Mismatch Losses in HelioScope

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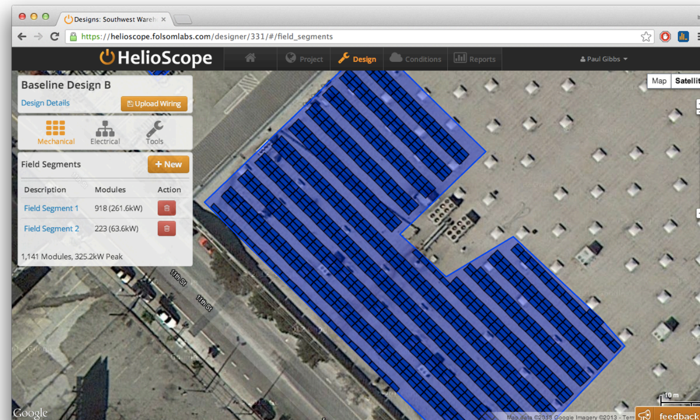
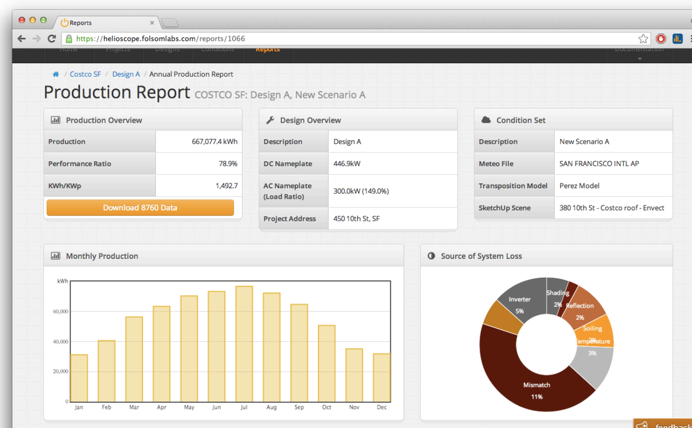
What is HelioScope?

- Component-driven
- Design-integrated
- Cloud-based
- Launching summer 2013





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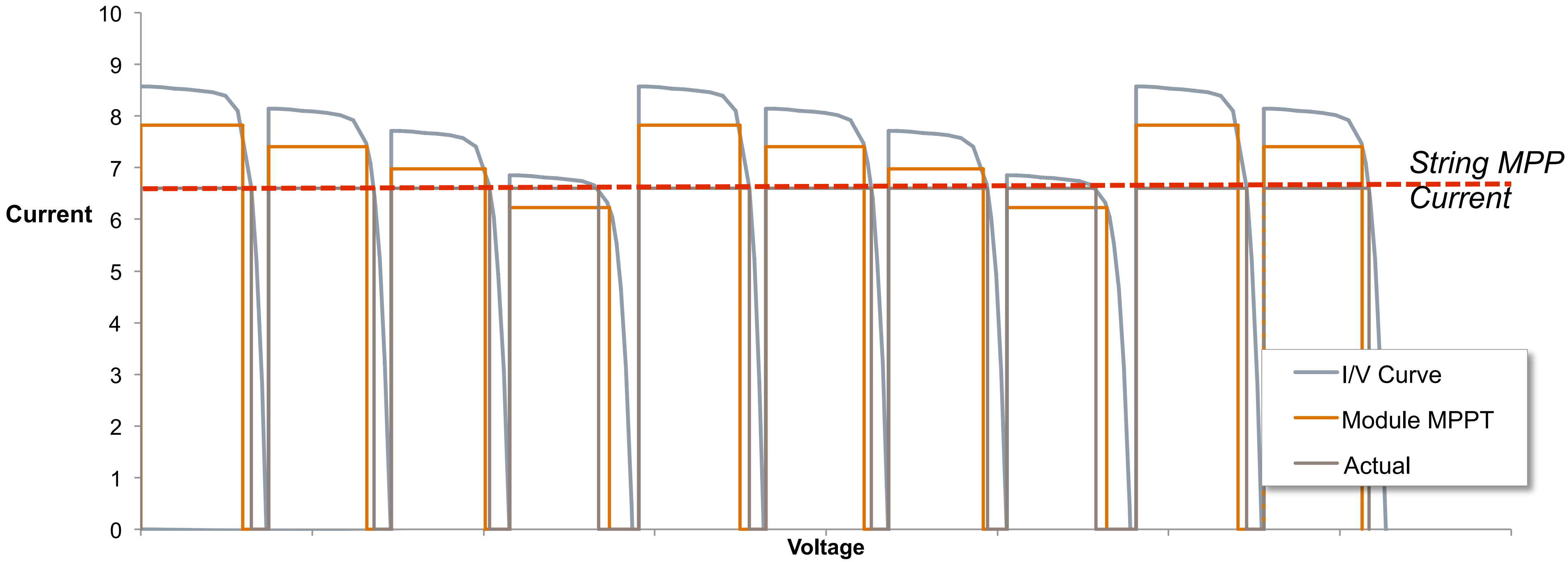
HelioScope defines mismatch as any power lost due to a module being driven off-MPP

- Mismatch losses are ***not*** an input factor
- Sources of mismatch are hard to disaggregate



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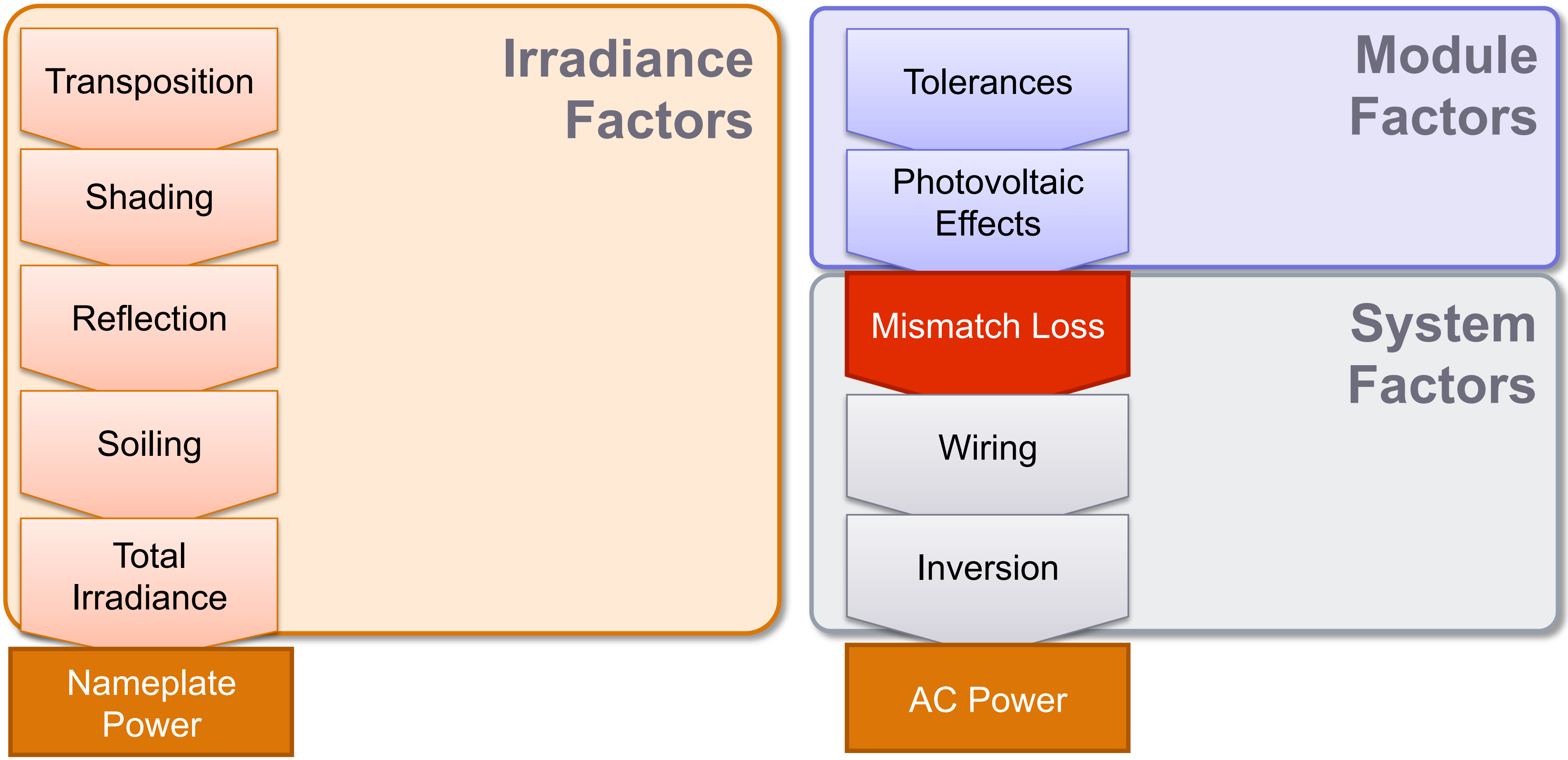
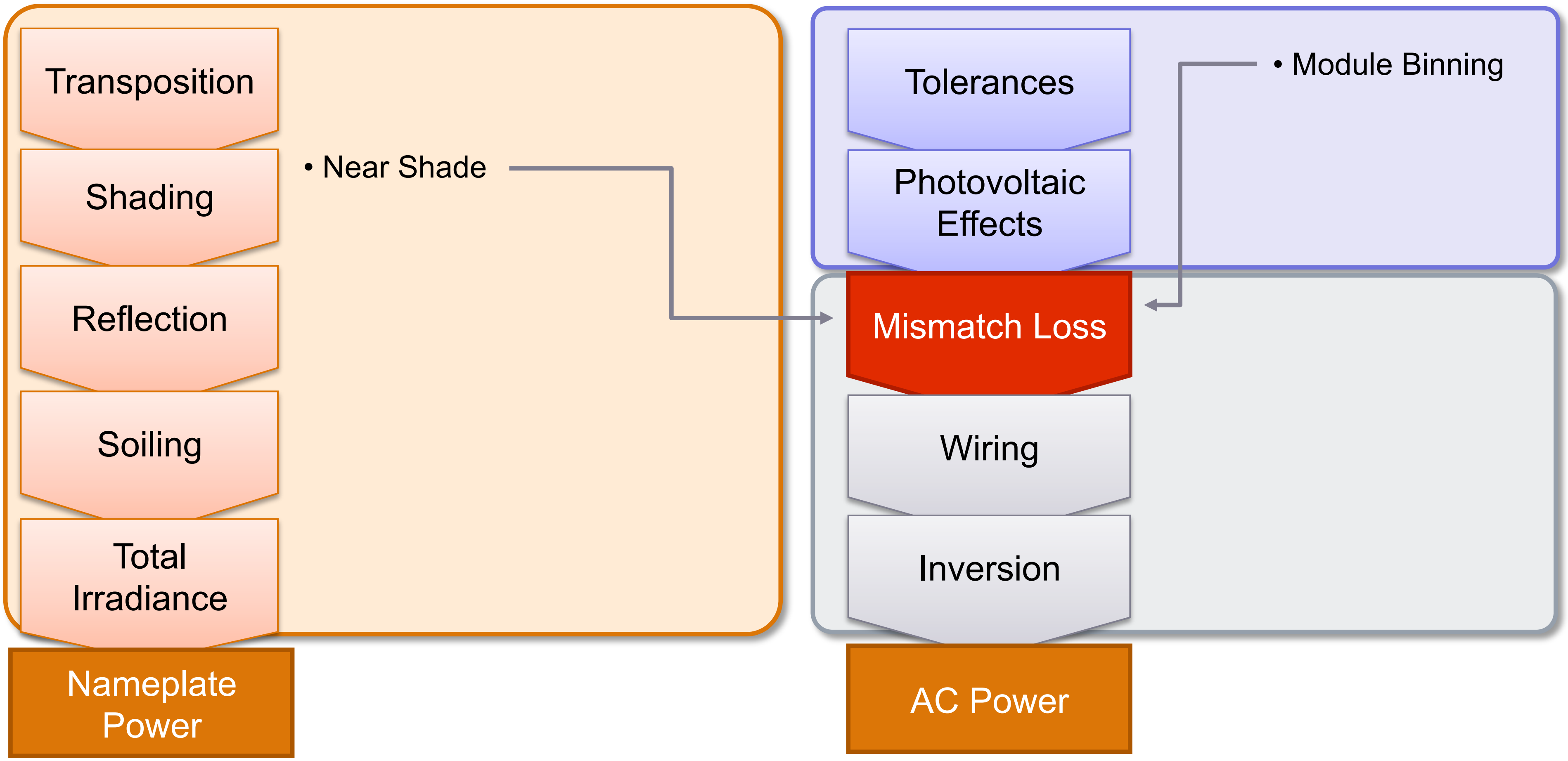
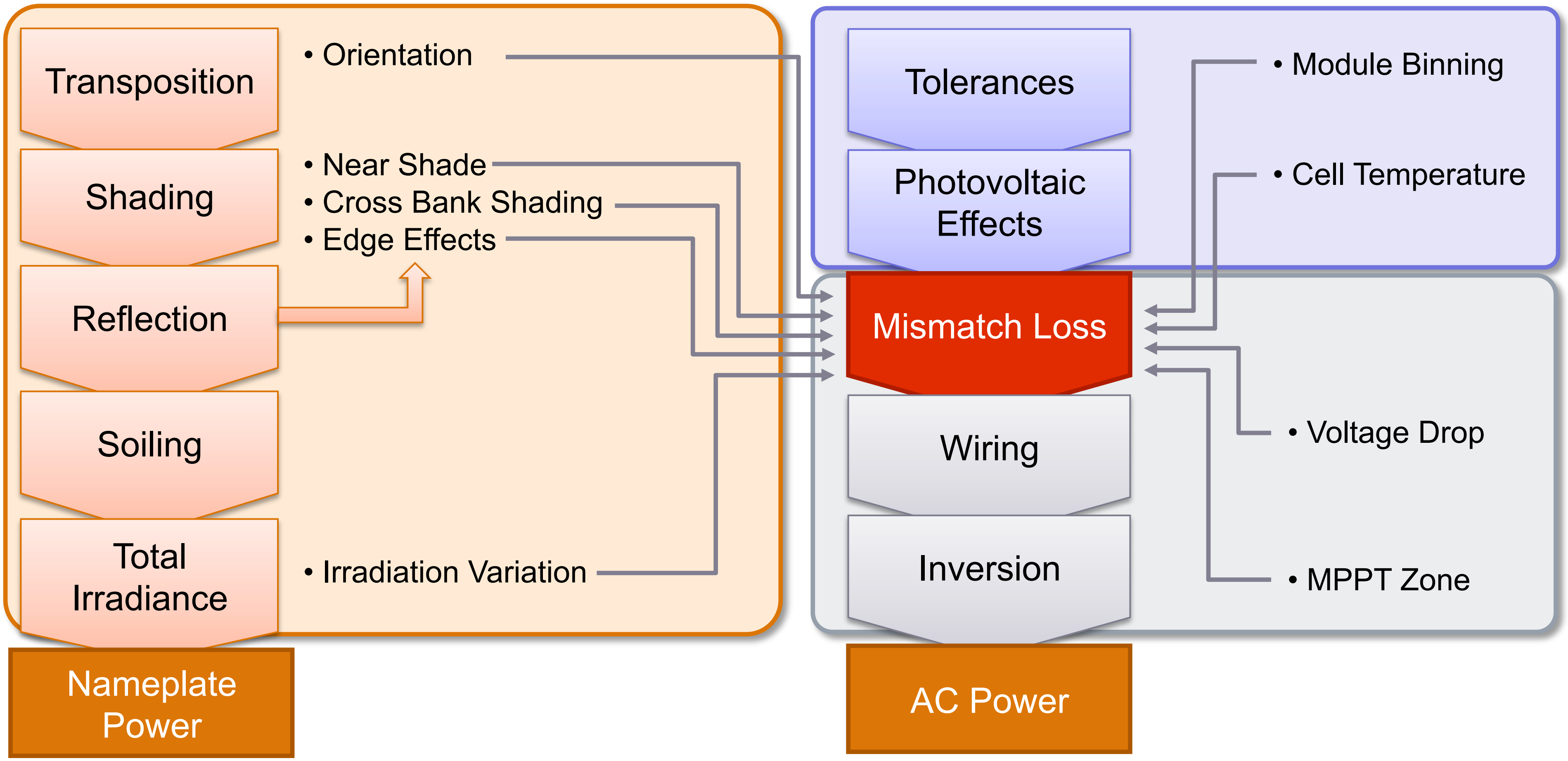
Mismatch is actually a system integration loss



Traditionally, mismatch is primarily based on two sources



In reality, there are many second-order sources of mismatch loss



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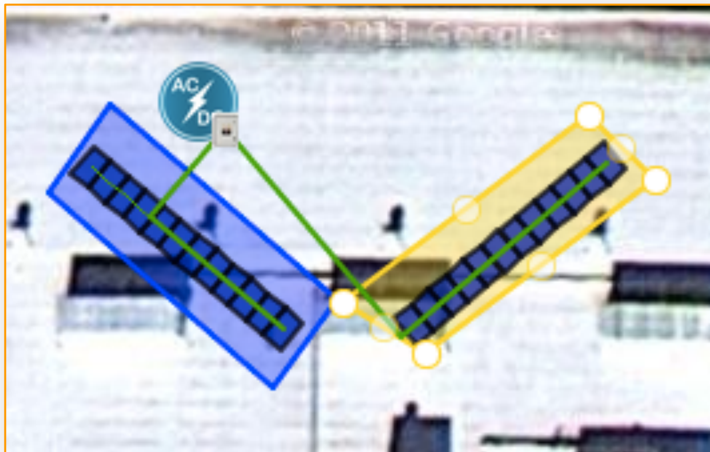
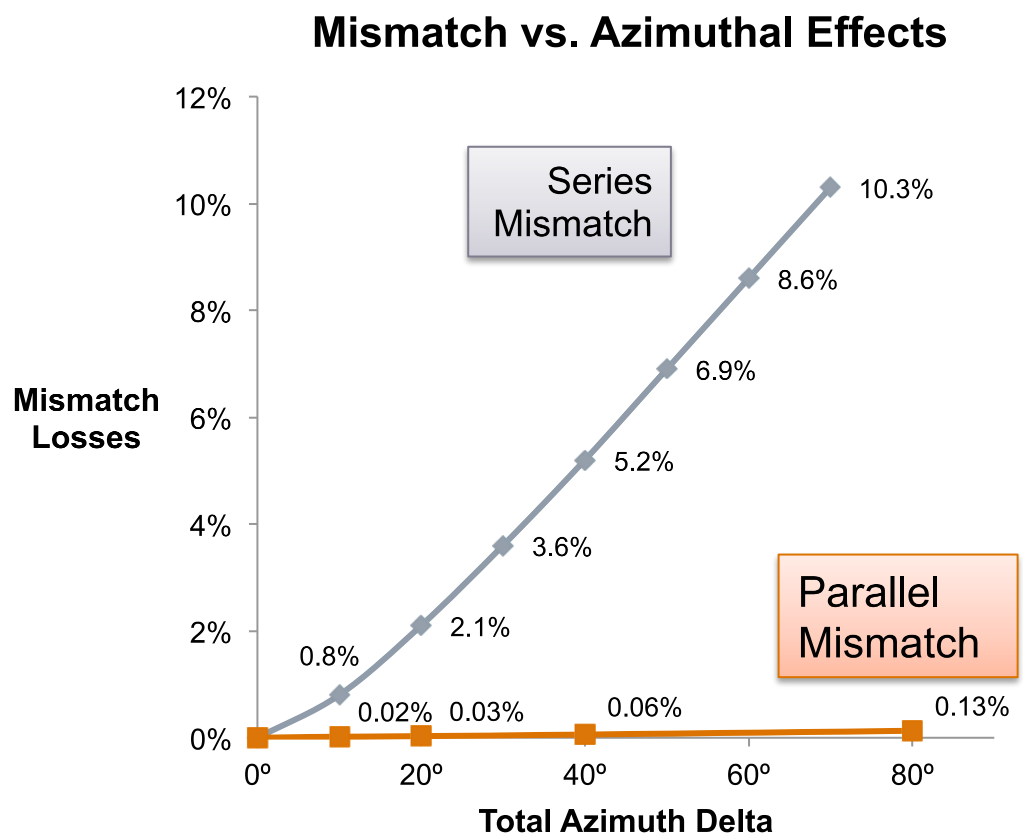
Orientation: can define heterogeneous arrays with one or multiple inverters



- Trina TSM-240PA05
- Sacramento TMY3
- 20º Tilt
- Strings of 12



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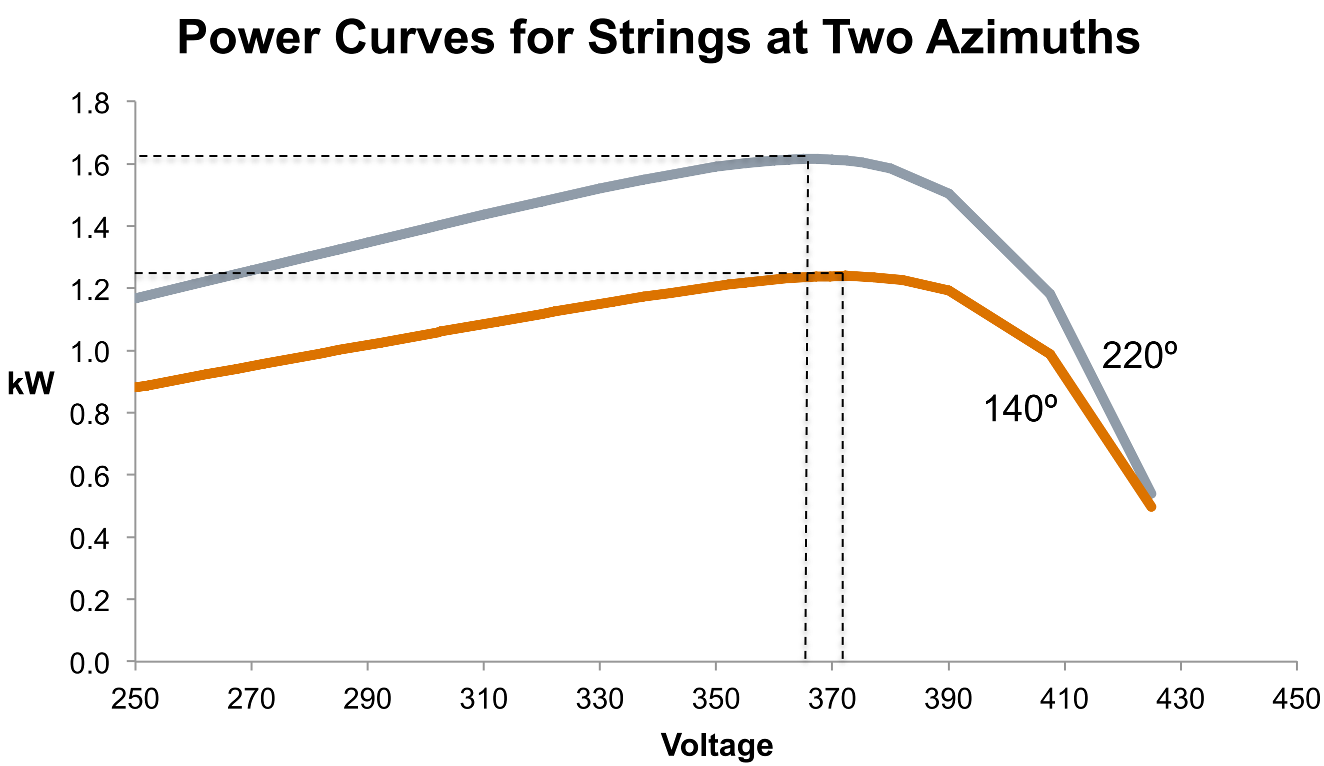
Orientation: mismatch losses are low when the strings are wired in parallel



Trina PA04 240W, Sacramento, 20º Tilt, Strings of 12, 10:00AM 1/12

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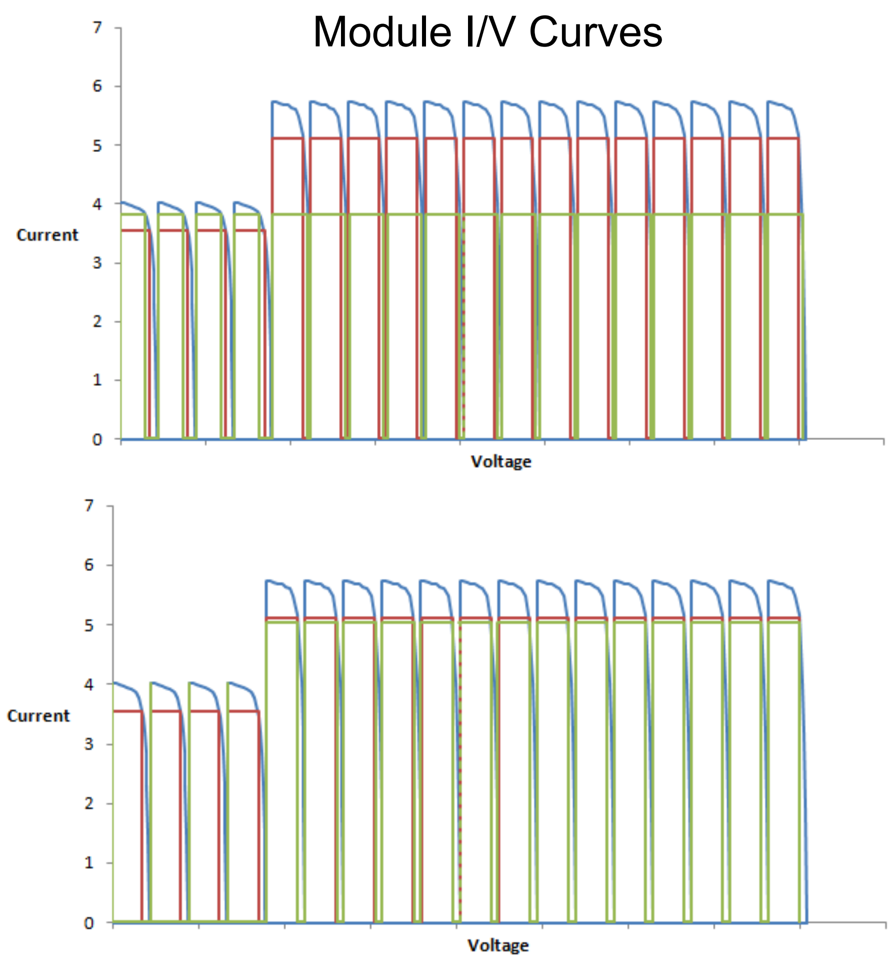
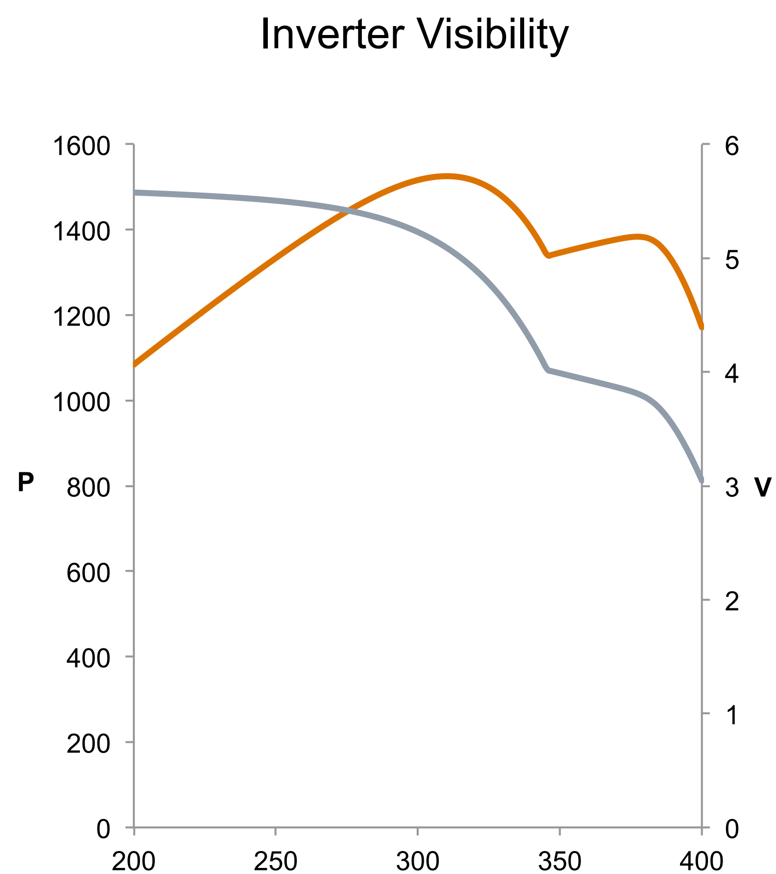
Near Shading: each module is treated as a single diode, string effects are modeled based on design

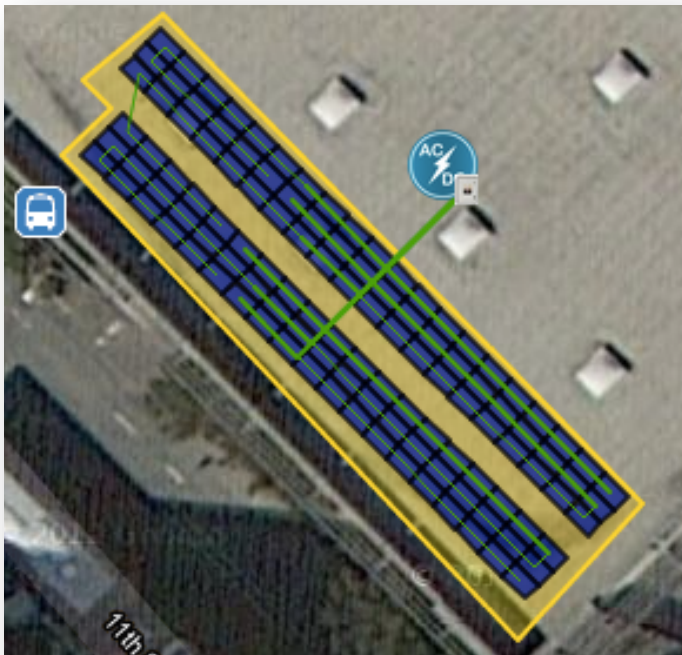
- 3d Models from Google Sketchup
- Every model in the array impaired individually
  - Considered single-diode
  - Only beam-irradiance lost
  - Impacts cell temperature
- HelioScope intrinsically calculates all string-effects

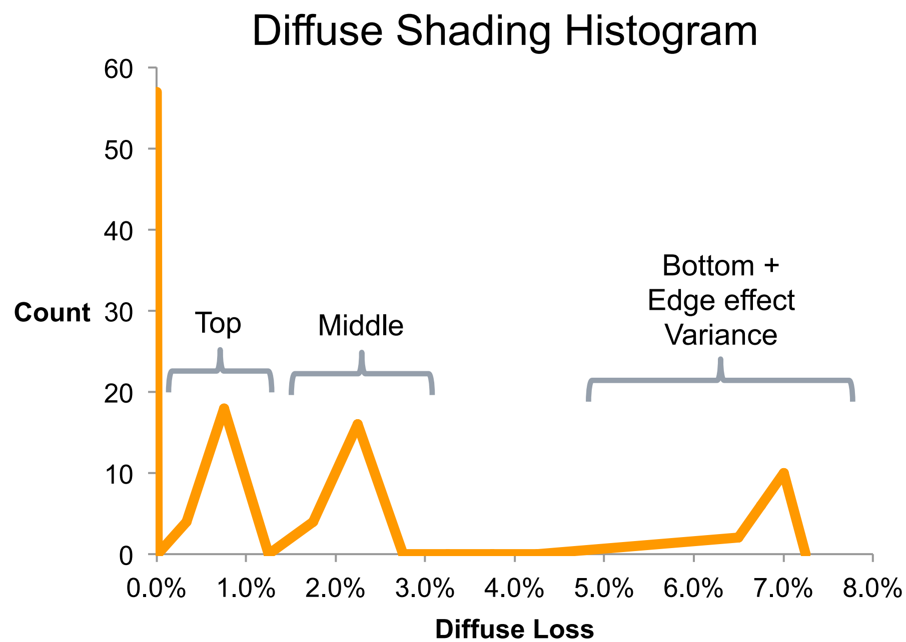
Near Shading: each module is treated as a single diode, the inverter must choose to bypass or not





Diffuse Shading: modules have location specific loss factors which can cause mismatch



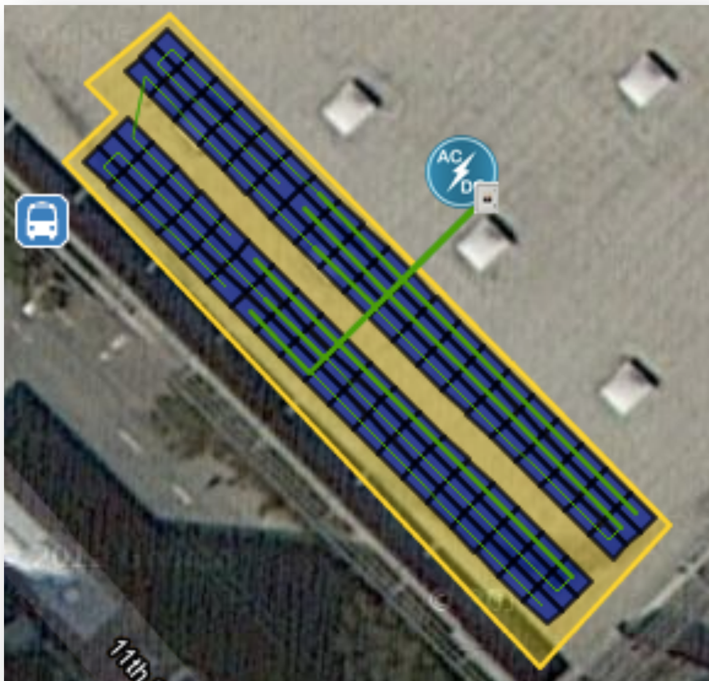


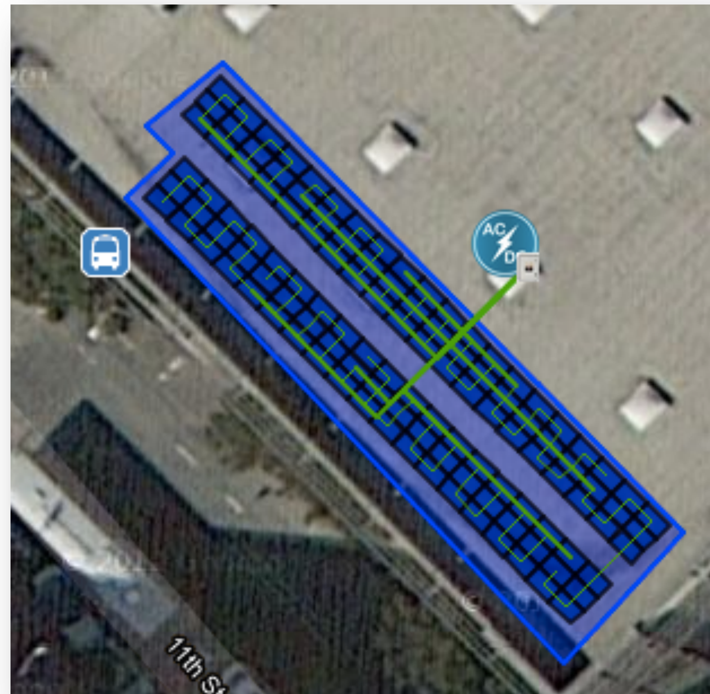
0.2%	0.3%	0.4%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.4%	0.3%	0.2%
0.7%	1.5%	2.0%	2.1%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%	2.1%	2.0%	1.5%	0.7%
1.4%	5.4%	6.5%	6.7%	6.7%	6.8%	6.8%	6.8%	6.8%	6.8%	6.8%	6.8%	6.8%	6.8%	6.8%	6.7%	6.7%	6.5%	5.4%	1.4%

	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

20º Tilt; 225º Azimuth; San Francisco, CA; 1.5m between rows

Diffuse Shading: losses change based on the stringing pattern



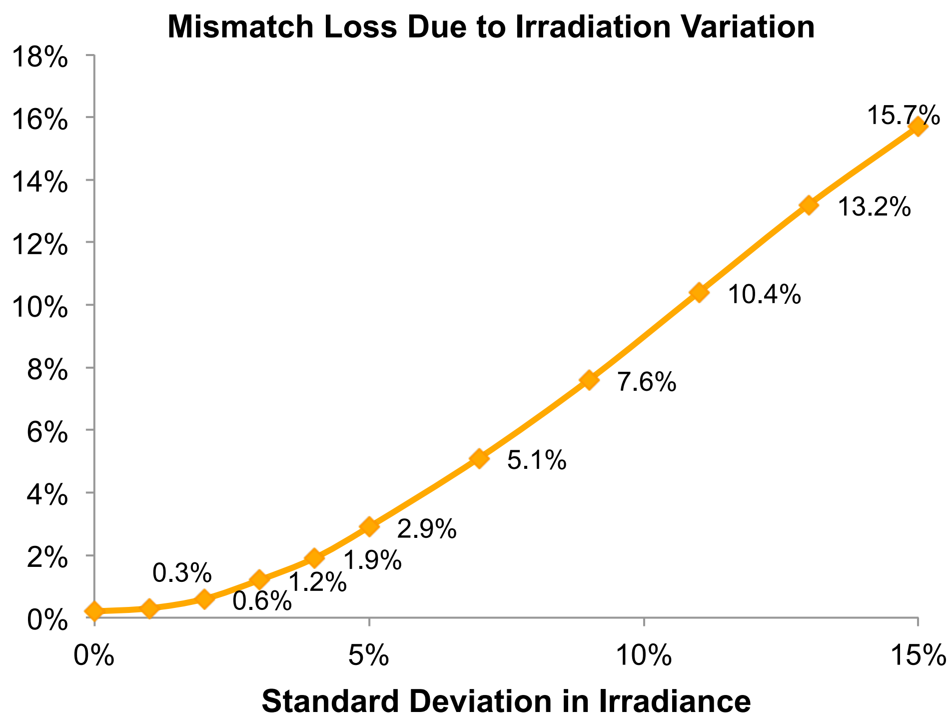


Along-Bank Stringing	
Performance Ratio:	87.6%
Mismatch:	0.2%

Across-Bank Stringing	
Performance Ratio:	87.2%
Mismatch:	0.7%

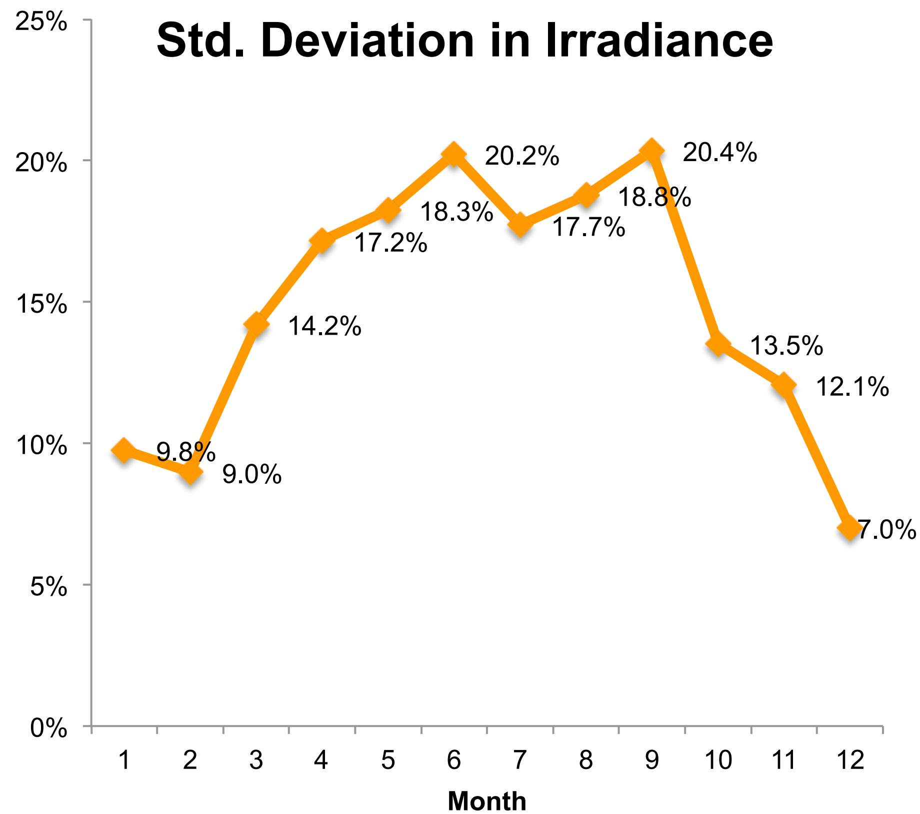
20º Tilt; 225º Azimuth; San Francisco, CA; 1.5m between rows

Irradiance Variation: ambient mismatch losses are determined by defining an irradiance distribution



- User defines the standard deviation
  - Normal distribution
  - Zero-mean
- Attempts to model cloud and other ambient effects
- Each module sampled independently, every hour
- All designs seeded equivalently

Irradiance Variation: NREL's Oahu dataset had a 15.4% average standard deviation[1] in irradiance



[1]Power-Weighted Average of the Std. Deviation of each one-second timeslice

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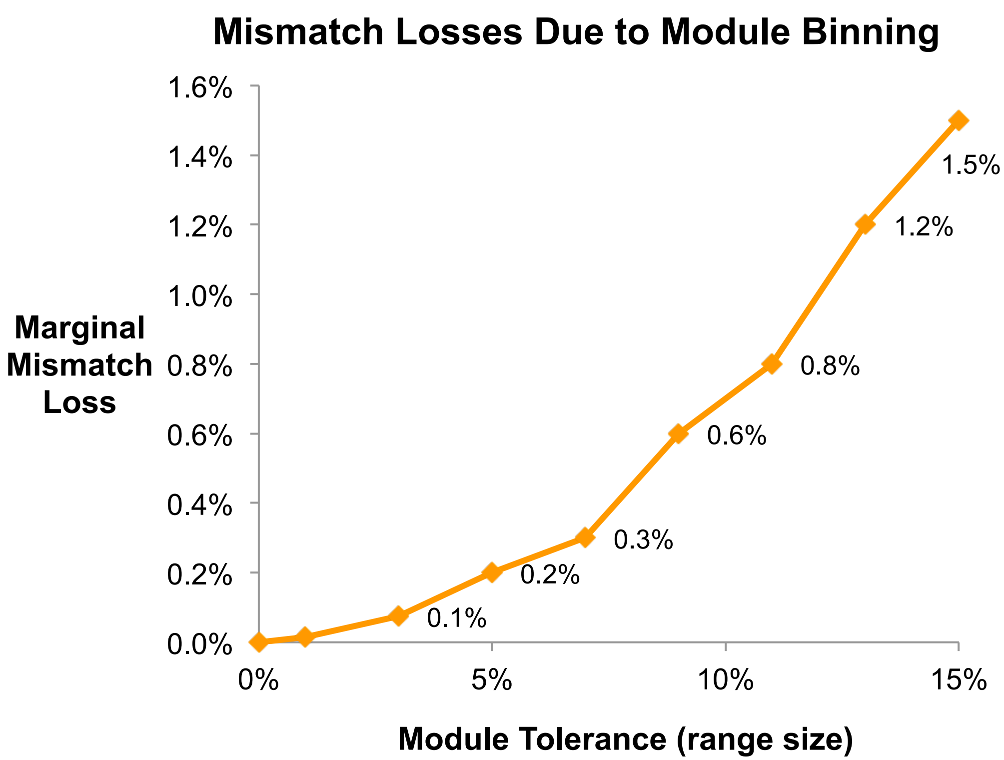
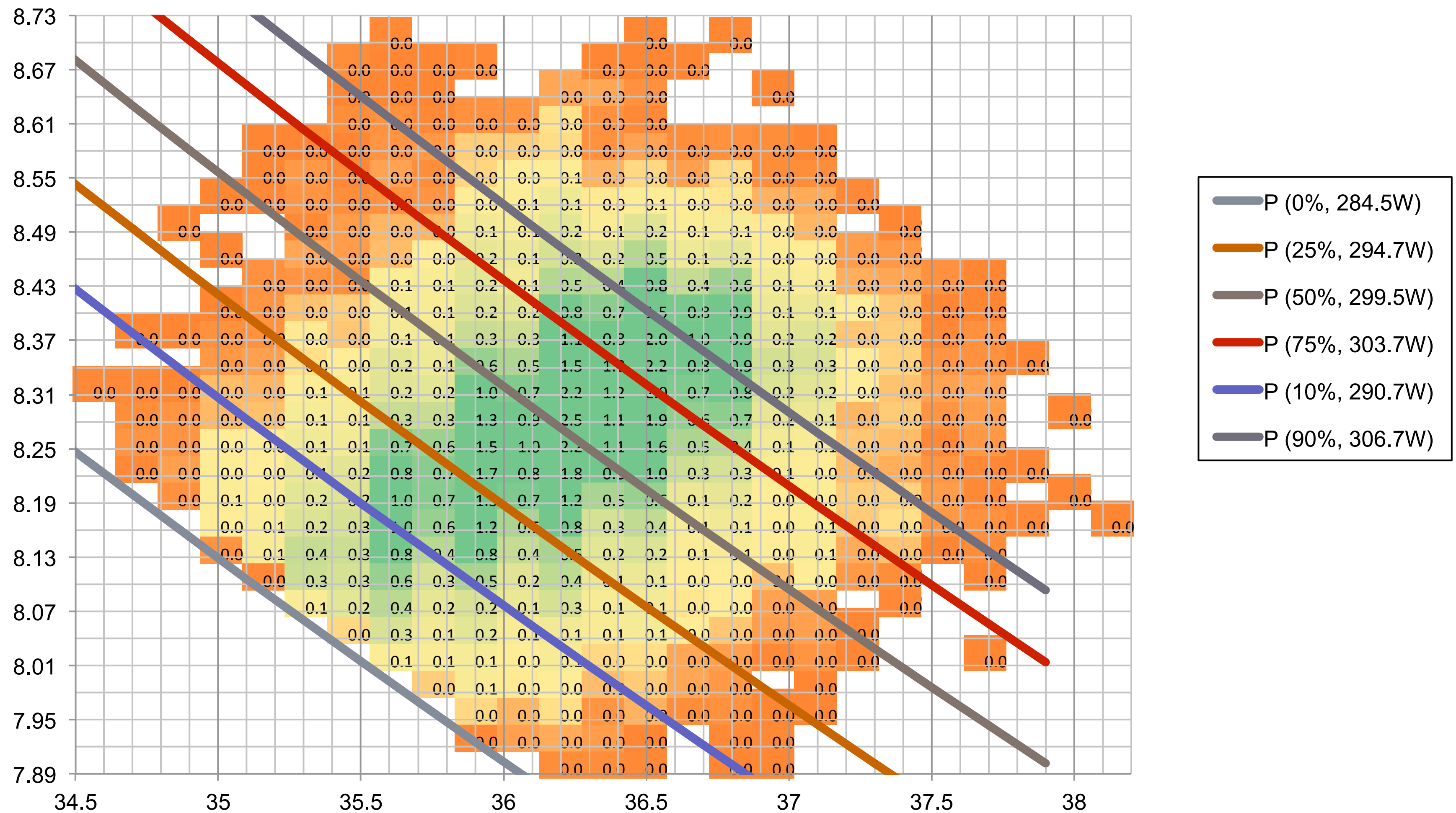
Module Quality: defined by a binning range, but mismatch losses are nominal



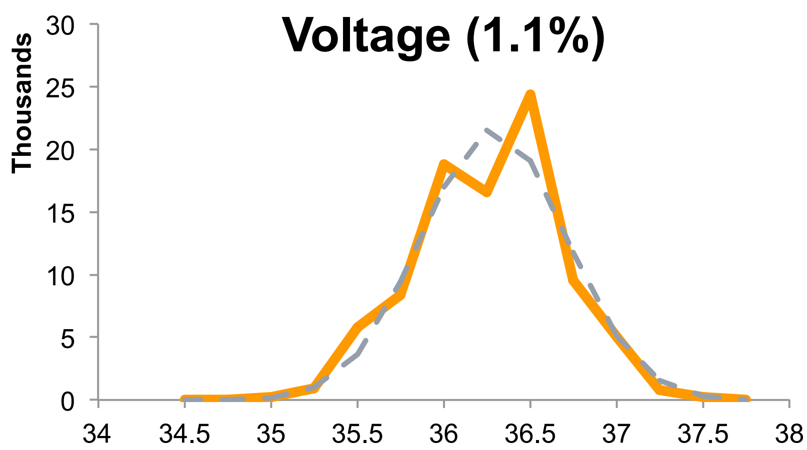
- Users define a lower and upper bound
  - Uniform Distribution
- Attempts to model module manufacturing tolerance
- Each module sampled once per design
- All designs seeded equivalently

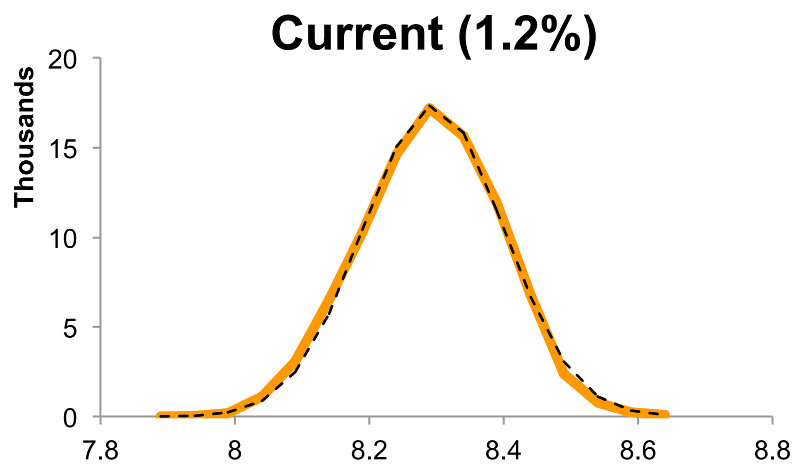
Includes baseline 5% standard deviation in irradiance, 4° temperature spread

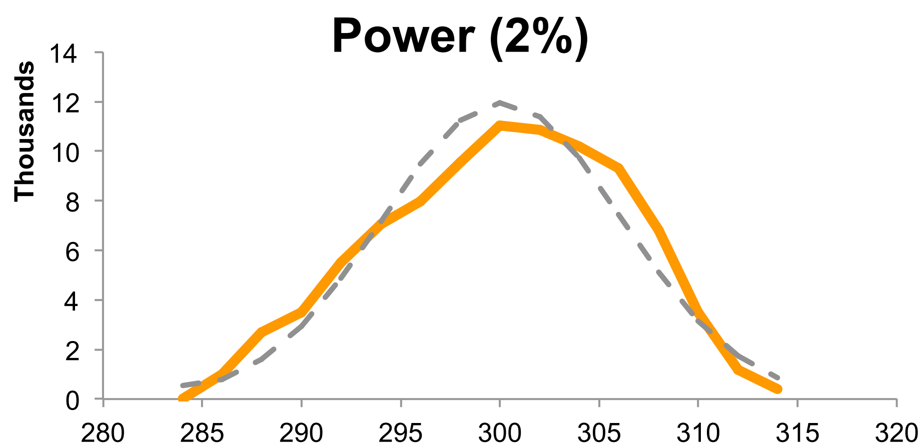
Module Quality: flash test voltage and current are correlated



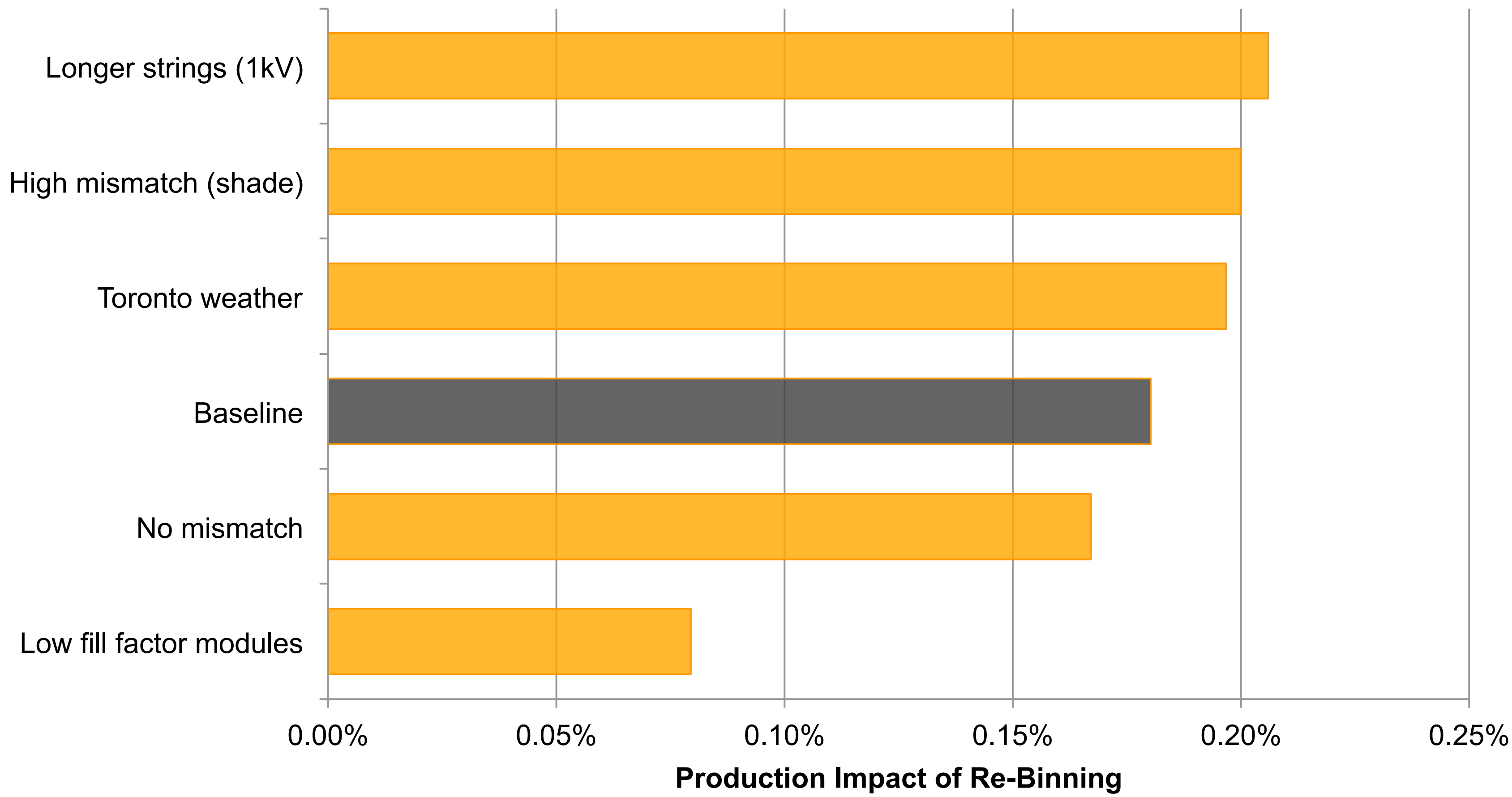
Module Quality: module voltages and currents appear to be normally distributed







Module Quality: Re-binning from a 5% range to a 1% range has small benefits



Baseline design: C-Si modules in 600V design, Imperial CA TMY3, standard mismatch factors

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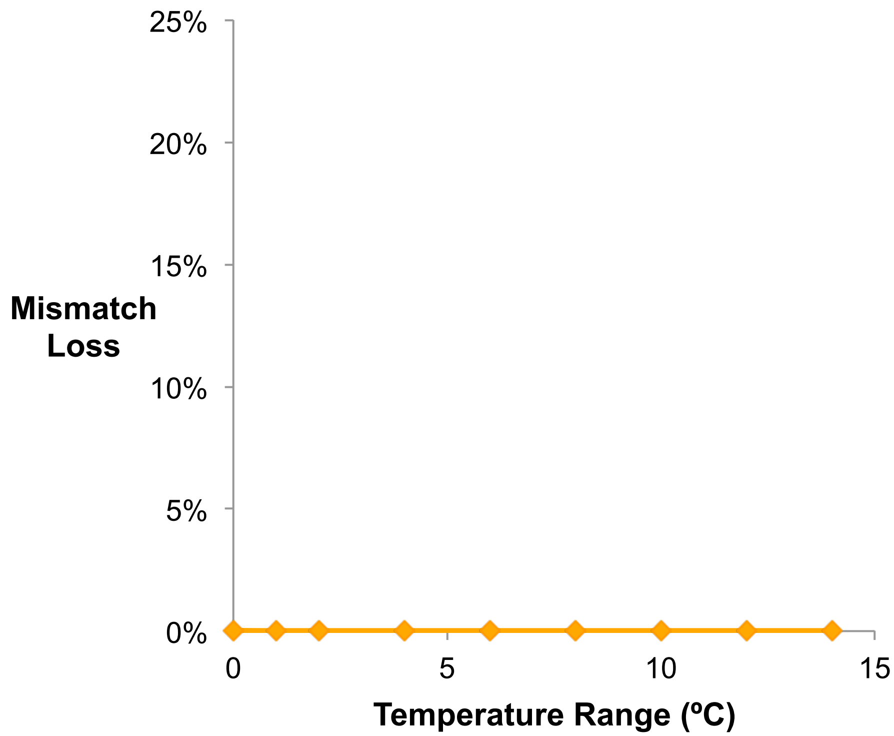
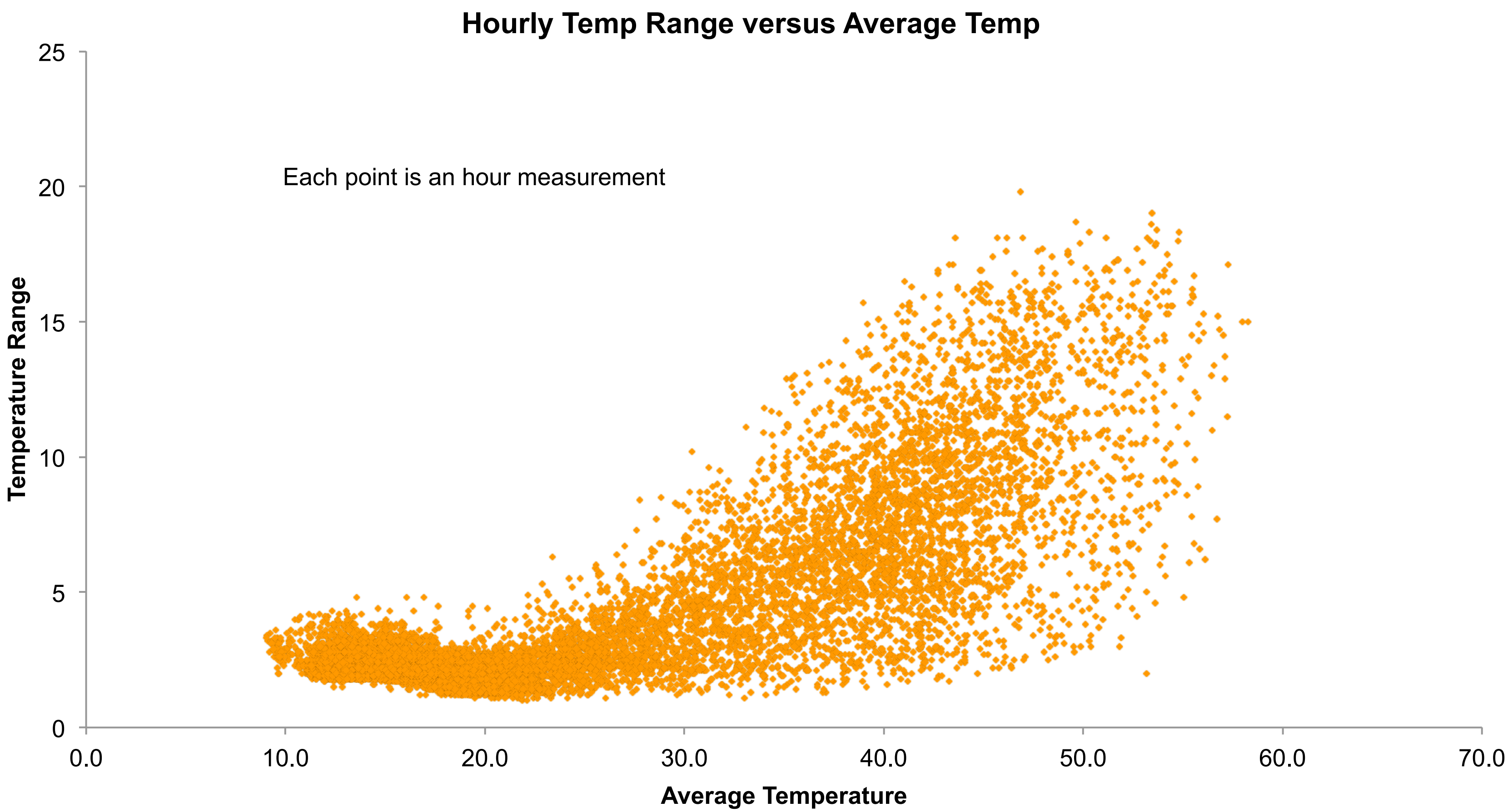
Temperature: available, but has almost no impact on performance



- Users define a total temperature range (ºC)
  - Uniform Distribution
  - Zero-centered
- Attempts to model module-to-module differences in temperature at the same point in time
- Each module sampled independently, every hour
- All designs seeded equivalently

Includes baseline 5% standard deviation in irradiance, 5% module binning

Temperature: Back-of-module temperatures vary considerably



Source: Tigo Fleet Data

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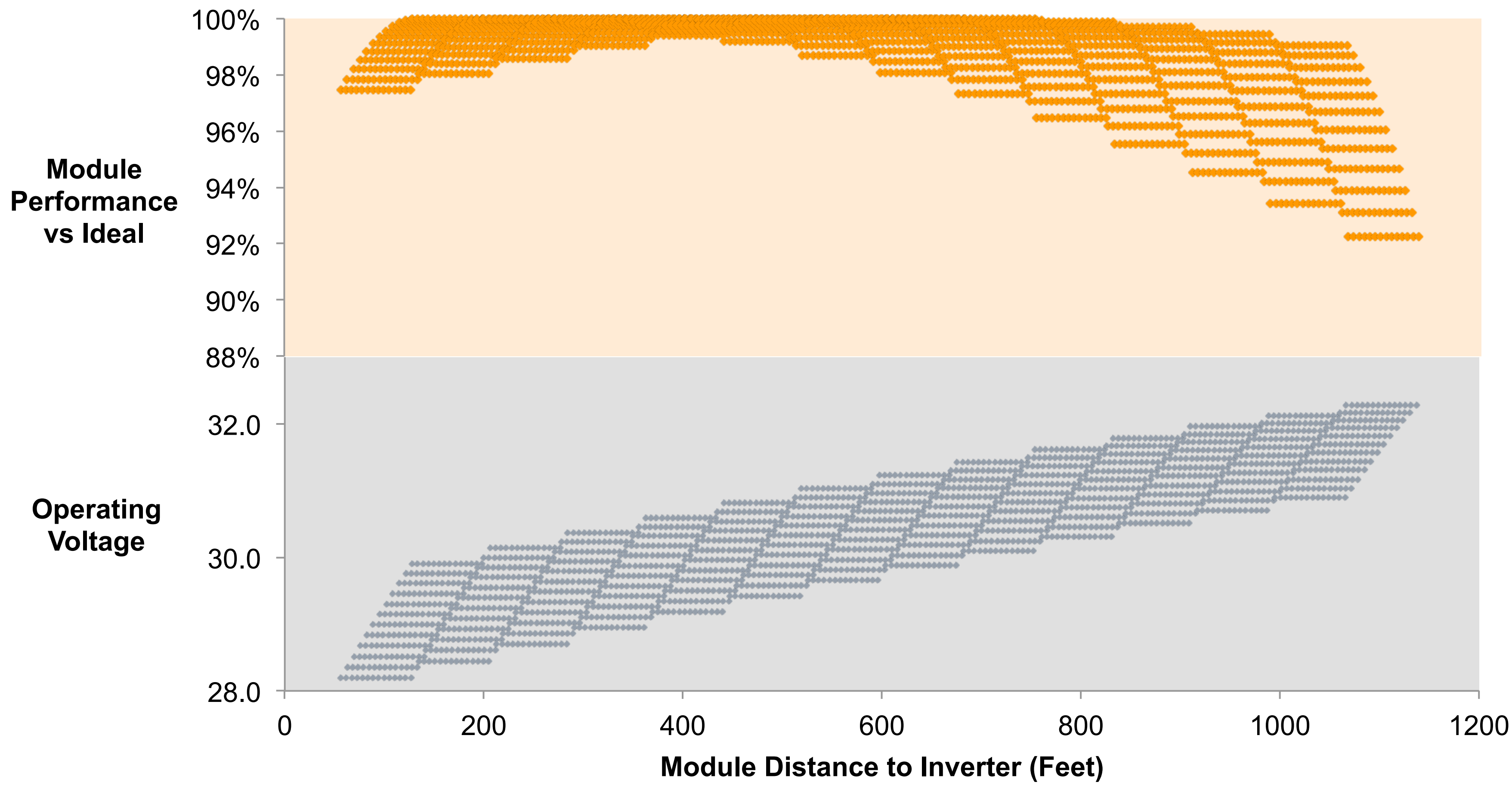
I^2R Losses: Voltage drop across the array affects all upstream components



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Our Path Forward

- Design granularity enables losses to flow directly through to mismatch
- We have introduced new mismatch parameters based on random distributions, but we need better physical models
  - Spatially correlated irradiance or temperature
  - Superior binning/quality distribution
- Will have to think carefully about how and when to disaggregate mismatch calculations, since they are inherently mixed in HelioScope

We look forward to working with the community to improve PV models

Research Interests

- Spatially correlated cloud models
- Spatially correlated temperature models
- More sophisticated binning distributions

Contact Us

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