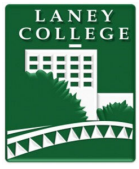
ECT 29 COURSE

LANEY COLLEGE
ENVIRONMENTAL CONTROL TECHNOLOGY

Commercial HVAC Systems Program

ECT 29 Data Analysis for Performance Monitoring - Course Development

National Science Foundation - National Center for Building Technician Education



5/14/2014, revised 2025

DATA ANALYSIS FOR PERFORMANCE MONITORING

Course Documentation

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Catalog description

Introduction to the methods of acquiring HVAC equipment performance data to improve operations and reduce energy consumption: Emphasis on data acquisition through the use of portable data loggers and DDC control systems; methods of trending and visualizing data through the use of electronic databases and spreadsheets such as Microsoft Excel.

Class hours

Lecture 26.25 Hours Lab 26.25 Hours

Units

Lecture 1.5 semester units Lab 0.5 semester units

Entry skills needed

- Reading level: College level English technical reading. Ability to decode new technical terminology with reference help.
- Writing level: Ability to express complex technical concepts in English.
- Math level: college technical math:
    1. Perform mathematical operations using real numbers, fractions, decimals and percentages.
    2. Solve simple linear equations.
    3. Demonstrate knowledge converting fractions to decimals and decimals to fractions.
    4. Solve basic math and geometry problems on area, angles, volume and percentages.
    5. Use algebraic equations to solve heating and cooling load calculation problems.
    6. Solve problems involving ratio and proportions.
    7. Interpret data in graphs in rectangular coordinate systems.
    8. Use and apply Imperial and Metric systems of measurement.
    9. Solve problems involving area and perimeter.

- Introduction to Building Commissioning skills:
    1. Explain the process of building commissioning, with distinctions between new and existing buildings.
    2. Explain the process of commissioning, re-commissioning and retro-commissioning.
    3. Describe the building system fundamentals.

4. Describe building equipment such as boilers, chillers, air-handlers, pumps and motors.
5. Explain commissioning terminologies.
6. Utilize the controls and energy management systems for commissioning.

Suggested co-requisite skills development

- Advanced Building Commissioning skills:
    1. Identify the key components of the commissioning process.
    2. Develop commissioning, recommissioning and retro-commissioning plans.
    3. Develop commissioning guide specifications and forms.
    4. Create appropriate test procedures and data collection protocols.
    5. Demonstrate proper analysis of data collection.
    6. Ensure building operation and maintenance staff is adequately trained.

Syllabus

See Appendix A for sample Syllabus, course schedule, and policies. For lessons to include in course, see below.

Student learning outcomes

The exit skills listed in the next section support these 3 outcomes:

Process & planning

Explain, design, and safely set up data collection systems.

Protocols

Analyze and interpret data to support energy saving measures..

Communication

Effectively communicate results and findings.

Exit skills

Course content to achieve 3 outcomes listed above.

Parameters

1. Determine the data parameters that need to be collected for decision making.
   Course Content for this objective:
   a. Fundamentals
   b. Survey systems and identify appropriate monitoring points.
   c. Data collection systems
      Lesson Topics:
      - Building Metrics
      - Units and Dimensions
      - Central plant performance
      - Air distribution systems
      - Unitary systems
      - Sensors
      - Loggers and temporary systems
      - Permanent systems: Energy management, SCADA, DAS, etc.
      - Wireless system
      - Data Collection Plan

Installation

2. Safely and properly install sensors, and data loggers.
   Lesson Topics:
   - Fundamentals
   - Building System Performance.
   - Data collection: Equipment used to collect data (data loggers, EMS, SCADA)
   - Spot Measurement
   - Monitoring
   - Trending

Data analysis

3. Use computer programs to analyze and graph the data.
   Lesson Topics:
   - Software tools
   - Spreadsheets
   - Universal translator
   - Descriptive statistics: data collection, analysis
   - Measures of central tendency

Synchronization

4. Combine data from multiple sources using time based or event-based synchronization.

   Lesson Topic: Whole Building Data and Information

Interpretation

5. Identify common equipment operating issues through interpretation of trended data.

   Lesson Topics:

   - Introduction to performance monitoring.
   - Data analysis.
   - Building System Performance Concepts and Measurement
   - HVAC Systems Performance
   - AHU and air distribution systems
   - Pumping and water circulation
   - Central plant and cooling towers

Comparison

6. Compare two datasets for changes, e.g. data taken before and after control changes.

Commissioning support

7. Use the data to support systems commissioning.

   Lesson Topic: How to convert data into information.

Energy conservation

8. Use of data to identify energy saving measures.

   Course Content for this objective:

   a. Applications

      Lesson Topics:

      - Lighting energy performance
      - Photovoltaic systems.
      - Utility rates and analysis
      - Benchmarking

Communication

9. Develop written and oral presentations of data and findings.

   Course Content for this objective:

   a. Reports

      Lesson Topics:

      - Reporting Format & Samples (Monitoring and Trending Plan)
      - Systems Performance Graphic Representation

Course materials

Principal text

None used in current version of course.

Listed on course outline: Althouse, Turnquist and Bracciano, *Modern Refrigeration and Air Conditioning,*
Goodheart and Willcox Co. Inc., (2004)

Lecture materials and handouts

- Reference: Excel2010_intro.pdf Document covering basic function of Excel, including graphs and statistical operationg. Office of Information Technology, West Virginia University. 25pp.
- Reference: Excel2010_intermediate.pdf Tutorial on managing worksheets and data entry strategies Office of Information Technology West Virginia University 17pp.
- Reference: EXCEL Tutorial.pdf Basic data entry and producing graphs. 9pp.
- Reference: Excelhandbook.pdf Excel for Data Analysis © National Research Center Inc. Detailed use of excel for statistics and presentation. 40pp.
- Presentation: Covers Descriptive Statistics 51 Slides.
- Presentation: Utility Analysis.pdf Intro and details for bill analysis, including using weather data. 27 Slides.

Other reference materials

ASHRAE, RSES and Internet

Software needed

Microsoft Excel. Google spreadsheet may suffice, applicability untested.

Lab materials

Data loggers, computer/software (Onset HOBO loggers, HOBOware).

Equipment & instruments required

Generally, hands-on implementation of concepts is key to successful learning of equipment function and relationships. Laney ECT department has a fully functional commercial building central plant system installed in the lab. All components of the system are accessible to students for operation, measurement, diagnosis, servicing, and commissioning. See Laney College - Commercial HVAC Systems program documentation for lab layout and more detailed information on equipment and instruments.

A connected and functional commercial HVAC system should include a boiler, chiller, water pumps, air handling units, terminal units, cooling towers, control systems (pneumatic and/or DDC), sensors, and actuators. Monitoring access point computers accompanied by one or more control system trainer boards (with equivalent connected controls and actuators) will allow students maximum access.

Samples of lesson plans & assignments

See **Appendix B** for sample lesson plan. Assignments include reading from textbooks and research of specialty items.

Project

Problem Based Learning (PBL) project under development for 2013: to have students research and create pneumatic control trainers using equipment existing in the lab. PBL should be planned to avoid student cohorts in concurrent courses having to complete multiple PBL projects simultaneously. PBL method should enable students to add to their course learning content. Students indicate the process takes time away from learning content.

For Project Based Learning framework see **PBL Worksheets** web page.

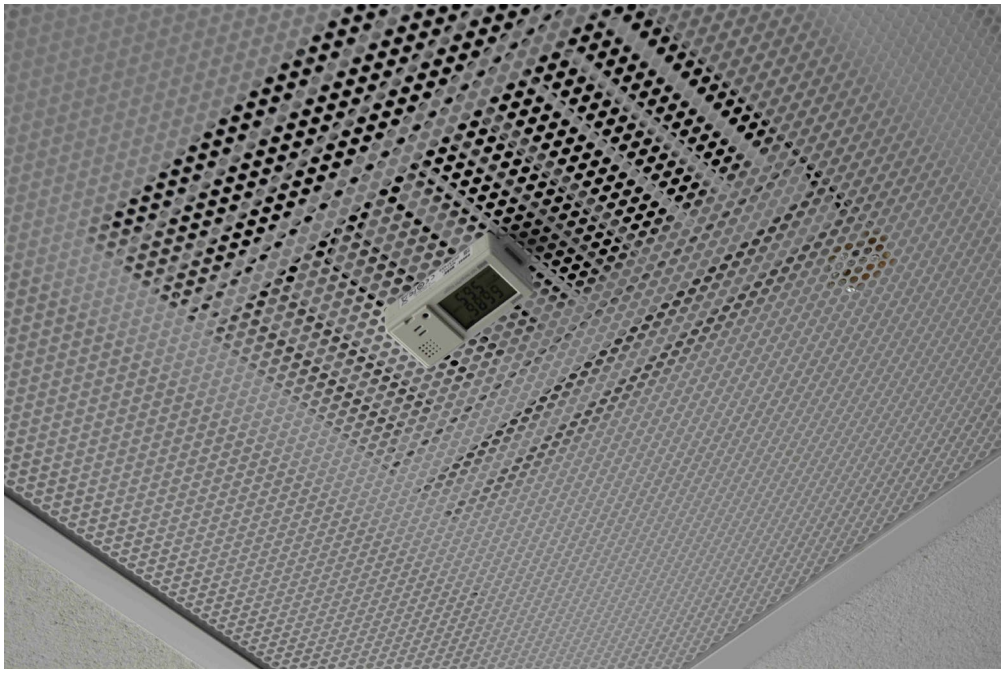
See **Appendix C** for sample project handout.

Assessment

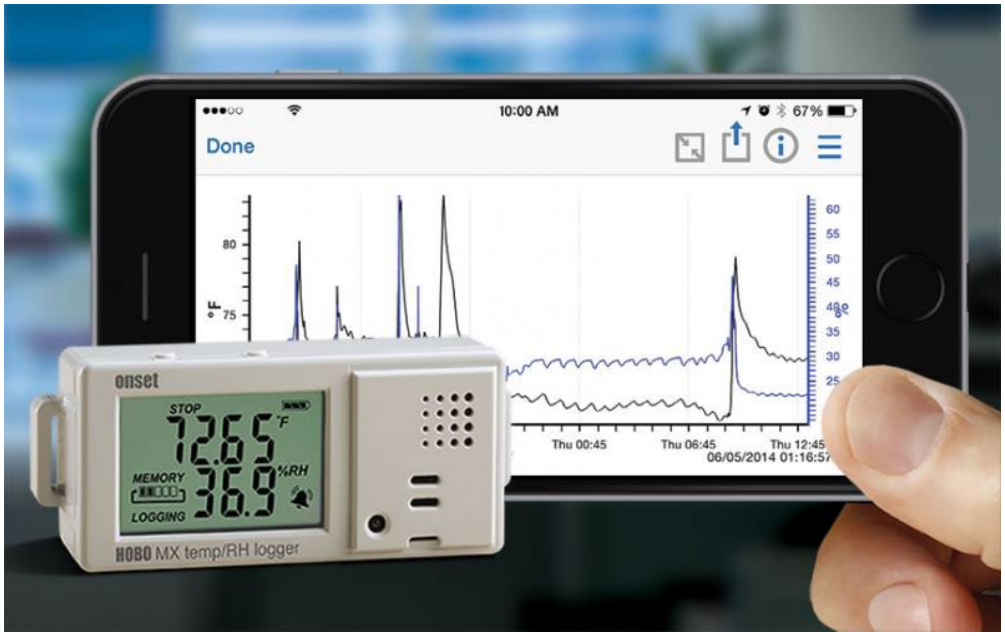
Methods

- Tests
- Peer-evaluated presentations
- Instructor verified hands-on lab work.

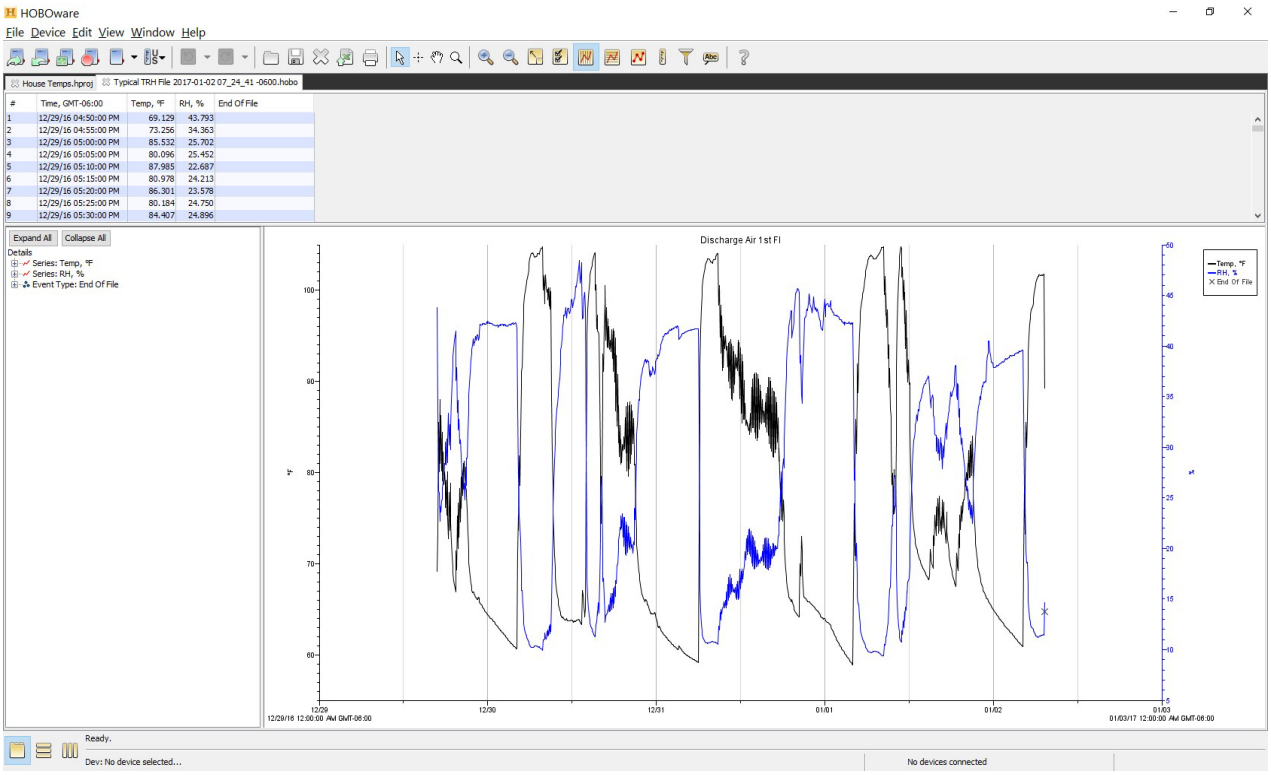
Photos of tools and equipment



Data logger deployed in the field



Data from logger can be downloaded into mobile devices for use with app.



Sample data graphically represented in HOBOware software

Adaptability to on-line format

The lecture portion can be delivered and assessed online with traditional methods. The laboratory portion requires hands-on experience with equipment, so on line delivery needs to be supported by real world access. Adaptation of Laboratory equipment to photographic presentation for web-based course may provide a substitute. Creation of interactive problem scenario. Reference "PNNL "Retuning Commercial Buildings".

Appendix A – Sample syllabus

(See Exit Skills section for lesson topics.)

LANEY COLLEGE
ENVIRONMENTAL CONTROL TECHNOLOGY
FALL SEMESTER 2013

Course: Data Analysis for Performance Monitoring
Course No. /Code: ECT 29
Units: 2 Units
Date/Time: Th 7:00 – 10:00 PM
Instructor:
Office: **Office Hours:** 6:00 – 7:00 Mo - F
Phone:
Email:

Course Description: Introduction to the methods of acquiring HVAC equipment performance data to improve operations and reduce energy consumption: Emphasis on data acquisition through the use of portable data loggers and DDC control systems; methods of trending and visualizing data through the use of electronic databases and spreadsheets such as Microsoft Excel.

Exit Skills:

Students will be able to:

1. Determine the data parameters that need to be collected for decision making.
2. Safely and properly install sensors, and data loggers.
3. Use computer programs to analyze and graph the data.
4. Combine data from multiple sources using time based or event based synchronization.
5. Identify common equipment operating issues through interpretation of trended data.
6. Compare two datasets for changes, e.g data taken before and after control changes.
7. Use the data to support systems commissioning.
8. Use of data to identify energy saving measures.
9. Develop written and oral presentations of data and findings.

Prerequisites/Corequisite: ECT 25 / ECT 26
Text: None. Students will be provided with electronic copies of notes through Dropbox.com; Students are responsible to download class materials from this site

Supplies Needed: Three ring binder, email account, laptop (not required but recommended)

Evaluation: The following classroom work and projects will be evaluated and graded.

1. Homework 15 100%-90% A
2. Midterm 30 89%-80% B
3. Attendance 15 79%-70% C

4. Final Exam 40 69%- 60% D
Below 60% F
Total points: 100
Attendance: Students may be dropped from the course if the number of absences exceeds two days' worth of class meetings. However, extenuating circumstances may warrant consideration.
Note: During class please shot off all cell phones, also no eating or drinking. You will be given two breaks of ten minutes each between classes.
Note: It is student's responsibility to drop the classes.
Please Note: CHEATING is not allowed during Tests; it will automatically get you an F grade and you may be expelled from college.

MTG	Topic/ Lecture	Assignment
Week 1	Introduction to performance monitoring and data analysis / how to convert data into information	
Week 2	Descriptive statistics: data collection, analysis and used to produce information	
Week 3	Descriptive statistics: measures of central tendency	Homework #1
Week 4	Descriptive statistics: measures of variance	
Week 5	Data analysis tools: spreadsheets tutorial	
Week 6	Data analysis tools: spreadsheets tutorial / other software tools used to analyzed data	
Week 7	Whole Building Data and Information: Utility rates and analysis	Homework #2
Week 8	Whole Building Data: Utility and Benchmarking	Homework #3
Week 9	Building System Performance Concepts and Measurement	
Week 10	Mid Term	
Week 11	Systems Performance Graphic Representation	
Week 12	Data Collection Plan	
Week 13	Data collection: Equipment used to collect data (data loggers, EMS, SCADA), Spot Measurement, Monitoring and trending plan design	Lab Practice #1
Week 14	HVAC Systems Performance: AHU and air distribution systems	
Week 15	Thanksgiving Weekend	Lab Practice #2
Week 16	HVAC Systems Performance: Pumping and water circulation loops	Lab Practice #2
Week 17	HVAC Systems Performance: Central plant and cooling towers	Lab Practice #4
Week 18	**FINAL EXAM**	

Appendix B – Sample lesson plan

This lesson plan was presented at the 2017 BEST Center Annual Institute as part of a hands-on activity for educators. The event was hosted at Laney College and Lawrence Berkeley National Lab, which provided use of its FLEXLAB facility for this lab exercise.

Setting Up Data Loggers

Context: Every facility experiences more than their share of comfort complaints, often centering on temperature. Using tools, such as data loggers, to validate qualitative information ("feels cold") helps to take the emotional component out of the analysis and resolve issues.

This lesson plan goes through the process of setting up a HOBO Bluetooth Low Energy Temperature/Relative Humidity Data Logger - MX1101. The same type of process can apply to any data logger.

Materials / Tools Required:

- Computer with:
    1. Internet access
    2. Spreadsheet Software – preferably MS Excel
    3. Data logger and associated software
        - HOBOWare: http://www.onsetcomp.com/hoboware-free-download (this is for working on a computer and does not communicate with Bluetooth loggers – Onset Computers is considering this as a future option)
- Smart Phone

  Download HOBOmobile app onto smart phone:
    - http://www.onsetcomp.com/products/data-loggers/mx1101
- HOBO Bluetooth Low Energy Temperature/Relative Humidity Data Logger - MX1101 (to be made available by BEST Center for exercise use during course)

Student Preparation (before this module):

- Install Free HOBOware software on laptop.
- Install HOBOmobile app on smart phone
- Review videos online

http://www.onsetcomp.com/products/software/hobomobile

1. How to connect to a HOBO MX1101 data logger
2. How to configure and start a HOBO MX1101 data logger using HOBOmobile
3. How to download and view your data in HOBOmobile
4. How to share/export your data in HOBOmobile

BEST Center will loan / provide:

- The data loggers.
- Reporting format and template.

Module Description:

LECTURE/DISCUSSION:

- Overview of Data Loggers:
  - Different types
    - Self-contained, wired, central or internet based data collection, or remote or interchangeable sensors
    - Temp, RH, Amp, kW, CO2 …..
  - Costs
  - For what a manufacturer of data logger thinks - http://www.onsetcomp.com/what-is-a-data-logger
- Project
  - See handout

GROUP WORK:

In assigned groups, do the following:

- Each person selects the number of measurement points and loggers they will use for this project – see Project handout
- Obtain loggers, following checkout protocol
- Each person is responsible for at least one logger and set-up:
  - Name logger
  - Determine and set up logging interval
  - Establish time to start/stop logging data
  - Establish "burst" high and low limits, if desired
- Discuss and set up loggers per handout/presentation
- At Flexlab site: Everyone is to place their loggers and leave to collect data
- Loggers will be collected by BEST Center staff and returned to attendees
- Each person will download the data from their assigned loggers and make sure logging is turned off and LCD is turned off.

ASSIGNMENT:
Analyze and write up a report on the information collected on the data logger.

1. Determine if what logging interval used was appropriate
2. Data summarized and graphed over time.
    a. Work with multiple loggers / attendees to combine data in HOBOware:
        i. Naming series
        ii. Selecting appropriate time to view data over
        iii. Changing line-styles and colors
        iv. Review of Details, data, and graph section of HOBOware
3. Explanation of data, graphs, and correlation to facility operations and occupancy
4. Discussion of results and recommendations including usefulness of data and logger.

Successful Completion of this module is when attendee demonstrates:

1. They can download and install appropriate software for using a data logger.
2. They configure and start logger collecting information.
3. They install and remove loggers from site.
4. They analyze information from loggers.
5. They document the process and results.

Appendix C – Sample project handout

Project: Data Collection

The project for this hands-on activity at the 2017 BEST Center Institute is to set up data loggers, install them at the FLEXLAB locations you have been assigned, and then to download and analyze the data.

Our project site is LBL's FLEXLAB. The scientists at LBL, Ari and Darryl, have prepared a series of different conditions for us to figure out.

You will program a logger for installing at the Lab on Friday morning. We will arrive at the lab at 8:30 AM and have only minutes to install the loggers so be ready to do this **quickly!**

Setting Up the Logger:

- When configuring the logger:
  - Select "Show LCD" when setting up the logger as described in the next section. If this option is disabled, you can still temporarily view the LCD screen by pushing the Start/Stop button for 1 second. The LCD will then remain on for 10 minutes.
  - NAMES: Make sure you name the logger accordingly so that it is easy to figure out what it is measuring.

Data Logging Intervals –

- Sensor mass may lead to slow response times.
  - For instance, a temperature sensor that is small may be a lot quicker to respond to temperature change than a data logger with the sensor built into it. If the reason for logging temperature is to catch fast changes or variance, then a logger with the sensor integrated into it may not be the best choice.
- How fast does the system or parameter being logged change?
  - For space comfort situations changes occur rather slow, minutes if not ¼ hour intervals or more.
  - Motor amperage can change rather quickly and therefore smaller increments of time may be needed. But if for a VFD application on an air handler, most likely 5 (if looking for changes) to 15 (if looking to determine demand) minute intervals are only needed.
- Should NOT be too detailed & create more info than needed.

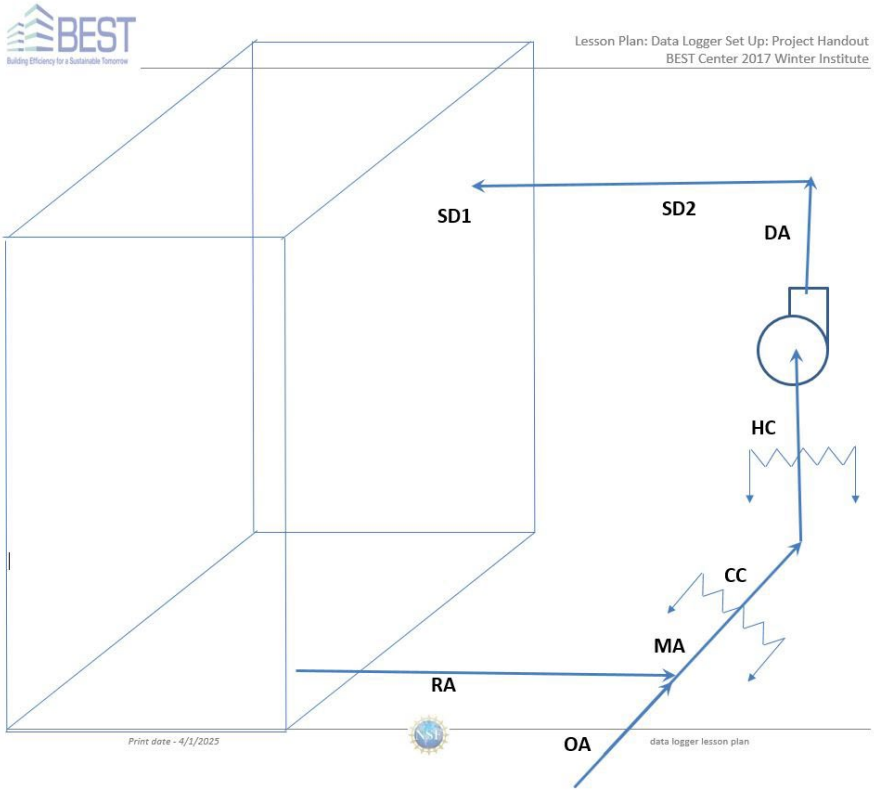
- Short logging intervals can create a lot of data very quickly making analysis more complicated.
- Short logging intervals can take up storage space on the logger very quickly and also take up more file space when downloading into spreadsheets.

Data Logging Start Time –

- Specific start times are typically used when needing to correlate more than one logger of information. Start say on the hour, at 1:00 PM. Then all the data points are on the same time scale. If you don't do this graphing data and data manipulation can get very messy and complicated. However, newer logger software is making this less cumbersome.
- Starting logging "now" is typically only used when using only one logger with no need to correlate to other data.

POTENTIAL ISSUES:

1. Energy loss in duct
2. Temperature rise across fan
3. Temperature stratification in duct (mixed air) and room
4. Solar influences
5. Different types of sensors
6. Relative humidity
7. Overall process



BEST Center Curricula, Resources & Recordings

Academic Programs
Georgia Piedmont Technical College - Building Automation Systems
Milwaukee Area Technical College - Sustainable Facilities Operations
Laney College - Commercial HVAC Systems
City College San Francisco - Commercial Building Energy Analysis & Audits

Professional Development Materials, Presentations & Videos
National Institutes
Building Automation Systems Instructor Workshops
Webinars (e.g., BEST Talks)

Faculty Profile Videos
Reports & Case Studies
Marketing Resources

BEST
Building Efficiency for a Sustainable Tomorrow

NSF National Science Foundation