**Mission:** IBPSA is founded to advance and promote the science of building performance simulation in order to improve the design, construction, operation, and maintenance of new and existing buildings worldwide.

**IBPSA-USA:** one of eleven regional affiliates from around the world.

[www.ibpsa.org/ibpsa_usa](http://www.ibpsa.org/ibpsa_usa)
Presentations and recommendations developed by OWP/P and MRIA are based on professional opinion and analysis at a given point in time and information provided by others deemed to be reliable. No warranties are expressed or implied.
LEARNING OBJECTIVES

- Acquire a *knowledge base* for simulation.
- Understand how it adds *value* to design services.
- Become aware of primary simulation *tools*.
- Learn how to integrate *applications* within the design process.
Building Performance Simulation: a computer-based, mathematical model of some aspect of building performance based on fundamental physical principles and engineering models.
DEFINITION > NOT REPRESENTATION

representation

simulation

PROJECT ► ILLINOIS SCIENCE CENTER / ARGONNE NATIONAL LABS ARCHITECT: OWP/P
Fundamental difference between computer simulation and other engineering calculations is one of complexity.

**Traditional Engineering Models**  
- maybe 10 variables

**Computer Simulation**  
- easily 10,000 variables
Time-dependent natural ventilation study

<table>
<thead>
<tr>
<th>DATE / TIME</th>
<th>OUTDOOR TEMP</th>
<th>DAY VENTILATION</th>
<th>NIGHT VENTILATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>07/05 00:00</td>
<td>70</td>
<td>75</td>
<td>65</td>
</tr>
<tr>
<td>07/05 12:00</td>
<td>85</td>
<td>80</td>
<td>70</td>
</tr>
<tr>
<td>07/06 00:00</td>
<td>75</td>
<td>80</td>
<td>70</td>
</tr>
<tr>
<td>07/06 12:00</td>
<td>80</td>
<td>85</td>
<td>75</td>
</tr>
</tbody>
</table>

DEFINITIONS > TIME-DEPENDENT

- **TIME-DEPENDENT**

Graph shows the trend of temperatures and ventilation over time.
### HISTORICAL TIMELINE

<table>
<thead>
<tr>
<th>GENERATION</th>
<th>CHARACTERISTICS</th>
<th>CONSEQUENCES</th>
</tr>
</thead>
</table>
| 1          | handbook oriented  
            | simplified and piecemeal  
            | familiar to users | easy to use  
            | non-integrative  
            | application limited |
| 2 mid-70s  | building dynamics stressed  
            | still piecemeal  
            | based on standard theories | difficult to translate  
            | deficiencies hidden |
| 3 mid-80s  | shift to numerical methods  
            | integrated modeling stressed  
            | graphical user interface | increasing integrity with the real world |
| 4 mid-90s  | intelligent knowledge-based  
            | fully integrated  
            | network compatible/interoperable | predictive  
            | multi-variate  
            | ubiquitous |
HISTORICAL TIMELINE > APPROACH

Tool Box Approach

Simulation Approach

designer → tool box

design process

tasks

decisions

implications

decisions

design process

support environment
CURRENT DEVELOPMENT

- Intelligent **GUI** (graphical user interfaces).
- Enhanced **integration** with other design software.
- Expanded **performance** due to single package availability and coupling of simulation engines.
- Improved **technology transfer** efforts from research to applications.
THEMES

VALUE

APPLICATIONS

TOOLS

OVERVIEW OF SIMULATION
THEME 1: VALUE

- Building design process
- Project team benefits
- Considerations

- Equipment and interfaces
- Interoperability
- Expertise
- Appropriate use
- LEED
THEME 2: TOOLS

- What they do
- How they work
- What’s available
- Demonstration

- Energy simulation
- Daylighting
- Interzonal airflow models
- CFD
- Conceptual design programs
**THEME 3: APPLICATIONS**

- Goal of seamless integration
- Any project type
- Any project phase
- Case studies

- Schematic Design
- Design Development
- Construction Documentation
- Postconstruction
THEME 1: VALUE
BUILDING VALU PROCESS
Quality / Performance

- Informed decision making
- Design synergy
- Cross fertilization

VALUE > BUILDING DESIGN PROCESS
Cost Effectiveness ($)

+ Increased design cost

+ Demand for simulation expertise.

- Reduction of re-designs costs.

- Quantification of building performance.
**Time Effectiveness ($)**

- Reduced performance problems.

± Difficult to estimate time allotted to simulation.

± Time factor dependent upon many factors.
PROJECT VALUE BENEFITS
**Developer**

- Confidence in performance results.
- Potential financial incentives linked to performance results.
- Public relations.
Design Professional

- Confidence in intended performance of building design.
- Informed decision making.
- Understanding of design impacts of other disciplines.
Building Operator

- Energy cost savings.
- Reduced building occupant complaints.
- Reduced commissioning-related problems.
- Public relations.

VALUE > PROJECT TEAM BENEFITS

THE QUEEN’S BUILDING

THE QUEENS BUILDING AT DE MONTFORT UNIVERSITY / LEICESTER, ENGLAND
**Building Occupant**

- Improved IEQ.
- Increased productivity.
- Enhanced control with personal environment.
CONSIDERATIONS

VALUES
Equipment and Interfaces

- Most applications run on standard PC.
- CFD may require more computing capabilities.
- GUI needed for most non-research applications.
- Data visualization is critical.

VALUE > CONSIDERATIONS

EnergyPlus text interface

PowerDOE graphic interface
Mean age of air with underfloor air distribution along vertical axis

Mean age of air with underfloor air distribution
Interoperability: What is it?

- Ability to archive and exchange detailed building data between project participants and their various software tools.

- Exchange is based on commonly agreed upon building data model standards.

- Different software tools import/export common data by mapping their internal representation to the data model standard.
• Separate programs require different types of data.
• Data acquisition is needed from upstream sources.
• Data archival is needed for downstream users.
Object Data Model

- Object-oriented model of the entire building.
  - Elements (e.g., walls) and relationships (e.g., wall-spaces)
- Archive and exchange complete project data set.
- Industry Foundation Classes (IFC).

Internet Data Exchange Models

- Extensible models of data subsets.
  - Product libraries
- Exchange of product and other data subsets to support transactions over the Internet.
- XML: aecXML, ifcXML
Implementation Concerns

- Certified Compliance VS. Full Functionality
- Focused on geometry
- Different released versions of standards
- Not mature implementations
- Minimal real project experience
Expertise

- More than number-crunching skills.
- Understanding of what is being simulated.
- Ability to interpret results.
- Conceptualize simplified, but useful, models.
What is the relationship between the formula and the interface?

The Room Air Heat Balance Equation is:

\[
C_z \frac{dT_z}{dt} = \sum_{i=1}^{N_{sl}} \dot{Q}_i + \sum_{i=1}^{N_{surfaces}} h_i A_i (T_{si} - T_z) + \sum_{i=1}^{N_{zones}} \dot{m}_i c_p (T_{zi} - T_z) + \dot{Q}_{sys}
\]
Natural ventilation comfort evaluation

- Existing Building
- No Lowered Ceiling
- No Raised Floor

Overview of Simulation

Expertise > Interpretation
LITTLE VILLAGE HIGH SCHOOL • CENTRAL GALLERY

**design concept**

**simulation model**

PROJECT ► LITTLE VILLAGE HIGH SCHOOL / CHICAGO, IL

ARCHITECT: OWP/P
Appropriate Use

- Limitations of model must be clearly identified.
- Manipulation to achieve desired results is not allowed.
- Final design to reflect the assumptions in the model.
CONSIDERATIONS > APPROPRIATE USE

Displacement Ventilation
Typical Temperature Profile

Energy Simulation Assumes
Well-mixed Conditions
LEED™ GREEN BUILDING RATING SYSTEM

Leadership in Energy and Environmental Design

- LEED™ was developed and is administered by USGBC.
- LEED™ is a rating system designed for new and existing buildings.
- Provides a standard for what constitutes a "green building."

http://www.usgbc.org/
<table>
<thead>
<tr>
<th>Design Category</th>
<th>Points (version 2.1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainable Sites</td>
<td>14</td>
</tr>
<tr>
<td>Water Efficiency</td>
<td>5</td>
</tr>
<tr>
<td>Energy and Atmosphere</td>
<td>17</td>
</tr>
<tr>
<td>Materials and Resources</td>
<td>13</td>
</tr>
<tr>
<td>Indoor Environmental Quality</td>
<td>15</td>
</tr>
<tr>
<td>Innovation and Design Process</td>
<td>5</td>
</tr>
<tr>
<td><strong>Totals Credits</strong></td>
<td><strong>69</strong></td>
</tr>
</tbody>
</table>
THEME 2: TOOLS
THE SIMULATION PROCESS

1. Information gathering
2. Data collection
3. Identification of modeling goals
4. Model-building
5. Run the simulation
6. Debug
7. Calibration
8. Optimization
9. Visualization of results
10. Interpretation of results
11. Design recommendations
Categories of Simulation

- Simple: few inputs, limited information needed.
- Detailed: many inputs, with detailed information needed.
- Special purpose: dedicated to a single task or purpose.
OVERVIEW OF SIMULATION ENERGY TOOLS
Energy Simulation: What it Does

Energy Storage

External Energy Sources

Internal Energy Sources

THERMAL ZONE

Energy Input

Energy Input by Air/Water HVAC Systems

Air HVAC Systems

Water HVAC Systems

Energy Input

Energy Input

Energy Simulation
ENERGY SIMULATION > HOW IT WORKS

- Solar models
- Building fabric models
- Glazing models
- Internal sources models
- HVAC systems

Inputs:
- Solar energy
- Weather data
- Materials properties
- Heat input
- Time history

Outputs:
- Overall air heat balance model
INPUTS
- Weather data
- Building geometry
- Construction type
- HVAC type / usage
- Occupancy info
  - Quantity of users
  - Lights
  - Equipment
  - Usage

OUTPUTS
- Space temperatures
- Surface temperatures
- Humidity levels
- HVAC parameters
- Energy consumption
  - Component
  - System
  - Whole-building
Energy consumption of various mechanical systems
ENERGY SIMULATION > ACCURACY
Any major building simulation program has been through extensive validation with small-scale experimental data.

A simulation expert should have some experience in comparing their results to actual measured data.

Assumptions are made concerning building operations, which may or may not be true in practice.

What is often more important than absolute values is relative performance of two or more options.
Intent

Establish the minimum level of energy efficiency for baseline building.

Simulation Integration

- Model the energy performance relative to baseline building.
- Identify the most cost effective energy measures.

Minimum Energy Performance

- Prerequisite 2

Energy and Atmosphere
Optimize Energy Performance

- Credit 1
- 1 – 10 points

Intent
Increase energy performance to reduce environmental impacts.

Simulation Integration
Model energy performance to demonstrate that design energy cost is < energy cost budget.
Intent

Provide for the ongoing accountability and optimization of energy and water performance.

Simulation Integration

Model the energy and water systems to predict saving, that will be compared with actual consumption.

Measurement and Verification

- Credit 5
- 1 point
ENERGY SIMULATION > WHAT’S AVAILABLE

- **DOE-2** > [simulationresearch.lbl.gov](http://simulationresearch.lbl.gov)
  - Interfaces
    - eQUEST > [www.energydesignresources.com/tools/equest.htm](http://www.energydesignresources.com/tools/equest.htm)
    - PowerDOE > [www.doe2.com](http://www.doe2.com)
    - VisualDOE > [www.eley.com](http://www.eley.com)

- **EnergyPlus** > [www.energyplus.gov](http://www.energyplus.gov)
  - Interfaces
    - DesignBuilder (currently beta testing) > [www.designbuilder.co.uk](http://www.designbuilder.co.uk)

- **ESP-r** > [www.esru.strath.ac.uk](http://www.esru.strath.ac.uk)
  - primarily used by European researchers.

- **TRYNSYS** > [sel.me.wisc.edu/trnsys](http://sel.me.wisc.edu/trnsys)
**PowerDOE® (v1.18g)**

- PC-based building energy performance tool.
- Includes DOE-2.2 as its simulation engine.
- GUI provides 2D and 3D display.
- PowerDOE license: $278.
PowerDOE > HVAC INPUT

PROJECT

ILLINOIS SCIENCE CENTER / ARGONNE NATIONAL LABS

ARCHITECT: OWP/P
DAYLIGHTING TOOLS ANALYSIS
DAYLIGHTING ANALYSIS > WHAT IT DOES

- Natural Light Sources
- Artificial Light Sources
- Direct Light
- Diffuse Light
- Reflected Light
- Internal Reflection and Absorption
Daylighting Analysis > How it Works

Radiosity
DAYLIGHTING ANALYSIS > OUTPUT

ILLUMINANCE LEVELS MAP

ILLUMINANCE LEVELS RENDERING

PROJECT ► IMAGES: COURTESY OF ANDREW LAU

ARCHITECT: OWP/P

Illuminance (fc)

0 20 40 60 80 100 120 140

120-140
100-120
80-100
60-80
40-60
20-40
0-20
Daylight and Views

- Credit 8.1
- 1 point

Intent

Provide a connection between indoor spaces and the outdoors via the use of daylight and views.

Simulation Integration

Model daylighting strategies to assess footcandle levels and daylight factors achieved.
DAYLIGHTING ANALYSIS > WHAT’S AVAILABLE

- **AGI**
  - web site: [www.lightinganalysts.com](http://www.lightinganalysts.com)

- **FormZ RadioZity**
  - web site: [www.formz.com/products/formz_radiozity.html](http://www.formz.com/products/formz_radiozity.html)

- **Lumen Micro**
  - web site: [www.lighting-technologies.com](http://www.lighting-technologies.com)

- **Lightscape**
  - web site: [www.autodesk.com/lightscape](http://www.autodesk.com/lightscape)

- **Radiance**
  - various interfaces exist, including Desktop Radiance.
  - difficult to use, but also produces the most detailed simulations.
  - web site: [http://radsite.lbl.gov/radiance](http://radsite.lbl.gov/radiance)
AGI32 (v1.61)

- Considers natural light contribution in interior and exterior environments.
- Results for specific and multiple dates and times.
- Able to import native DWG format CAD files, and extract 3Dface entities.
AGI32 > GEOMETRY & MATERIAL DEFINITION

PROJECT ► FIELDHOUSE / EVANSTON, IL

ARCHITECT: OWP/P
AGI32 > LUMINAIRE DEFINITION

PROJECT ► FIELDHOUSE / EVANSTON, IL
ARCHITECT: OWP/P
AGI32 > DAYLIGHTING DEFINITION

PROJECT: FIELDHOUSE / EVANSTON, IL
ARCHITECT: OWP/P
MULTIZONE TOOLS FOR SIMULATION
MULTIZONE AIRFLOW > WHAT IT DOES
MULTIZONE AIRFLOW => WHAT IT DOES

ZONE 1: LARGE OPENING

ZONE 2: CRACK

ZONE 3: POLLUTANT SOURCE

ZONE 4
Multizone airflow > How it works

- Airflow paths
- Zones
- External pressures
- Resistances (windows, doors, cracks, other openings)
- Pressure source (fan)
**Indoor Environmental Quality**

**Ventilation Effectiveness**
- Credit 2
- 1 point

**Intent**
Provide for the effective delivery and mixing of fresh air to support the safety, comfort and well-being of building occupants.

**Simulation Integration**
Include a table summarizing the airflow simulation results for each zone.
Indoor Environmental Quality

**Thermal Comfort**
- Credit 7.1
- 1 point

**Intent**
Provide a thermally comfortable environment that supports the productivity and well-being of building occupants.

**Simulation Integration**
Establish temperature and humidity comfort ranges and design the building envelope and HVAC system to maintain these comfort ranges.
MULTIZONE AIRFLOW > WHAT’S AVAILABLE

- **CONTAMW** > [www.bfrl.nist.gov/IAQanalysis/](http://www.bfrl.nist.gov/IAQanalysis/)
  - Includes simple graphical interface

- **COMIS** > [epb1.lbl.gov/comis/users.html](http://epb1.lbl.gov/comis/users.html)
**CONTAMMW (v2.0)**

- Multizone airflow and contaminant transport analysis software.
- Predicts the following:
  - Airflows
  - Contaminant concentrations
  - Personal exposure
CONTAMW > AIRFLOW PATH

SKETCHPAD RESULTS DISPLAY FEATURE
CFD > WHAT IT DOES

At any point:
- Speed,
- Direction,
- Temperature,
- Other variables

Heat source

Air inlet

Air outlet
OVERVIEW OF SIMULATION

CONSERVATION OF: MASS, MOMENTUM, AND ENERGY

CFD > HOW IT WORKS
INPUTS
- Building geometry
- Heat / pollutant sources
- Boundary conditions
  - State of fluid at edge of domain.
- Mesh

OUTPUTS
- Temperature
- Speed and direction
- Pollutant concentration
- Wholefield values
- Calculated metrics
  - Thermal comfort
  - Mean age of air
WHAT’S AVAILABLE

- **Fluent** > [www.fluent.com](http://www.fluent.com)
  - including Airpak interface for building applications

- **Flovent** > [www.flovent.com](http://www.flovent.com)
  - by Flomerics
  - also a building-specific interface for a general CFD package

- **PHOENICS** > [www.cham.co.uk](http://www.cham.co.uk)
  - mostly used by researchers
3D DXF CADD file imported as basis for airflow model
Airflow modeling can compute local conditions and predict thermal comfort

Fume Hood + 3-Way Diffuser

Time = 0.0 (seconds)

concentration drops below 125 ppmv at 1560 s

Click on image to run animation.

Flad & Associates

PROJECT ► WYETH BUILDING 260 ARCHITECT: FLAD & ASSOCIATES
AIRPAK (v2.0)

- Airflow modeling software.
- Predicts the following:
  - Airflows
  - Heat transfer
  - Contaminant transport
  - Thermal comfort
- Joint development of Fluent and ICEM-CFD Engineering Flow Modeling Software & Services
AIRPAK > PROBLEM DEFINITION

Problem setup

Time variation
- Steady
- Transient

Start: 0.0
End: 1.0

Variables solved
- Flow (velocity/pressure)
- Temperature
- Radiation
- Species
- IAQ/Comfort
- Solar loading

Flow regime
- Laminar
- Turbulent
- Two equation

Discrete ordnates radiation model

Gravity vector:
- X: 0.0 ft/s²
- Y: -32.17484 ft/s²
- Z: 0.0 ft/s²

Ambient values:
- Temperature: 68.0°F
- Pressure: 0.0 lb/ft²
- Radiation temp: 68.0°F

Default fluid: Air
Default solid: Brick building
Default surface: Paint non-metallic

Initial conditions:
- X velocity: 0.0 ft/s
- Y velocity: 0.0032174 ft/s
- Z velocity: 0.0 ft/s
- Temperature: 68.0°F

Accept | Reset | Cancel
AIRPAK > GEOMETRY & BOUNDARY INPUTS
AIRPAK > MESH GENERATION

Overview of Simulation
“MASSLESS” PARTICLE TRACE FROM FOUR-WAY DIFFUSERS

EXISTING CONFIGURATION

NOTE THE ENTRAINMENT

OPERATING ROOM
LAMINAR FLOW

- PROPOSED CONFIGURATION
Ventilation of a Partitioned Office

- Containing two occupants working at computers.
- Particle traces colored by mean age of air shows the path of supply air.
Velocity Vectors (on a horizontal cross-plane)

- Show the weaving flow pattern induced by the supply jet.
- As well as the convective plume which moves upward from the baseboard radiator.
Mean Radiant Temperature Contours

• Represent the temperature of an idealized enclosure which would have the same amount of radiant heat transfer exchange with a person at a particular location.
Mean Age of Air Contours

- Show that the area behind the partition and corners of the room are not well ventilated.
- One worker will breath air that is significantly fresher than that for the other worker.
Predicted Mean Vote (PMV) Contours

- Show that the expected perception of thermal sensation is relatively uniform and slightly warm.
Goal is to provide **immediate feedback** during schematic design phase.

Includes elements of the previously listed tools.

Often **includes basic tools**, such as a solar calculator.

Often **uses simplified models** and relies on material databases.
**INNOVATION IN DESIGN**

**Credit 1**

- 1 – 4 points

**Intent**

To provide the opportunity to be awarded points for exceptional and/or innovative performance.

**Simulation Integration**

Submittals are required to demonstrate compliance, as well as the design approach used to meet compliance.
CONCEPTUAL DESIGN  >  WHAT’S AVAILABLE

- Building Design Advisor
  - gaia.lbl.gov/bda
- EcoTect
  - www.squ1.com
- IES Virtual Environment
  - www.ies4d.com
- MIT Design Advisor
  - http://18.80.2.250:8080/design/
  - TAS Building Designer
  - http://212.23.11.237/Tas.htm

TAS 3D Modeler
Simulation within a Computer-Supported Design Environment
APPLICATIONS > OVERVIEW

SCHEMATIC DESIGN

POSTCONSTRUCTION

SIMULATION

DESIGN DEVELOPMENT

CONSTRUCTION DOCUMENTS
APPLICATIONS > ANY PROJECT TYPE

San Francisco Federal Building
Architect: Morphosis

Chicago Police Department District 22 Station
Architect: OWP/P
Computational flowchart from EnergyPlus

- Simple model of the geometry for a classroom for a natural ventilation energy study

interzonal mixing and surface T data for current zone timestep

set \( T_h = \) setpoint temperature

solve for \( T_e \) using \( \theta_h \) from previous iteration, \( T_s \), and \( T_h \)

find \( T_f \) and \( T_z \) using \( \theta_f \) from previous iteration

Solve for \( Q_{sys} \)

Use \( m_{sys_c} \), \( T_e \), and \( T_s \) to calculate new \( \theta_j \) values

\( \Delta T_z < 0.3°C, \Delta \theta_j < 0.005? \)

repeat with new \( \delta t = \delta t/2 \)

iterate with \( \theta_j = 0.5 \theta_{j,old} + 0.5 \theta_{j,new} \) no

\( \theta_j = 0.85 \theta_{j,old} + 0.15 \theta_{j,new} \) yes

move to next system timestep

find \( T_f \) and \( T_z \) using \( \theta_f \) from previous iteration

Use \( m_{sys_c} \), \( T_e \), and \( T_s \) to calculate new \( \theta_j \) values

\( \Delta \theta_j < 0.01? \)

iterate with \( \theta_j = 0.85 \theta_{j,old} + 0.15 \theta_{j,new} \) no

\( \theta_j = 0.5 \theta_{j,old} + 0.5 \theta_{j,new} \) yes

Solve for \( Q_{sys} \)
SCHEMATIC DESIGN PHASE

APPLICATIONS
Process integration

- Required Information
- Expected results
- Typical process
- Expected challenges

- External factors evaluation.
- Concept development.
- Modeling needs defined.
- Many decisions left to modeler.
- Modeling limitations.
- Funding for modeling that is required prior to commission.
IS THE VENTILATION RATE SUFFICIENT?

AT WHAT POINT DOES THE CHANGE IN ORIENTATION BECOME SIGNIFICANT?
NATURAL VENTILATION STRATEGY COMPARISON WITH ENERGYPLUS + COMIS

- WIND ONLY
- INTERNAL STACK
- INTERNAL + EXTERNAL STACK
- INTERNAL STACK + WIND
- INTERNAL + EXTERNAL STACK + WIND

SD PHASE > CASE STUDIES

SAN FRANCISCO FEDERAL BUILDING
BY LBNL / ARUP / MORPHOSIS
CONCLUSIONS:
1. Wind-driven ventilation produces reasonable comfort; stack ventilation alone is less effective.
2. Combination of wind + internal stack produces a slight improvement
3. External stack only assists when wind is absent
Little Village High School, Chicago, IL

- Central atrium space in high school, designed to act as a solar calendar.
- Demonstration of stack-driven natural ventilation was proposed because of stack design already existing for solar calendar.
- CFD analysis performed to evaluate feasibility.
Results

- Lines show paths and temperature of air particles.

Conclusions

- Strong stack effect will occur, providing natural ventilation.
- Excessive air is drawn from corridors, affecting the mechanical systems for rest of building.
DESIGN APPLICATIONS PHASE
**Process integration**

- **Required Information**
- **Expected results**
- **Typical process**
- **Expected challenges**

- Options development: select the design strategies to be modeled.
- Options specification: select the parameters that will be used.
- Fewer decisions left to modeler.
- Optimization, if needed.

**DD PHASE > PROCESS INTEGRATION**
DD PHASE > SAMPLE APPLICATIONS

SKYLIGHTS
LIGHT SHELF
CLERESTORY W/VISION GLASS

Possible Application > Daylighting
Possible Application > HVAC System Selection
CLEARVIEW ELEMENTARY SCHOOL
Hanover, Pennsylvania
SECTION THROUGH CLASSROOM WING
DAYLIGHTING DISTRIBUTIONS WITH RADIANCE SOFTWARE
MAY 21, 11 AM, CLEAR SKY

SKYLIGHTS

CLERESTORY

CLEARVIEW ELEMENTARY SCHOOL
ARCHITECT: L.R. KIMBALL & ASSOC.
DD PHASE > CASE STUDIES

SEASONAL DAYLIGHTING LEVELS
CLERESTORY PROVIDES MOST CONSISTENT LIGHTING LEVELS
Daylighting Design

- 0.97 watts / SF
- Daylight Factor: > 2.0
- 3.5 times more natural illumination
NEW OFFICE: INCLUDING TRADING FLOOR WITH HIGH DENSITY OF PEOPLE AND ELECTRONICS

CFD: AIR DISTRIBUTION COMPARISON
EXTREMELY UNIFORM TEMPERATURE DISTRIBUTION WITH OVERHEAD AIR DISTRIBUTION

ROOM AIR TEMPERATURES

STRONG THERMAL PLUMES FROM HEAT SOURCES WITH UNDERFLOOR AIR
**MEAN AGE OF AIR**

Fresh air is drawn toward occupied space with underfloor air, whereas it is uniformly less fresh with overhead air.
CONSTRUCTION DOCUMENTS PHASE APPLICATIONS
Process integration

- Required Information
- Expected results
- Typical process
- Expected challenges

- Information availability.
- Cross-platform information sharing.
- Modeling limitations.
- Selecting appropriate metrics.

- Benchmark comparisons are more relevant.

CD PHASE > PROCESS INTEGRATION
MECHANICAL NIGHT COOLING SCHEMES

BUILDING DESIGNED FOR NIGHT FLUSH-OUT WITH OUTDOOR AIR (CONTINUOUS FLUSH OUT, EVENING ONLY, OR MORNING ONLY)
AIRFLOW PATTERN ON WINDWARD SIDE OF BUILDING

CFD ANALYSIS

VELOCITY (M/S)

- 5.174E-01
- 4.829E-01
- 4.484E-01
- 4.139E-01
- 3.795E-01
- 3.450E-01
- 3.105E-01
- 2.760E-01
- 2.415E-01

JET ATTACHES TO WINDOW SURFACE
FINAL DESIGN FOR FLOW DEFLECTOR

CFD ANALYSIS

PROJECT ► SAN FRANCISCO FEDERAL BUILDING BY LBNL / ARUP / MORPHOSIS
CD PHASE > CASE STUDIES

BASE CASE

FINAL DESIGN

TITLE I ENERGY USE COMPARISON

ENERGY USE OF ACTUAL DESIGN IS COMPARED TO A “BASE” BUILDING DESIGN THAT IS WITHOUT MANY OF THE ENERGY SAVING FEATURES

PROJECT ► ILLINOIS SCIENCE CENTER AT ANL

ARCHITECT: OWP/P
Design Strategies Beyond Base Building Design

- High performance glazing with a low-e coating. $U$-value $= 0.3$, $\text{SHGC} = 0.24$
- Increased insulation in the roof and walls
- Overhangs on windows
- Daylighting controls
- Hybrid Ventilation
- Absorption chillers
- Increased lighting efficiency (0.8 w/sq.ft.)
The final design uses 47% less energy than the base case.
POSTCONSTRUCTION APPLICATIONS PHASE
POSTCONSTRUCTION PHASE > APPLICATIONS

- **Commissioning**: initial operational data to be compared to simulation results to identify systems that are not functioning as intended.

- **Operation and Management**: simulations used to evaluate improvements to an existing building, or to identify existing practices that might be changed.

- **Control Scheme Optimization**: simulation used to evaluate and optimize building operation controls.

- **Building Pressure Evaluation**: CFD or interzonal airflow models used to evaluate sources of building pressurization problems, and evaluate proposed solutions.
EXISTING SWIMMING POOL WITH GLARE PROBLEMS
(LIFEGUARDS COULD NOT SEE UNDER THE WATER)
CALIBRATED RADIANCE MODELS USED TO EVALUATE SOLUTIONS

PROJECT ► CHILSON RECREATION CENTER
CONSULTANT: ARCHITECTURAL ENERGY CORP.
LESSONS LEARNED

- Early involvement is critical to maximize value.
- Simulation can be used for all types of projects.
- Required time and expense can vary widely.
- Apply the appropriate tool for the project need.
INFORMATION RESOURCES

IBPSA > www.ibpsa.org

ASHRAE > www.ashrae.org
  ▫ Technical Committee 4.7: Energy Calculations
  ▫ Technical Committee 4.10: Indoor Environment Modeling

Building Energy Software Tools Directory
  ▫ www.eere.energy.gov/buildings/tools_directory/

BLDG-SIM Mailing List > www.gard.com/ml/bldg-sim.htm
  ▫ Forum for users of energy simulation programs.

Radiance Knowledge Database > www.radiance-online.org/
  ▫ Website for Radiance users and a platform for further development.

CFD Online (all industries) > www.cfd-online.com

Research publications
  ▫ ASHRAE Transactions
  ▫ Energy and Buildings (Elsevier)
  ▫ Building and Environment (Elsevier)
QUESTIONS?