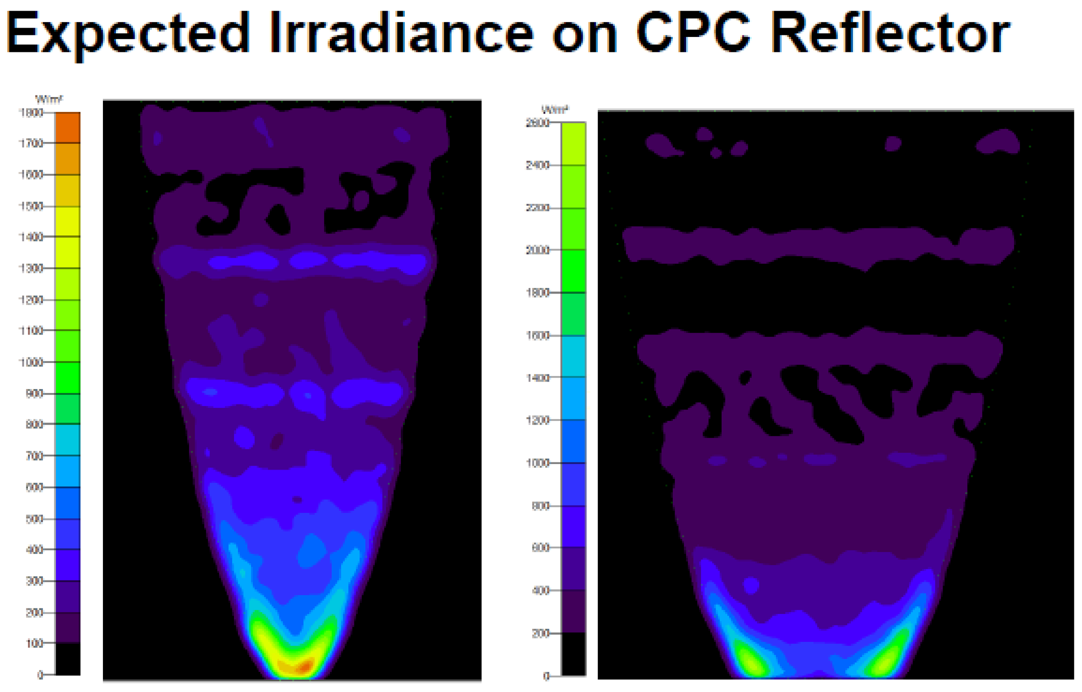
Expected Irradiance on CPC Reflector



Non-tracking N/S direction
Max irradiance = 1800 W/m²

Tracking E/W direction
Max irradiance = 2800 W/m²

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Optical Efficiency: Al vs. Ag

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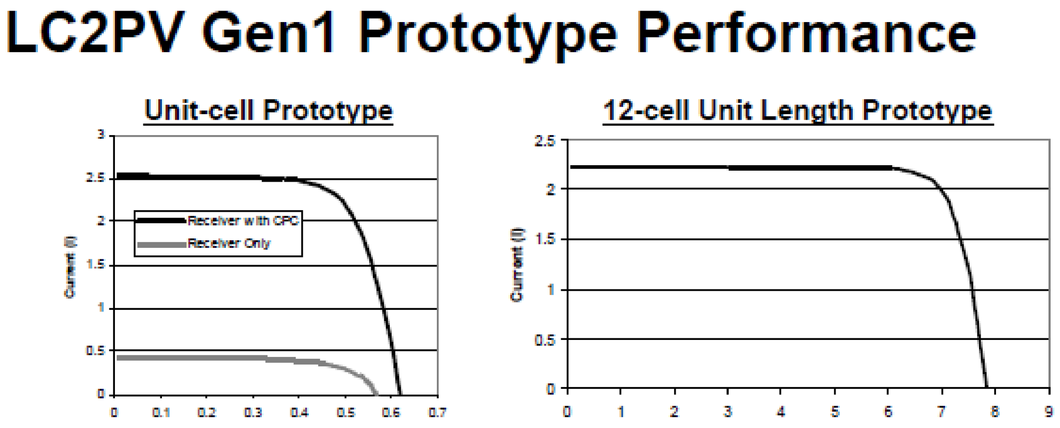
LC2PV Gen1 Prototype Performance



Unit-cell Performance	Receiver Only	With CPC
I_{sc}	0.43	2.53
V_{oc}	0.56	0.56
P_{max}	0.17	1.11
Fill Factor	0.69	0.77
Conc. Factor	-	6.6
Efficiency	15.0%	7.9%

12-cell Length Performance	With Glass
I_{sc}	2.29
V_{oc}	7.78
P_{max}	14.7
Fill Factor	0.83
Conc. Factor	7.1
Efficiency	10.0%

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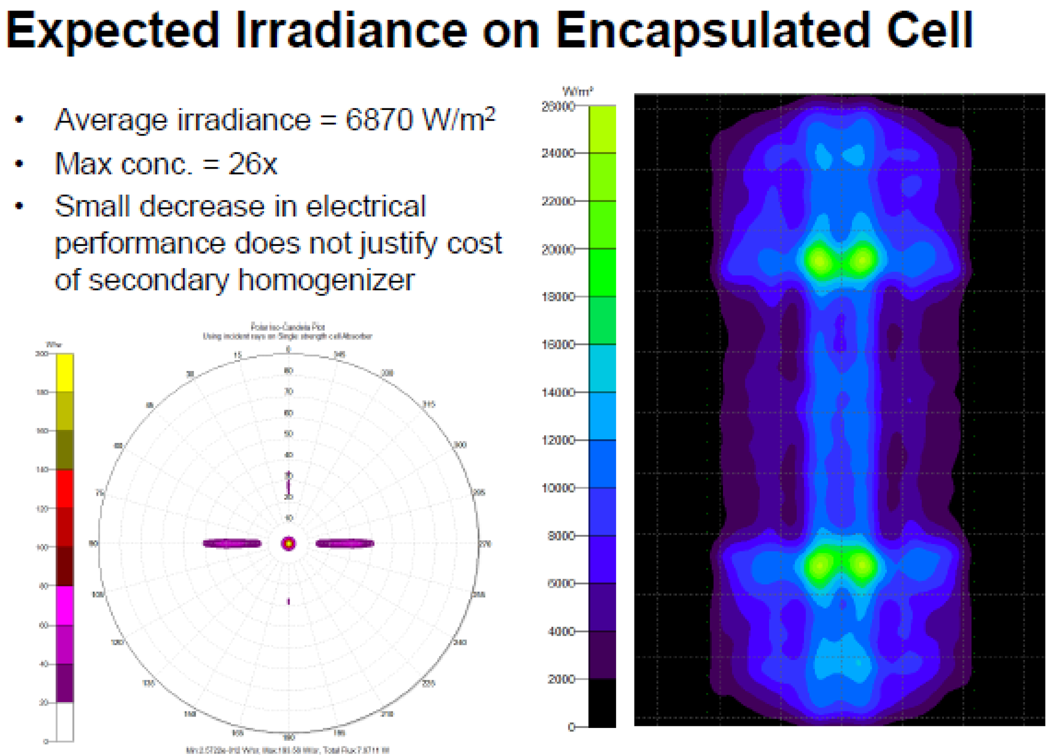
Expected Irradiance on Encapsulated Cell

- Average irradiance = 6870 W/m²
- Max conc. = 26x
- Small decrease in electrical performance does not justify cost of secondary homogenizer



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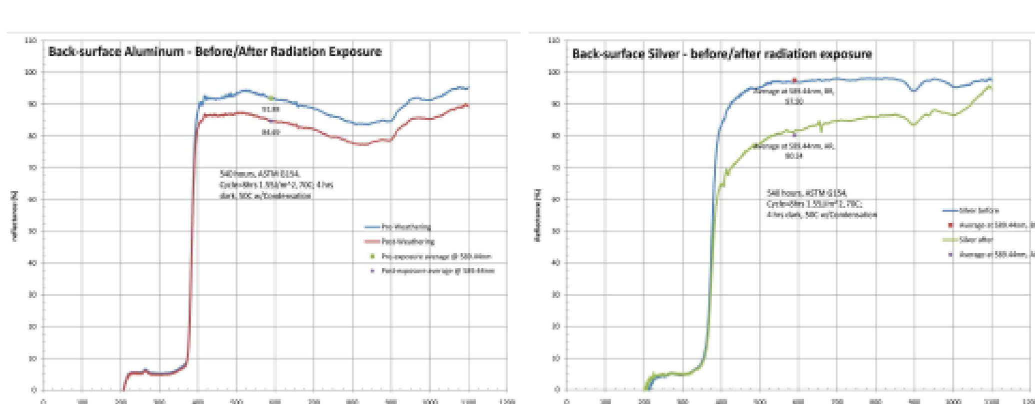
Mirror Durability: Accelerated Testing



- Conditions most closely resemble a Florida-type environment. Addition of moisture + heat in addition to UV changes the rate of degradation as compared to Arizona-type conditions.
- Aluminum: average 7% reduction in specular reflectance
- Silver: Average 17% reduction in specular reflectance
- Aluminum shows greater durability under adverse conditions.

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LC2PV Performance Over Time

- Glass Breakage
  - PV glass was not available to fit the form factor needed (2" width).
  - Almost all modules exhibited significant cracks in the cover glass.
- Moisture Intrusion
  - Pockets of moisture or voids between cover glass and cells, both at cracks and near the ends of the laminations.
- Delamination
  - Which occurred first: Glass breakage, moisture intrusion, or delamination?
  - Did Glass breakage or moisture intrusion cause delamination?
  - Potentially result of improper glass cleaning
- Significant decrease in power output
  - From material degradation or optical losses from glass breakage, voids and moisture intrusion?

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Heat Dissipation Requirements

Designed a custom extruded aluminum heatsink to dissipate the heat and optically align the reflectors.

R_{th} = thermal resistance of heat sink

$$R_{th} = \frac{T_{cell} - T_{air}}{P} = 1.9°C/W$$

Desired $\Delta T_{cell-air}$ = 20℃

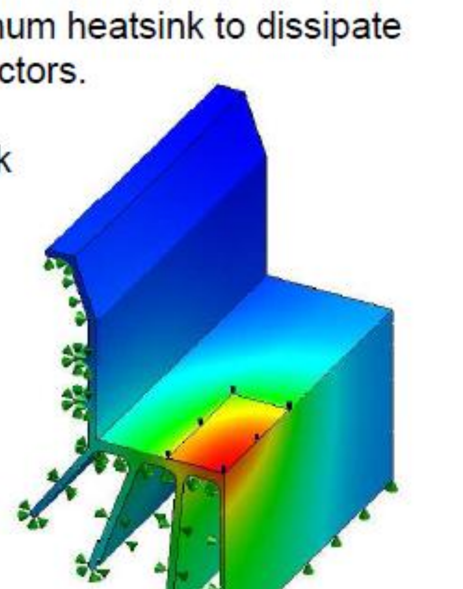
$P = I \times (1-\eta) \times CF \times A_{cell}$

I = solar irradiance, W/m^2

η = cell efficiency

CF = concentration factor

A_{cell} = cell area, m^2



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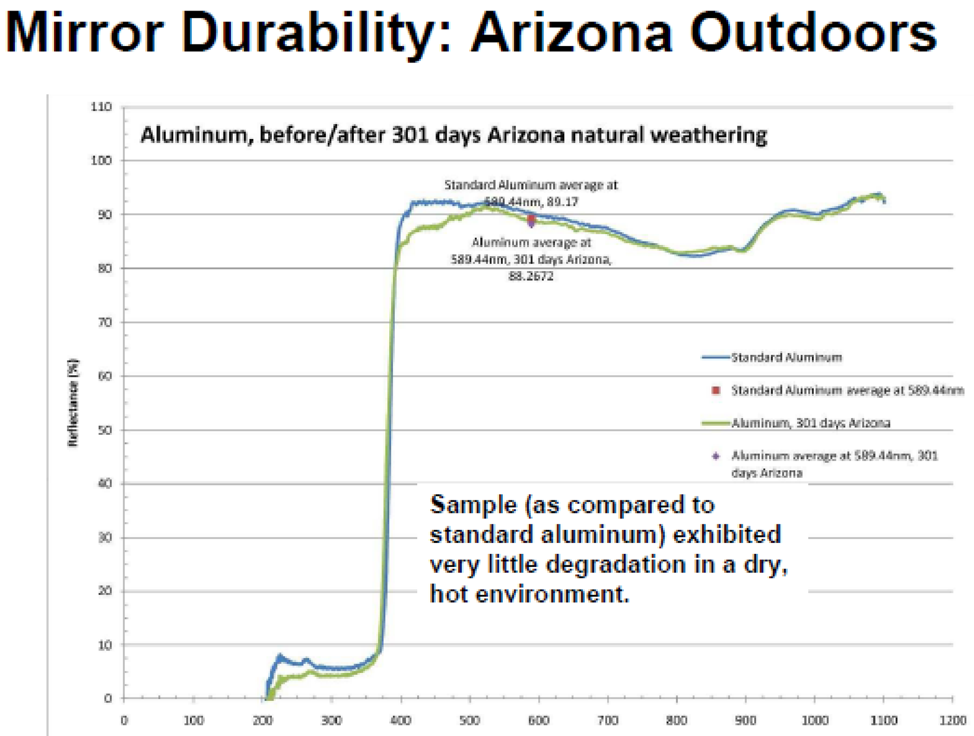
Mirror Durability: Arizona Outdoors



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Conclusions

- Low-concentration PV with inexpensive acrylic mirrors works
- Form factor unsuitable for cost-effective installation
  - Heat sink design complicated mounting procedure to tracker racking
  - Too many junction box leads increases installation time
  - Too heavy
  - Difficult to manufacture using standard equipment
- Next generation receiver design must be simplified to improve cost, manufacturability, and durability
  - Allow for use of PV glass in available sizes
  - Able to utilize industry-standard equipment
  - Simplify installation
  - Reduce weight

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This poster does not contain any confidential information.

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