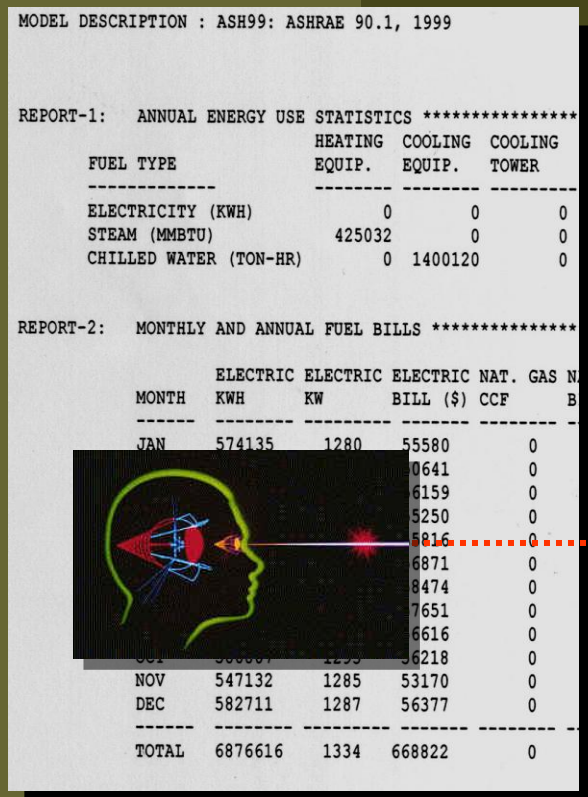
OVERVIEW OF SIMULATION



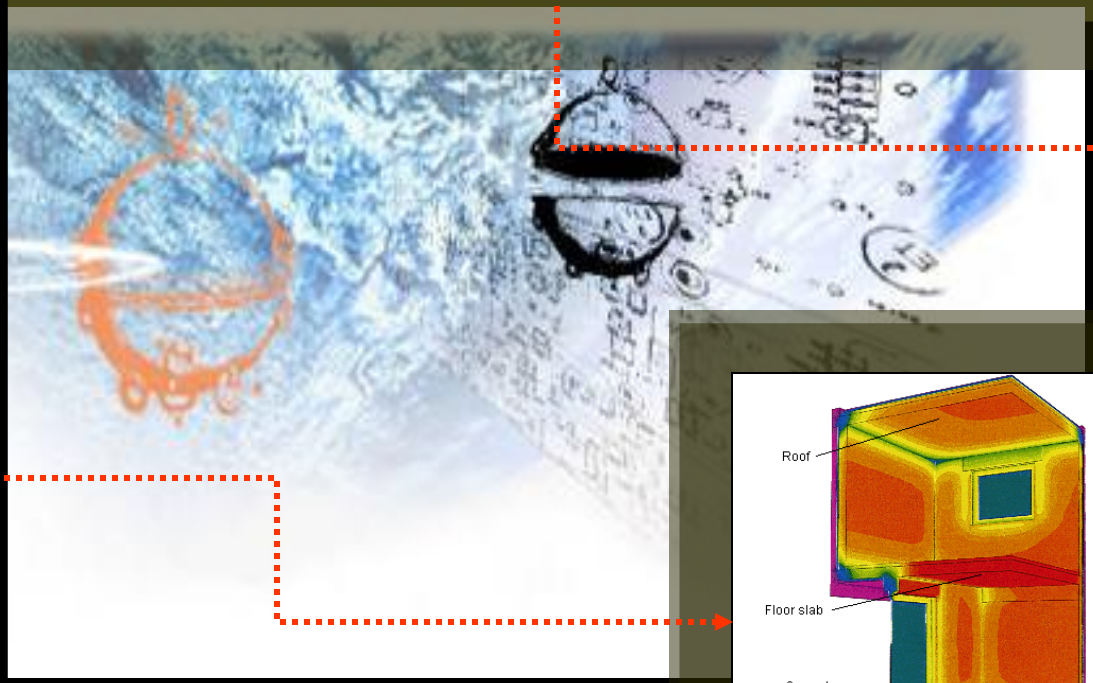
MODEL DESCRIPTION : ASH99: ASHRAE 90.1, 1999

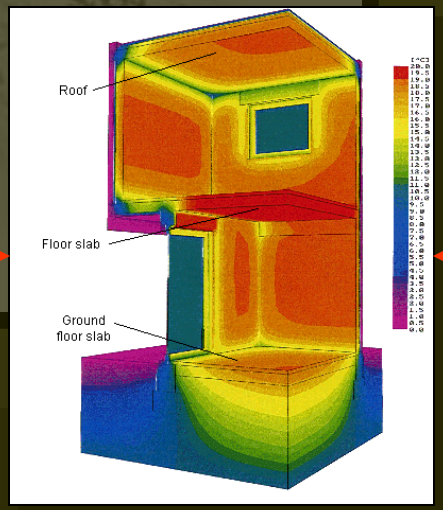
REPORT-1: ANNUAL ENERGY USE STATISTICS **********

FUEL TYPE	HEATING EQUIP.	COOLING EQUIP.	COOLING TOWER
ELECTRICITY (KWH)	0	0	0
STEAM (MMBTU)	425032	0	0
CHILLED WATER (TON-HR)	0	1400120	0

REPORT-2: MONTHLY AND ANNUAL FUEL BILLS **********

MONTH	ELECTRIC KWH	ELECTRIC KW	ELECTRIC BILL ($)	NAT. GAS CCF	N B
JAN	574135	1280	55580	0	
			0641	0	
			6159	0	
			5250	0	
			5816	0	
			6871	0	
			8474	0	
			7651	0	
			6616	0	
			6218	0	
NOV	547132	1285	53170	0	
DEC	582711	1287	56377	0	
TOTAL	6876616	1334	668822	0	





PRESENTATION FOR ARCHITECTS

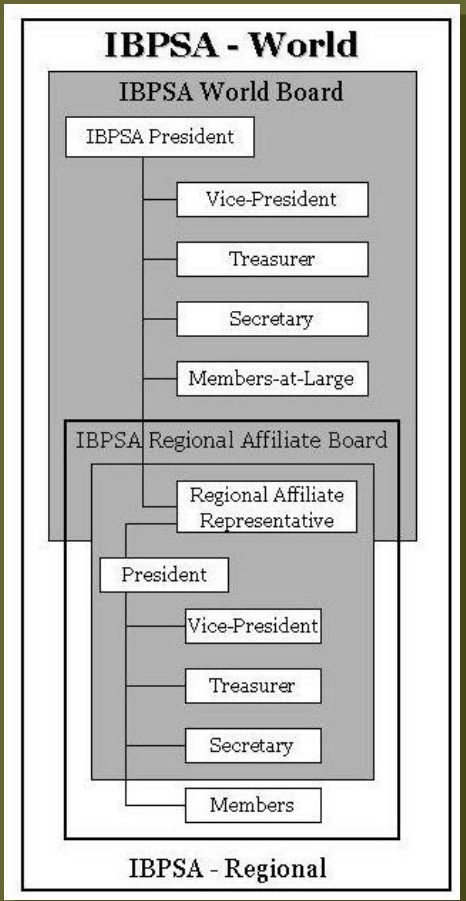
PRESENTER'S NAME

NAME OF EVENT • LOCATION

IBPSA - USA

- **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



ACKNOWLEDGMENTS

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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.

OUTLINE

OVERVIEW

VALUE

TOOLS

APPLICATIONS

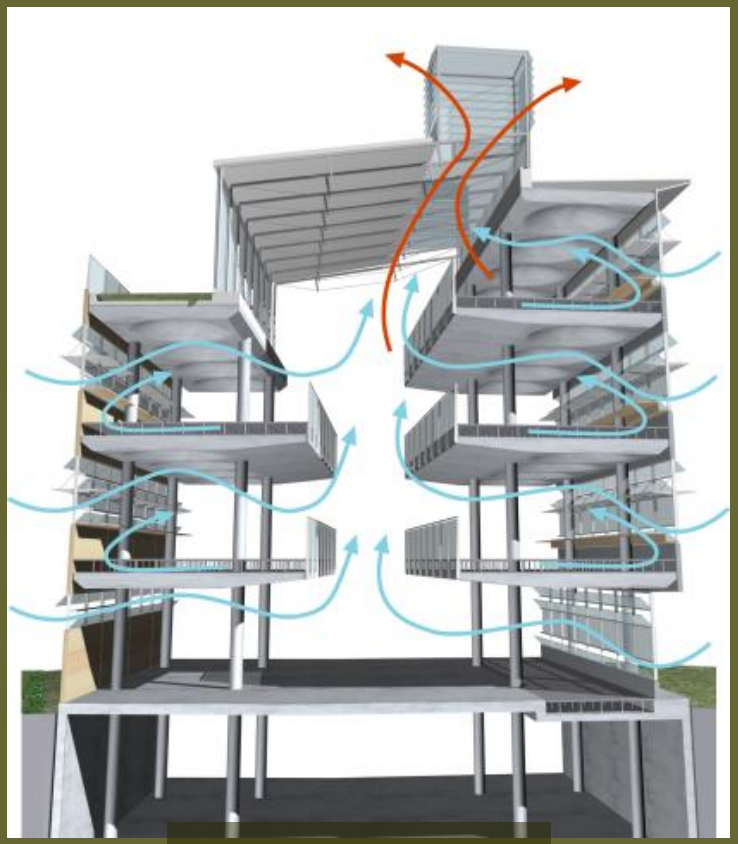
CONCLUSIONS

DEFINITION AND PRINCIPLES

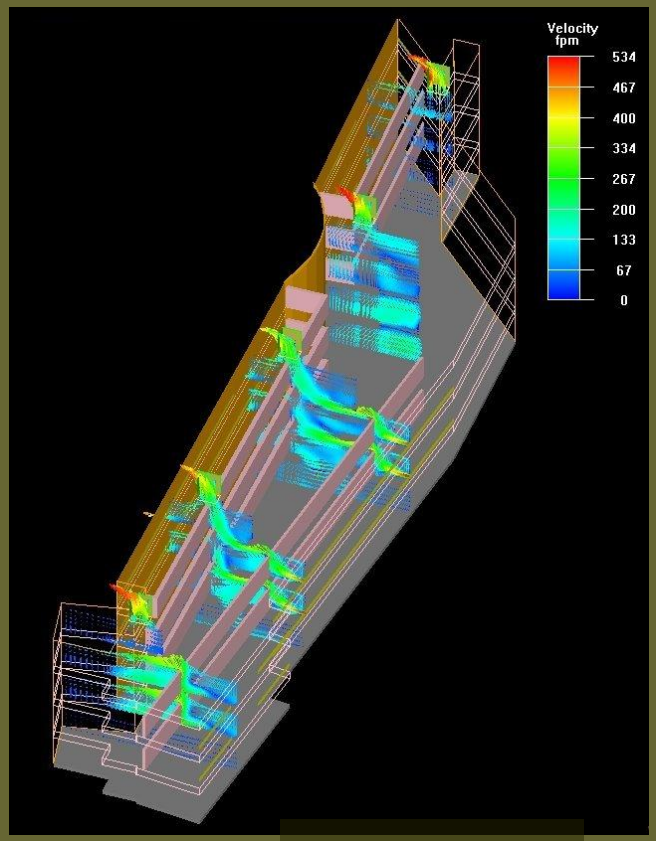
Building Performance Simulation:

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 ►

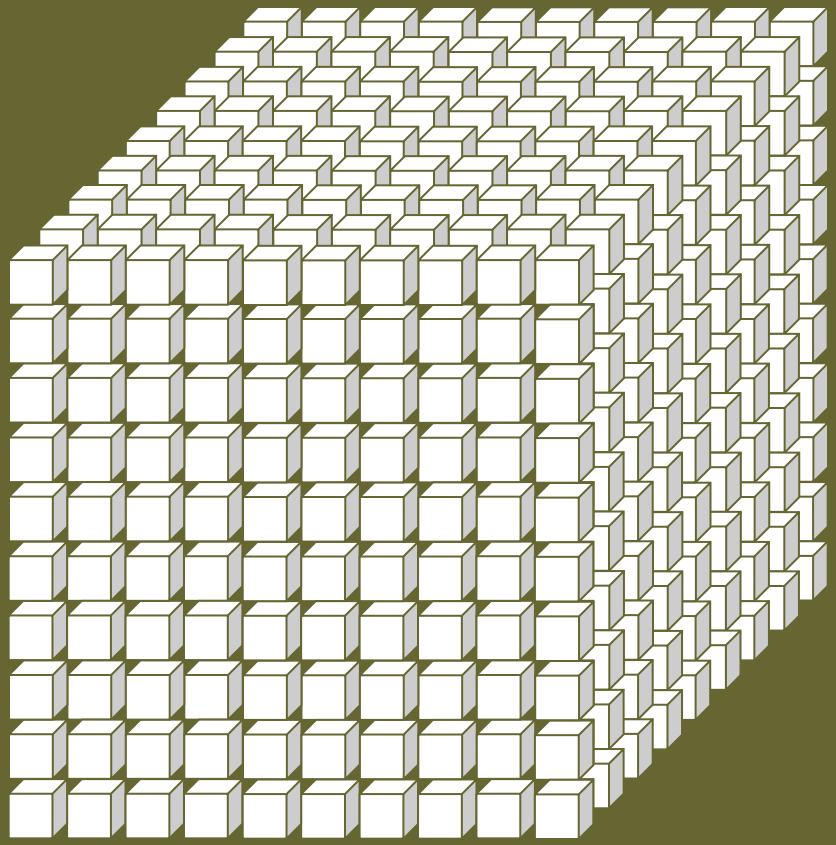
ILLINOIS SCIENCE CENTER / ARGONNE NATIONAL LABS

ARCHITECT: OWP/P

DEFINITION > **COMPLEXITY**

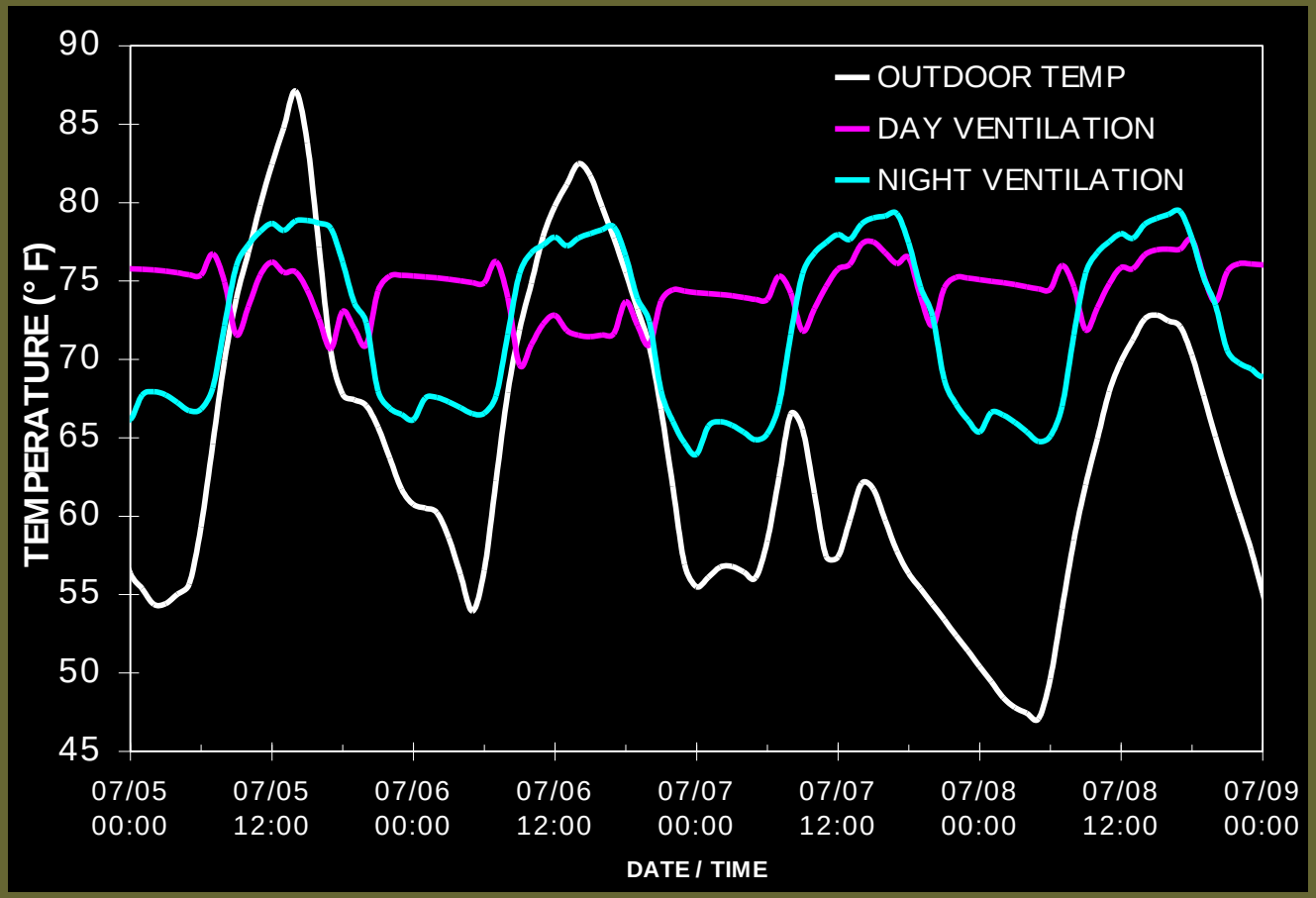
Fundamental difference between computer simulation and other engineering calculations is one of complexity.

Traditional Engineering Models
– maybe 10 variables



Computer Simulation
– easily 10,000 variables

DEFINITIONS > **TIME-DEPENDENT**



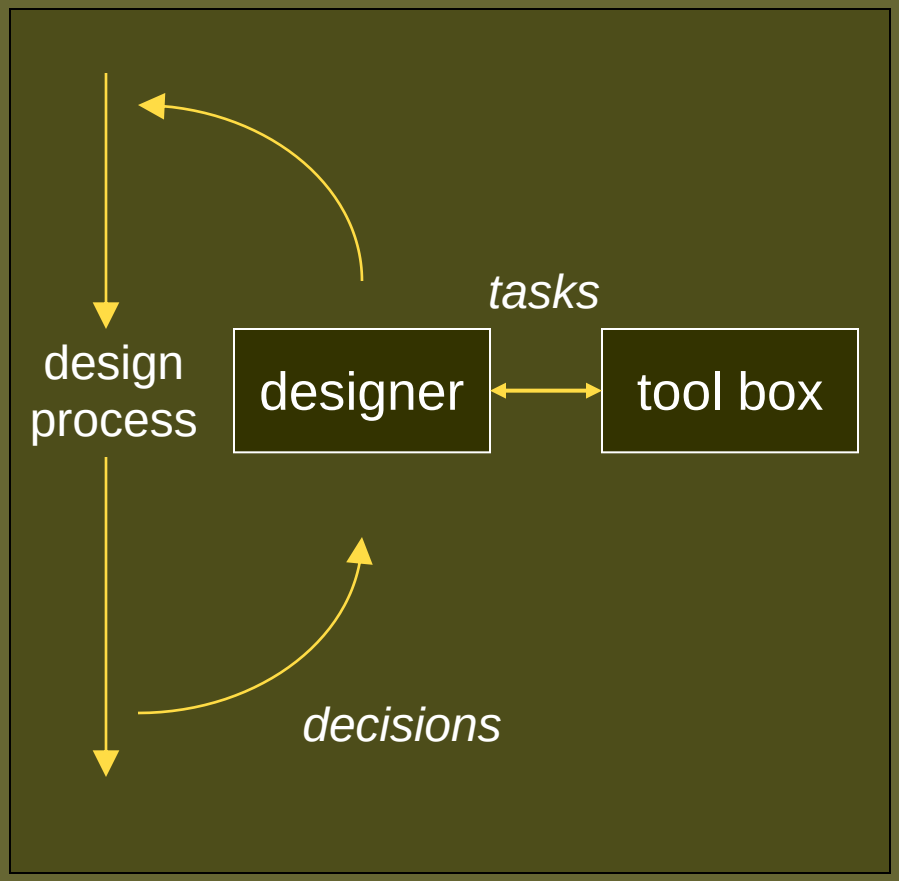
Time-dependent natural ventilation study

HISTORICAL TIMELINE

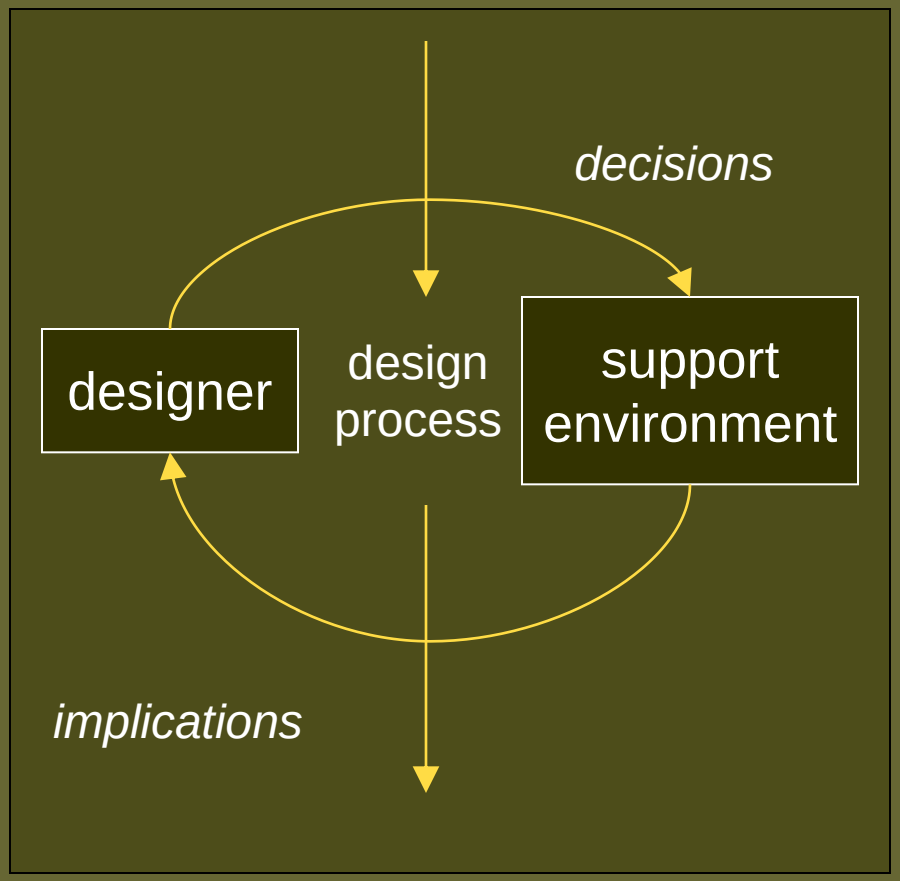
TIMELINE

GENERATION	CHARACTERISTICS	CONSEQUENCES
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

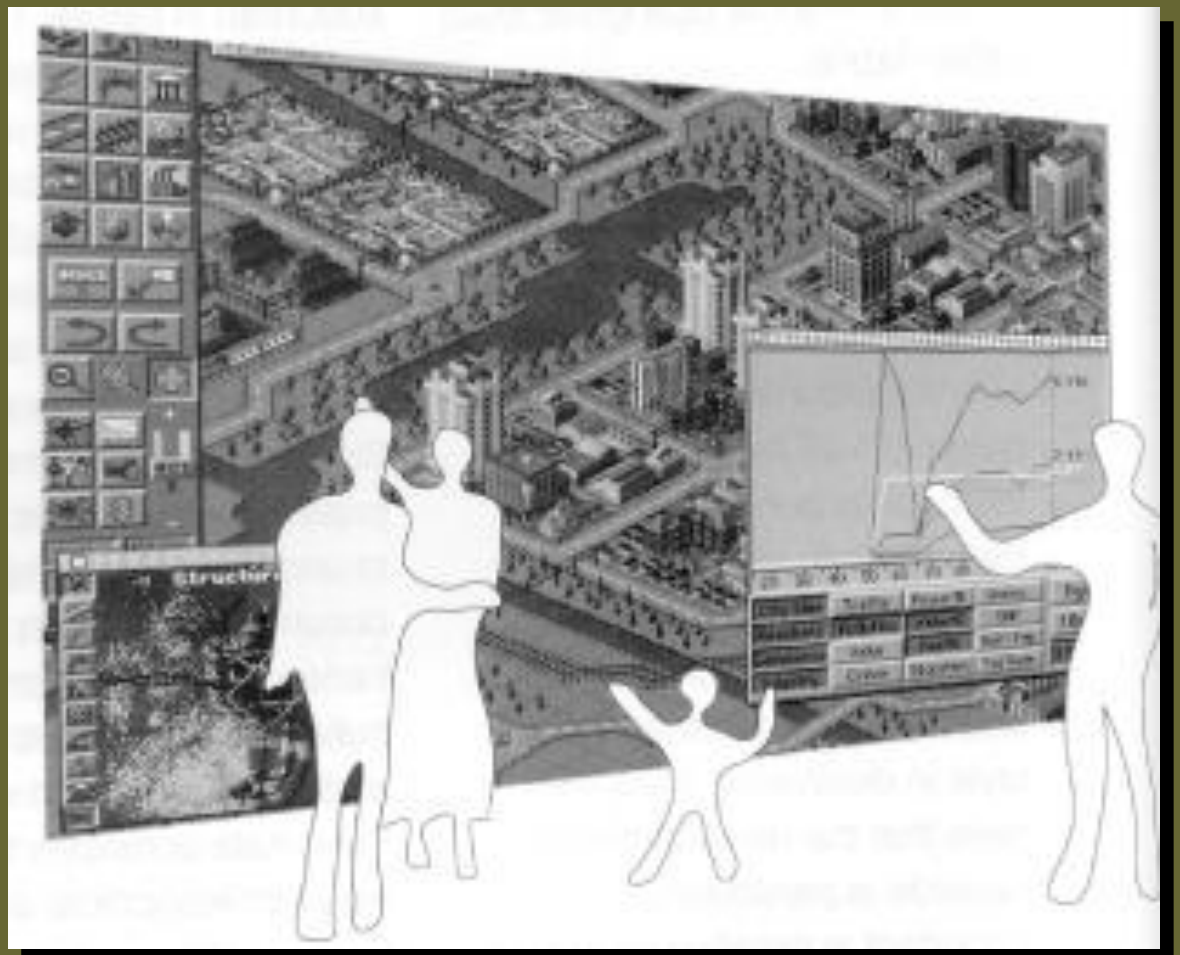


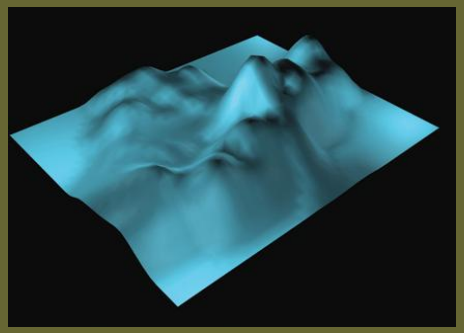
Simulation Approach

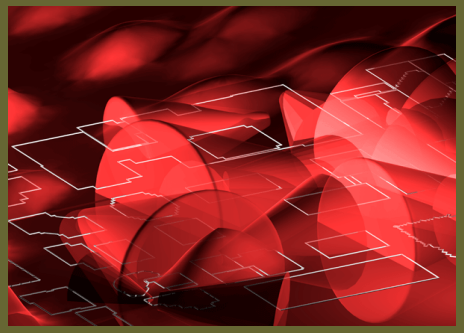
CURRENT DEVELOPMENT

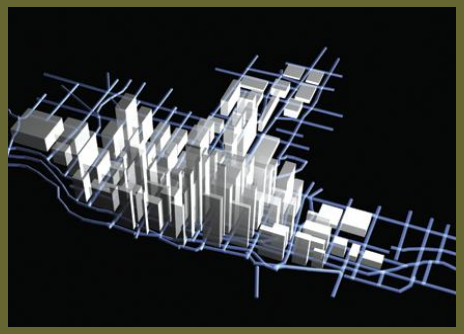
- Intelligent ***GUI*** (graphical user interfaces).
- Enhanced ***integration*** with other design software.
- Expanded ***performance*** due to single package availability and coupling of simulation engines.
- Improved ***technology transfer*** efforts from research to applications.

FUTURE DEVELOPMENT



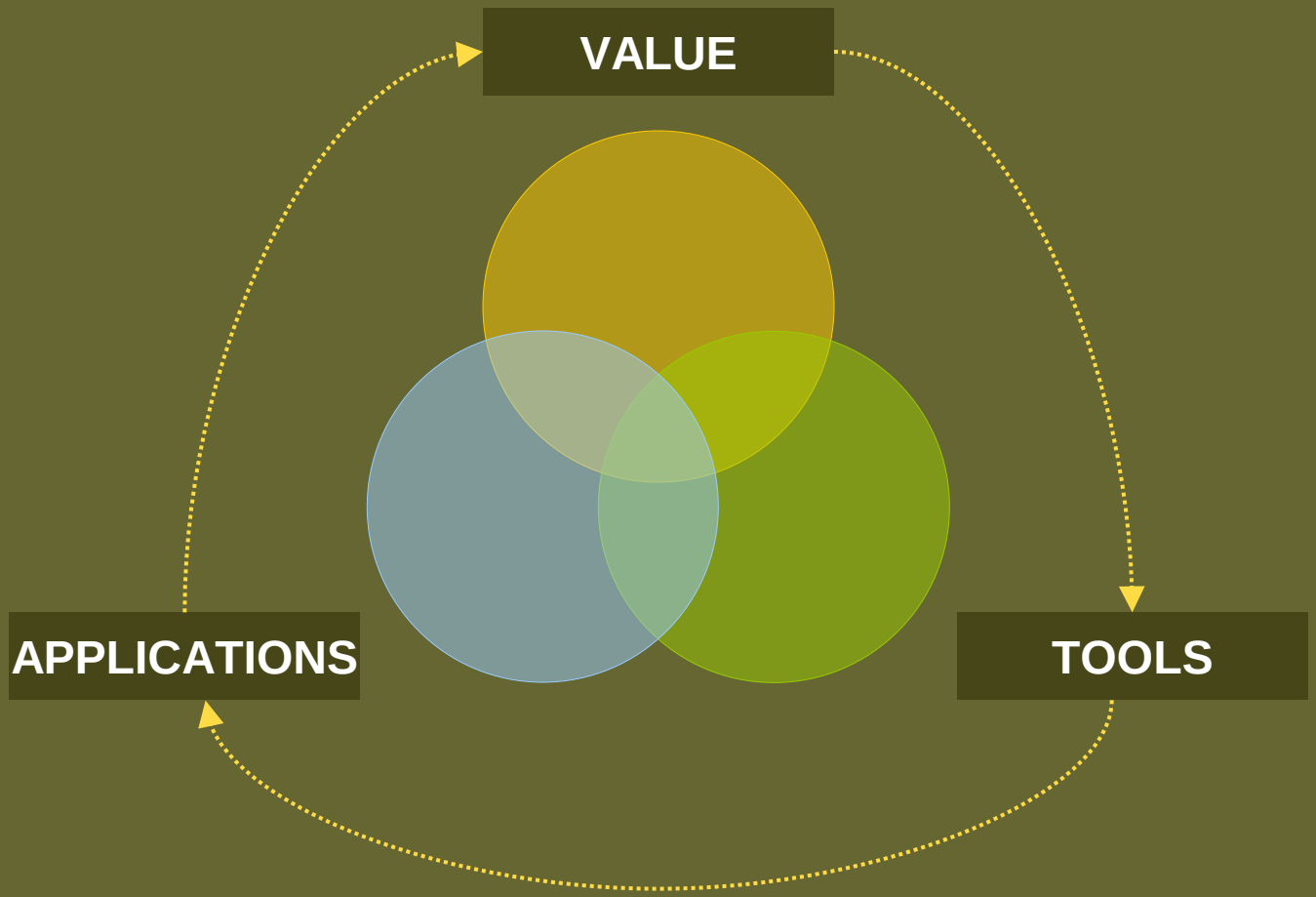






IMAGES: COURTESY OF BATTLE MCCARTHY AND PROF. NADIA AMOROSO

THEMES



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

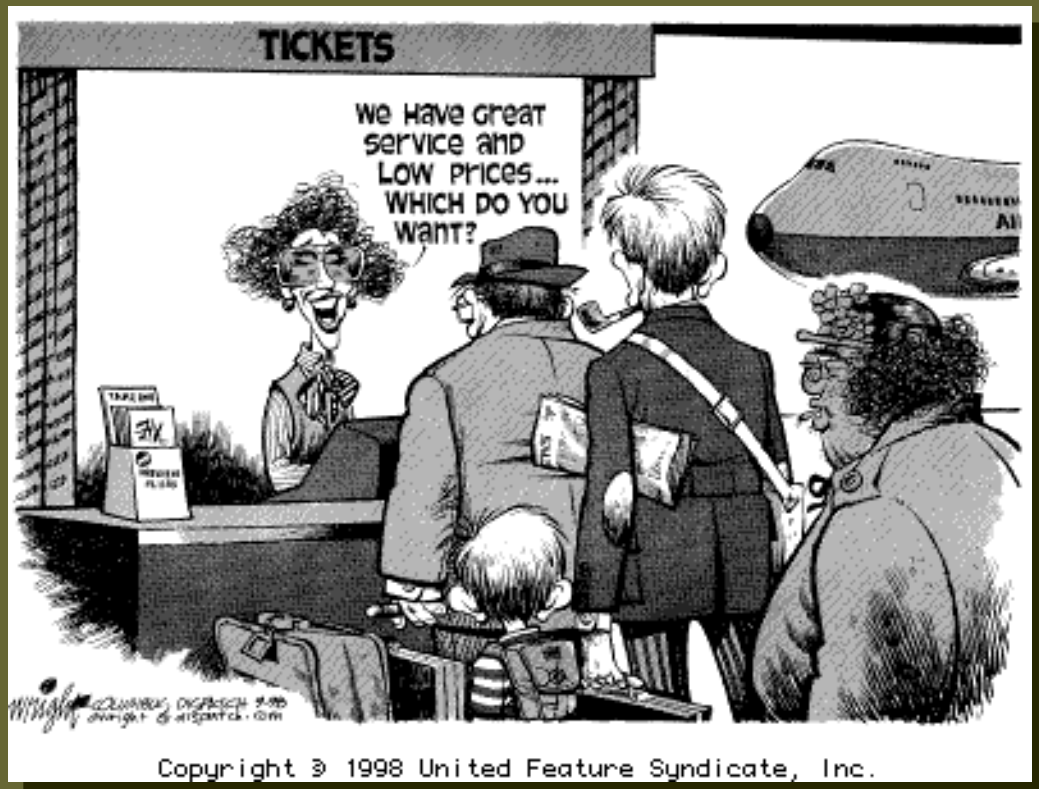
BUILDING DESIGN PROCESS

VALUE

VALUE > BUILDING DESIGN 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.

VALUE > BUILDING DESIGN PROCESS

Time Effectiveness ($)

- Reduced performance problems.

± Difficult to estimate time allotted to simulation.

± Time factor dependent upon many factors.

PROJECT VALUE BENEFITS

VALUE > PROJECT TEAM BENEFITS

Developer

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

CHICAGO CENTER FOR GREEN TECHNOLOGY

VALUE > PROJECT TEAM BENEFITS

Design Professional

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

THE QUEEN'S BUILDING

VALUE > PROJECT TEAM BENEFITS

Building Operator

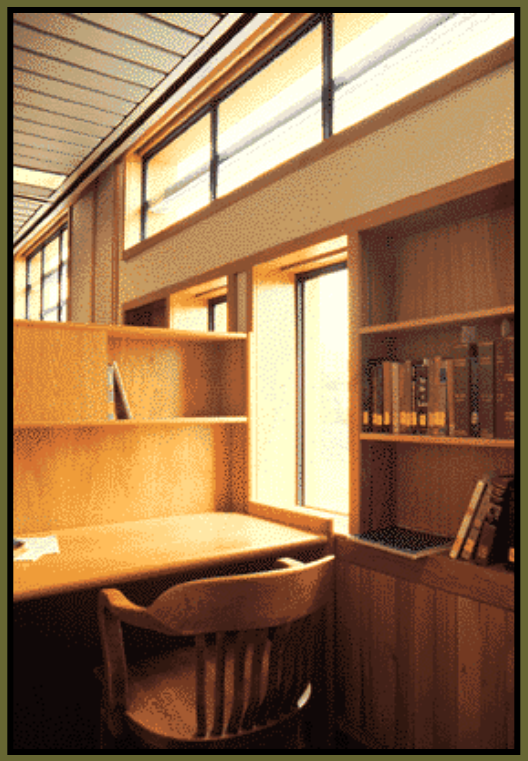
- Energy cost savings.
- Reduced building occupant complaints.
- Reduced commissioning-related problems.
- Public relations.

THE QUEEN'S BUILDING

VALUE > PROJECT TEAM BENEFITS

Building Occupant

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



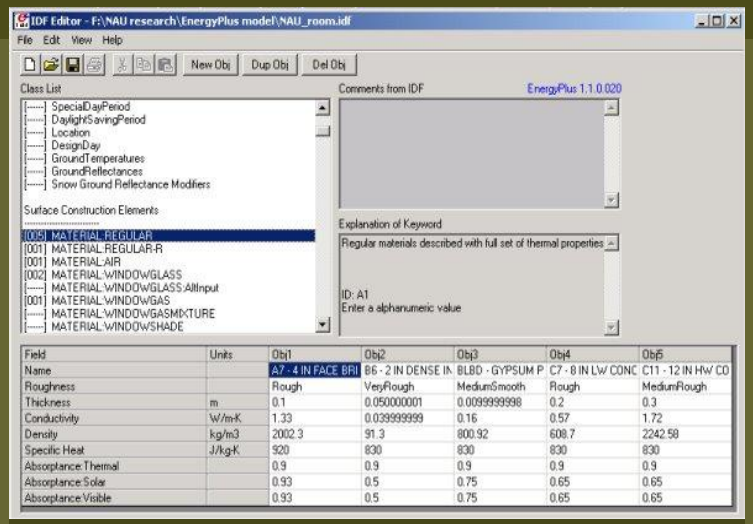
CONSIDERATIONS

VALUE

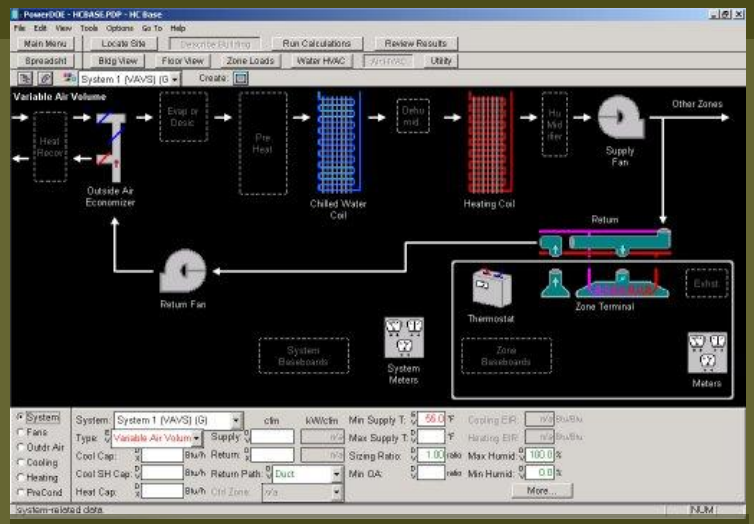
VALUE > CONSIDERATIONS

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.

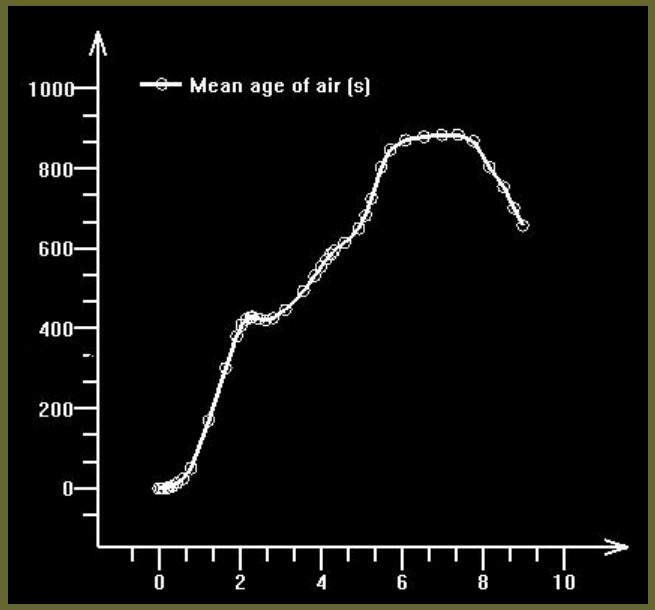


EnergyPlus text interface

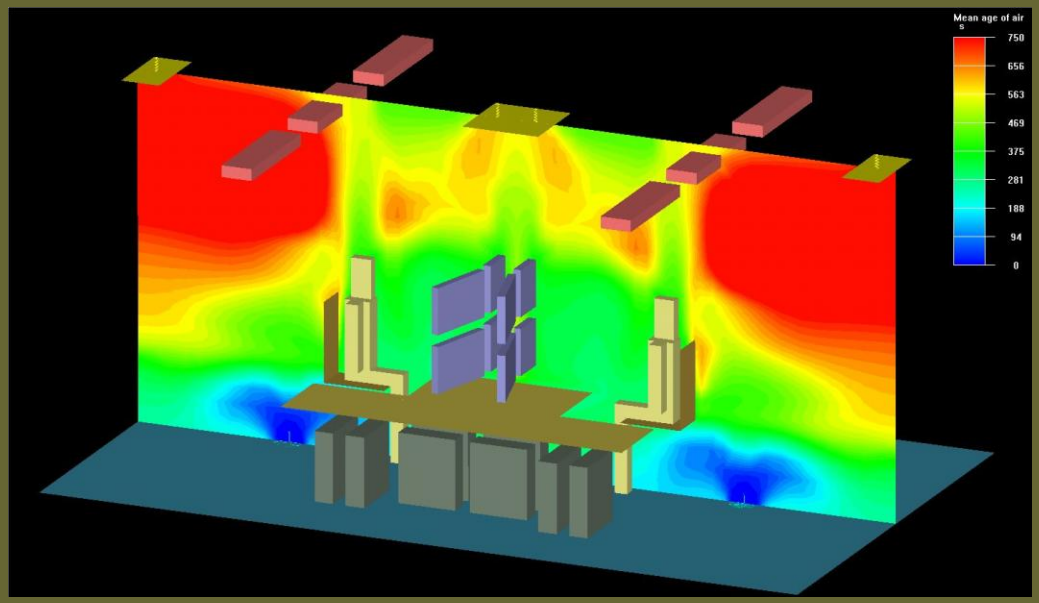


PowerDOE graphic interface

EQUIPMENT & INTERFACES > **VISUALIZATION**



Mean age of air with underfloor air distribution along vertical axis



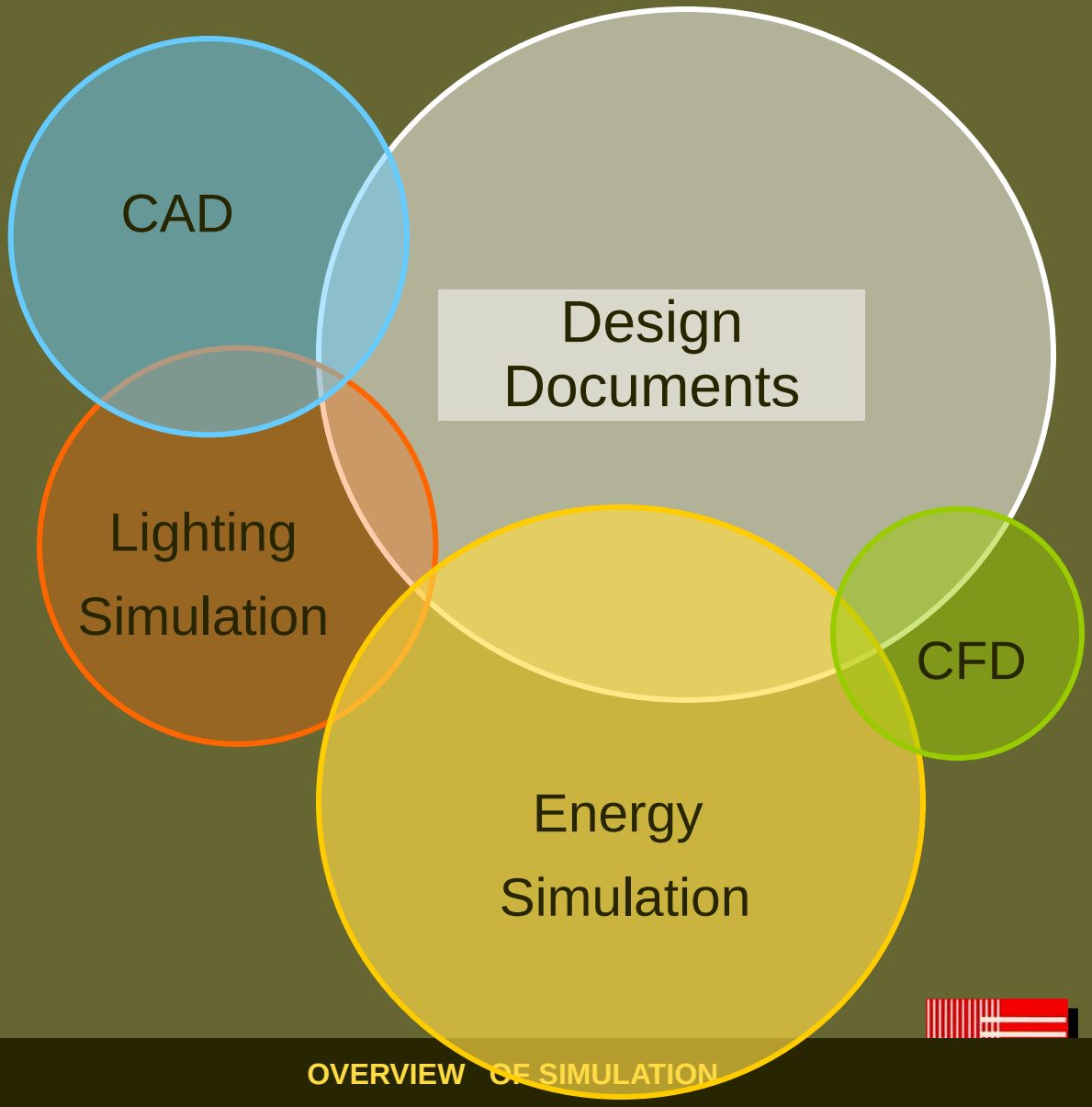
Mean age of air with underfloor air distribution

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.

INTEROPERABILITY > **DATA EXCHANGE**

- Separate programs require different types of data.
- Data acquisition is needed from upstream sources.
- Data archival is needed for downstream users.



INTEROPERABILITY > **CURRENT STANDARDS**

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

VALUES > **CONSIDERATIONS**

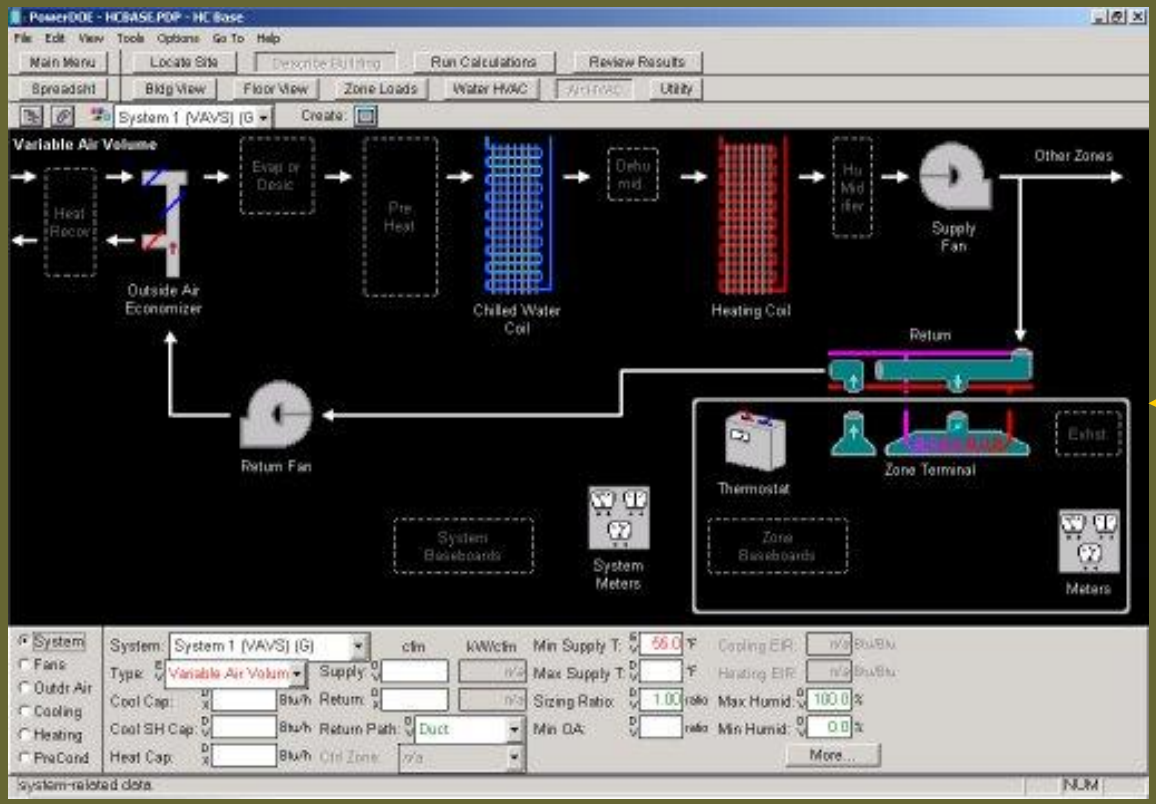
Expertise

- More than number-crunching skills.
- Understanding of what is being simulated.
- Ability to interpret results.
- Conceptualize simplified, but useful, models.

EXPERTISE > **UNDERSTANDING**

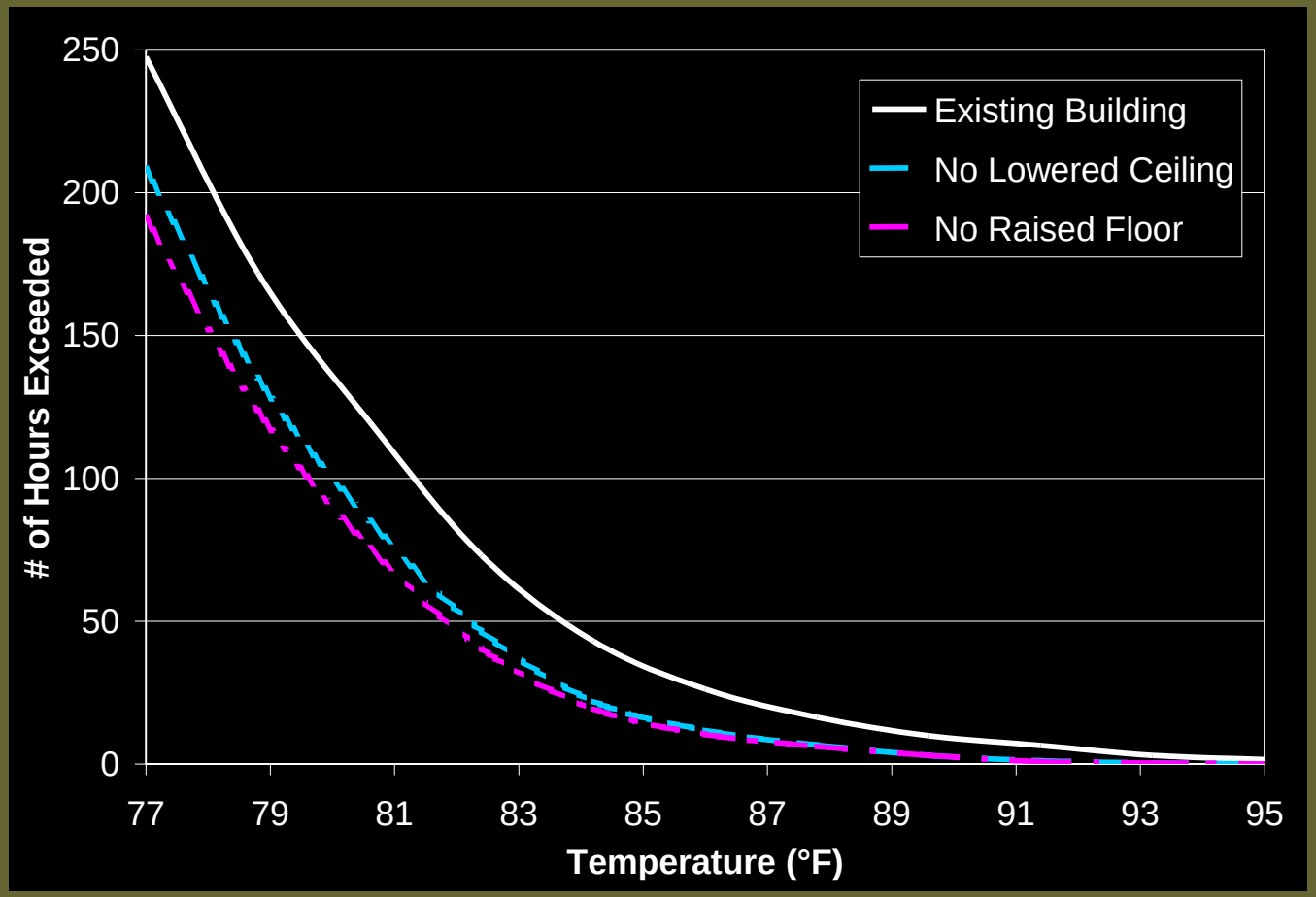
$$C_z \frac{dT_z}{dt} = \sum_{i=1}^{N_{sl}} \dot{Q}_i + \sum_{i=1}^{N_{surfaces}} h_i A_i \left(T_{si} - T_z\right) + \sum_{i=1}^{N_{zones}} \dot{m}_i c_p \left(T_{zi} - T_z\right) + \dot{m}_{inf} c_p \left(T_{inf} - T_z\right) + \dot{Q}_{sys}$$

Room Air Heat Balance Equation



What is the **relationship** between the formula and the interface ?

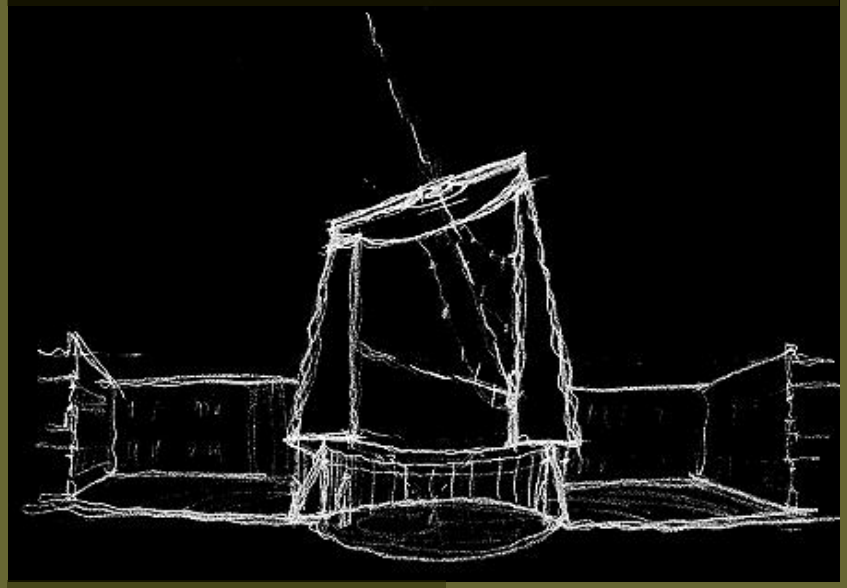
EXPERTISE > INTERPRETATION



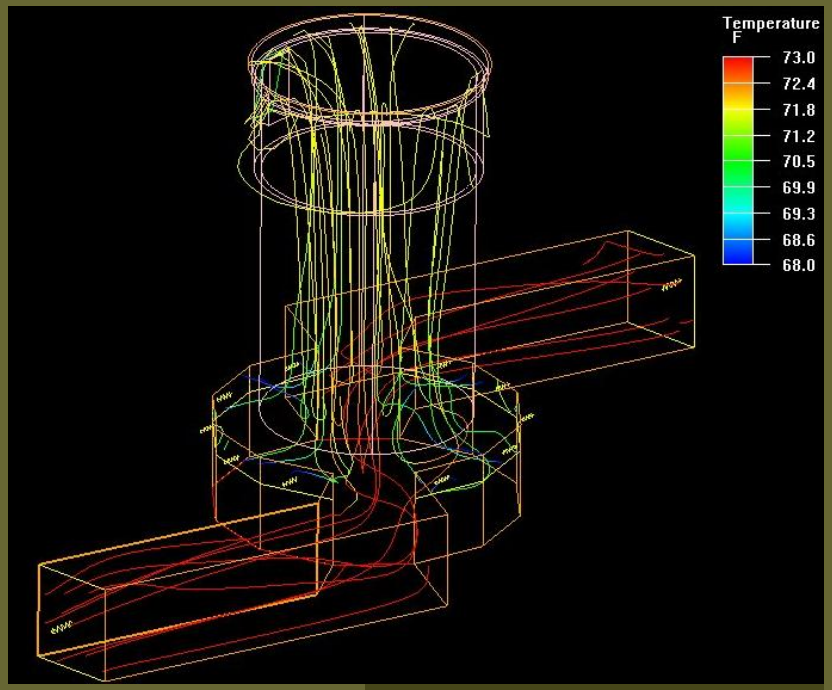
Natural ventilation comfort evaluation

EXPERTISE > **CONCEPTUALIZATION**

LITTLE VILLAGE HIGH SCHOOL • **CENTRAL GALLERY**



design concept



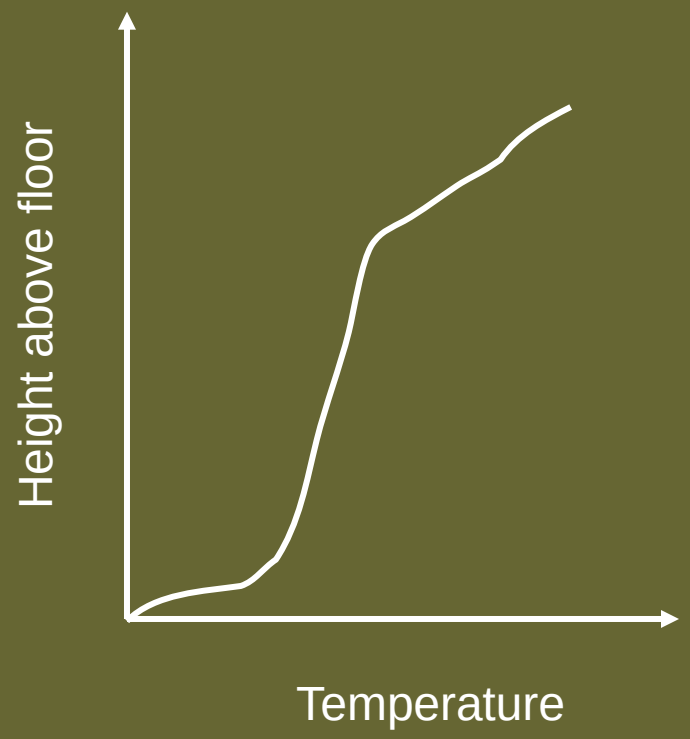
simulation model

VALUES > **CONSIDERATIONS**

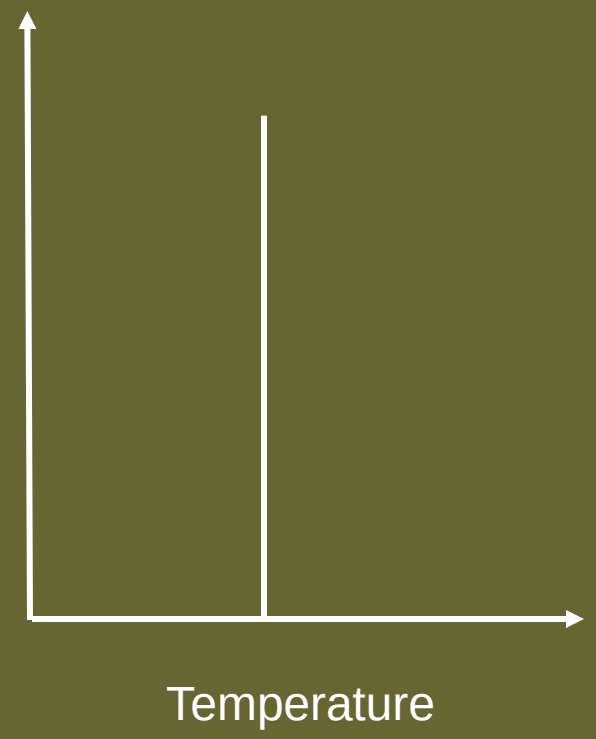
Appropriate Use

- 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

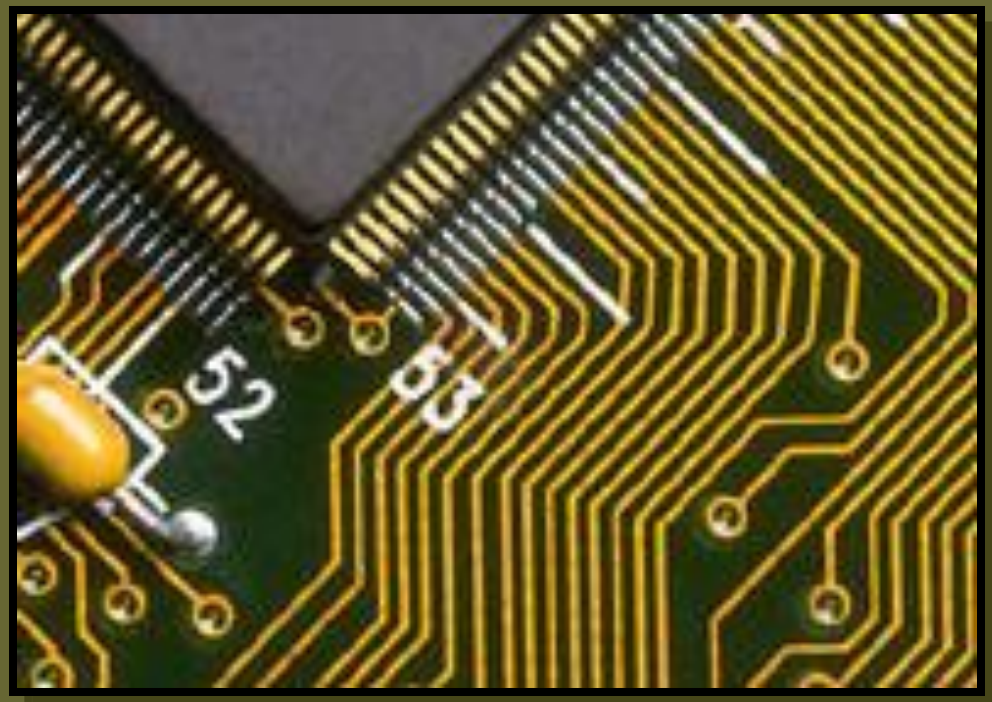
- LEED™ was developed and is administered by USGBC.
- LEED™ is a rating system designed for new and existing buildings.
- Provides a standard for what constitutes a "green building."

http://www.usgbc.org/

LEED™ > INTEGRATION

Design Category	Points (version 2.1)
Sustainable Sites	14
Water Efficiency	5
Energy and Atmosphere	17
Materials and Resources	13
Indoor Environmental Quality	15
Innovation and Design Process	5
Totals Credits	69

THEME 2: TOOLS



THE SIMULATION PROCESS

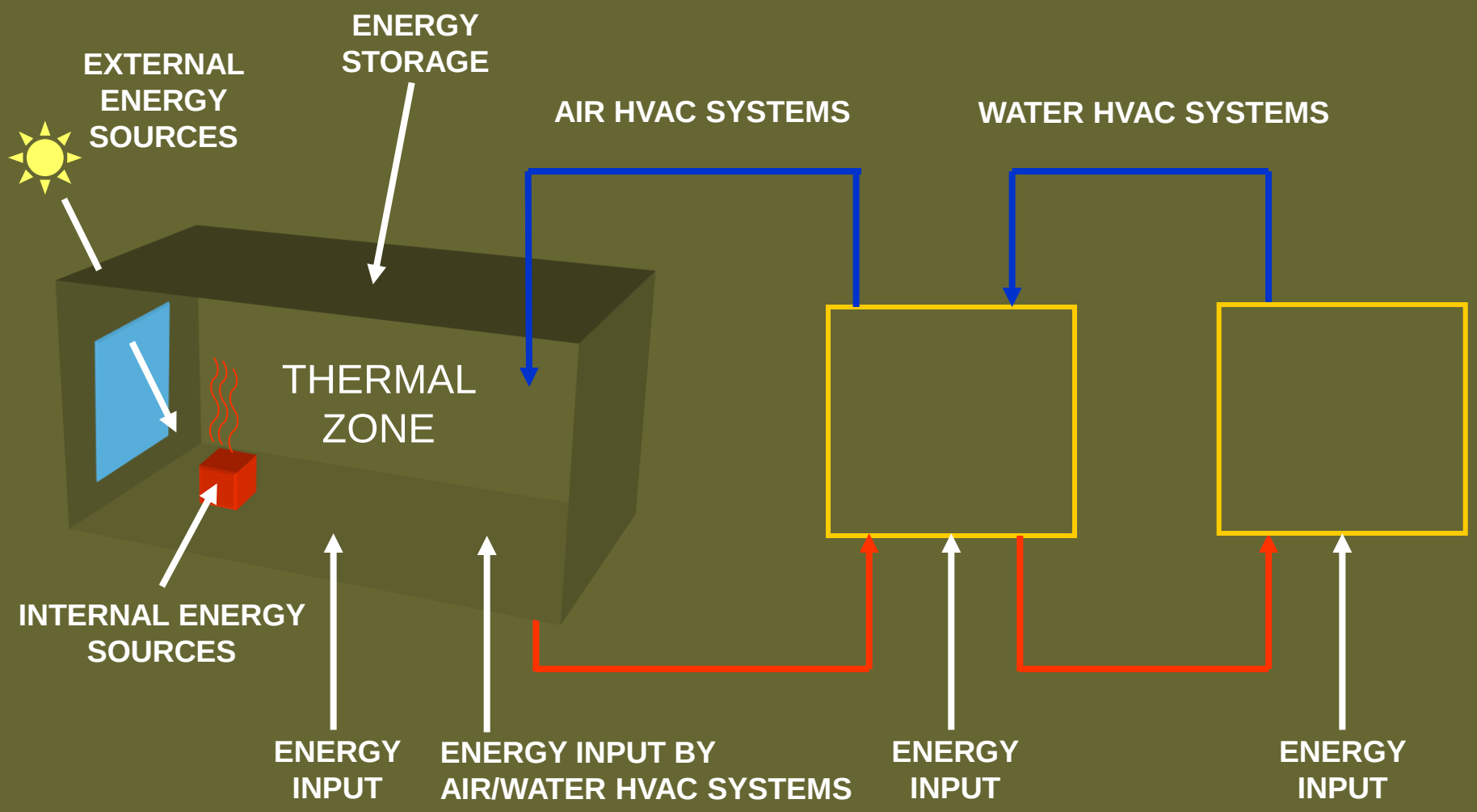
1. Information gathering
2. Data collection
3. Identification of modeling goals
4. Model-building
5. Run the simulation
6. Debug
7. Calibration
8. Optimization
9. Visualization of results
10. Interpretation of results
11. Design recommendations

Categories of Simulation

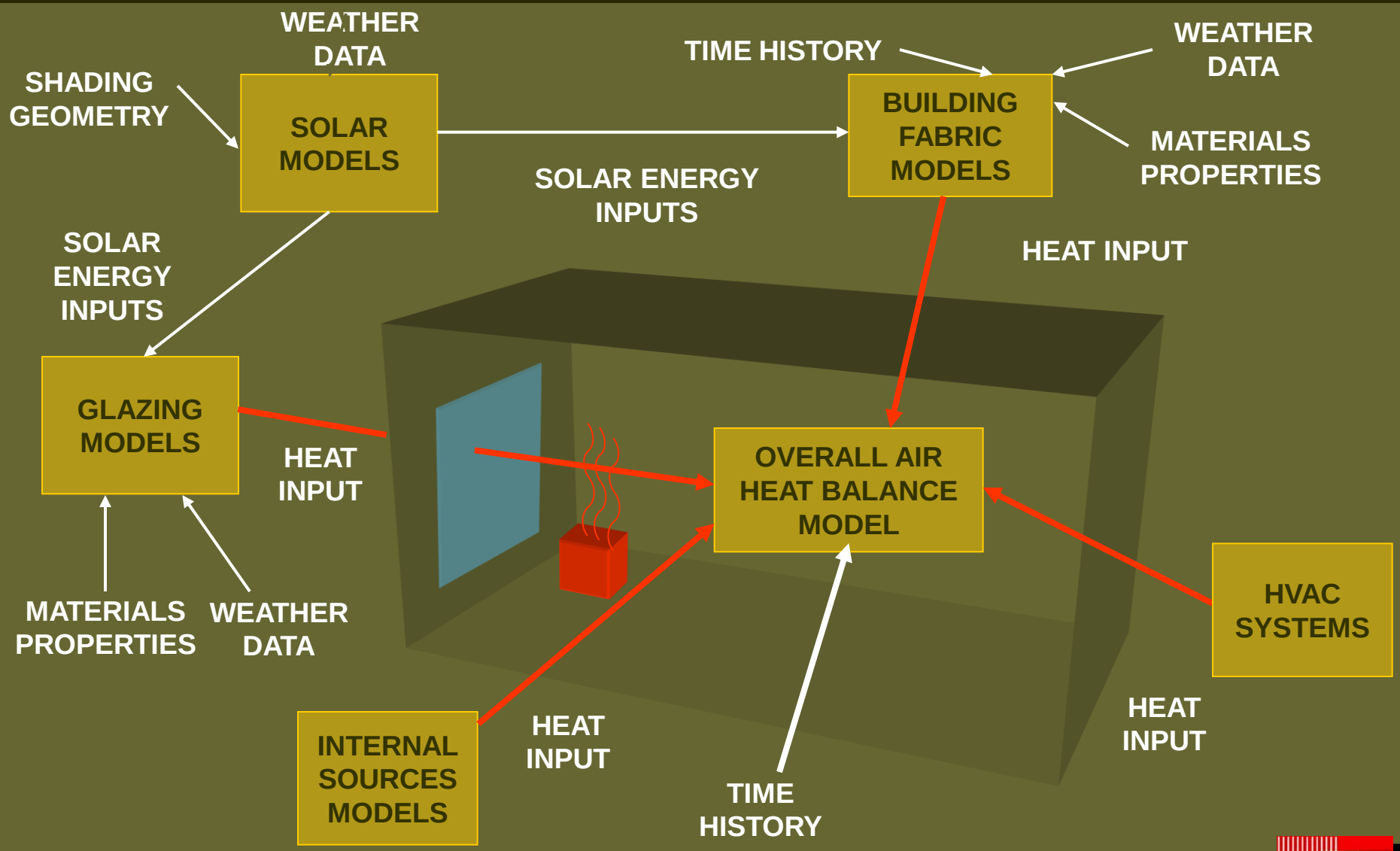
- Simple: few inputs, limited information needed.
- Detailed: many inputs, with detailed information needed.
- Special purpose: dedicated to a single task or purpose.

ENERGY SIMULATION TOOLS

ENERGY SIMULATION > **WHAT IT DOES**



ENERGY SIMULATION > **HOW IT WORKS**



ENERGY SIMULATION > **INPUTS & OUTPUTS**

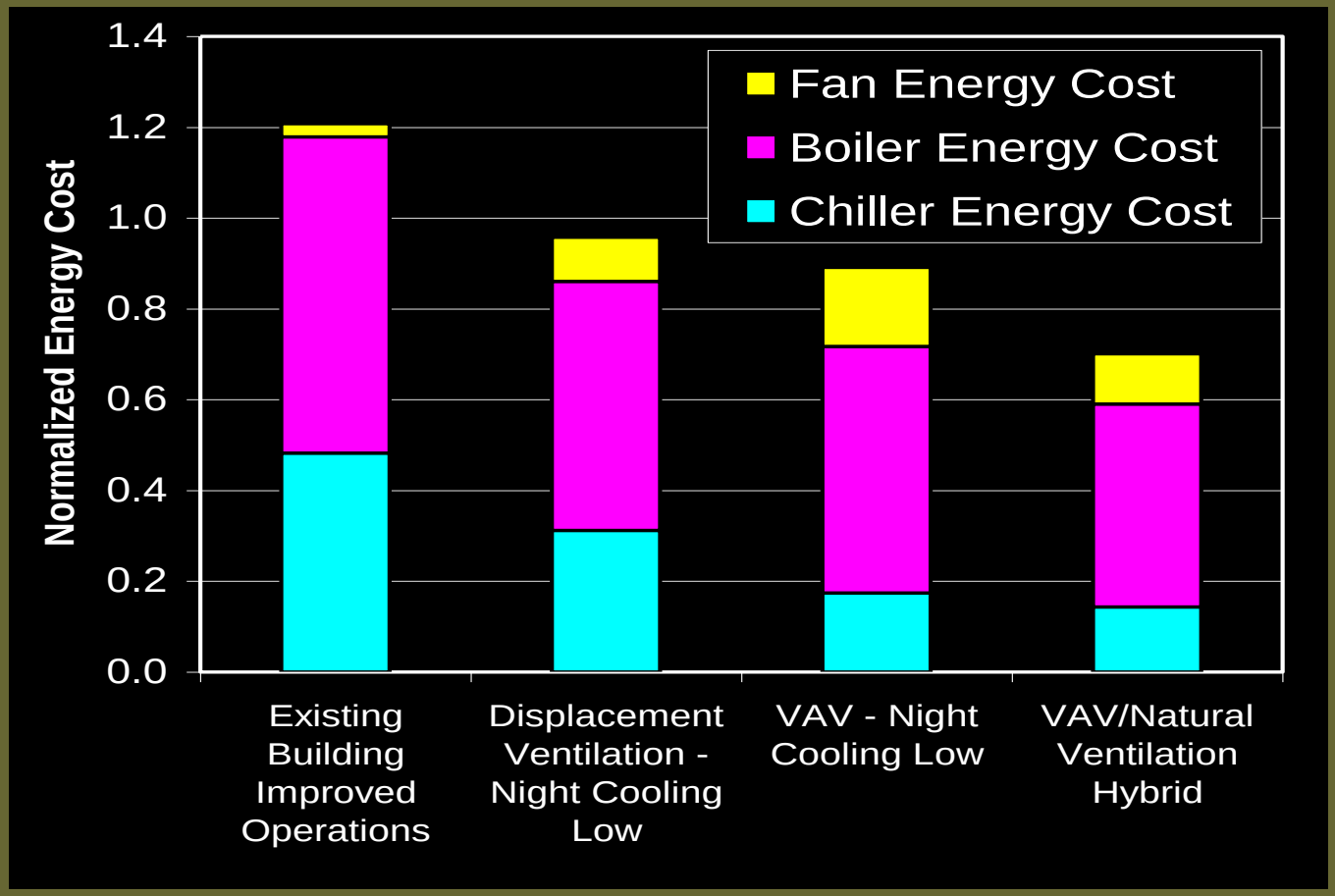
INPUTS

- Weather data
- Building geometry
- Construction type
- HVAC type / usage
- Occupancy info
  - Quantity of users
  - Lights
  - Equipment
  - Usage

OUTPUTS

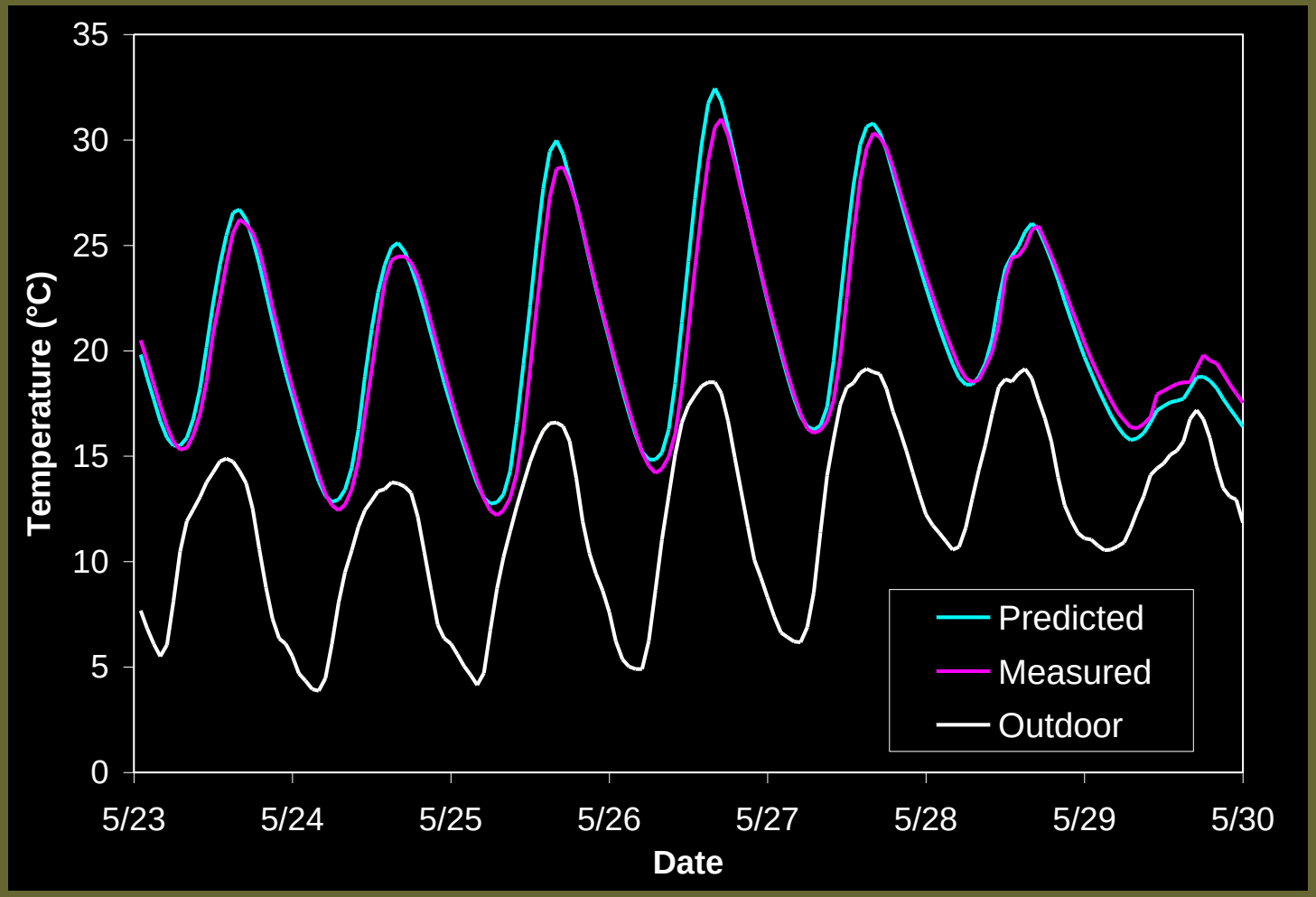
- Space temperatures
- Surface temperatures
- Humidity levels
- HVAC parameters
- Energy consumption
  - Component
  - System
  - Whole-building

ENERGY SIMULATION > **OUTPUTS**



Energy consumption of various mechanical systems

ENERGY SIMULATION > **ACCURACY**



ENERGY SIMULATION > **VALIDATION**

- 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.

ENERGY SIMULATION > LEED™

LEED

Energy and Atmosphere

Minimum Energy Performance

- Prerequisite 2

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.

ENERGY SIMULATION > LEED™

LEED

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.

ENERGY SIMULATION > LEED™

LEED

Energy and Atmosphere

Measurement and Verification

- Credit 5
- 1 point

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.

ENERGY SIMULATION > **WHAT'S AVAILABLE**

- **DOE-2** > simulationresearch.lbl.gov

  Interfaces

  - eQUEST > www.energydesignresources.com/tools/equest.htm
  - PowerDOE > www.doe2.com
  - VisualDOE > www.eley.com

- **EnergyPlus** > www.energyplus.gov

  Interfaces

  - DesignBuilder (currently beta testing) > www.designbuilder.co.uk

- **ESP-r** > www.esru.strath.ac.uk

  - primarily used by European researchers.

- **TRYNSYS** > sel.me.wisc.edu/trnsys

ENERGY SIMULATION > **DEMONSTRATION**

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 > SURFACE CONSTRUCTION INPUT

Surface Construction, Layers, and Material Data

Construction | Layers | Material

Currently Active Construction: Interior wall 1

Surface Construction Parameters

Construction: Interior wall 1

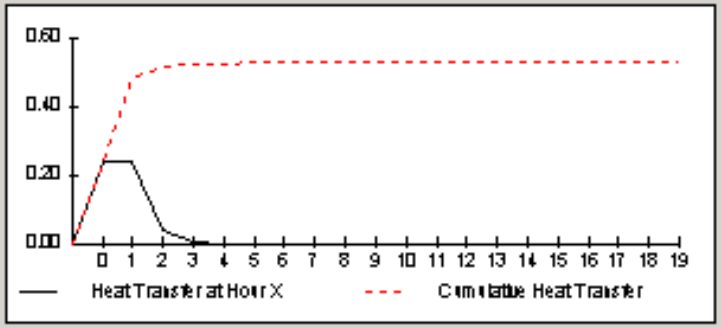
Specification Method: Layers Input

Calculated U-Val (Btu/h-SF): 0.528

Surface Roughness: 3

Ext. Color (absorpt.): 0.700

Heat Transfer From Outside To Inside



Construction Layers: Interior wall layers 1 (material layers ordered from outside to inside)

	Material Name	Thickness (ft)	Conductivity	Density	Spec. Heat	R-Value
1	GypBd 3/4in (HF-E1)	0.063	0.4200	100.00	0.200	
2	Air Space (HF-B1)					0.910
3	GypBd 3/4in (HF-E1)	0.063	0.4200	100.00	0.200	
4	- undefined -					

Default | OK | Cancel

PowerDOE > INTERNAL LOAD INPUT

PowerDOE - ANLBASE.PDP - ANL BASE

File Edit View Tools Options Go To Help

Main Menu | Locate Site | Describe Building | Run Calculations | Review Results

Spreadsht | Bldg View | Floor View | Zone Loads | Water HVAC | Air HVAC | Utility

Floor 2 | Space A2

Building Coordinates:
X: Y:

Daylighting Lighting
People Equipment
Infiltration Other Prop.

Zone Properties: Space A2

Occupancy | Equipment | Infiltration | Daylighting | Int Mass / Furniture

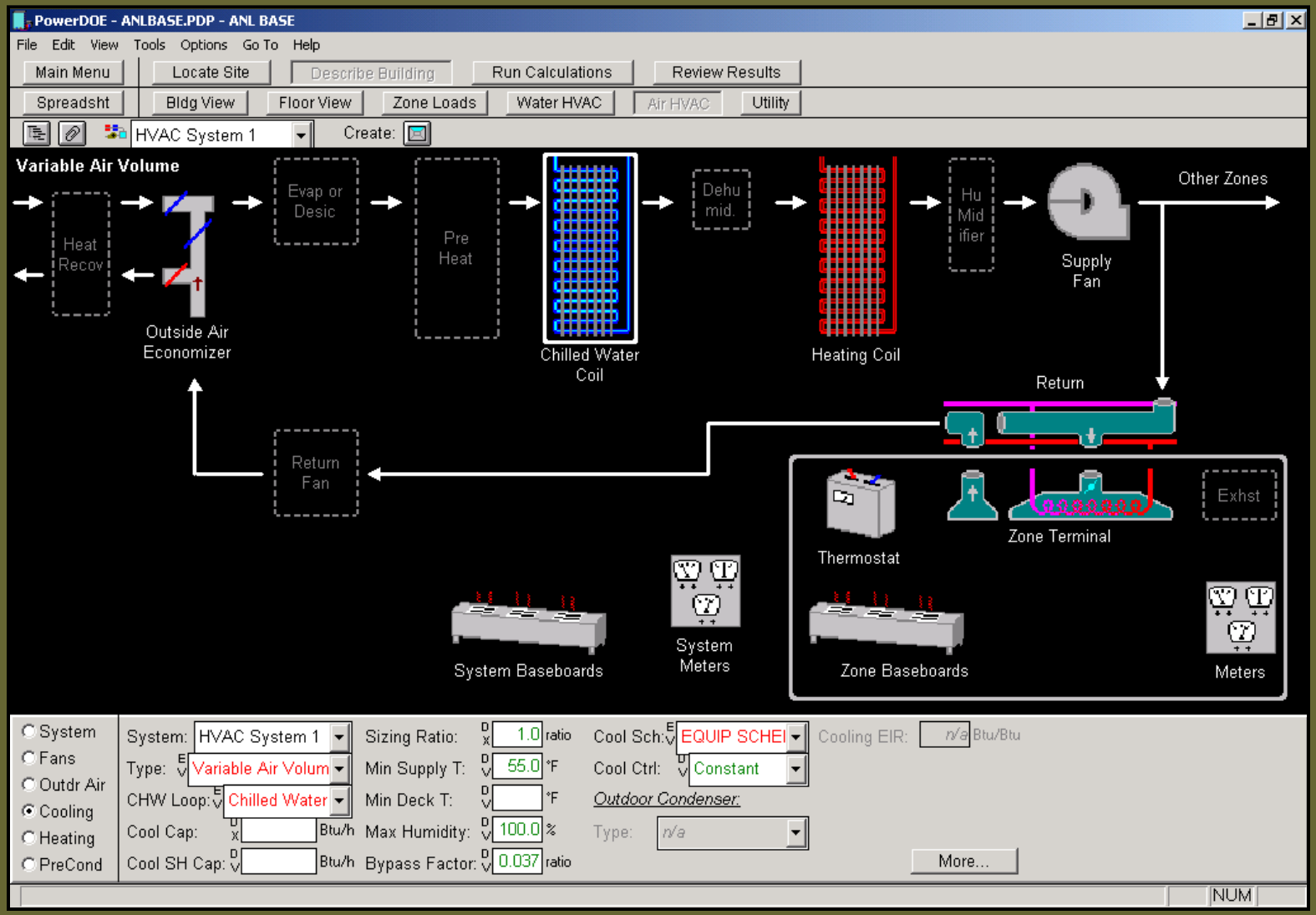
Schedule:	E V	OCCUP YEAR 1	
Area/Person:	E V	200	ft2
Number of People:	D X	12.89	
Total Heat Gain:	D X	450	Btu/h-person
Sensible Heat Gain:	D X	268	Btu/h-person
Latent Heat Gain:	D X	177	Btu/h-person

Default | OK | Cancel

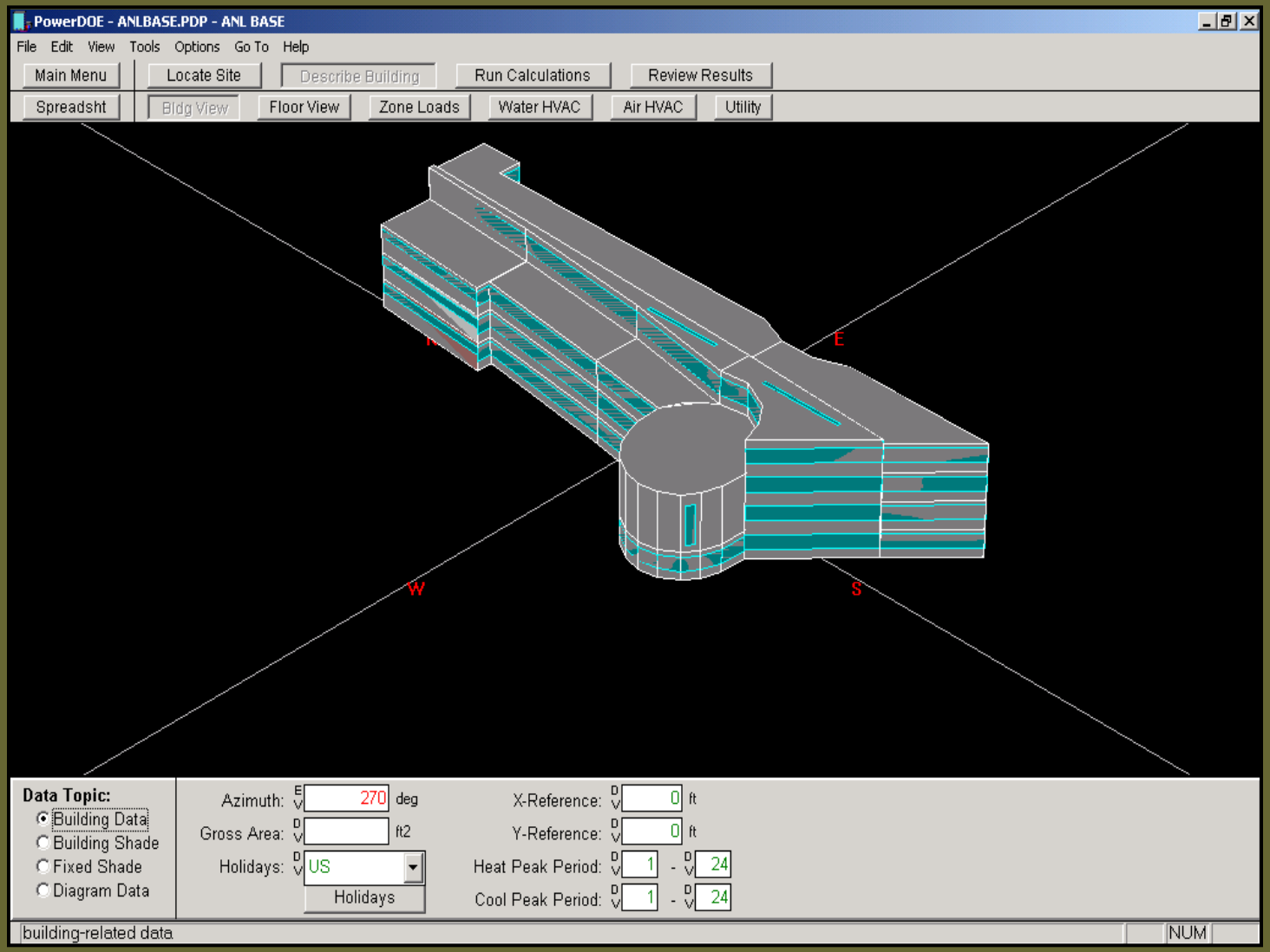
Space:		Space A2			General Lighting:	D V	1.60 W/ft2
Zone Type:	D X	Conditioned			Fixture Type:	D V	Sus Fluor
Sunspace:	D V	No	Infiltration:	D V	None	Task Lighting:	D V 0.00 W/ft2
Loads Calc Temp:	E V	74.0 °F	AirChngs/Hr:		n/a	Electric Equipment:	D V 0.00 W/ft2
Area/Person:	E V	200.0 ft2	Daylighting:	D V	No	Process Equipment:	n/a Btu/h

Name of the schedule that governs occupancy in the selected space | NUM

PowerDOE > **HVAC INPUT**

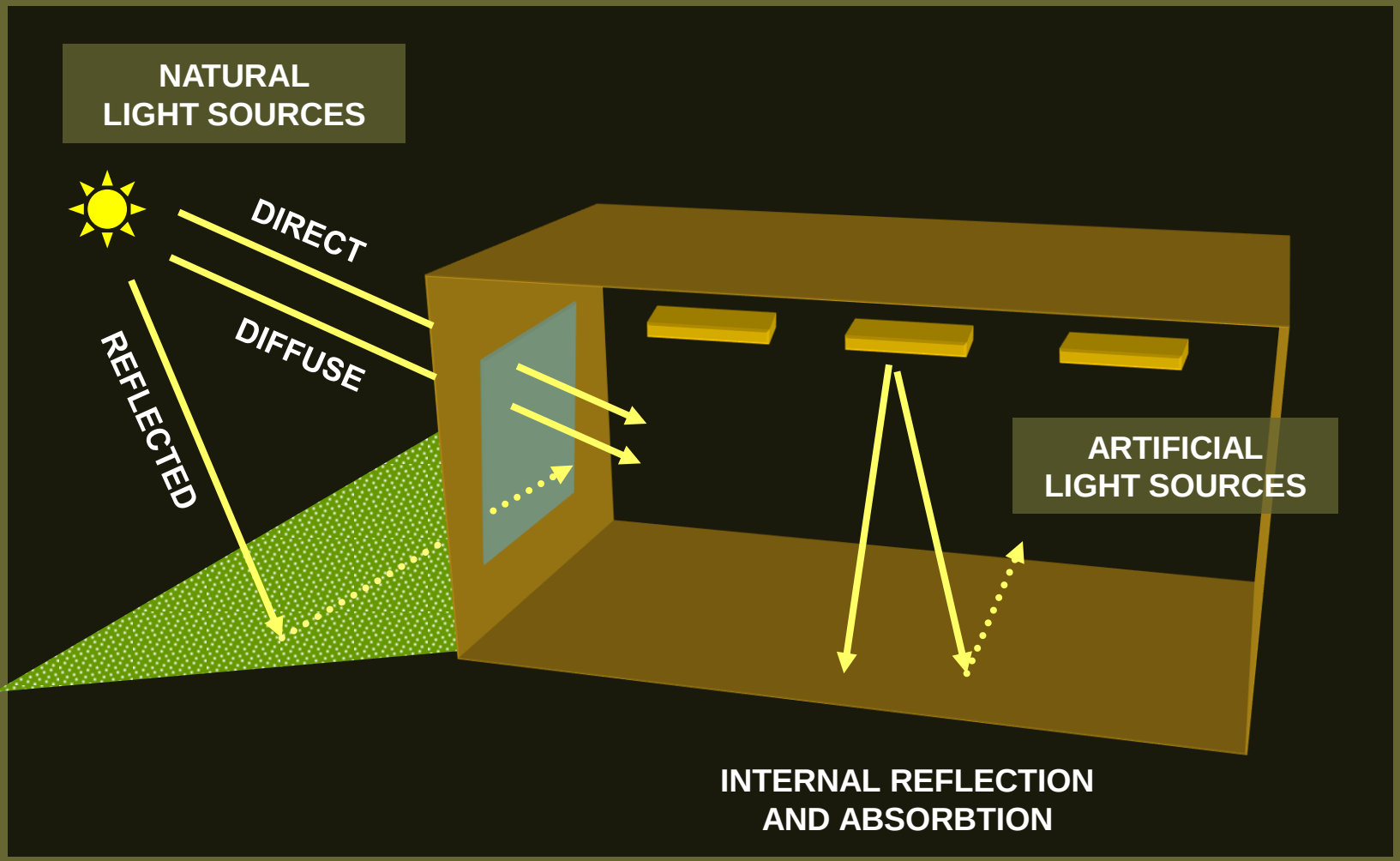


PowerDOE > BUILDING GEOMETRY INPUT

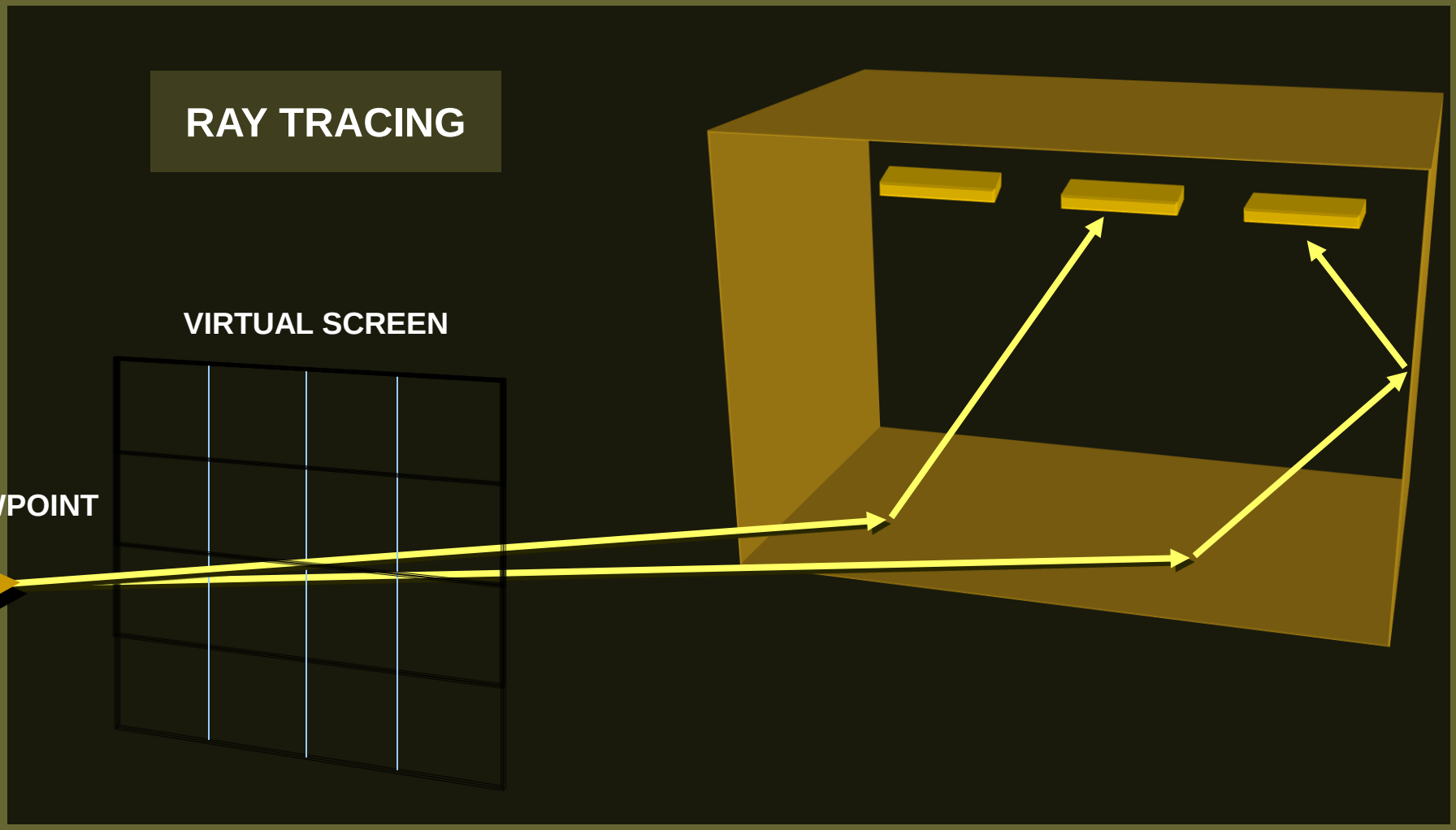


DAYLIGHT TOOLS ANALYSIS

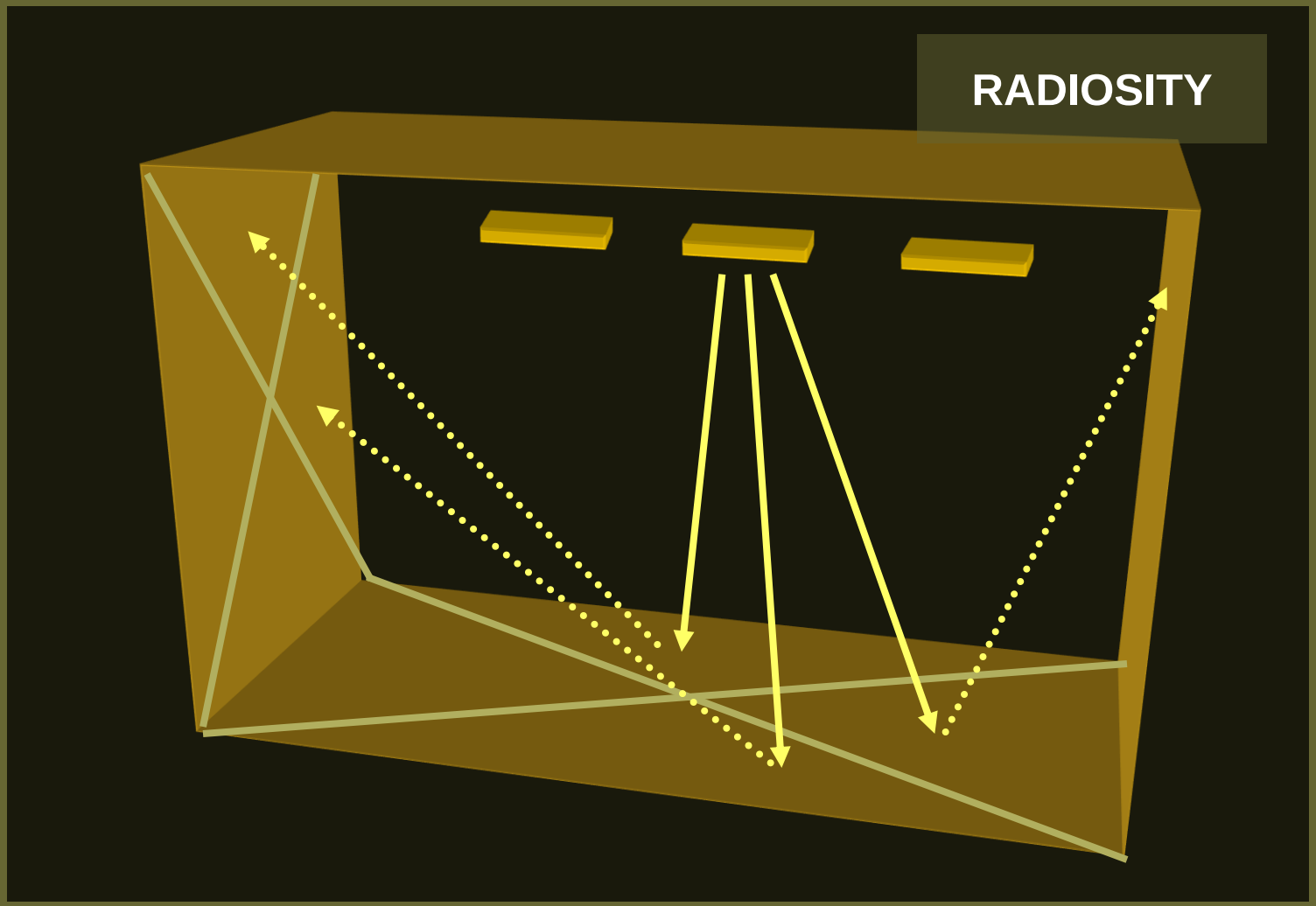
DAYLIGHTING ANALYSIS > **WHAT IT DOES**



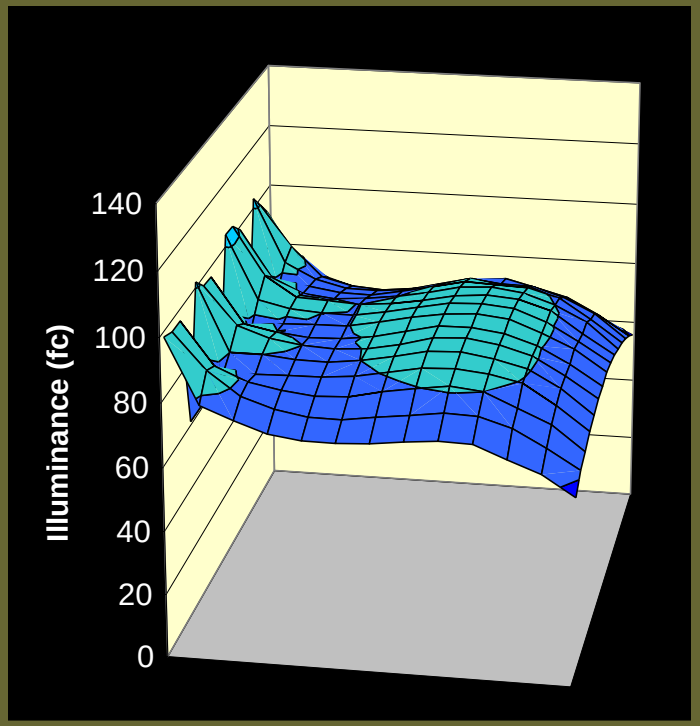
DAYLIGHTING ANALYSIS > **HOW IT WORKS**



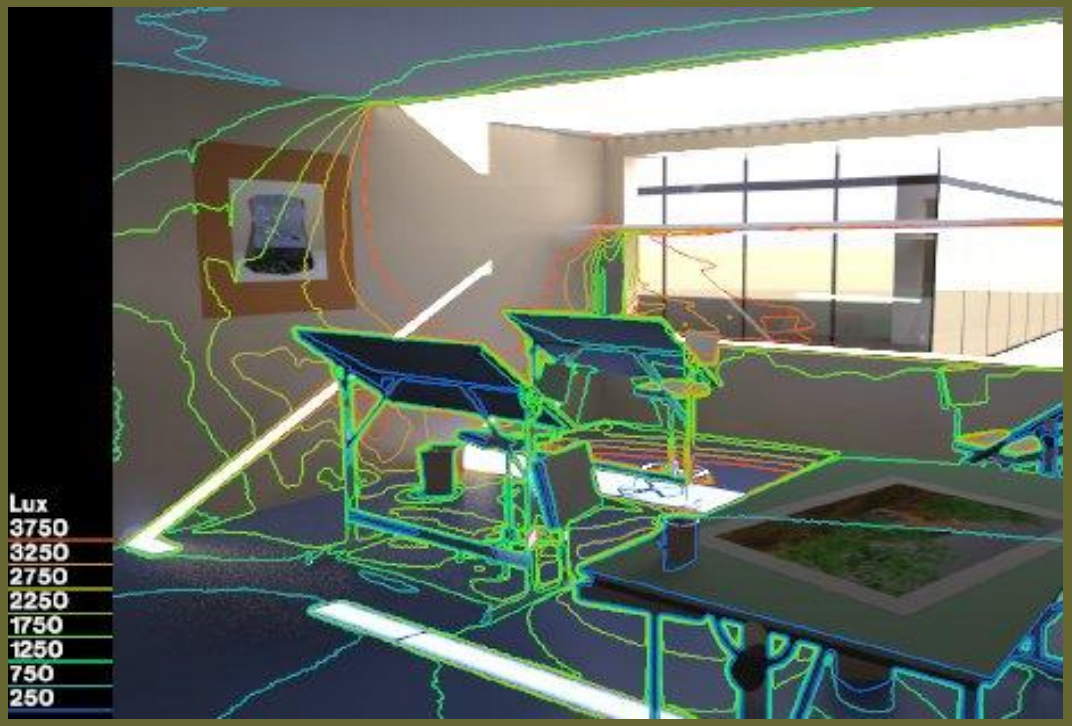
DAYLIGHTING ANALYSIS > **HOW IT WORKS**



DAYLIGHTING ANALYSIS > **OUTPUT**



ILLUMINANCE LEVELS **MAP**



ILLUMINANCE LEVELS **RENDERING**

IMAGES: COURTESY OF ANDREW LAU

ARCHITECT: OWP/P

DAYLIGHTING ANALYSIS > LEED™

LEED

Indoor Environmental Quality

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**

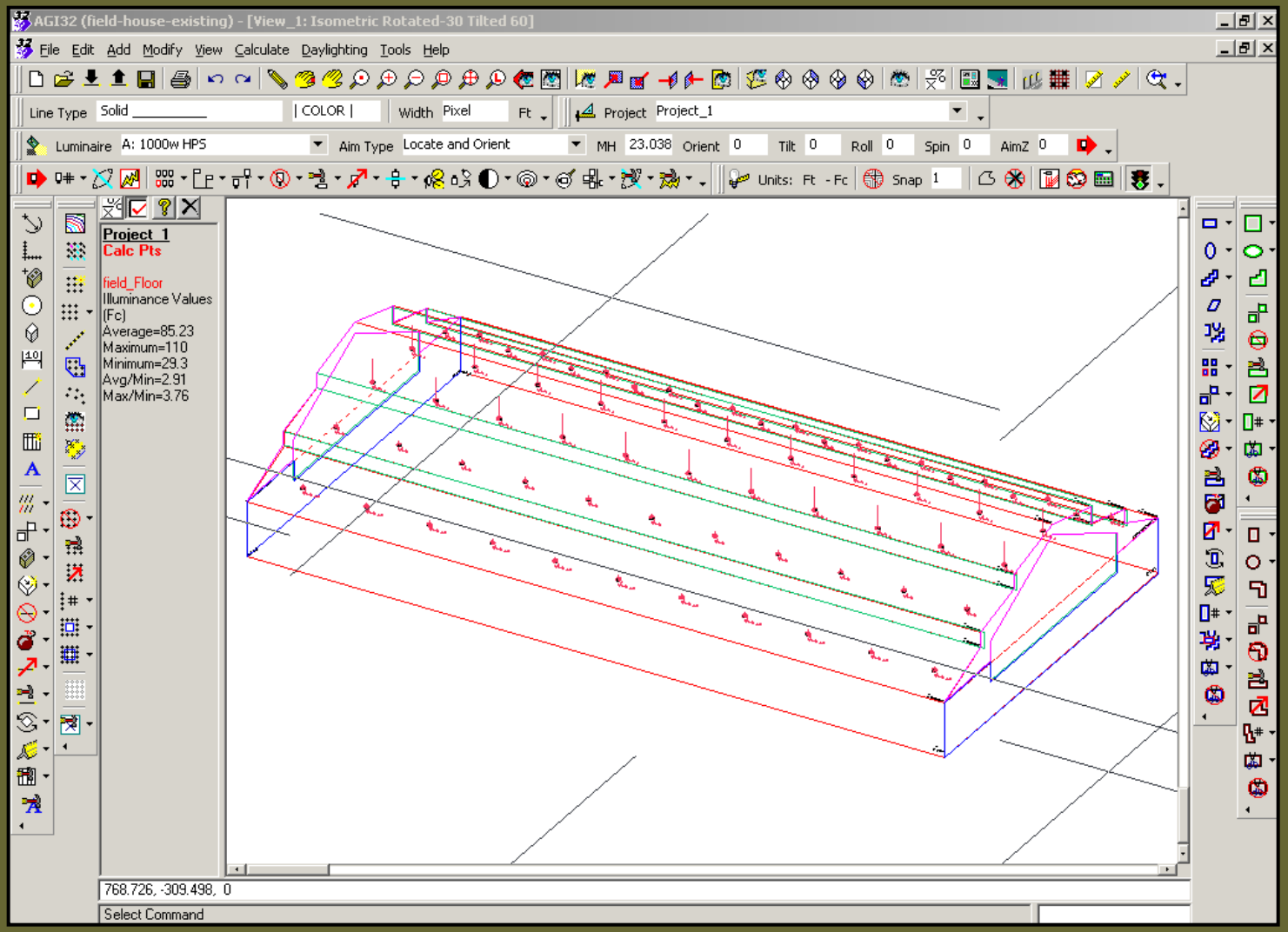
- **AGI**
  - web site: www.lightinganalysts.com
- **FormZ RadioZity**
  - web site: www.formz.com/products/formz_radiozity.html
- **Lumen Micro**
  - web site: www.lighting-technologies.com
- **Lightscape**
  - web site: www.autodesk.com/lightscape
- **Radiance**
  - various interfaces exist, including Desktop Radiance.
  - difficult to use, but also produces the most detailed simulations.
  - web site: http://radsite.lbl.gov/radiance

DAYLIGHTING ANALYSIS > **DEMONSTRATION**

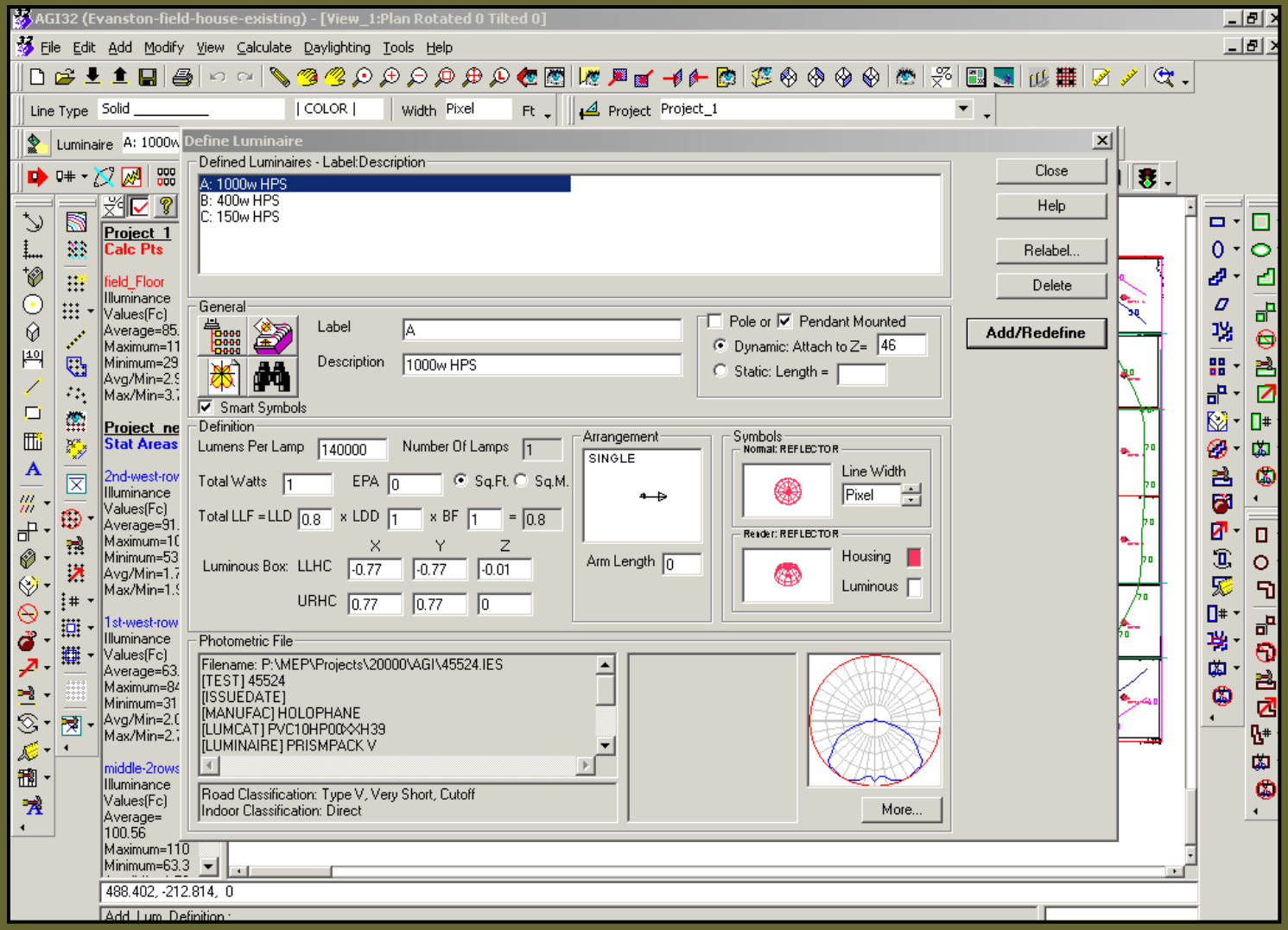
AGI32 (v1.61)

- 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



AGI32 > LUMINAIRE DEFINITION



PROJECT ▶ FIELDHOUSE / EVANSTON, IL ARCHITECT: OWP/P

AGI32 > DAYLIGHTING DEFINITION

AGI32 (field-house-new-calcDec21) - [Render]

Render Edit View Calculate Daylighting Help

Project_1
Calc Pts

field_Floor
Illuminance
Values(Fc)
Average=22.38
Maximum=50.7
Minimum=6.4
Avg/Min=3.50
Max/Min=7.92

Stat Areas

2nd-west-row
Illuminance
Values(Fc)
Average=19.73
Maximum=36.1
Minimum=8.0
Avg/Min=2.47
Max/Min=4.51

1st-west-row
Illuminance
Values(Fc)
Average=12.85
Maximum=19.4
Minimum=6.4
Avg/Min=2.01
Max/Min=3.03

middle-2rows
Illuminance
Values(Fc)
Average=29.05
Maximum=50.7
Minimum=10.0
Avg/Min=2.91
Max/Min=5.07

2nd-east-row
Illuminance
Values(Fc)
Average=22.08
Maximum=41.6
Minimum=8.5
Avg/Min=2.60

Daylight Parameters

- [x] Enable Daylighting
- [ ] Consider Electric Lighting In Daylight Calculations

Sky Conditions: Clear Sky / Partly Overcast / Overcast

- [x] Sky Dome

Site Location
Name: Manage...
Latitude: 41.79 Degrees
Longitude: 87.68 Degrees
Compass: 180 Degrees — Set Compass...

Date And Time
Date: Sunday , December 21, 2003
Time: 3:00:00 PM — Daylight Savings

Daylighting is only active in Full Calculation Mode.

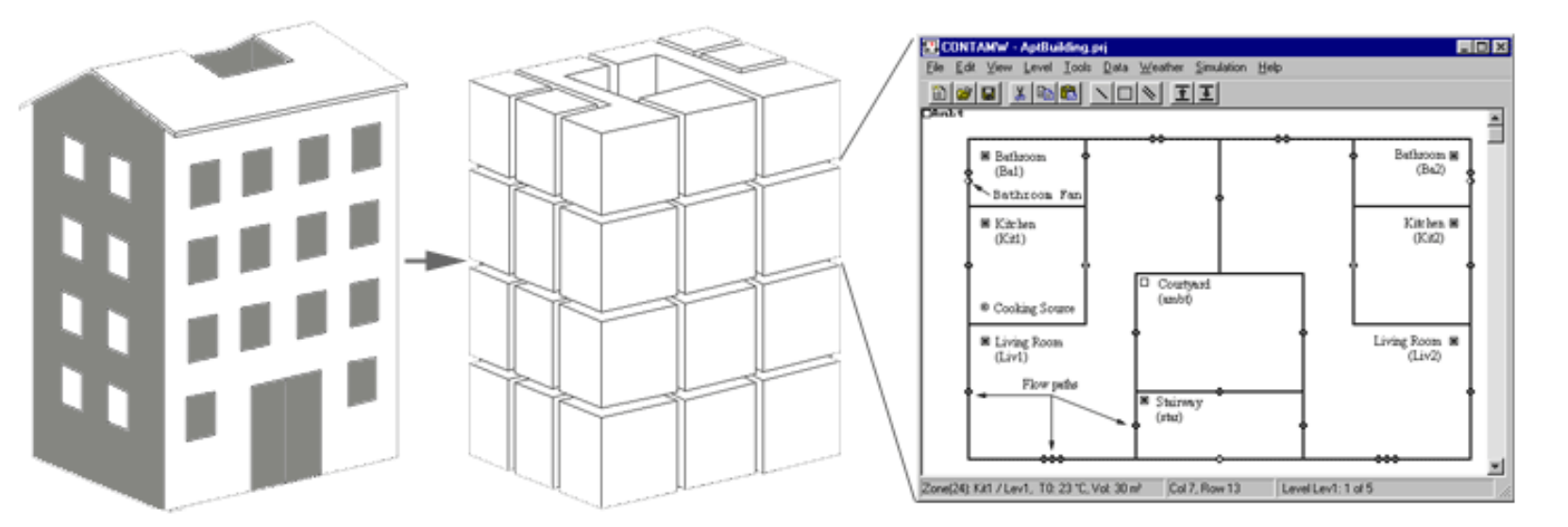
Ok
Cancel
Help

Day Daylighting :

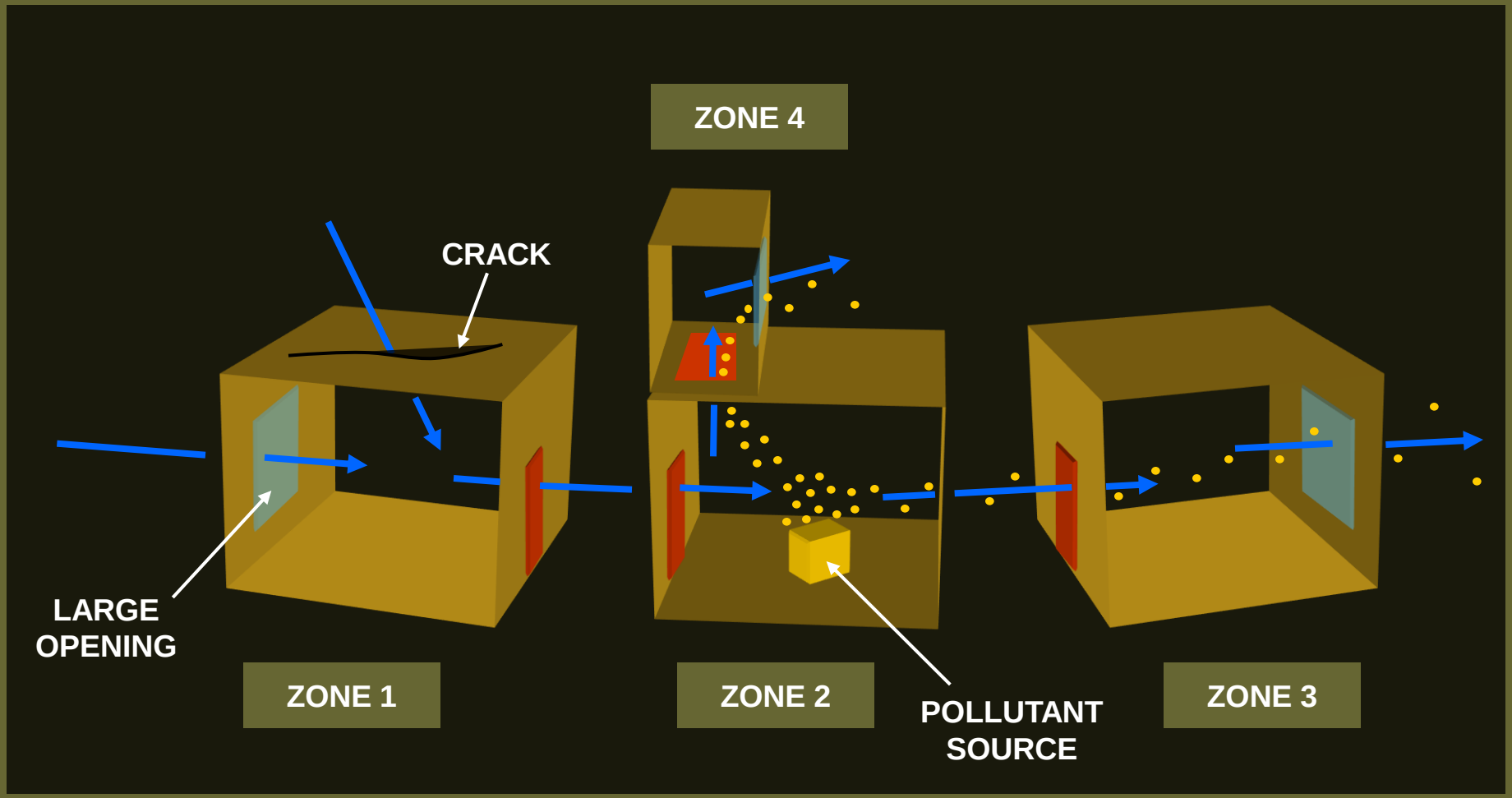
PROJECT ▶ FIELDHOUSE / EVANSTON, IL ARCHITECT: OWP/P

MULTIZONE AIRFLOW TOOLS

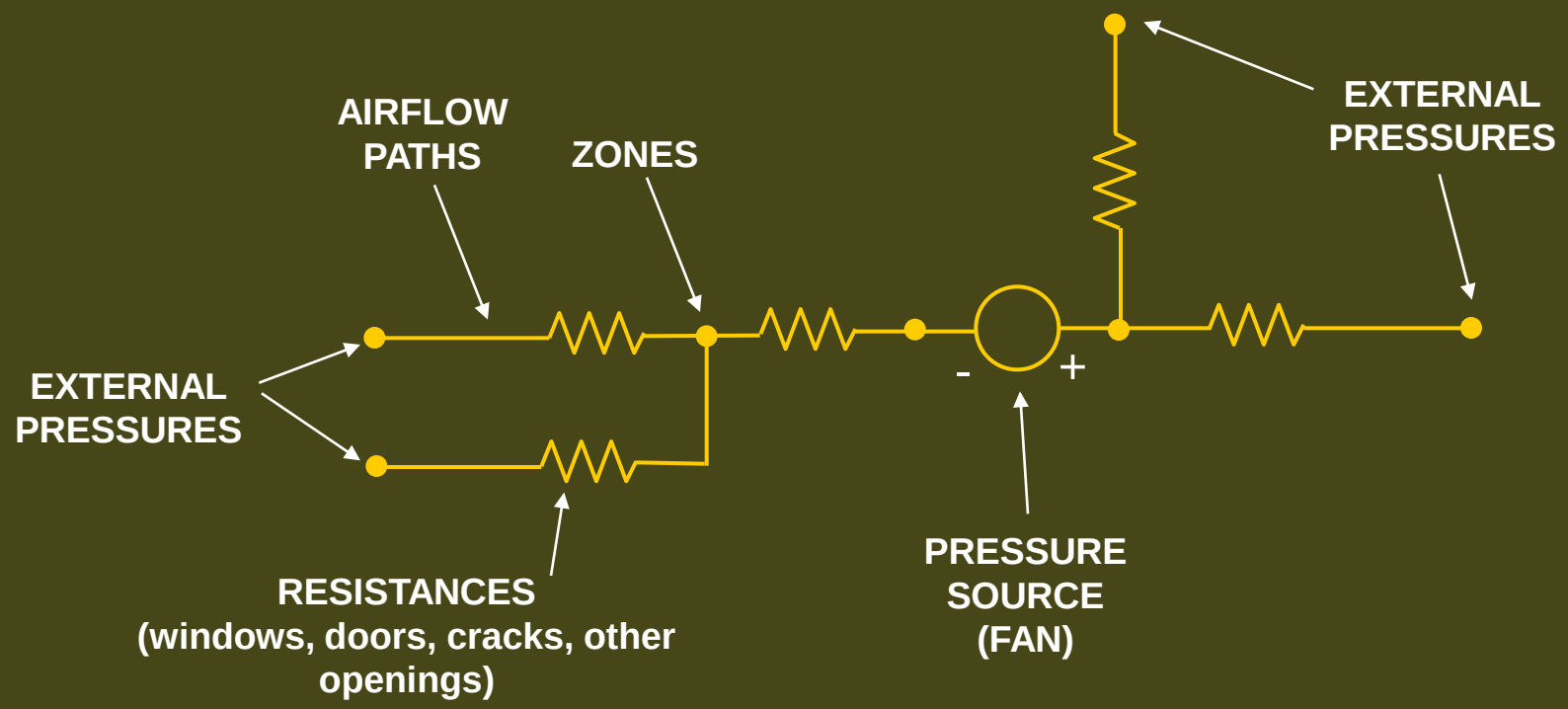
MULTIZONE AIRFLOW > **WHAT IT DOES**



MULTIZONE AIRFLOW > **WHAT IT DOES**



MULTIZONE AIRFLOW > **HOW IT WORKS**



MULTIZONE AIRFLOW > LEED™

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.

MULTIZONE AIRFLOW > LEED™

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/
  - Includes simple graphical interface
- **COMIS** > epb1.lbl.gov/comis/users.html

MULTIZONE AIRFLOW > **DEMONSTRATION**

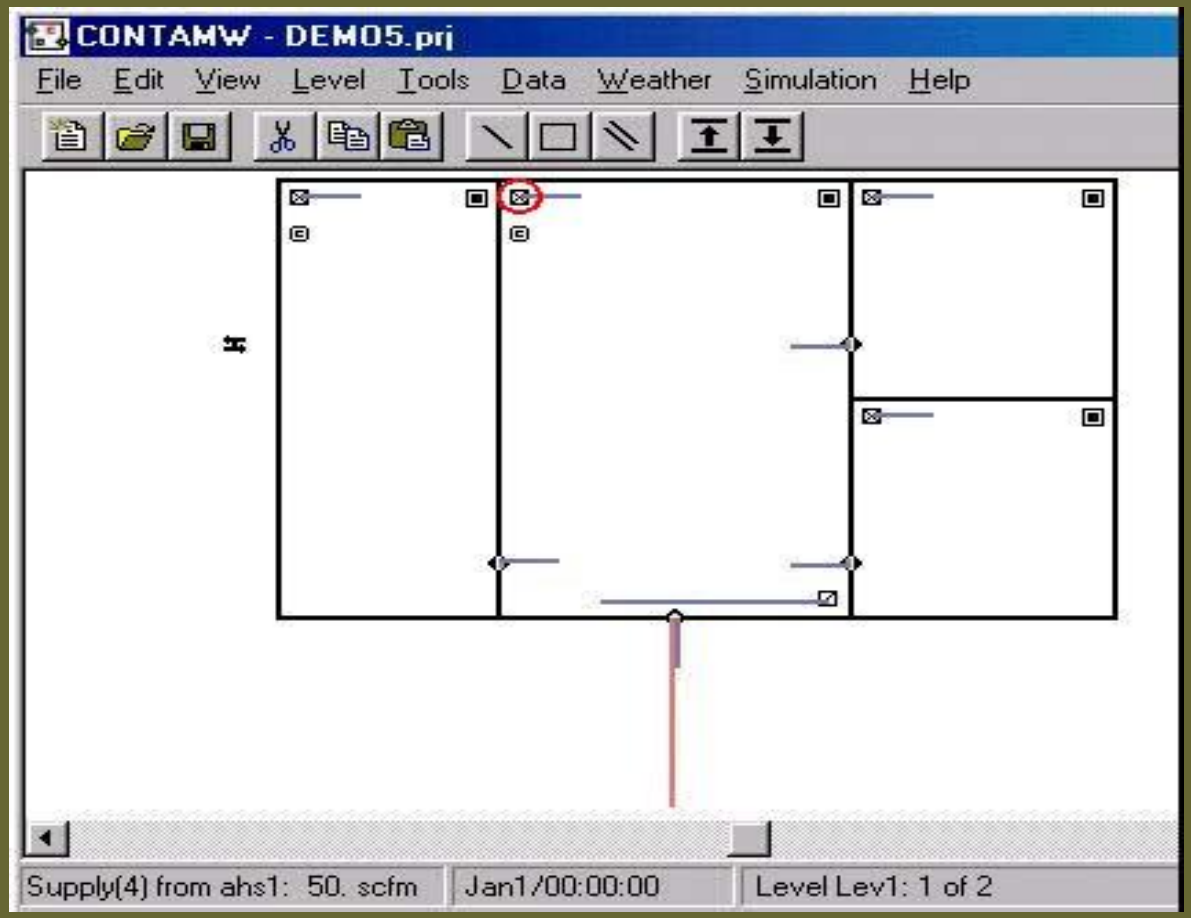
CONTAMW (v2.0)

- Multizone airflow and contaminant transport analysis software.
- Predicts the following;
  - Airflows
  - Contaminant concentrations
  - Personal exposure

CONTAMW 2.0

Multizone Airflow and Contaminant Transport Analysis Software

CONTAMW > AIRFLOW PATH



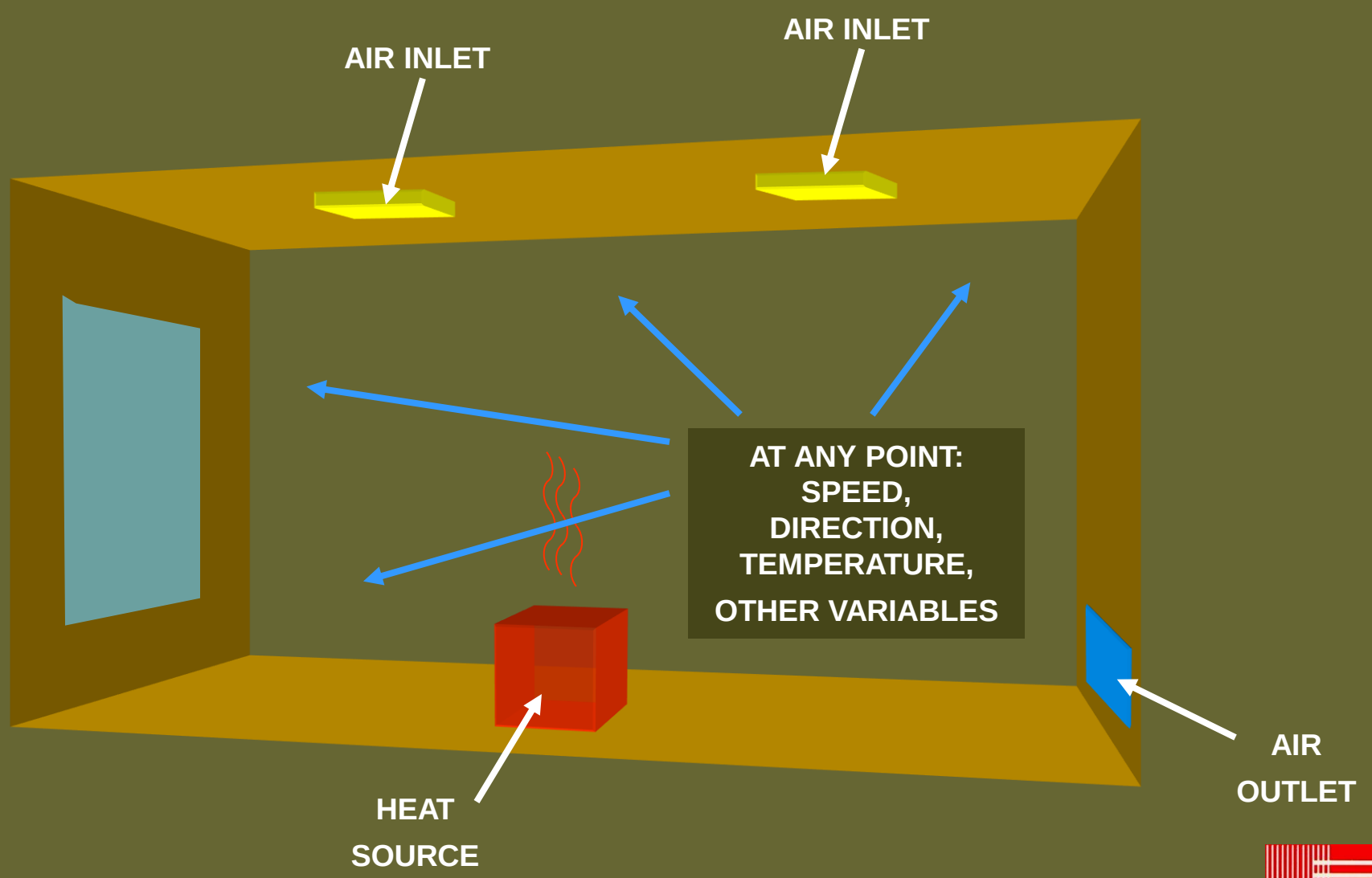
SKETCHPAD RESULTS DISPLAY FEATURE

COMPUTATIONAL FLUID DYNAMICS

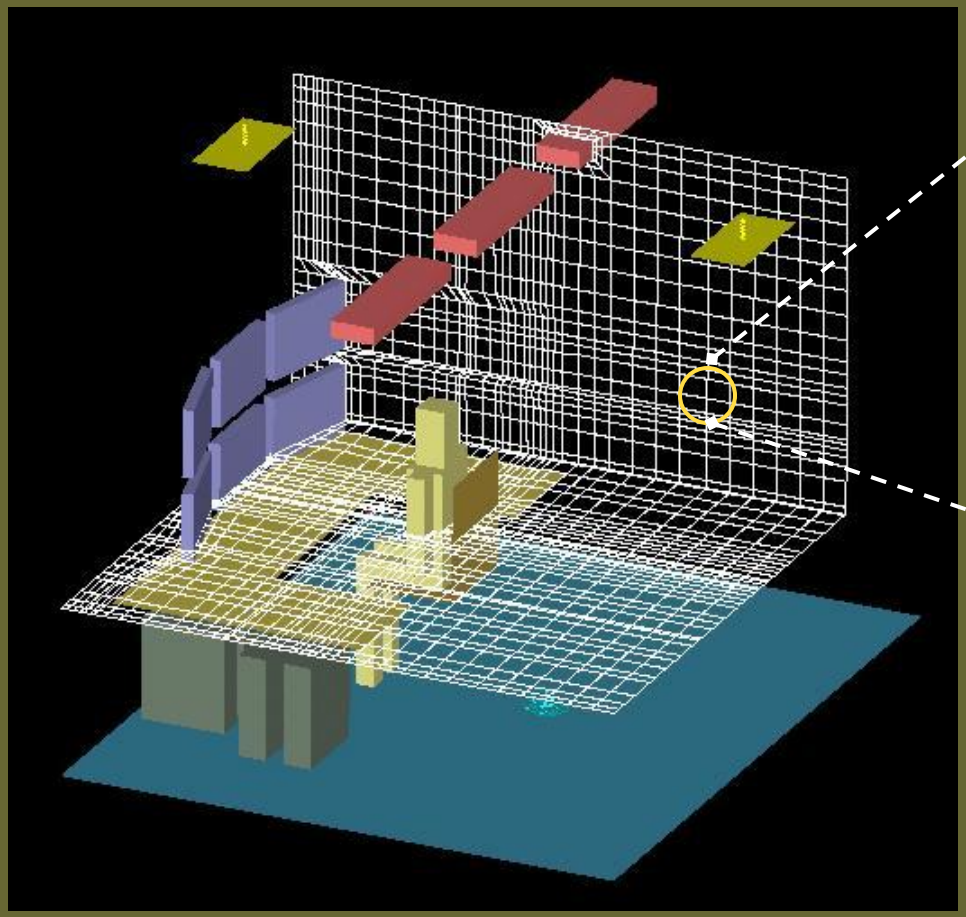
CFD

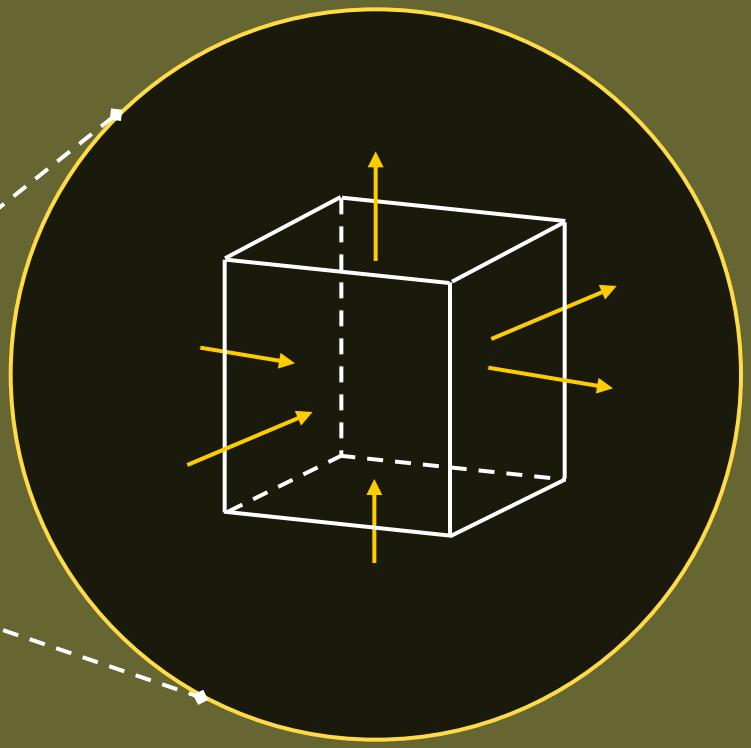
TOOLS

CFD > WHAT IT DOES



CFD > HOW IT WORKS





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

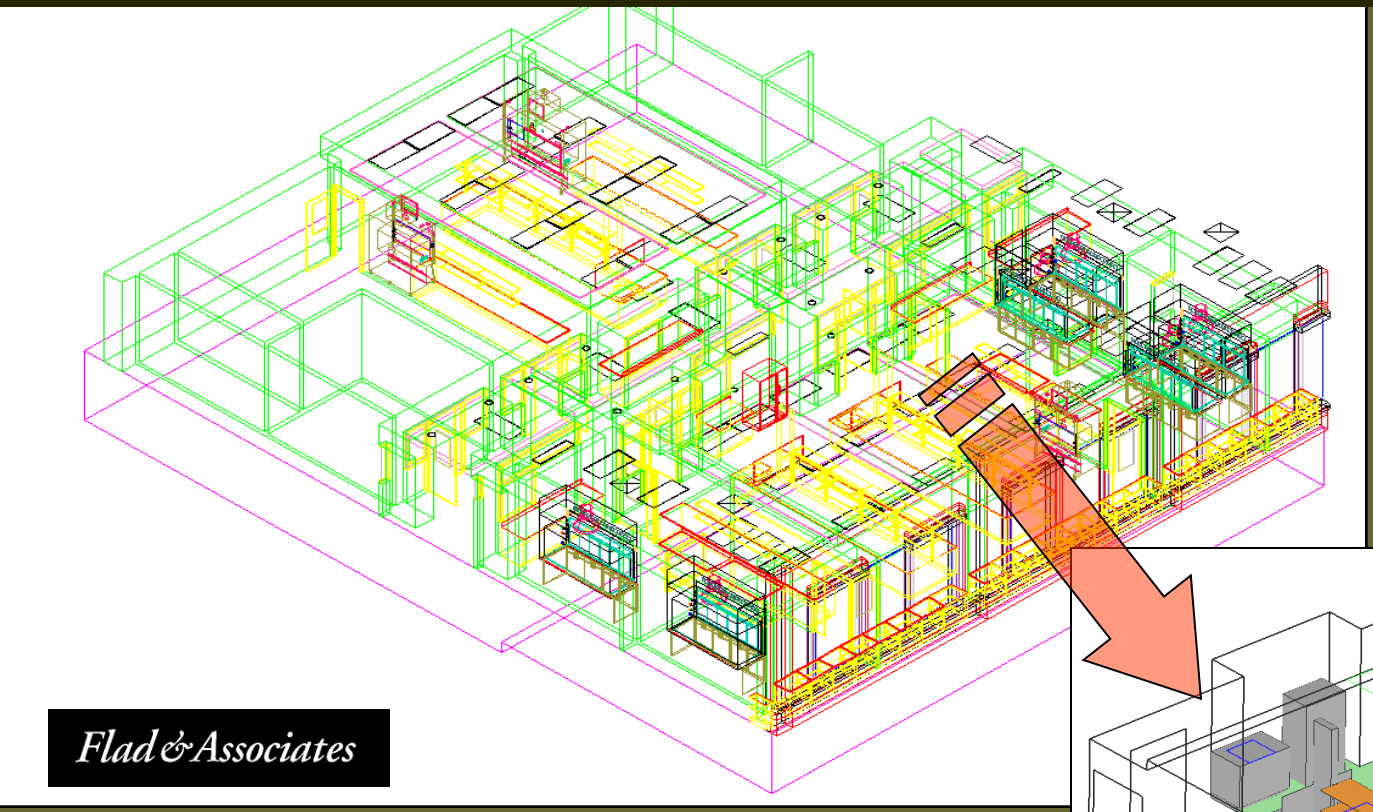
OUTPUTS

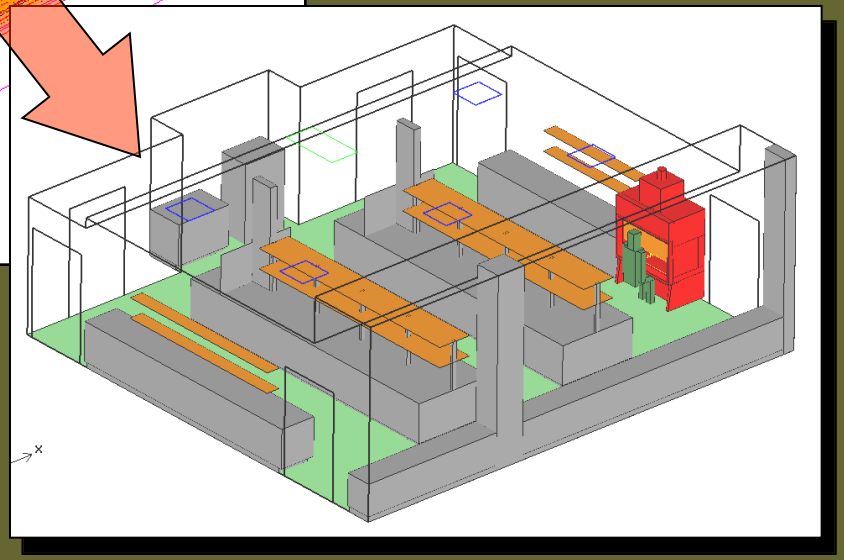
- Temperature
- Speed and direction
- Pollutant concentration
- Wholefield values
- Calculated metrics
  - Thermal comfort
  - Mean age of air

CFD > WHAT'S AVAILABLE

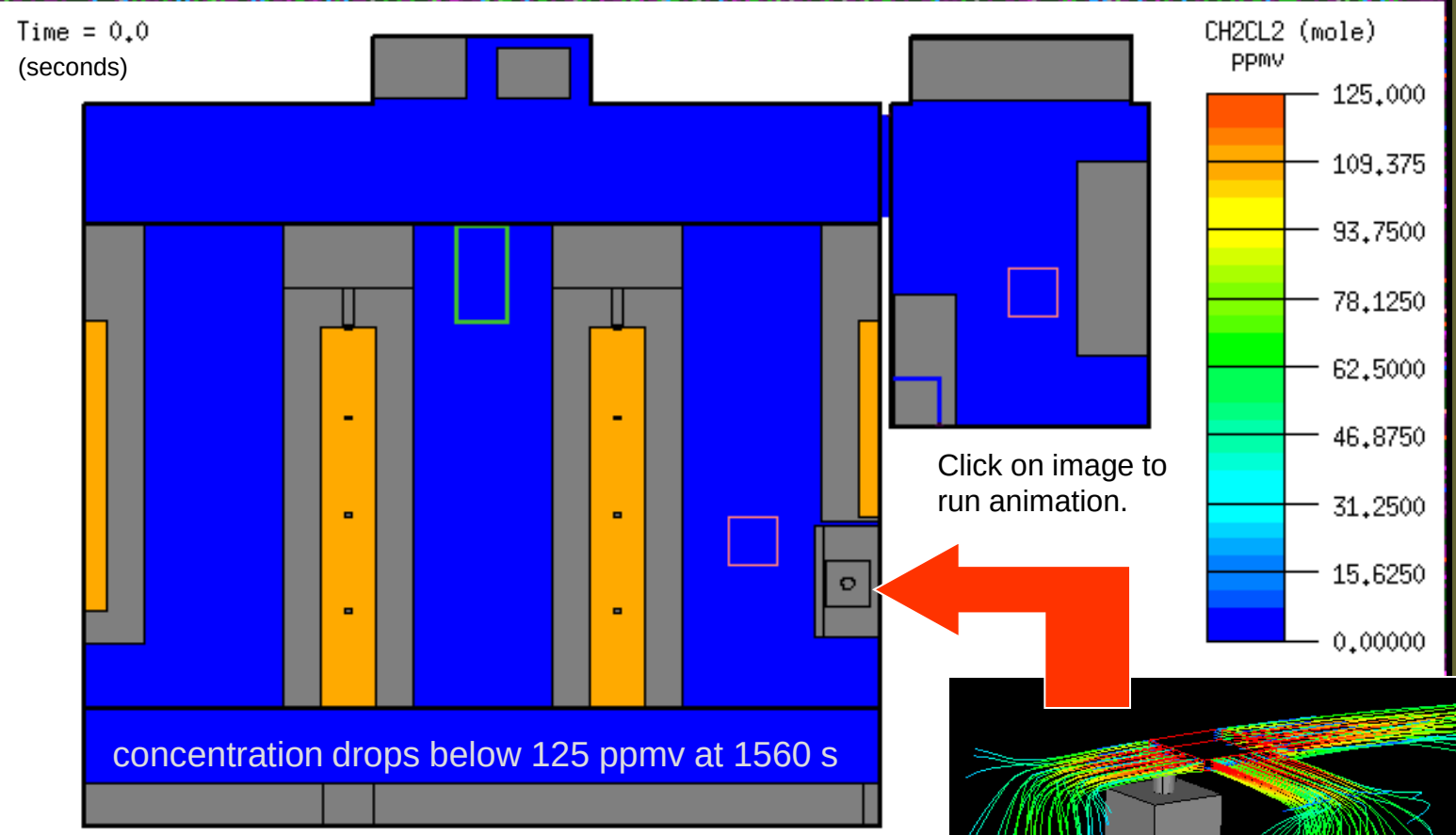
- **Fluent** > www.fluent.com
  - including Airpak interface for building applications
- **Flovent** > www.flovent.com
  - by Flomerics
  - also a building-specific interface for a general CFD package
- **PHOENICS** > www.cham.co.uk
  - mostly used be researchers

CFD > DEMONSTRATION



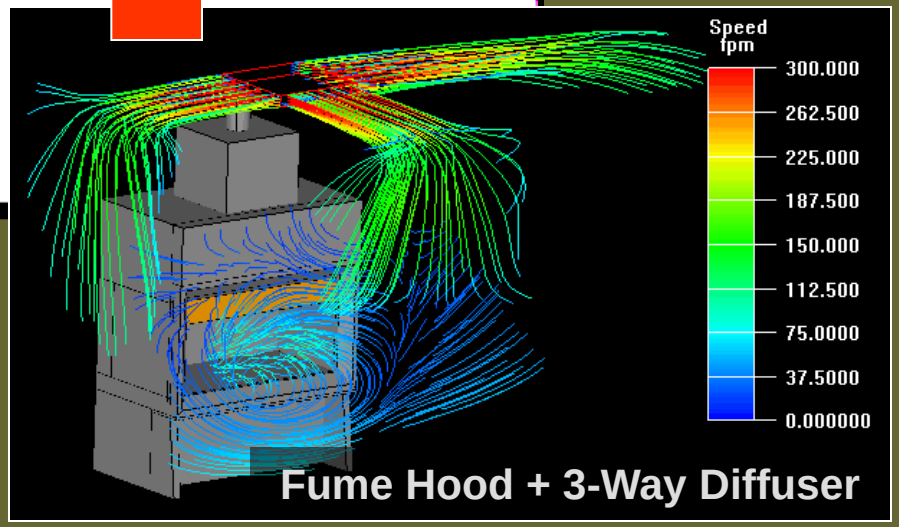


3D DXF CADD file imported as basis for airflow model



Click on image to run animation.

12 ACH



Flad & Associates

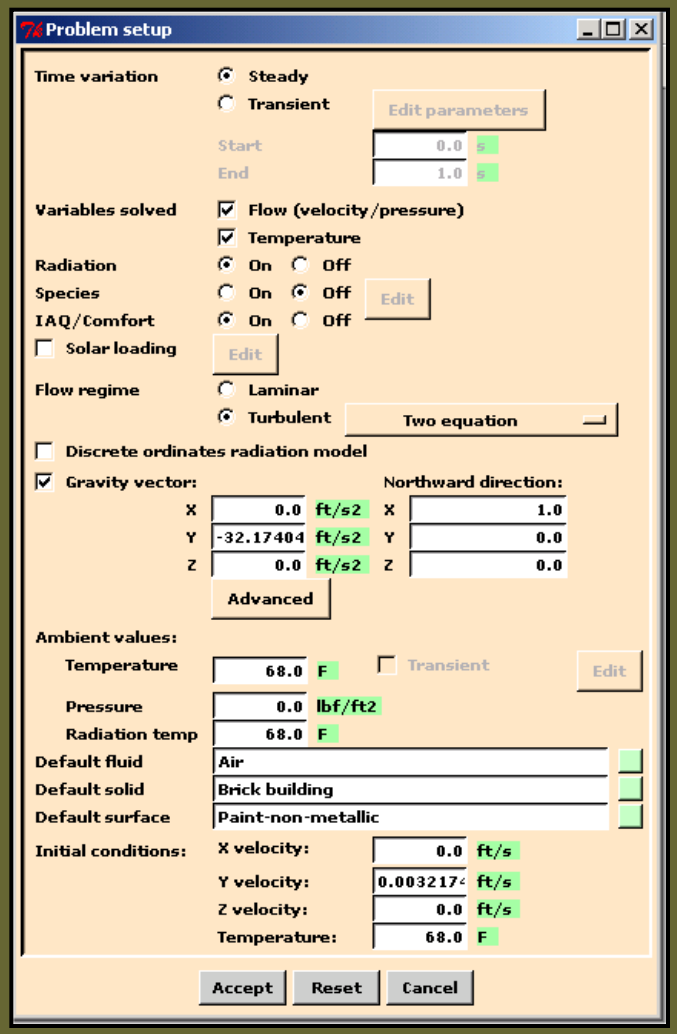
Airflow modeling can compute local conditions and predict thermal comfort

CFD > DEMONSTRATION

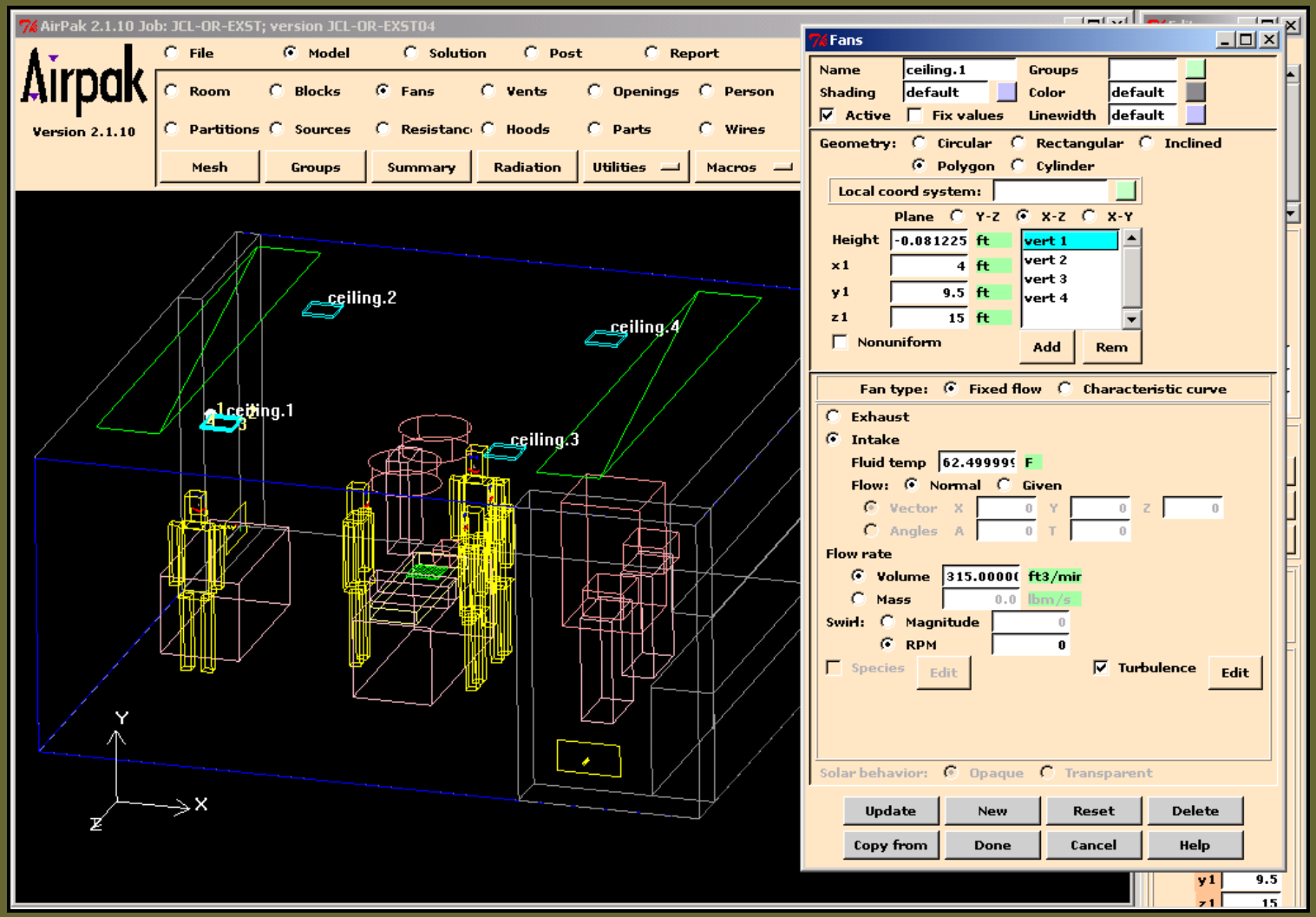
AIRPAK (v2.0)

- 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

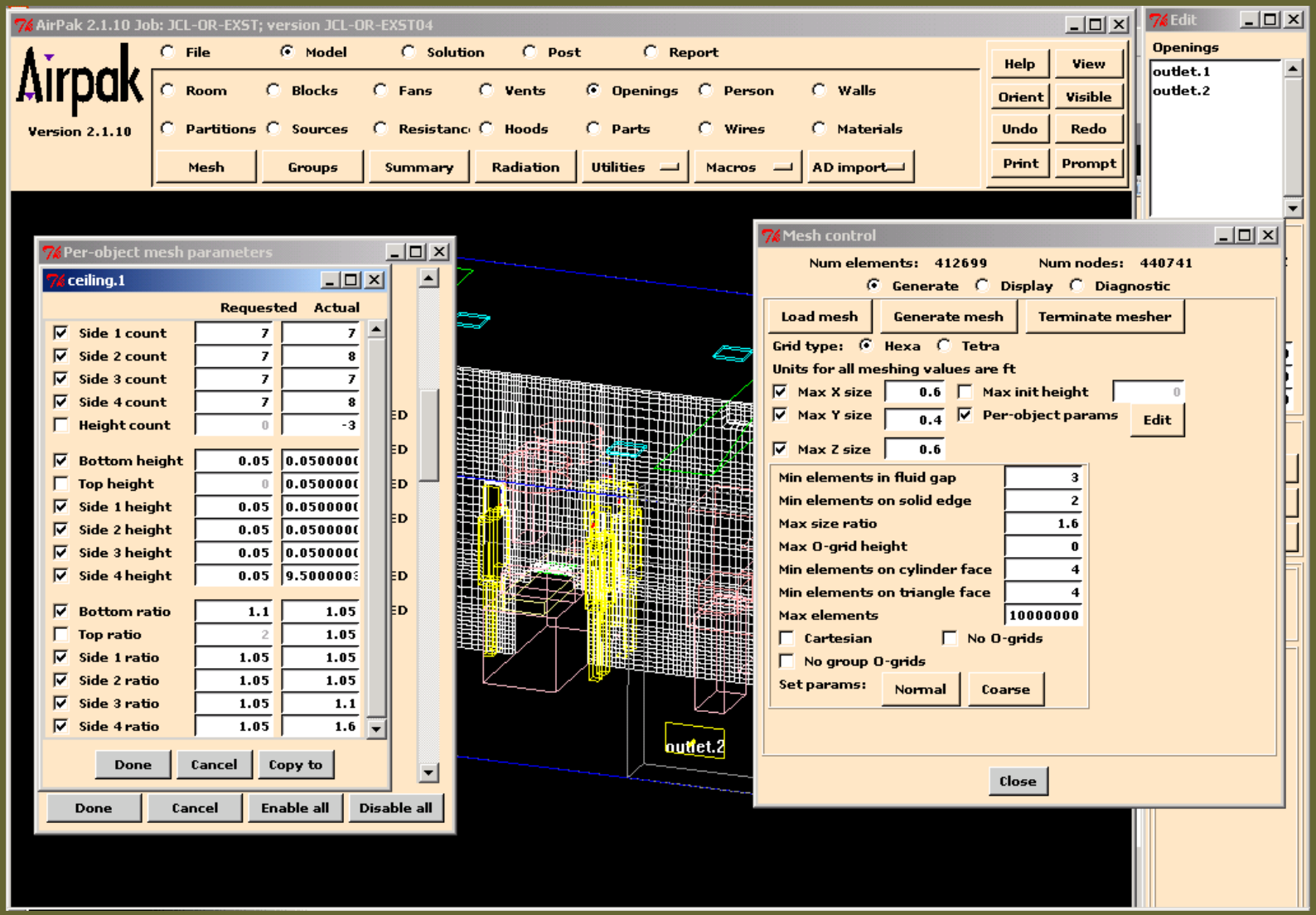
AIRPAK > PROBLEM DEFINITION



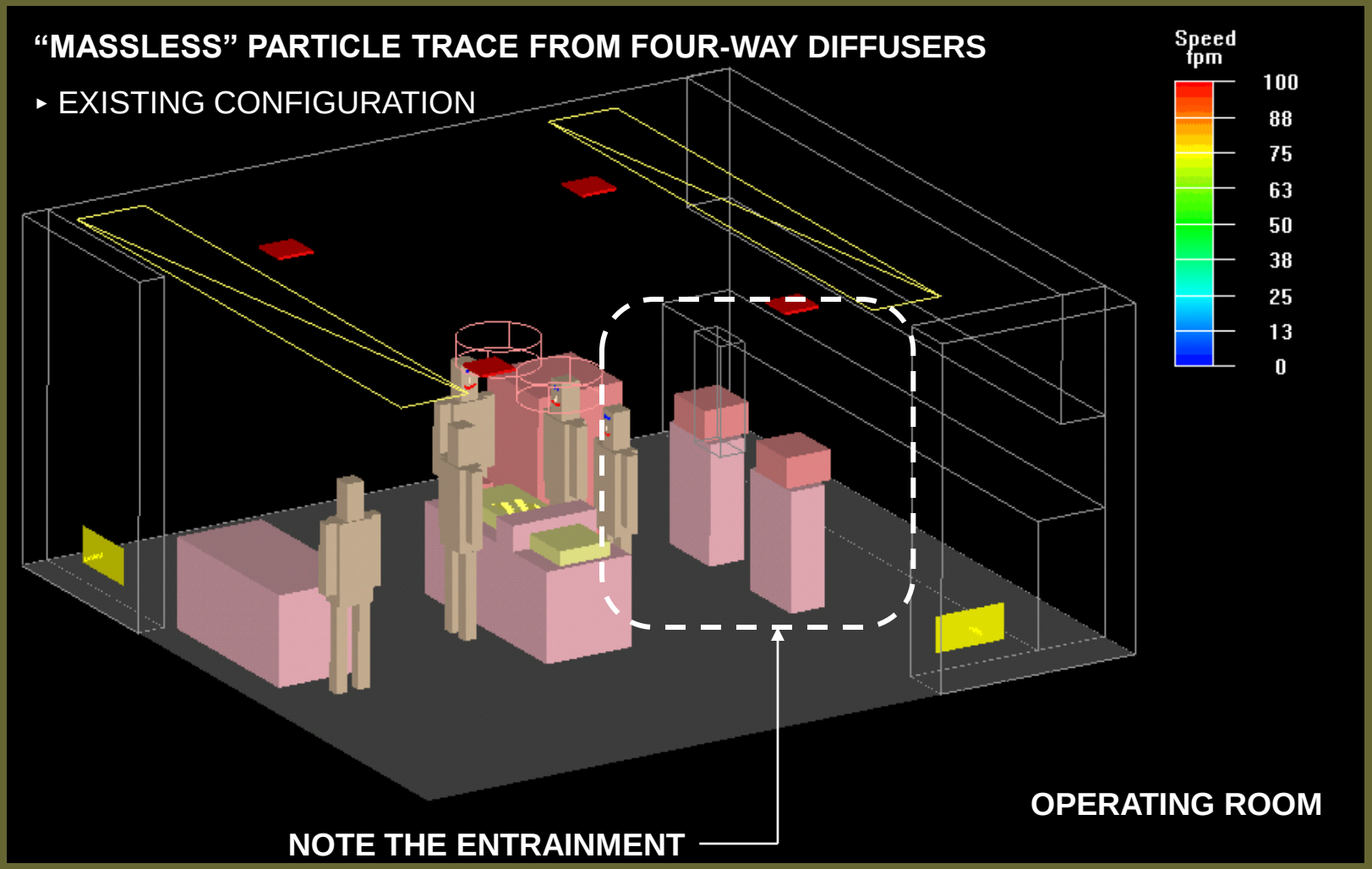
AIRPAK > GEOMETRY & BOUNDARY INPUTS



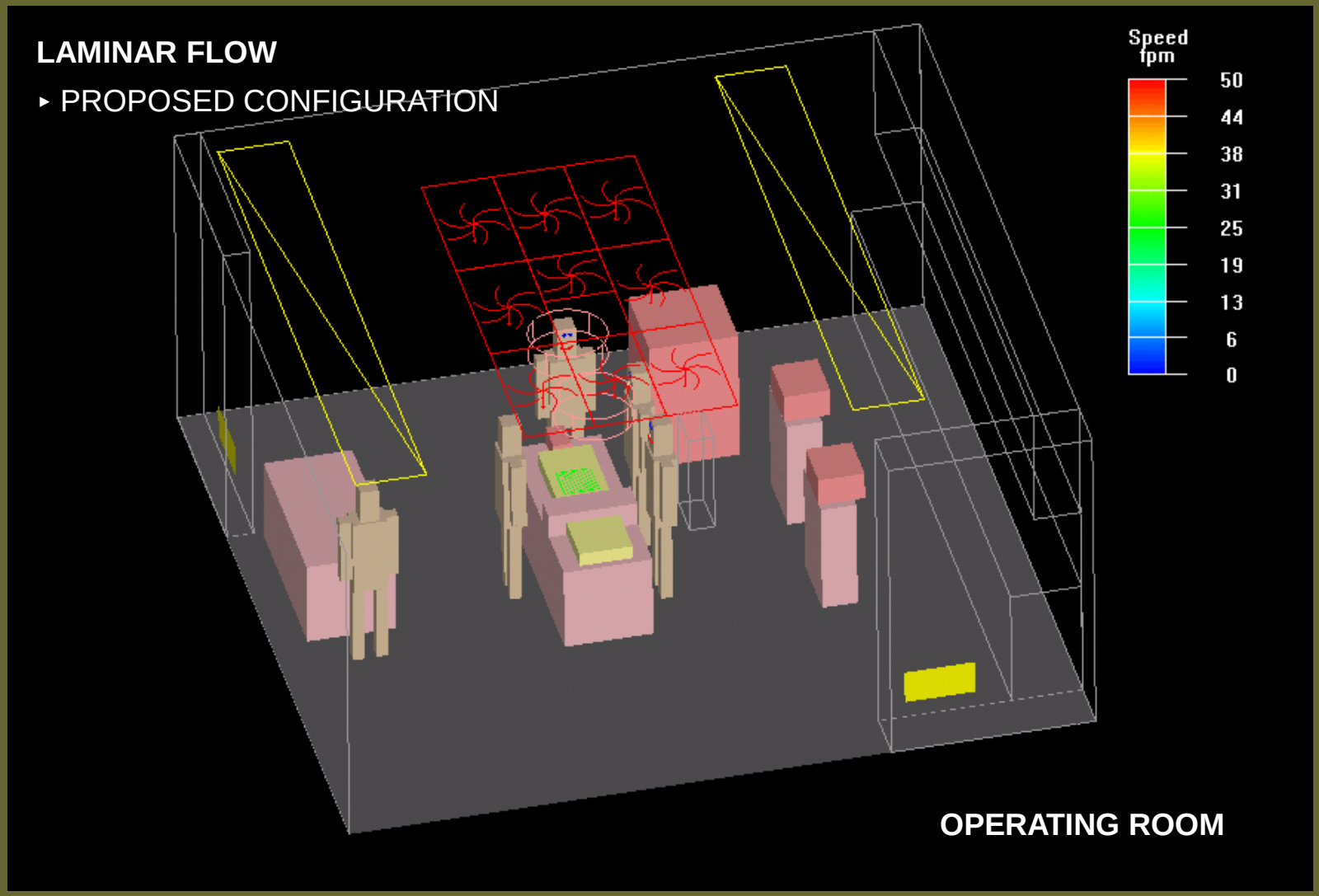
AIRPAK > MESH GENERATION



AIRPAK > OPERATING ROOM



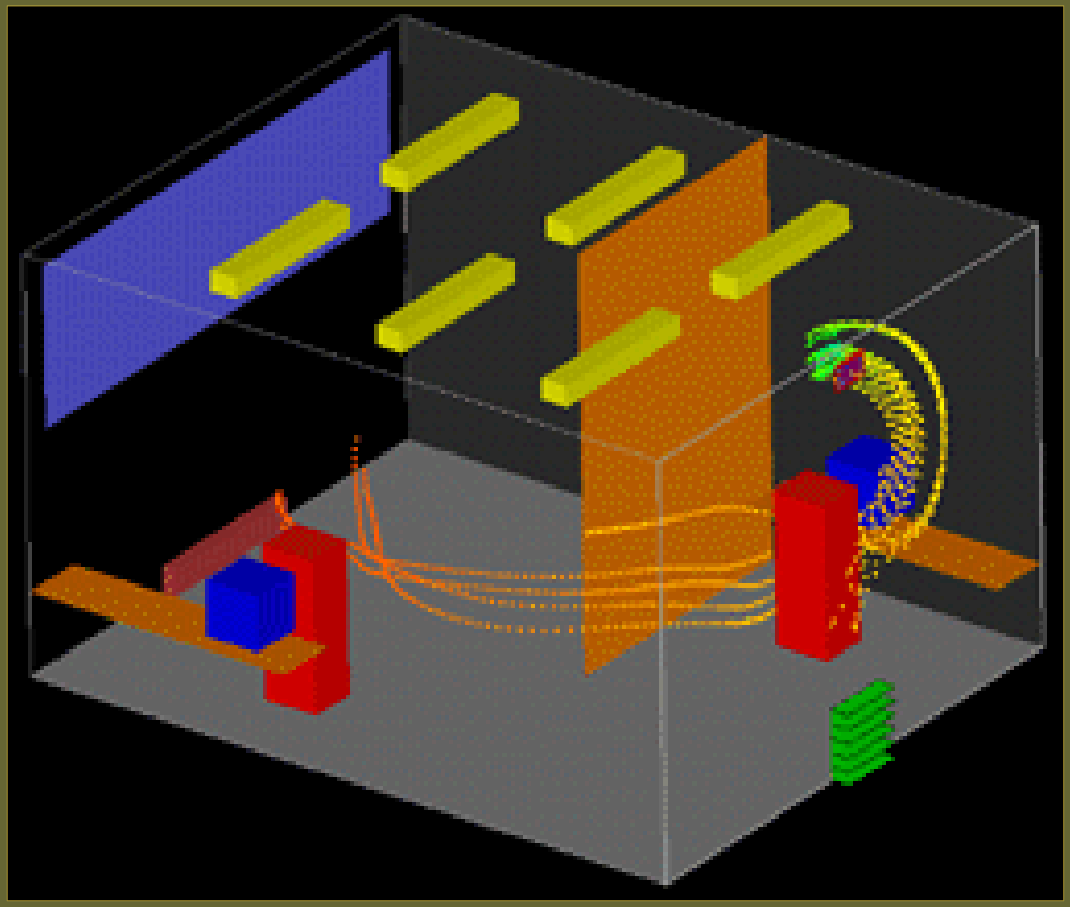
CFD > OPERATING ROOM



AIRPAK > PARTITIONED OFFICE

Ventilation of a Partitioned Office

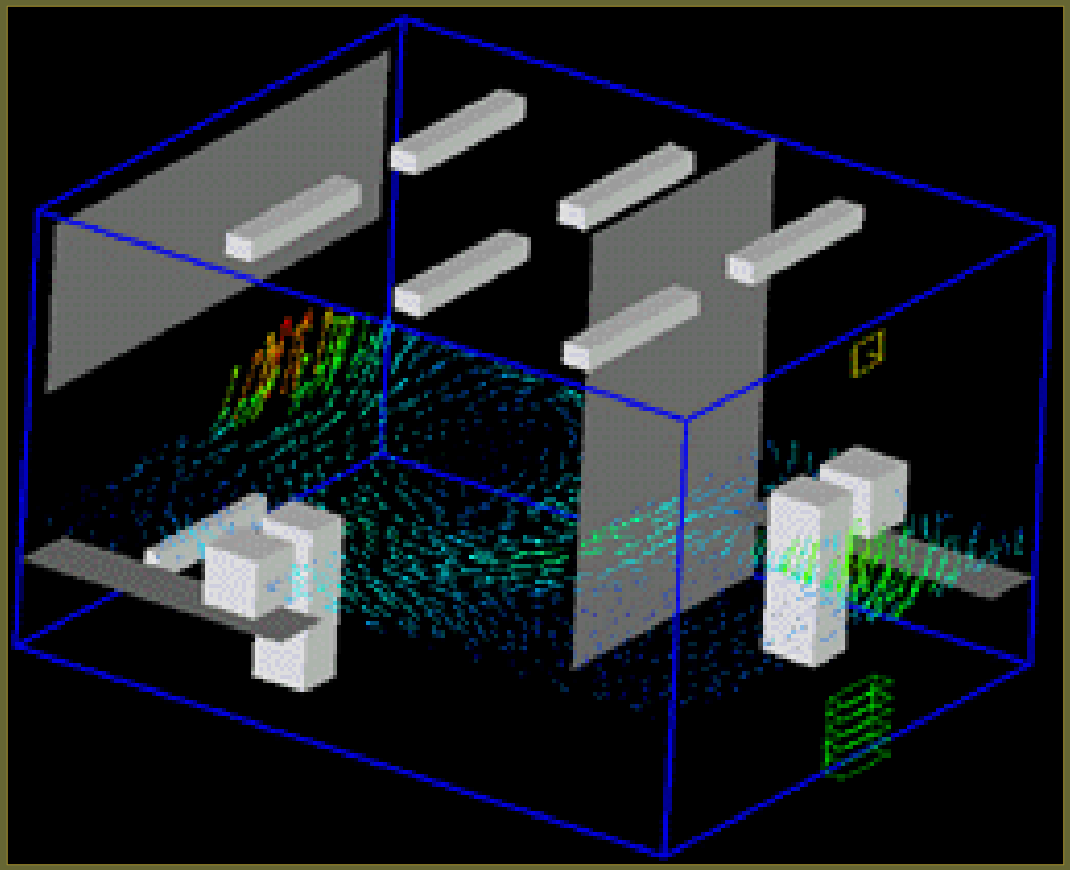
- Containing two occupants working at computers.
- Particle traces colored by mean age of air shows the path of supply air.



AIRPAK > **PARTITIONED OFFICE**

Velocity Vectors (on a horizontal cross-plane)

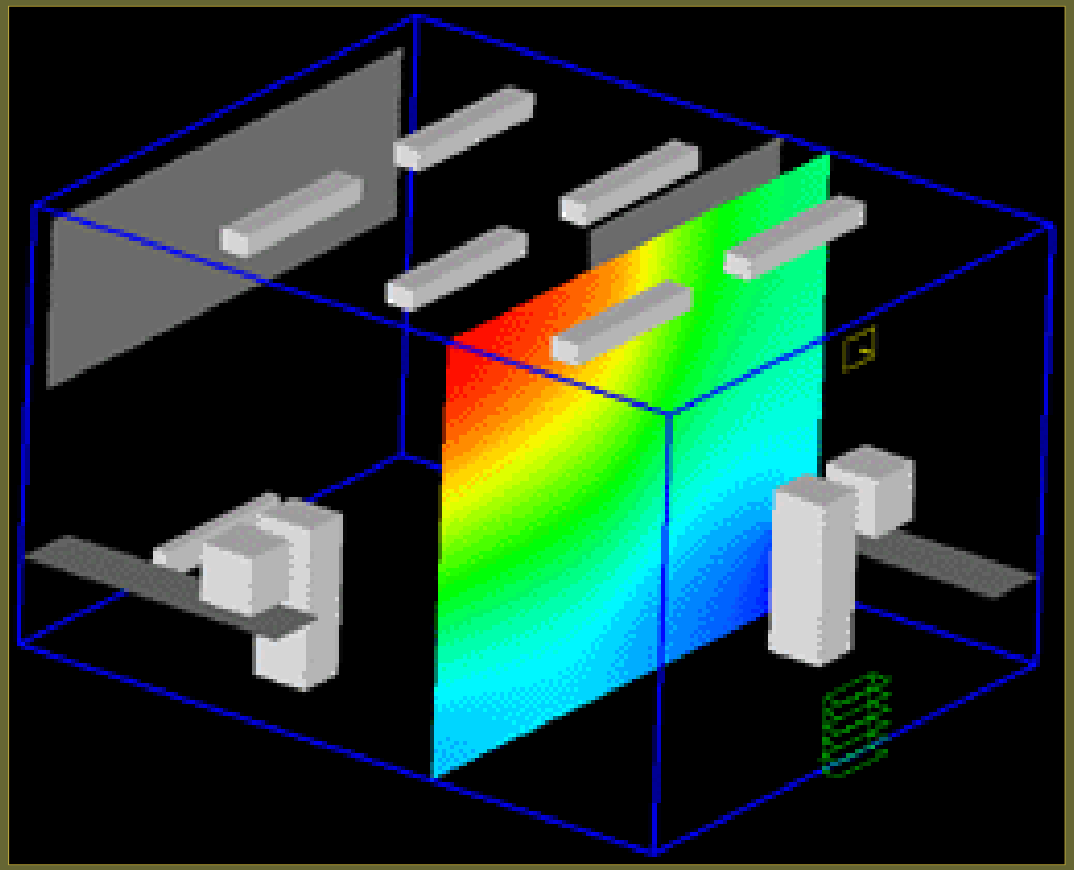
- Show the weaving flow pattern induced by the supply jet.
- As well as the convective plume which moves upward from the baseboard radiator



AIRPAK > **PARTITIONED OFFICE**

Mean Radiant Temperature Contours

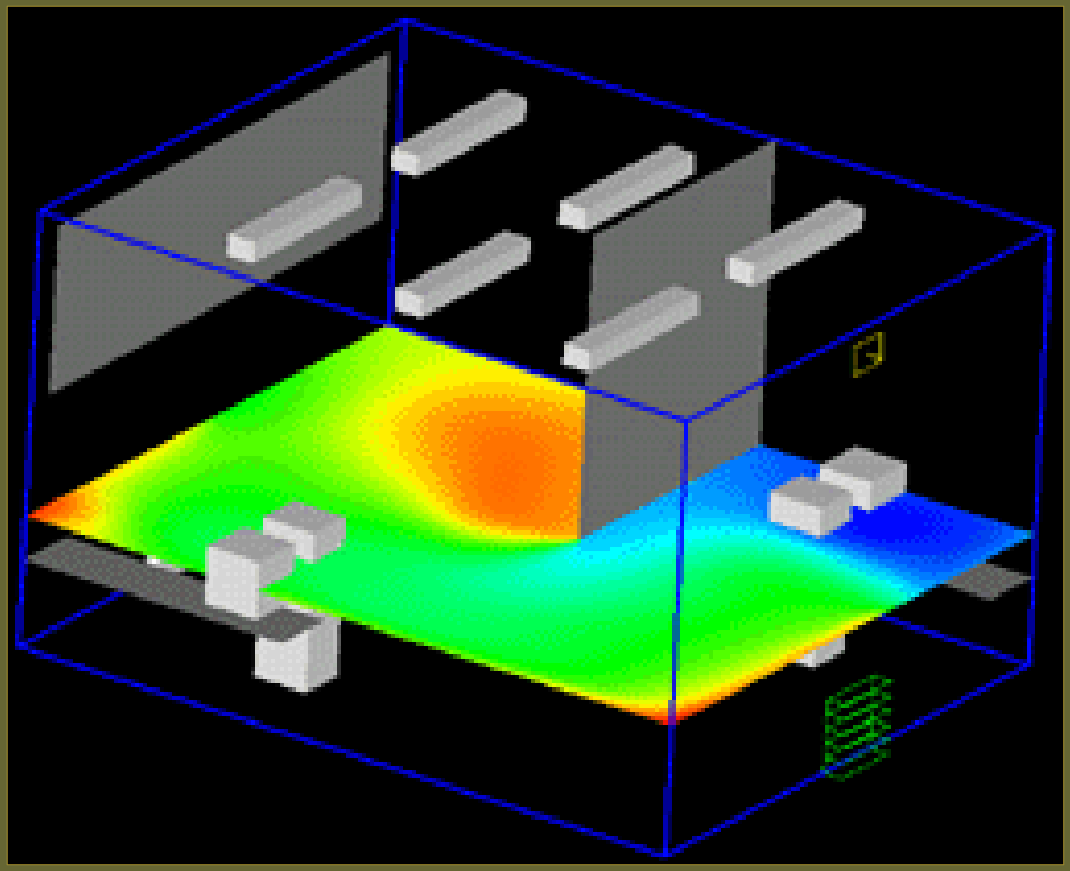
- Represent the temperature of an idealized enclosure which would have the same amount of radiant heat transfer exchange with a person at a particular location.



AIRPAK > **PARTITIONED OFFICE**

Mean Age of Air Contours

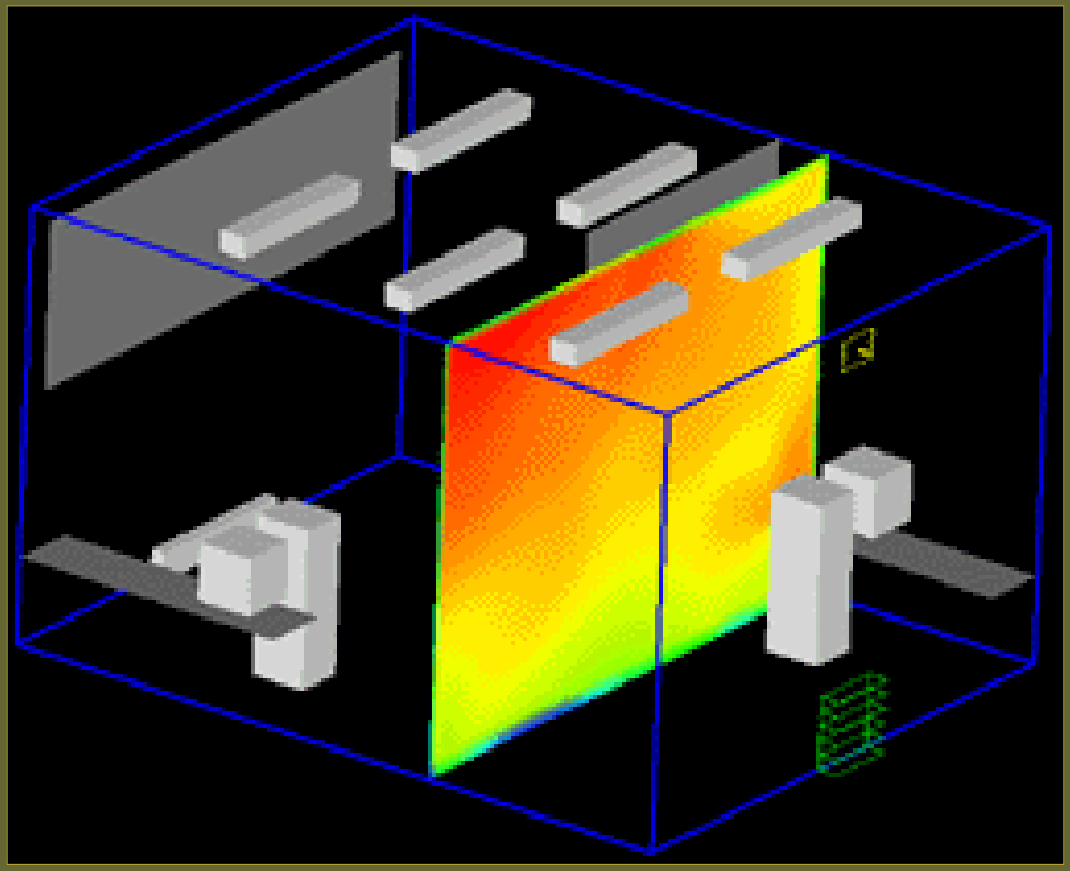
- Show that the area behind the partition and corners of the room are not well ventilated.
- One worker will breath air that is significantly fresher than that for the other worker.



AIRPAK > **PARTITIONED OFFICE**

Predicted Mean Vote (PMV) Contours

•Show that the expected perception of thermal sensation is relatively uniform and slightly warm.



CONCEPTUAL DESIGN TOOLS

CONCEPTUAL DESIGN > **WHAT IT DOES**

- 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.

CONCEPTUAL DESIGN > LEED™

LEED

Innovation and Design Process

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

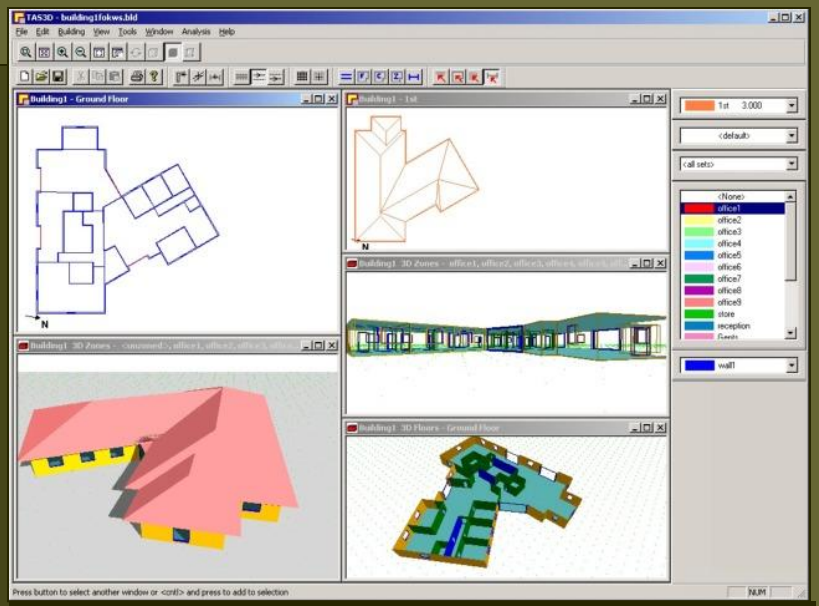
Submittals are required to demonstrate compliance, as well as the design approach used to meet compliance.

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/

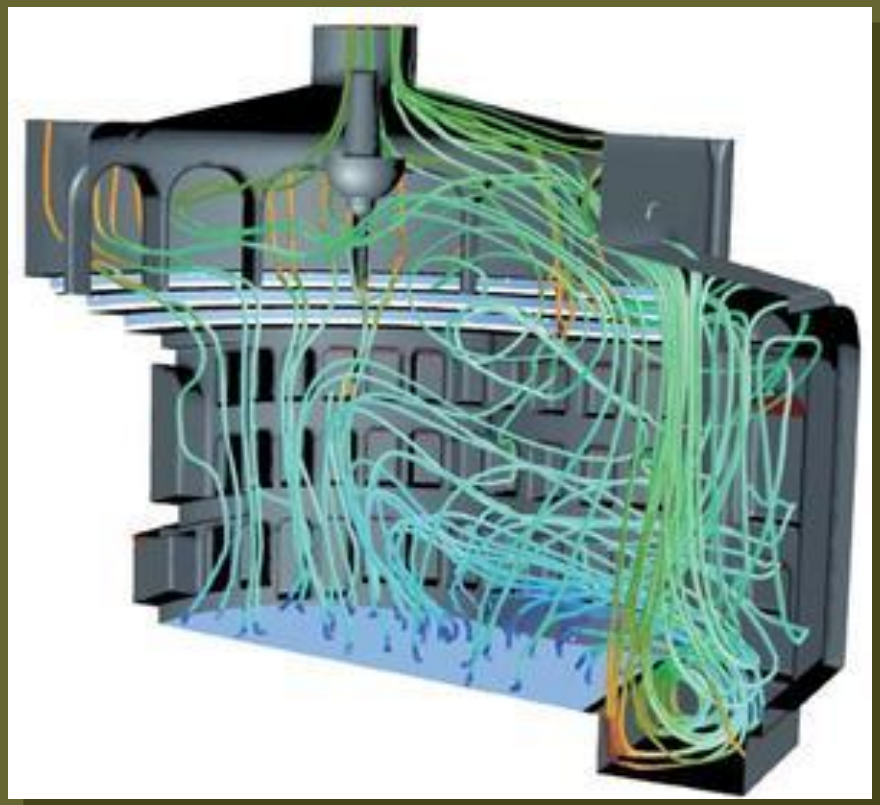
TAS Building Designer

  - http://212.23.11.237/Tas.htm

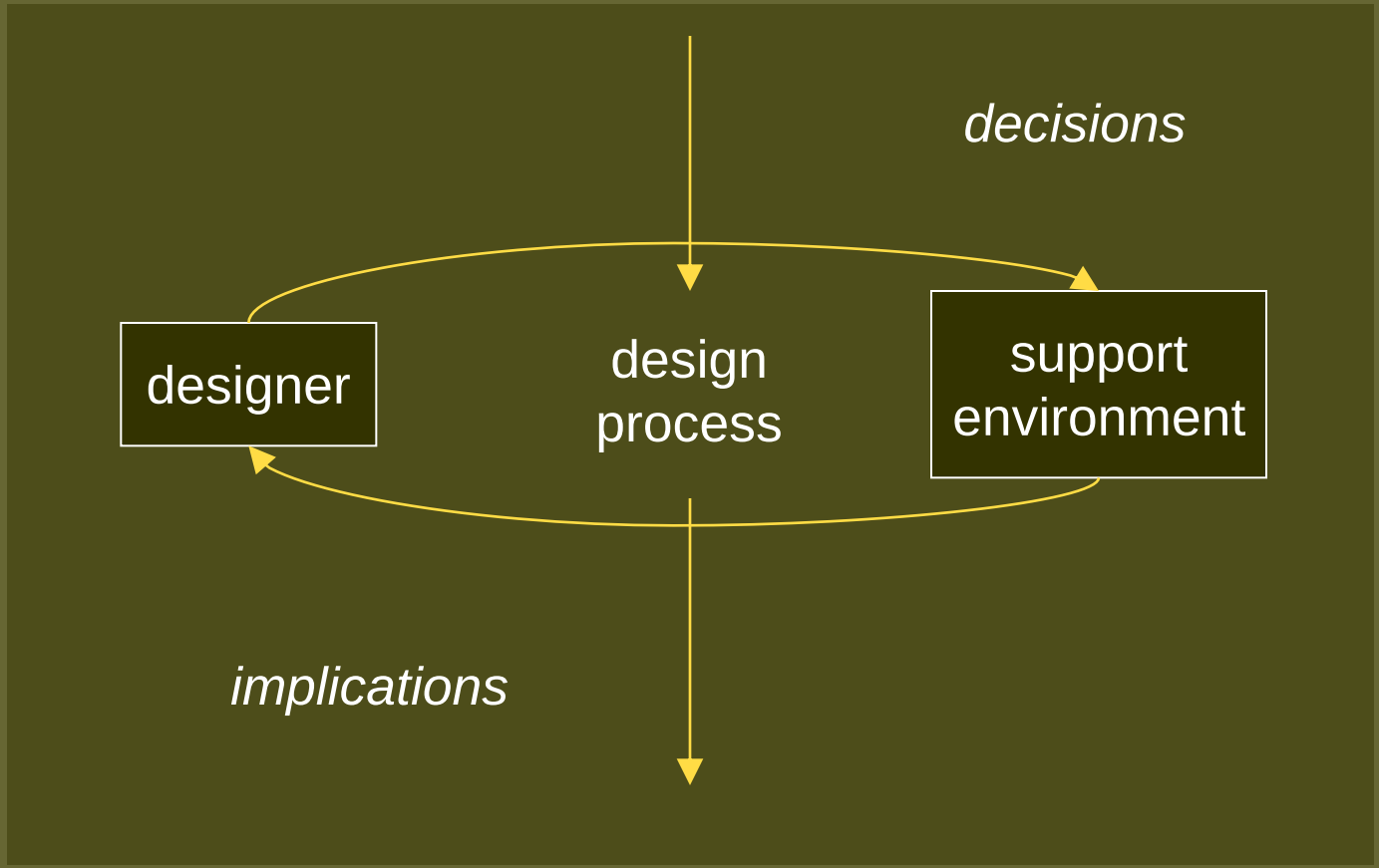


TAS 3D Modeler

THEME 3: APPLICATIONS

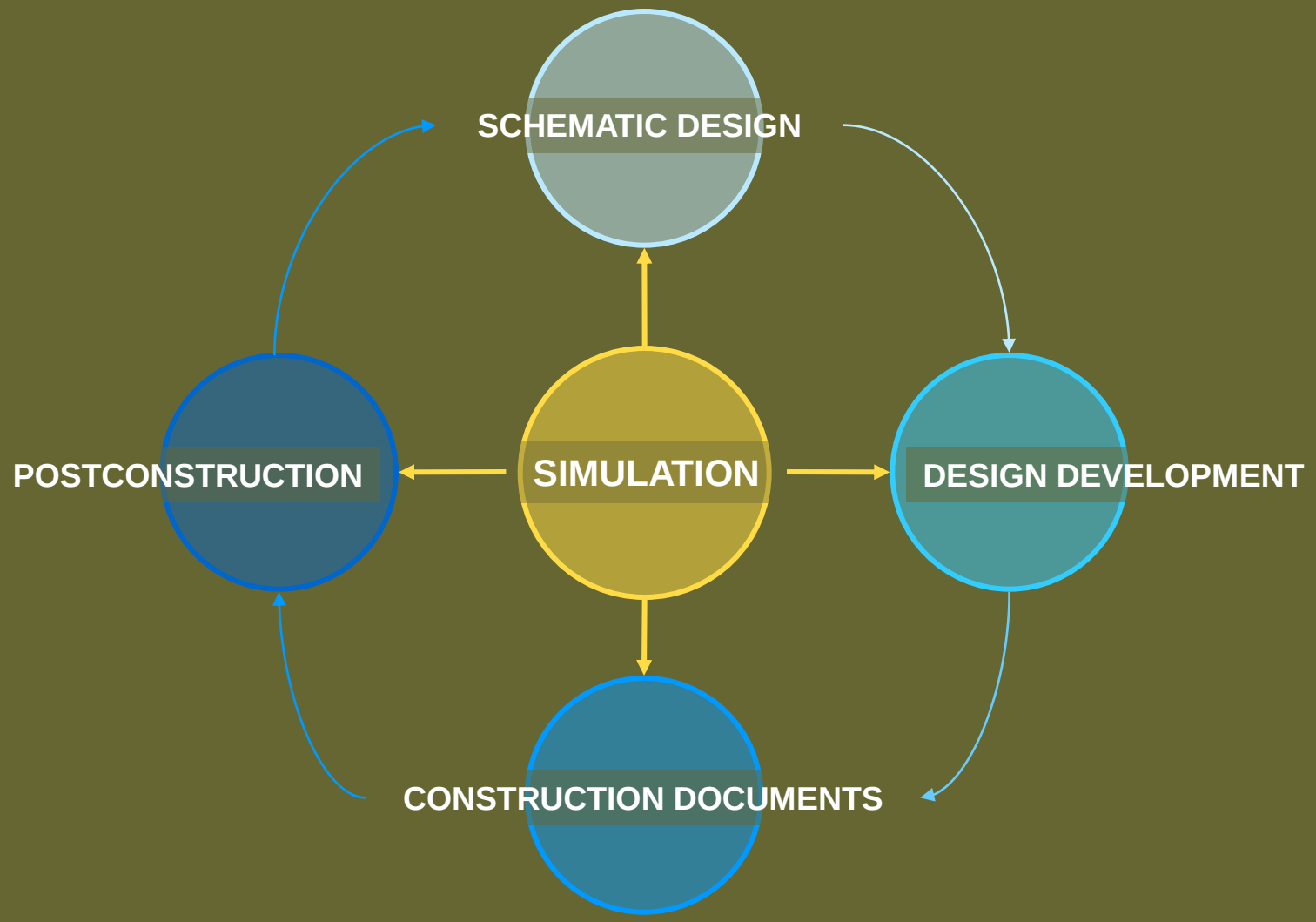


APPLICATIONS > **OVERVIEW**



Simulation within a Computer-Supported Design Environment

APPLICATIONS > **OVERVIEW**

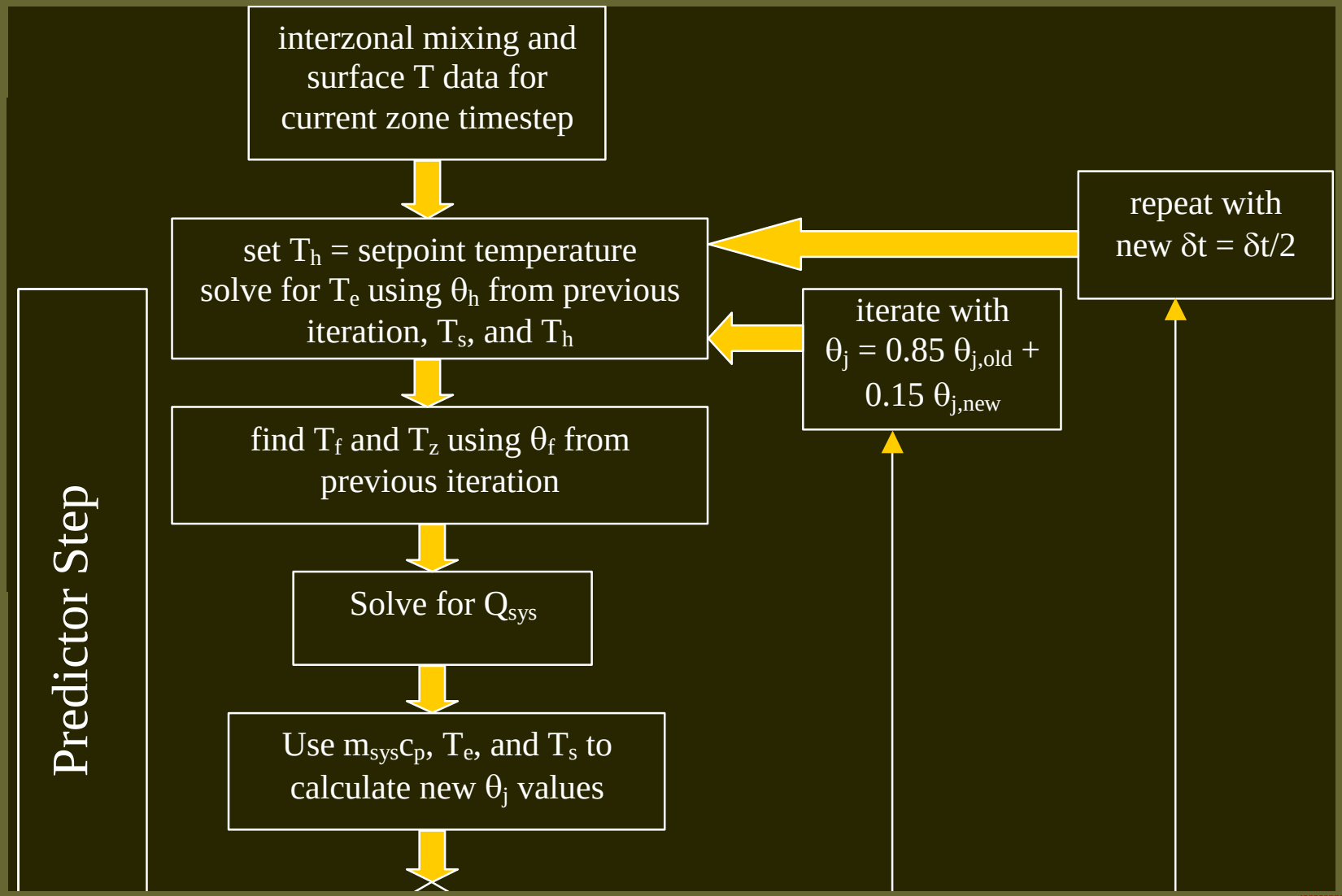


APPLICATIONS > **ANY PROJECT TYPE**

San Francisco Federal Building
Architect: Morphosis

Chicago Police Department District 22 Station
Architect: OWP/P

APPLICATIONS > ANY PROJECT TYPE



SCHEMATIC DESIGN PHASE APPLICATIONS

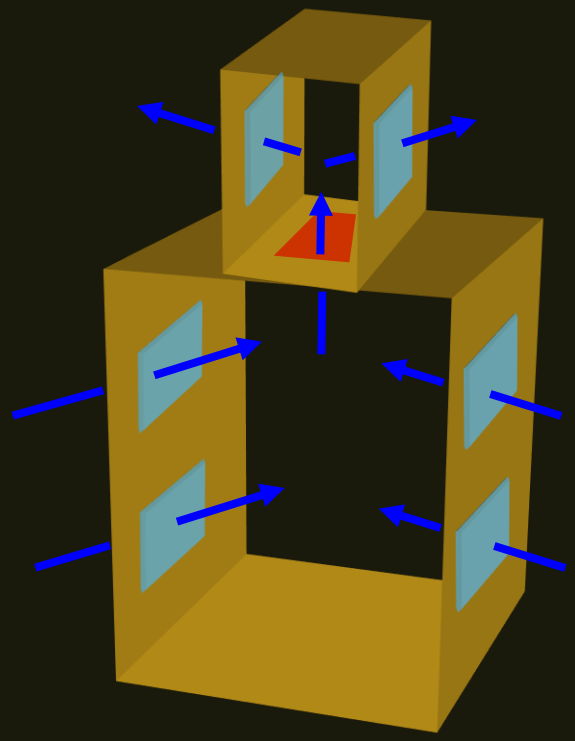
SD PHASE > **PROCESS INTEGRATION**

Process integration

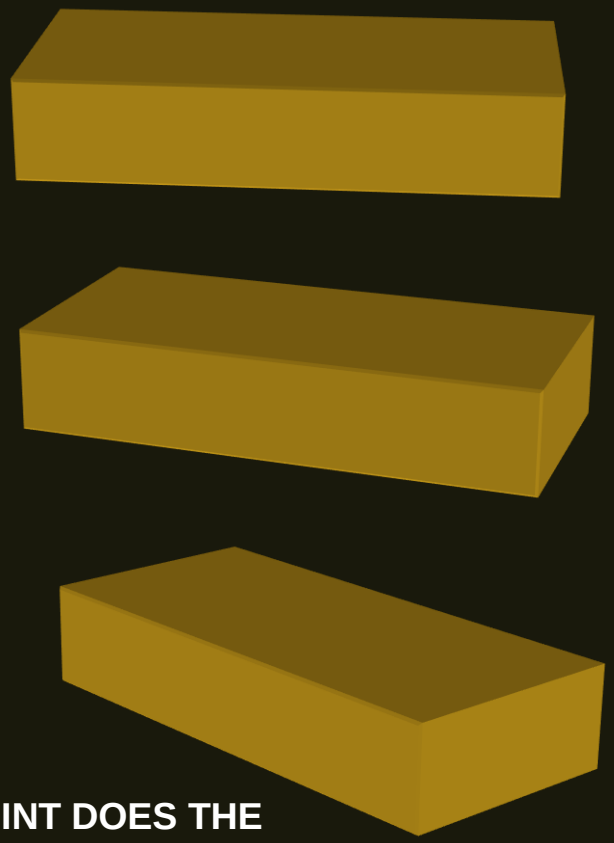
- ✓ Required Information
- ✓ Expected results
- ✓ Typical process
- ✓ Expected challenges

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

SD PHASE > **SAMPLE APPLICATIONS**



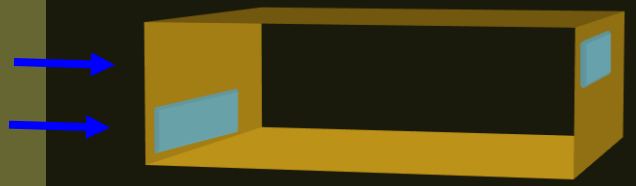
IS THE VENTILATION RATE SUFFICIENT?



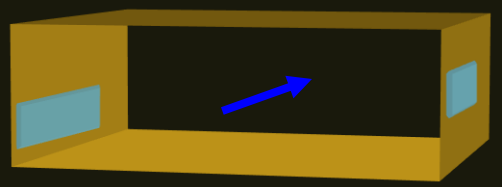
AT WHAT POINT DOES THE CHANGE IN ORIENTATION BECOME SIGNIFICANT?

SD PHASE > CASE STUDIES

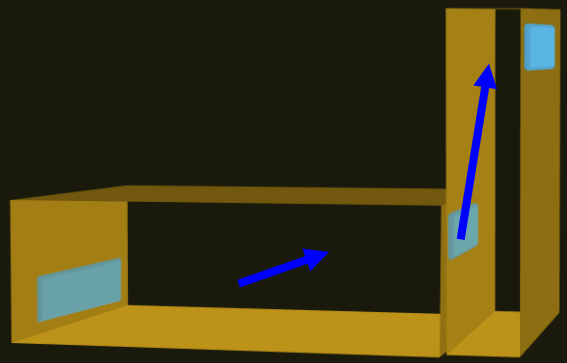
NATURAL VENTILATION STRATEGY COMPARISON WITH ENERGYPLUS + COMIS



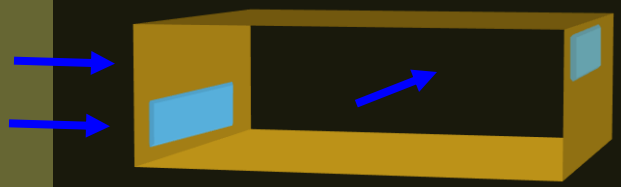
WIND ONLY



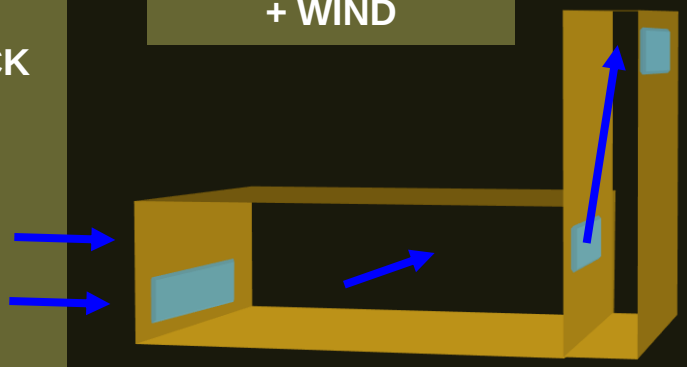
INTERNAL STACK



INTERNAL + EXTERNAL STACK

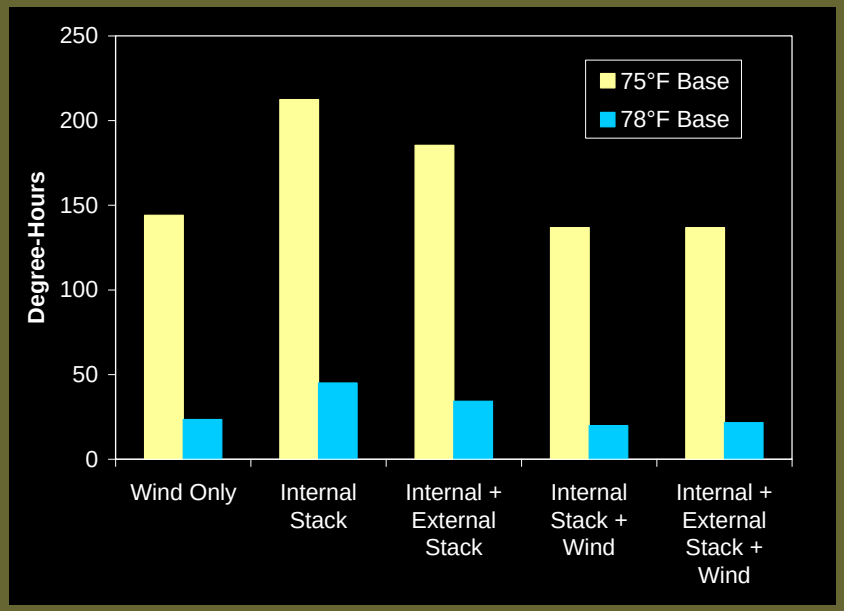


INTERNAL STACK + WIND



INTERNAL + EXTERNAL STACK + WIND

SD PHASE > CASE STUDIES



RESULTS

Annual indoor degree-hours above a base temperature

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**

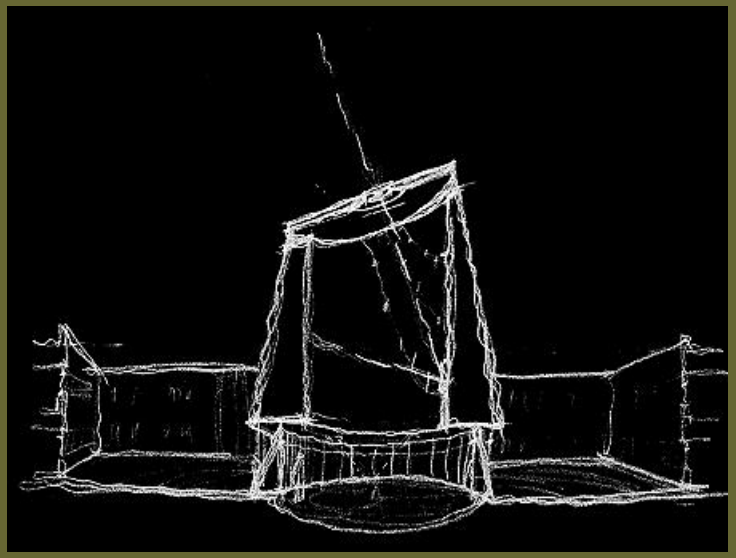
SD PHASE > **CASE STUDIES**

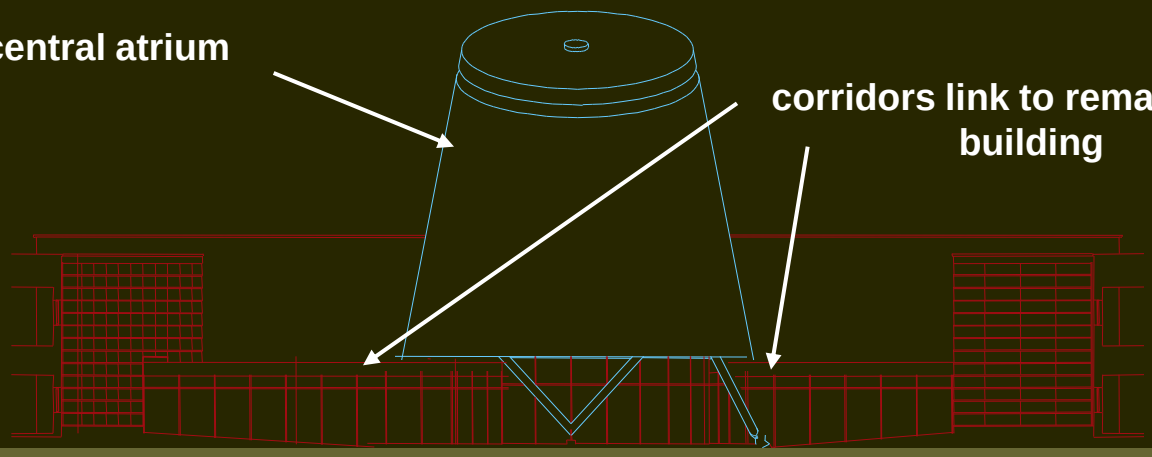
FINAL SECTION

SD PHASE > **CASE STUDIES**

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.





Architect: OWP/P

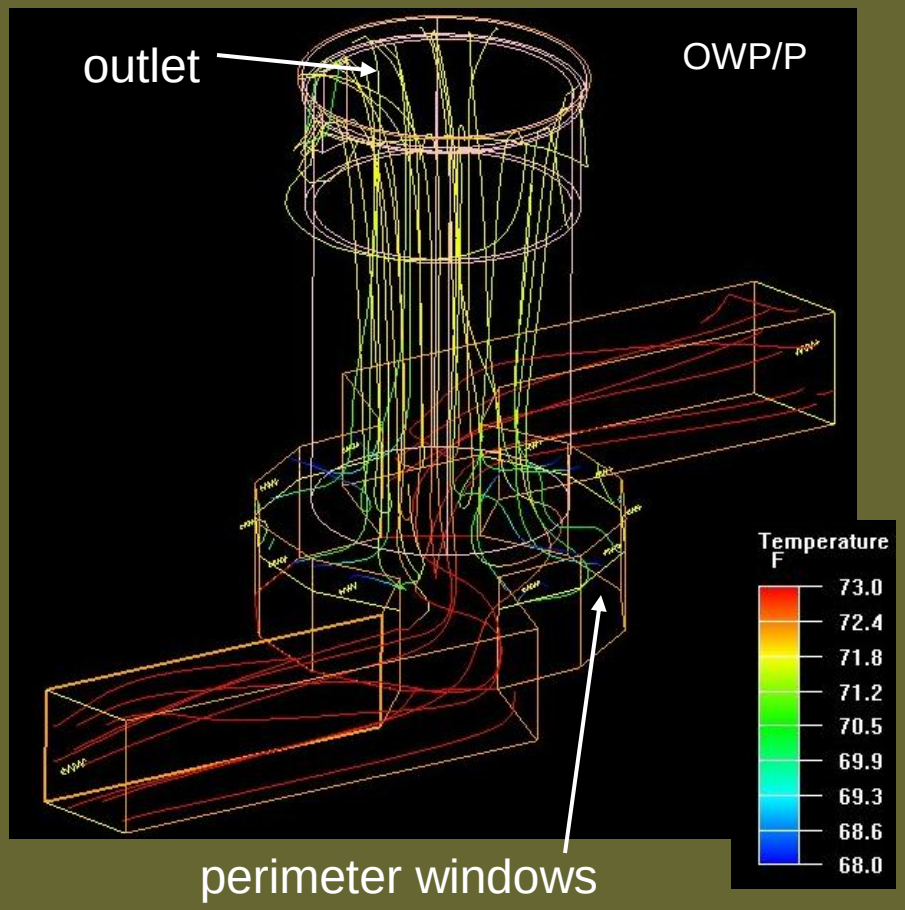
Drawings: OWP/P

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 DEVELOPMENT PHASE APPLICATIONS

DD PHASE > **PROCESS INTEGRATION**

Process integration

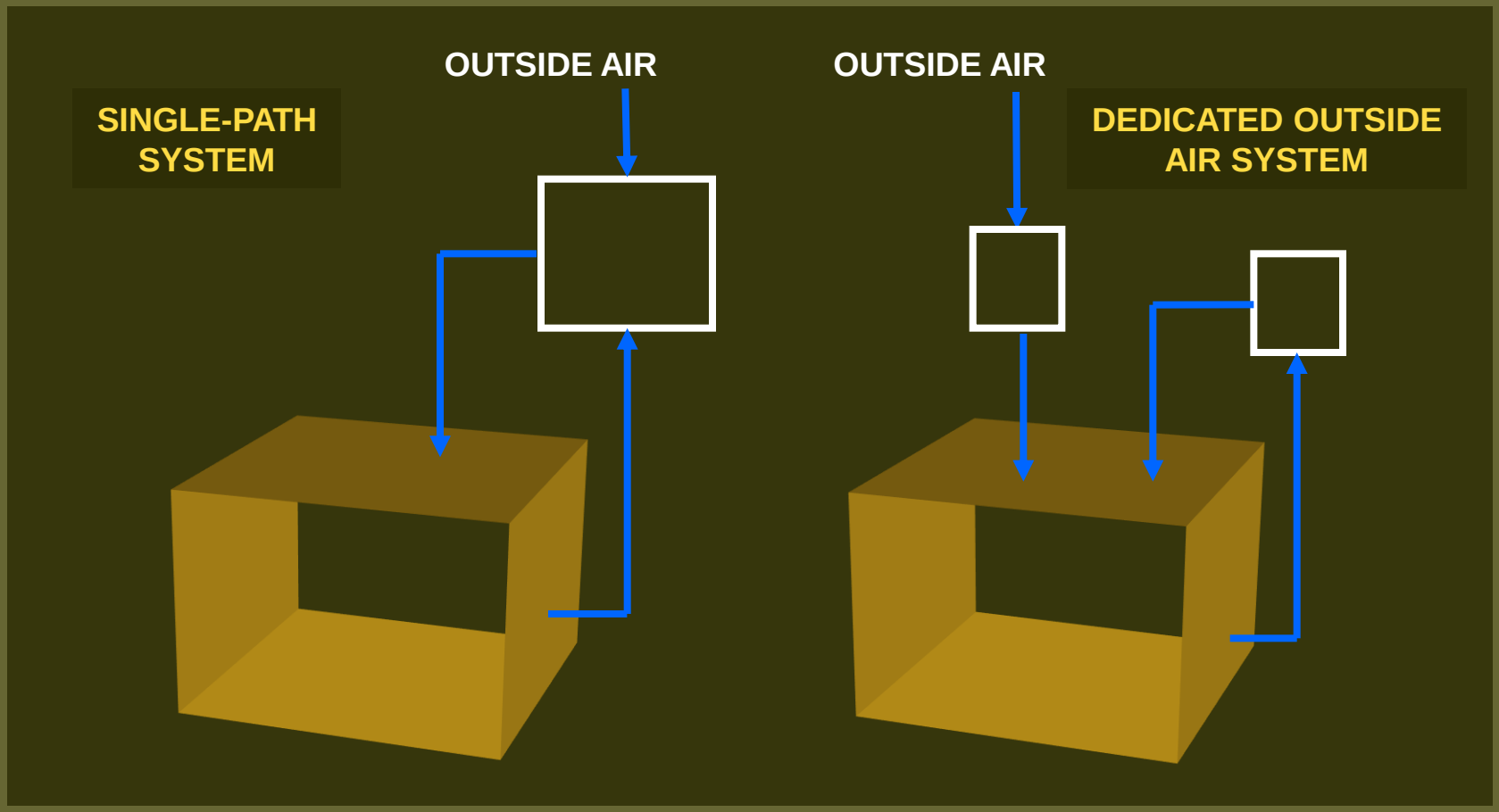
- ✓ Required Information
- ✓ Expected results
- ✓ Typical process
- ✓ Expected challenges

- 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 > SAMPLE APPLICATIONS

Possible Application > Daylighting

DD PHASE > SAMPLE APPLICATIONS



Possible Application > HVAC System Selection

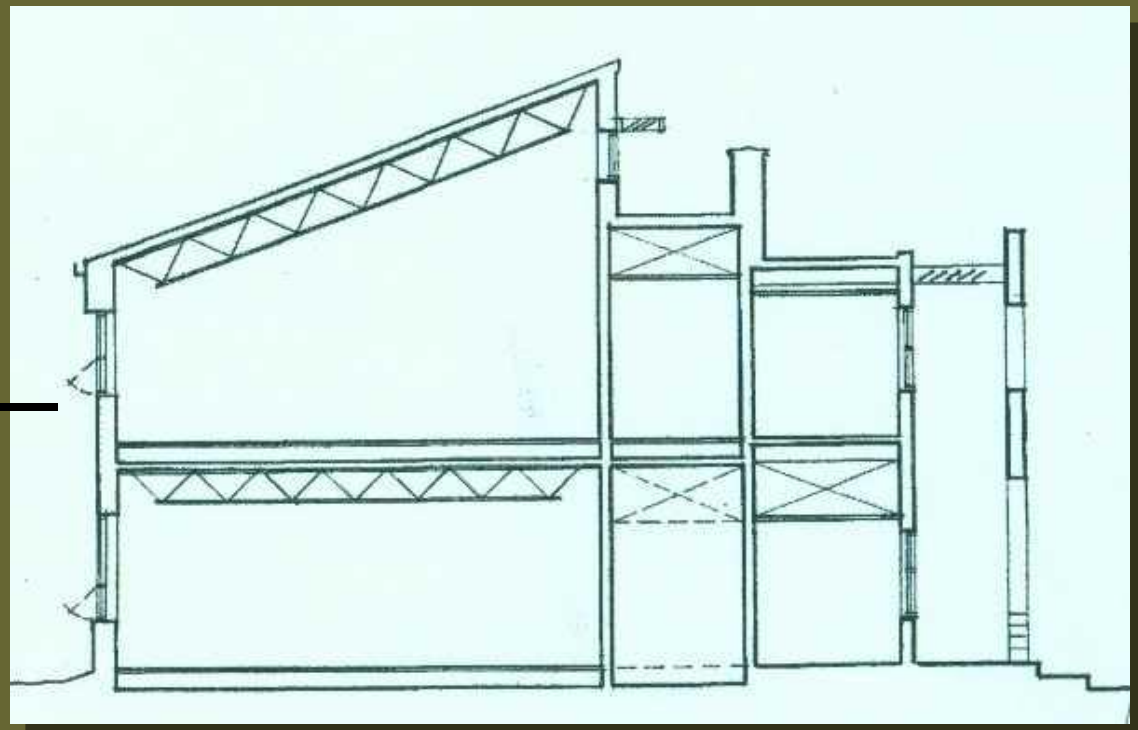
DD PHASE > **CASE STUDIES**

CLEARVIEW ELEMENTARY SCHOOL

Hanover, Pennsylvania

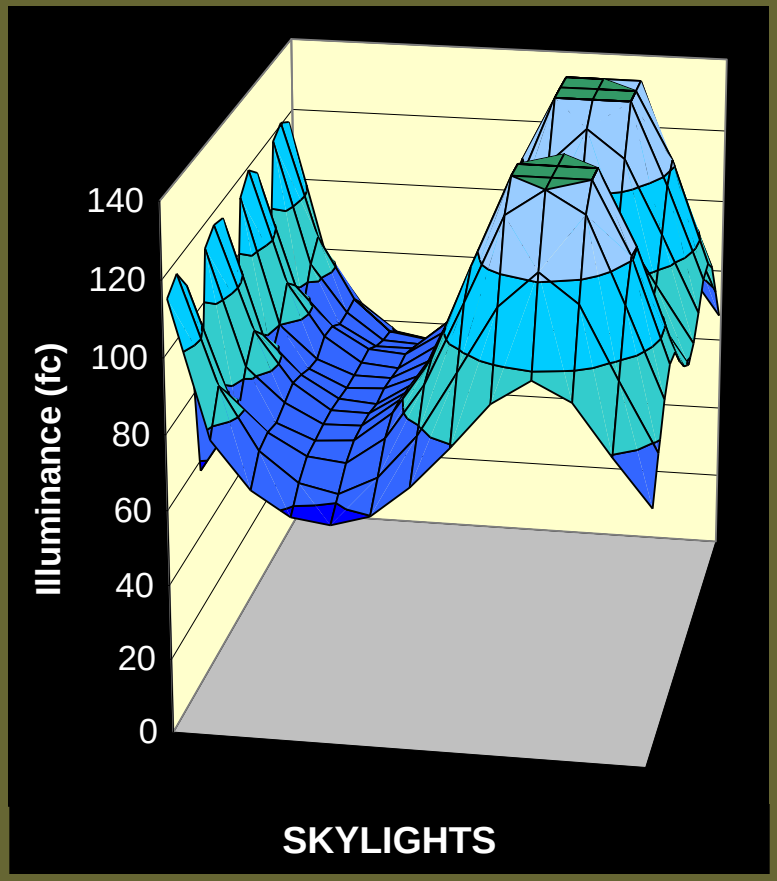
DD PHASE > **CASE STUDIES**

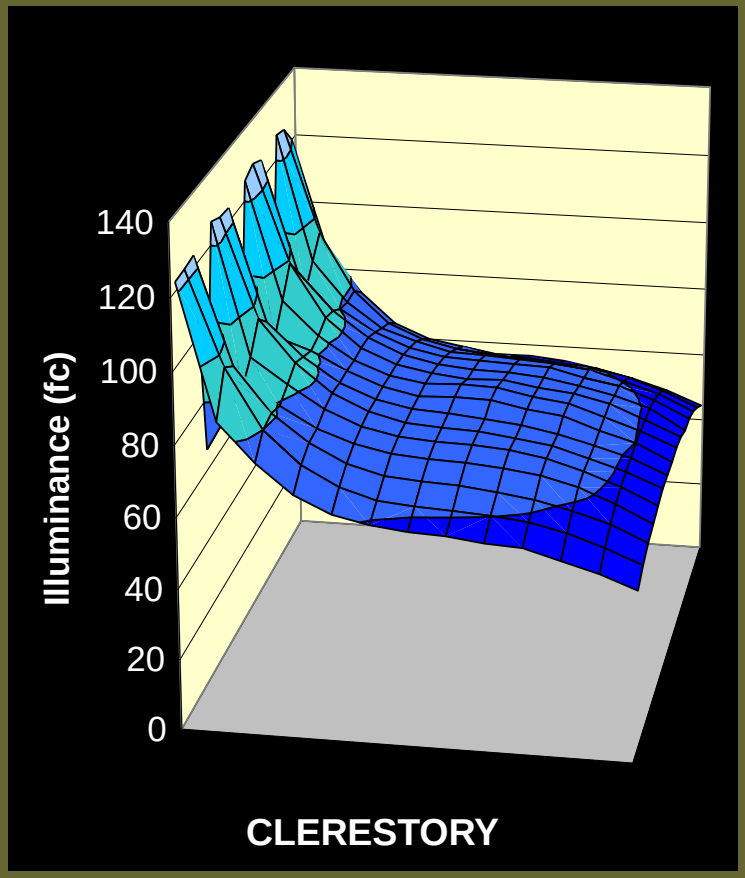
NORTH



SECTION THROUGH CLASSROOM WING

DD PHASE > **CASE STUDIES**



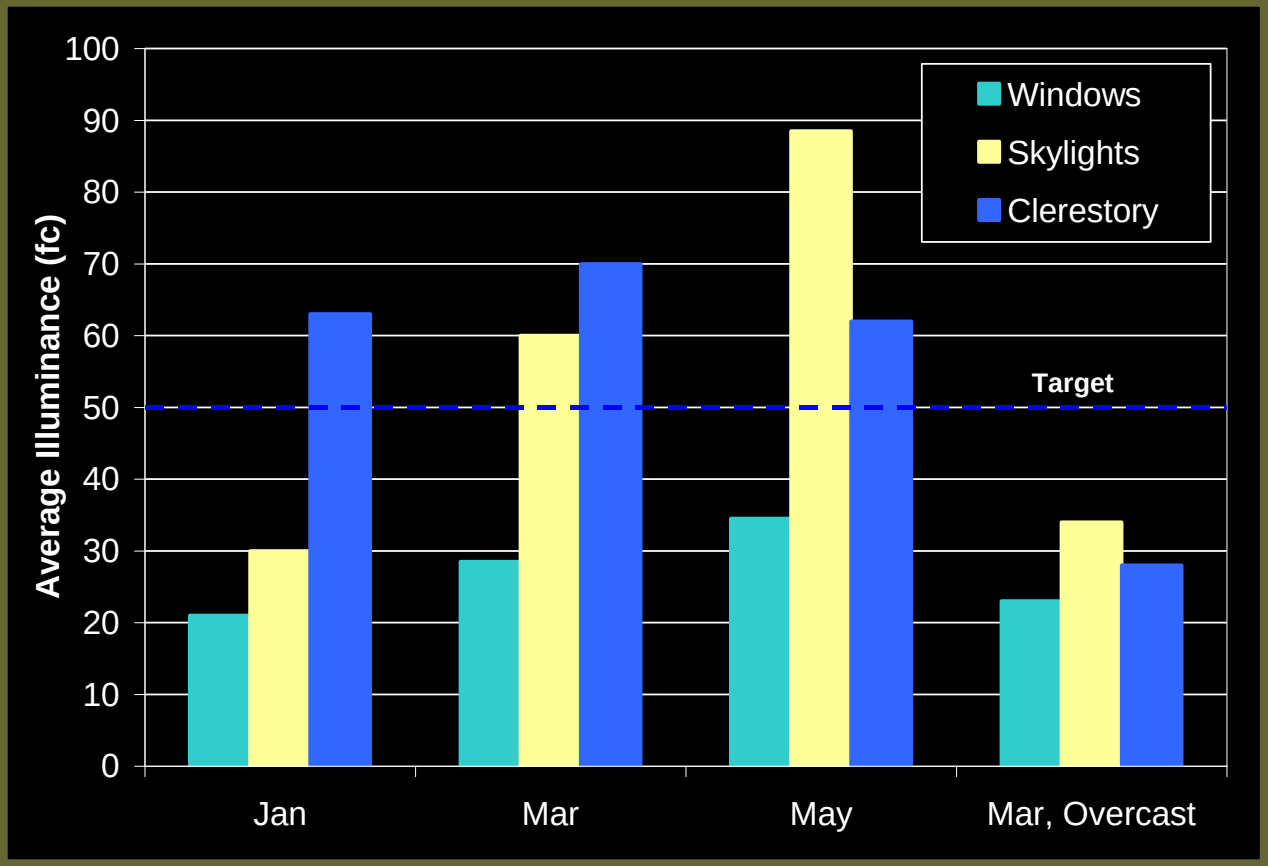


DAYLIGHTING DISTRIBUTIONS WITH RADIANCE SOFTWARE

MAY 21, 11 AM, CLEAR SKY

PROJECT ► **CLEARVIEW ELEMTARY SCHOOL** **ARCHITECT: L.R. KIMBALL & ASSOC.**

DD PHASE > **CASE STUDIES**



SEASONAL DAYLIGHTING LEVELS

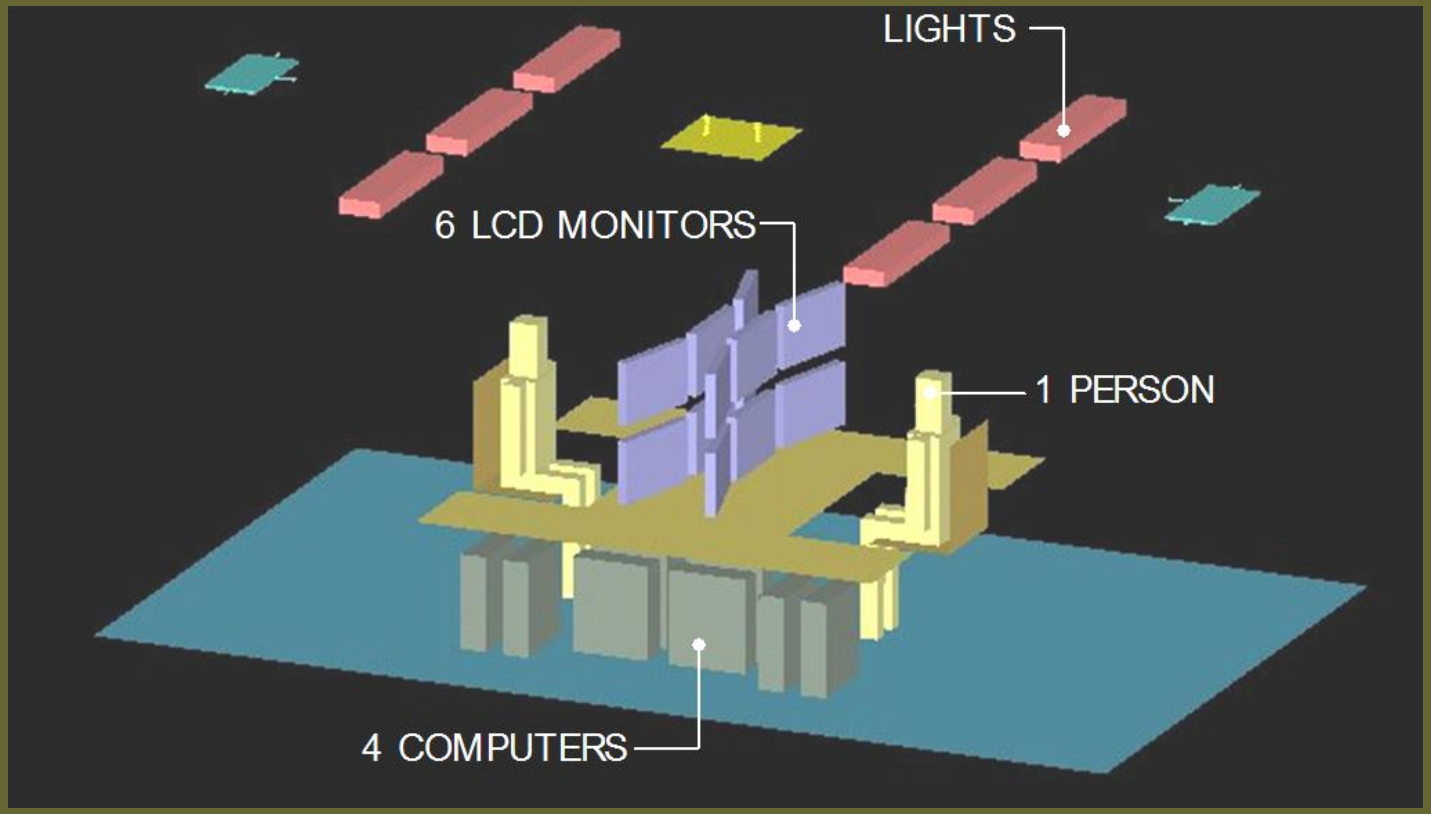
CLERESTORY PROVIDES MOST CONSISTENT LIGHTING LEVELS

DD PHASE > **CASE STUDIES**

Daylighting Design

- 0.97 watts / SF
- Daylight Factor: > 2.0
- 3.5 times more natural illumination

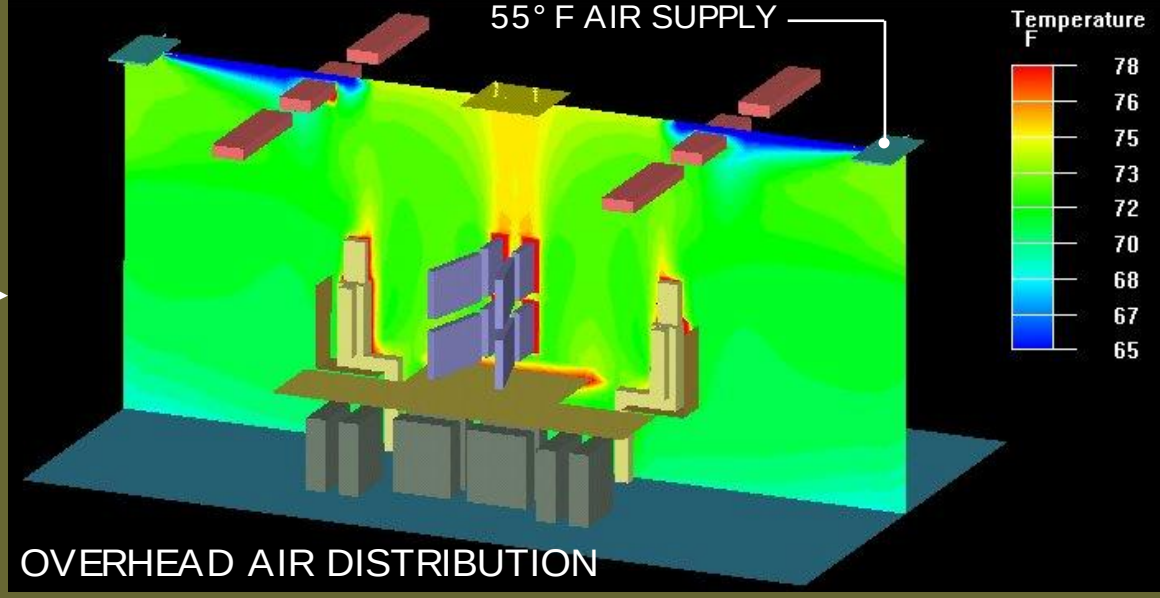
DD PHASE > **CASE STUDIES**



CFD: AIR DISTRIBUTION COMPARISON

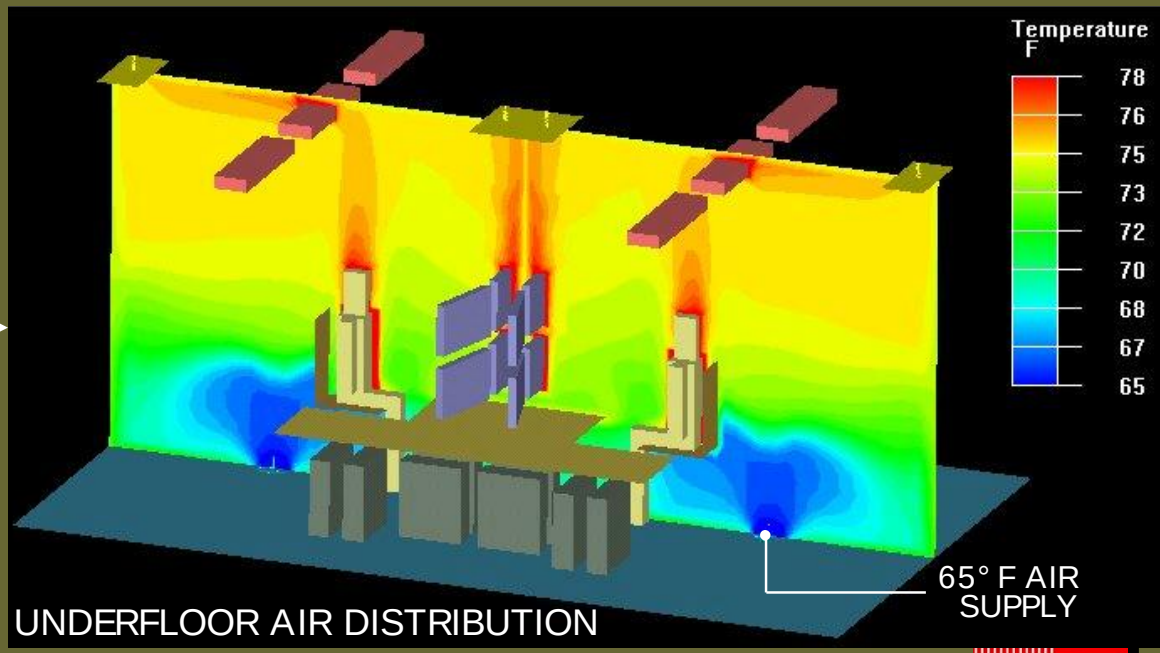
NEW OFFICE: INCLUDING TRADING FLOOR WITH HIGH DENSITY OF PEOPLE AND ELECTRONICS

EXTREMELY UNIFORM TEMPERATURE DISTRIBUTION WITH OVERHEAD AIR DISTRIBUTION



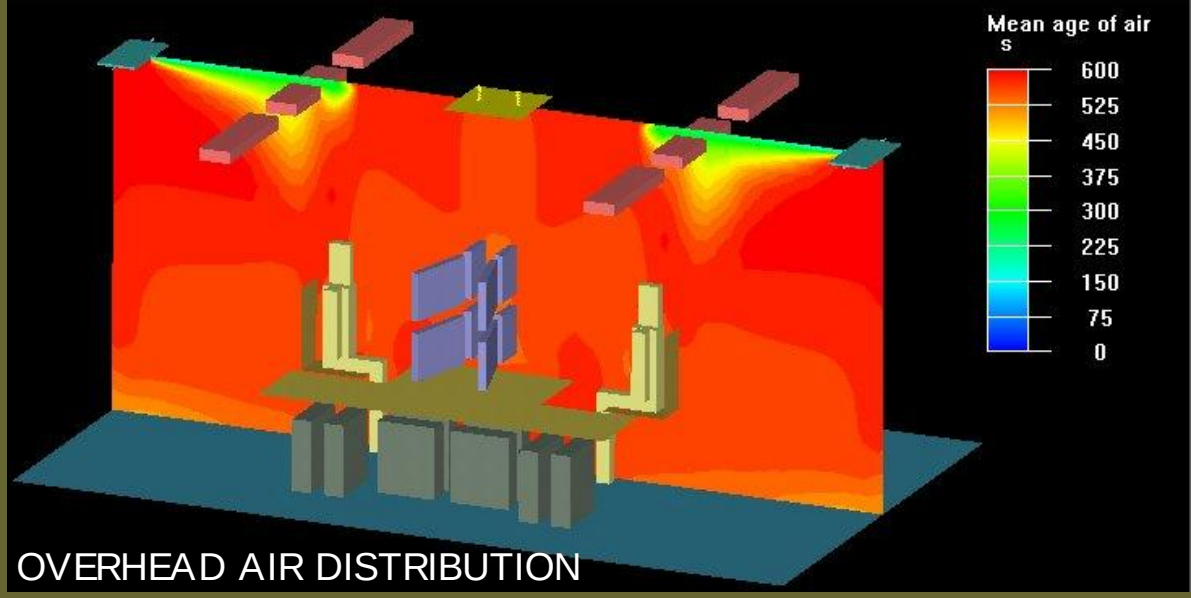
ROOM AIR TEMPERATURES

STRONG THERMAL PLUMES FROM HEAT SOURCES WITH UNDERFLOOR AIR

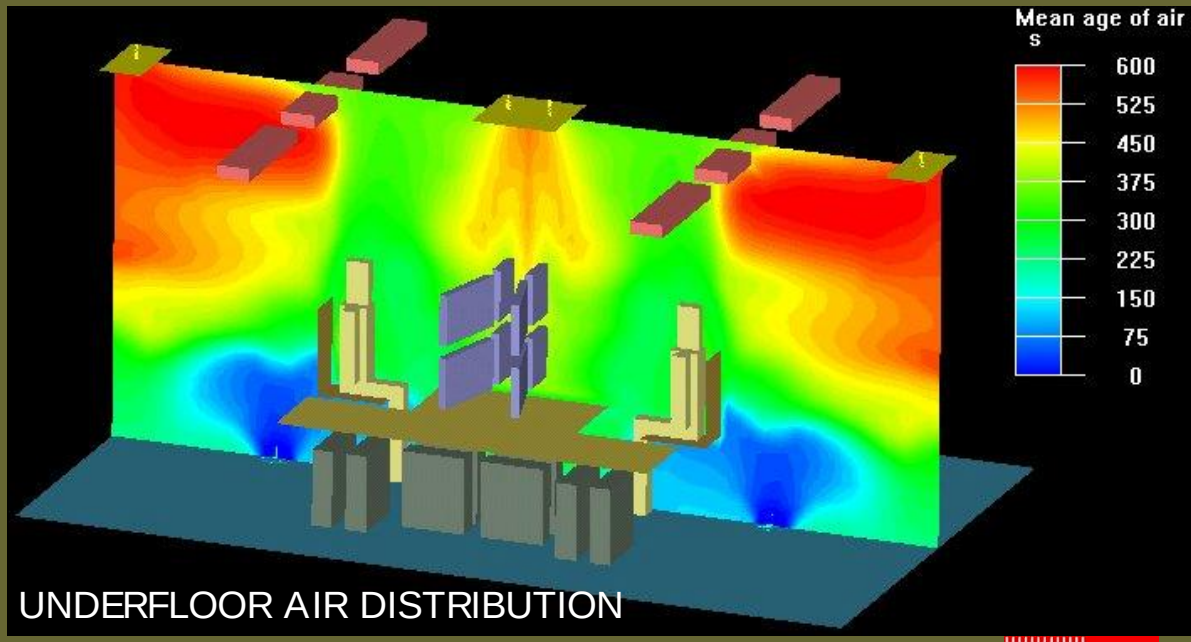


MEAN AGE OF AIR

FRESH AIR IS DRAWN TOWARD OCCUPIED SPACE WITH UNDERFLOOR AIR, WHEREAS IT IS UNIFORMLY LESS FRESH WITH OVERHEAD AIR.



OVERHEAD AIR DISTRIBUTION



UNDERFLOOR AIR DISTRIBUTION

CONSTRUCTION DOCUMENTS PHASE

APPLICATIONS

CD PHASE > **PROCESS INTEGRATION**

Process integration

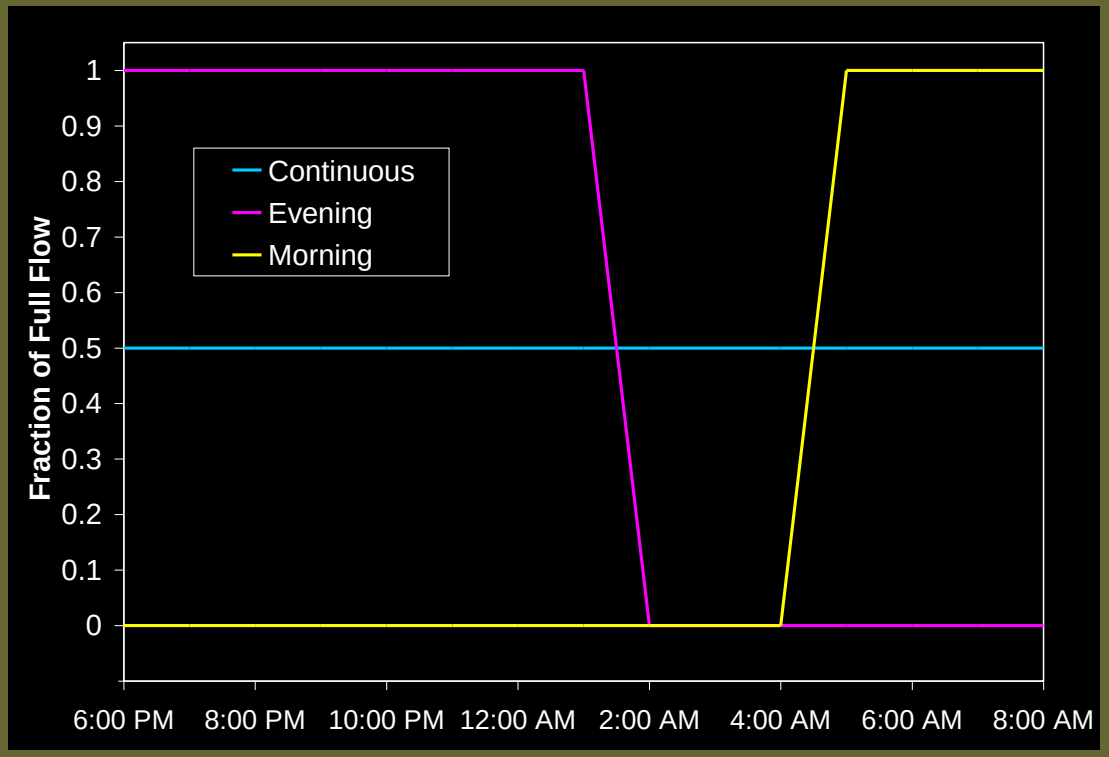
- ✓ Required Information
- ✓ Expected results
- ✓ Typical process
- ✓ Expected challenges

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

estimated.

- Benchmark comparisons are more relevant.

CD PHASE > **SAMPLE APPLICATIONS**

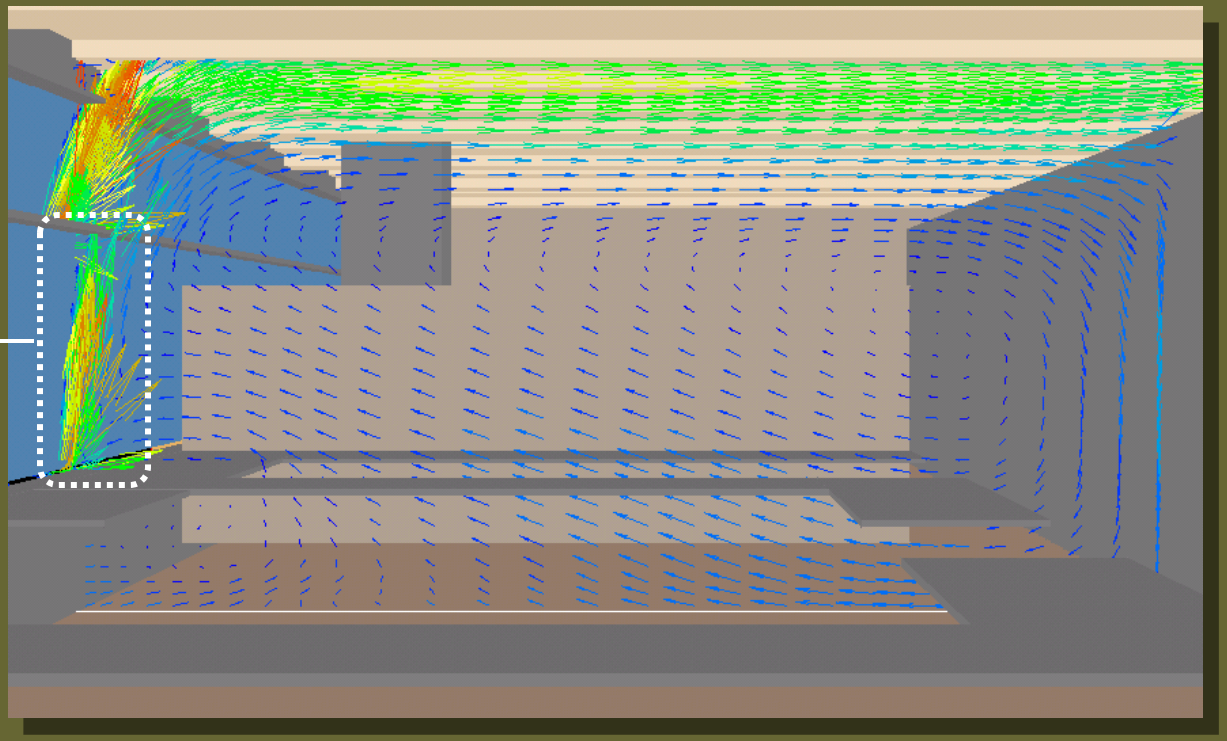


MECHANICAL NIGHT COOLING SCHEMES

BUILDING DESIGNED FOR NIGHT FLUSH-OUT WITH OUTDOOR AIR (CONTINOUS FLUSH OUT, EVENING ONLY, OR MORNING ONLY)

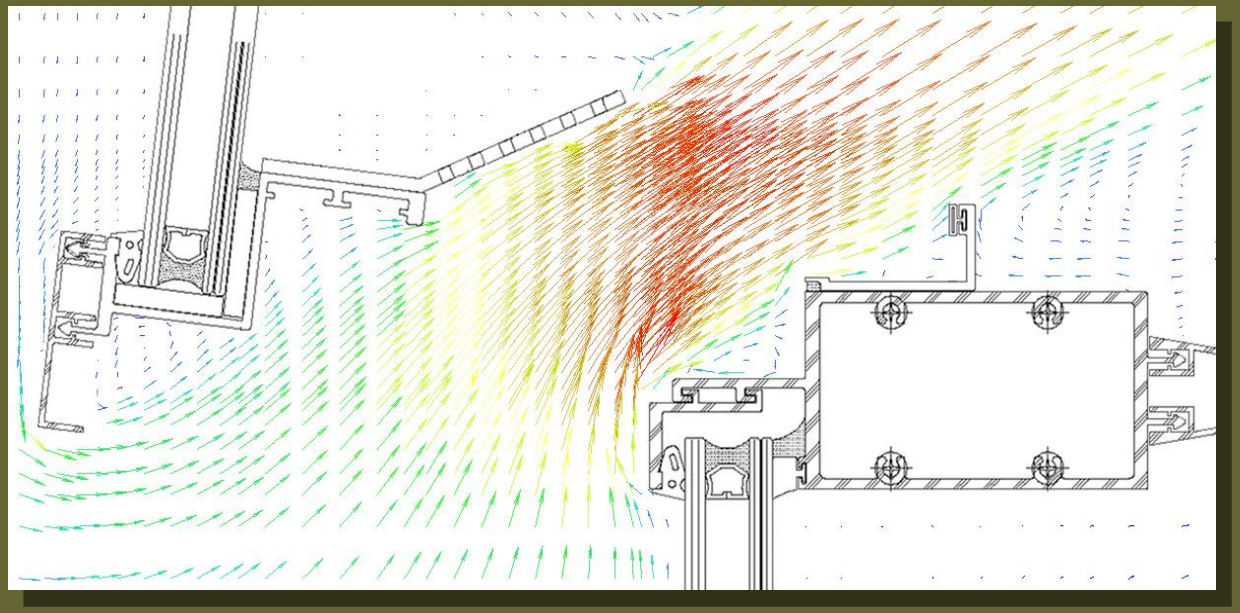
CD PHASE > **CASE STUDIES**

JET ATTACHES TO WINDOW SURFACE



AIRFLOW PATTERN ON WINDWARD SIDE OF BUILDING

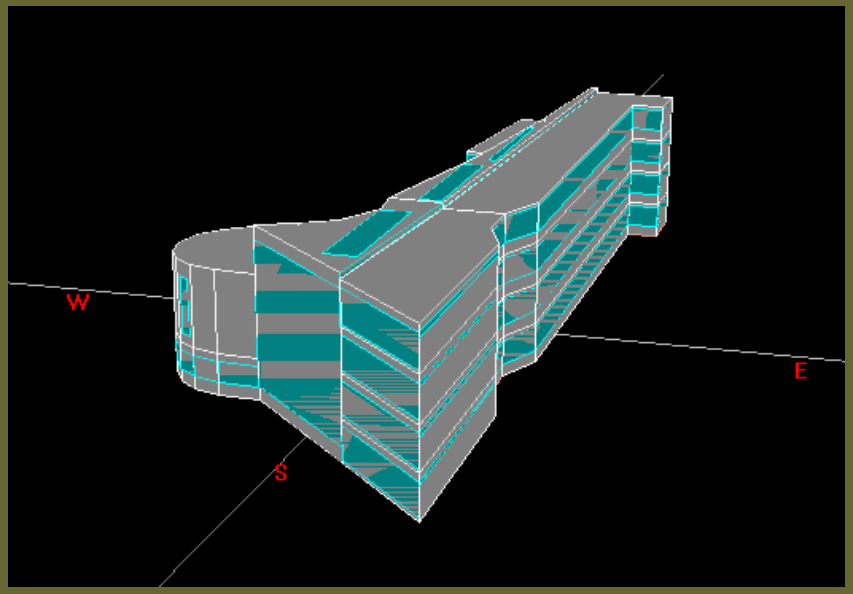
CFD ANALYSIS



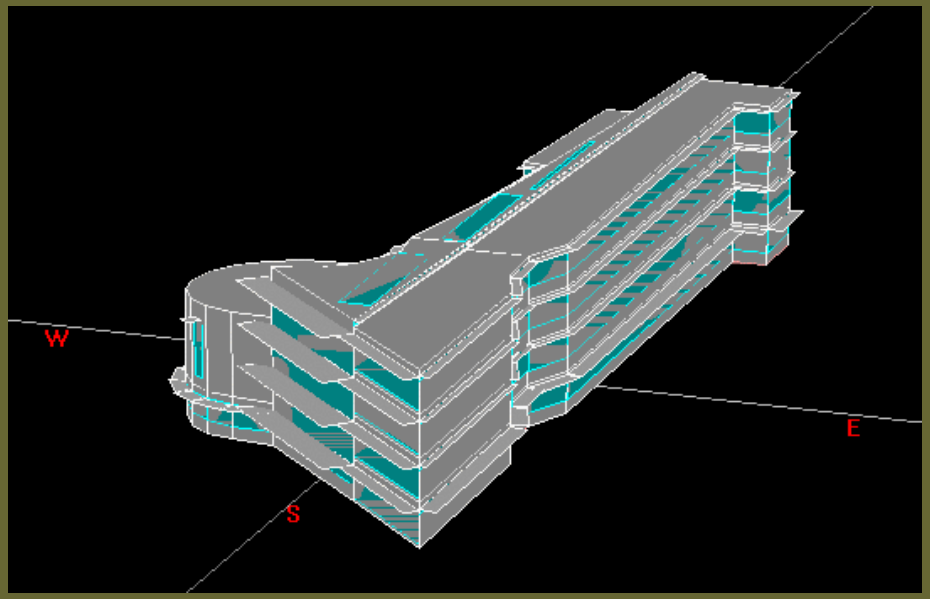
FINAL DESIGN FOR FLOW DEFLECTOR

CFD ANALYSIS

CD PHASE > **CASE STUDIES**



BASE CASE



FINAL DESIGN

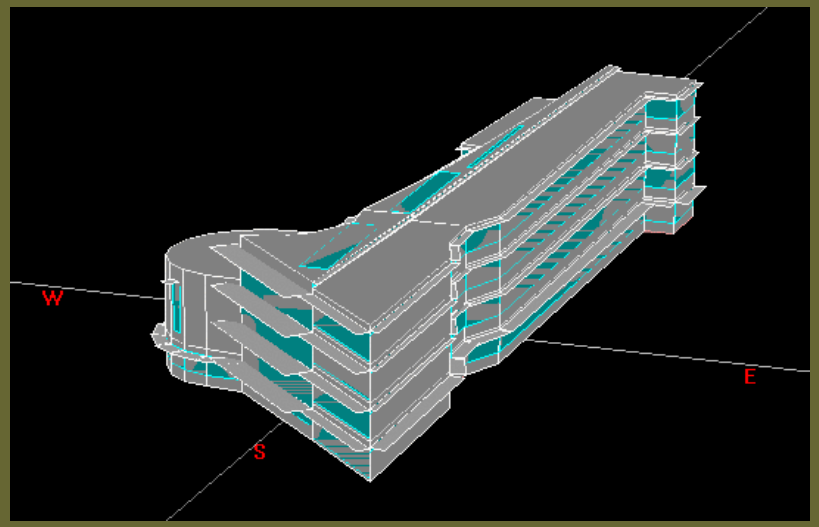
TITLE I ENERGY USE COMPARISON

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

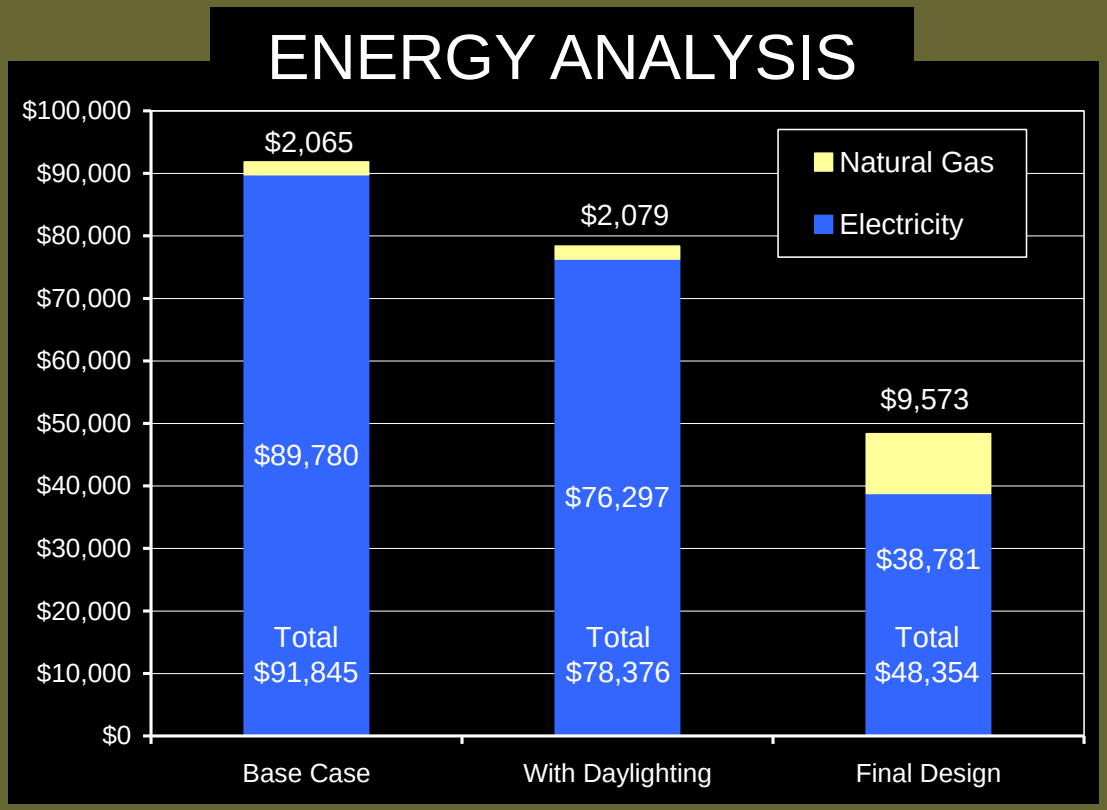
CD PHASE > **CASE STUDIES**

Design Strategies Beyond Base Building Design

- High performance glazing with a low-e coating. U-value= 0.3, 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.)



FINAL DESIGN



PREDICTED ANNUAL ENERGY COSTS

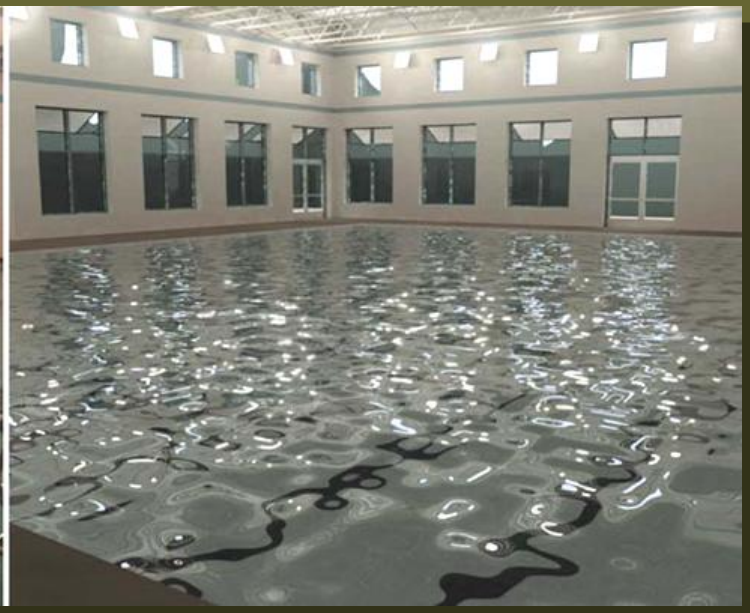
THE FINAL DESIGN USES 47% LESS ENERGY THAN THE BASE CASE

POSTCONSTRUCTION PHASE APPLICATIONS

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.

POSTCONSTRUCTION PHASE > **CASE STUDIES**



EXISTING CONDITIONS PHOTOGRAPH

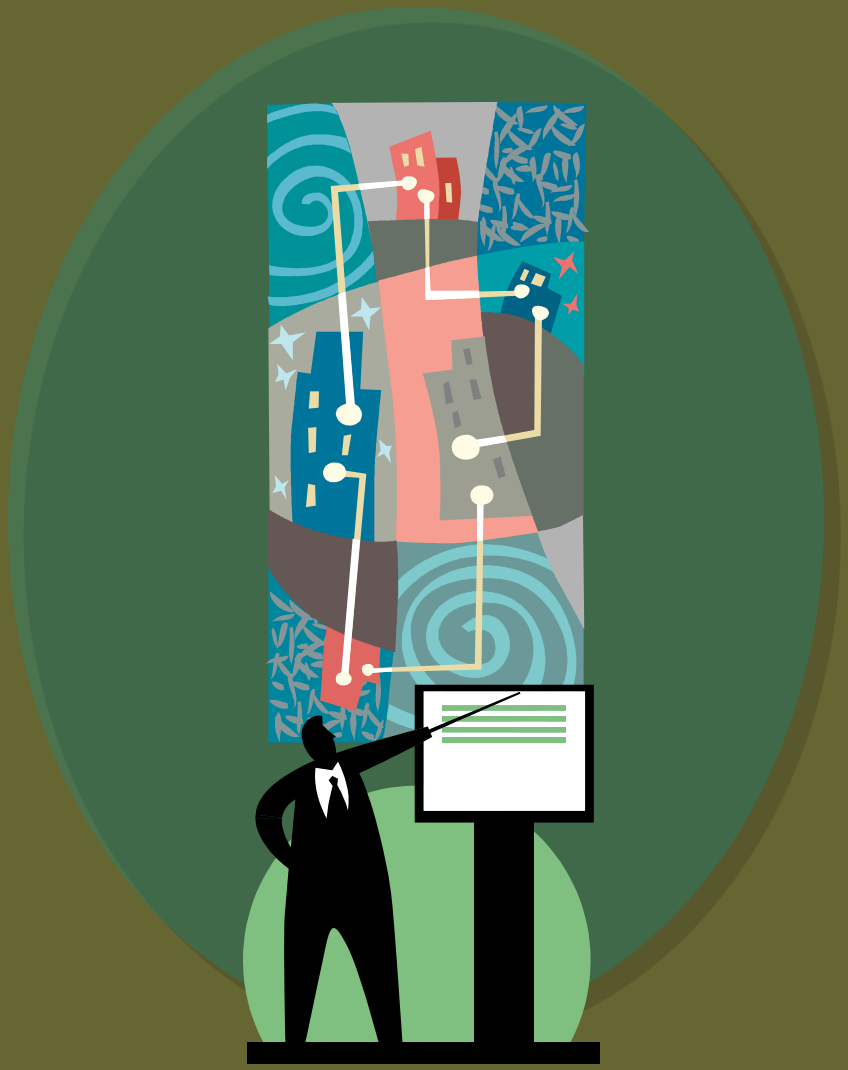
EXISTING CONDITIONS RENDERING

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.

PROPOSED SOLUTION

CONCLUSIONS



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)

DISCUSSION