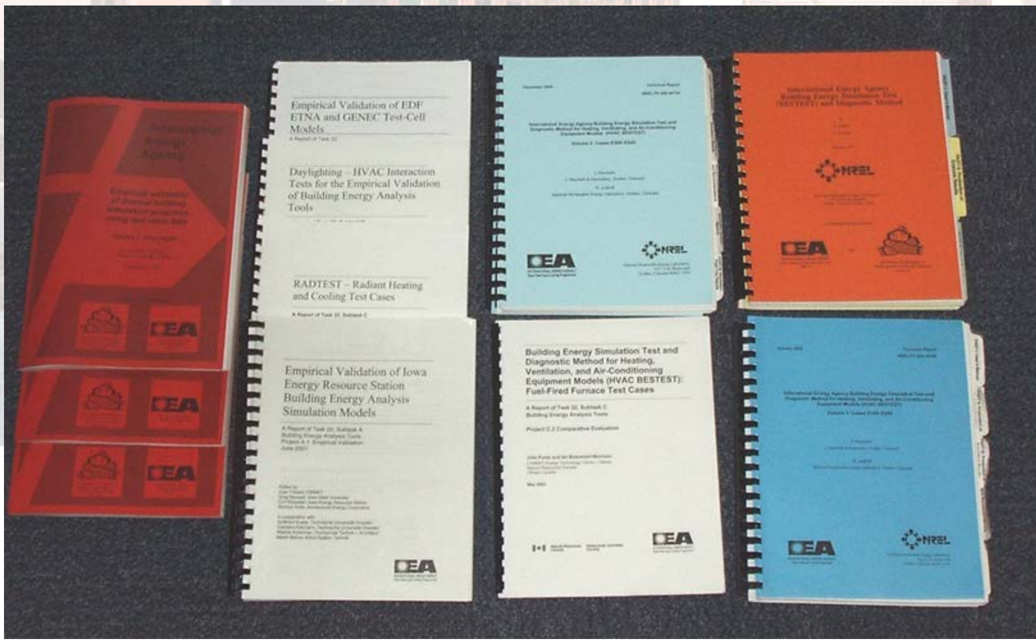
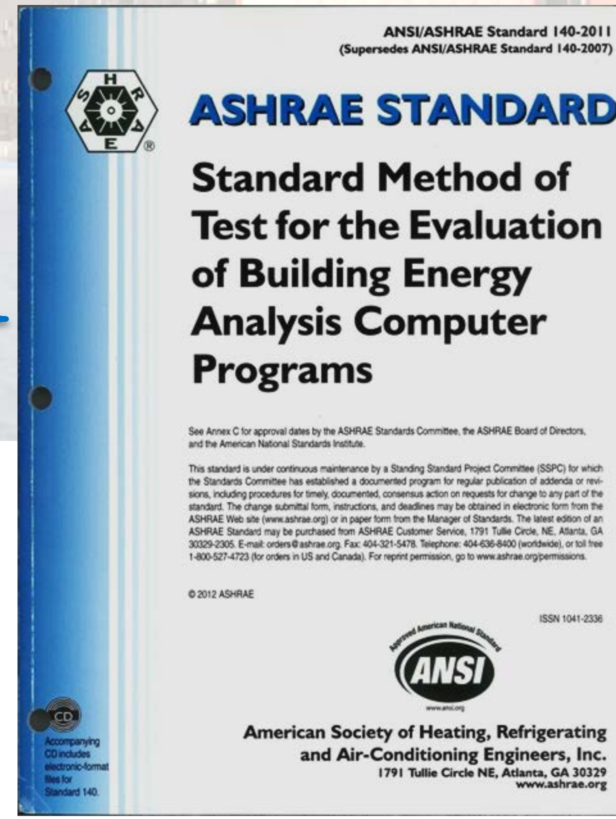
Empirical Validation Workshop: Need and Theory, Jan 28-29, 2015

Model vs Measured

Pre-normative work by Labs, IEA, ASHRAE etc. becomes…



Normative ANSI/ASHRAE Standard 140


ANSI/ASHRAE Standard 140-2011
(Supersedes ANSI/ASHRAE Standard 140-2007)

ASHRAE STANDARD

Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs

See Annex C for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

This standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE Web site (www.ashrae.org) or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

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Accompanying CD includes electronic-format files for Standard 140.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
1791 Tullie Circle NE, Atlanta, GA 30329
www.ashrae.org

Software Testing & Diagnostic Method: Finding needles in haystacks (BESTEST)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Ron.Judkoff@nrel.gov

IRS & RESNET Qualified Software BESTESTed with Standard 140

179D Commercial Building Tax Credits (13 Simulation Tools)

EnergyPlus

EDSL Tas

EnergyGauge®
Energy Analysis & Rating Software

DesignBuilder

TESS
Experts in Energy Modeling & Analysis

TRNSYS 17

DOE-2

CoolTool
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EnergyPro

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INTEGRATED ENVIRONMENTAL SOLUTIONS

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RESNET (HERS, IECC, Tax Credits)(6 Tools)

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APOGEE® INTERACTIVE
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U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Validation Test Matrix

Test Type	Building Envelope	Mechanical Equipment	On-site Gen Eq.
Analytical	•Ground Coupling (NREL 7/14) •Multizone Non-air (NREL) •Working Doc of IEA Task 22 (Finland) •ASHRAE RP 1052 (OkSU) •Multizone Air (Japan)	•HVAC BESTEST vol 1 (NREL) •HVAC BESTEST Fuel-Fired Furnace (NRCan) •ASHRAE RP 865 (Penn St/ TAMU/NREL) Airside HVAC	
Comparative	•Fabric BESTEST (NREL) •Fabric BESTEST update •HERS BESTEST (NREL) •Ground Coupling (NREL) •Multizone non-air (NREL) •Multizone Airflow (Japan) •Double-Skin Facade (Denmark)	•HVAC BESTEST vol 2 (NREL) •RADTEST Radiant Htg (Switz.) •E+ Plant Tests (GARD) •Hydronic Systems (Germany) •RESNET/IECC Equipment Tests	•Fuel Cell IEA Task (NRCan)
Empirical LACKING (Replicable Tests)	•ETNA BESTEST (NREL/EDF) •ETNA/GENEC Tests (EDF-Fr) •BRE/DMU Tests (BRE-UK) •EMPA:Daylite/shade/cool (Sw) •ERS – Daylighting (US/Iowa) •Double-Skin Façade (Denmark)	•Iowa ERS: VAV •Iowa ERS: Economizer Control •Iowa ERS: Daylite/HVAC •Iowa ERS: Daylite/HVAC2 •Hydronic Systems (Germany)	
Calibration	•BESTEST-EX (NREL)	•Hydronic Systems (Germany)	

Red is 2013 - 2017

Validation Test Matrix

Red = Tests in Standard 140

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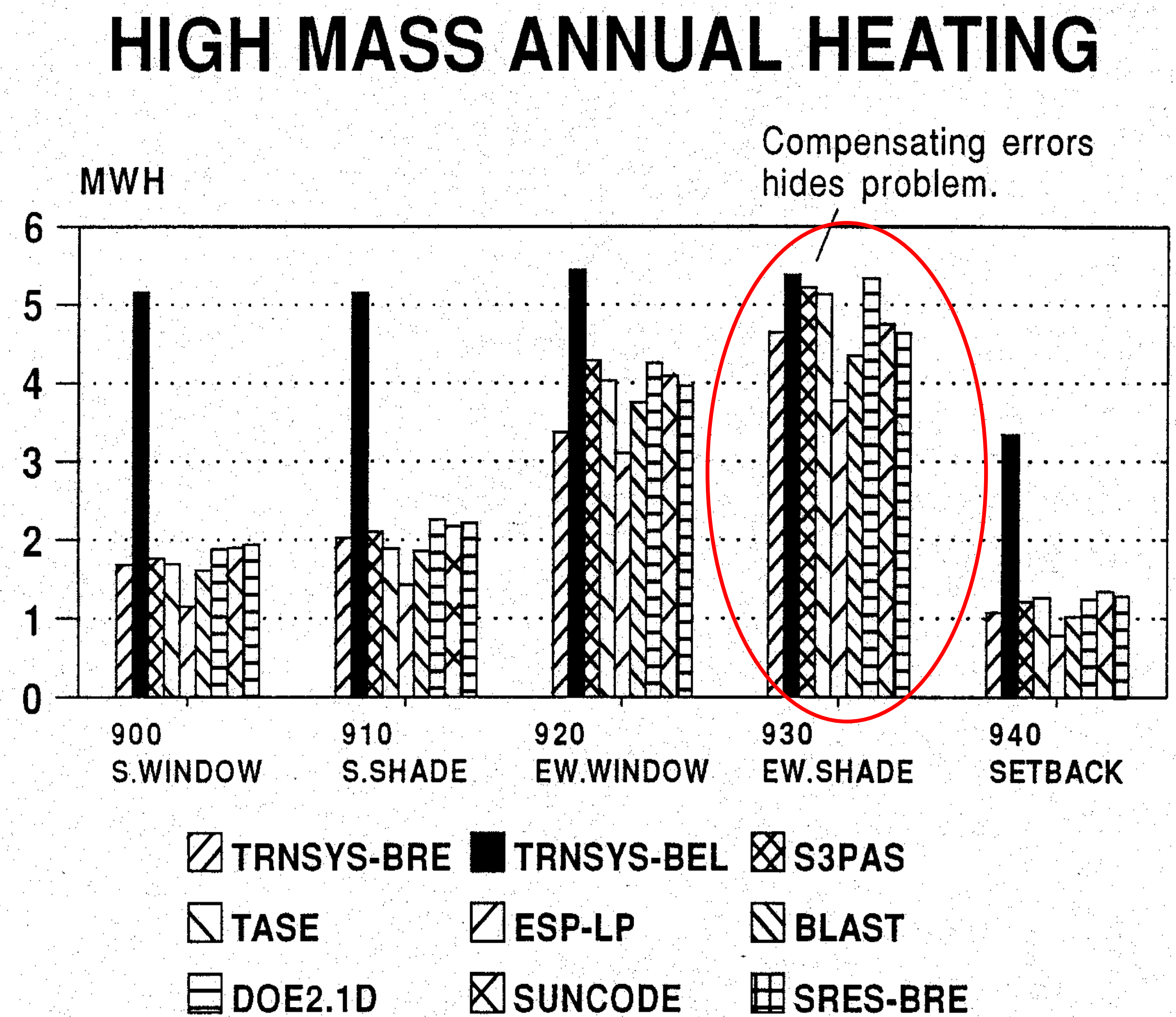
Validation Methods Pros/Cons

Technique	Pros	Cons
EMPIRICAL (tests model & solution)	Approximate truth standard. Any level of complexity.	Input uncertainty. Experiment uncertainty. Expensive. Limited sample of param-space. Compensating errors?
ANALYTICAL (tests solution only)	No input uncertainty. Exact truth standard within constraints. Inexpensive.	No test of model. Limited to highly constrained cases.
COMPARATIVE (Relative test of model & solution) (Help design Empirical tests)	No input uncertainty. Any level of complexity. Inexpensive. Diagnostic Power.	No truth standard.

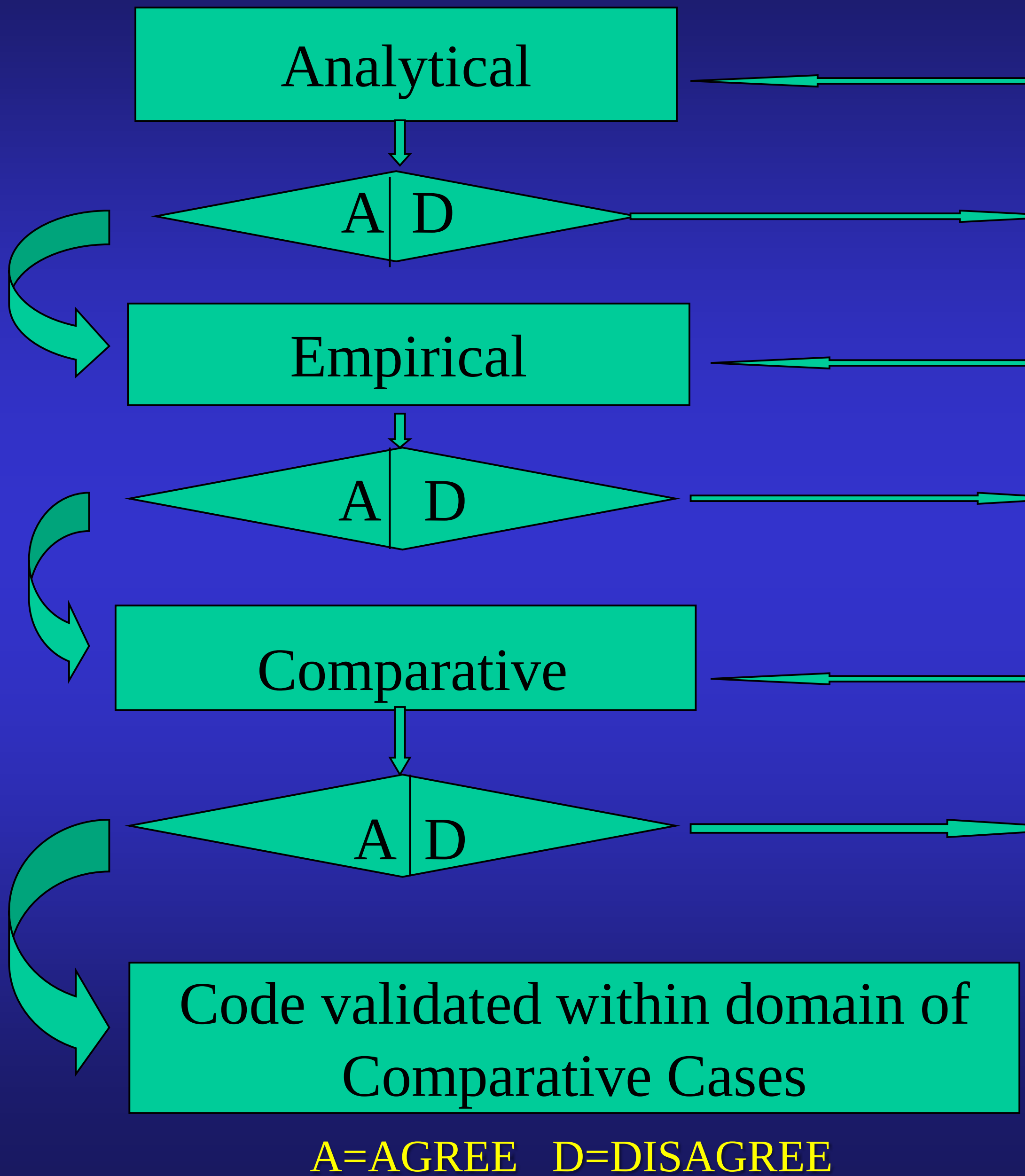
Why not just do Empirical Validation?

RJ's Archive of Simulation Bloopers



TRNSYS BEFORE DEBUG (Transposed transfer function coefficient)

VALIDATION METHOD: One of several useful flow paths



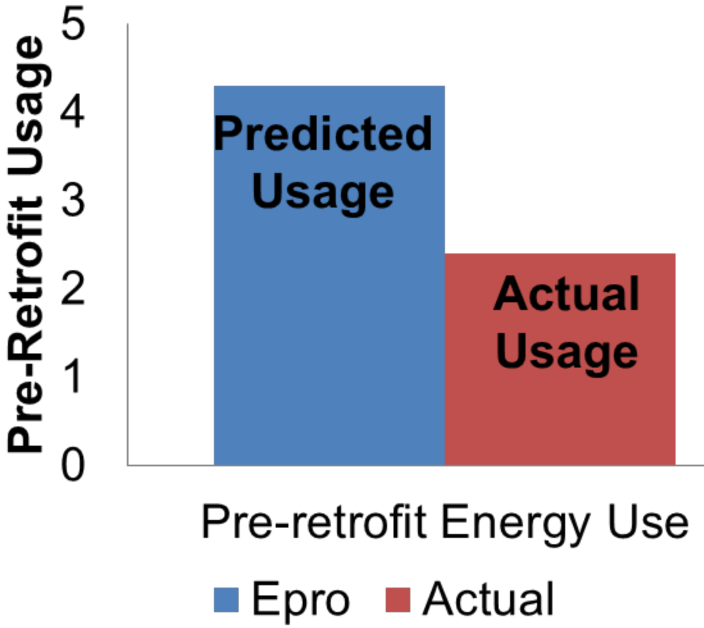
The 3 methods work together

Why Need Empirical Validation?

- CPUC, CEC, & Home Upgrade California concerned about accuracy for Residential Retrofits
- Federal Low income Wx Program correction factor of 0.5
- NBI report on LEED Commercial Buildings
- Amount of disagreement among world's leading software in BESTEST comparative test suites (inputs are perfectly known, HVAC is idealized and easy to model)

Frequent 50% differences in real bldgs

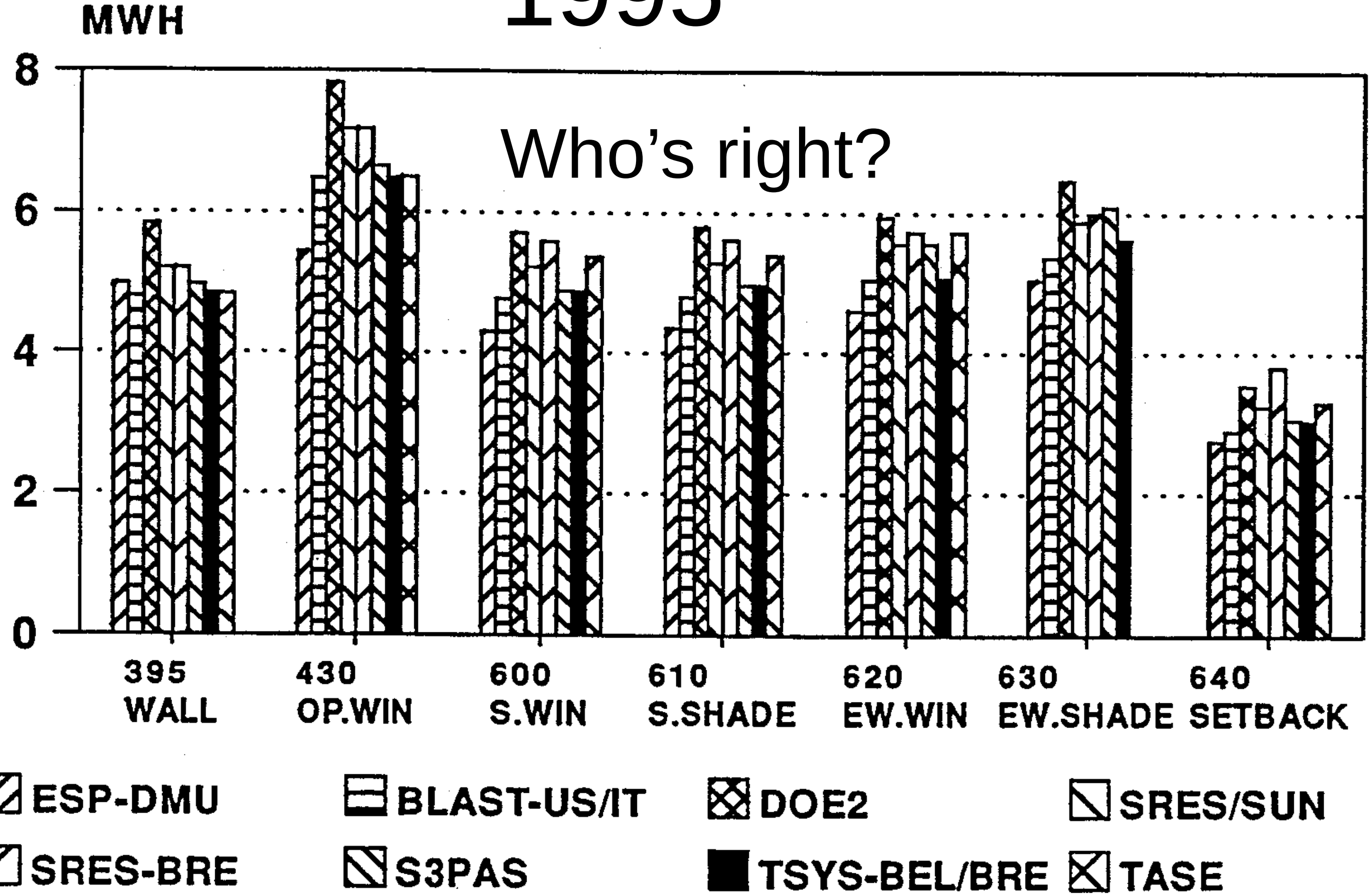
½ of differences are internal to codes



CAL-TEST

Gas Site Number	PASS (Uncalibrated)			
	Cake	Optimiser	TREAT	Snugg
1	76%	80%	78%	76%
2	119%	99%	95%	124%
3	112%	114%	98%	117%
4	110%	106%	118%	90%
5	43%	36%	26%	39%
6	41%	30%	32%	30%
8	114%	81%	85%	85%
9	109%	92%	59%	85%
14	144%	152%	120%	161%
17	75%	360%	118%	286%
18b	86%	46%	30%	48%
19b	105%	172%	80%	226%
Average	**101%**	**91%**	**75%**	**94%**
Site Pass %	**75%**	**58%**	**67%**	**42%**

BESTEST BASIC
LOW MASS ANNUAL HEATING
1995



AHLQ9.CH3; DEC 22, 1997

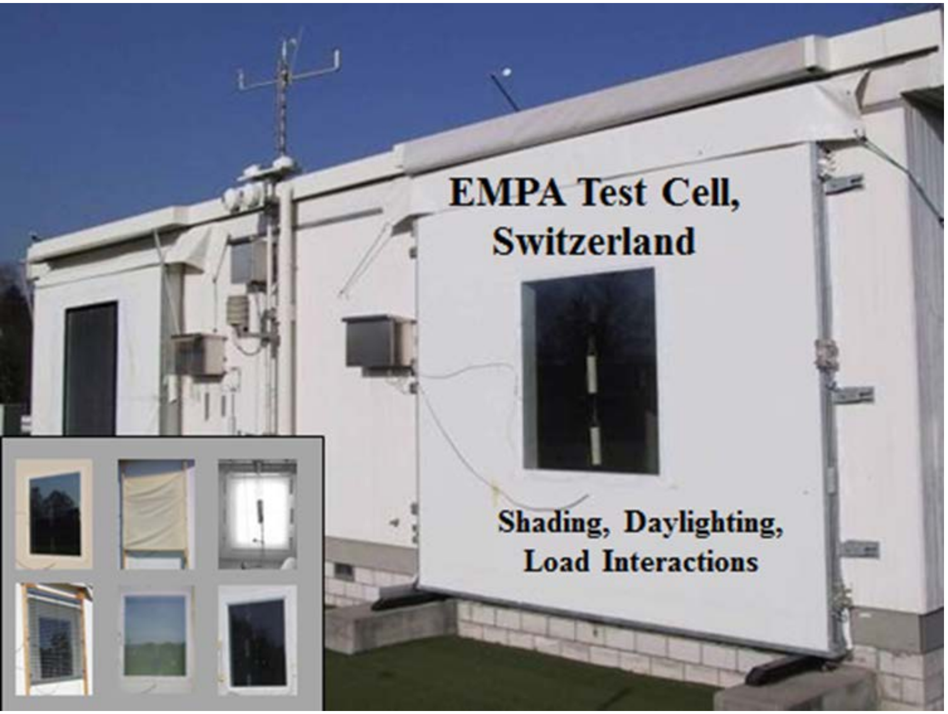
Some Potential Reasons for Model to Meter Differences (internal to the code)

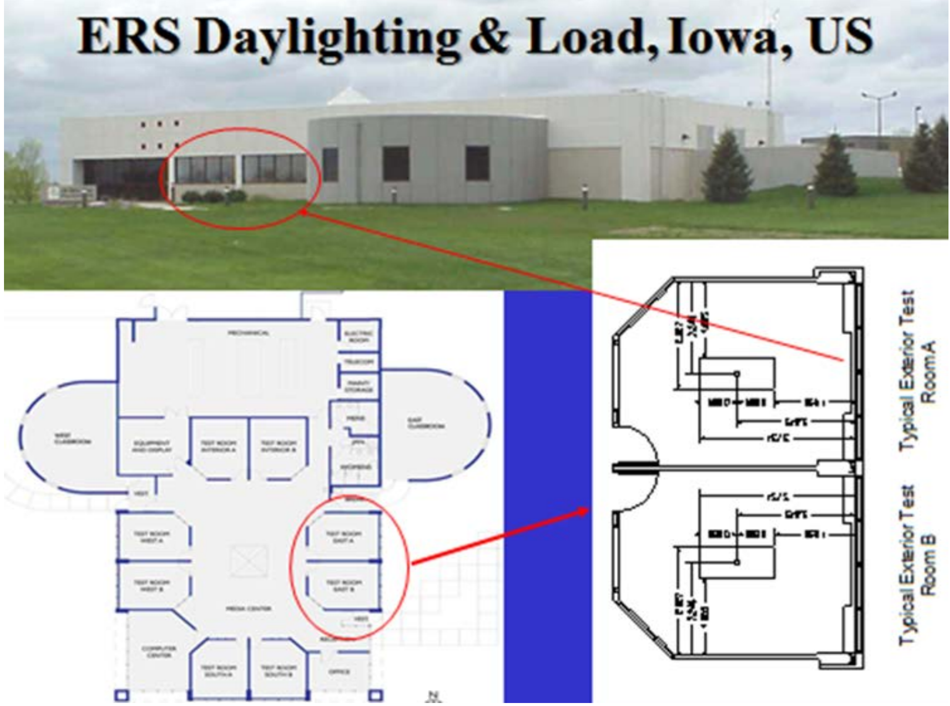
Retrofits

- Empty or under-insulated wall cavities are harder to model because of the dominance of convection loops as compared to well insulated walls where solid conduction dominates
- Empty or under-insulated walls are more sensitive to hard-to-model surface heat transfer and 2 or 3-D conduction than well-insulated walls
- Poorly insulated envelopes result in internal zone temperature gradients, but the models assume well-mixed isothermal zones
- The efficiency of older equipment is more uncertain than new equipment
- “Take-back” by building occupants

New Efficient Bldgs and ZEBs

- New technologies, controls and systems that are hard to model with current BEMs such as displacement ventilation, natural ventilation, radiant cooling systems, etc..





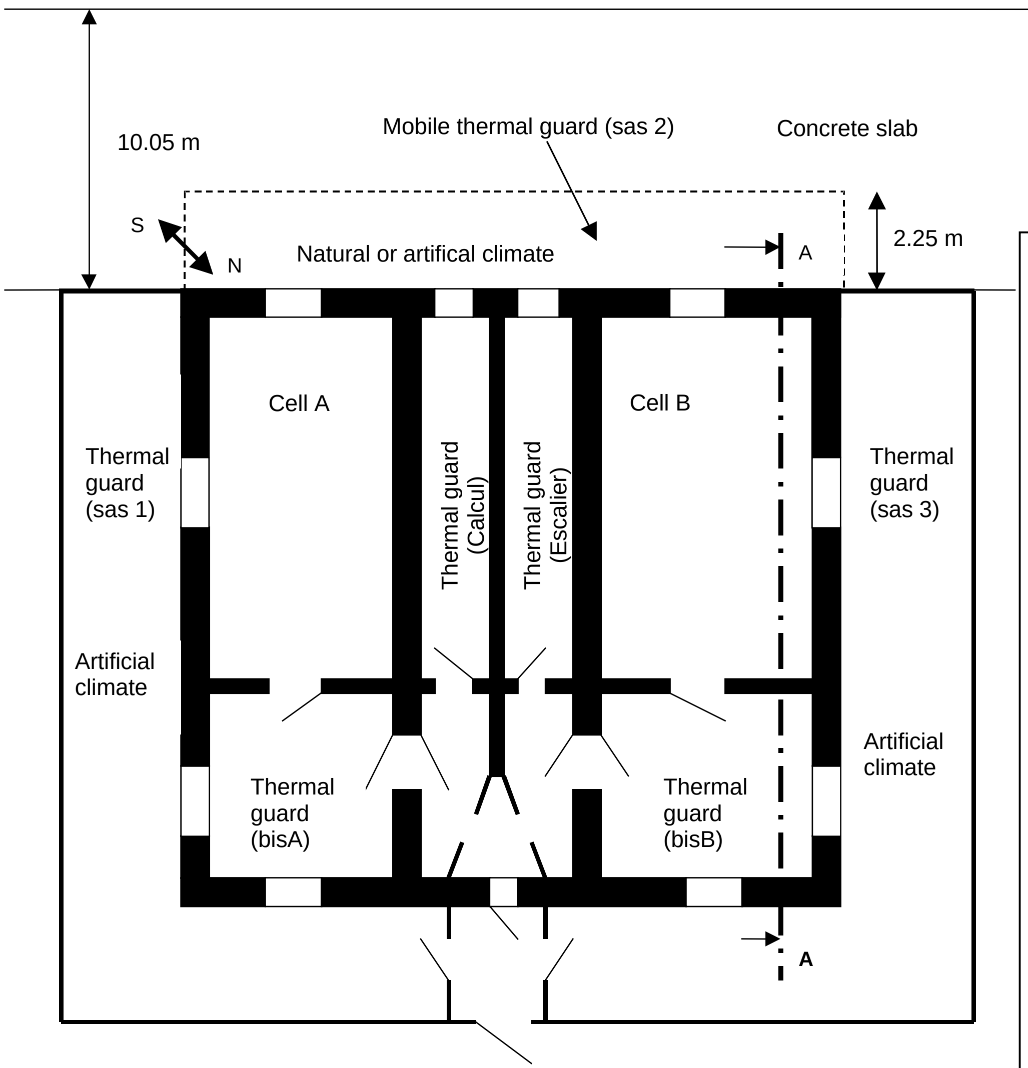
<u>Aalborg</u>: Good measurements of natural convection proved difficult. Turned into an intermodel comparison.
<u>EMPA</u>: Issues with the South Guard. Final report did not document the experiments well enough such that other software could participate in future.
<u>ERS:</u> Schedule prevented eliminating some ambiguities in the data.

Empirical Validation is Hard to do Well Many Smart Qualified Teams have Tried

- PASSYS (1989), IEA 12/21 (1994), IEA 22 (2000)
- Substantial differences between measured and modeled results were observed
- Flaws in experiments limit usefulness
- There was no way to definitively reconcile differences except to recommend <u>additional experiments:</u>
  – To **isolate the validity of specific models/algorithms** applied within the overall simulation tools (e.g., using a BESTEST approach).
  – To **empirically characterize** key parameters such as overall heat transmission coefficient, diurnal heat capacity, etc..

EDF ETNA Facility (75km SE of Paris, France)

EDF ETNA Facility



Plan View

- 2 “duplicate” fully guarded test cells
- 6 separately controllable guard zones for each test cell
- Removable south wall to give artificial and natural climate
- **Test logic based on Comparative BESTEST**

Importance of Empirically Determined Inputs

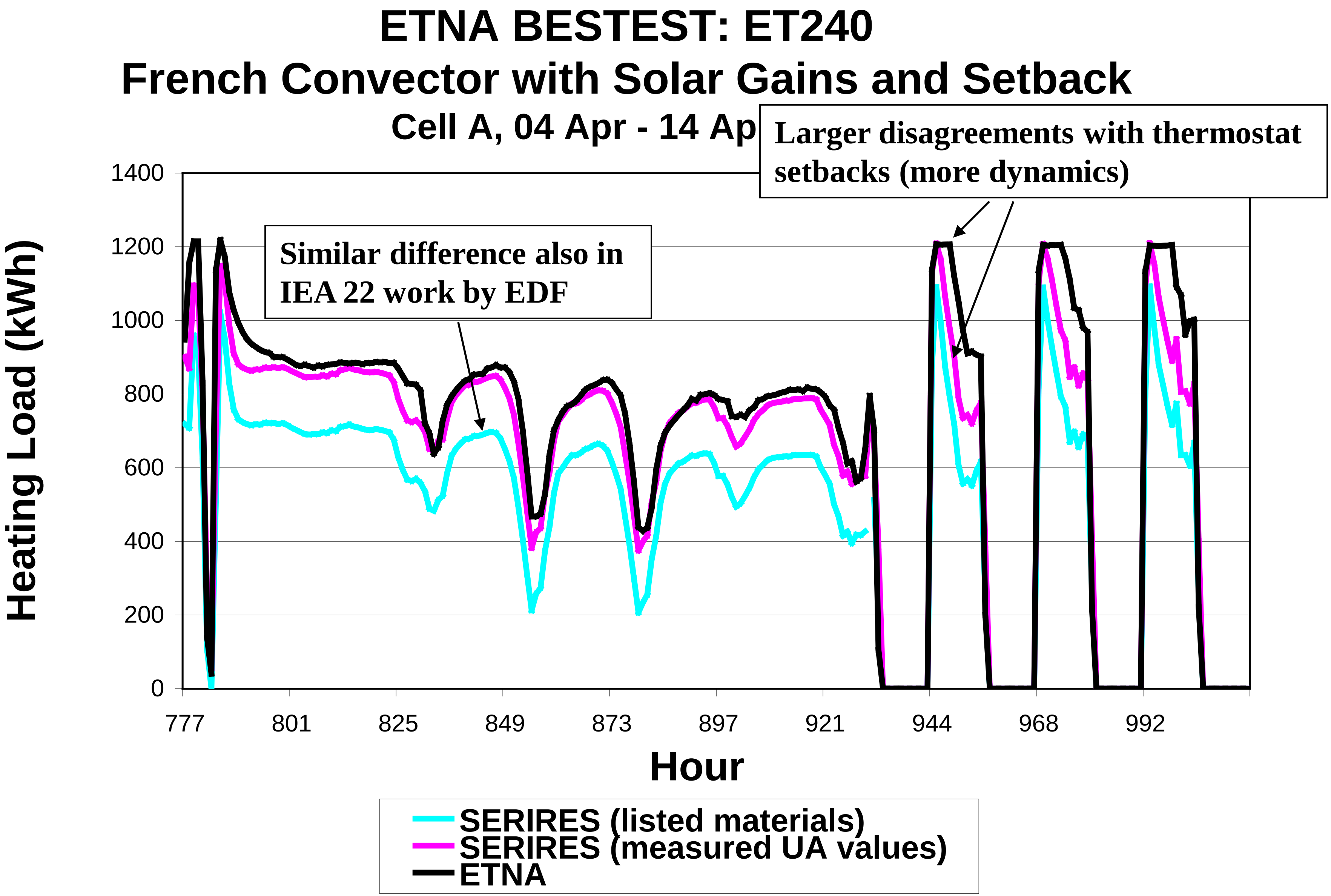
#2. Calorimetrically measured as-built conductances

#1. Based on mfg.-listed matl. properties

% diff. #1 v. #2

	UAmeas (W/C)	Case	Cell-Grd delta T (C)	UAlist (W/C)	% var meas v list
BLC Unins Win	35.91	ET100	24.5		
Sas2 (unins win)	8.23	ET131	28.5	7.2	14.3%
Cellar	6.48	ET132	15.0	3.9	66.2%
Sas1 (unins win)	9.43	ET134	20.1	8.3	13.6%
Attic	2.79	ET136	19.9	3.1	-10.0%
Bis	6.04	ET137	20.1	3.9	54.9%
Calcul	3.41	ET138	20.0	2.7	26.3%
BLC Sum Surf	36.38			29.1	25.0%

Importance of Empirically Determined Inputs



Model vs Meter

Is What's Inside the Code Good Enough?

Internal Error Types

- Differences between the actual energy related physics mechanisms in the real building and its HVAC systems versus the models of those processes in the simulation (model too simple)
- Errors or inaccuracies in the mathematical solution of the models
- Coding errors
- Documentation errors or ambiguities

External Error Types

- Differences between actual building microclimate versus weather input used by the program
- Differences between actual schedules, control strategies, effects of occupant behavior, and other effects from the real building versus those assumed by the program user
- Differences between actual physical properties of the building and HVAC systems versus those input by the user
- Faulty energy related measurements for the building(s)

Empirical Validation Conclusions

- Use well characterized test facilities where input uncertainties have been minimized via measurements wherever possible
- Define tests that provide a robust signal to noise ratio for the most important and fundamental simulation capabilities
- Construct and order the tests with diagnostic logic that progress one parameter at a time from simple to realistic
- Start by matching the simplifying assumptions in the BEMs so that when more realism is added the resulting errors can be quantified.
- Provide clear test specs usable by different BEM tools to minimize input errors
- Collaboration between model developers and experimentalists is essential so that all model inputs that can be measured, are measured
- Provide for future access to the specifications and data (REPRODUCIBLE!)
- Adhere to the principle of parsimony
- The evidence suggests that there are errors in basic building physics models as well as issues with HVAC systems

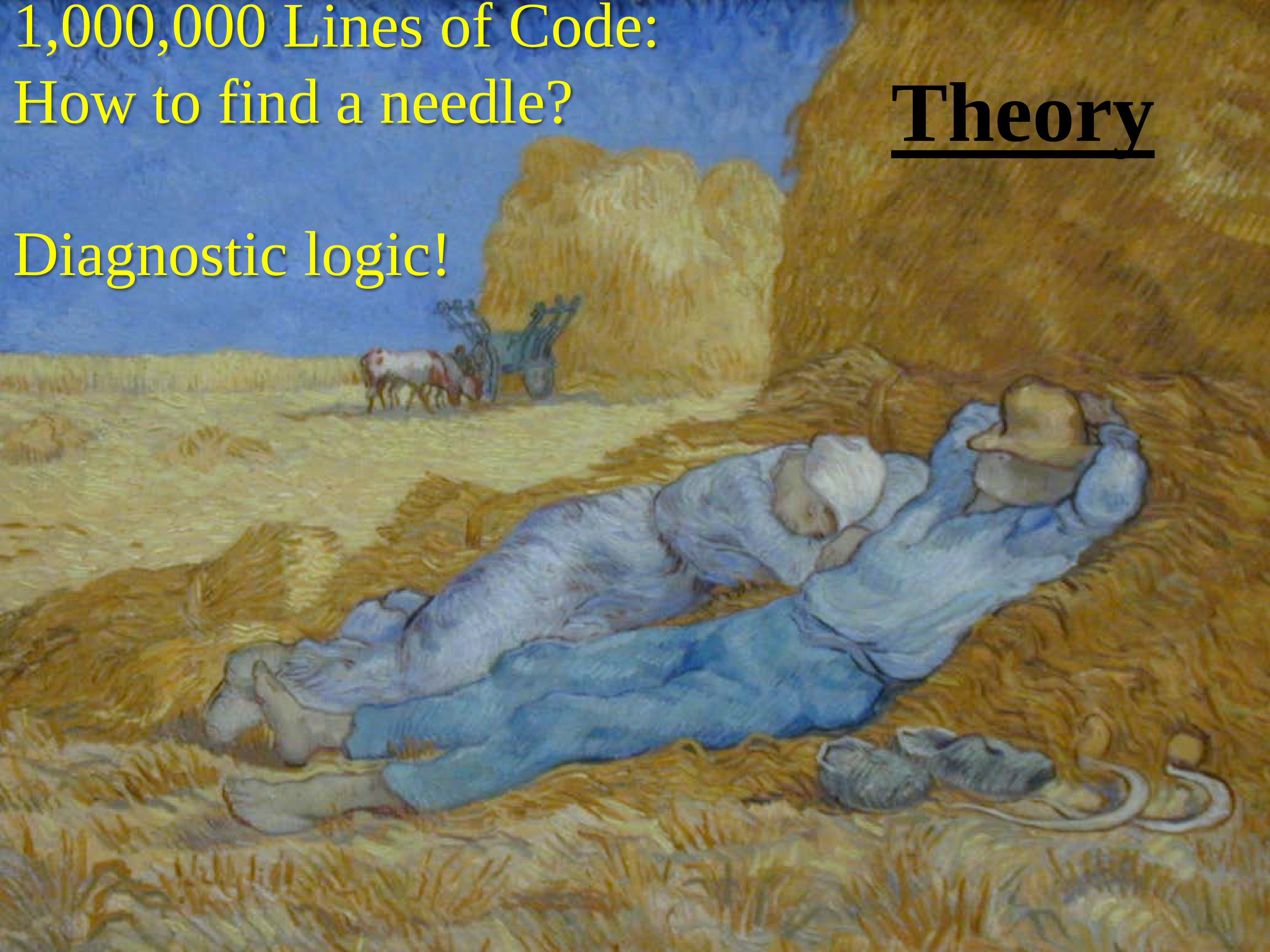
Workshop Objectives

- ID highest priority items in buildings needing empirical validation
- Describe the kinds of facilities that would be needed
- Describe at a conceptual level the kinds of experiments that would be needed
- ID existing empirical validation studies/data/facilities that have been done that could be used instead of new experiments

1,000,000 Lines of Code:
How to find a needle?

Diagnostic logic!

Theory



A well conceived Empirical Validation Experiment with definitive results

END