# Development of a Low Cost, Residential Plug and Play PV System

SunShot Grant: Prime Awardee: N.C. State University

Sub Awardee ($1.25 Million Project): *University of Toledo*

Principal Investigator – Brandon Cohen, College of Business and Innovation
Co-Investigator – Randy Ellingson, Dept. of Physics and Astronomy
Co-Investigator – Michael Heben, Dept. of Physics and Astronomy

**Student Interns**
Eric Holmes, Chemical Engineering UT
Hunter Rupp, Mechanical Engineering UT
Harry Thaman, Engineering MIT
Jordan Keefe, Chemical Engineering UT

## Project Objective

*Reduce total installed cost of residential solar photovoltaic systems through intermediate objectives*
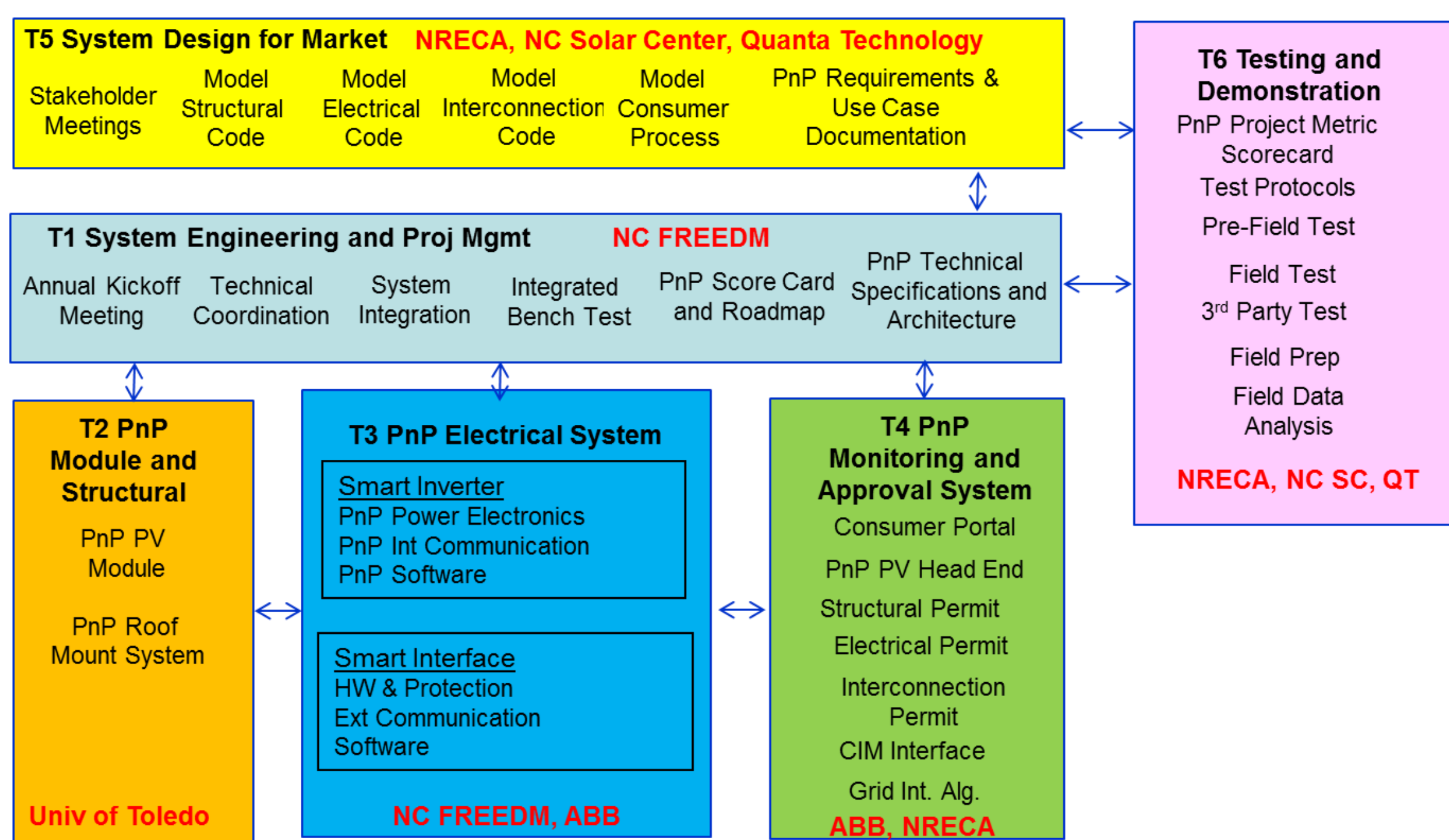
## Background
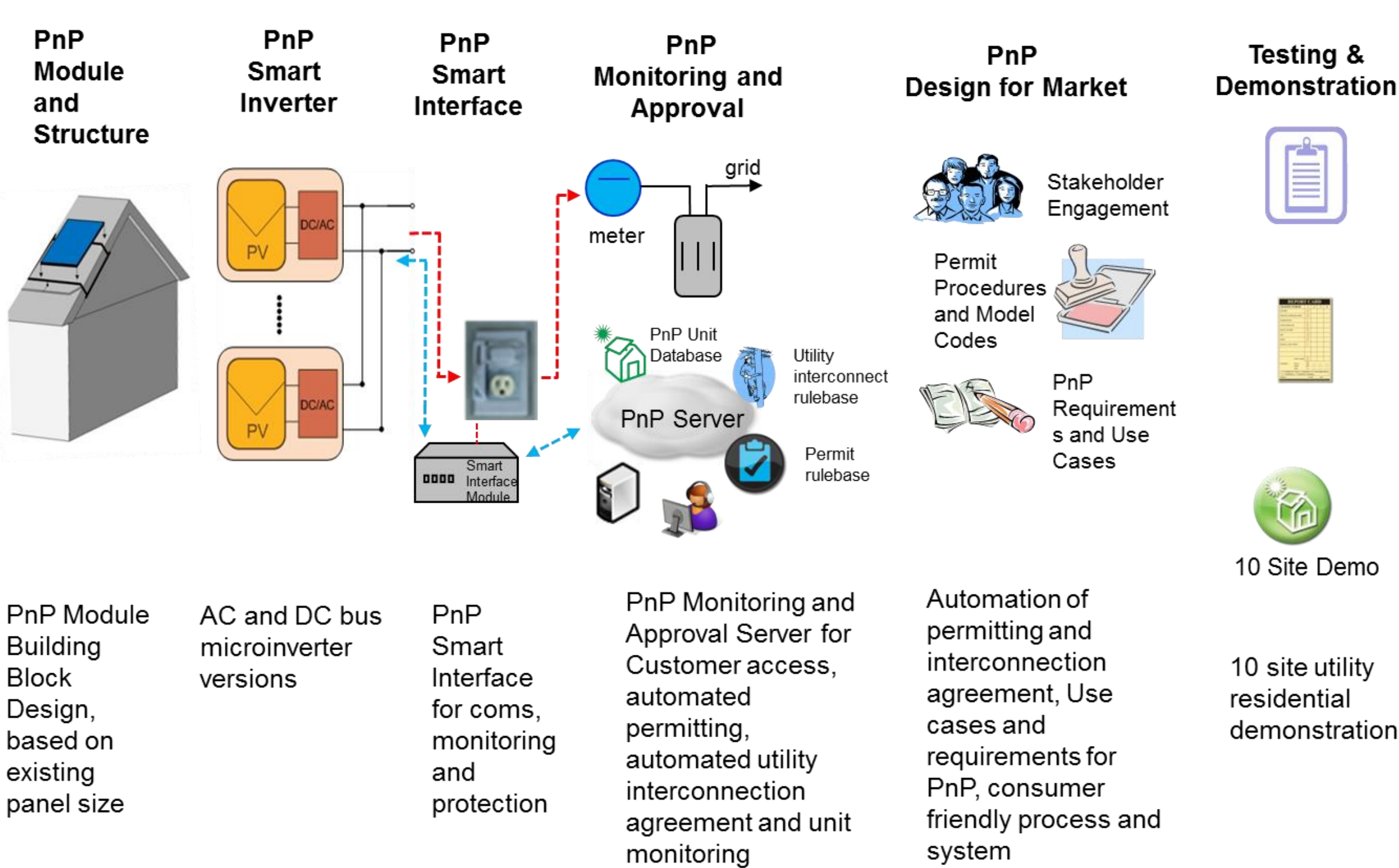
Two Generations of development:

Each Generation has four tasks addressing–
• the structure
• the electrical components
• the interface to the utility
• operation in a market/regulatory environment

### Gen I – Task Overview

T5 System Design for Market — NRECA, NC Solar Center, Quanta Technology
Stakeholder Meetings | Model Structural Code | Model Electrical Code | Model Interconnection Code | Model Consumer Process | PnP Requirements & Use Case Documentation

T6 Testing and Demonstration
PnP Project Metric Scorecard
Test Protocols
Pre-Field Test
Field Test
3rd Party Test
Field Prep
Field Data Analysis
NRECA, NC SC, QT

T1 System Engineering and Proj Mgmt — NC FREEDM
Annual Kickoff Meeting | Technical Coordination | System Integration | Integrated Bench Test | PnP Score Card and Roadmap | PnP Technical Specifications and Architecture

T2 PnP Module and Structural
PnP PV Module
PnP Roof Mount System
Univ of Toledo

T3 PnP Electrical System
Smart Inverter
PnP Power Electronics
PnP Int Communication
PnP Software
Smart Interface
HW & Protection
Ext Communication Software
NC FREEDM, ABB

T4 PnP Monitoring and Approval System
Consumer Portal
PnP PV Head End
Structural Permit
Electrical Permit
Interconnection Permit
CIM Interface
Grid Int. Alg.
ABB, NRECA

### Gen I - PnP System Program

PnP Module and Structure | PnP Smart Inverter | PnP Smart Interface | PnP Monitoring and Approval | PnP Design for Market | Testing & Demonstration

PnP Module Building Block Design, based on existing panel size

AC and DC bus microinverter versions

PnP Smart Interface for coms, monitoring and protection

PnP Monitoring and Approval Server for Customer access, automated permitting, automated utility interconnection agreement and unit monitoring

Automation of permitting and interconnection agreement, Use cases and requirements for PnP, consumer friendly process and system

10 Site Demo

10 site utility residential demonstration

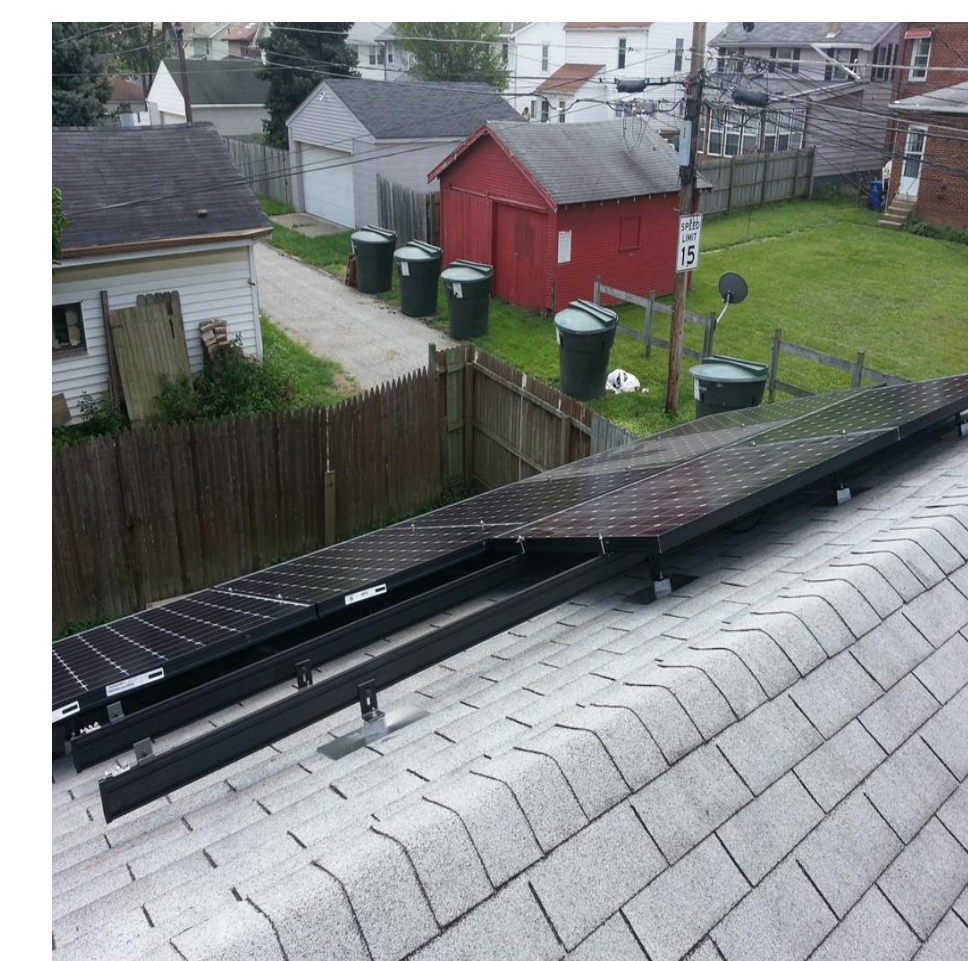## Field Studies of Real World Residential Rooftop Installations

• Perrysburg, OH & Columbus, OH
• Yellowlite & Heirloom Energy Installations
• Avg. Labor Costs: $0.32/Watt
• Average Installation Time: 23 minutes/Module
• Time and Cost Algorithms developed for installation practices
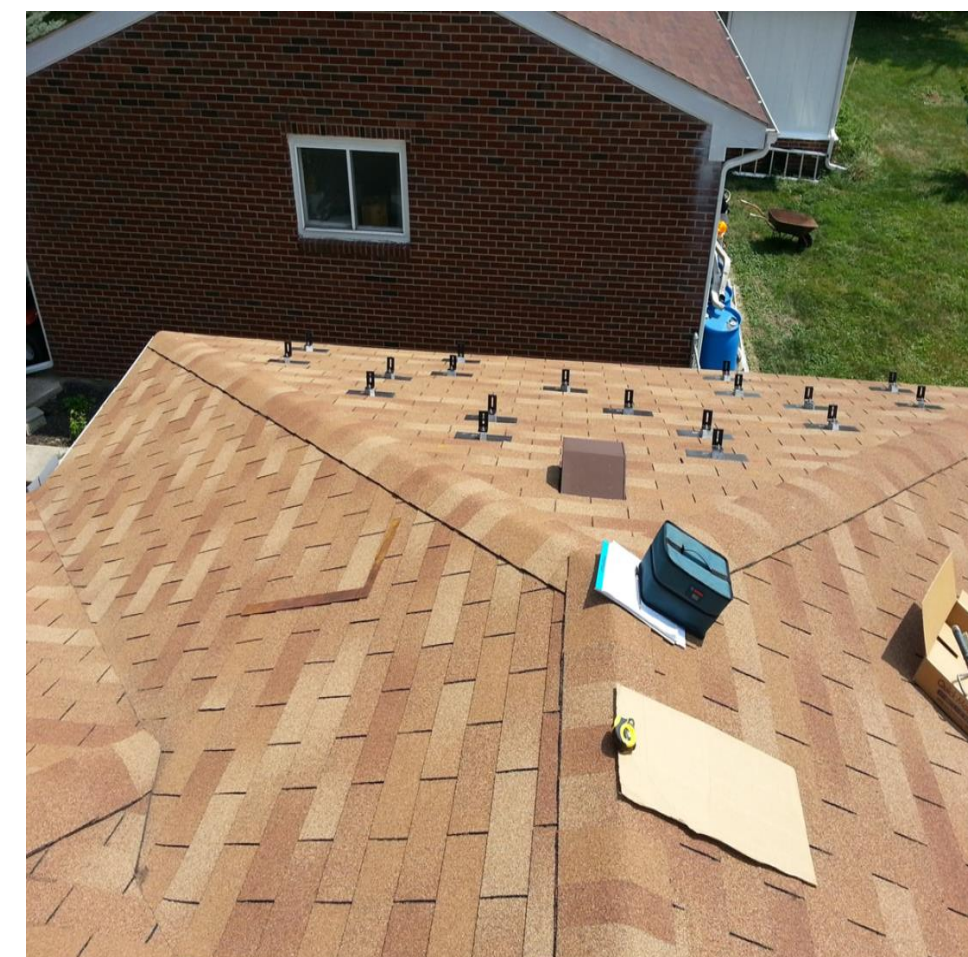
Flashing & L-Feet Located First

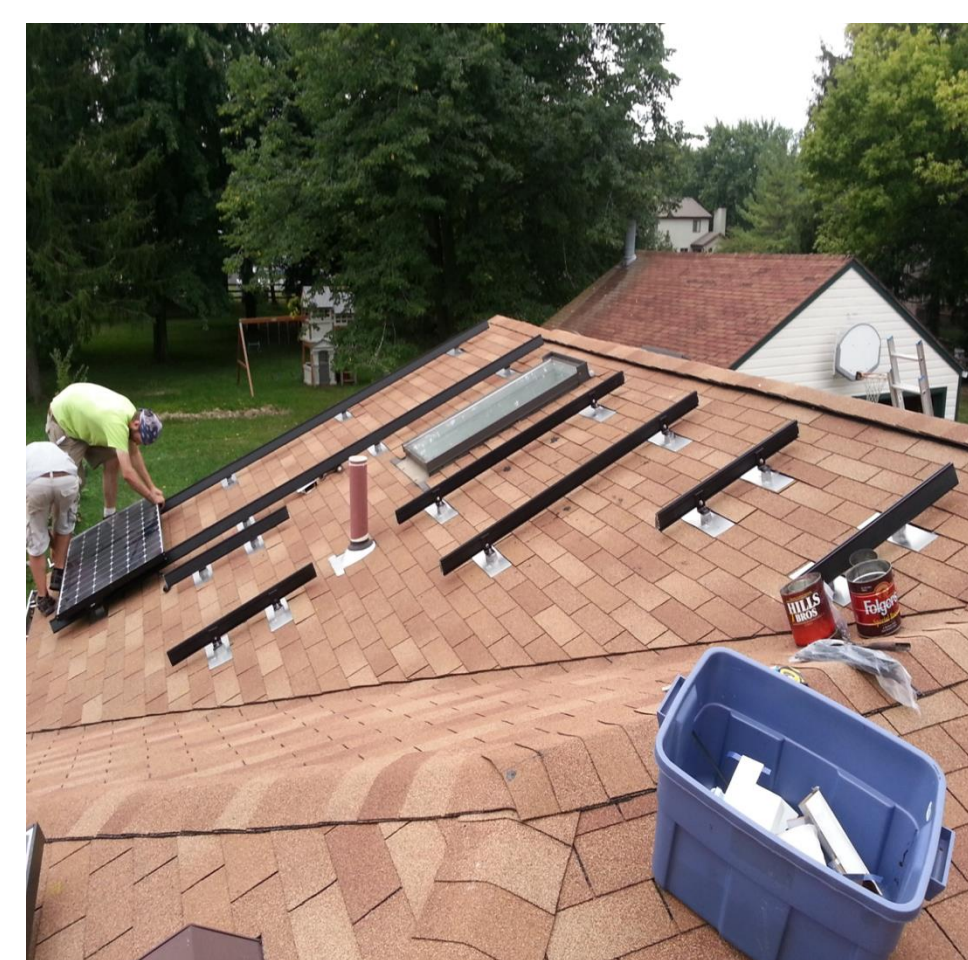Two Rails Connected to Each Panel Row

Modules Clipped Onto Rails

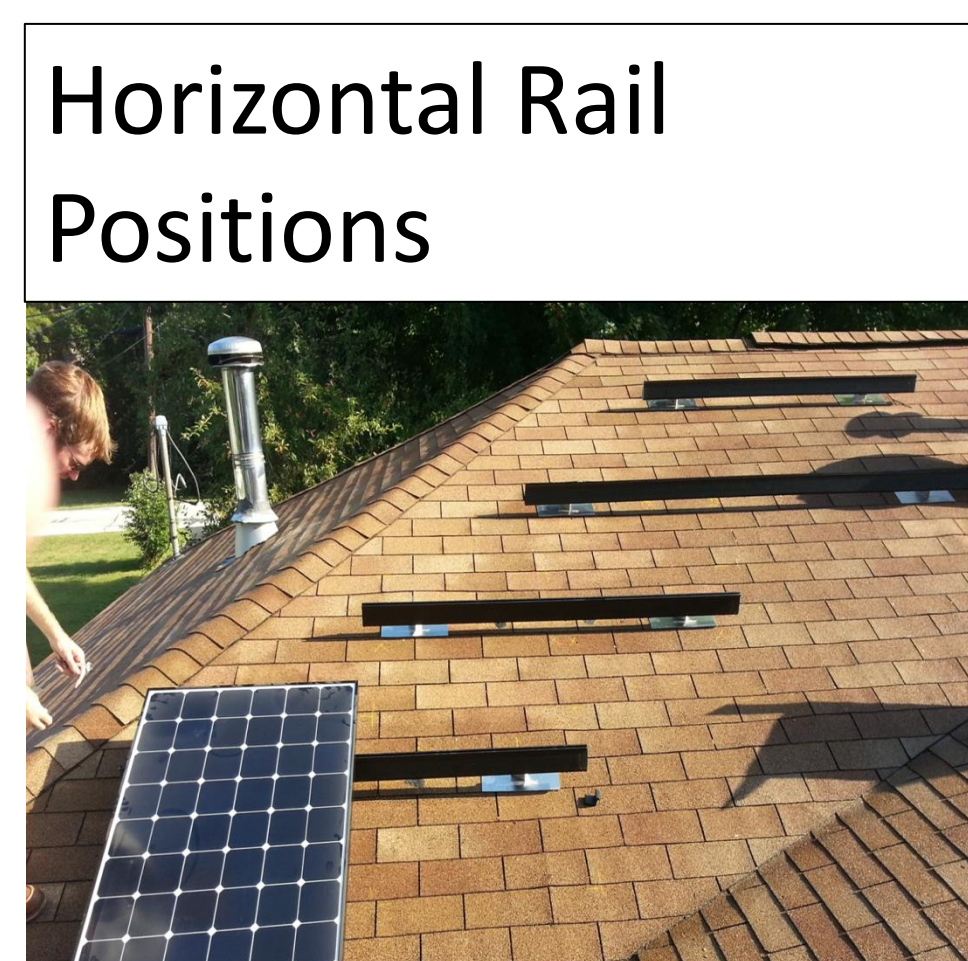Finished Pyramidal Design

Pyramidal Design of Mounts & L-Feet

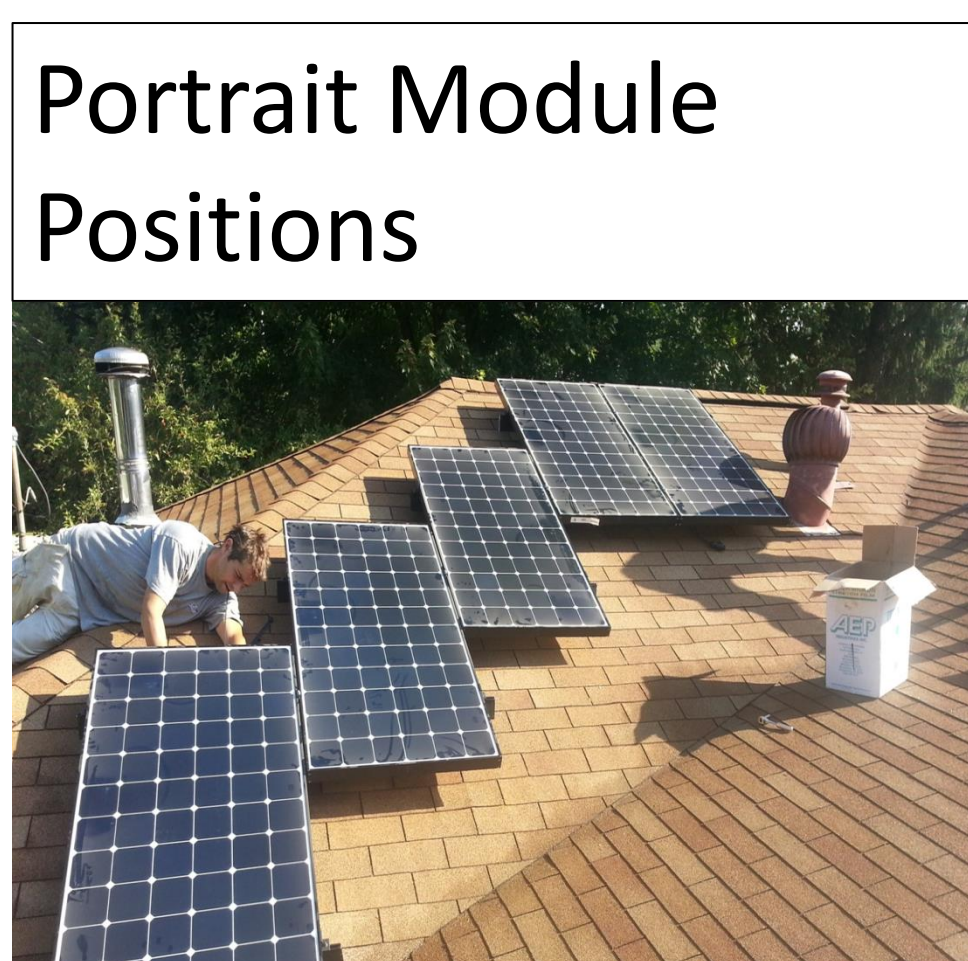Level Rails are Critical for Aesthetics

Vertical Rail Positions

Landscape Module Positions

Horizontal Rail Positions

Portrait Module Positions

## NCSU Plug and Play Project

### Desired Outcomes

**In 5 Years, demonstrate PnP system that**
• Can potentially reach $1.5/Watt target.
• Contractor/homeowner can install without special training/tools in 10 man-hours.
• Supports automation of:
  • Electrical permitting and inspection
  • Structural permitting and inspection
  • Utility interconnection agreement.
• Delivered, installed, inspected and commissioned on same day.

### Task 2 Team (UT)

• Cost reductions in refining over-all residential rooftop system design by reducing weight of mount, improving mount design, and integration of balance of systems
• Analyze market practices in design and installation to compare progress against for new PnP systems

Central Rail Prototype
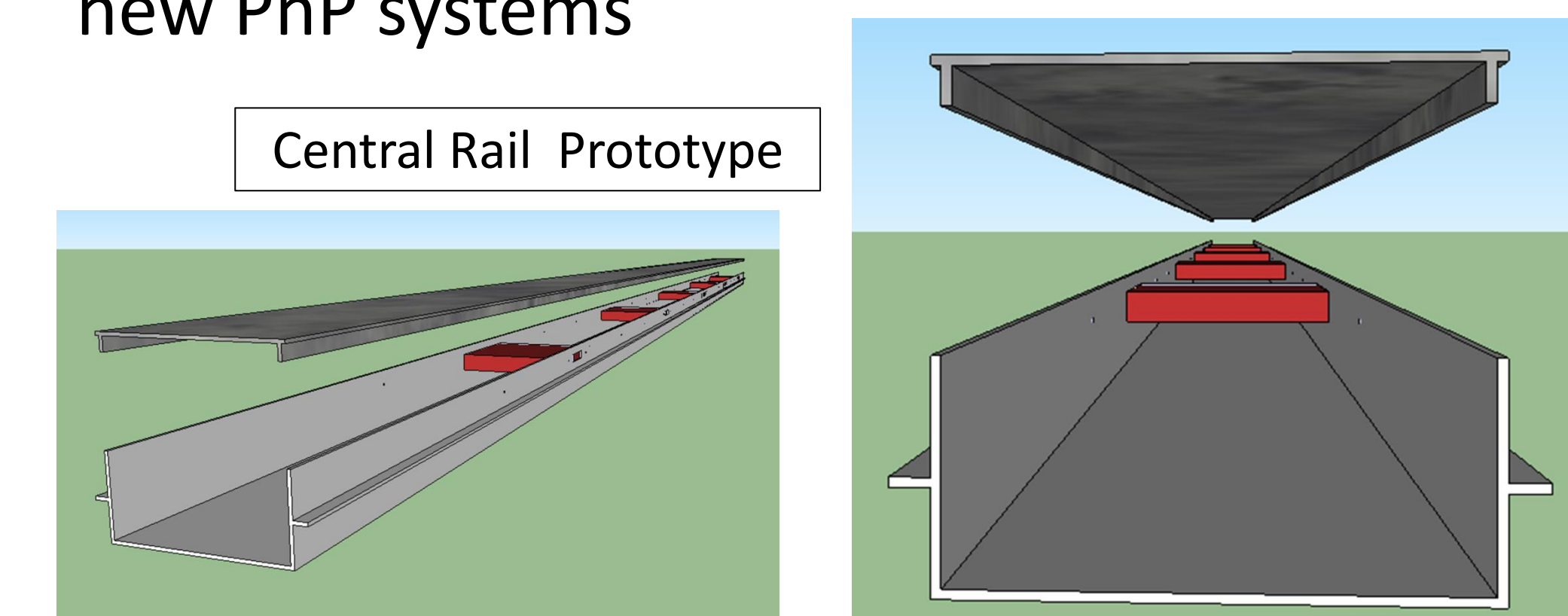
## Installation Simulation Lab

Bosch D-Tect Scanner: Intern Study

• Stud-finding for rack mount is a slow process
• European installations are known to be faster
• Trials have been done at UT and in the field using the Bosch D-Tect 150 wallscanner. Techniques have raised accuracy to > 85% accuracy, and installers have improved upon this.
• Yellowlite & Heirloom Energy intend on utilizing this product

Simulation Roof

|  | Trial 1 | Trial 2 |
|---|---|---|
| **Intern 1** | 83% | 67% |
| **Intern 2** | 100% | 100% |
| **Intern 3** | 92% | 83% |
| **Net** | 92% | 83% |

* Percentage of Accurately Located Studs out of 24

Bosch D-Tect 150

Simulation Roof