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Reducing California PV Balance of System Costs by Automating Array Design, Engineering and Component Delivery

Final Project Webinar
Tuesday December 18, 2012

Agenda

- Introductions
- Project Scope and Vision
- Automated Layout and Design Tools
- Document Management
- California Permitting Agency Database
- Shaking Table Experiments
- SunLink Publications
- Building Code Developments
- Wrap Up
- Questions and Answers

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Introductions

SunLink	
Mike Williams	SVP Engineering and PI
Rob Ward	Chief Structural Engineer
Kate Miller	P.E.
Chris Harbich	Project Engineer
Eric Franzen	Director, Operations & IT
Rutherford and Chekene	
Andreas Schellenberg	Ph.D., P.E.

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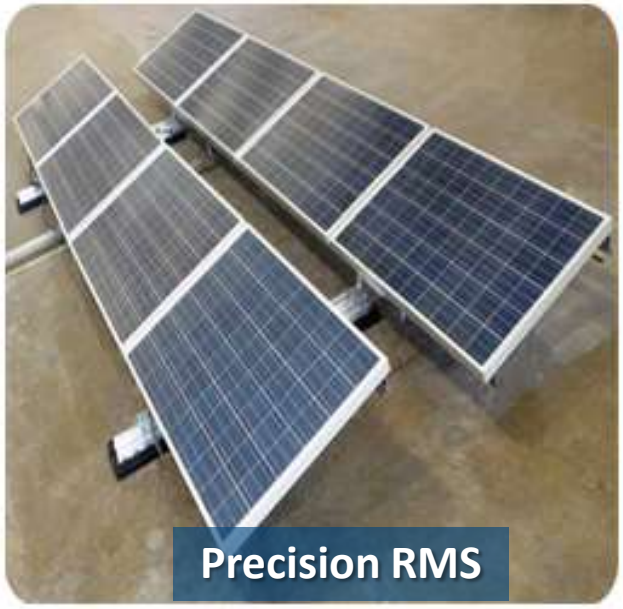

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SunLink Overview

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SunLink's Project Partners

Thanks!

GO solar CALIFORNIA

About | Consumers | Professionals | Equipment | Resources | Solar Basics | News&Media | Contacts

CSI RD&D >

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Welcome

The CalSolarResearch website provides information about the California Solar Initiative (CSI) Research, Development, Demonstration, and Deployment (RD&D) Program activities, including the program's history and current CSI RD&D solicitations. Please check back regularly for updates!

Latest Updates

Dec 6, 2012

SUNLINK WEBINAR

Date: Tuesday, December 18, 2012
Time: 10:00 AM - 12:00 PM PST

REDUCING CALIFORNIA PV BALANCE OF SYSTEM COSTS BY AUTOMATING ARRAY DESIGN, ENGINEERING, AND COMPONENT DELIVERY

Itron

REDUCING CALIFORNIA PV BOS COSTS

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BoS Definition

Balance of System = (Installed Cost of PV Array) – (Cost of Modules):

- Mounting System
- Inverters (typically)
- Wiring and wiring management components
- Combiner Boxes
- Monitoring
- Installation labor
- Engineering and permitting fees
- Interconnection fees
- Financing costs

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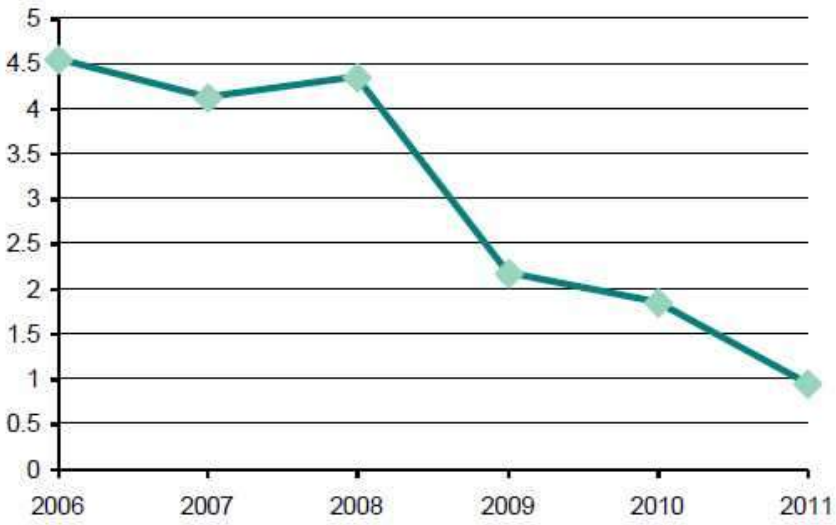
Solar PV BoS Costs

Grid Parity for Solar PV with Balance of System Cost Reductions

By John Farrell | April 29, 2011

RENEWABLE ENERGY WORLD.COM

" Half of the installed cost of a solar PV array is the solar module, but the other half (the "balance of system") involves labor, assembly, and other components. With module prices continually falling, ***significant decreases in total installed cost depend on reducing balance of system costs.*** *"*



Chinese c-Si PV module prices ($/W) [1]

SOLAR NOVUS TODAY
Delivering Today's Global SOLAR Technology News, Today

As reported in Solar Novus Today - www.solarnovus.com

Solar PV BOS Costs to Surpass PV Module Costs by 2012

30 June 2011

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Reducing PV BoS Costs in California

What's Needed:

- **Design optimization tools**
  - Lower design time and costs
  - All project sizes
- **Documentation tools**
  - Done faster
  - Less opportunity for error
- **Consistent state-wide acceptance criteria**
  - Understood by plan reviewers
  - Accepted by the engineering community
  - Allows for optimal designs
  - Demonstrated code-level performance

Project Tasks:

- Structural Design Automation
- Documentation Automation
- Wiring Software and Components
- Document Management
- Permitting Database
- Seismic and Wind Research
- Industry Publications

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AUTOMATED LAYOUT AND DESIGN TOOLS

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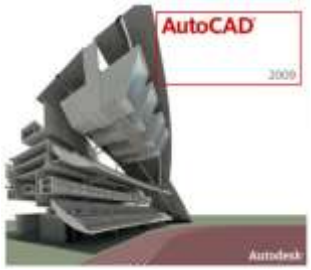
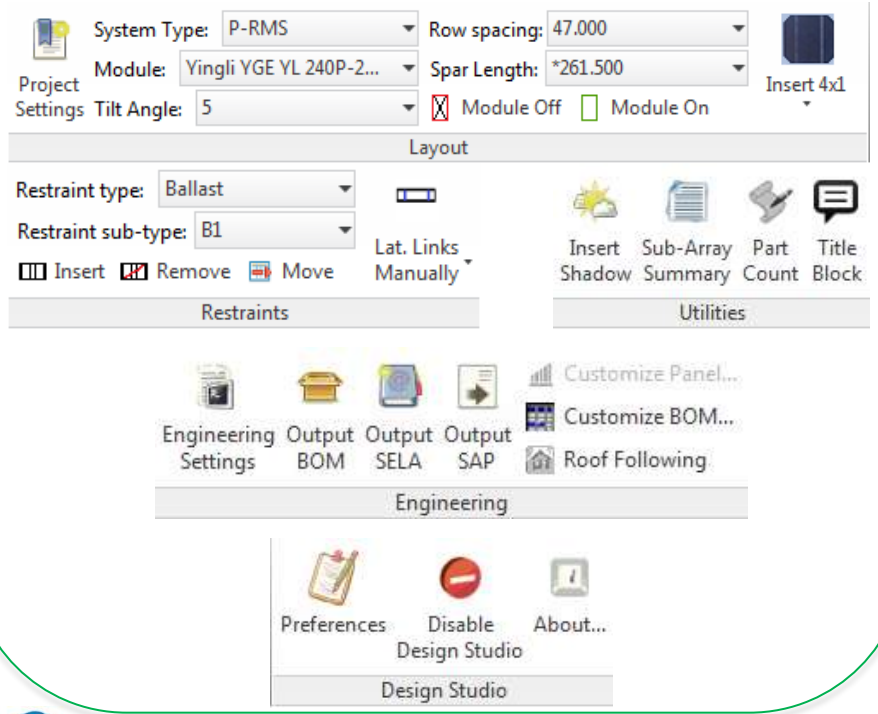
Layout and Engineering Tools

SunLink Design Studio





PV-SAP

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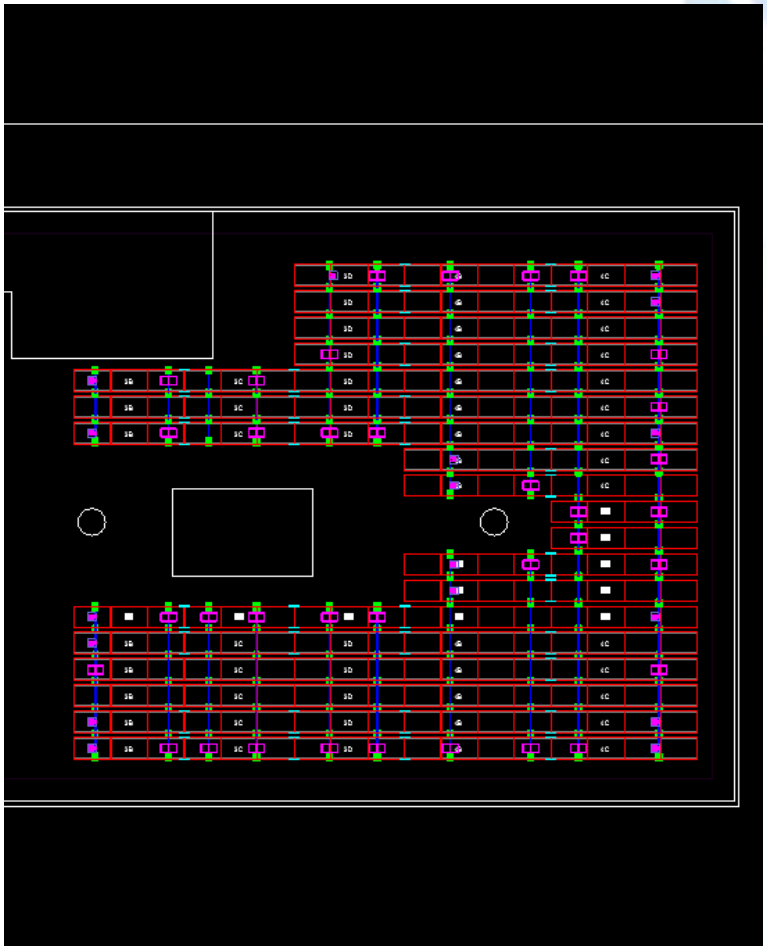
SunLink Design Studio

- Driven by a database that contains the specifications and constraints of each product
- Supports the creation of any size projects through layout automation
- Easily supports the placement of engineering components into the drawing for analysis
- Integrated with Microsoft Excel & SAP2000 to create analytical models for wind & seismic analysis
- Provides tools to create and setup drawing sets for permitting and installations



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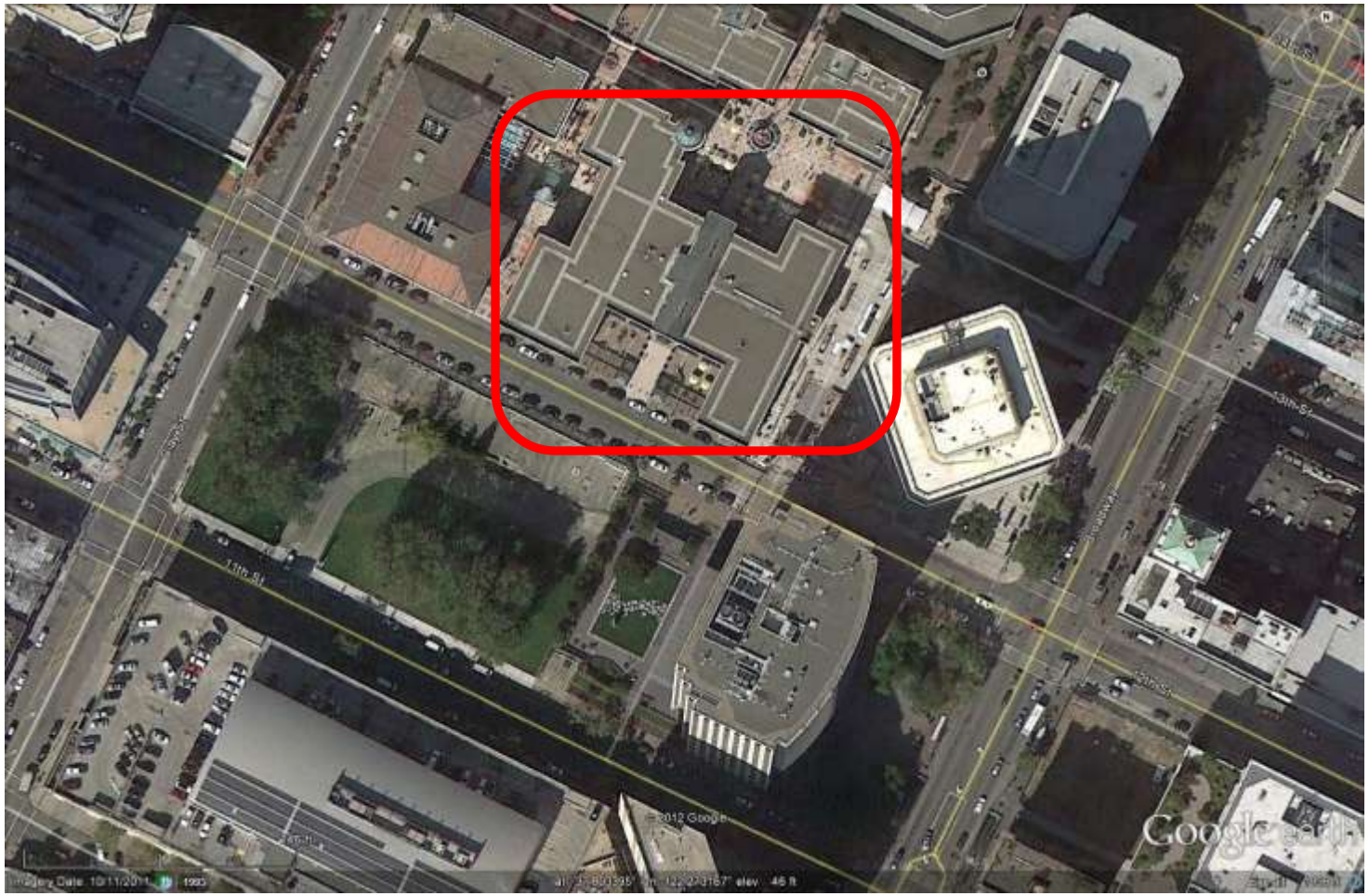
SunLink Design Studio Demonstration



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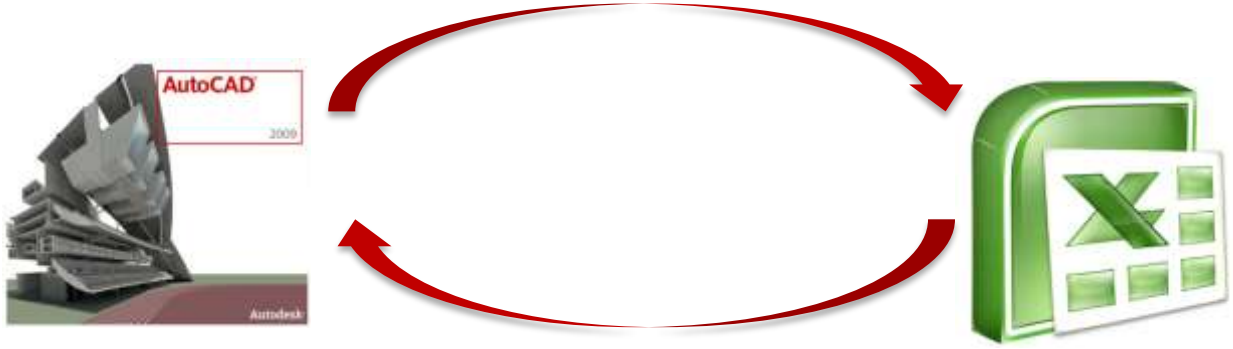
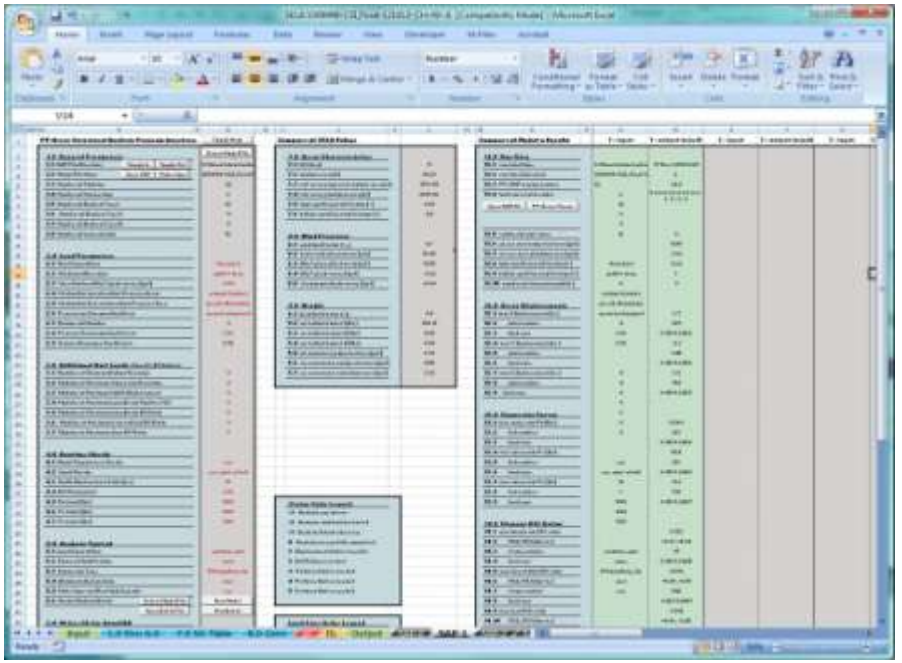
PV-SAP Automation



- SunLink's Structural Engineering Load Advisory (SELA) generated from Design Studio

- Uploads all project specific inputs to calculate Wind, Seismic, and Snow loads

- Automatically formatted to provide as customer deliverable



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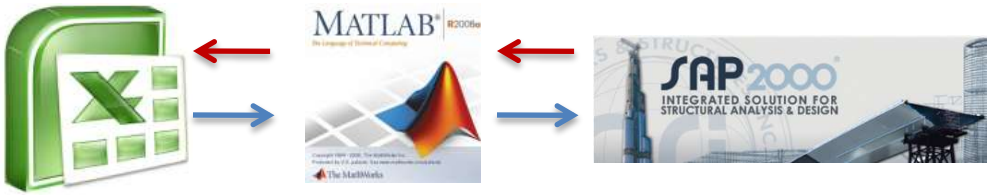
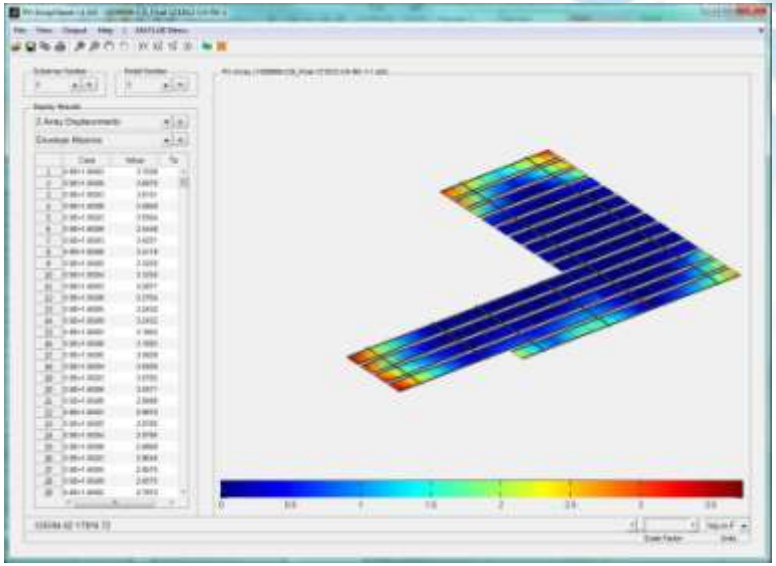
PV-SAP Automation Cont.

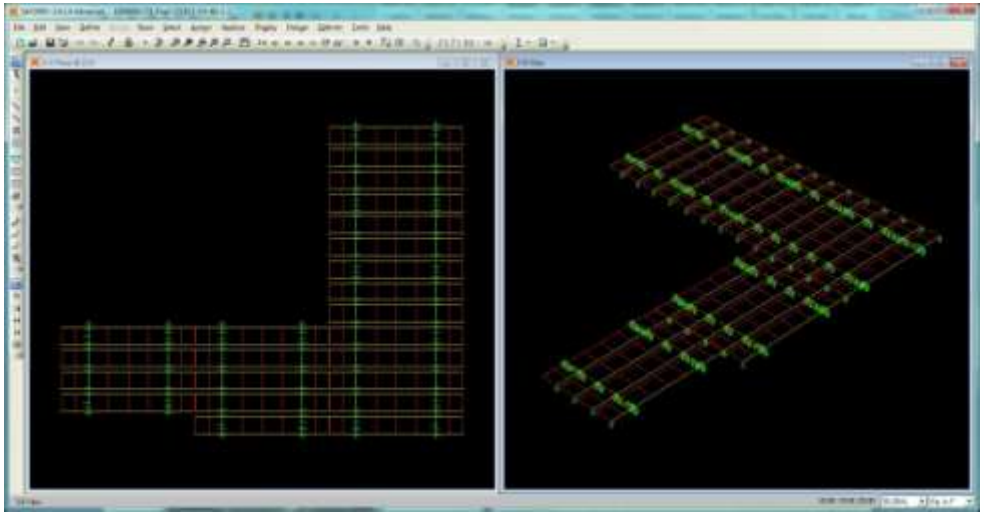




- Analyzes structural model generated from Design Studio

- Writes and reports all results to the SELA excel document

- Graphical user interface (GUI) allows ease of interpreting results



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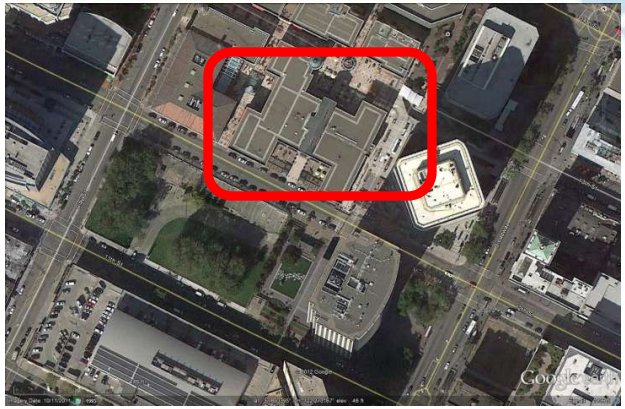
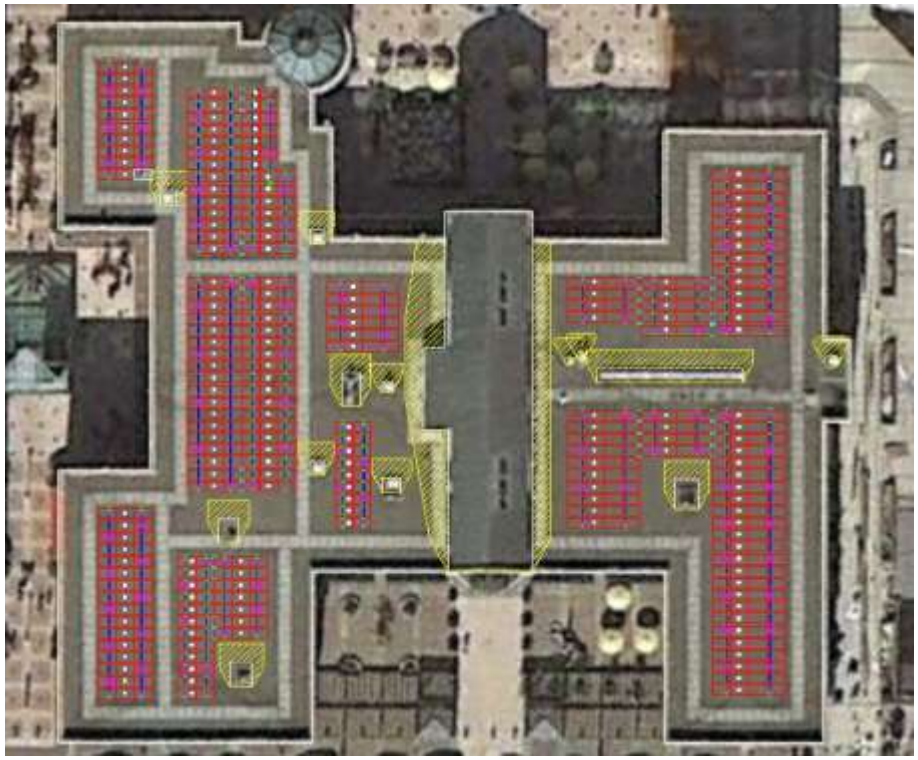
Benefits to California

- Better customer communication
- Lower cost of PV systems by quickly automating multiple layouts
- Reduce design time for both SunLink and its customers
- Deliver projects with less opportunity for error





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DOCUMENT MANAGEMENT

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Why Investigate DMS?

- Solar projects involve a number of documents including drawings, contracts, engineering reports, permitting documents, etc.

- Challenges:
  - Locating files on a file share
  - Version Control
  - Security
  - Document Processes
  - Collaboration
  - Sharing documents with external partners

- Seek more efficient means of working with documents

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Process

- Gathered high level requirements
- Held interdepartmental workshops to establish process steps, activities, and associated documents and data
  - Workflow Drawing & Excel Workbook
- Researched document management system capabilities and offerings
- Established scope for evaluating DMS
  - Roof mount products
  - Quote Request -> Customer Contract
- Selected DMS for pilot
- DMS configuration
- DMS pilot

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DMS Selection

M-Files®
Simply Easy Document Management

DMS Features :

- Document Versioning / Tracking
- Integrated MS Windows Explorer Client
- Web Client / Portal
- Work Flow / BPM & Project Tracking
- Microsoft Office, Outlook & AutoCAD integration
- Reporting
- Mobile Device Browser
- Digital Signing / Certificate Module
- Document Security
- OCR – Optical Character Recognition
- CRM Integration

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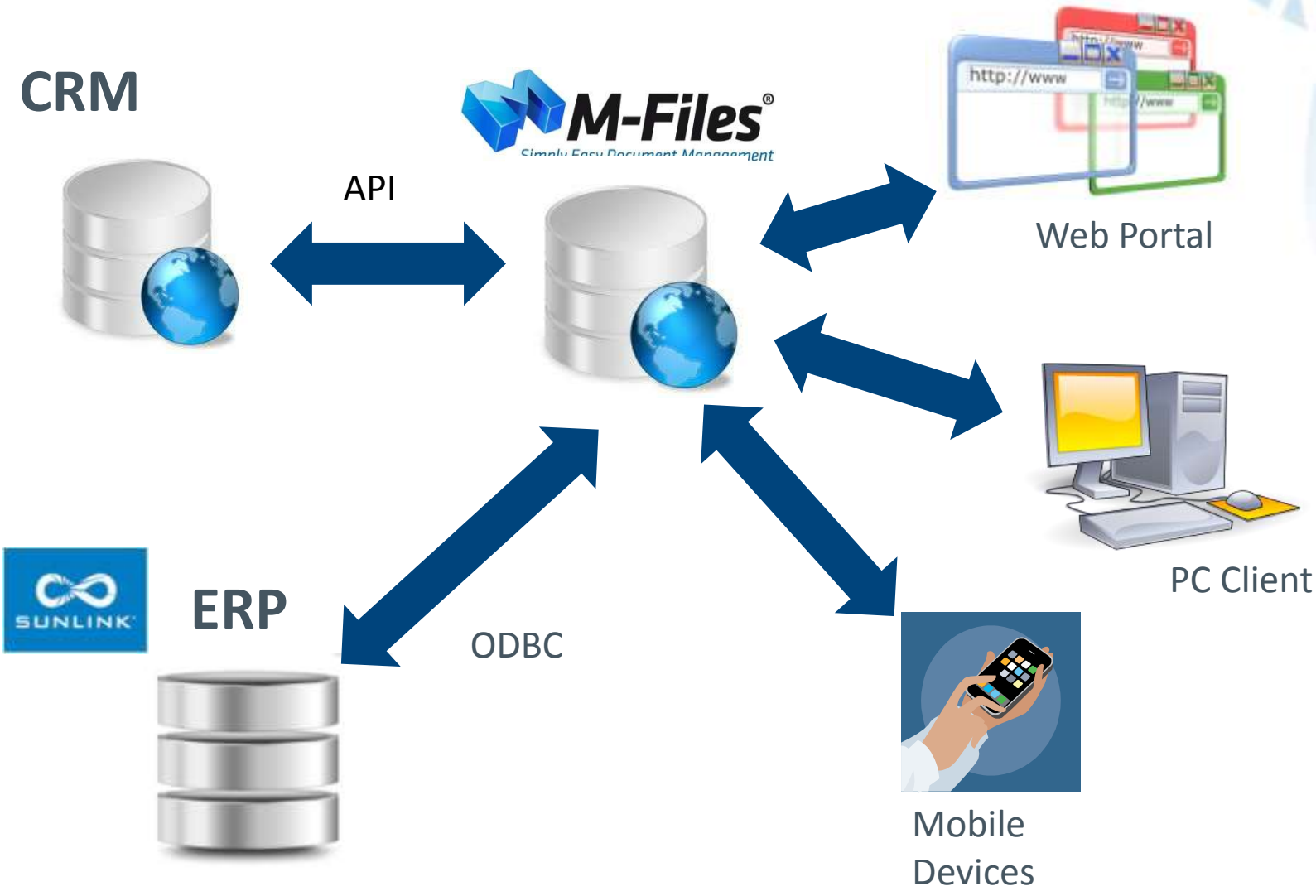
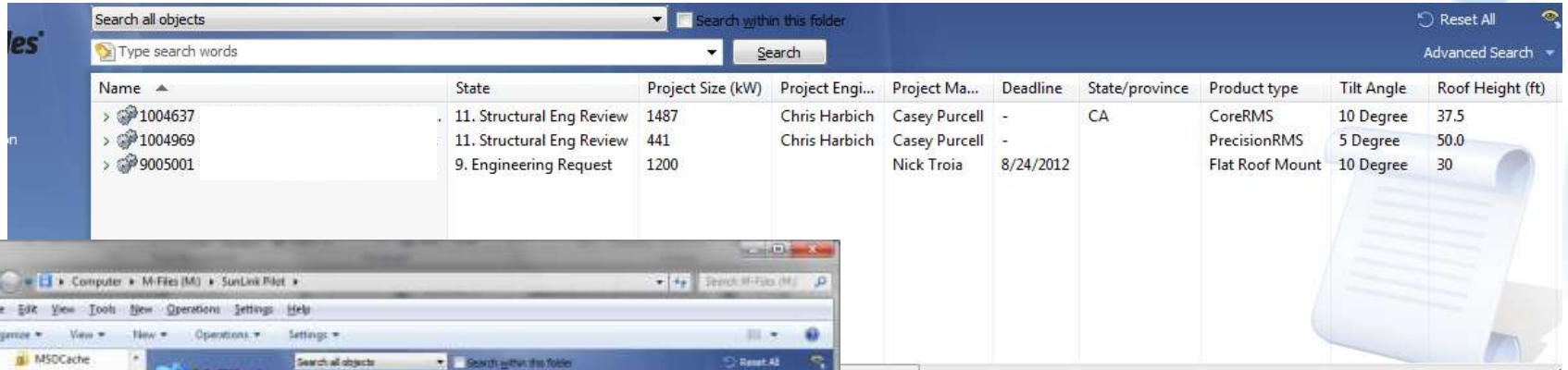
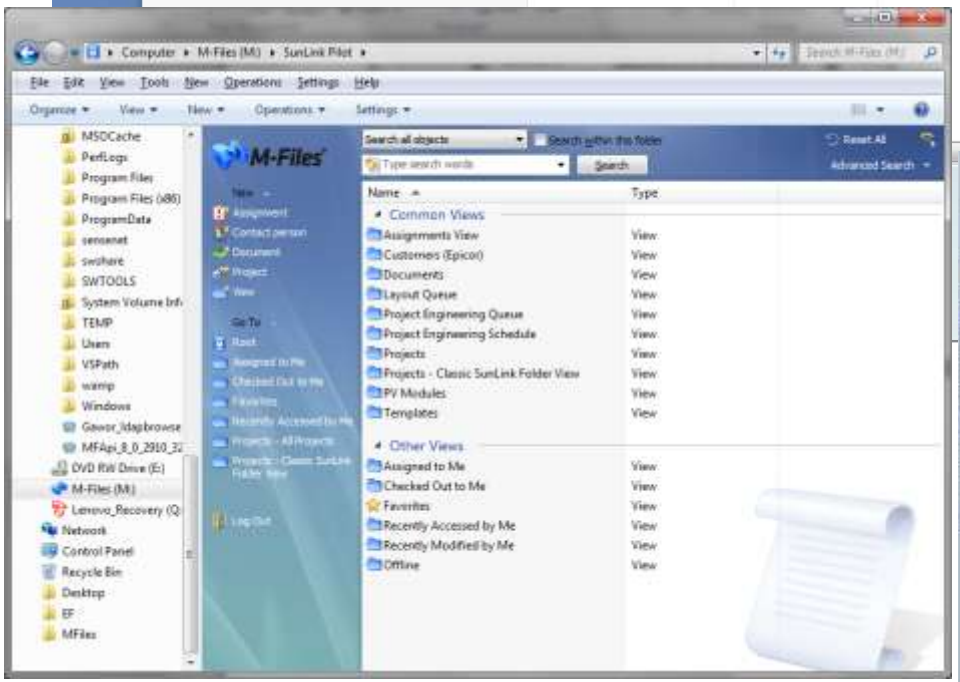
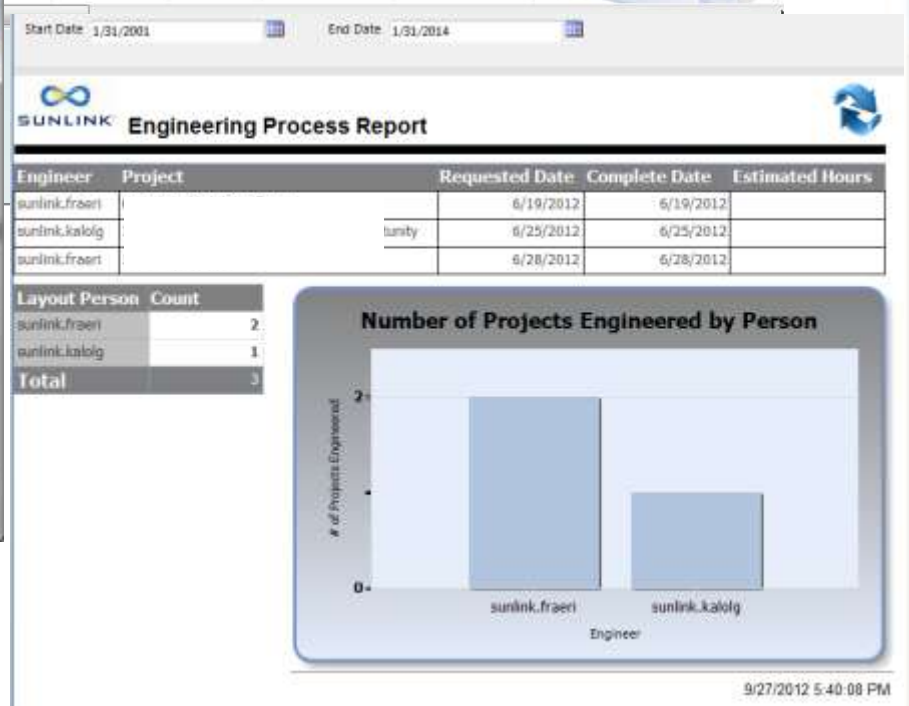
DMS Pilot Architecture



DMS Screen Shots







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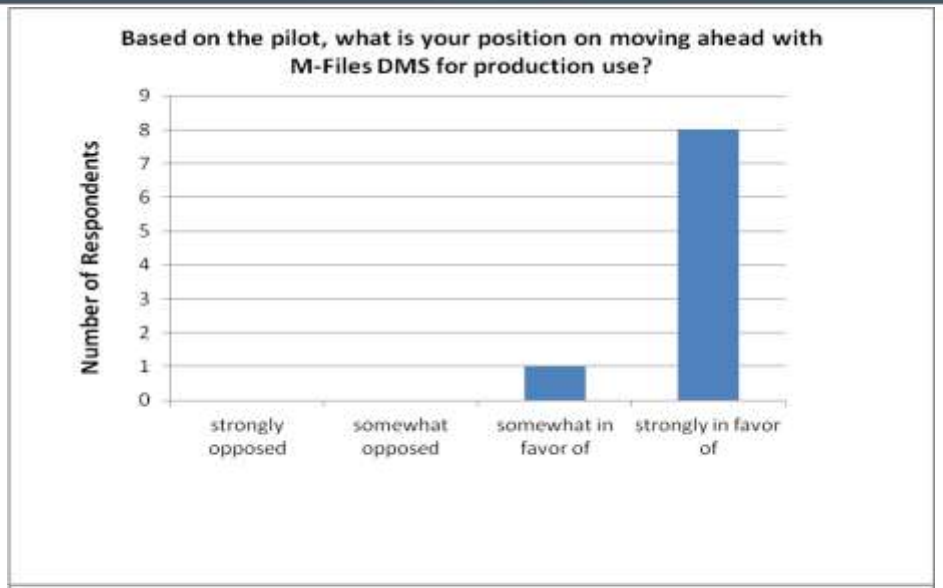
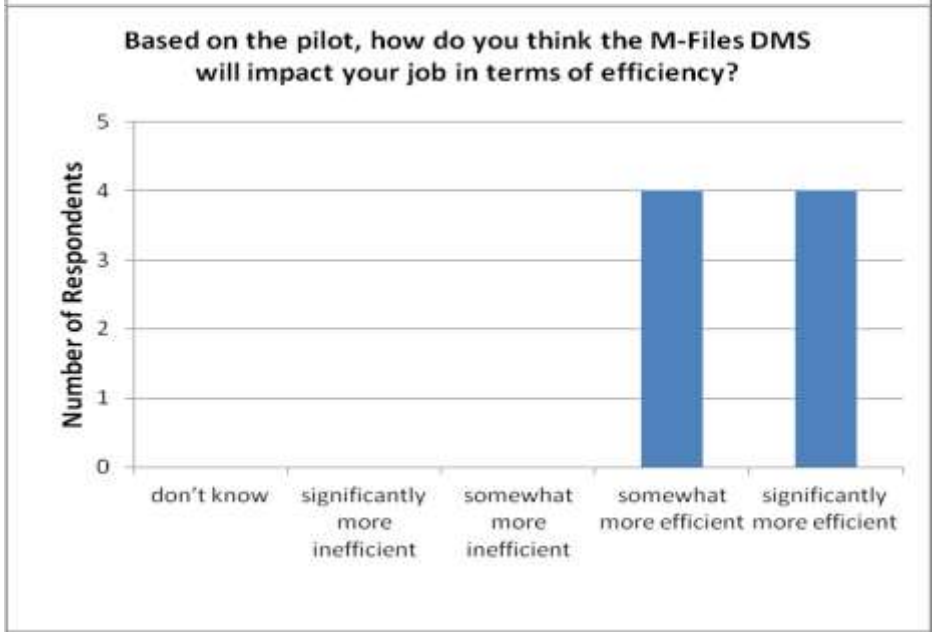
DMS Pilot Feedback





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Benefits to California

- Established Document Management systems can play a vital role in creating organizational efficiencies and reducing errors
- Our work serves as a starting point for solar organizations to pursue document management
- Identified and reviewed DMS products
- Identified key functionality and features worthy of consideration as DMS selection criteria

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CALIFORNIA PERMITTING AGENCY DATABASE

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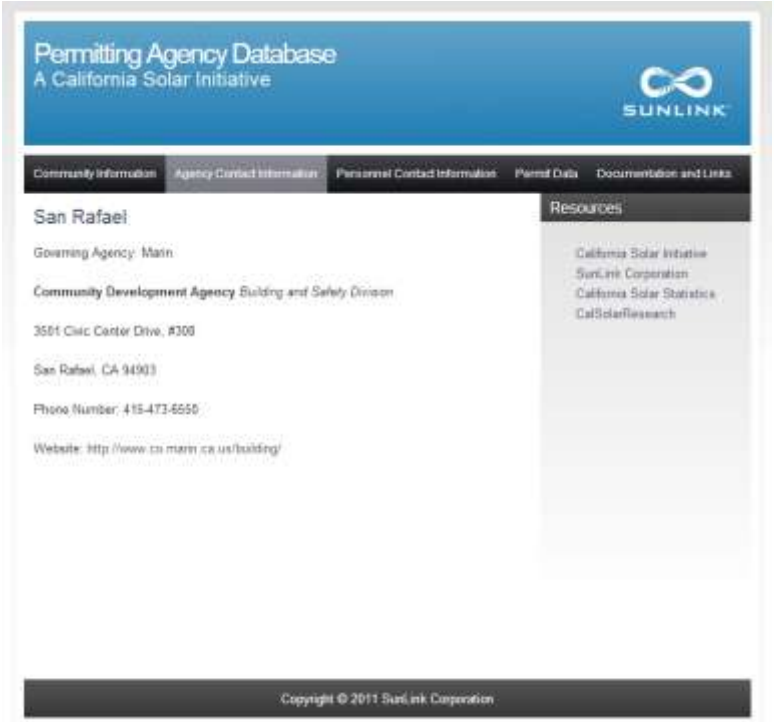
Benefits of the Database Application

- Improve visibility and efficiency of permitting process in California
- Improve communication between building owners, solar installers, engineers, and permitting departments
- Reduce the time and effort required in gathering engineering requirements
- Encourage future universal code requirements for solar installations

What it Does

- Web-accessible database application
  - Engineering parameters for solar projects
  - Building official contact information
  - Links to adopted building codes
  - 1,527 California cities and towns already added



http://ec2-54-245-104-33.us-west-2.compute.amazonaws.com/

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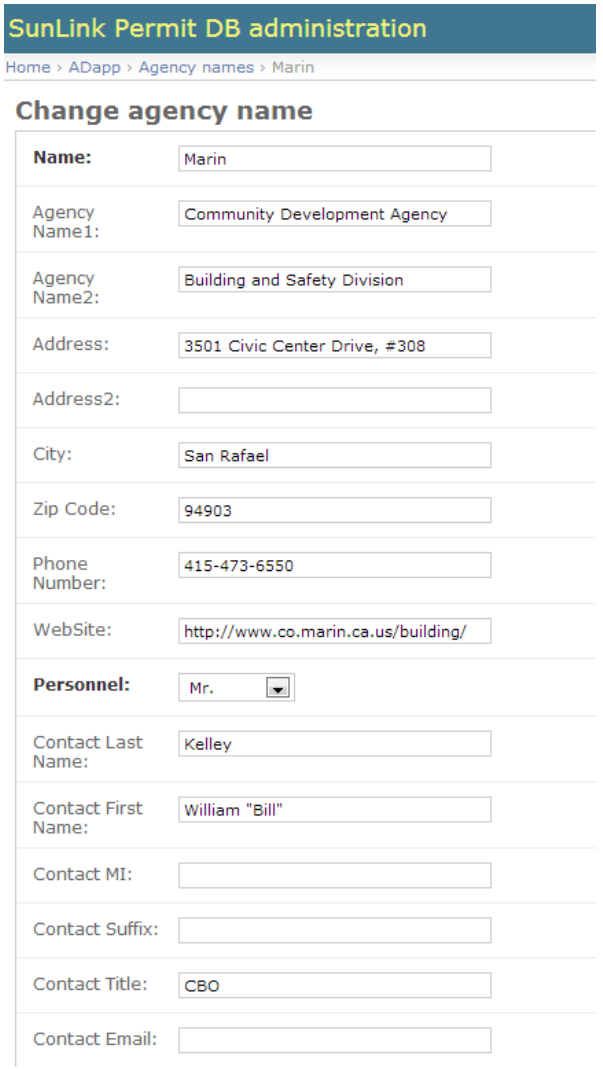
The Future of the Database

- SunLink-hosted for one year
- Administrator privileges to be determined
  - Potential to transition to a public wiki
- Future database management



SHAKING TABLE EXPERIMENTS

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Unattached PV Solar Arrays

Rooftop arrays where ballast, self-weight, and friction provide wind resistance.

THE ADVANTAGE:

- Overall reduced project costs
  - Installation
    - Penetrations, flashing, etc.
  - Maintenance

THE CHALLENGE:

- Seismic design in high seismic areas
  - Code-level “life safety” performance

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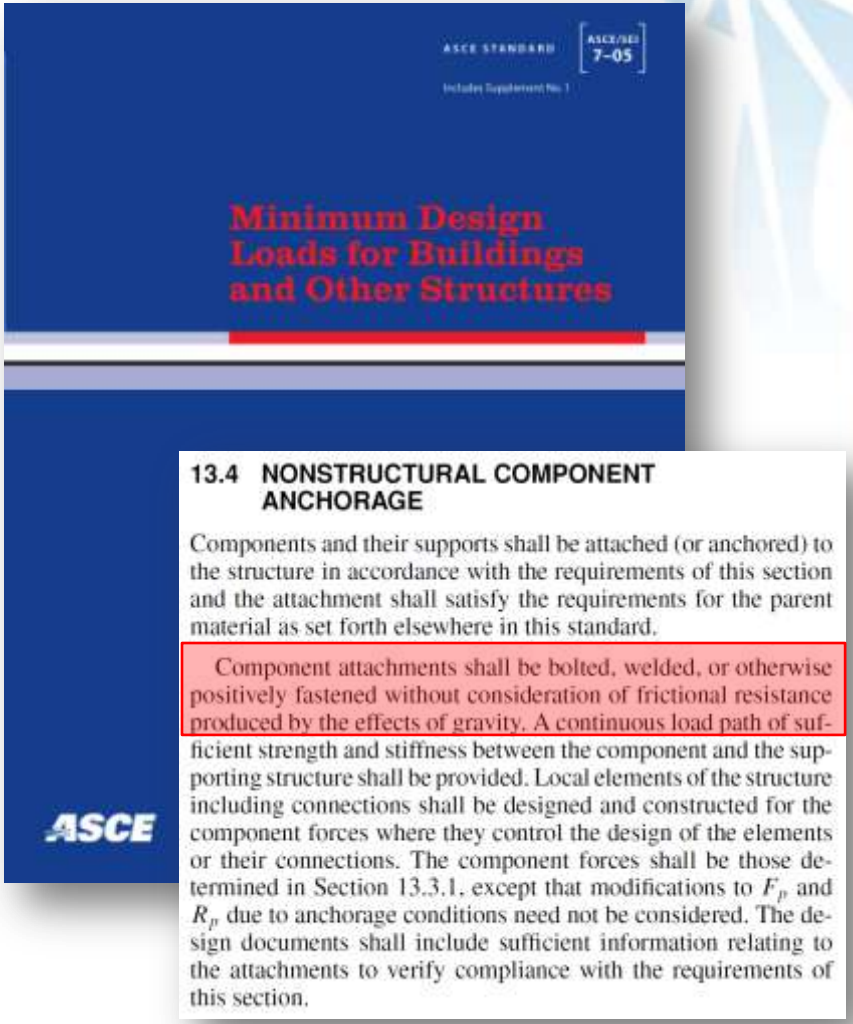
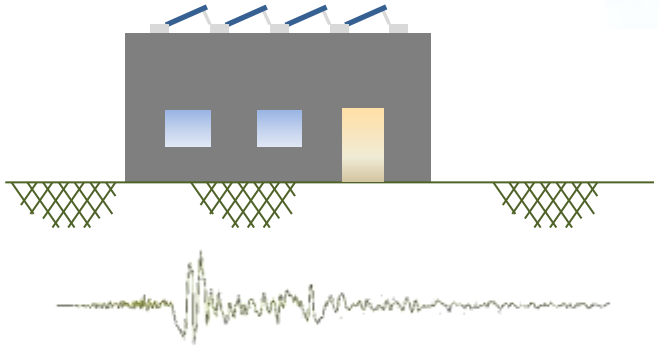
U.S. Building Codes

- Seismic design per ASCE 7
- Chapter 13 prescriptive requirements for building equipment in high seismic areas:
  - *"…bolted, welded or otherwise positively fastened …"*



Part 1 - Structural Analysis

1. Build structural analysis models that accurately capture the parameters that influence seismic behavior
2. Determine a set of appropriate earthquake roof motions to be used as inputs to the analyses
3. Run analyses and record sliding displacement demands
4. Develop design tables so that the engineer can look up sliding displacements for different SDS, COF and roof slope values



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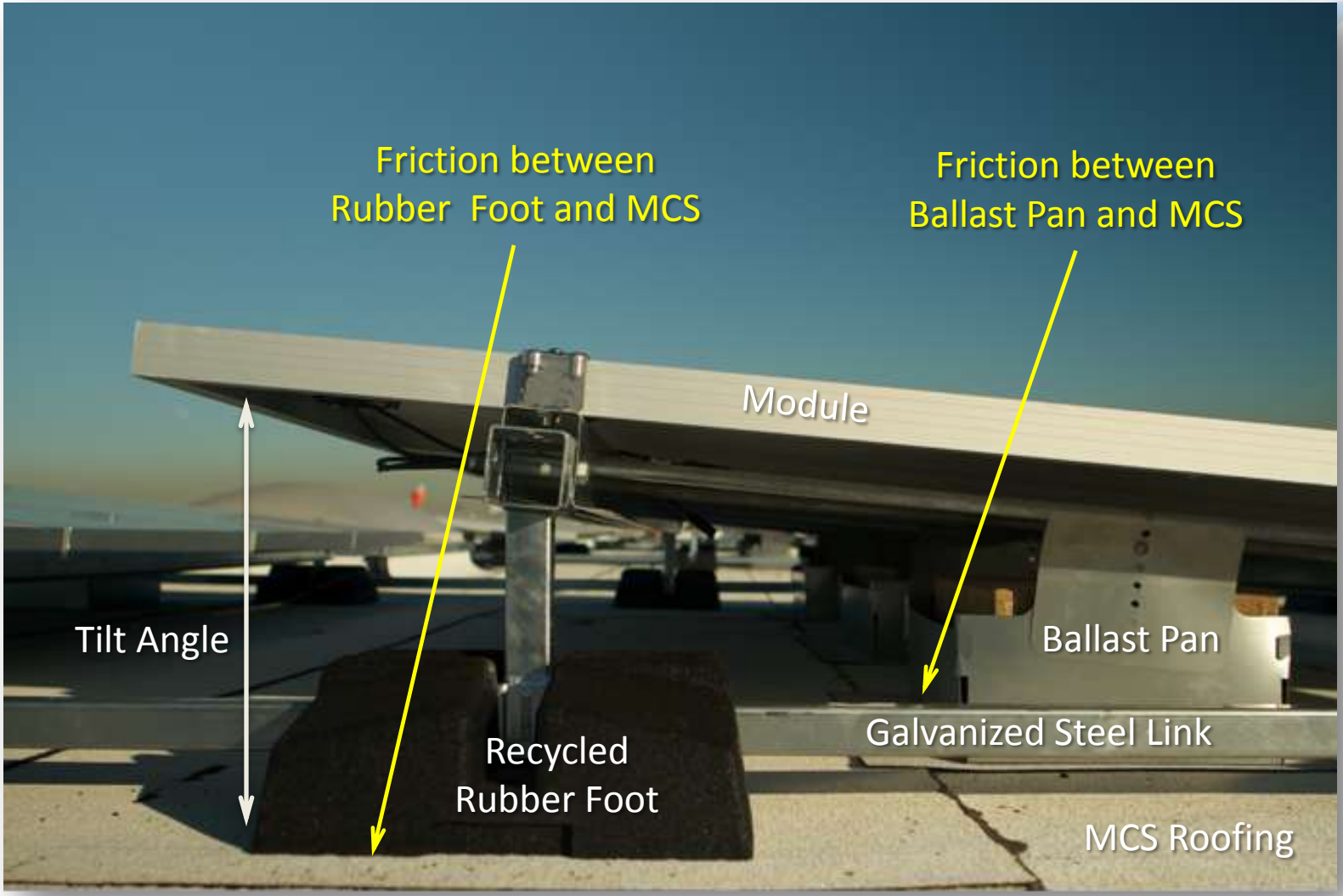
Development of Analysis Models



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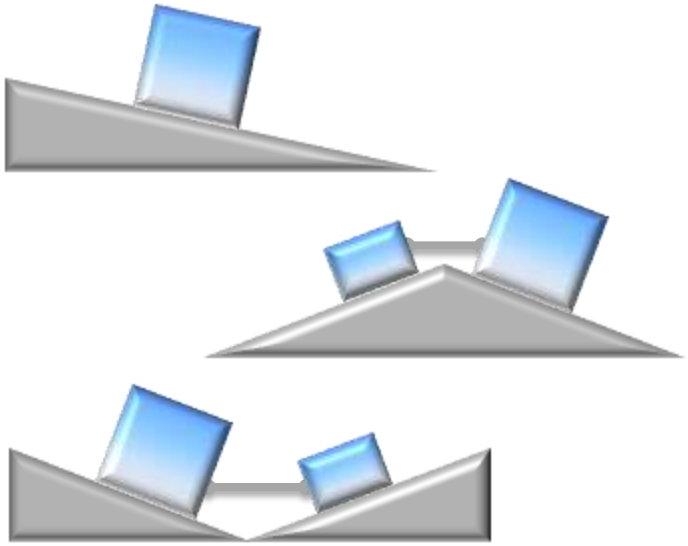
Development of Analysis Models

- Friction is assumed to be constant (Coulomb friction) and is determined from pull-tests of the feet and ballast pans
- Due to the low CG sticking and sliding are the primary modes of response (no rocking, no uplift)
- Model arrays in plane w/o vertical dimensions or as lumped masses w/o internal flexibility
- Internal damping of the solar array structure is conservatively ignored



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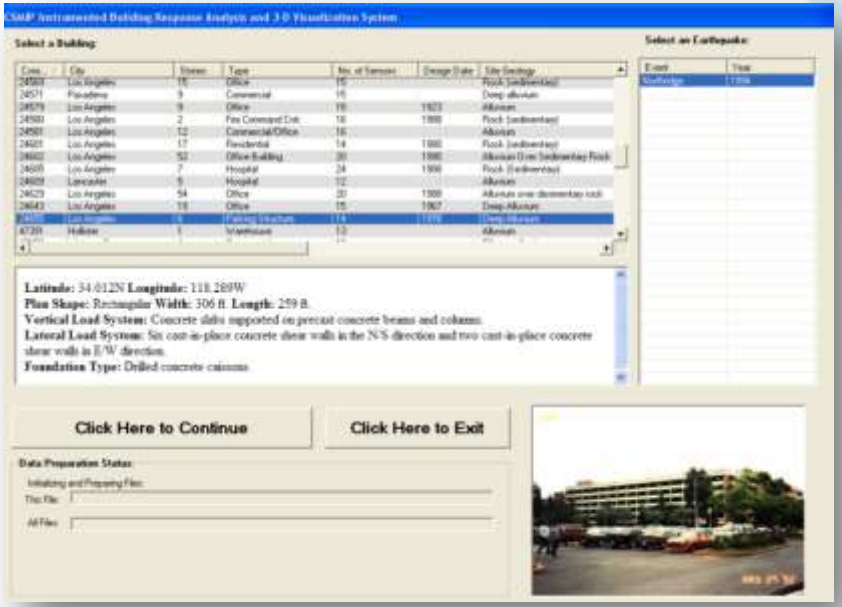
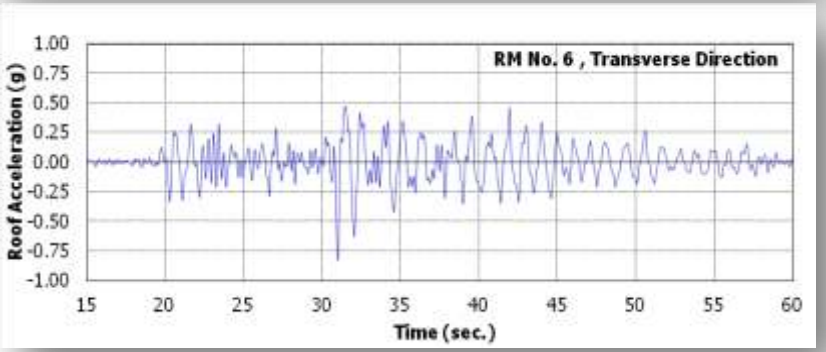
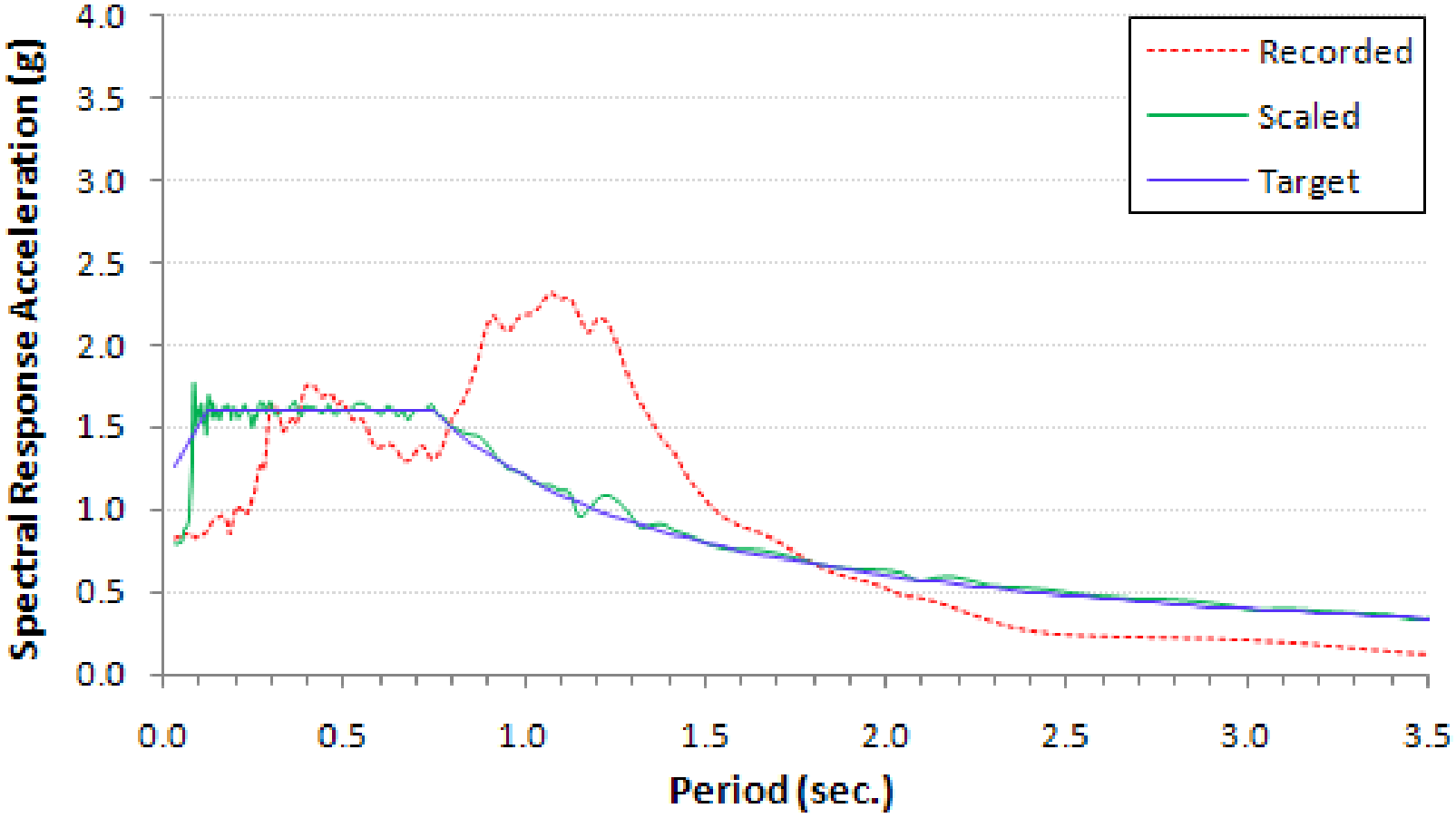
Selection of Earthquake Roof Motions

- Use roof accelerations from CSMIP database
- Use only 3-component roof motions
- Select 7 roof motions
  - different earthquakes
  - geographical locations
  - soil conditions
  - building types





Effect of Scaling and Spectral-Matching



Roof Motion 6: Transverse Direction

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Shaking Table Testing

- Needed a real-world experiment to validate and calibrate the nonlinear computer analysis models developed in phase 1

PEER Earthquake Shaking Table Facility

- Table = 20 ft x 20 ft
- Largest 6 DOF shaking table in U.S.
- Can test structures, weighing 100,000 lbs, to horizontal accelerations of 1.5 G
- +/- 5 inches horizontal displacement capacity
- +/- 2 inches vertical displacement capacity
- +/- 40 inches/sec velocity capacity

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Roof Surfaces

Testing the CORE System on a 4% Incline Polyvinyl Chloride (PVC) Roof

Switching to the Mineral Cap Sheet (MCS) Roof

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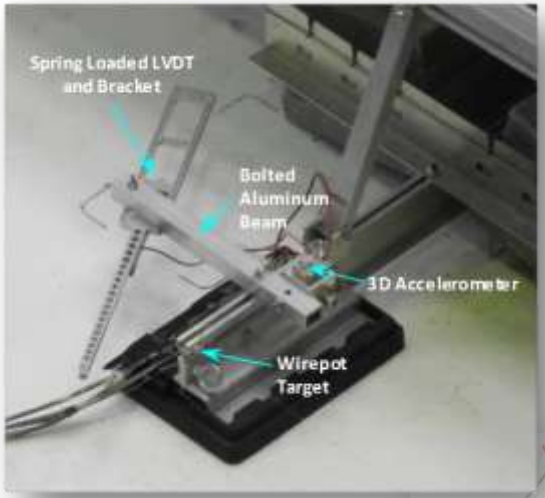
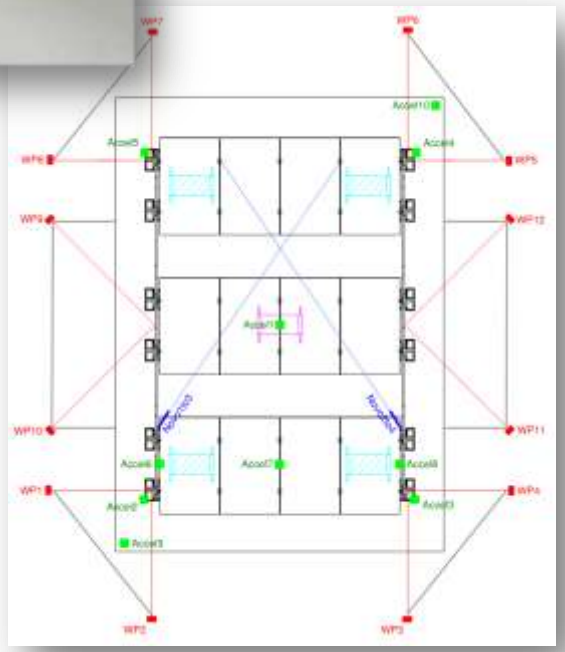
Instrumentation Setup

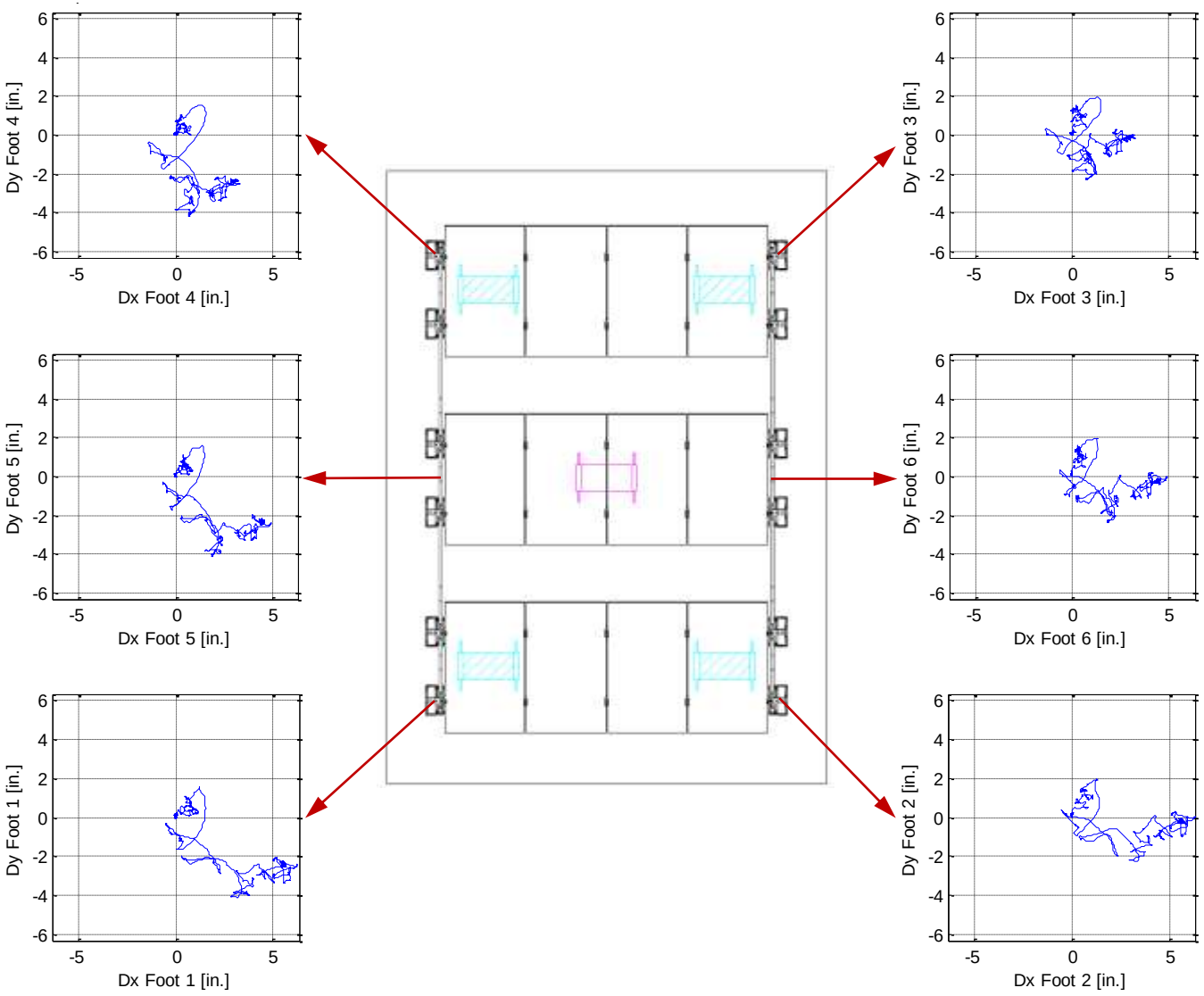
- 12 Wire Potentiometers
- 2 Linear Variable Displacement Transducers
- 10 Accelerometers
- 60 DAQ Channels
- Approximately 1.4 million data points/test



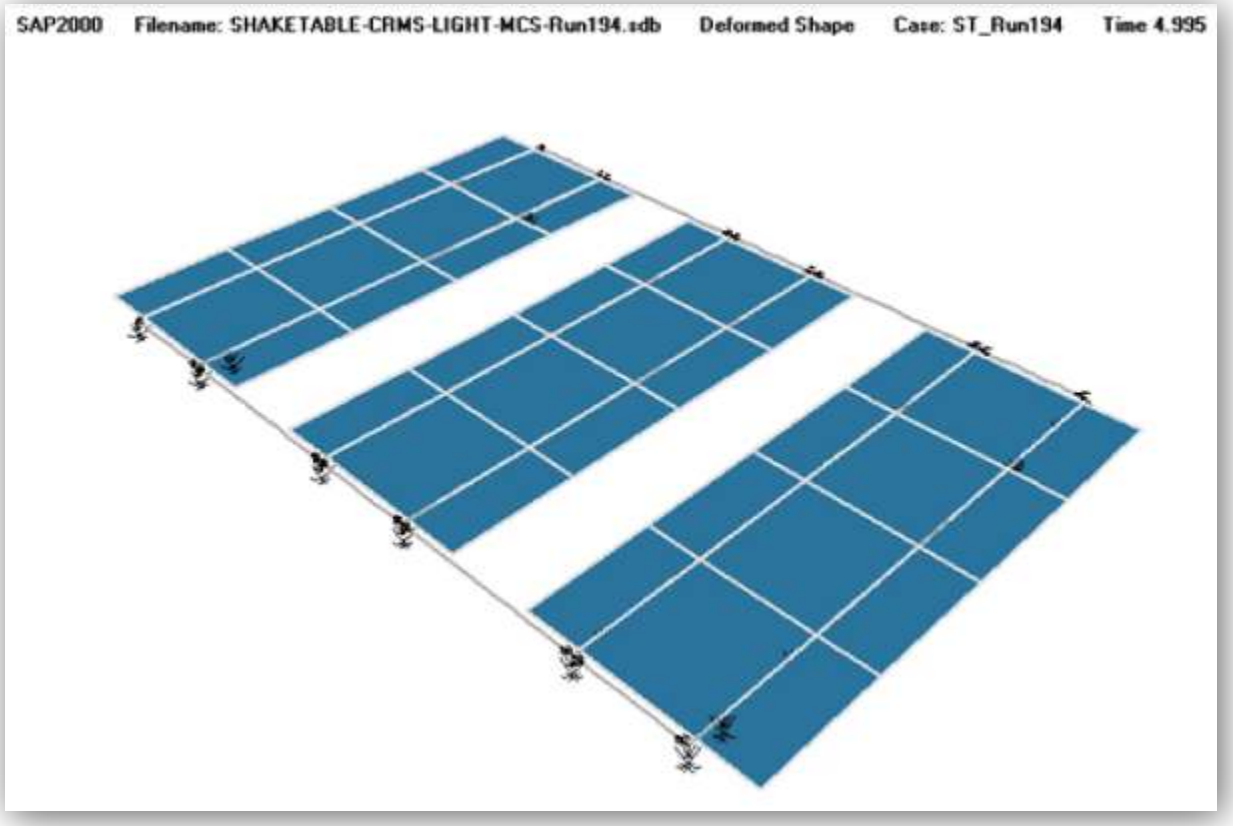


Shaking Table Video

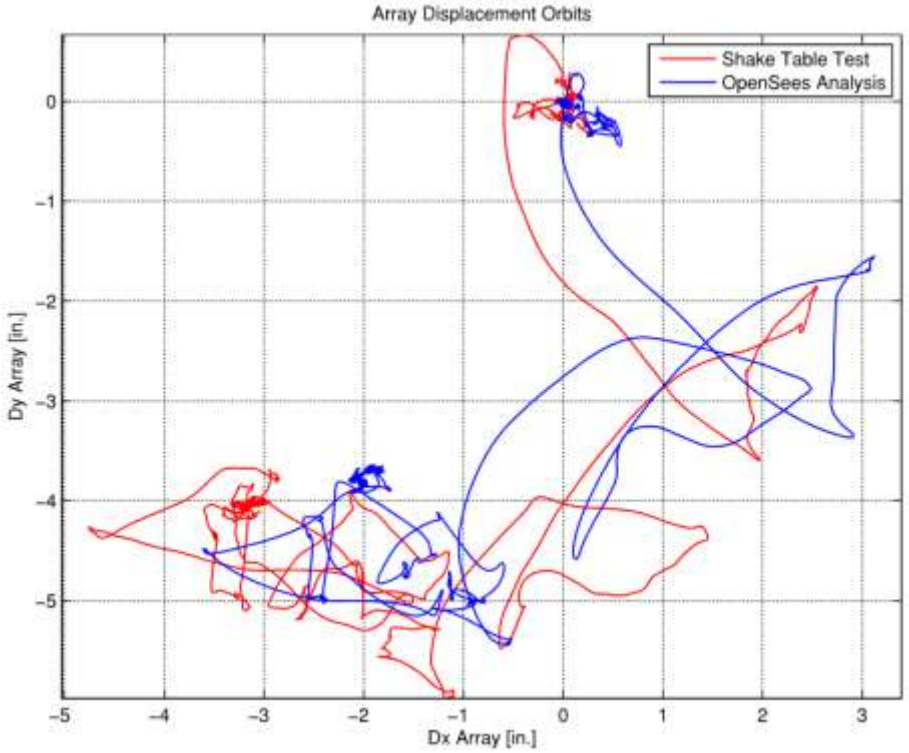
Data Acquisition and Processing

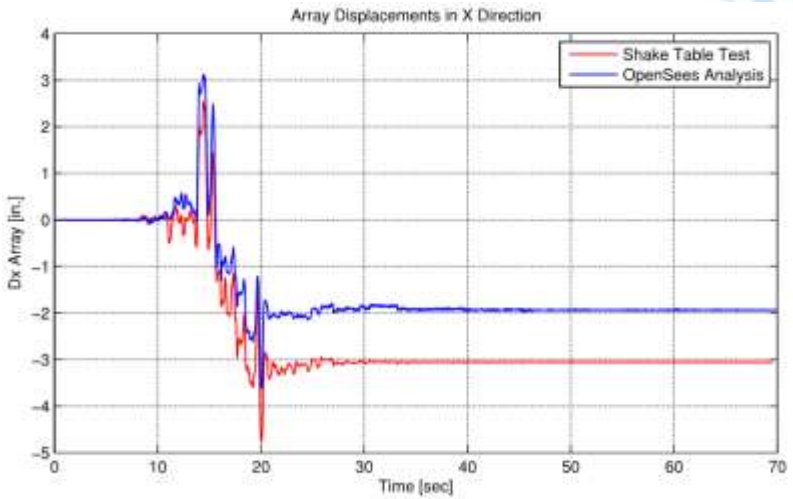


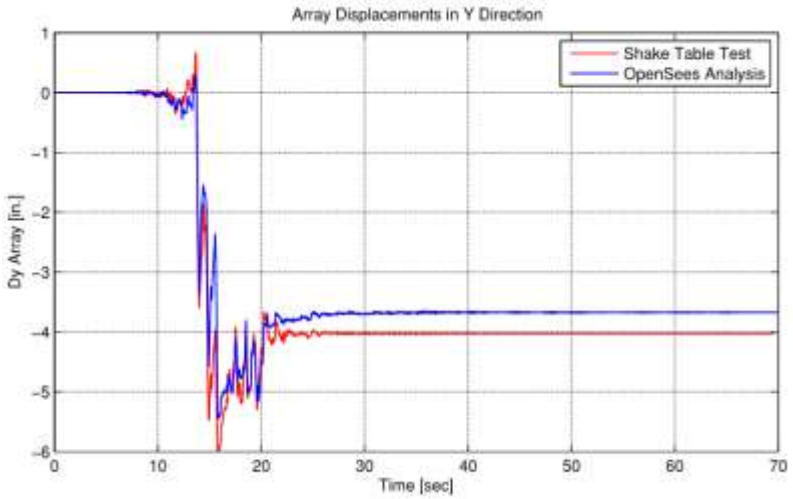
Animation of Analysis Results



Data Collection and Comparative Analysis







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SEISMIC R&D FINDINGS

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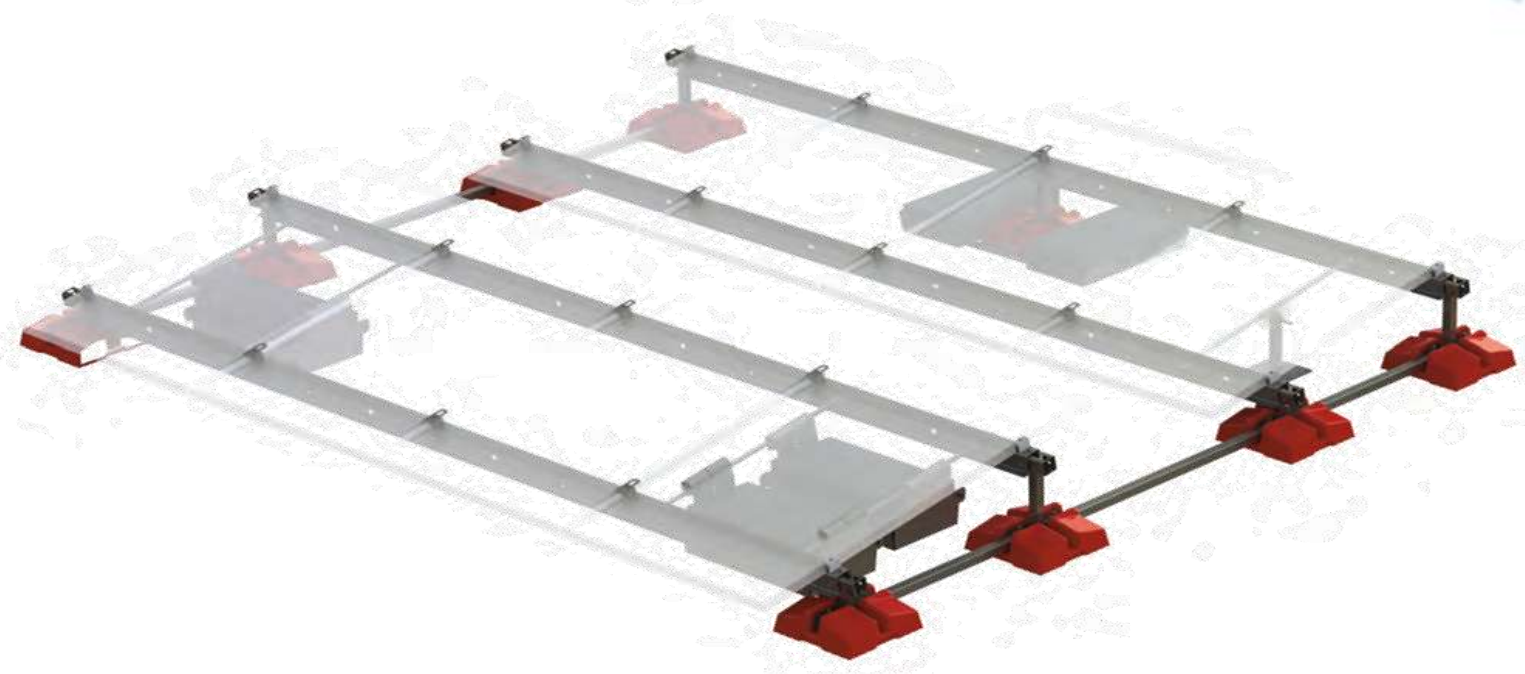
System Movement

System movement during high seismic events is smaller than many think, and is manageable.

Friction



Friction plays a role in restraining forces during seismic events.

Roof Integrity

After 100 earthquakes each: No roof damage.

Read the full report at www.sunlink.com/seismictesting.

PUBLIC BENEFITS TO CALIFORNIA

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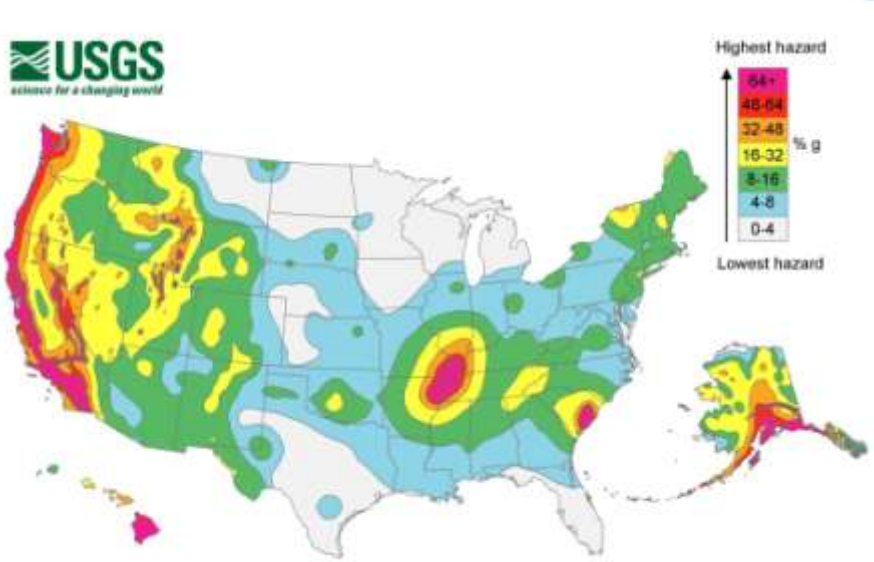
Seismic R&D Benefits

- Greater Solar Penetration
  - Decreased system and installation cost of unattached systems
  - Potential for projects on building roofs previously considered unsuitable
- Furthering the conversation toward permitting unattached systems in seismic regions



INDUSTRY PUBLICATIONS

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SunLink Publications

- CSI RD&D program
- Technical conferences
- SunLink white papers and webinars
- Trade journal articles
- Peer-reviewed journal papers

Tech Transfer 1

Trade Journals and Press

Carlsen, R. "U.C. Berkeley's PEER Center Hosts Shake Test for Alternative Solar Racking System," Engineering News-Record, March 19, 2012

Riddell, L., "Sunlink studies seismic effects on solar," San Francisco Business Times, March 6, 2012

Ward, R., Miller, K., "Ballasted Solar Systems in High Seismic Areas," Solar Novus, 24 October 2012

Technical Conferences

Holland, R.H., Miller, K., and Schellenberg, A. "Approach to Parametric Analysis of Wind Load Effects on PV Solar Roof Bearing Arrays Using OpenSees" PEER OpenSees Days presentation, 16 August 2012.

Schellenberg, A., Fathali, S., Maffei, J., Miller, K., "Seismic Behavior of Unattached Solar Arrays on Flat Roofs: Analysis, Shake Table Testing, and Proposed Requirements," Proceedings Structural Engineers Association of California / Structural Engineers Association of New Mexico Convention, Santa Fe, NM September 2012.

Tilley, C., "Accelerating BOS Cost Reduction through Integration," 4th PV Power Plants Conference, Phoenix, AZ, November, 2012

Williams, J. M., "Engineering Challenges for Photovoltaic Power Systems," 2nd International Conference for Sustainable Design, Engineering and Construction, Fort Worth, TX, November 2012.

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Tech Transfer 2

Trade Shows

Tilley, C., "Standardization of Codes for Solar Project Development," Solar Power International Orlando, FL, September 2012

SunLink White Papers

SunLink Seismic Testing Roof Integrity Report

SunLink Webinars

Miller, K., Ward, R.,"Designing for Earthquakes: Lessons from SunLink's Full-Scale Shaking Table Experiments," September 25, 2012

Peer Reviewed Journals

Maffei, J., Fathali, S., Telleen, K., Ward, R., and Schellenberg, A. (2012). "Seismic Design of Ballasted Solar Arrays on Low-Slope Roofs." Submitted to ASCE Journal of Structural Engineering, 2012

Technical Committees

Structural Engineers Association of California Solar Photovoltaic Systems Committee, "Structural Seismic Requirements and Commentary for Rooftop Solar Photovoltaic Arrays" SEAOC PV1-2012 August 2012.

Structural Engineers Association of California Solar Photovoltaic Systems Committee, "Wind Design for Low-Profile Solar Photovoltaic Arrays on Flat Roofs" SEAOC PV2-2012 August 2012.

University Lectures

Mike Williams – Stanford University – Civil and Environmental Engineering – Spring 2011 and Spring 2012

Mike Williams – UC Berkeley – Civil Engineering – Fall 2011

CALIFORNIA BUILDING CODE DEVELOPMENT

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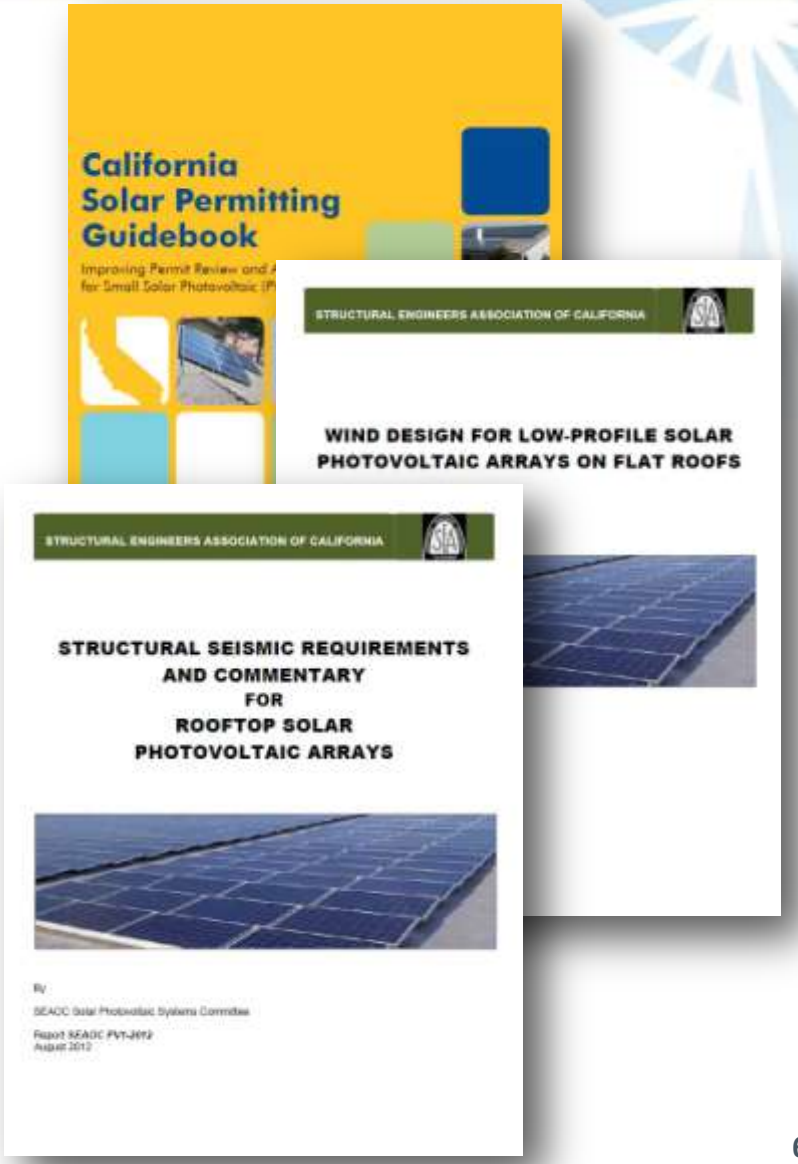
New 2012 California Guidelines

1. GOPR Solar Permitting Work Group: *California Solar Permitting Guidebook*
   - Residential and smaller systems

2. SEAOC PV1 – *Structural Seismic Requirements and Commentary for Rooftop Solar Photovoltaic Arrays*

3. SEAOC PV2 – *Wind Design for Low-Profile Solar Photovoltaic Arrays on Flat Roofs*



www.seaoc.org

Path to the 2019 CBC

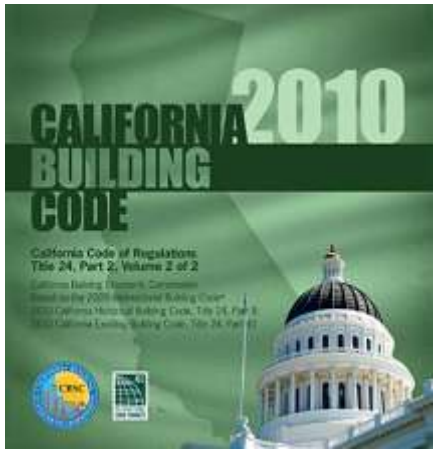
ASCE	ICC	CBSC
ASCE 7-05 →	2009 IBC →	2010 CBC
ASCE 7-10 →	2012 IBC →	2013 CBC*
ASCE 7-10 →	2015 IBC* →	2016 CBC
ASCE 7-16* →	2018 IBC →	2019 CBC

* in progress

ASCE AMERICAN SOCIETY OF CIVIL ENGINEERS

ICC INTERNATIONAL CODE COUNCIL

CALIFORNIA BUILDING STANDARDS COMMISSION CBSC



www.asce.org

www.iccsafe.org

www.bsc.ca.gov

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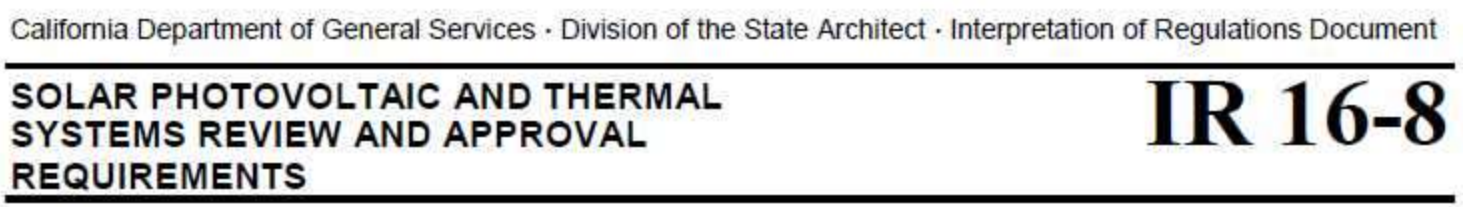
California Code Development

- **2013 California Building Code:**
  - Housing and Community Development: requirements for ballasted systems on residential roofs up to 1:12 slope.

- **DSA IR 16-8**
  - Incorporates SEOAC Guidelines from PV-1 and PV-2



California Department of General Services · Division of the State Architect · Interpretation of Regulations Document

SOLAR PHOTOVOLTAIC AND THERMAL SYSTEMS REVIEW AND APPROVAL REQUIREMENTS

IR 16-8

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National Code Development

- **2015 International Building Code:**
  - Proposed language for ballasted systems on residential roofs up to 1:12 slope.
- **ASCE 7-16:**
  - SEAOC Guidelines Presented to Subcommittee on Rooftop PV Wind Loads

SUMMARY & CONCLUSIONS

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The Impact of SunLink's Project

- **Design optimization tools**
  - Layout and Design Tools
  - Better customer communication
  - Lower cost of PV systems by quickly automating multiple layouts
  - Reduce design time for both SunLink and its customers
  - Deliver projects with less opportunity for error

  Documentation tools
  - Document Management
  - Established Document Management systems can play a vital role in creating organizational efficiencies and reducing errors
  - Our work serves as a starting point for solar organizations to pursue document management
  - Identified and reviewed DMS products
  - Identified key functionality and features worthy of consideration as DMS selection criteria
- **Consistent state-wide acceptance criteria:**
  - Permitting Database
  - Seismic Research
  - Decreased system and installation cost of unattached systems
  - Potential for projects on building roofs previously considered unsuitable
  - Furthering the conversation toward permitting unattached systems in seismic regions
  - Industry Publications

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Thank You

Questions?