ORNL Flexible Research Platforms

Presented by: Joshua New

January 28, 2015
Empirical Validation of Whole-Building Energy Simulation Programs

Patrick Hughes
Ed Vineyard

Melissa Lapsa

PM: Joshua New

PIs – Piljae Im and Mahabir Bhandari (Model)

PI – Jibo Sanyal (Provenance)

PI – Charles Castello (Sensor QA)

PI – Joshua New (Visual Analytics)

PI – Philip Boudreaux (Occupancy)

PIs – Tony Gehl and Chris Halford (Sensors)

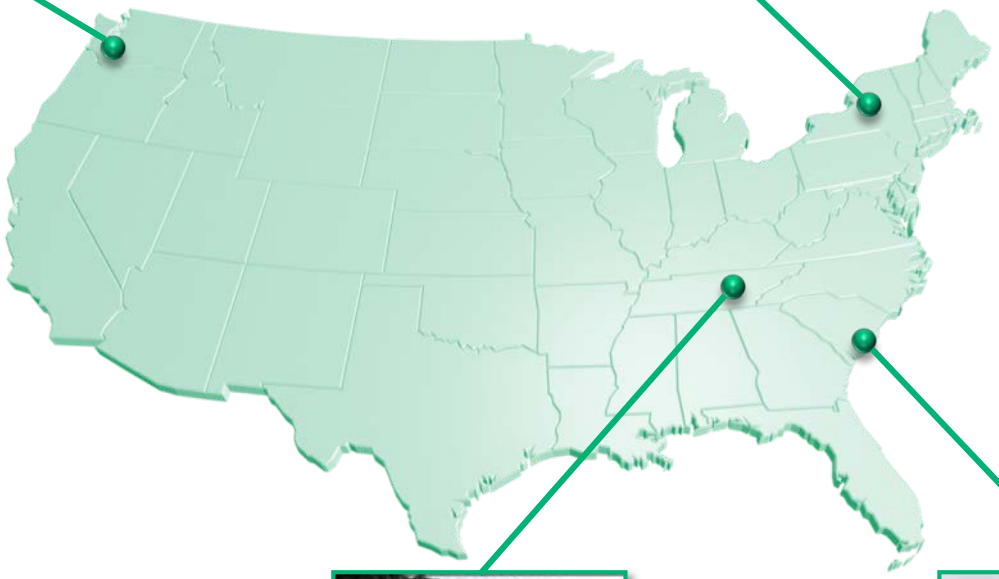
PI – F&O (Installation)

ORNL works with industry to accelerate delivery of solutions to market

Envelope research: Natural exposure facilities

Tacoma, Washington (cool/humid)

Syracuse, New York (cold/humid)



Oak Ridge, Tennessee (mixed/humid)

Charleston, South Carolina (hot/humid)

Envelope research: Lab facilities

Heat flow through roof/attic assemblies

Heat flow through wall assemblies

Air/moisture flow through wall assemblies

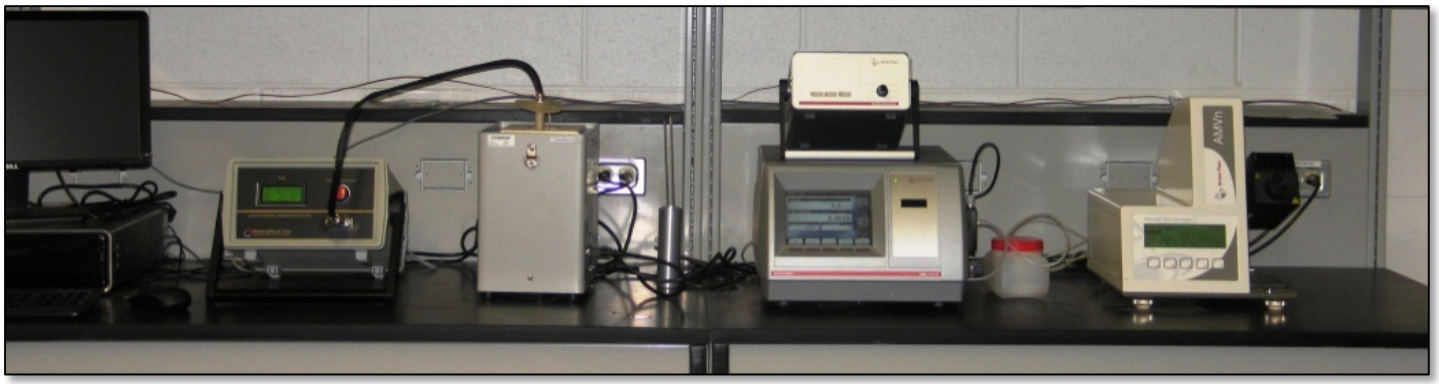
Hygrothermal properties of materials

Equipment research: Lab facilities

Environmental chambers

Compressor calorimeters

Heat exchanger R&D loops



Working fluid physical properties measurement

FRP one-stop shop

OAK RIDGE National Laboratory

Page | Discussion | Read | Edit | View history | Search | Go | Search

Projects:FRP

(Redirected from Projects FRP)

Navigation

Main page
Community portal
Current events
Recent changes
Random page
Help

Toolbox

Flexible Research Platforms [edit]

Project Data [edit]

1. Master Directory - \\strider\FRP_Readiness
2. Emulated Occupancy files - \\strider\FRP_Readiness\Boudreaux
3. Sensor Data Quality Assurance - \\strider\FRP_Readiness\Castello
   - Old test files, code, and installer - https://www.dropbox.com/work/Data_Validation_Software/SensorDVC
4. FRP Instrumentation (with pictures) - \\strider\FRP_Readiness\ChrisTony
5. Server hardware and visualization - \\strider\FRP_Readiness\New
6. Model files - \\strider\FRP_Readiness\ImBhandari
7. Meeting Minutes - \\strider\FRP_Readiness\Meetings
8. Publications - \\strider\FRP_Readiness\Publications
9. Provenance and visualization - \\strider\FRP_Readiness\Sanyal

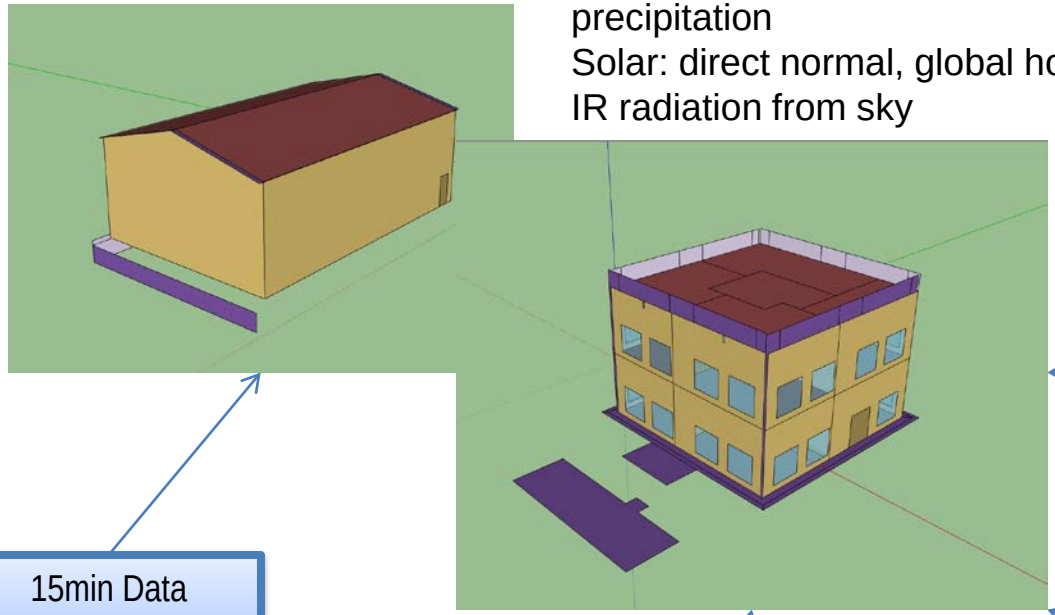
Files may require permission to access, please contact newjr@ornl.gov to request access.

Software Tools [edit]

1. FRP Logbook - used to track changes to the FRPs
2. ProvDMS - provenance system for downloading FRP sensor data, tracking sensor use, uploading experiment files, creating dashboard visualizations, and exploring FRPs in 3D
   - Sensor status - 3-sigma hourly data for outlier detection and eventual notification
3. SensorDVC - sensor data validation and correction
   1. Windows installer - \\strider\FRP_Readiness\Castello\setupSensorDVC.exe
   2. User manual - capabilities of the desktop application for sensor quality assurance and control
   3. SVN repo - source code and setupSensorDVC installer
   4. Developer manual - doxygen documentation of software code
   5. Dropbox - software design documents, test files, analysis, and application domains

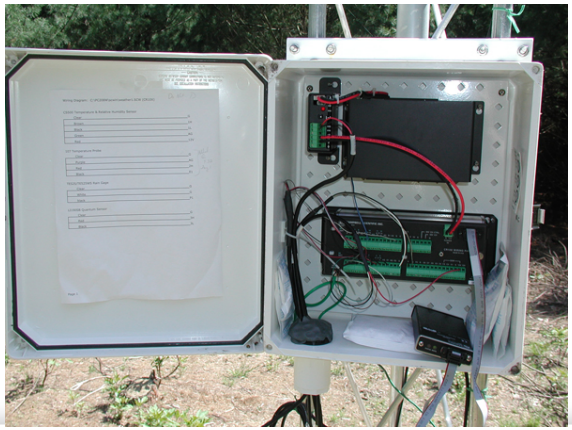
Reduce Uncertainties in Modeling

Temperature, RH, wind speed/direction, barometric pressure, precipitation
Solar: direct normal, global horizontal, IR radiation from sky

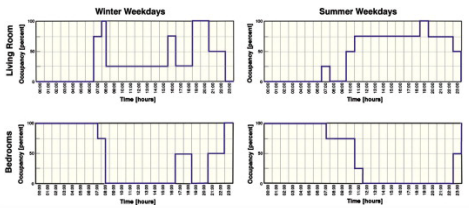


Real weather file from the weather station

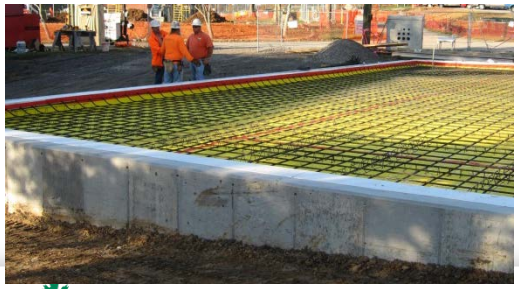
15min Data Measurements



Simulated Occupancy



Active Foundation (adiabatic)



Flexible Research Platform

- HVAC System Performance Measurement, Modeling, Calibration and Validation

HVAC #1: RTU

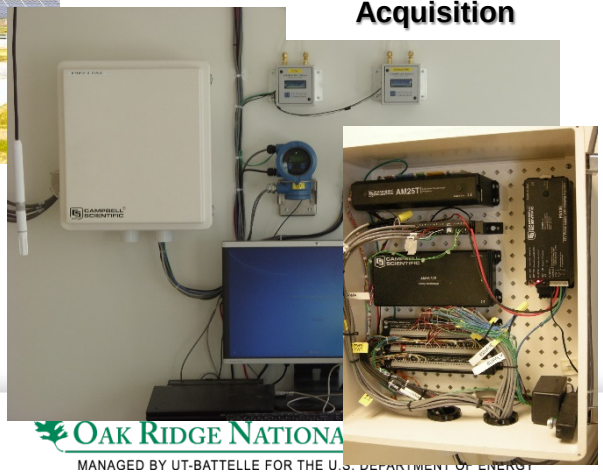
Weather Station

HVAC #3: Integrated GSHP

→ Being Installed

HVAC #2: VRF

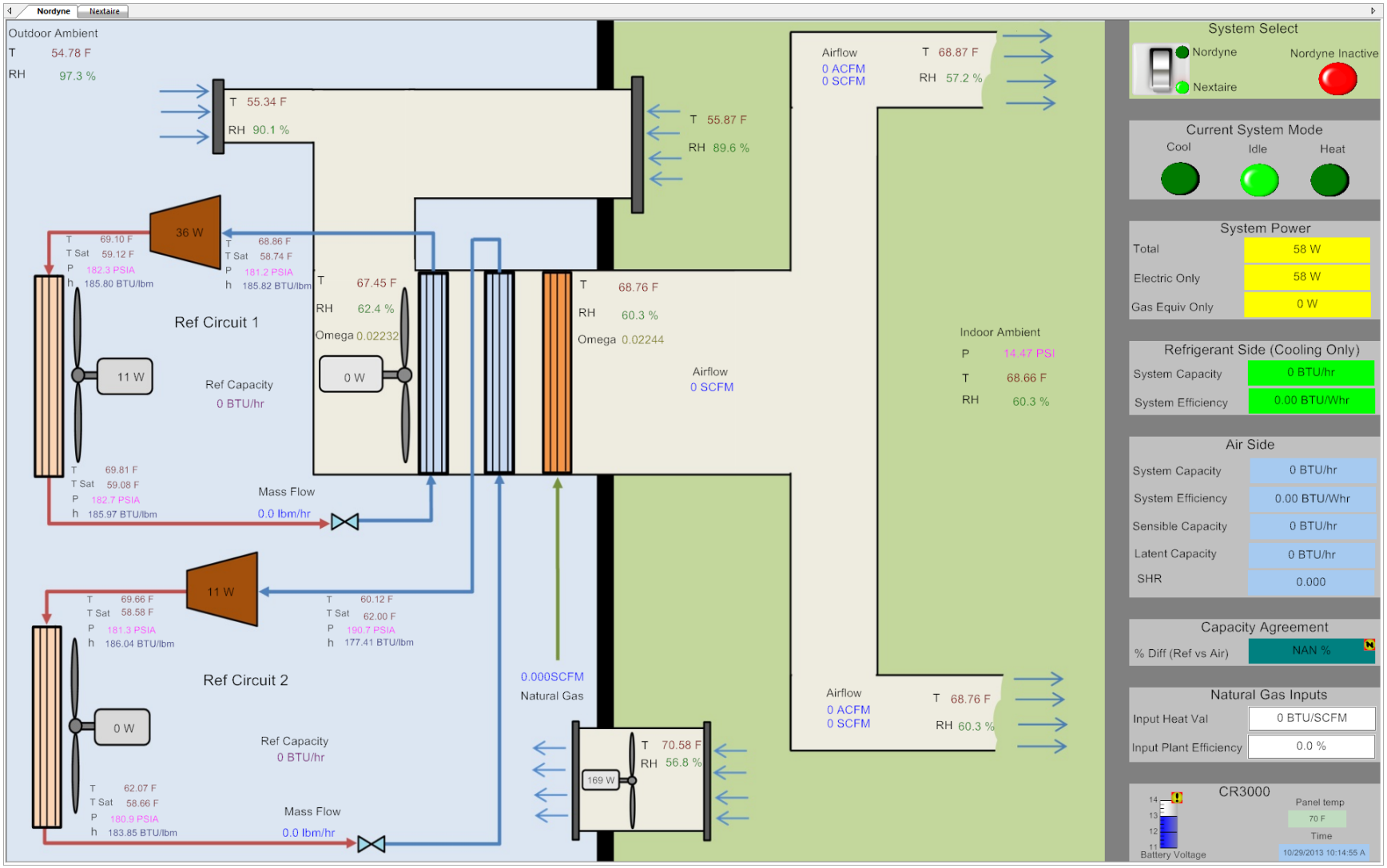
Sensors & Data Acquisition



FRP1 DAQ Hardware

- 1 Master Cabinet
- 2 Peripheral Cabinets
- 128 Thermistor Channels
- 128 Single Ended Voltage Channels
- 50 Thermocouple Channels
- 32 Frequency input or 5V control Channels
- Integrated Refrigerant and Psychrometric Lookup Tables
- Linear Interpolation Routine To Calculate Thermodynamic Properties From Measured Quantities
- GUI For Real Time Data Picture and System Switch

FRP1 DAQ Hardware

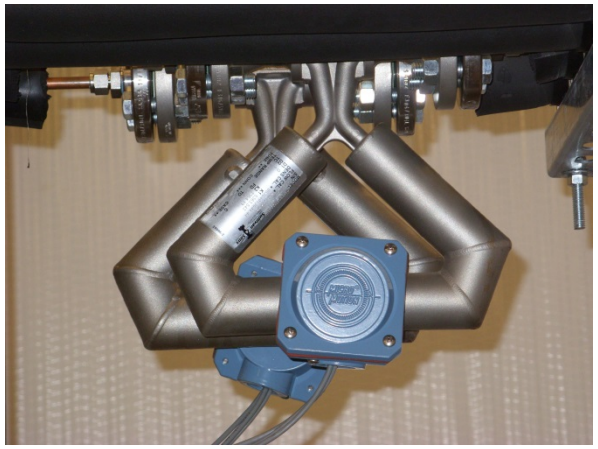


Nordyne GUI Tab

FRP1 Installed Sensors

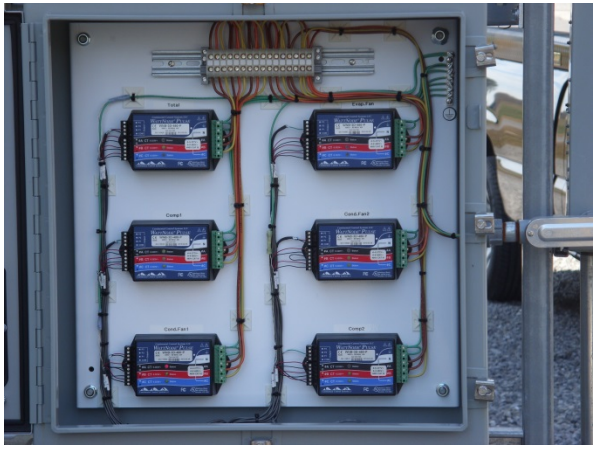
- 25 Temp/RH Probes
- 12 Refrigerant Side Immersion Thermistors
- 12 Refrigerant Side Pressure Transducers
- 4 Refrigerant Mass Flow Sensors
- 2 Natural Gas Mass Flowmeters
- 2 Airflow Measurement Stations
- 9 HVAC Power Measurements (Wattnode and CTs)
- 16 General Building Power Measurements (Wattnode and CTs)

FRP1 Sensors

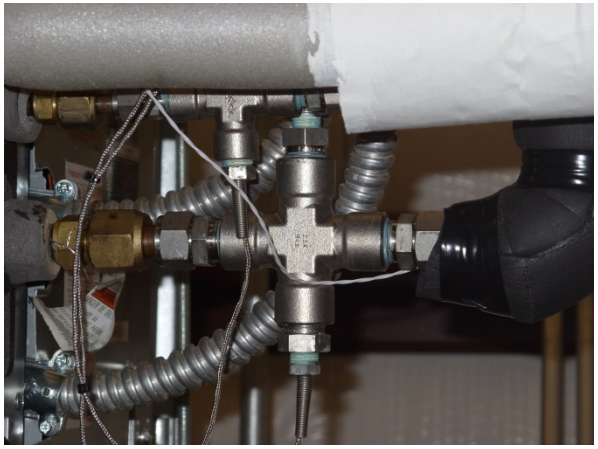


Refrigerant Mass Flow

Natural Gas Flow



Electrical Power



Refrigerant Temp and Press

Airflow

Air Temp And RH

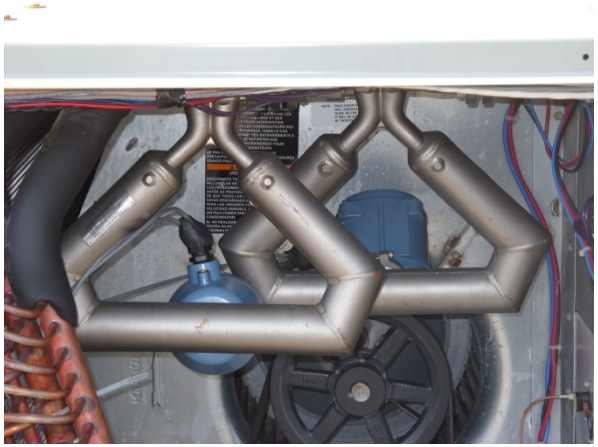
FRP2 DAQ Hardware

- 1 Master Cabinet
- 4 Peripheral Cabinets
- 256 Thermistor Channels
- 256 Single Ended Voltage Channels
- 100 Thermocouple Channels
- 64 Frequency input or 5V control Channels

FRP2 Installed Sensors

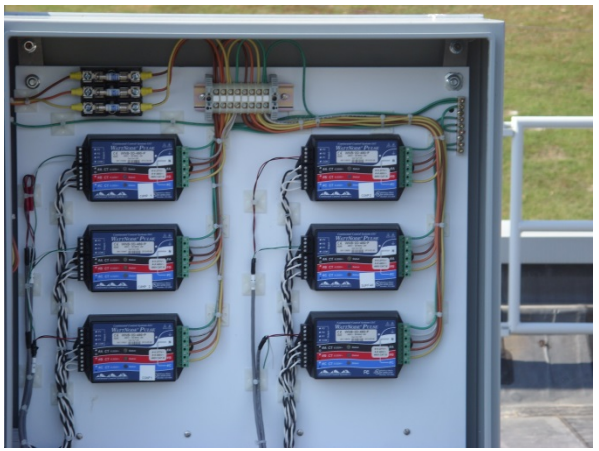
- 35 Temp/RH Probes
- 6 Refrigerant Side Immersion Thermistors
- 6 Refrigerant Side Pressure Transducers
- 2 Refrigerant Mass Flow Sensors
- 1 Natural Gas Mass Flowmeters
- 2 Airflow Measurement Stations
- 16 HVAC Power Measurements (Wattnode and CTs)
- 21 General Building Power Measurements (Wattnode and CTs)

FRP2 Sensors

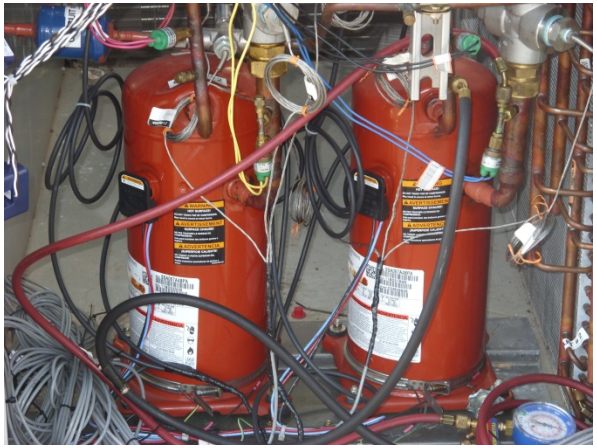


Refrigerant Mass Flow

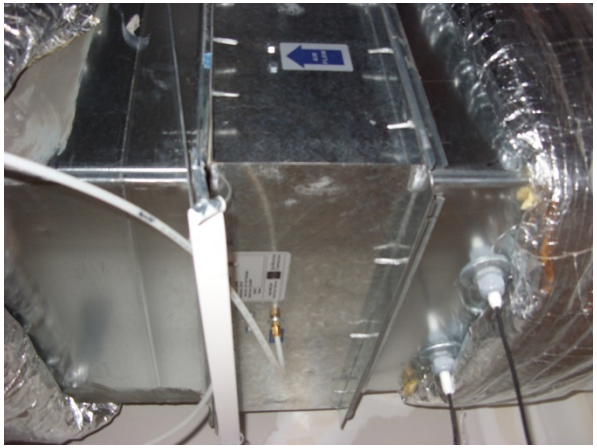
Natural Gas Flow



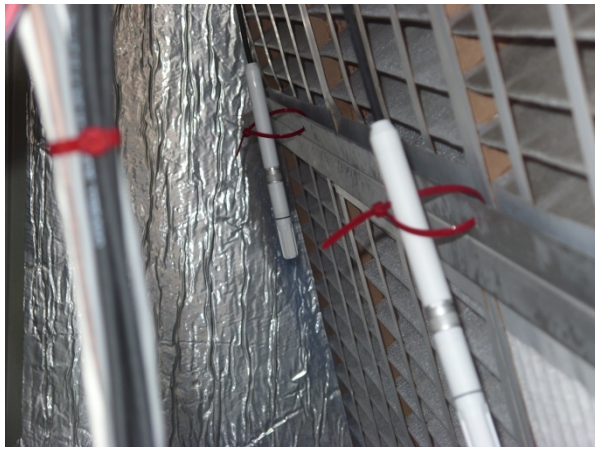
Electrical Power



Refrigerant Temp and Press



Airflow



Air Temp And RH

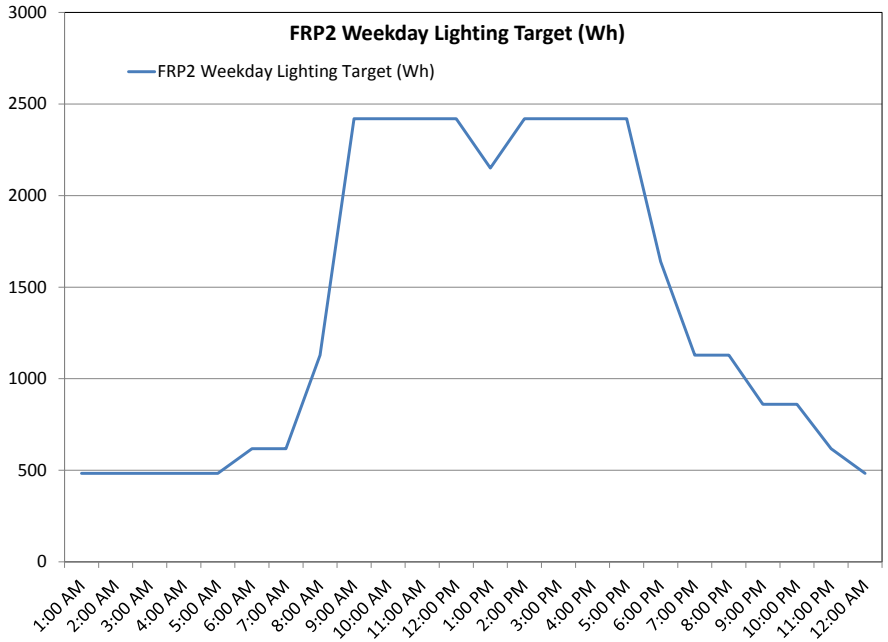
FRP Occupancy Simulation

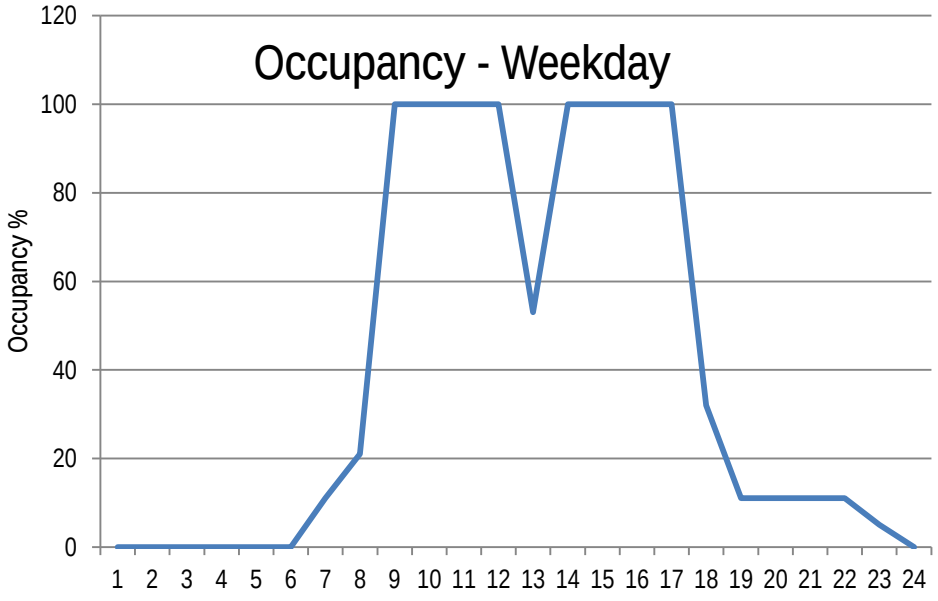
Philip Boudreaux

Tony Gehl

Deliverable: Add latent, sensible, and lighting load to space according to occupancy schedule

- Various sources to define the schedules & power density
  - ASHRAE 90.1-1989
  - Huang et al. (1990) 481 PROTOTYPICAL COMMERCIAL BUILDINGS FOR 20 URBAN MARKET AREAS, LBL-29798
  - Huang and Franconi (1999) COMMERCIAL HEATING AND COOLING LOADS COMPONENT ANALYSIS
  - PNNL report (1990) ARCHITECT'S AND ENGINEER'S GUIDE TO ENERGY CONSERVATION IN EXISTING BUILDINGS: Volume 1 - Energy Use Assessment and Simulation Methods





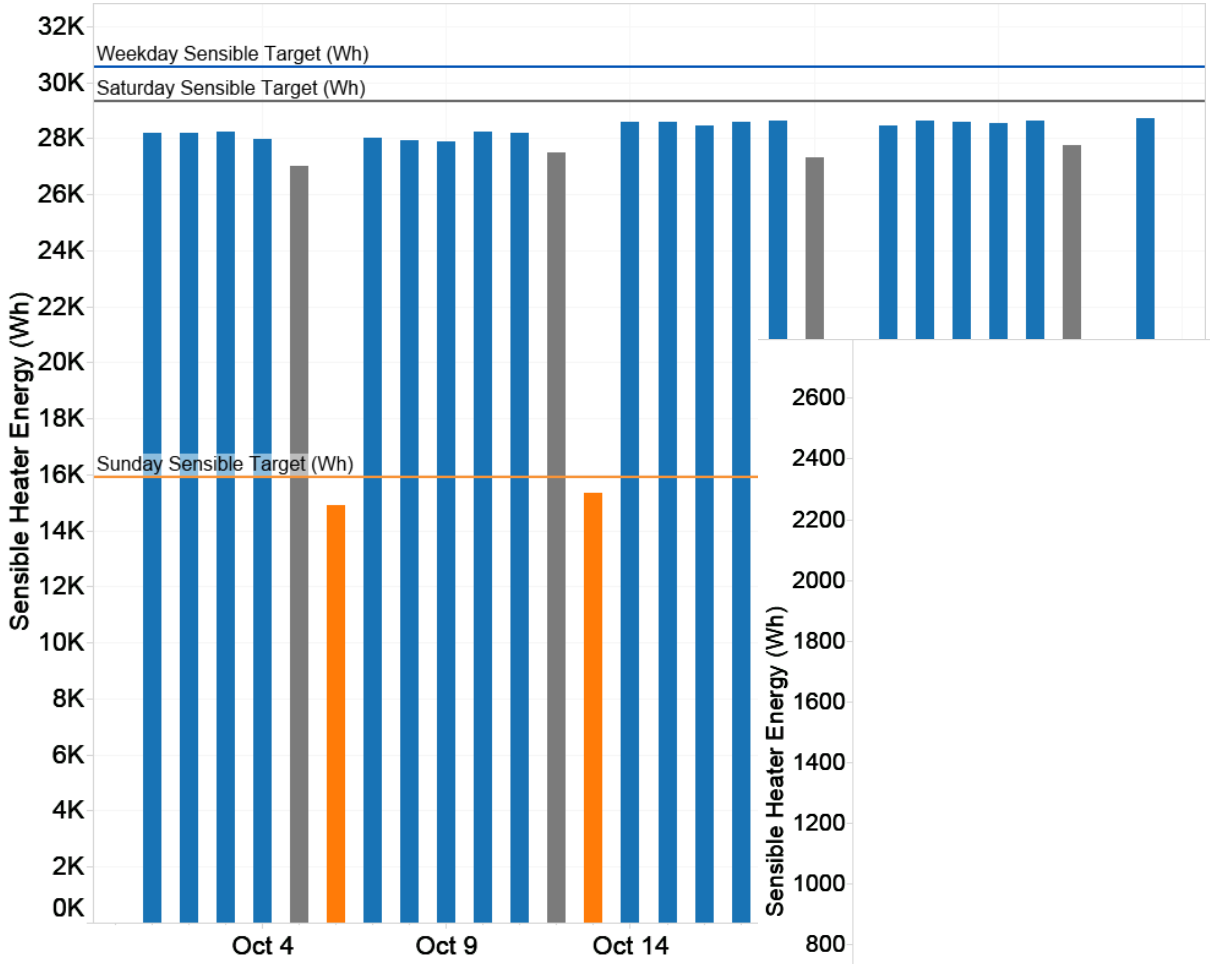
Deliverable: Add latent, sensible, and lighting load to space according to occupancy schedule

Sensible: from occupants and MELs

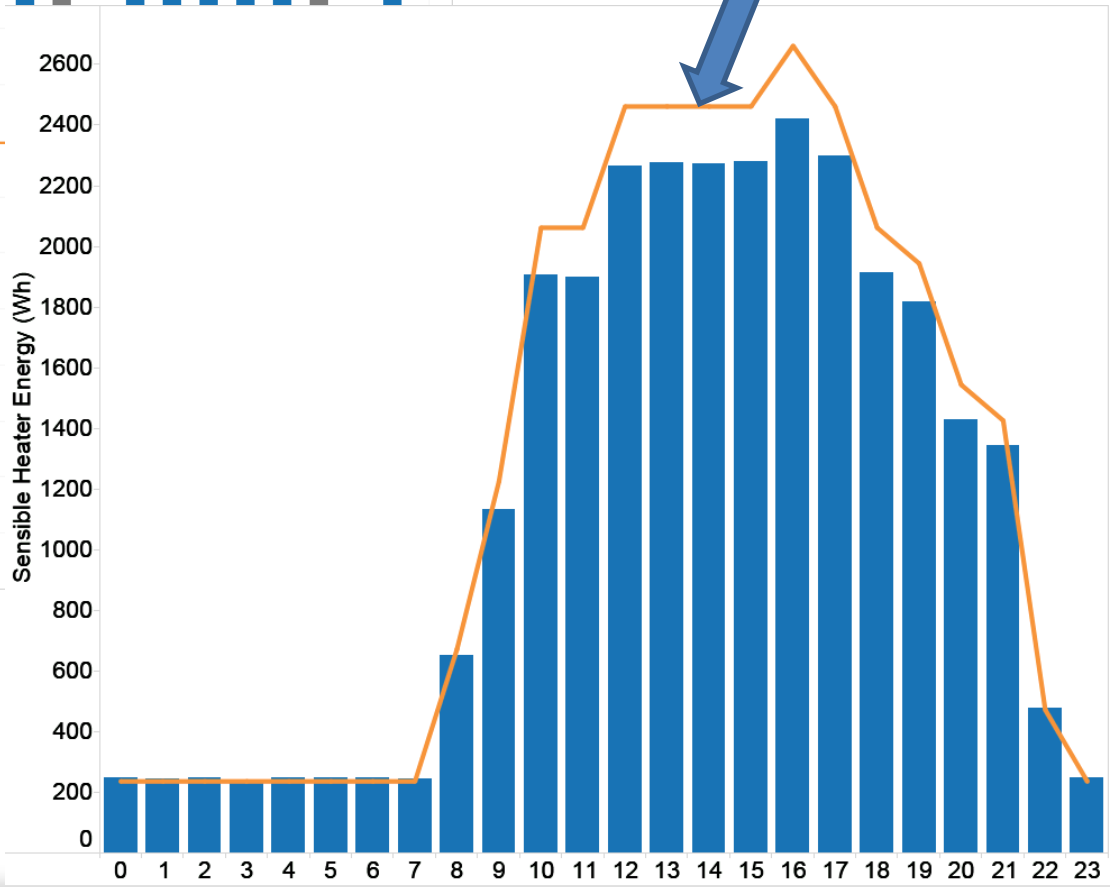
Latent: from occupants

Lighting

Validation Example – FRP1 Sensible



Hourly targets
Oct 15, 2013



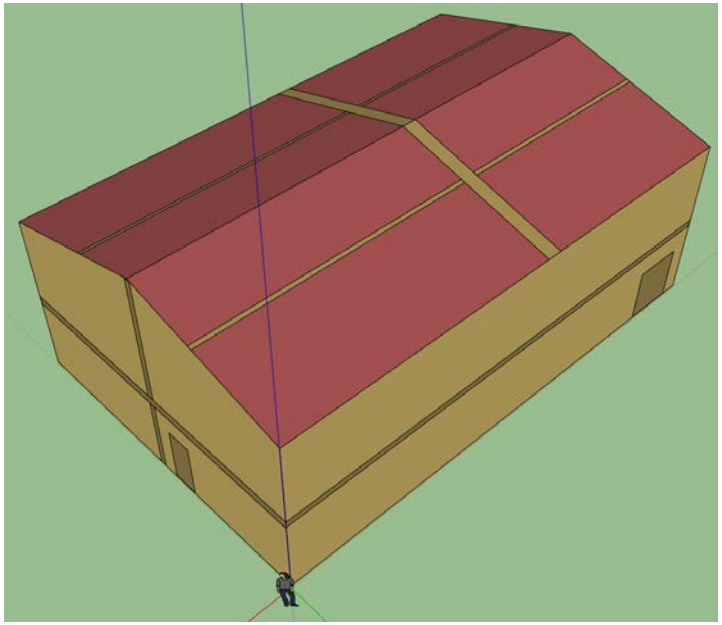
FRP Energy Modeling for 1- and 2-Story Flexible Research Platforms

Mahabir Bhandari

Piljae Im

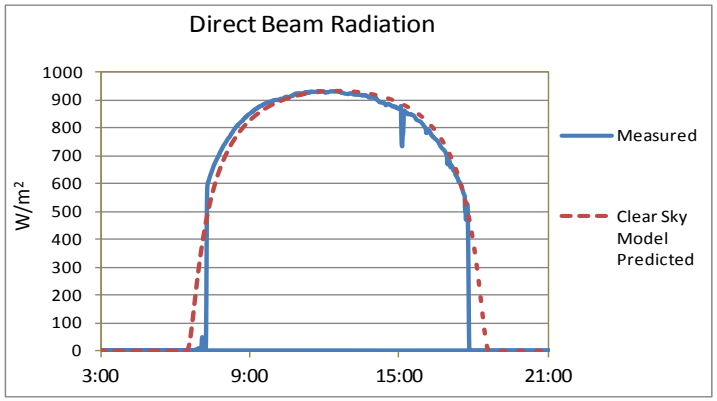
FRP 1 : Initial E+ models

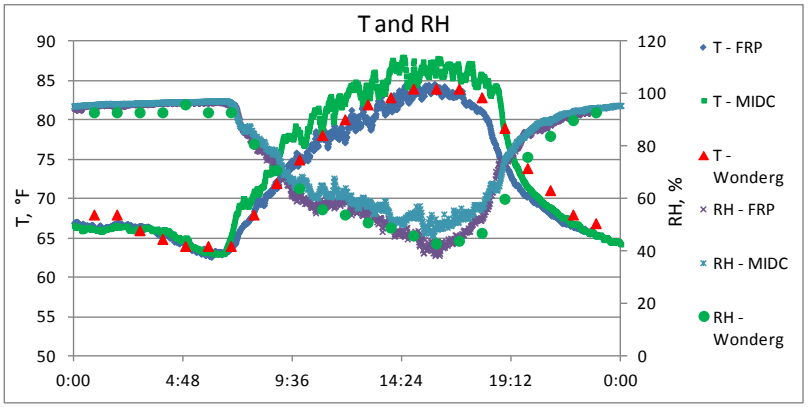
- Data preparation – Geometry, Thermal bridging
- Internal loads/schedules/Setpoints
- Infiltration – blower door test
- HVAC performance
  - Nordyne system : 2 stage RTU
  - NextAire : Engine Driven HP
- DesignBuilder/E+



Weather file for 2013 – weather data, QA, formatting from monthly template

Weather station		
Temperature	Campbell Scientific	CS215
Relative humidity	Campbell Scientific	CS215
Wind speed/direction	Gill	WindSonic
Rainfall	Texas Electronics	TE525WS
Global Horizontal solar radiation	LI-COR	LI-200X
Direct beam radiation	Eppley	NIP
IR radiation from sky	Eppley	PIR
Atmospheric pressure	Vaisala	CS106





Templates for Measured vs. Simulated Data

- Tableau
- Excel

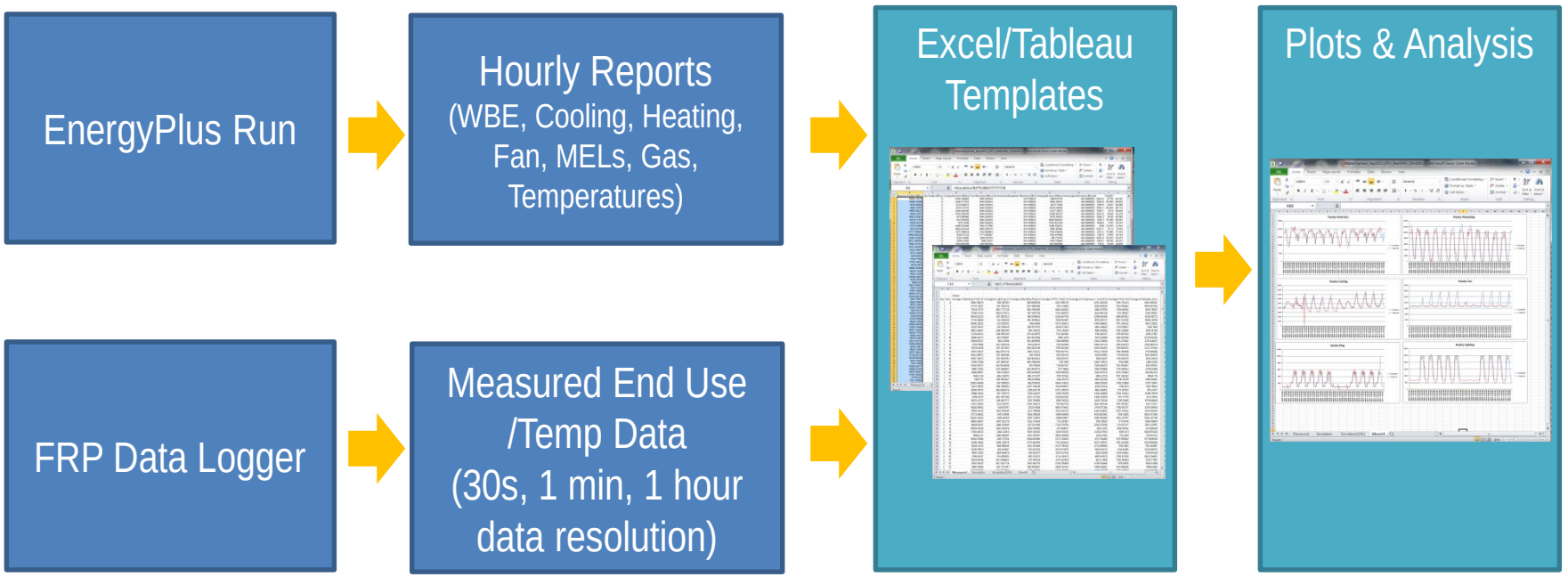
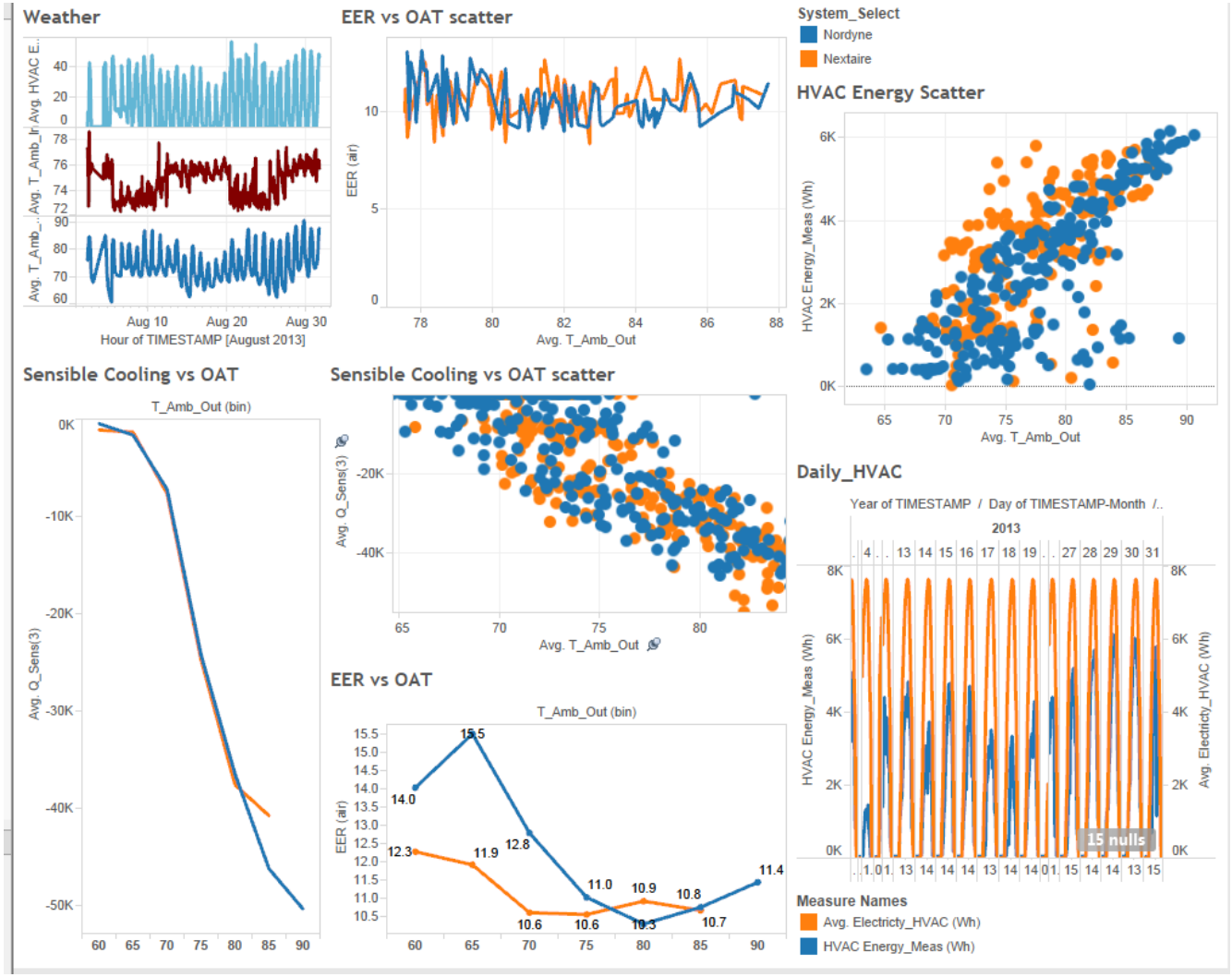


Tableau Template for 2 HVAC Systems (Screenshot)

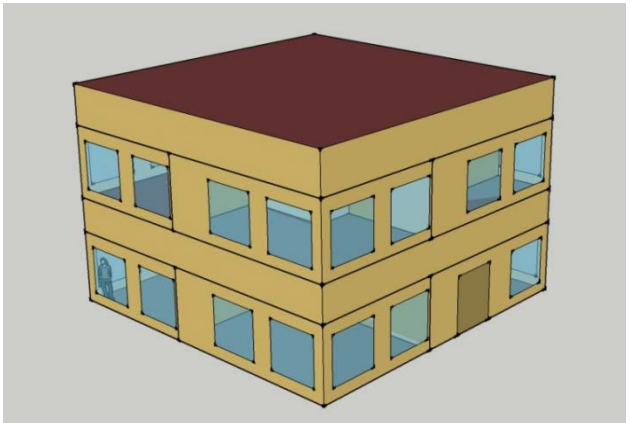


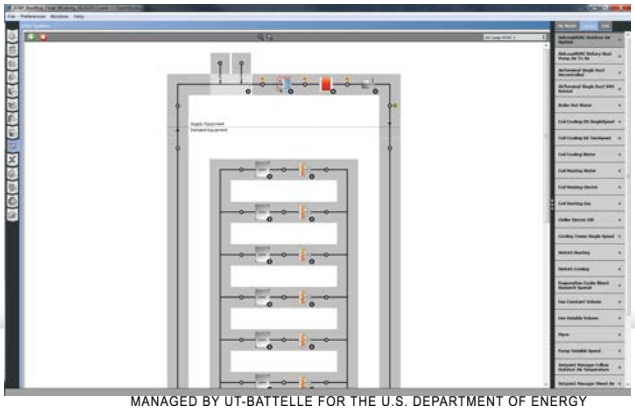
2 Story FRP EnergyPlus Model

- Available models (as of 4/17/2014)
  1. EPlus v.8.1
     1. Building Envelope Model w/ Ideal System
     2. w/ Packaged rooftop unit (Existing)
        - 12.5 ton VAV w/ Gas heating (Elec. reheat)
     3. w/ VRF with DOAS system (Future)
        - 1 outdoor/10 indoor VRF units with 5 ton DOAS RTU
        - 1 outdoor/10 indoor VRF units without DOAS
        - 4 external and 1 internal thermal zone per floor
  2. OpenStudio Model

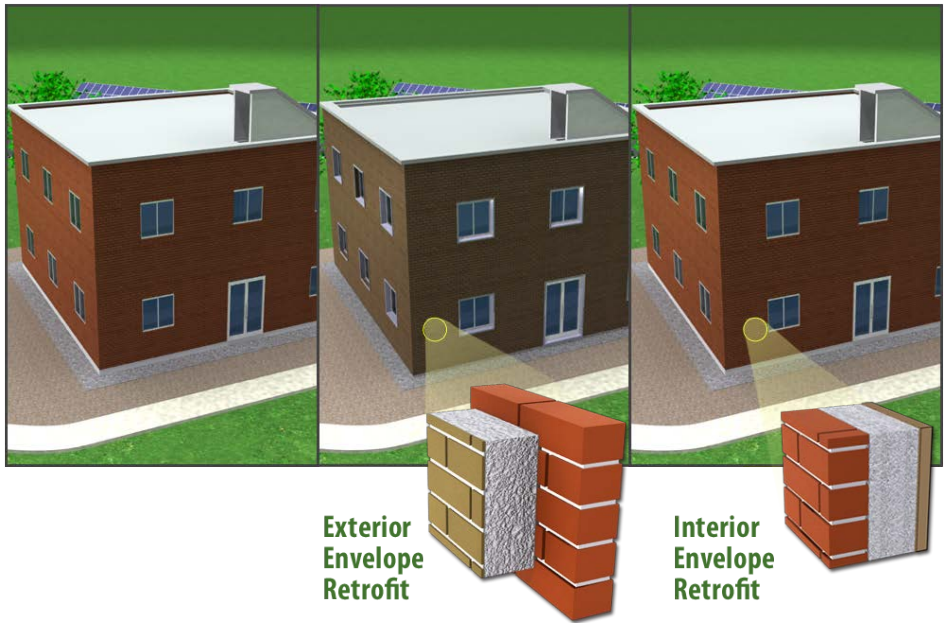
- Weather files

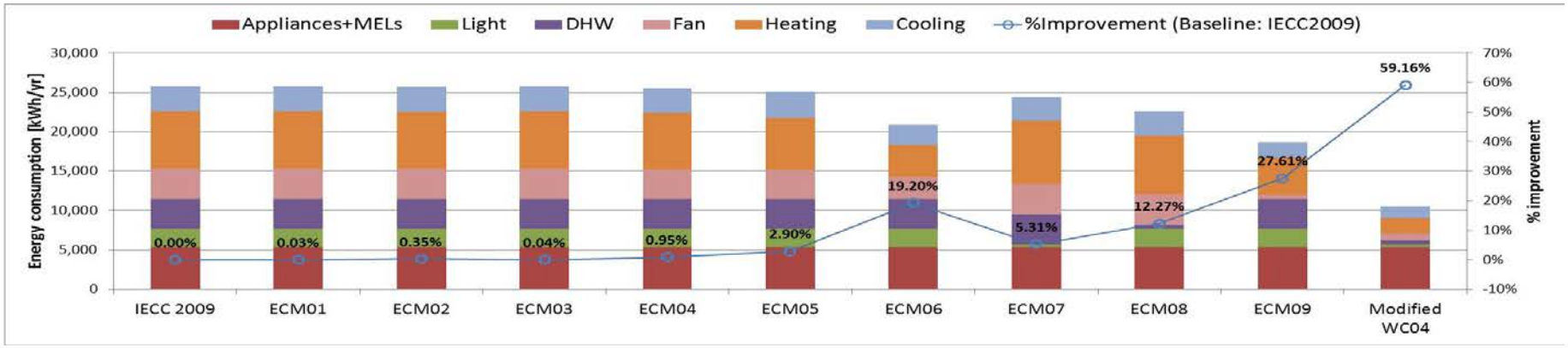
  Actual weather files: 2011, 2012, & 2013



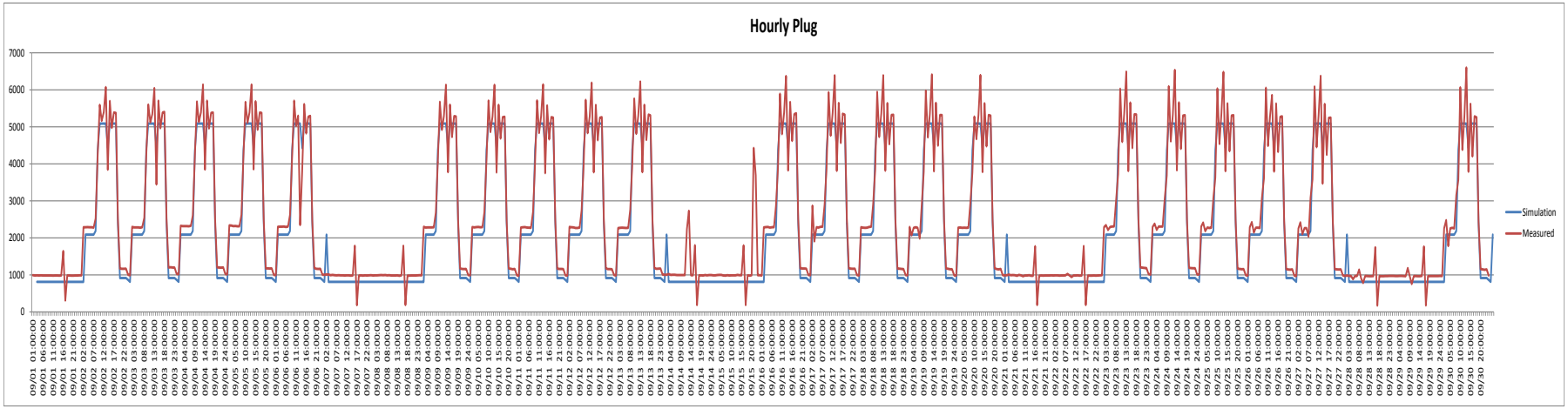


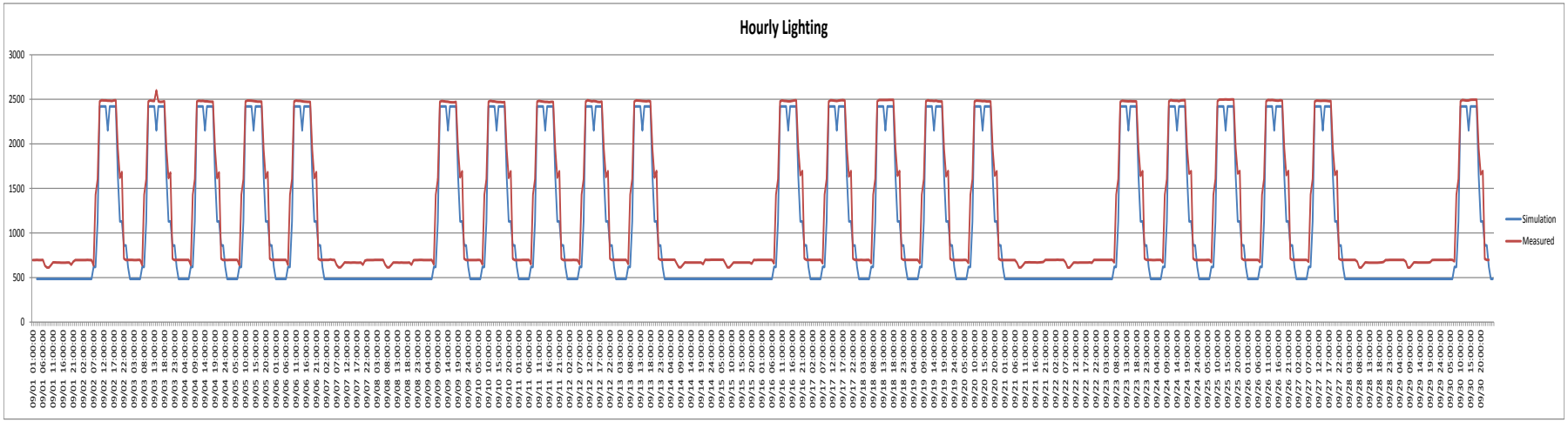
Retrofit Pre-assessment





Preliminary comparison: Measured vs. Simulated (September 2013)





FRP
Visual Analytics

Visual Analytics

Project Investigators:

Joshua New

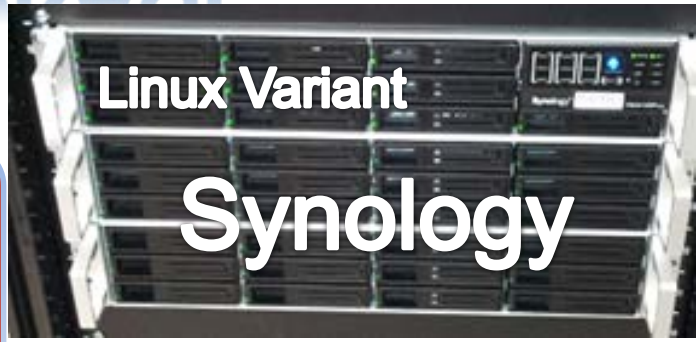
Jibo Sanyal

et al.

Final Architecture

ORNL WORLD

STORAGE



Research (Linux) Hadoop Stack

Safety Plan

Same as Maxlab

Public/Deployment Server (Win)

Maxlab-Linux Research/Development/Testing

Safety Plan

Same as Maxlab-Linux

Public/Deployment Server (Linux)

COMPUTE

FRP Data Collection

Tony Gehl

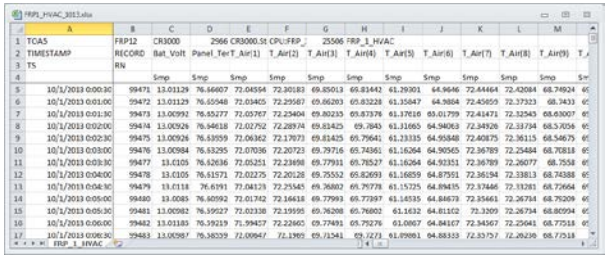
Jibo Sanyal

Data Path (MAXLAB Server):

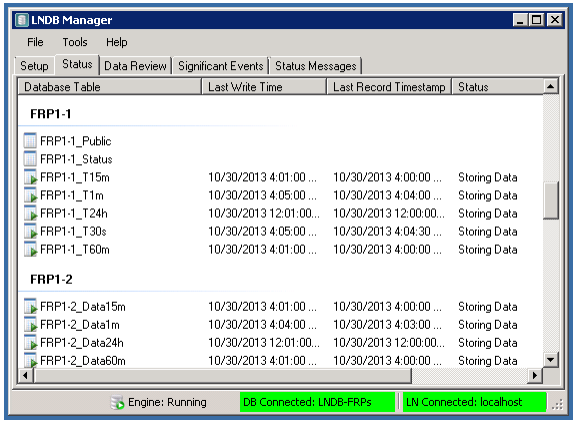
CR3000 Dataloggers store data internally with battery backup.

LoggerNET software
(Scheduled data collection)

ASCII file storage



LNDB software



4020, Rm A103

Database

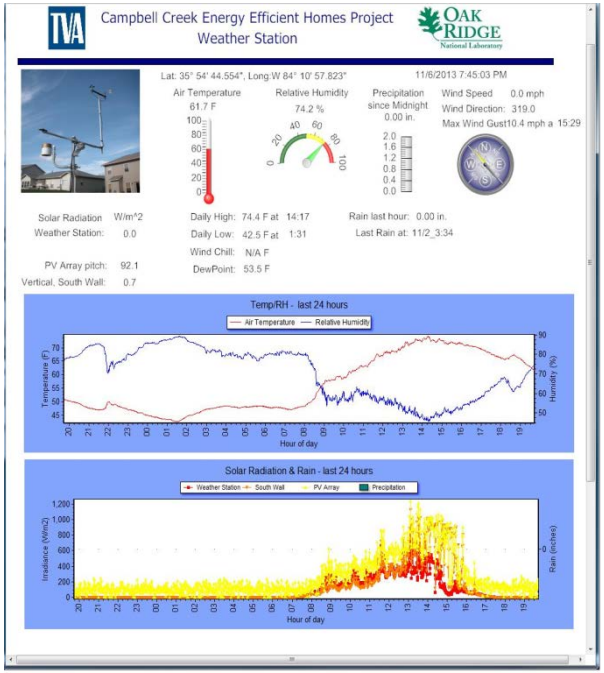
Tape Backup

Real-Time Monitoring & Control (RTMC) Software, Professional

RTMC Pro is used to create and run graphical screens that provide real-time monitor and control capabilities. It can be used to design displays with graphical components including alarms, switches, status bars, charts, and gauges.

Benefits and Features

- Large library of components: alarms, switches, charts, gauges, etc.
- Interactive components allows user to set datalogger values.
- Securely monitor and control your data from virtually anywhere by publishing your RTMC projects to your intranet or the Internet using the included Web Publisher and CSI Web Server
- View data from multiple LoggerNet servers, data files, LNDB databases, HTTP dataloggers, and virtual data sources.
- Send emails or execute code when alarms are triggered.
- Create reports.
- Use the extensive math and logic expression library to convert and/or combine your data for display.



FRP Sensor Data Validation and Correction (SensorDVC)

Data Quality Assurance

Project Investigator: Charles Castello

HERE Intern: Jeffrey Rossiter

Project Manager: Joshua New

What is our motivation?

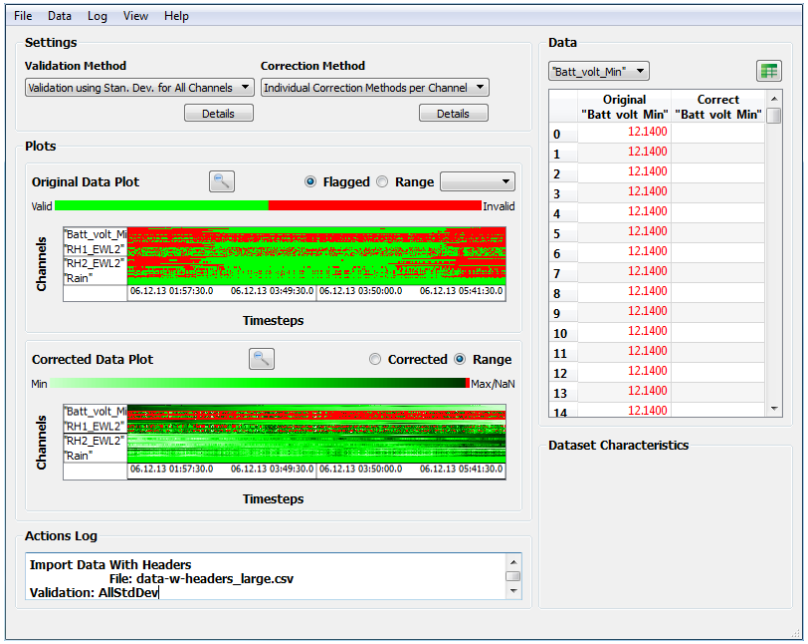
- A wide range of sensors are being used in our research to develop and characterize performance of buildings on a component, system, and whole-building level.
- Missing and corrupt sensor data can be an issue due to:
  - Sensor failure
  - Sensor fouling
  - Calibration error
  - Data logger failure

	A	B	C	D	E	F	G
1	TIMESTAMP	RECORD	Bat_Volt	Panel_Temp	T_Air(1)	T_Air(2)	T_Air(3)
19318	7/8/13 16:19:12	15052	12.97223	79.85068	57.62332	58.21236	66.72047
19319	7/8/13 16:19:42	15053	12.97289	79.85155	57.39069	57.94401	66.65437
19320	7/8/13 16:20:12	15054	12.96894	79.85155	57.21815	57.70008	66.62462
19321	7/8/13 16:20:42	15055	12.97158	79.85155	57.05751	57.51563	66.54727
19322	7/8/13 16:21:12	15056	12.97092	79.85233	56.94398	57.39021	66.48131
19323	7/8/13 16:32:00	15078	12.97217	79.80981	61.66223	61.97161	65.92816
19324	7/8/13 16:32:30	15079	12.97151	79.80981	61.75147	62.00731	65.98765
19325	7/8/13 16:33:00	15080	12.97152	79.80371	61.77525	62.03705	66.04713
19326	7/8/13 16:33:30	15081	12.97086	79.79678	61.79906	62.08464	65.95194
19327	7/8/13 16:34:00	15082	nan	79.79678	61.87045	62.21553	66.02928
19328	7/8/13 16:34:30	15083	12.97032	79.79619	61.90062	62.19215	66.08327
19329	7/8/13 16:35:00	15084	12.97164	79.78926	61.98987	62.30519	66.08922
19330	7/8/13 16:35:30	15085	12.96966	79.78926	62.05531	62.3528	7999
19331	7/8/13 16:36:00	15086	12.97362	79.78926	62.06126	62.37659	7999
19332	7/8/13 16:36:30	15087	12.97097	79.78311	62.13852	62.4836	7999
19333	7/8/13 16:37:00	15088	12.97097	79.78311	62.21586	62.5074	66.24381

Typical Flow of SensorDVC

Import data (.csv file)

Validate data

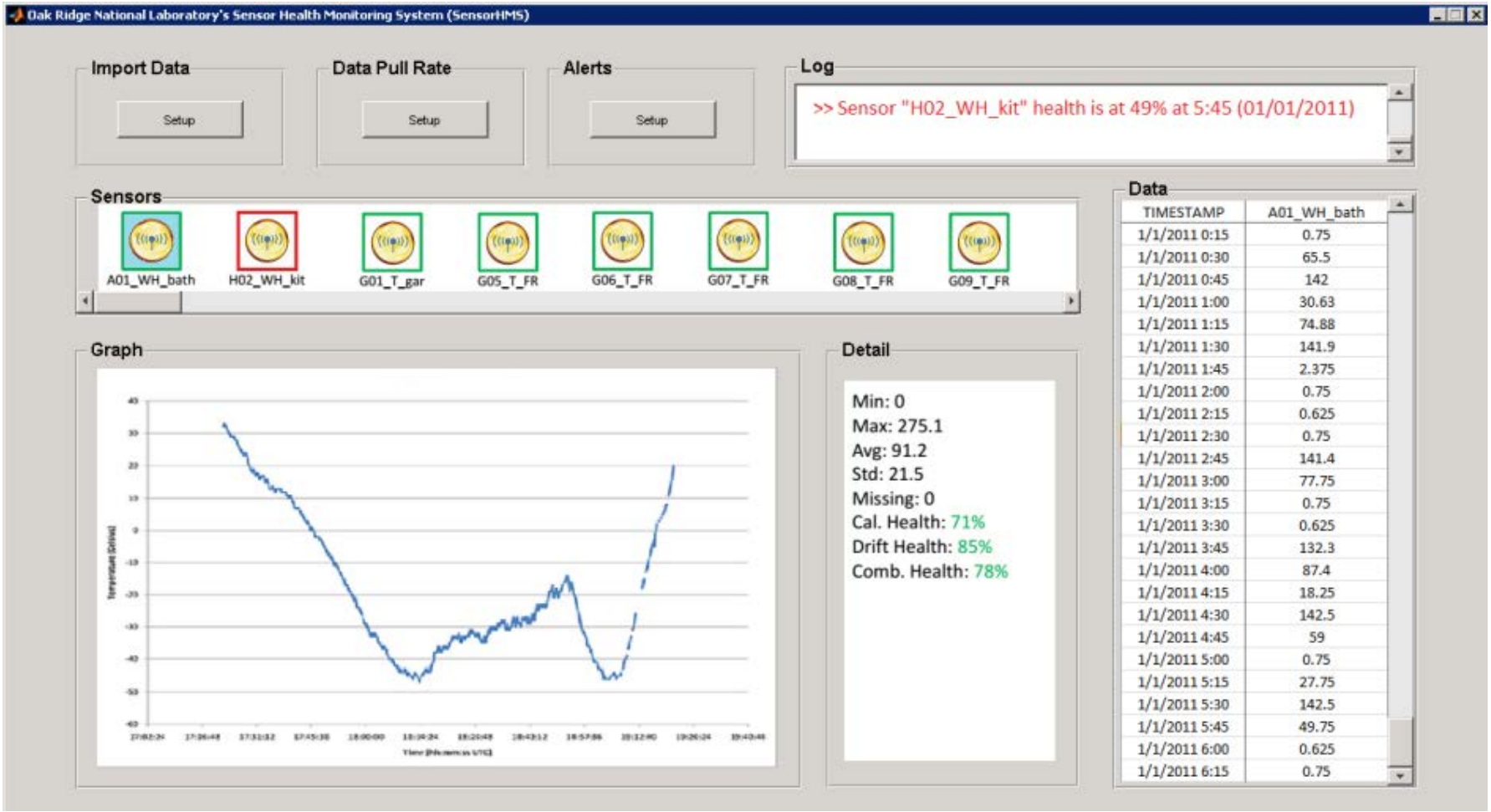


Correct data

Visualize data (spectrograms)

Output corrected data (.csv file)

Mockup of Senor Health Monitoring System (SensorHMS)



ProvDMS

Provenance Data Management System

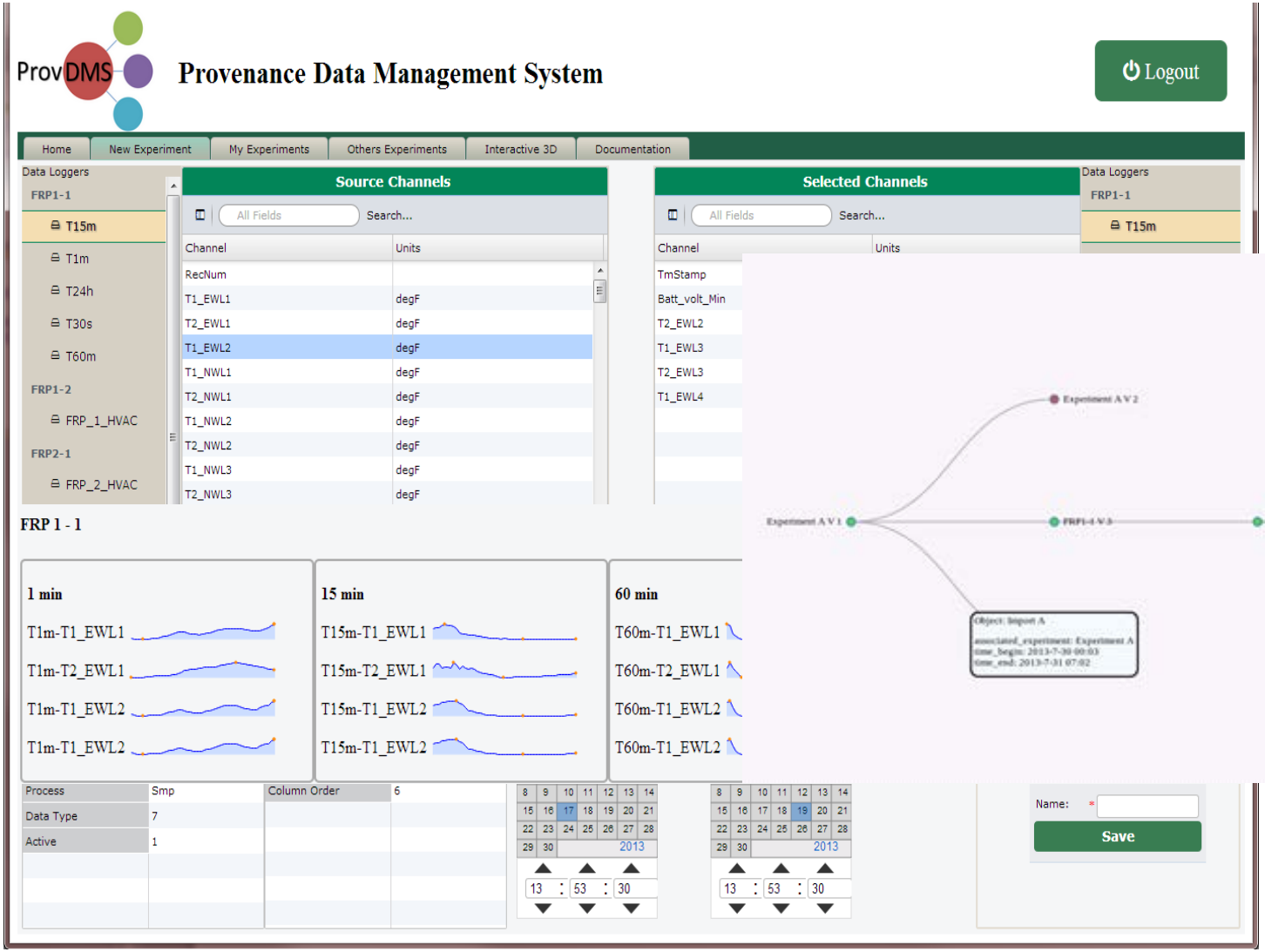
Jibo Sanyal

Provenance Data Management

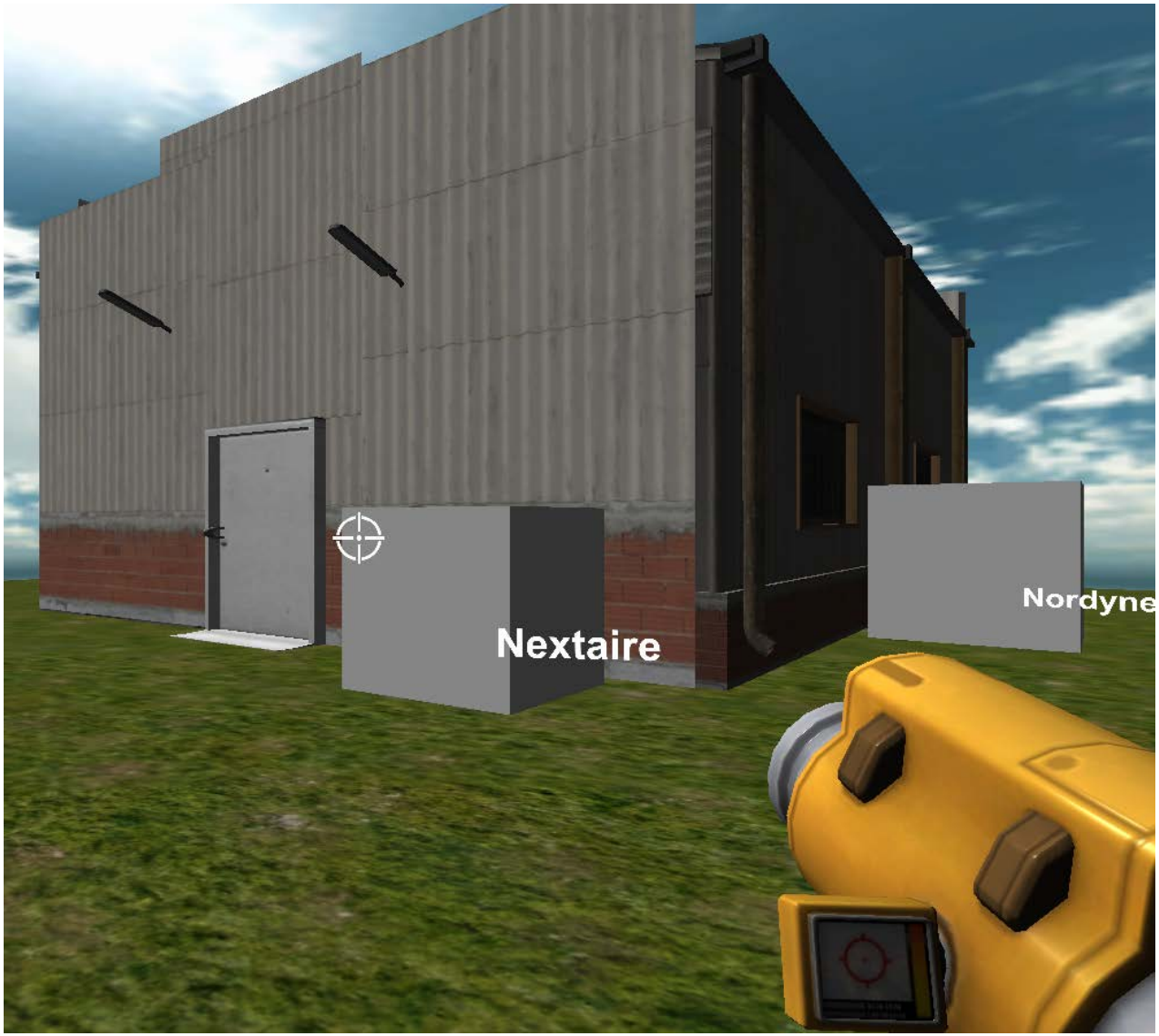
- Files are shared by email, network drives, USB sticks
- No history or lineage is maintained
- Derivative works often lose their ancestry
- Impediment to productivity

Provenance Data Management System for FRPs

Provenance – sensor lineage



Gamification of Building Data



Major National Lab Bldg Technology R&D Test Facilities

Environmental Energy Technologies Division

(DRAFT – Illustrative only)

Buildings Materials & Components → Systems, Controls, Tools & Energy Information for Buildings → Grid & EV Interactions with Buildings