Labs 21 Phone Forum

Optimizing Laboratory Ventilation Design

with:

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Princeton University Guyot Hall Addition and Alterations Project

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Project Team

Boston

Payette Associates, Inc.

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Rowan Williams Davies & Irwin Inc.

R.W. Sullivan Code Group

Kalin Associates

Environmental Sciences Building

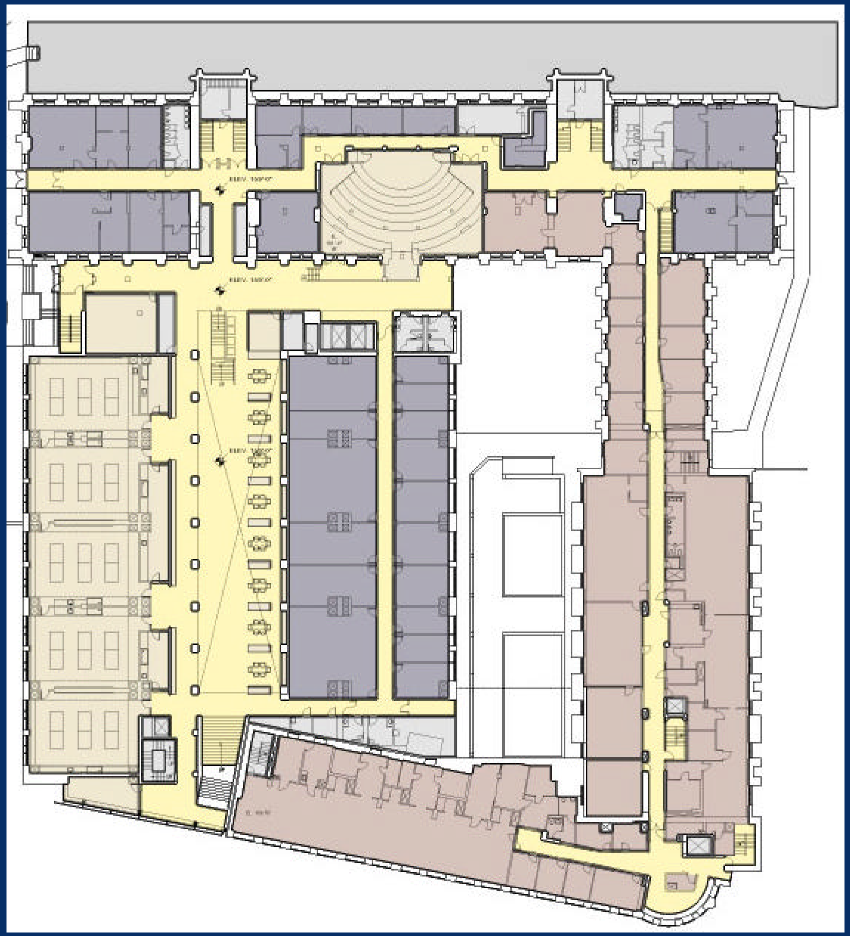
Size: 185,000 SF new and renovated

Building program

- Teaching labs
- Research labs
- Offices

Three departments

- Princeton Environmental Institute
- Geosciences
- Ecology and Evolutionary Biology



Green or LEED?

- Project's prospective donor *advocates* "Green"
- Building's E.S. program *advocates* "Green"
- If green, how green? (LEED)
- University does not pursue LEED registration
- University undertakes campus-wide environmental initiative

LEED provided:

- Client's definition of "green"
- Yardstick of defined goals

LEED did not provide:

- Goals and strategies for lab process loads

Green Strategies

- Recycled Content Materials
- Low-toxicity materials
  - Alternatives to epoxy
  - Alternatives to VCT
  - Trespa composite material
- Construction waste management
- CO^2 sensors, HVAC and lighting in offices and labs on occupancy sensors
- Daylight harvesting
- Radiant atrium flooring
- Green Roof

- Reduction of Air Change Rates

Air Change Rates - Guidelines

Source	Budget Building Design
ASHRAE 62-2001	20 CFM/person = 3.6 ACH w/ 24 students & 10’ ceiling (University Labs).
NFPA 45-2000	4 ACH Unoccupied, Occupied typically exceeds 8 ACH
OSHA 1910.1450 – 1994	4 to 12 ACH is normally adequate of local exhaust (fume hoods are used).
Prudent Practices – 1995	6 to 12 ACH is normally adequate. Cooling may require higher rates.
ASHRAE Applications - 2003	General Labs: 6 to 10 ACH normally adequate Animal: 15 ACH from NIH Guide BSL-1: 3 to 4 ACH commonly used BSL-2: 6 to 15 ACH typical

Princeton University Standard = 10 Air Changes

Air Change Rates – What the team found

- No codes, just guidelines
- No Standard Industry Practice
- Questioned client’s standard for air change rates in laboratories
- Higher Rates Alone DO NOT EQUAL Assured Effective Ventilation

Air Change Rates – Design Process

- Baseline Criteria - Initial Model
  - Based on client standard of 10 Air Changes
  - Effectiveness
  - Layout
- Intermediate Modeling
  - 6 Air Changes
  - Diffuser Locations
  - Effectiveness
- Final Model
  - 8 Air Changes
  - Diffuser Locations
  - Effectiveness
  - Client Responsiveness

Air Change Rates – Design Process

- Success of CFD Model Process

  - Client's Acceptance of Operating Standard

    8 Air Changes as Occupied Building Standard

    10 Air Changes for Emergency Use

    6 Air Changes for Unoccupied Mode

- Cost and/or Savings?

- For every air change rate that is reduced, the maximum fan energy that is saved is 3%:

  - 10 Air Changes to 8 Air Changes Resulted in 6% Savings of Supply and Exhaust Fan Energy
  - 10 Air Changes to 6 Air Changes Resulted in 12% Savings of Supply and Exhaust Fan Energy

CFD Modeling of Lab Spaces: Case Study of Guyot Hall

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Outline

- What is CFD
- The CFD Process/How it Works
- What you get after running CFD
- Types of CFD Modeling – Representing Turbulence
- Two Examples

What is CFD

- CFD = Computational Fluid Dynamics
- The standard conservation equations for mass, momentum and energy along with others representing turbulence, humidity and contaminants are solved for discrete volumes in space.

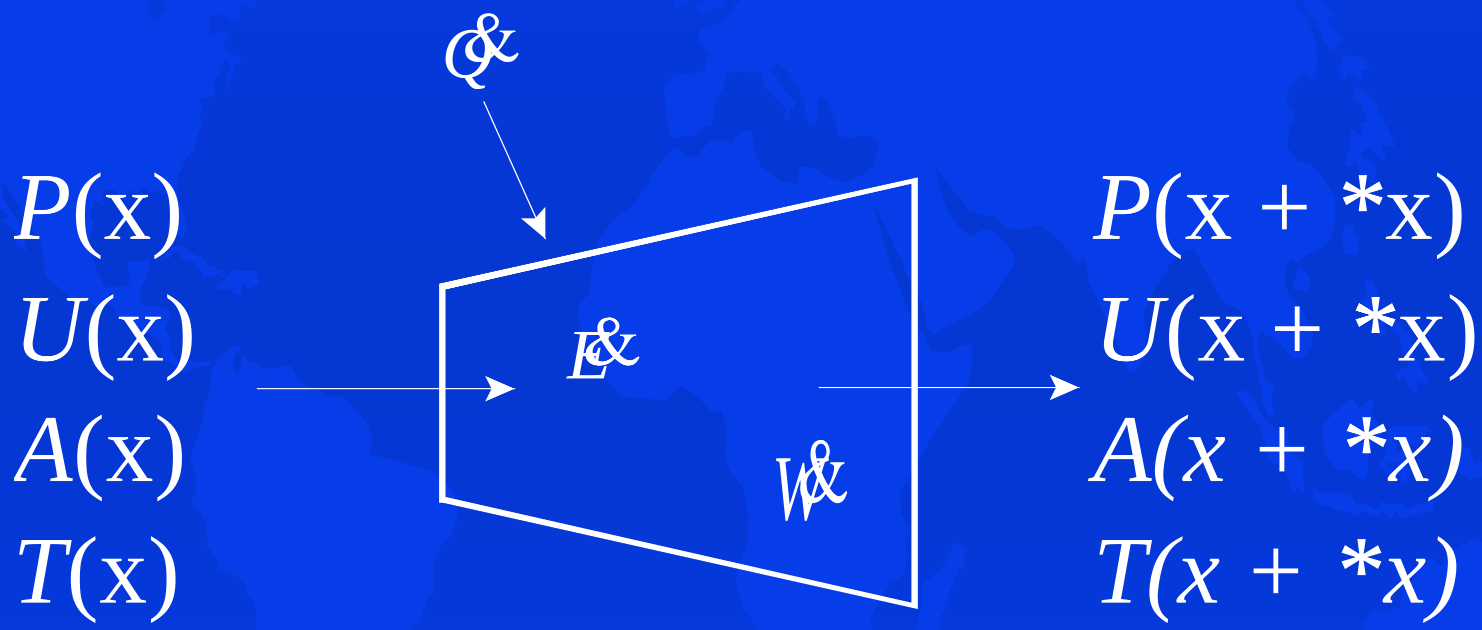
CFD Modeling Methodology

- Need to define objective - what is to be assessed:
  - Fume hood containment challenges
  - Energy efficiency
  - Thermal comfort
  - Spill scenario
- The objectives will steer the modeling decisions and in some cases in result in different approaches

The CFD Process

- Define the region to be modeled and divide it into smaller volumes called cells - *gridding*
- Apply conservation equations to each cell
- Ensure each cell knows about its neighbors
- Solve conservation equations

How CFD Works



- One uses CFD to predict flow field properties by solving the Navier Stokes Equations

What you get After Running CFD

- The solution for a simulation in a typical laboratory generates a set of data for pressure, air speeds, temperature, turbulence quantities, and contaminant concentrations.
- These variables can be further analyzed to generate information such as fumehood capture challenges, occupant comfort, age of air/ventilation efficiency.

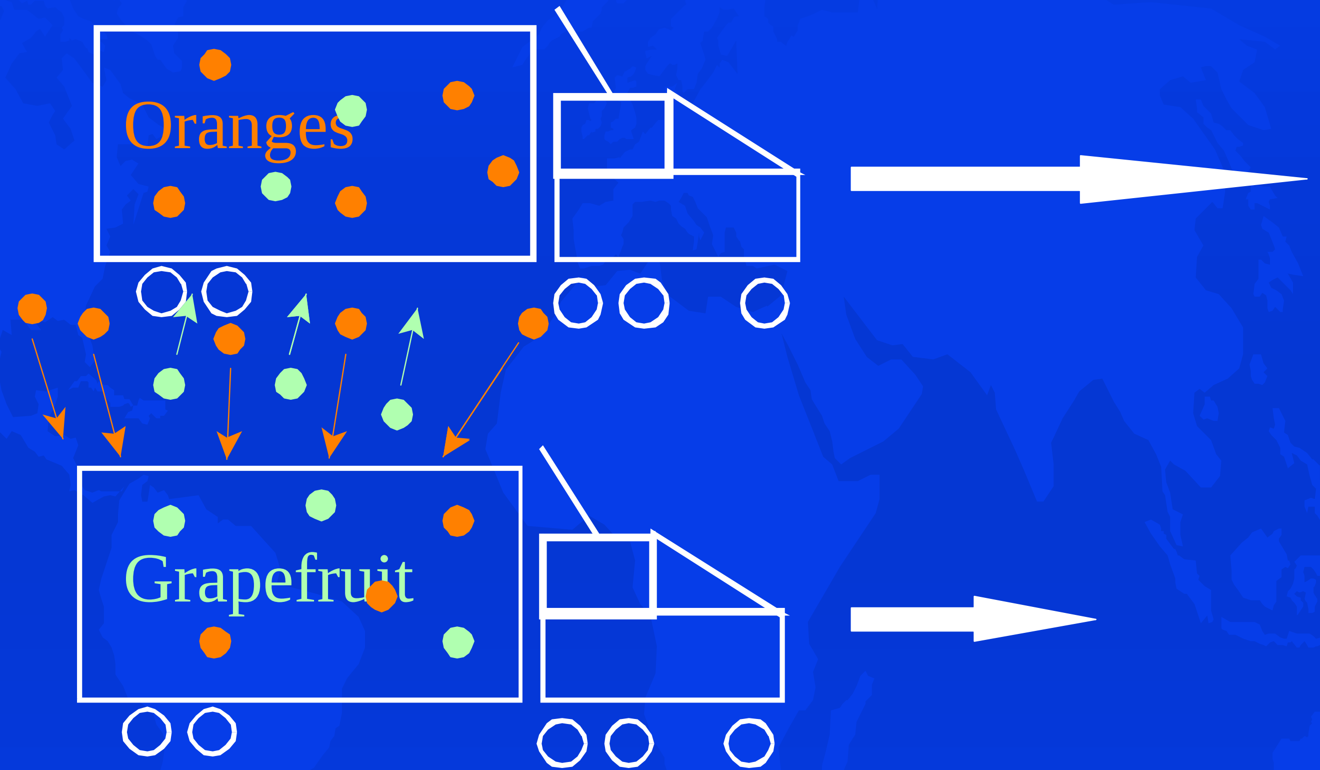
Types of CFD Modeling

- For our purposes this is associated with the method by which turbulence is handled and whether the results represent steady or transient conditions
  - DNS – Direct Numerical Simulation
  - LES – Large Eddy Simulation
  - RANS – Reynolds Averaged Navier Stokes
- Turbulence and the effects it causes represents one of the major uncertainties in CFD modeling

Turbulence – Why Worry?

- Turbulence is observed in most natural and engineering flows
- Turbulence is responsible for:
  - Increased heat transfer
  - Increased drag losses
  - Increased pollutant release from surfaces
  - Increased dispersion/transport of heat and contaminants about a space
- These effects can cause contaminants to escape from a fumehood and be rapidly transported about a lab

Turbulence Mechanisms



- Turbulent motion transporting packets of “information” – temperature, momentum, contaminants

Including the Effects of Turbulence in a CFD Model

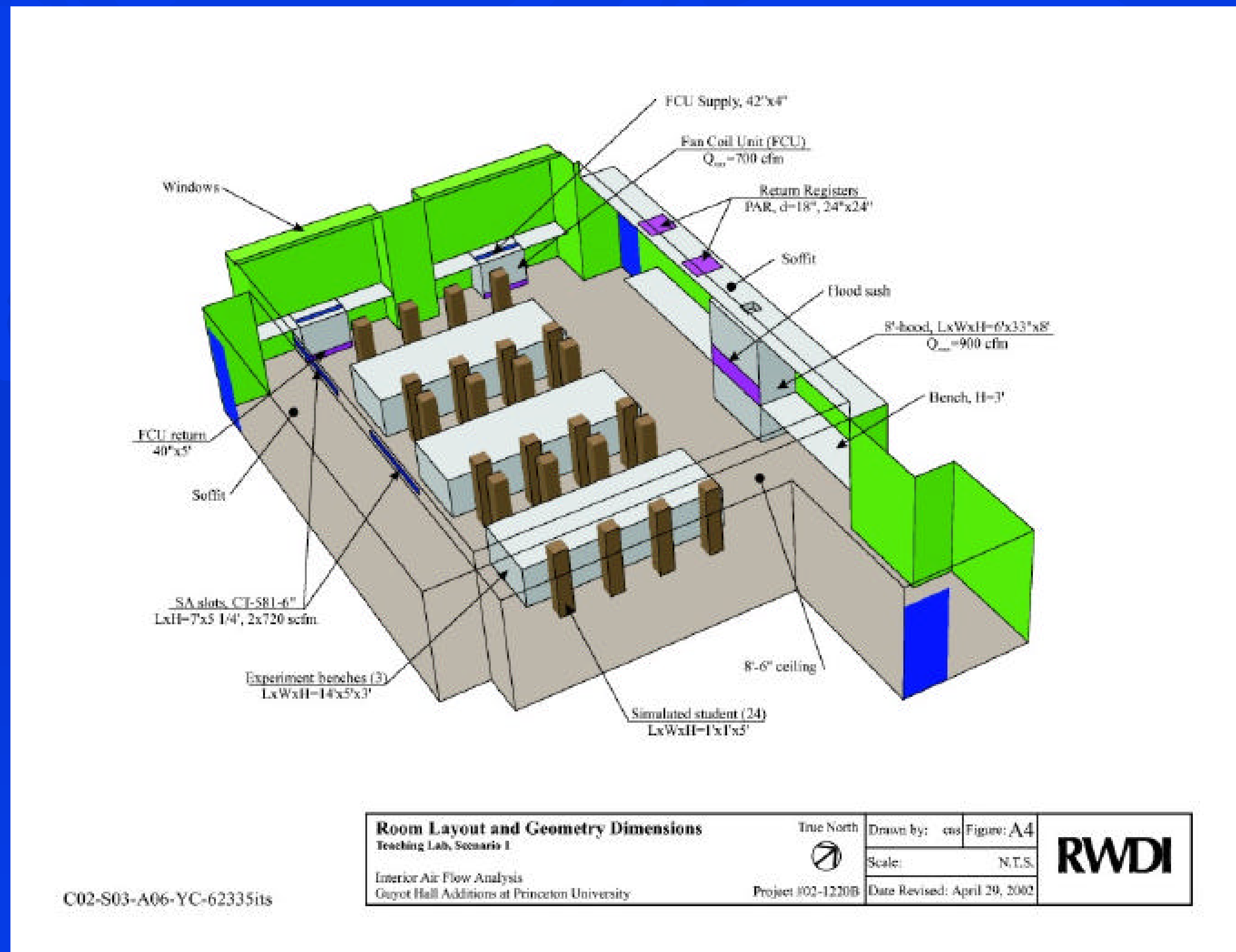
- DNS – Direct Numerical Simulation
  - Currently unrealistic
- LES – Large Eddy Simulation
  - Gaining momentum
- RANS – Reynolds Averaged Navier Stokes
  - Current method of choice

Examples of CFD Modelling in Labs

- Guyot Hall Lab Ventilation (RANS)
  - Thermal Comfort
  - Energy Costs
  - Spill Scenario
- Industrial Lab Ventilation (RANS & LES)
  - Diffuser selection and effects at face of fumehood – 3 scenarios
  - Assessment of fumehood containment challenges

Guyot Hall Teaching Lab - Geometry

Figure 1



Guyot Hall Teaching Lab – Result

- The purpose of the simulation was to assess the lower ventilation rate

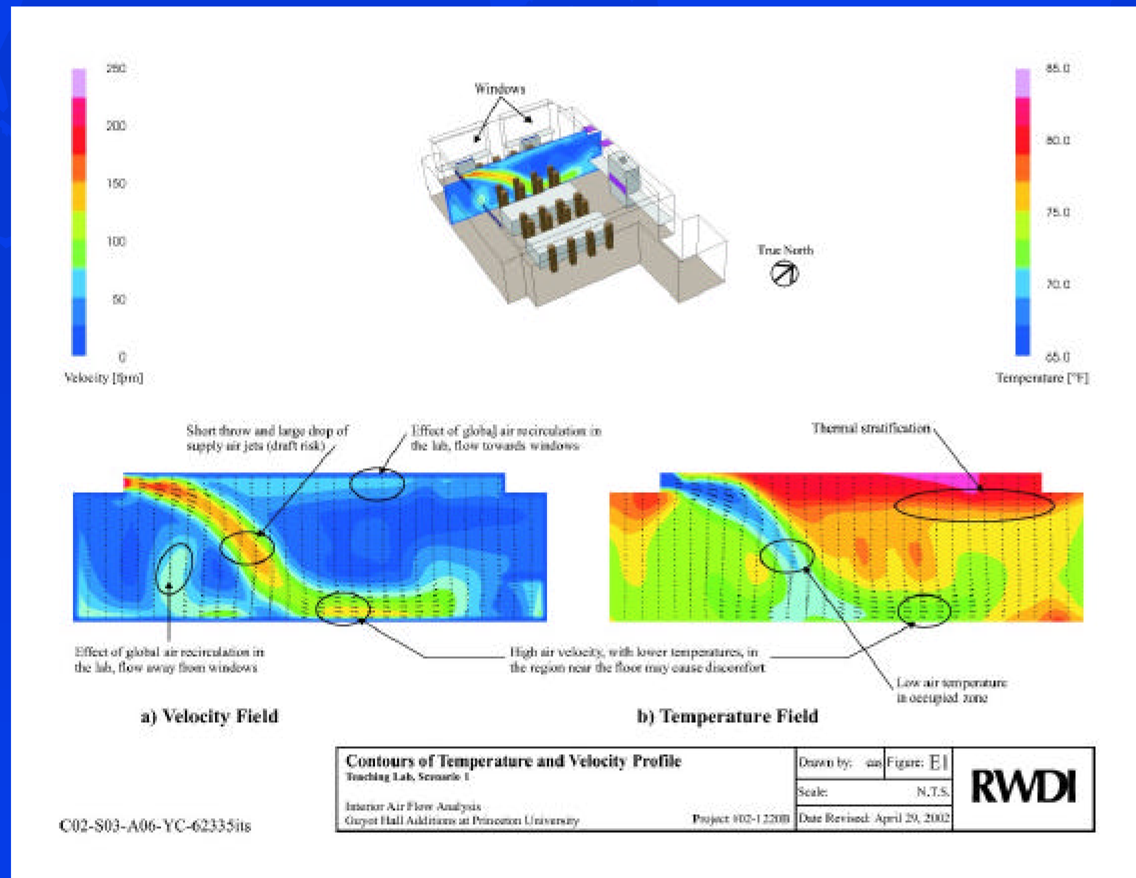
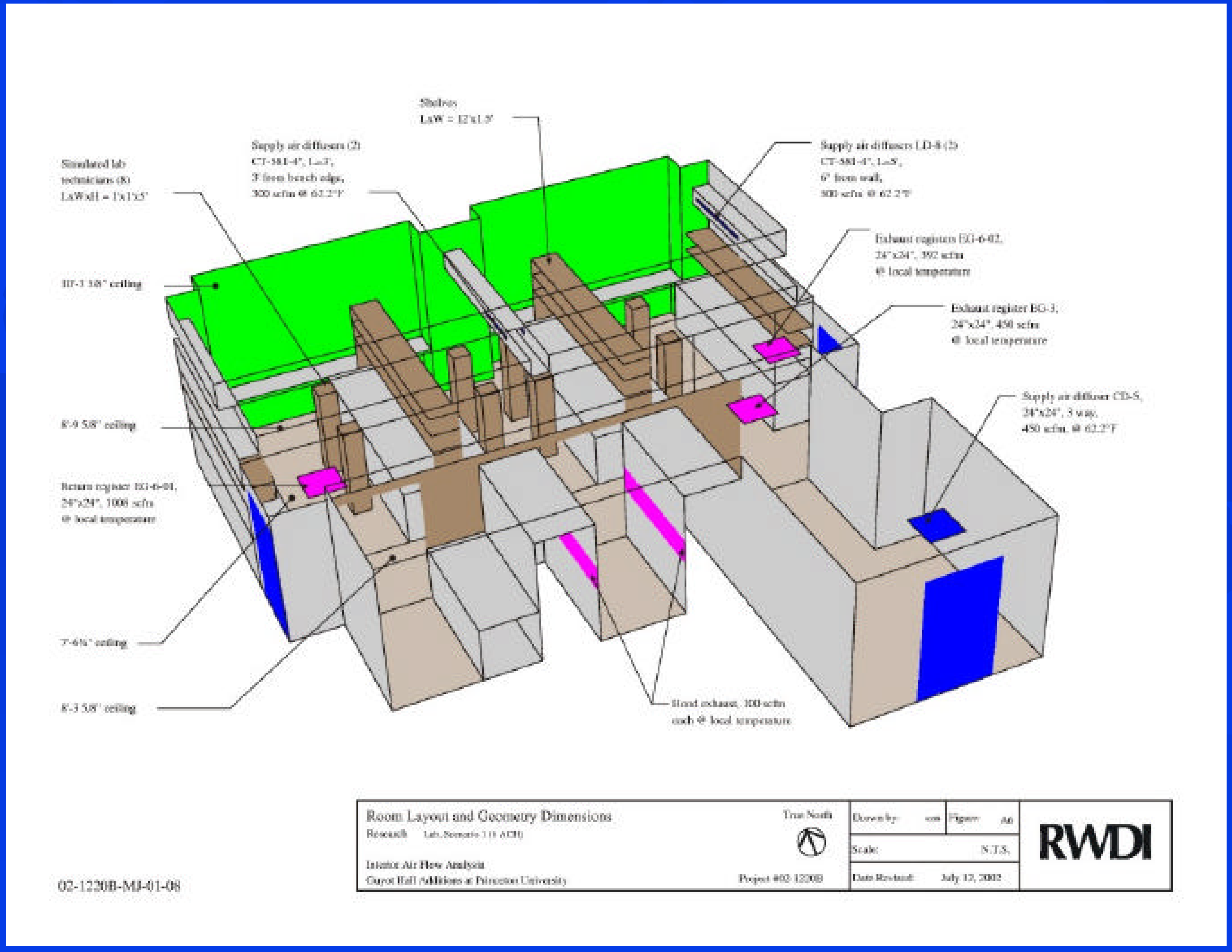


Figure 2

Guyot Hall Research Lab – Geometry

Figure 3



Guyot Hall Research Lab – Results

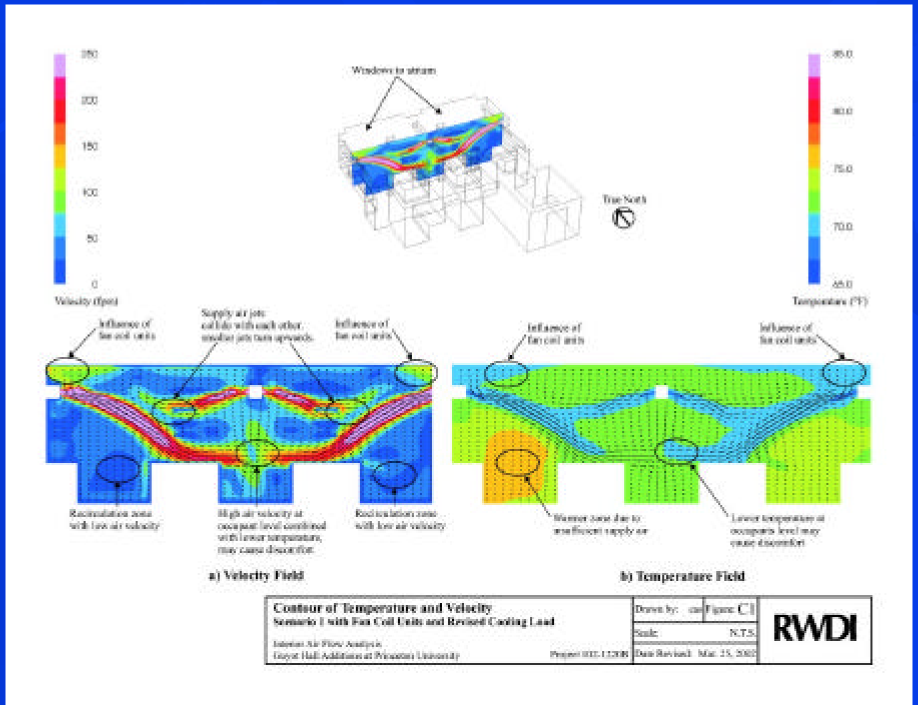


Figure 4

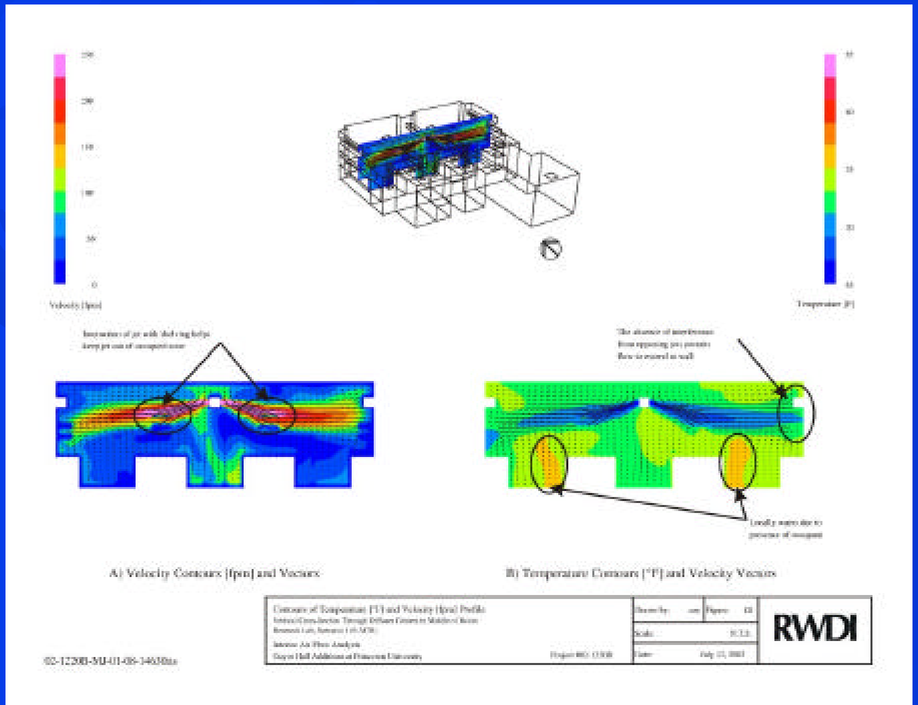


Figure 5

Animation 1

Animation 2

Industrial Lab – RANS Model

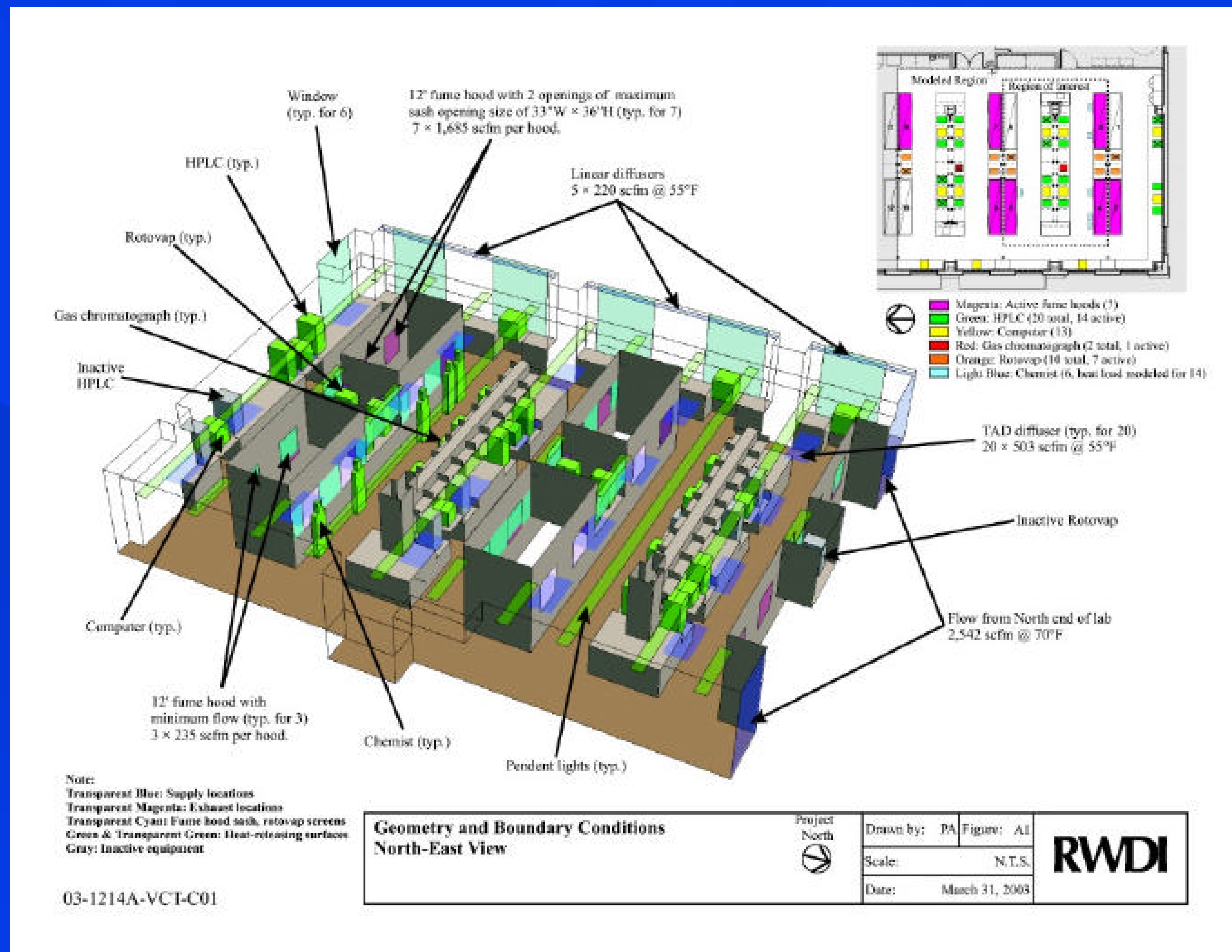


Figure 6

Industrial Lab – RANS Result

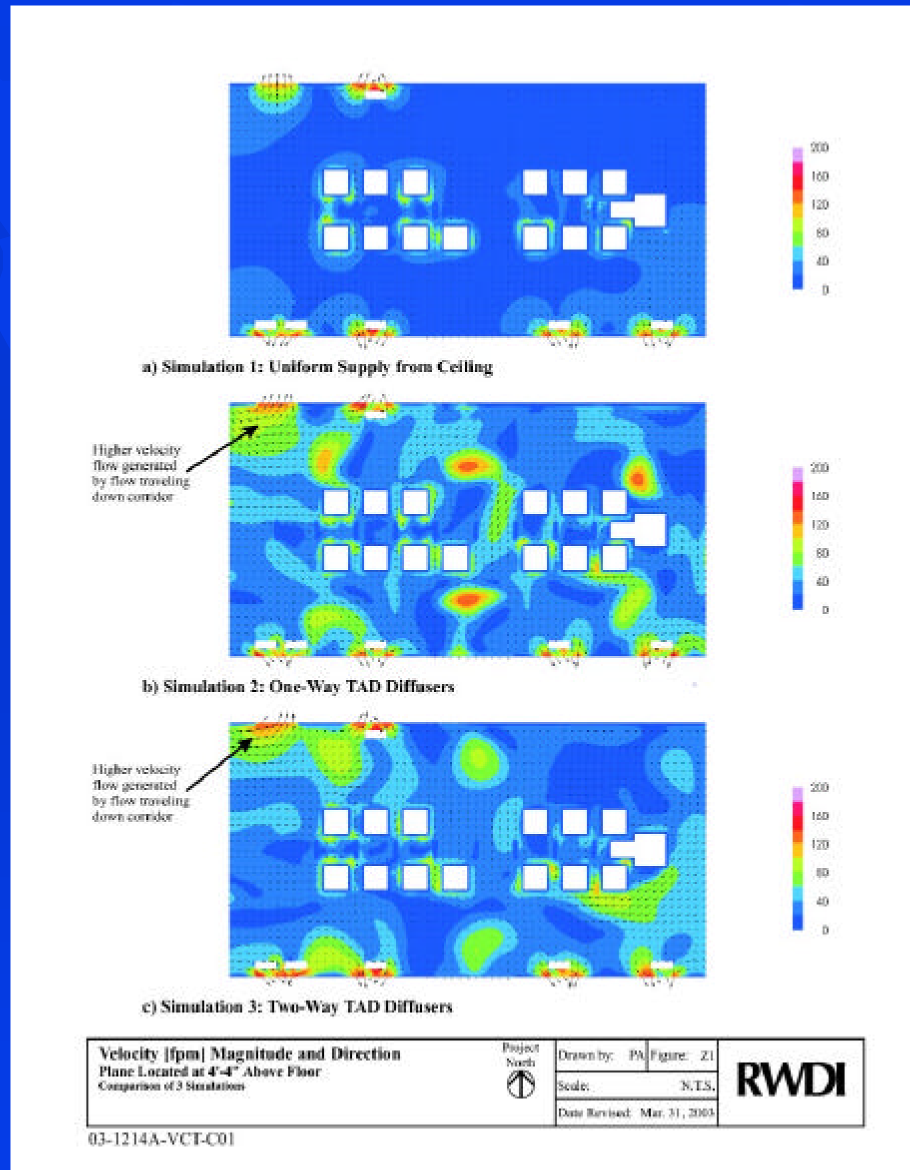
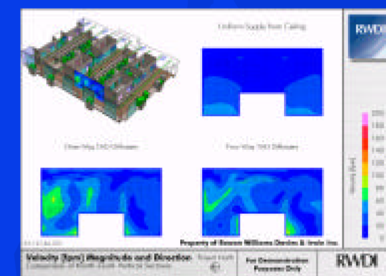
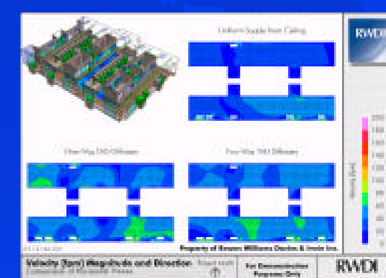


Figure 7



Animation 3



Animation 4

Industrial Lab – LES Result

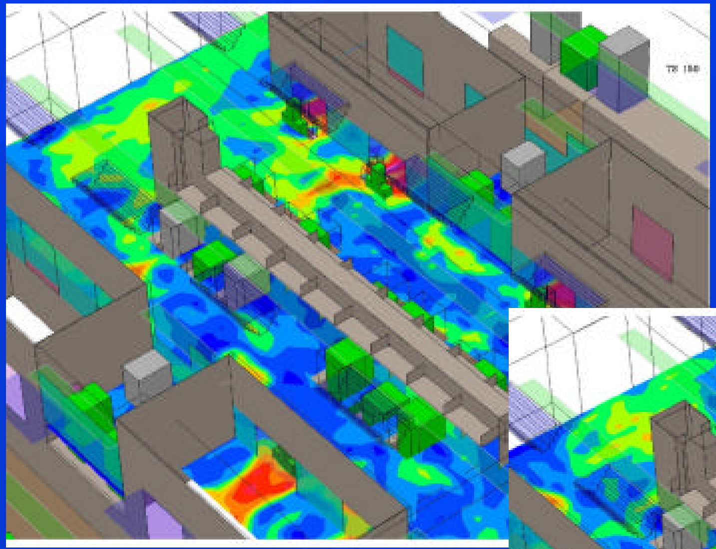


Figure 8a

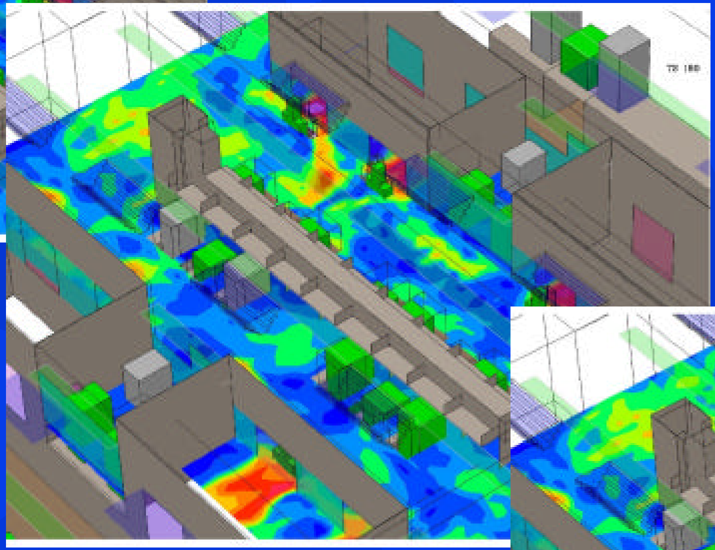


Figure 8b

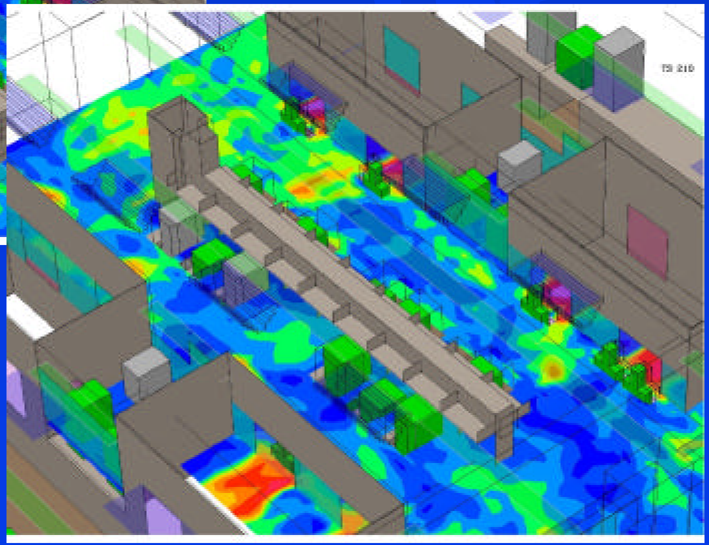


Figure 8c

LES Animation 5

LES Animation 6

Conclusions

- We have shown
  - CFD modeling is a valuable tool that designers and engineers can use to evaluate designs.
  - It permits one to compare and optimize alternatives.
  - Poor application of the technique can result in incorrect answers.
  - For Guyot Hall and the Industrial Lab application, use of CFD permitted the team to enhance the design for the client, reduce costs and evaluate risks

Where do we go from here?

- How do we apply knowledge in next project?
- How does a designer take stock in results seen in CFD Modeling?
- How do we intend to use CFD Modeling in the future?
- CFD Modeling as Performance Illustration for Compliance
- Ultimate Goal:

  To provide a safe environment in laboratories while using less energy.