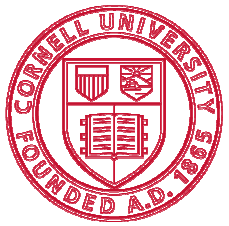

Control and Automation in Solar-Powered Homes

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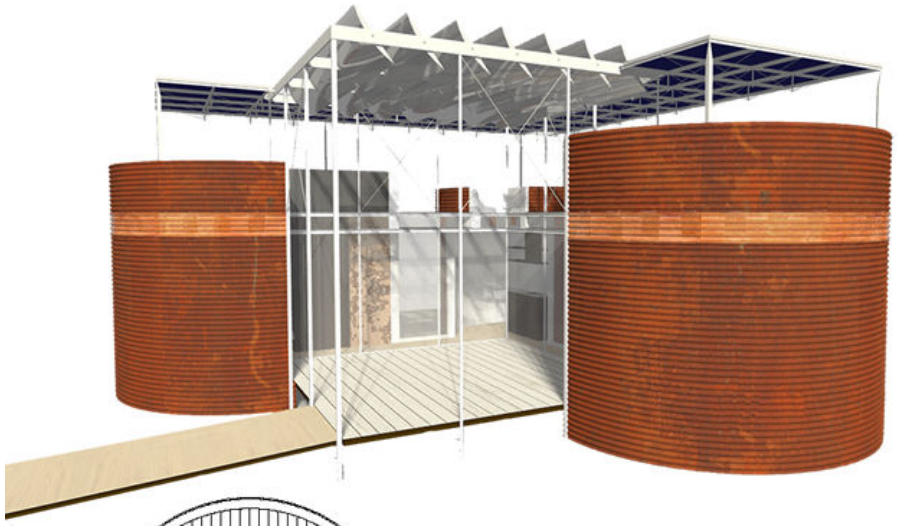
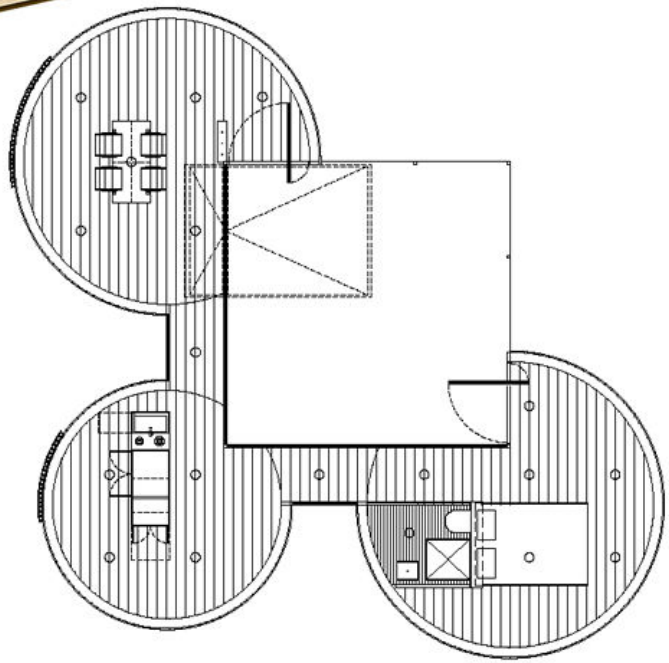
2009 Cornell University Solar Decathlon

- About Cornell Solar Decathlon (CUSD)
  - Undergraduate students (all backgrounds/majors)
  - Build completely solar-powered house
  - Competes with other schools

- About the Engineering Team
  - Design control system for house (lighting, HVAC)
  - Early Start = No House (no HVAC) = Big Challenge!

The Bigger Picture





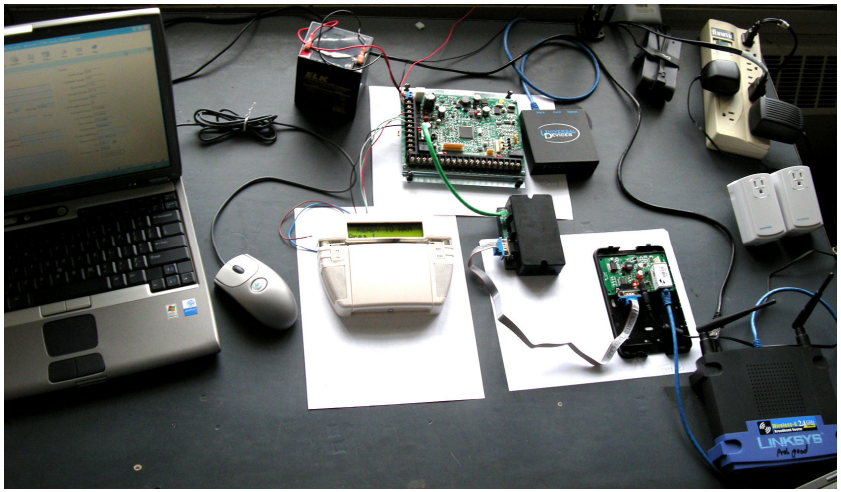
- Floor Specifications
  - 460 sq. ft.
  - Three Cylindrical Silos
    - 1 Bedroom
    - 1 Bath
    - 1 Living Room
    - Kitchen w/ Island
    - 15’ x 15’ Courtyard
  - Meant for 1-2 residents
- Design Specifications
  - PV Panels on Roof
  - Mechanical Closet
  - Corrugated Steel Wall

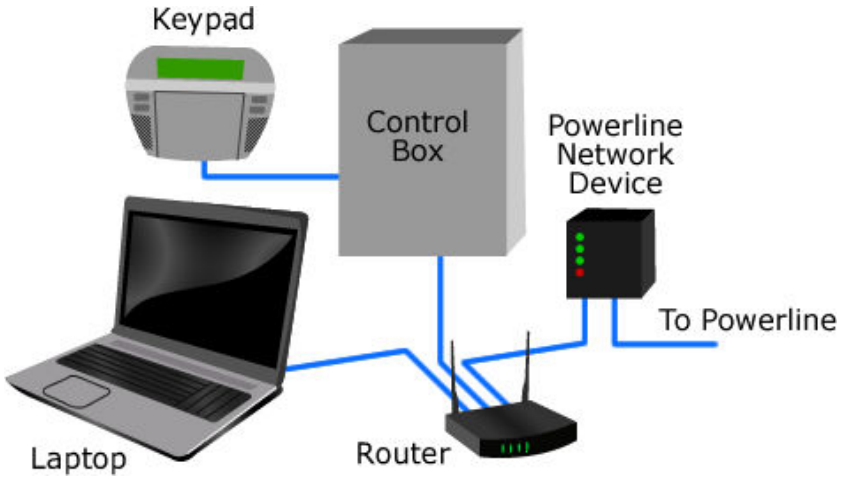
Background

- The Goal to reach by end of Summer:
  - Design & Build bench-top model to simulate control system
  - Develop easy-to-follow protocol for installation
- Donated Equipment
  - ELK Products
  - Smart Homes Insteon

Hardware Methodology

"Putting It Together"



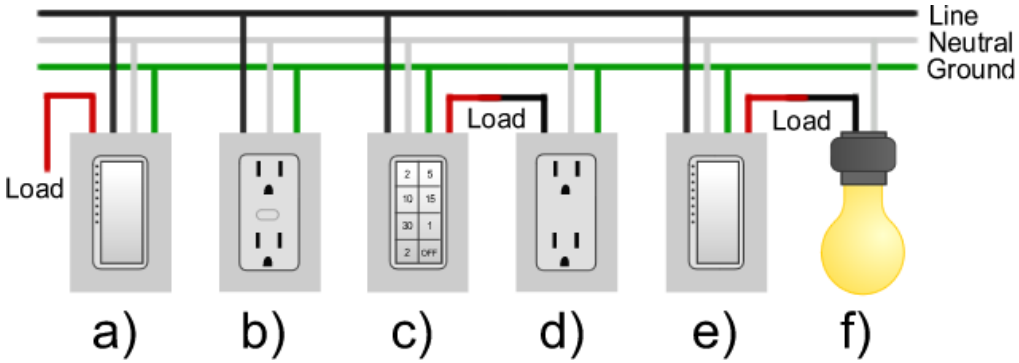


- Implementing Hardware
  - Control Box
    - Ethernet Interface
    - Serial Interface
    - Control Board
  - Two Controllers
    - Keypad
    - Computer Software
  - Powerline Network Device

Hardware Methodology

"Putting It Together"

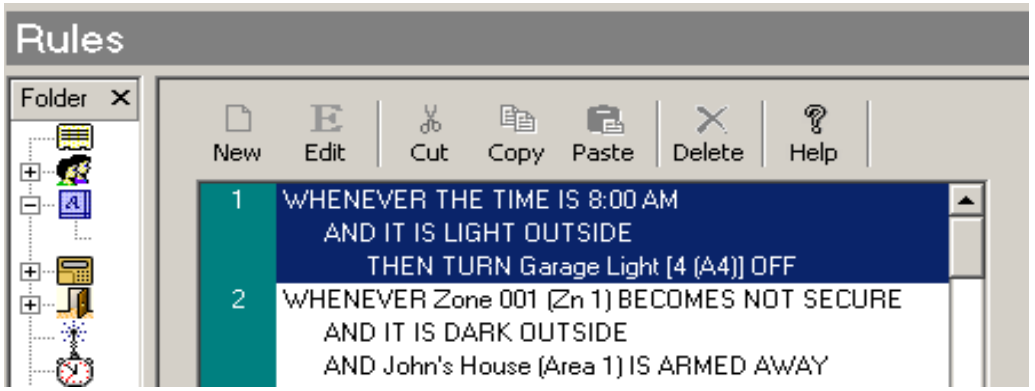
- Three Configurations (but anything controls anything)
  - A controls B
    - Not Hardwired
    - Network-Linked
  - C controls D
    - Regular outlet
    - Hardwired
  - E controls F
    - Regular bulb
    - Hardwired



Engineering Design

"How It Works"

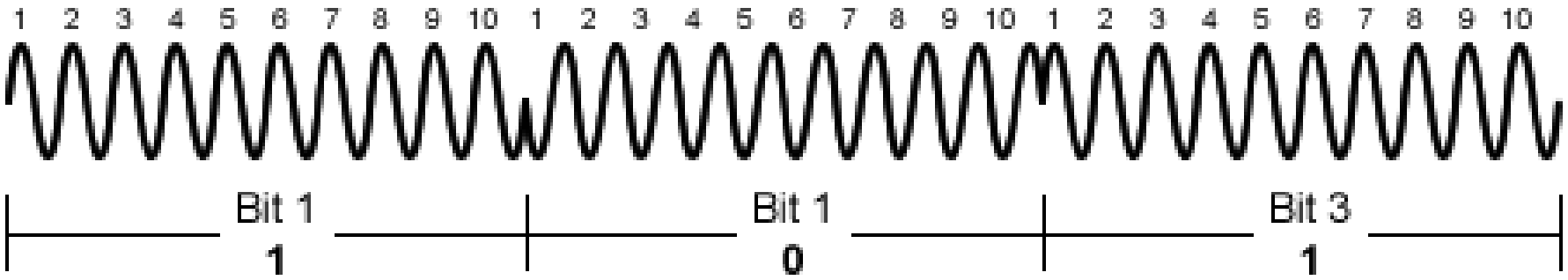
- User's Perspective
  - Centralized Control
  - Remote Control (Virtual & Real Keypad)
  - GUI Software = Easy-to-Use Interface

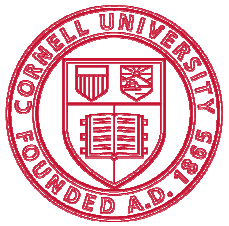


Engineering Design

"How It Works"

- Engineer's Perspective
  - Add carrier frequency (131.65 kHz) to powerline voltage.
  - Data is modulated on carrier frequency using Binary Phase-Shift Keying (BPSK).
    - 10 cycles per bit

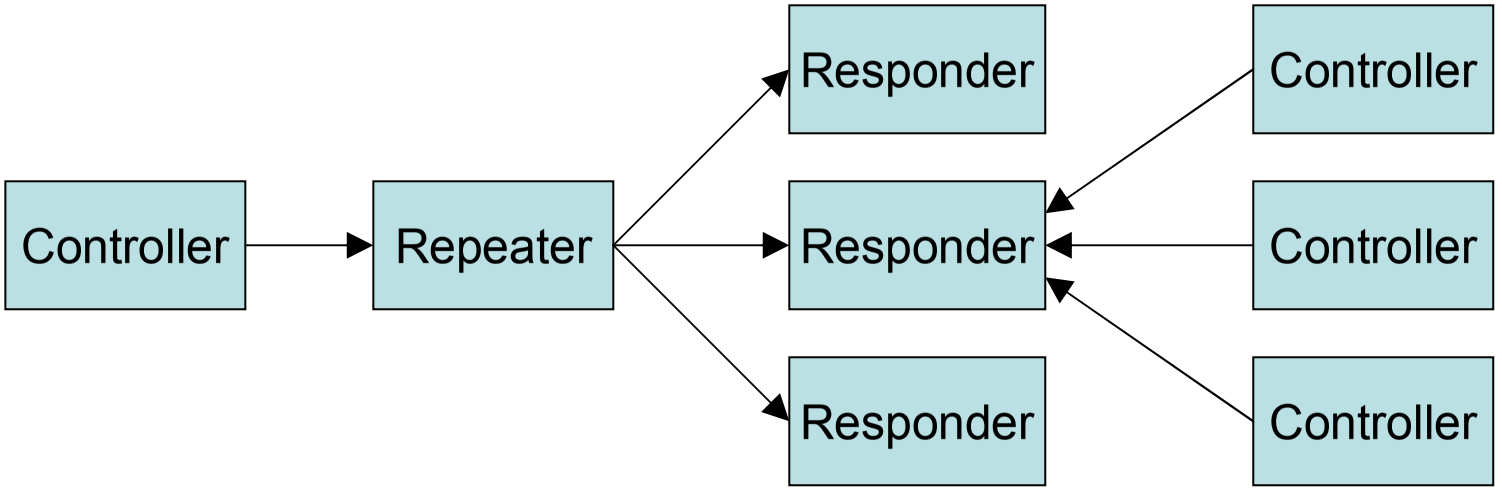


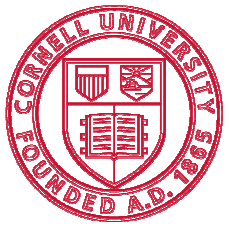


Engineering Design

"How It Works"

- Engineer's Perspective
  - Peer-to-Peer Networking
    - Controller (sends data)
    - Responder (receives data)
    - Repeater (relays data)

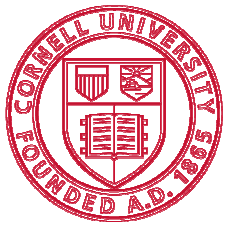




Results

"Did It Work?"

- Initial Malfunctions/Discrepancies
  - Main Control Board
  - Bad Powerlinc Modem
  - Broken SwitchLinc Dimmer
- Debugging the Control Board/Modem
  - Able to connect (ping)
  - Not able to communicate
- Cooperative Vendors



Results

"Did It Work?"

- Manual Test
  - Testing switches to turn on corresponding outlets/bulb
- Remote Access Test
  - Being able to turn on/off switches through keypad and rules we wrote
- Simple Automation Test
  - Program to toggle switches/outlets every two minutes
- Interoperability Automation Test
  - Takes temperature readings
  - If it gets warm, control turns on fan and shuts off lights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