Graduate Program in Historic Preservation
Stuart Weitzman School of Design, University of Pennsylvania

HSPV 552  Building Diagnostics and Monitoring
Michael C. Henry, PE, AIA,  Adjunct Professor of Architecture

Course Syllabus

Class Meetings
Fridays, 1:45 PM to 4:45 PM (Eastern Daylight Time/Eastern Standard Time)
Class meetings for lectures will be synchronous via Zoom.
Class meetings for group exercises will be in-person, dependent on Covid-19 risk factors.

Communications
Each student is expected to meet with the instructor at least twice during the semester.
Office hours:   Fridays, 10:00 AM to 1:00 PM (EDT/EST) via Zoom on Lecture days
Telephone:  By appointment, Monday-Thursday, 9:00 AM to 5:00 PM (EDT/EST)
E-mail:  henrmic@design.upenn.edu
Note: Subject heading of emails should state “HSPV 552”.
Note: I send emails from mhenry@watsonhenry.com, please add this address to your “Safe Senders”.

Research/Graduate Assistant: Xiyue He, xiyuehe@design.upenn.edu

Course Description

Building diagnostics are the identification and analysis of a problem in a building’s condition or performance. We diagnose a building through qualitative and quantitative observation and by investigation of its history, context, and use, yielding the identification of the possible causes of that condition/performance problem, concluding with a formal professional opinion as the probable cause(s).

Monitoring is the consistent observation and recordation of a selected condition or a performance attribute and the probable enabling factor(s) of either, taking qualitative and/or quantitative measures over a period of time. Monitoring results in useful data and information for analysis, development of a causal hypothesis. Ultimately, monitoring may be used to validate the hypothesis.

Building diagnostics and monitoring inform the development of appropriate interventions or corrective measures to address the cause(s) of the identified problem. In heritage buildings, the process informs the selection of interventions that satisfy the stewardship goals for the resource.

HSPV 552 Building Diagnostics and Monitoring examines the diagnostic process, including:
- Metacognition of our processes of collection and analysis of data, evidence, and information;
- Recognition of diagnostic bias;
- Application of systems thinking in framing problems of building condition and/or performance;
- The human vision system and qualitative observation of conditions or performance;
- Identification of potential mechanisms that may have resulted in the observed conditions and identification of necessary and sufficient enabling factors for those mechanisms;
- Analysis and development of multiple hypotheses as to the probable mechanism(s);
- Identification and validation of the strongest hypothesis.

Building Diagnostics and Monitoring presents the fundamentals of monitoring as a diagnostic tool, including:
- Basics of measurement theory and practice;
- Sampling and statistics;
- Diagnostic tools, such as instruments, imaging, dosimetry, and tests;
- Design of a diagnostic monitoring program, including selection of measurement and monitoring devices;
- Collection, analysis, and presentation of data.
Learning Objectives
Upon successful completion of Building Diagnostics and Monitoring, students should be able to:

- Apply the principles of critical thinking, systems thinking and creative problem solving;
- Develop a structured and logical diagnostic methodology for analysis of a building condition/performance;
- Research information in the professional literature concerning building pathology and diagnostics;
- Observe and describe conditions qualitatively and quantitatively;
- Organize and present data and information to facilitate analysis;
- Develop preliminary hypotheses correlating observed condition/performance problems to causal mechanism and the necessary and sufficient factors to enable those mechanisms;
- Develop a methodology to validate/invalidate the hypotheses through monitoring;
- Evaluate the available devices for monitoring;
- Present data and information to support conclusions; and,
- Prepare a professional-level technical proposal/report for diagnosis and monitoring for a particular building condition/performance problem.

Teaching and Learning
Building Diagnostics and Monitoring will be taught using the following platforms:

Canvas will be used to access lecture slides, readings, quizzes, and tests.

In-person class meetings will be used for exercises and group work applying the course material to real buildings in case studies and to the final assignment.

Zoom will be used live on-line class meetings for lectures.

Zoom and telephone will be used for meetings with individuals and teams.

On-Line class meeting time will be structured to maximize active learning and interaction among students and between students and the instructor and as a consequence, class discussion of lecture content is expected. This approach will require thorough preparation before class, including review of the readings and lecture slides. Class meetings will not be recorded unless a student cannot attend due to exceptional circumstances, such as an acute health issue.

In-person class meetings will be used for exercises and group work applying the course material to real buildings in case studies and to the final assignment.

The final assignment will be introduced at the beginning of the semester. Drafts of the major sections of the final assignment will be submitted incrementally during the semester, so that feedback can be provided in time for more research and refinement of the final work product by the student teams.

After two and one-half semesters of on-line teaching, enough benefits and opportunities have emerged to retain the on-line approach for some class meetings, combined with in-person class experiences for collaborative problem-solving and exercises.

Feedback on the effectiveness of the methods used in this course will be welcome, so that we can make mutually agreeable adjustments and introduce improvements as Building Diagnostics and Monitoring proceeds through the semester. Your candid feedback on course content, readings, class exercises and teaching methods are encouraged so that the course may be continuously developed and improved. Course feedback may be delivered directly, or through the Teaching Assistant. Real time feedback, rather than feedback at the end of the course, is preferred.
Learning - Your Responsibilities as a Student

- **Attendance**
  You are expected to attend all classes and attendance will be taken. Notify me by email before class if you will not be able to attend a class meeting. The Course Absence Report system will not be used for this course.

- **Preparation for Class**
  The learning and teaching process is most effective when students and faculty thoroughly prepare for each class or individual meeting, whether on-line or in-person. At a minimum, you must absorb the assigned material, regardless of format. Preparatory materials for each week are listed in the syllabus.

- **On-line Conduct**
  You should treat on-line class meetings as if you are in a live business meeting with other professionals. Eliminate distractions to you and your fellow students. Turn-off your phones, email, and texting apps/programs. Eat your lunch/dinner before or after, but not during, class.

- **Class Exercises and Problem-based Learning**
  Class exercises and problem-based learning are an important part of the student-centered learning process and will apply information or methods addressed by the readings and lectures. Class exercises require reasoning, analysis, basic mathematical calculations, and sketching. Some exercises will be done individually; others will be collaborative. You will need a simple calculator, graph paper and writing/sketching instruments (or the digital equivalent) to complete the class exercises.

- **Quizzes**
  Periodic quizzes demonstrate your progress with assimilation of the course material in the lectures and the readings. All quizzes will be “closed-book.” You will need a simple calculator, graph paper and writing instruments to complete the quizzes.

- **Test of Knowledge**
  The test of knowledge demonstrate that you have command of information that is essential to successful completion of the course. The test of knowledge requires your comprehension and retention of information contained in the readings and lectures. The test will be “closed-book.” You will need a simple calculator, graph paper and writing instruments to complete the test.

- **Final Assignment Deadline**
  The deadline for the final assignment is firm and there will be ample time for you to plan and execute the assignment. Short of hospitalization, no extensions will be granted. Late delivery of your assignment will be reflected in your grade.

- **Academic Integrity**
  Honesty is fundamental to your future practice as a professional and academic honesty is fundamental to our community at the University of Pennsylvania. Honesty includes attributing and citing the sources used in your assignments.

  The UPenn Code of Academic Integrity can be found at [https://catalog.upenn.edu/pennbook/code-of-academic-integrity/](https://catalog.upenn.edu/pennbook/code-of-academic-integrity/). A confirmed violation of that Code in this course will result in failure for the course.

**Prerequisites for this course**

HSPV students must have successfully completed HSPV 551 *Building Pathology* prior to this course unless specifically waived by the Instructor due to equivalent education or professional experience.

MHPD and MEBD students must have a working knowledge of psychrometrics, climate factors, building envelopes and building environmental systems.

All students should complete the psychrometric tutorial [http://www4.uwsp.edu/papersci/biasca/currentpages/](http://www4.uwsp.edu/papersci/biasca/currentpages/) prior to the start of the course.
Metrics for Student Performance

Letter grades and their numerical equivalents will be based awarded upon successful completion of the course. The final grade will be based on the following allocation:

- Participation in class: 25%
- Test of Knowledge: 35%
- Building Diagnosis & Monitoring Proposal: 40%
- Total (maximum): 100%

The final course grade will be adjusted to reflect unexcused absences and late assignments.

Participation in class will be based on:
- Preparation, including readings;
- Exercises - participation and outcomes;
- Engagement in discussions.

The Building Diagnosis & Monitoring Proposal will be graded on:
- Focused, substantive and concise content, founded on clear and logical analysis, substantiated by facts and independent research beyond the course materials;
- Clear and logical narrative exposition of the information, substantially free of grammatical, punctuation and spelling errors;
- Graphical presentation of key concepts illustrating the important or complex points of the narrative.
- Conformance with format requirements.

The full range of grades will be awarded in this course:
- **A**
- **B**
  Very good work, near-professional quality, thorough grasp, and synthesis of nearly all information. Rare lapses in preparation for class, occasional lack of engagement and participation in class. Writing: rare lapses in clarity or application of technical terminology. Research of the problem at hand: limited citation of professionally acceptable sources beyond course materials. Evaluation of proposed measurement/monitoring devices/method: representative of range. Proposed graphics demonstrating causality: dual variant, clear and convincing.
- **C**
  Average work, sub-professional quality, understanding of basic information. Marginal class preparation, moderately engaged, occasional participation. Writing: Weak organization or structure, poor application of technical terminology. Research of the problem at hand: citation of professionally acceptable sources limited to course materials. Evaluation of proposed measurement/monitoring devices/method: limited options; Proposed graphics demonstrating causality: clear, but single variant.
- **F**
  Unacceptable work.
Overview of the Final Assignment

For the final assignment, you and your assigned teammate(s) will prepare a Building Diagnosis & Monitoring Proposal, consisting of a professional-level technical proposal for diagnosis and monitoring for a specific building material/performance problem.

In preparing the Building Diagnosis & Monitoring Proposal, you will apply and extend the critical concepts, fundamental principles, methods and information from the lectures and readings. You will also investigate and evaluate suitable methods/devices for measurement or monitoring as part of the Building Diagnosis & Monitoring Proposal. This effort will constitute the active learning component of the course and will provide student-centered, learning in the context of authentic, real-world building problems.

The Building Material/Performance Problem

The problem for the final assignment will be based on an actual building, but some information specific to definition of the problem will be fictionalized for simplicity. Some information will be released incrementally over the course, simulating the normal evolution and discovery process of a diagnostic problem in real practice. You are responsible for researching all other information necessary to address the problem and complete the assignment.

Submission

Students must submit the Final Assignment at the time specified in the Syllabus. Each team member must sign the cover sheet indicating that they have contributed equally to the assignment.

The Building Diagnosis & Monitoring Proposal

The Building Diagnosis & Monitoring Proposal is a professional-level technical proposal containing:

- Qualitative narrative and graphical description of the building material condition/performance problem;
- Analysis of the problem and identification of at least two possible and differential hypotheses as to the probable cause and the necessary and sufficient enabling factors, substantiated by citations found outside of the course materials;
- Proposed diagnostic monitoring methodology to differentiate the two hypotheses and validate one of the hypotheses while invalidating the other. Identification of the expected outcomes, and possibility for unexpected results;
- Proposed methods for analyzing and presenting the information that will result from the proposed diagnostic monitoring methodology.

The narrative must be a clear and logical exposition of the facts. Writing must be substantially free of grammatical and spelling errors. Graphics should illustrate the important or complex points of the narrative. Conclusions and recommendations must be substantiated by facts and reflect a rational thought process.

The Building Diagnosis & Monitoring Proposal shall be organized as follows:

- **Cover sheet**
- **Title page**
  - Property name and location/address;
  - Course number, title, and program
  - Date of report
  - Each student’s printed name and signature with statement “I have contributed equally with my team partner(s) in this assignment”
- **Table of contents**

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1. *Elements of Style Illustrated* by William Strunk, Jr. and E. B. White is a classic guide to writing. The current edition is delightfully illustrated by Maira Kalman.

• **Executive Summary** (1-2 pages of text)
  Provide a brief introduction and overview of the condition and the important points of the *Building Diagnosis & Monitoring Proposal*.

• **Background and Overview of the Building** (2 pages of text, maximum, plus necessary graphics)
  Describe the spatial, environmental, and temporal contexts of the building and/or site, in order to orient the reader generally. Provide contextual details that are pertinent to the specific condition addressed by the *Building Diagnosis & Monitoring Proposal*.

• **Description of the Condition/Performance Problems** (3 pages of text, maximum, plus necessary graphics)
  Describe the selected building condition/performance problem qualitatively using professionally-recognized terminology.

• **Analysis of the Condition/Performance Problem and Two Hypotheses of Cause and Enabling Factors** (4 pages of text, maximum, plus necessary graphics)
  Analyze the condition/performance problem, the contextual information and identify two distinct possible mechanisms and the necessary and sufficient factor(s) that enable those mechanisms. Identify two hypotheses for the most probable mechanisms.

• **Proposed Validation Methodology** (4 pages of text, maximum, plus necessary graphics)
  Describe the proposed methodology for differentiating the two hypotheses, validating one and invalidating the other, including:
  - Data/information required, including the necessary accuracy, resolution, and repeatability;
  - Method and equipment necessary to collect the data/information, such as laboratory testing, sampling, in-situ monitoring;
  - Evaluation of available data/information acquisition methods;
  - Identification of recommended data/information acquisition methods.

• **Proposed Method for Analysis and Interpretation of Data** (3 pages of text, maximum, plus necessary graphics)
  Describe the proposed method/format for analysis and presentation of the results.

• **Appendices**
  Maps
  Floor plans or plan sketches
  Conditions maps (elevation drawings or photographs)
  Conditions glossary
  Manufacturers data sheets for devices/equipment
  Bibliography listing citations related to the problem and the development of the hypotheses

The **digital format** of the *Building Diagnosis & Monitoring Proposal* shall conform to the following:

- White paper, 8.5 by 11.0-inch, portrait orientation for text, single-sided;
- White paper, 11.0 by 17.0-inch, landscape orientation, single-sided printing, z-folded for large graphics;
- Calibri font, 11-point, black print, single spaced lines;
- Margins set at 1.25 inches (binding edge), 1.00 inches (other edges);
- Single-line footer with Project Name (left) and page number (right);
- Pages numbered sequentially:
  - i, ii,... for contents;
  - 1, 2,... for report body;
  - A1, A2, ... for appendix A, similar for B, et cetera;
- Endnotes for each section;
- Photographs, images, and charts/graphics:
  - Landscape format (top edge to rings) or portrait format.
  - Black and white or color, laser/bubble jet printed from digital images or scans.
  - 4 inches in the least dimension.
  - Captioned with self-evident descriptive text, source name and date;
- Individually tab each report section and appendix and label tabs;
- Bind entire document as a single .pdf;
- Upload the entire document as a single digital file in .pdf format to a Canvas or Dropbox location to be designated later in the course.
Information Sources for the Course
In addition to the readings in the syllabus, the following books are also required for the course:


Chapter 5: *Survey and Assessment*.

Other Resources


Engineering Weather Data: a compilation of National Climate Data Center Charts and Tables for worldwide locations as used in the course. Can be accessed for free at University of Indiana University, Bloomington website. http://webapp1.dlib.indiana.edu/cgi-bin/virtcdlib/index.cgi/4910250 at bottom of page select either “Download” for the entire file or “Browse” then open “EngineeringWeather.html” to find a location.


Although not required, the learning experience can be enhanced by the following texts:

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<thead>
<tr>
<th>Date</th>
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<tr>
<td>03 September</td>
<td>Course introduction:</td>
<td>Henry. HSPV 552 Course Syllabus</td>
<td>Henry. Lecture Slides Class 1</td>
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<tr>
<td>Class 1</td>
<td>Content, learning methodologies, quizzes,</td>
<td>Diagram: Watt. Building Pathology. Fig 5.13</td>
<td>Question:</td>
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<tr>
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<td>test of knowledge, final assignment, &amp;</td>
<td>Diagram: ASCE Guideline for Condition Assessment of the Building</td>
<td>1. Compare flowcharts by Watts, ASCE</td>
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<td>student work product.</td>
<td>Envelope. SEI/ASCE 30-00</td>
<td>and ASHRAE. How might they apply to</td>
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<td>Diagnostics</td>
<td>Diagram: ASHRAE-Guideline-0-The-Commissioning-Process</td>
<td>a diagnostic process for built</td>
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<td>Their importance</td>
<td>Start reading Tufte, finish by class 5</td>
<td>cultural heritage?</td>
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<td>Failures in problem identification &amp;</td>
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<td>Model for diagnostic reasoning</td>
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<td>10 September</td>
<td>Thinking in Systems</td>
<td>Keene, S. A systems view of museums. In Managing Conservation in</td>
<td>Henry. Lecture Slides Class 2</td>
</tr>
<tr>
<td>Class 2</td>
<td>Systems structures</td>
<td>Museums. 2nd ed., 2002, pp. 79-96.</td>
<td>Question:</td>
</tr>
<tr>
<td>(On-line)</td>
<td>Stacks, flows &amp; dynamic equilibrium</td>
<td>Meadows, Donella H. Thinking in Systems, a primer. (pp. 1-72)</td>
<td>1. How does “systems thinking” apply</td>
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<td>Thinking in</td>
<td>Feedback loops, types &amp; effects</td>
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<td>to a diagnostic process for built</td>
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<td>systems</td>
<td>System response</td>
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<td>cultural heritage?</td>
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<td>Introduction to the Final Assignment</td>
<td>Review available documentation and the Final Assignment Brief.</td>
<td>Question:</td>
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<tr>
<td></td>
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<td>Croskerry. A Universal Model of Diagnostic Reasoning. Academic</td>
<td>1. Provide examples of systems 1 and 2</td>
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<td>Medicine 2009/84:8/pp 1022-8</td>
<td>thinking in the diagnosis of</td>
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<tr>
<td>17 September</td>
<td>Exercises &amp; Problem Solving</td>
<td>Read articles regarding Notre Dame Fire and Champlain Towers South</td>
<td>Question:</td>
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<tr>
<td>Class 3</td>
<td>1. Timelines</td>
<td>Condominium collapse</td>
<td>1. List the subsystems that comprise</td>
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<td>3. In each case, when you assemble all of</td>
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<td>the subsystems into a single system,</td>
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<td>what is the starting point in time for</td>
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<td>Date</td>
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<tr>
<td>01 October</td>
<td>Exercises &amp; Problem Solving</td>
<td>Croskerry, P. <em>The Cognitive Imperative: Thinking About How We Think</em>. Academic Emergency Medicine 2000/7:11/pp 1223-31.</td>
<td>Henry. Lecture Slides Class 5 Question: 1. Are there parallels or similarities between active listening and careful observation?</td>
</tr>
<tr>
<td>(In-Classroom)</td>
<td></td>
<td>Croskerry, P. <em>Context is everything or How could I have been that stupid?</em> Healthcare Quarterly 2009/v12 special/pp 171-7.</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Bondeau, Cassell, Fuks. <em>Preparing Medical Students to become Attentive Listeners</em>. Medical Teacher 31 (2009)</td>
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<td></td>
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<td><em>Defining Critical Thinking/Our Concept of Critical Thinking/Becoming a Critic of Your Thinking</em>, The Foundation for Critical Thinking</td>
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*HSPV 552 Building Diagnostics & Monitoring*

**Syllabus**

Revision 0, 02 September 2021

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<td>08 October</td>
<td>Creative problem solving:</td>
<td>Thoughts on Problem Solving</td>
<td>Henry. Lecture Slides Class 6</td>
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<tr>
<td></td>
<td>Open ended &amp; closed ended problems, problem definition, creative problem solving</td>
<td><a href="http://www.engin.umich.edu/~problemsolving/index.htm">http://www.engin.umich.edu/~problemsolving/index.htm</a></td>
<td>Question: 1. How do System 1 and System 2 thinking relate (or not relate) to Bloom’s Taxonomy and CPS Model of divergent and convergent thinking phases?</td>
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<td>Aids to the diagnostic process:</td>
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<td>Visualizing information, making connections.</td>
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<td>15 October</td>
<td>Fall Break</td>
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<td>22 October</td>
<td>Exercises &amp; Problem Solving</td>
<td>Submit Draft Assignment Section by 6:00 PM Thursday prior to class:</td>
<td>Prepare Draft Assignment Section</td>
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<td>Presenting flows and data as information</td>
<td>Analysis of the Condition/Performance and a system diagram</td>
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<td>29 October</td>
<td>The measurement process:</td>
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<td>Henry. Lecture Slides Class 8</td>
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<td></td>
<td>Accuracy, precision &amp; specification, device error &amp; process error, recording, repeatability</td>
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<td>Question: 1. Why is precision important in preservation measurements?</td>
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<td>Moisture in air and materials:</td>
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<td>Principles and practicalities of measurement</td>
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</table>
| 05 November         | Exercises & Problem Solving                     | 1. *Measuring loss*  
2. *What data & testing are needed?*  
3. *How much is enough?*                                                                                                      | Henry. Lecture Slides Class 10                                              |
| Class 9 (In-Classroom) |                                                 |                                                                                                                            |                                                                             |
| 12 November         | Imaging:  
*Infrared thermography.*  
*Surface Penetrating Radar*  
*Moisture Surveys*                                                                                                              | Colantonio, Antonio. *Detection of Moisture and Water Intrusion Within Building Envelopes by Means of Infrared Thermographic Inspections.*  
Journal of Building Envelope Design. 2008/pp 47-54  
Exterior Building Envelope Inspections Using Thermal Infrared Imaging.  
General Services Administration. 2006                                                                                         | Questions:  
1. What are limitations of IRT imaging as a diagnostic tool?  
2. What must be known if IRT images are to be meaningful?                                                                     |
Friedman, Donald. *Ambiguity in Building Investigation A Study of Sampling and Decision-Making.* 2000  
APTI PracticePoints 03, 09, 10  
ASCE 30 selections by Instructor  
ASCE 11 selections by Instructor                                                                                                  | Henry. Lecture Slides Class 11                                              |
| Visualizing Processes |                                                 |                                                                                                                            |                                                                             |
| 19 November         | Critical review of Draft Assignment Sections     | *Submit Draft Assignment Sections by 6:00 PM Thursday prior to class:*  
- Information required for Diagnosis  
- Proposed Method for Analysis and Interpretation of Data                                                                        | Prepare Draft Assignment Sections                                                                                               |
| Class 11 (In-Classroom) |                                                 |                                                                                                                            |                                                                             |
| 24 November         | Hypothesis development  
*Correlation versus Causality*  
Validating the hypothesis  
Modeling & simulations:  
Past exposures  
WUFI Handbook for hygrothermal modelling  
[http://discovery.ucl.ac.uk/2287/1/Microsoft_Word_-_ICOM_14.pdf](http://discovery.ucl.ac.uk/2287/1/Microsoft_Word_-_ICOM_14.pdf)  
| Class 12 (On-line)  |                                                 |                                                                                                                            | Questions:  
1. From this week’s readings, identify recommendations for hypothesis development at are relevant and irrelevant.   |
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<tr>
<td>03 December</td>
<td>Final Assignment Review and Feedback</td>
<td>Submit Draft Final Assignment and present to Class.</td>
<td>Prepare Draft Final Assignment</td>
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<td>Course Review</td>
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<td>Request content review by Instructor</td>
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<td>Test of Knowledge</td>
<td>Review test results</td>
<td>Prepare for test</td>
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<tr>
<td>17 December</td>
<td>Submit Final Assignment <em>Building Diagnosis &amp; Monitoring Proposal</em> and Final Exam no later than 12:00 noon EST online</td>
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