Walk-in Slide: AU 2014 Social Media Feed

1. Click on the link below, this will open your web browser

http://aucache.autodesk.com/social/visualization.html

2. Use “Extended Display” to project the website on screen if you plan to work on your computer. Use “Duplicate” to display same image on screen and computer.

AB5381 - Using Simulation 360 CFD: Patient Comfort and Energy Performance in Healthcare Design

Michael Ramsay

Associate / Digital Practice Leader

Class summary

The NBBJ healthcare practice is currently using Simulation CFD 360 software to study patient comfort in healthcare design. This class will show examples of the work, and we will examine analysis of the results of this work. We will examine in-depth studies of natural ventilation, infection control, and patient comfort, and we will discuss methods and results. We will investigate other uses of Simulation CFD 360 software in the study of energy-saving concepts as they relate to healthcare design and the design of other sustainable design solutions.

Key learning objectives

At the end of this class, you will be able to:

- Set up a basic Simulation CFD 360 simulation
- Understand energy concepts being studied in healthcare design
- Understand new patient comfort concepts being studied in healthcare design
- Investigate the possible uses of Simulation 360 CFD software to enable design research

What we're going to do

Agenda

- Introduction
- Program
- Case Studies
- Future
- Questions

Simulation = Comparative

Program

Autodesk Simulation CFD 360 2015 Human Figure Test::Design 1::Scenario 1 - Base

Type a keyword or phrase michaelramsa...

Setup | Results | View | Vault | Autodesk 360 | Start & Learn | Community

Add/Update Design | Templates | Rules — Design Study Tools

Geometry Tools | Materials | Boundary Conditions | Initial Conditions | Mesh Sizing | Motion — Setup Tasks

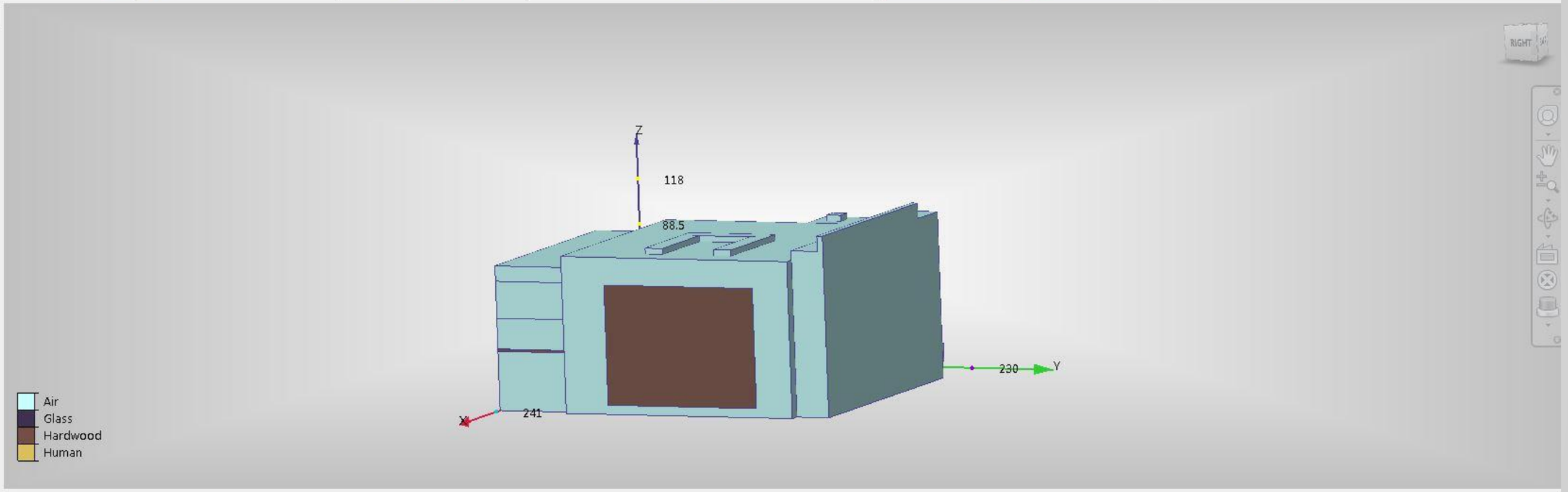
Solve | Solver Manager | Notifications — Simulation

Volume | Surface | Edge | Direct | Select Previous | Select All | Show All | Deselect | Deselect All — Selection

Edit | Remove | Material Editor | Scenario Environment — Materials

Design Study Bar

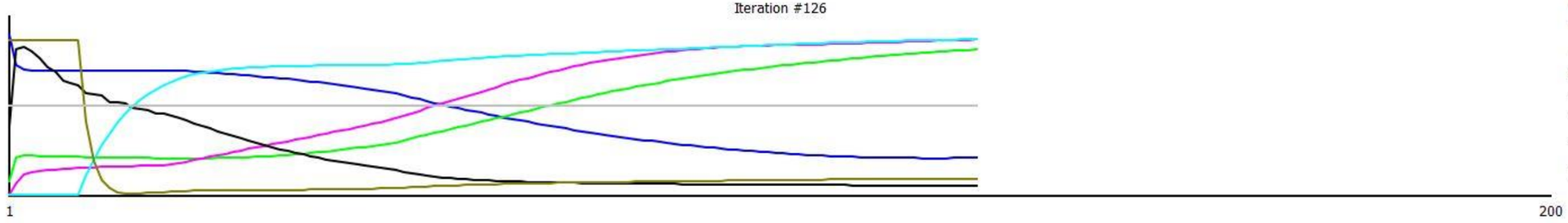
- Note
- **Design 1**
  - Geometry (inch-BTU/s)
  - 12 ACH
  - 9 ACH
  - **6 ACH**
    - Material
      - Air [Variable]
      - Glass [Fixed]
      - Hardwood [Fixed]
      - Human [Fixed]
    - Boundary Conditions
      - [Total Heat Generati...
      - [VelocityZ(-17.4 ft/mi...
      - [Film Coefficient(0.45...
      - [Film Coefficient(3.36...
      - [Volume Flow Rate(1...
      - [Pressure(0 psi Gage)]
    - Initial Conditions
    - Mesh Size (auto)
      - Model mesh settings
      - Mesh History
    - Motion
    - Groups
    - Solve
      - Flow: On
      - Heat Transfer: Off



Output Bar

Plot | Table

Iteration #126



Vx Vel
Vy Vel
Vz Vel
Pres
Temp
TKE
TED
Scalar

Global | All | Avg | Log scale | Save...

Start: 1 End: 200

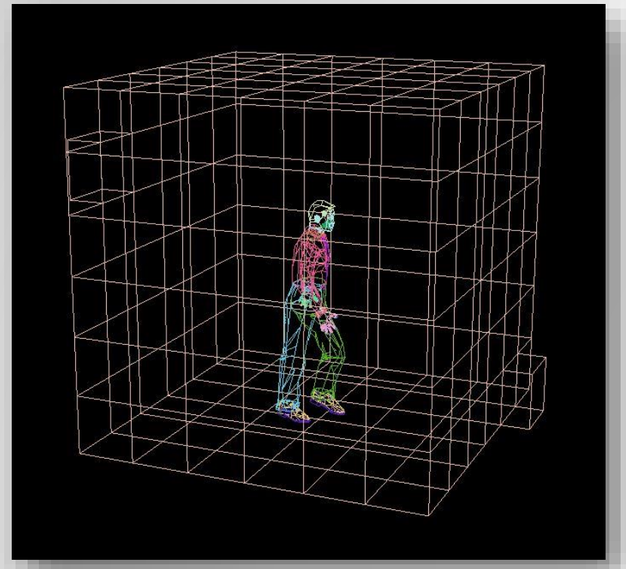
Message Window | Convergence Plot | Critical Values | Design Review Center

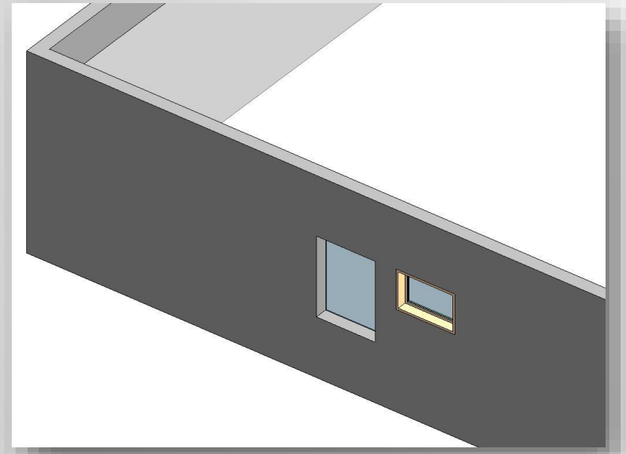
0 Volume(s) selected

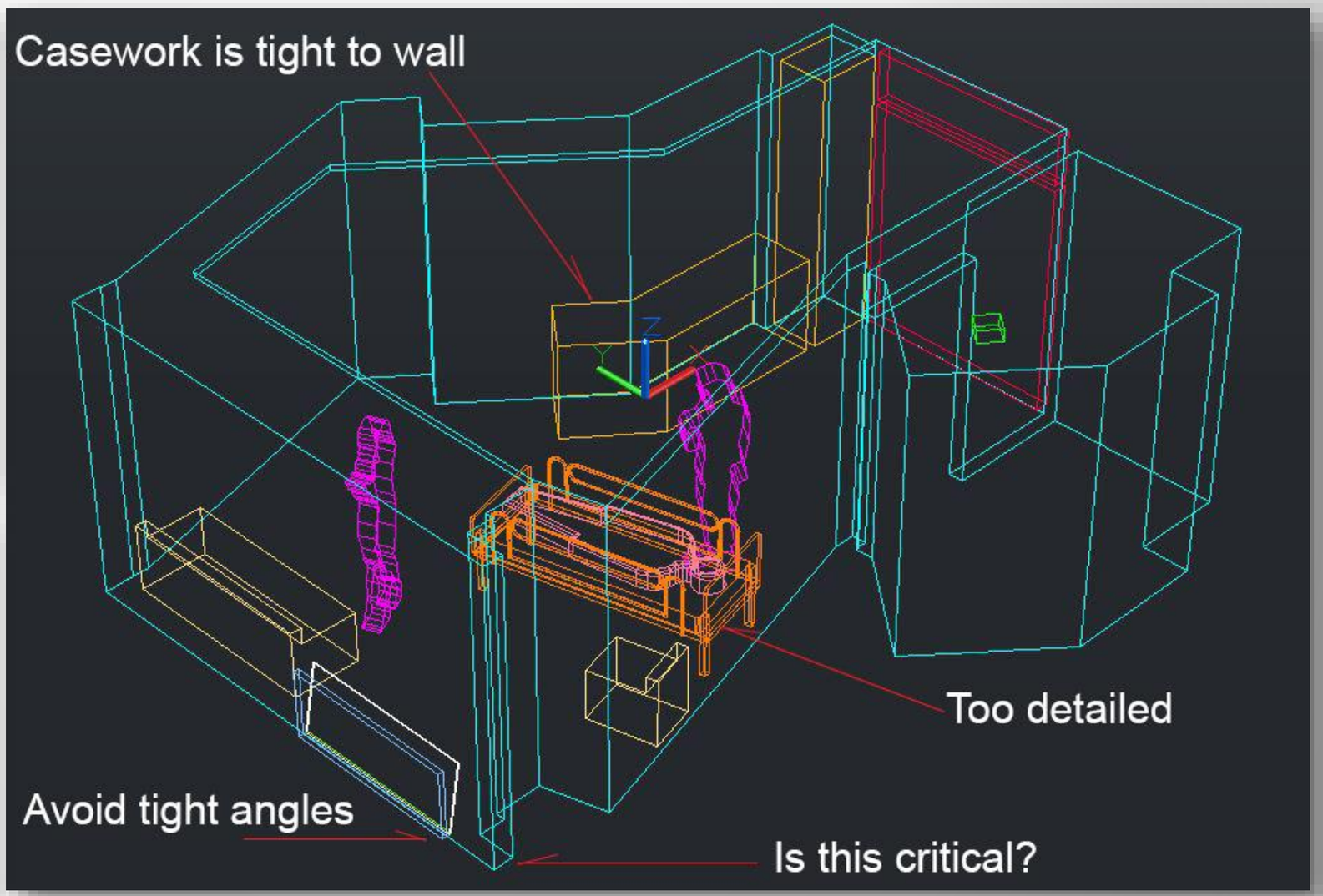
Basics – The simple “how to”

- Model your design in some authoring software (Revit, MAX, AutoCAD, other)
- Import the model into the Simulation CFD 360 software
- Apply materials to the model
- Apply boundary conditions to the model (BCs)
- Mesh the model.
- Setup the solver and solve options
- Submit the simulation to the solver
- Solve
- Download the results
- Analyze

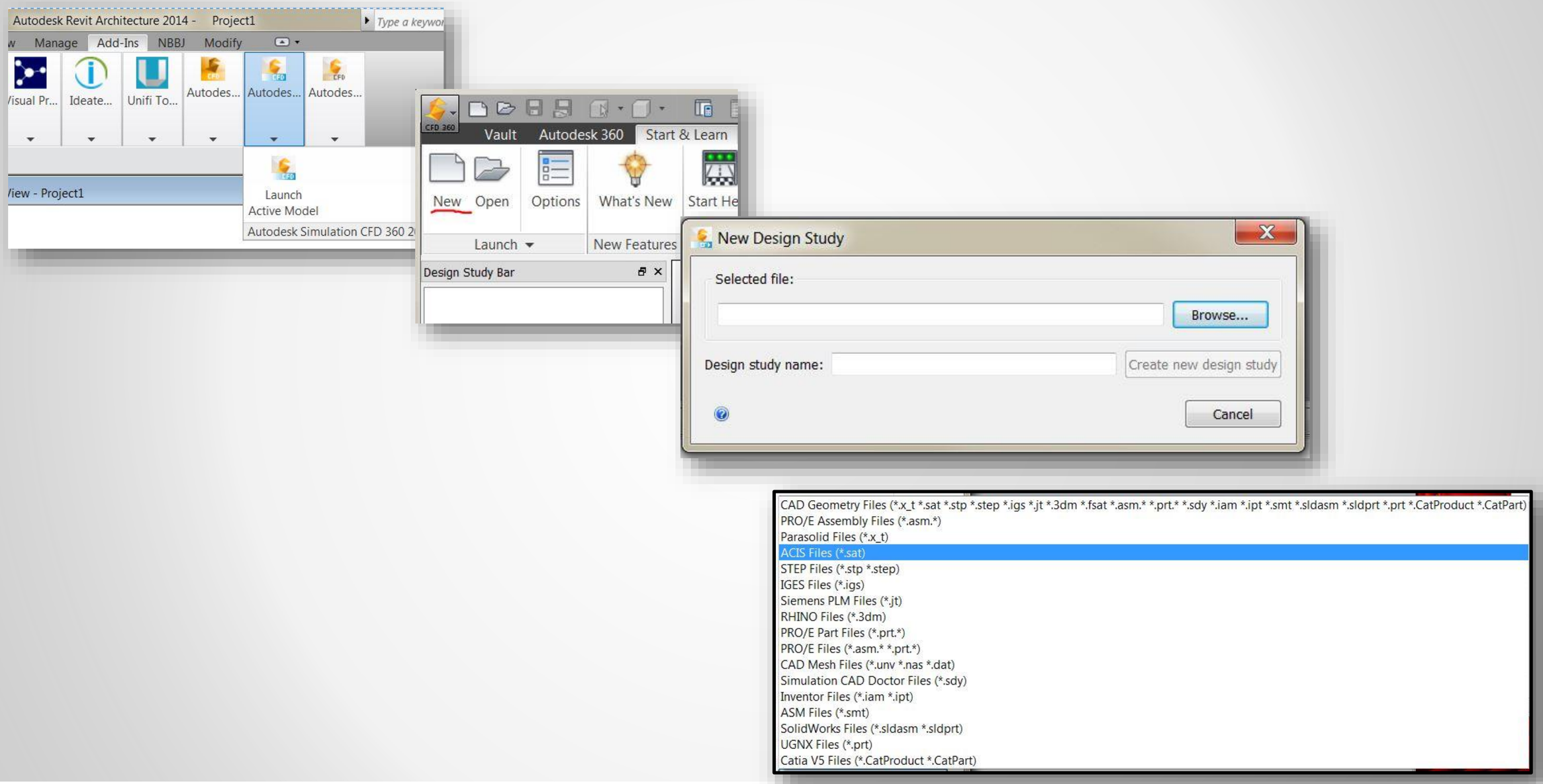
Modeling



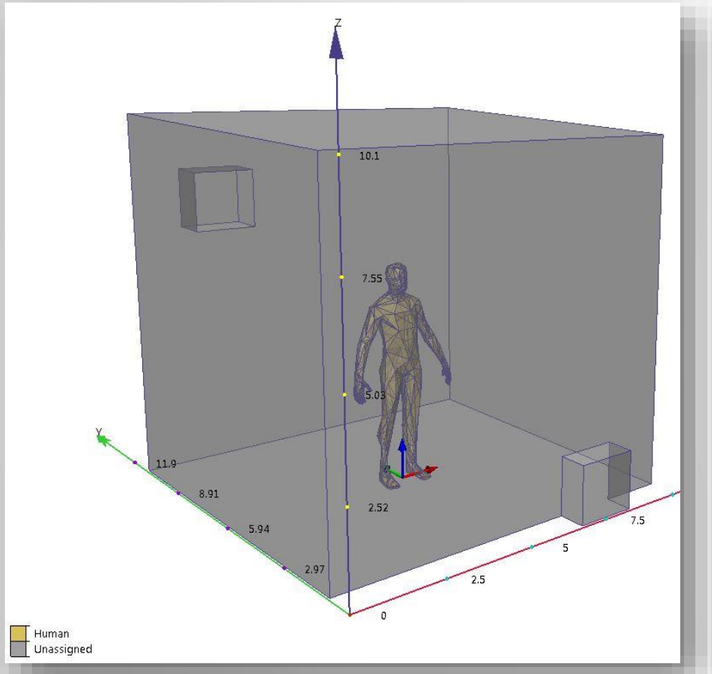


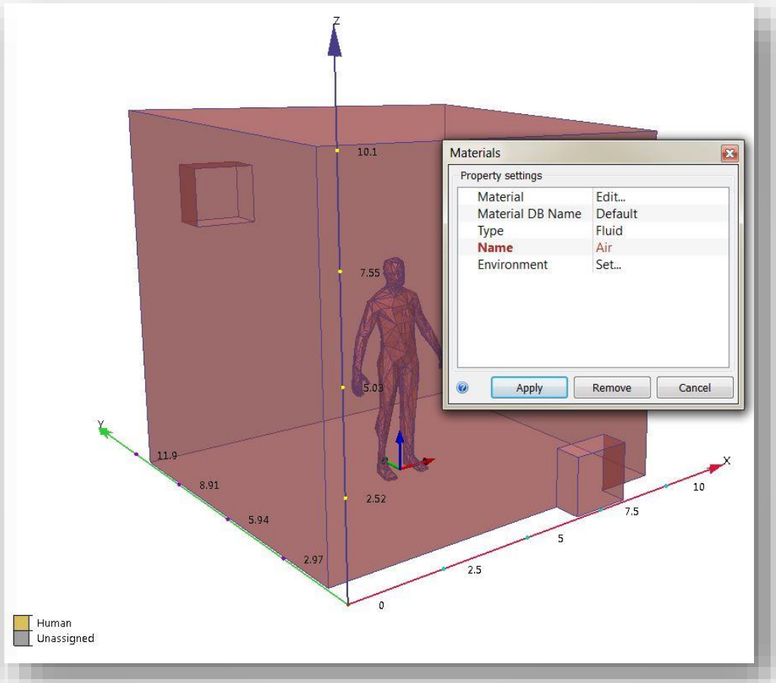

Casework is tight to wall
Too detailed
Avoid tight angles
Is this critical?

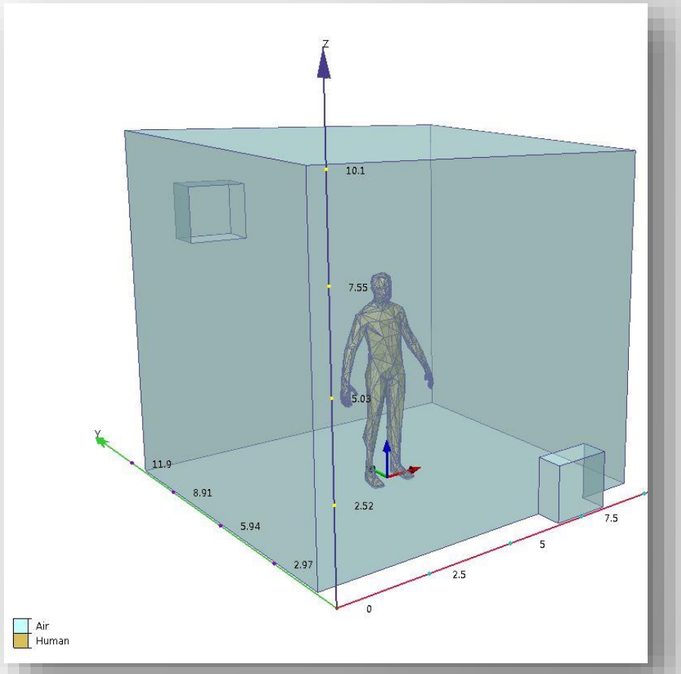
Import


Autodesk Revit Architecture 2014 - Project1
Manage
Add-Ins
NBBJ
Modify
Launch
Active Model
Autodesk Simulation CFD 360
CFD 360
Vault
Autodesk 360
Start & Learn
New
Open
Options
What's New
Launch
New Features
Design Study Bar
New Design Study
Selected file:
Browse...
Design study name:
Create new design study
Cancel
CAD Geometry Files (*.x_t *.sat *.stp *.step *.igs *.jt *.3dm *.fsat *.asm.* *.prt.* *.sdy *.iam *.ipt *.smt *.sldasm *.sldprt *.prt *.CatProduct *.CatPart)
PRO/E Assembly Files (*.asm.*)
Parasolid Files (*.x_t)
ACIS Files (*.sat)
STEP Files (*.stp *.step)
IGES Files (*.igs)
Siemens PLM Files (*.jt)
RHINO Files (*.3dm)
PRO/E Part Files (*.prt.*)
PRO/E Files (*.asm.* *.prt.*)
CAD Mesh Files (*.unv *.nas *.dat)
Simulation CAD Doctor Files (*.sdy)
Inventor Files (*.iam *.ipt)
ASM Files (*.smt)
SolidWorks Files (*.sldasm *.sldprt)
UGNX Files (*.prt)
Catia V5 Files (*.CatProduct *.CatPart)

Materials


Z
10.1
7.55
5.03
2.52
Y
11.9
8.91
5.94
2.97
0
2.5
5
7.5
Human
Unassigned


Z
10.1
7.55
5.03
2.52
Y
11.9
8.91
5.94
2.97
0
2.5
5
7.5
10
X
Materials
Property settings
Material
Edit...
Material DB Name
Default
Type
Fluid
Name
Air
Environment
Set...
Apply
Remove
Cancel
Human
Unassigned

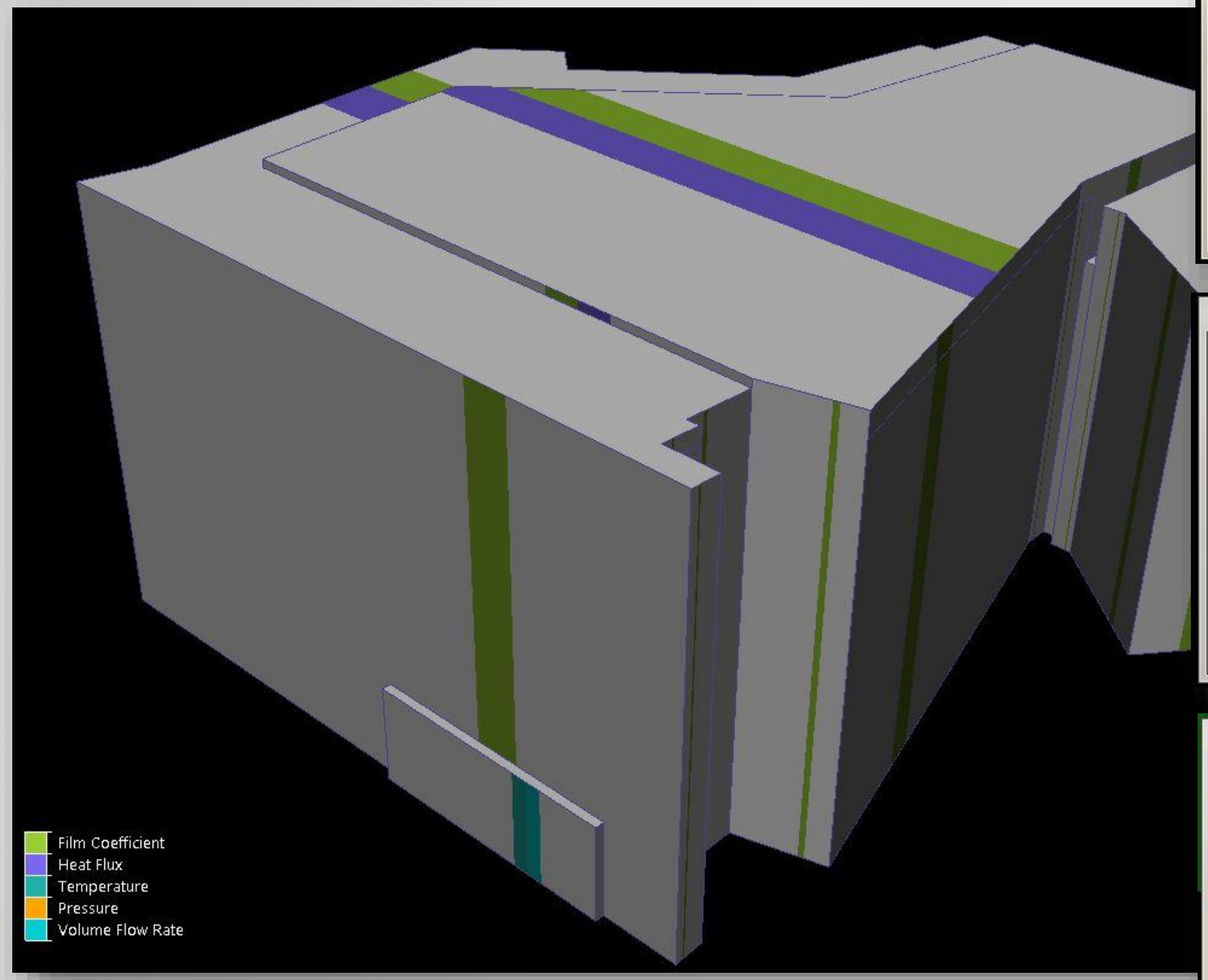

Z
10.1
7.55
5.03
2.52
Y
11.9
8.91
5.94
2.97
0
2.5
5
7.5
Air
Human

Boundary Conditions

*"**Boundary conditions define the inputs of the simulation model**. Some conditions, like velocity and volumetric flow rate, define how a fluid enters or leaves the model. Other conditions, like film coefficient and heat flux, define the interchange of energy between the model and its surroundings.*

***Boundary conditions connect the simulation model with its surroundings**. Without them, the simulation is not defined, and in most cases cannot proceed. Most boundary conditions can be defined as either steady-state or transient. Steady-state boundary conditions persist throughout the simulation. Transient boundary conditions vary with time, and are often used to simulate an event or a cyclical phenomena."*

Boundary Conditions



Boundary Conditions

Property settings

Type	Heat Flux
Unit	W/m2
Time	Steady State
Heat Flux	0.32

Apply | Remove | Cancel

Boundary Conditions

Property settings

Type	Volume Flow Rate
Unit	ft3/min
Time	Steady State
Volume Flow Rate	391
Direction	Reverse Normal
Fully Developed	☐

Apply | Remove | Cancel

Boundary Conditions

Property settings

Type	Film Coefficient
Time	Steady State
Coefficient Units	W/m2/K
Film Coefficient	3.36
Temperature Units	Fahrenheit
Ref Temperature	75

Apply | Remove | Cancel

Boundary Conditions

Property settings

Type	Pressure
Unit	Pa
Time	Steady State
Pressure	0
Gage / Absolute	Gage
Static / Total	Static

Apply | Remove | Cancel

Boundary Conditions

Property settings

Type	Film Coefficient
Time	Steady State
Coefficient Units	W/m2/K
Film Coefficient	0.45
Temperature Units	Fahrenheit
Ref Temperature	68

Apply | Remove | Cancel

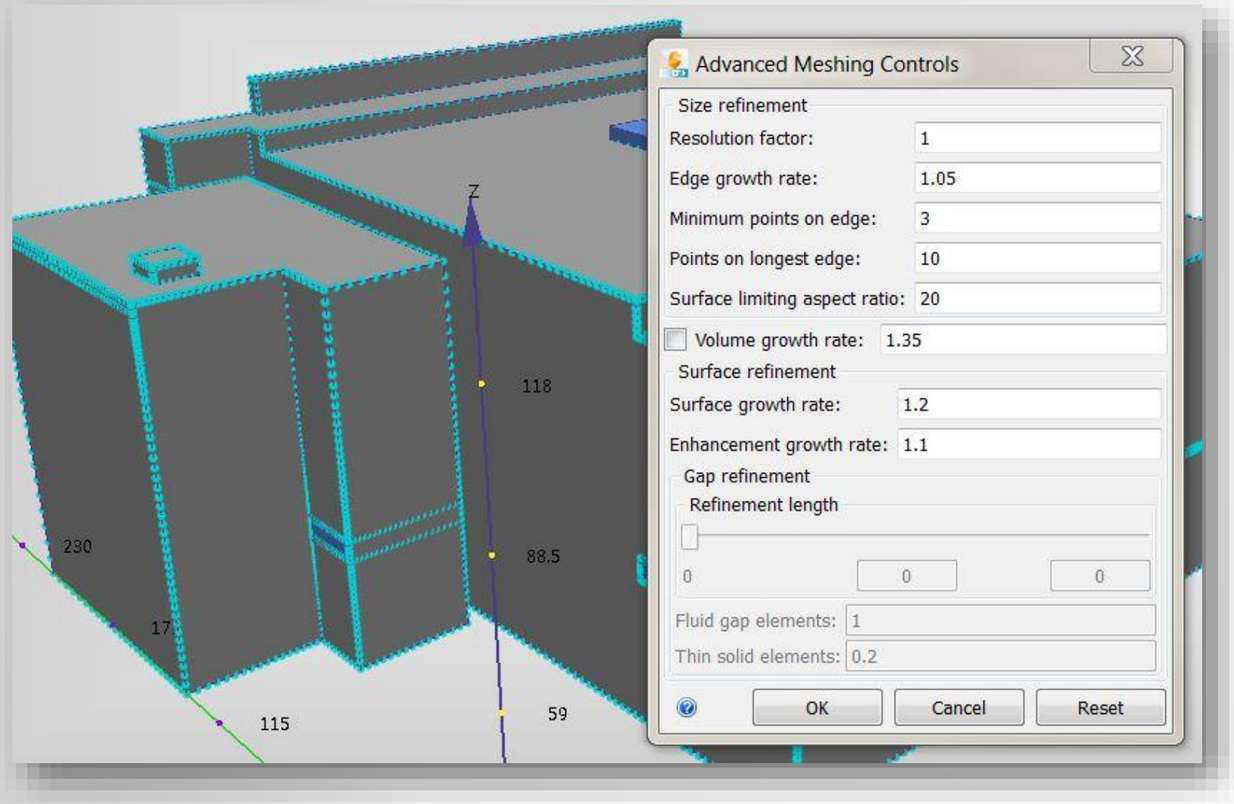
Boundary Conditions

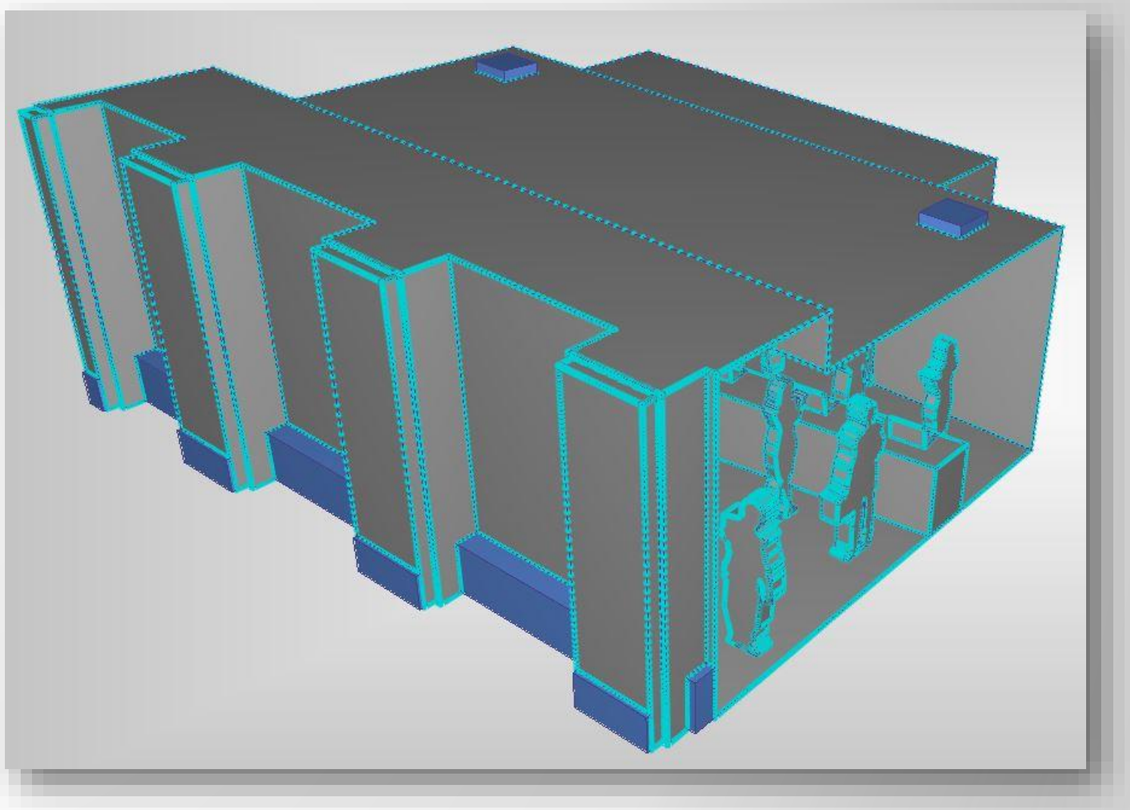
Property settings

Type	Velocity
Unit	ft/min
Time	Steady State
Method	Normal
Direction	Reverse Normal
Spatial Variations	Constant
Velocity Magnitu...	400

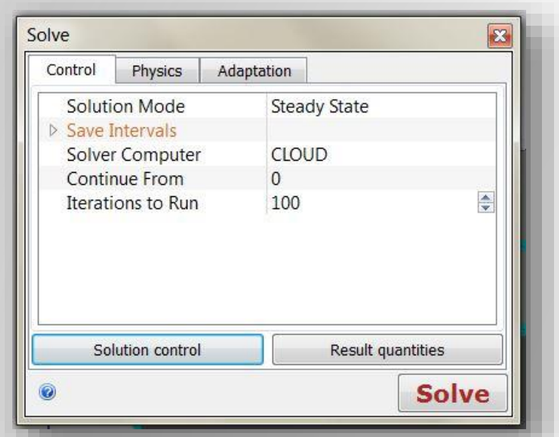
Apply | Remove | Cancel

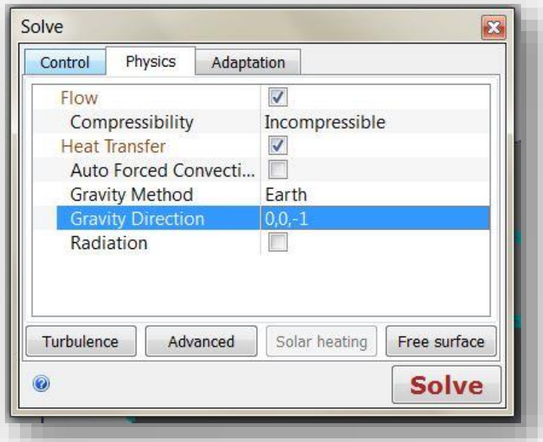
Mesh

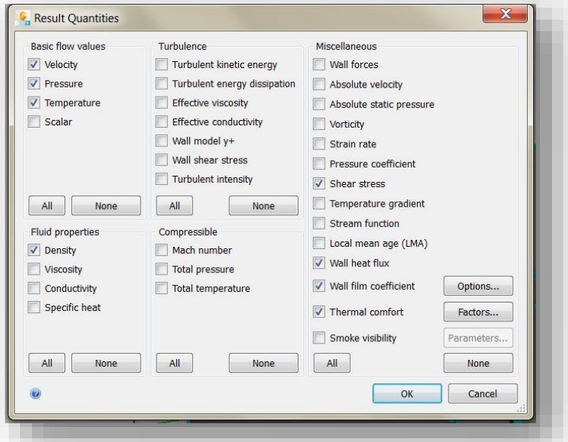

Z
118
88.5
230
17
115
59
Advanced Meshing Controls
Size refinement
Resolution factor: 1
Edge growth rate: 1.05
Minimum points on edge: 3
Points on longest edge: 10
Surface limiting aspect ratio: 20
Volume growth rate: 1.35
Surface refinement
Surface growth rate: 1.2
Enhancement growth rate: 1.1
Gap refinement
Refinement length
0
0
0
Fluid gap elements: 1
Thin solid elements: 0.2
OK
Cancel
Reset

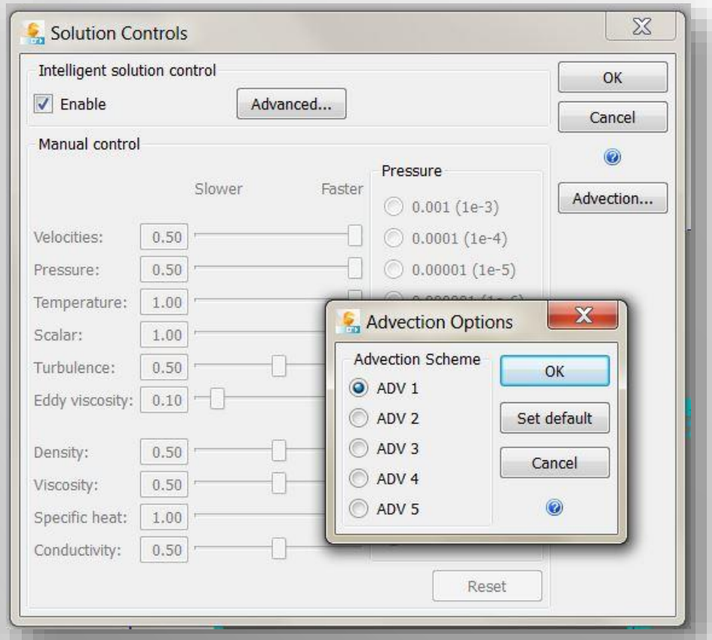


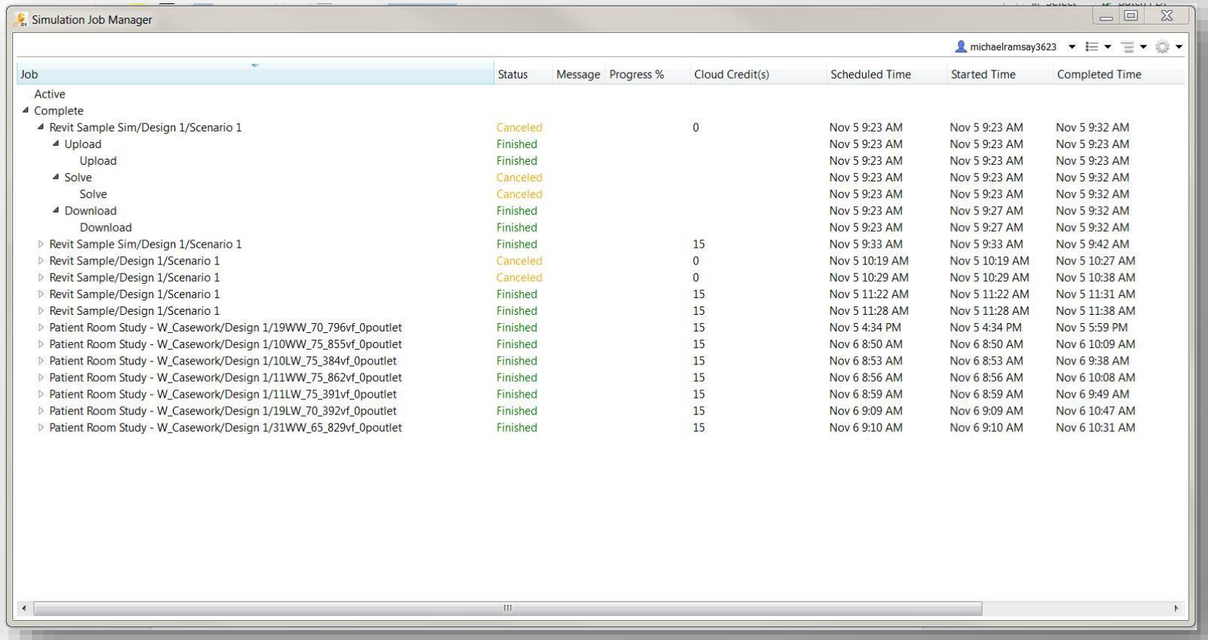
Solve


Solve
Control
Physics
Adaptation
Solution Mode
Steady State
Save Intervals
Solver Computer
CLOUD
Continue From
0
Iterations to Run
100
Solution control
Result quantities
Solve

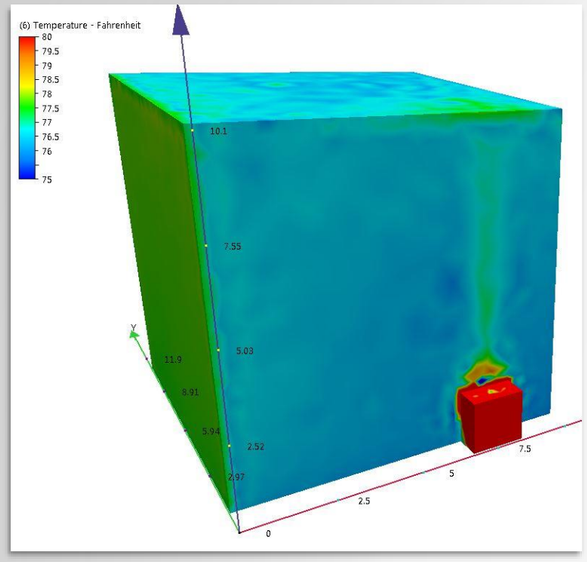

Solve
Control
Physics
Adaptation
Flow
Compressibility
Incompressible
Heat Transfer
Auto Forced Convecti...
Gravity Method
Earth
Gravity Direction
0,0,-1
Radiation
Turbulence
Advanced
Solar heating
Free surface
Solve

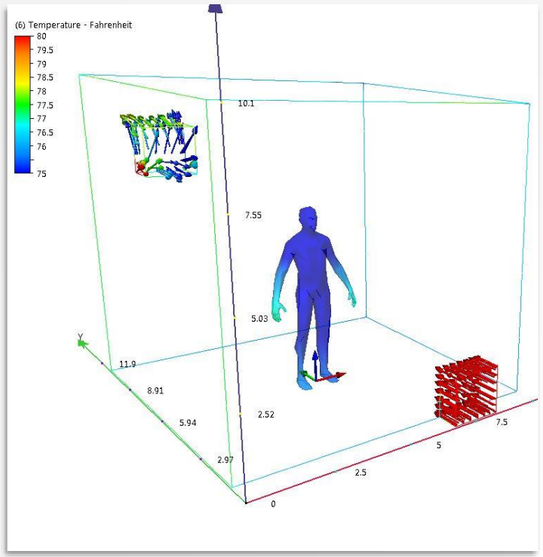

Result Quantities
Basic flow values
Velocity
Pressure
Temperature
Scalar
Turbulence
Turbulent kinetic energy
Turbulent energy dissipation
Effective viscosity
Effective conductivity
Wall model y+
Wall shear stress
Turbulent intensity
Miscellaneous
Wall forces
Absolute velocity
Absolute static pressure
Vorticity
Strain rate
Pressure coefficient
Shear stress
Temperature gradient
Stream function
Local mean age (LMA)
Wall heat flux
Wall film coefficient
Thermal comfort
Smoke visibility
Options...
Factors...
Parameters...
Fluid properties
Density
Viscosity
Conductivity
Specific heat
Compressible
Mach number
Total pressure
Total temperature
All
None
OK
Cancel

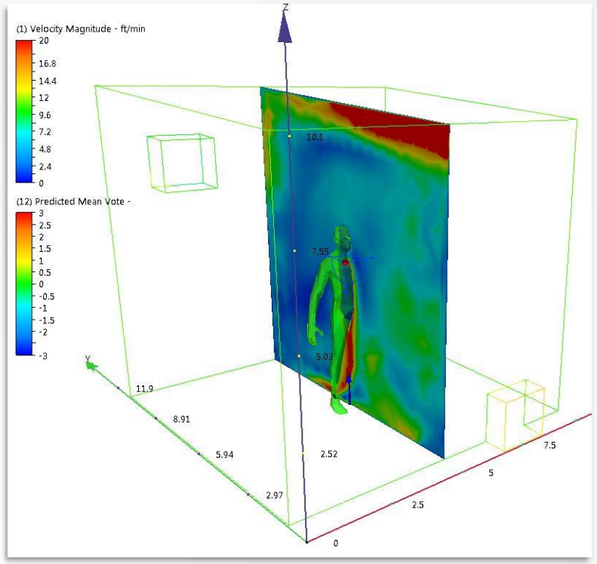

Solution Controls
Intelligent solution control
Enable
Advanced...
OK
Cancel
Advection...
Manual control
Slower
Faster
Pressure
0.001 (1e-3)
0.0001 (1e-4)
0.00001 (1e-5)
Velocities:
Pressure:
Temperature:
Scalar:
Turbulence:
Eddy viscosity:
Density:
Viscosity:
Specific heat:
Conductivity:
0.50
1.00
0.10
Reset
Advection Options
Advection Scheme
ADV 1
ADV 2
ADV 3
ADV 4
ADV 5
OK
Set default
Cancel

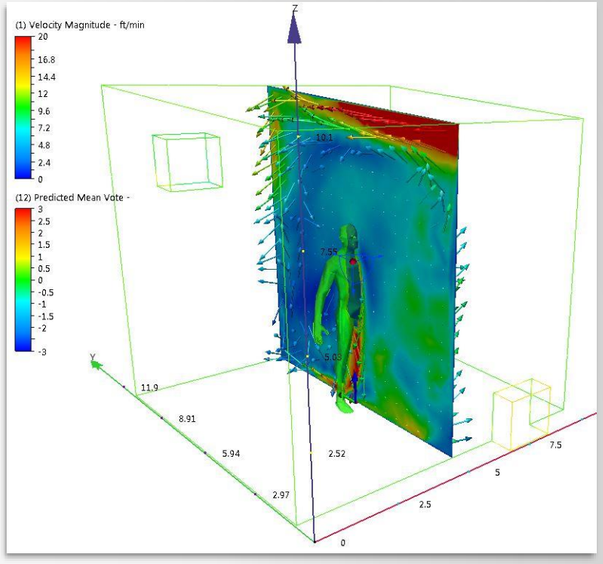

Simulation Job Manager
michaelramsay3623
Job
Status
Message
Progress %
Cloud Credit(s)
Scheduled Time
Started Time
Completed Time
Active
Complete
Revit Sample Sim/Design 1/Scenario 1
Canceled
0
Nov 5 9:23 AM
Nov 5 9:23 AM
Nov 5 9:32 AM
Upload
Finished
Nov 5 9:23 AM
Nov 5 9:23 AM
Nov 5 9:23 AM
Solve
Canceled
Download
Revit Sample Sim/Design 1/Scenario 1
Finished
15
Nov 5 9:33 AM
Nov 5 9:33 AM
Nov 5 9:42 AM
Revit Sample/Design 1/Scenario 1
Canceled
0
Nov 5 10:19 AM
Nov 5 10:19 AM
Nov 5 10:27 AM
Nov 5 10:29 AM
Nov 5 10:29 AM
Nov 5 10:38 AM
Finished
15
Nov 5 11:22 AM
Nov 5 11:22 AM
Nov 5 11:31 AM
Nov 5 11:28 AM
Nov 5 11:28 AM
Nov 5 11:38 AM
Patient Room Study - W_Casework/Design 1/19WW_70_796vf_0poutlet
Nov 5 4:34 PM
Nov 5 4:34 PM
Nov 5 5:59 PM
Patient Room Study - W_Casework/Design 1/10WW_75_855vf_0poutlet
Nov 6 8:50 AM
Nov 6 8:50 AM
Nov 6 10:09 AM
Patient Room Study - W_Casework/Design 1/10LW_75_384vf_0poutlet
Nov 6 8:53 AM
Nov 6 8:53 AM
Nov 6 9:38 AM
Patient Room Study - W_Casework/Design 1/11WW_75_862vf_0poutlet
Nov 6 8:56 AM
Nov 6 8:56 AM
Nov 6 10:08 AM
Patient Room Study - W_Casework/Design 1/11LW_75_391vf_0poutlet
Nov 6 8:59 AM
Nov 6 8:59 AM
Nov 6 9:49 AM
Patient Room Study - W_Casework/Design 1/19LW_70_392vf_0poutlet
Nov 6 9:09 AM
Nov 6 9:09 AM
Nov 6 10:47 AM
Patient Room Study - W_Casework/Design 1/31WW_65_829vf_0poutlet
Nov 6 9:10 AM
Nov 6 9:10 AM
Nov 6 10:31 AM

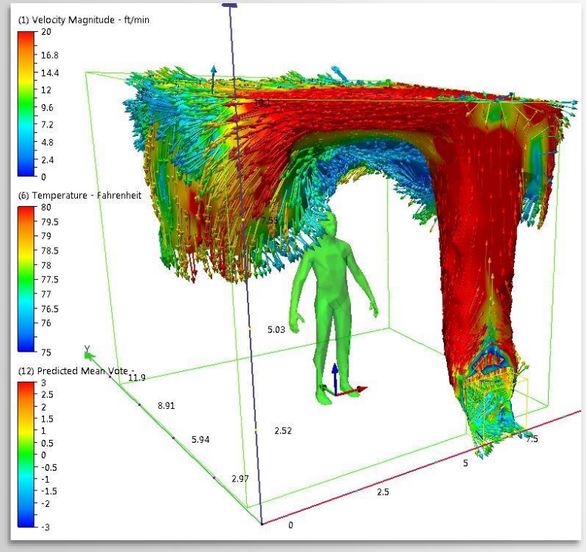
Analyze

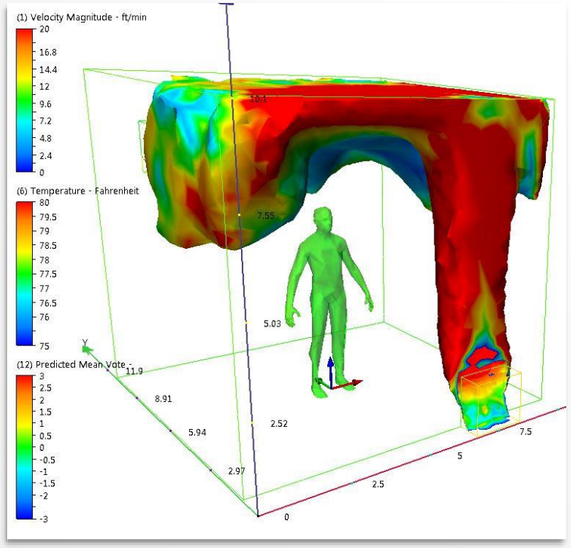

(6) Temperature - Fahrenheit
80
79.5
79
78.5
78
77.5
77
76.5
76
75

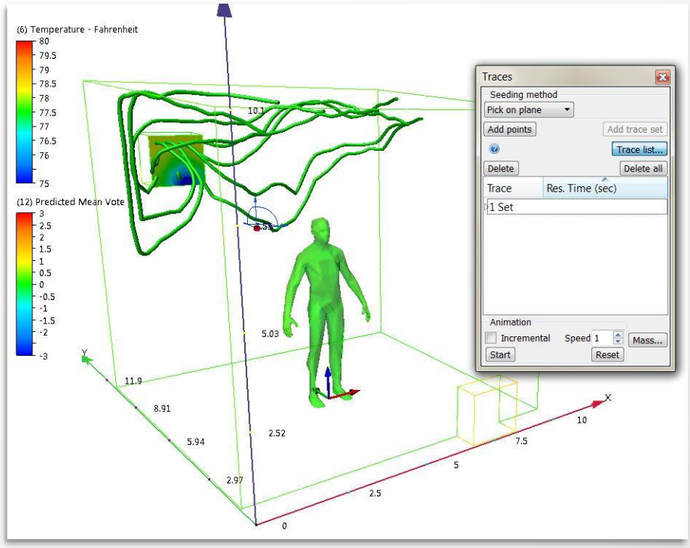

(6) Temperature - Fahrenheit
80
79.5
79
78.5
78
77.5
77
76.5
76
75


(1) Velocity Magnitude - ft/min
20
16.8
14.4
12
9.6
7.2
4.8
2.4
0
(12) Predicted Mean Vote -
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-3


(1) Velocity Magnitude - ft/min
20
16.8
14.4
12
9.6
7.2
4.8
2.4
0
(12) Predicted Mean Vote -
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-3

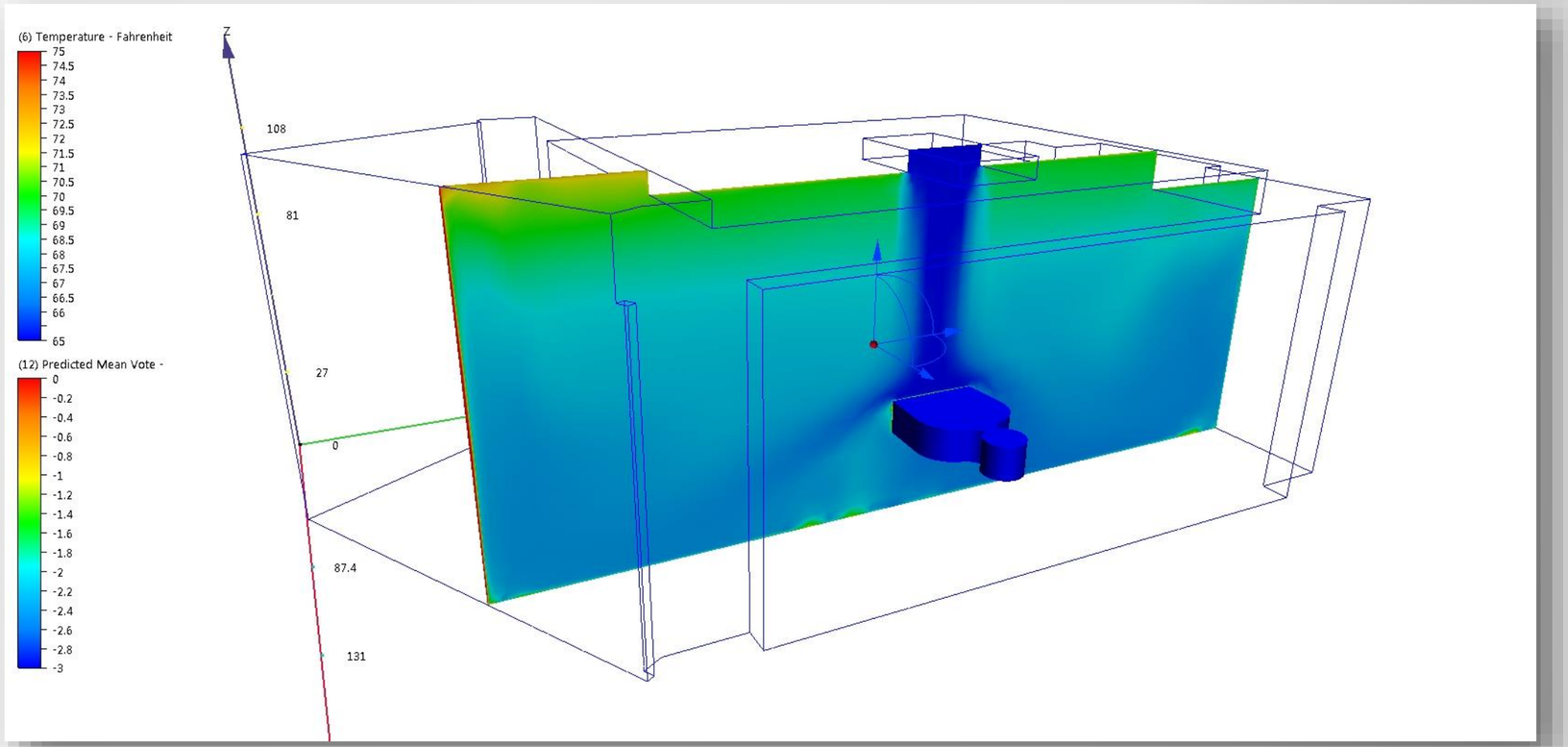

(1) Velocity Magnitude - ft/min
20
16.8
14.4
12
9.6
7.2
4.8
2.4
0
(6) Temperature - Fahrenheit
80
79.5
79
78.5
78
77.5
77
76.5
76
75
(12) Predicted Mean Vote -
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-3


(1) Velocity Magnitude - ft/min
20
16.8
14.4
12
9.6
7.2
4.8
2.4
0
(6) Temperature - Fahrenheit
80
79.5
79
78.5
78
77.5
77
76.5
76
75
(12) Predicted Mean Vote -
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-3


(6) Temperature - Fahrenheit
80
79.5
79
78.5
78
77.5
77
76.5
76
75
(12) Predicted Mean Vote
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-3
Traces
Seeding method
Pick on plane
Add points
Add trace set
Trace list...
Delete
Delete all
Trace
Res. Time (sec)
1 Set
Animation
Incremental
Speed 1
Mass...
Start
Reset

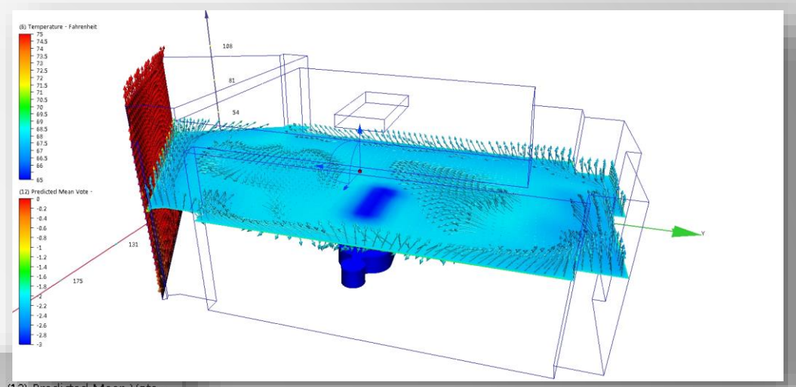
Case Studies

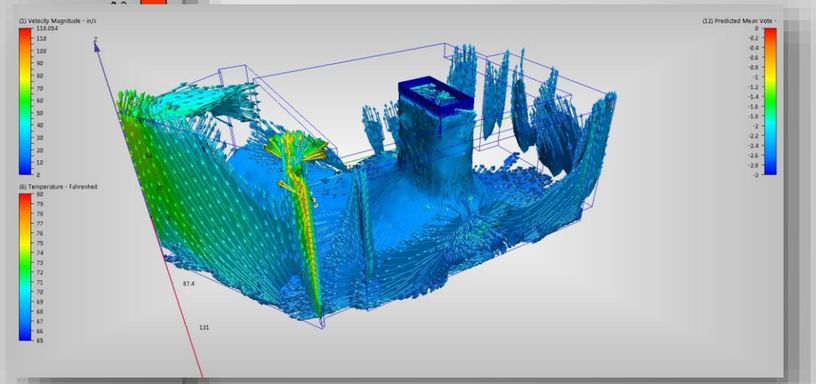
Amateur

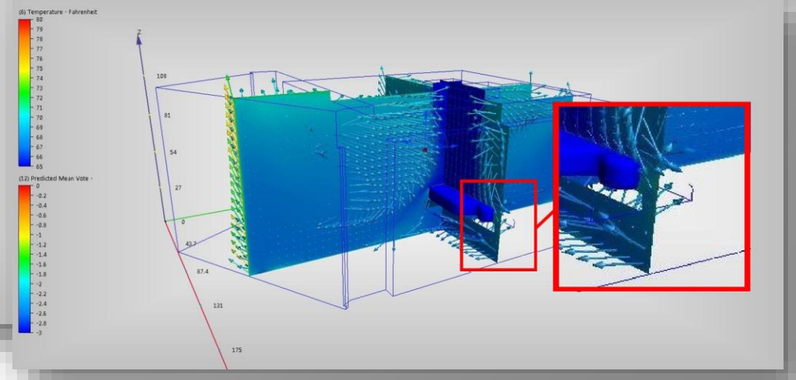

(6) Temperature - Fahrenheit
75
74.5
74
73.5
73
72.5
72
71.5
71
70.5
70
69.5
69
68.5
68
67.5
67
66.5
66
65
(12) Predicted Mean Vote -
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
-2.2
-2.4
-2.6
-2.8
-3
Z
108
81
27
0
87.4
131

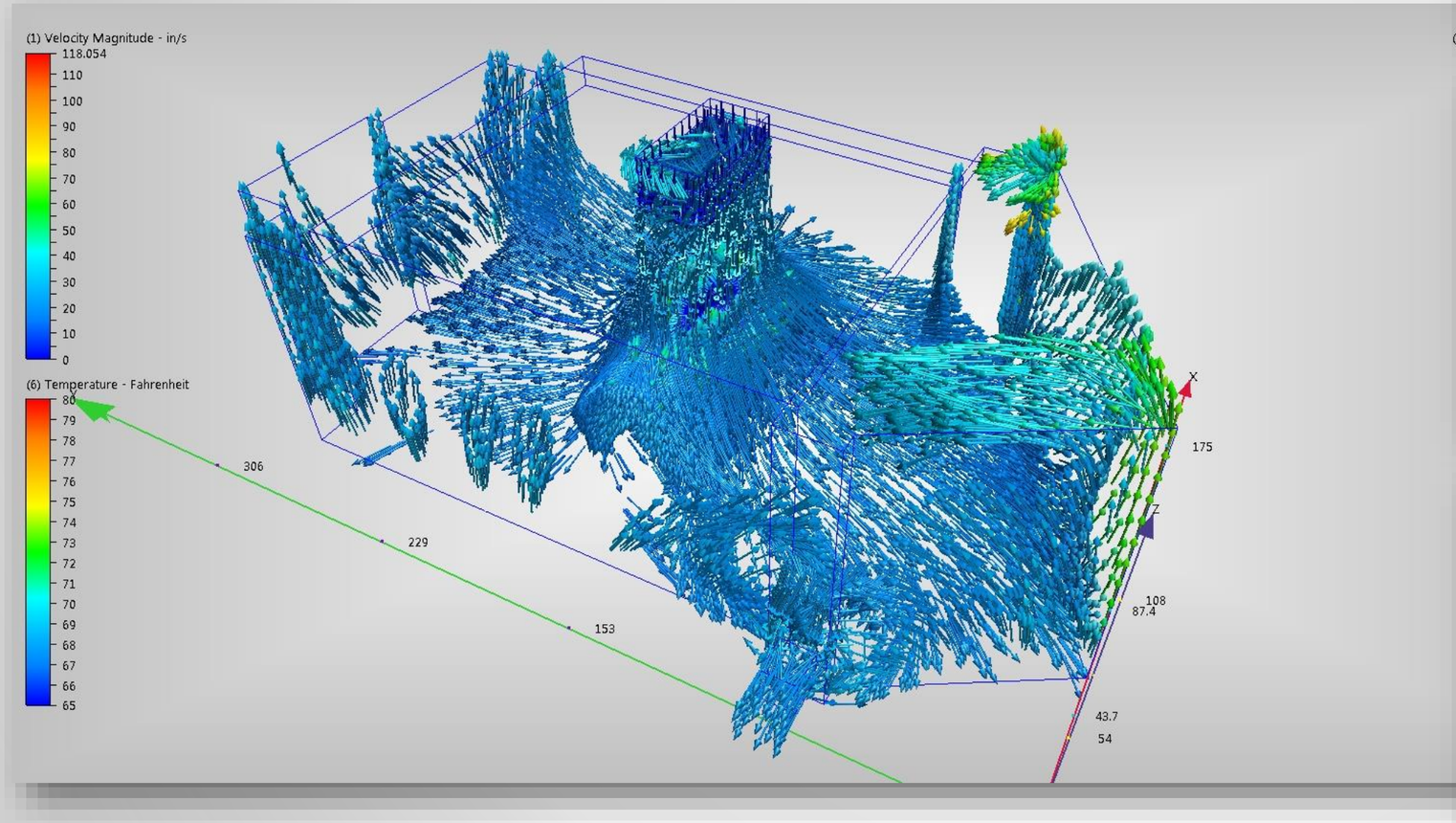
Single Patient Room - Study

- Patients are cold – Build tents above beds
- Analyze existing design



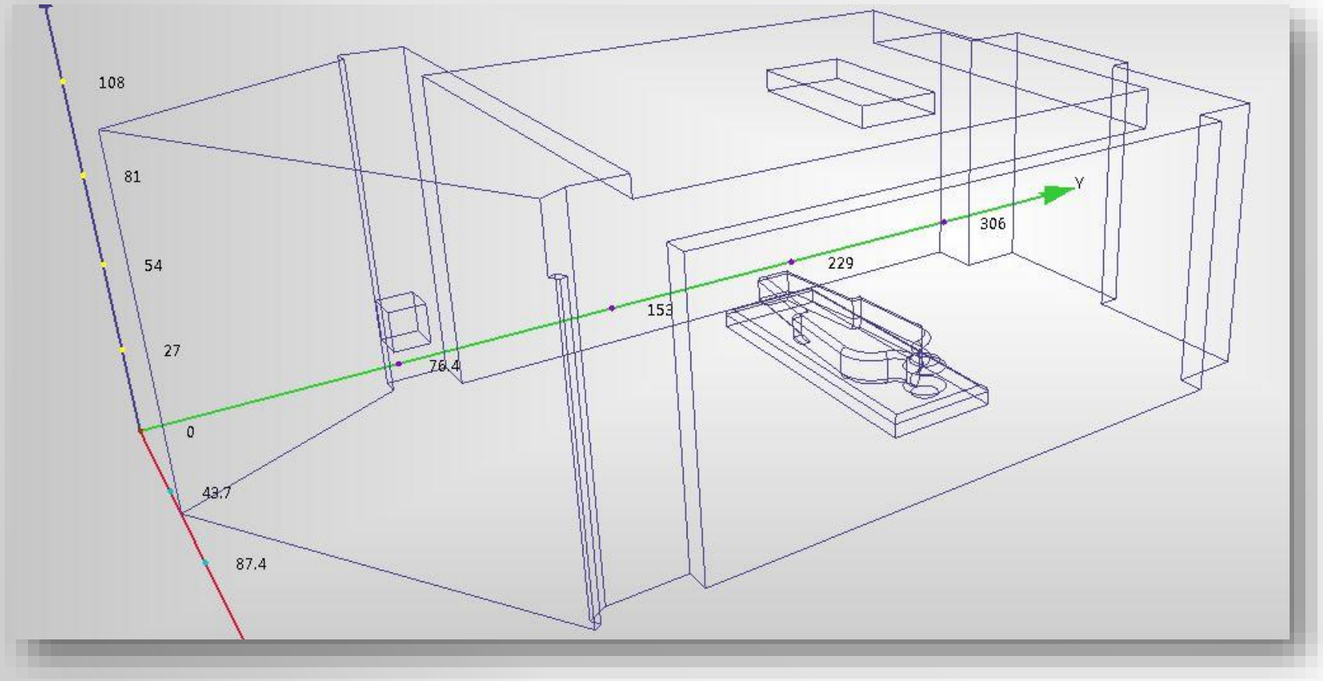


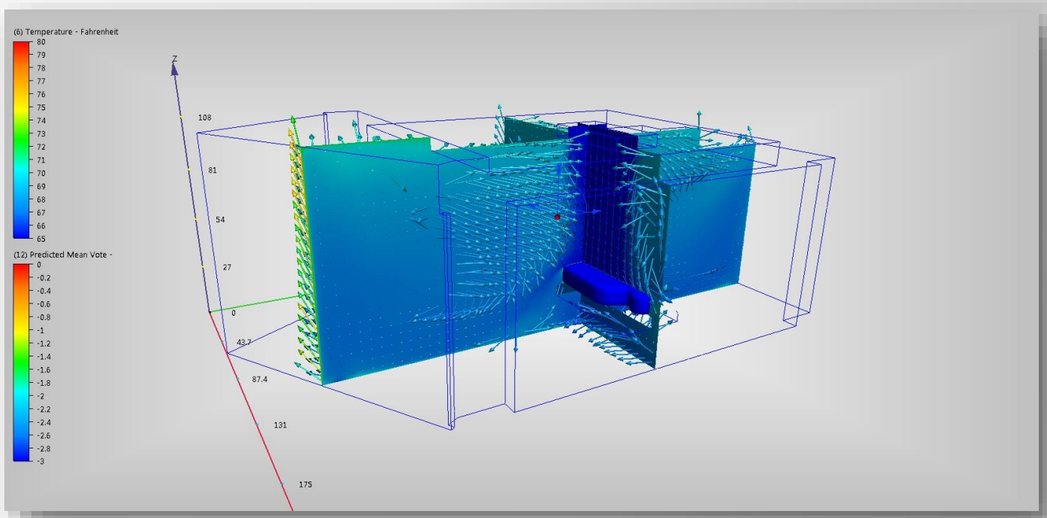


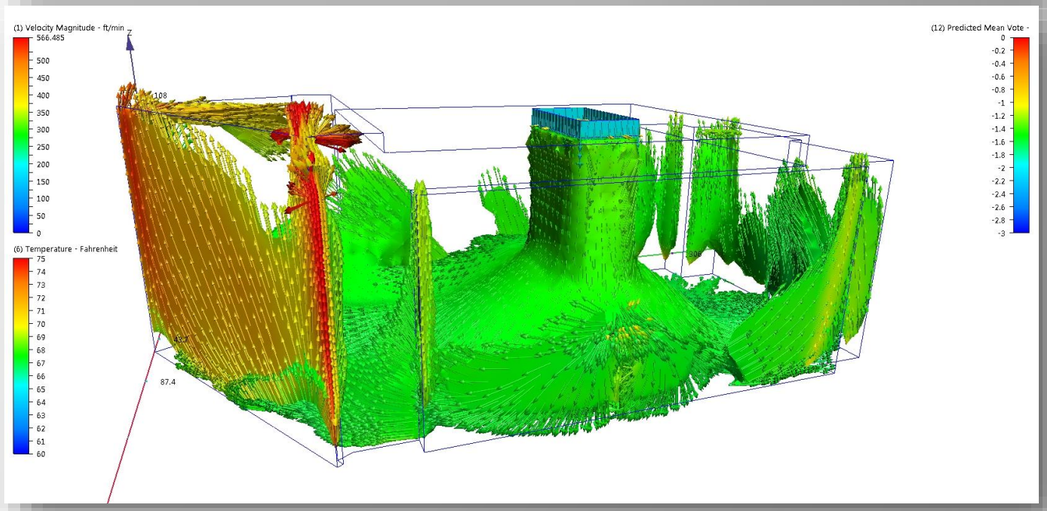


Single Patient Room – First try

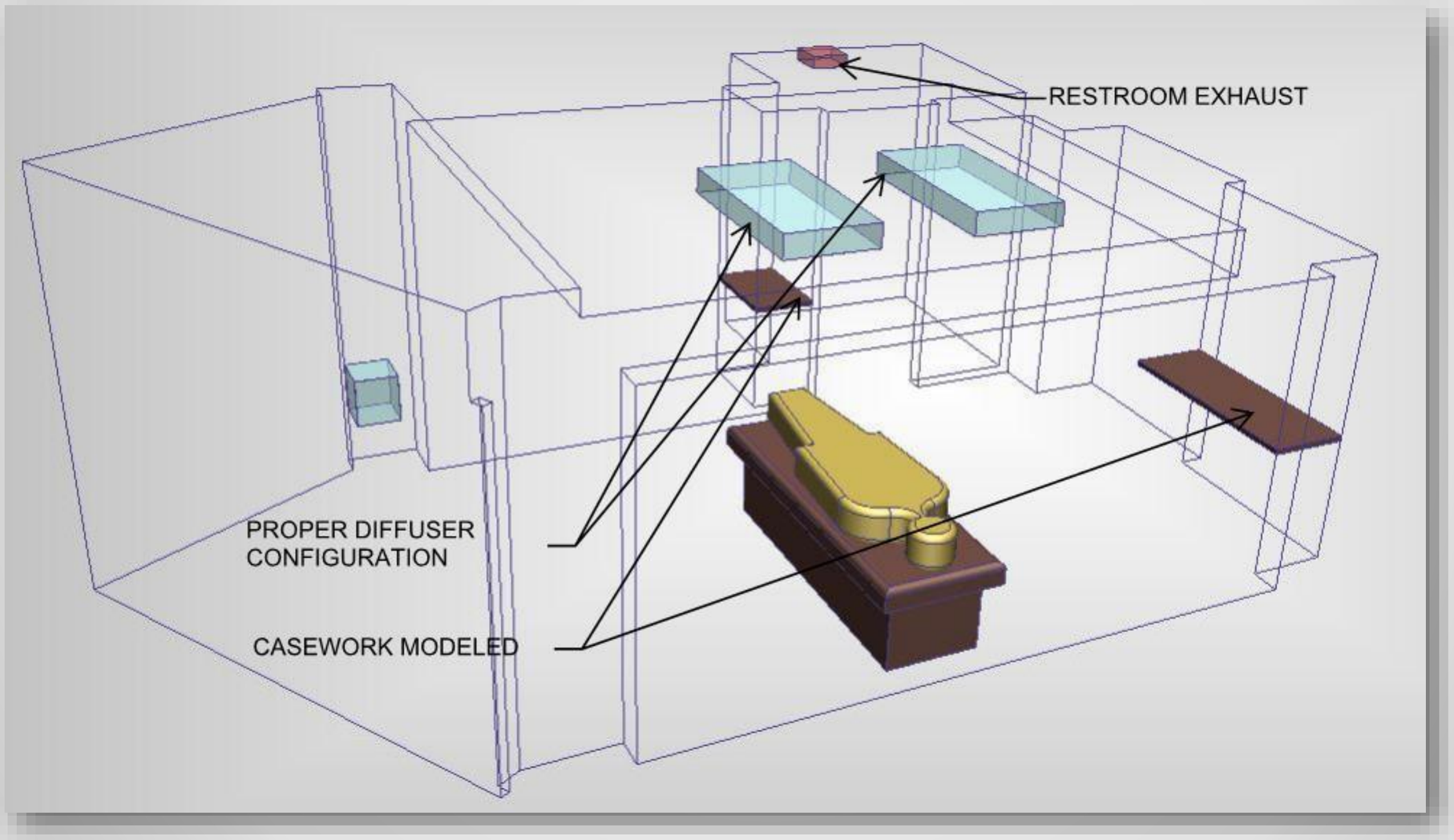
- Model – Simple (too simple)
- Single diffuser is wrong
- Combo of existing + proposed
- Completed after reviewing Autodesk training materials



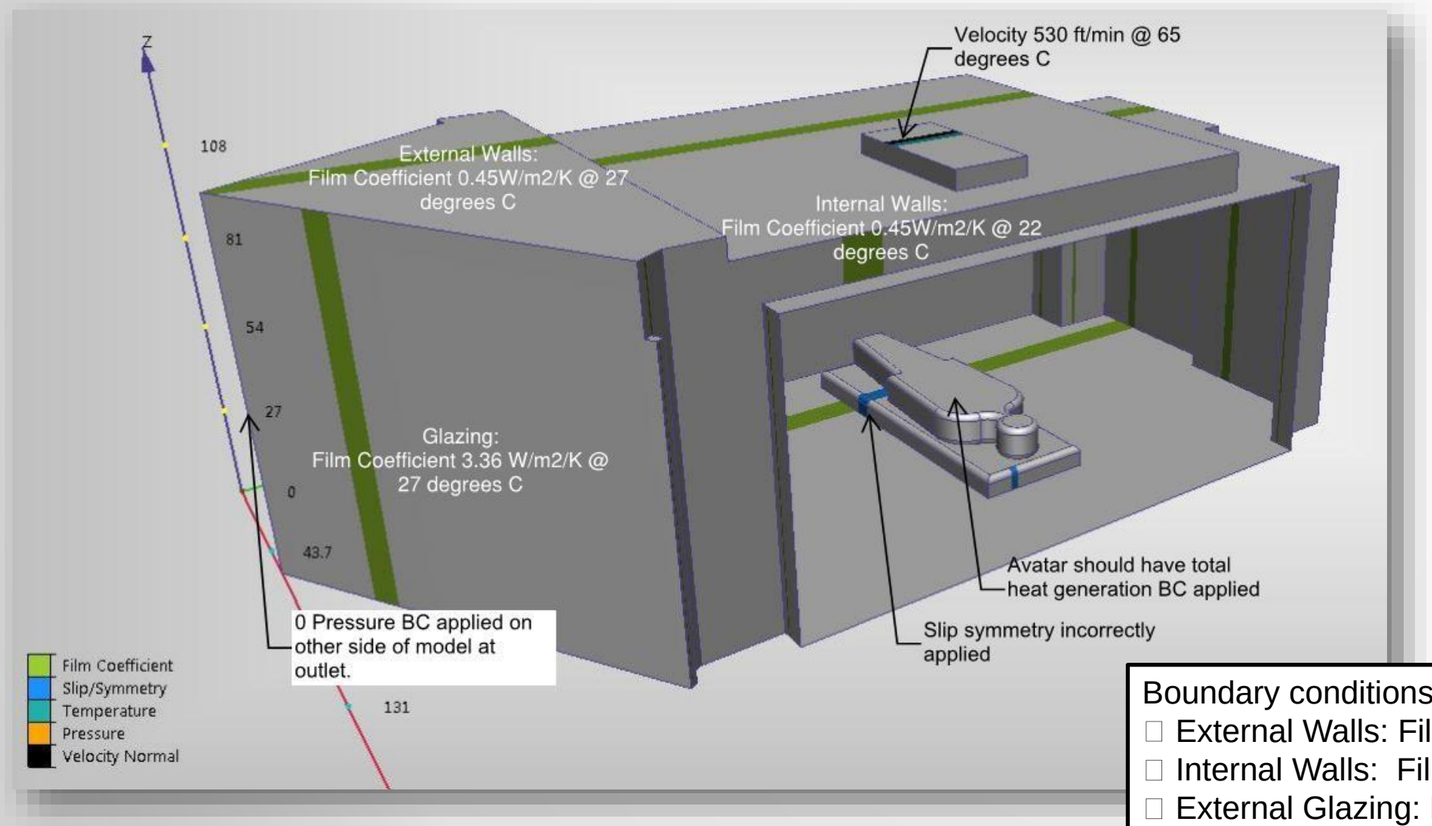




Single Patient Room - Model



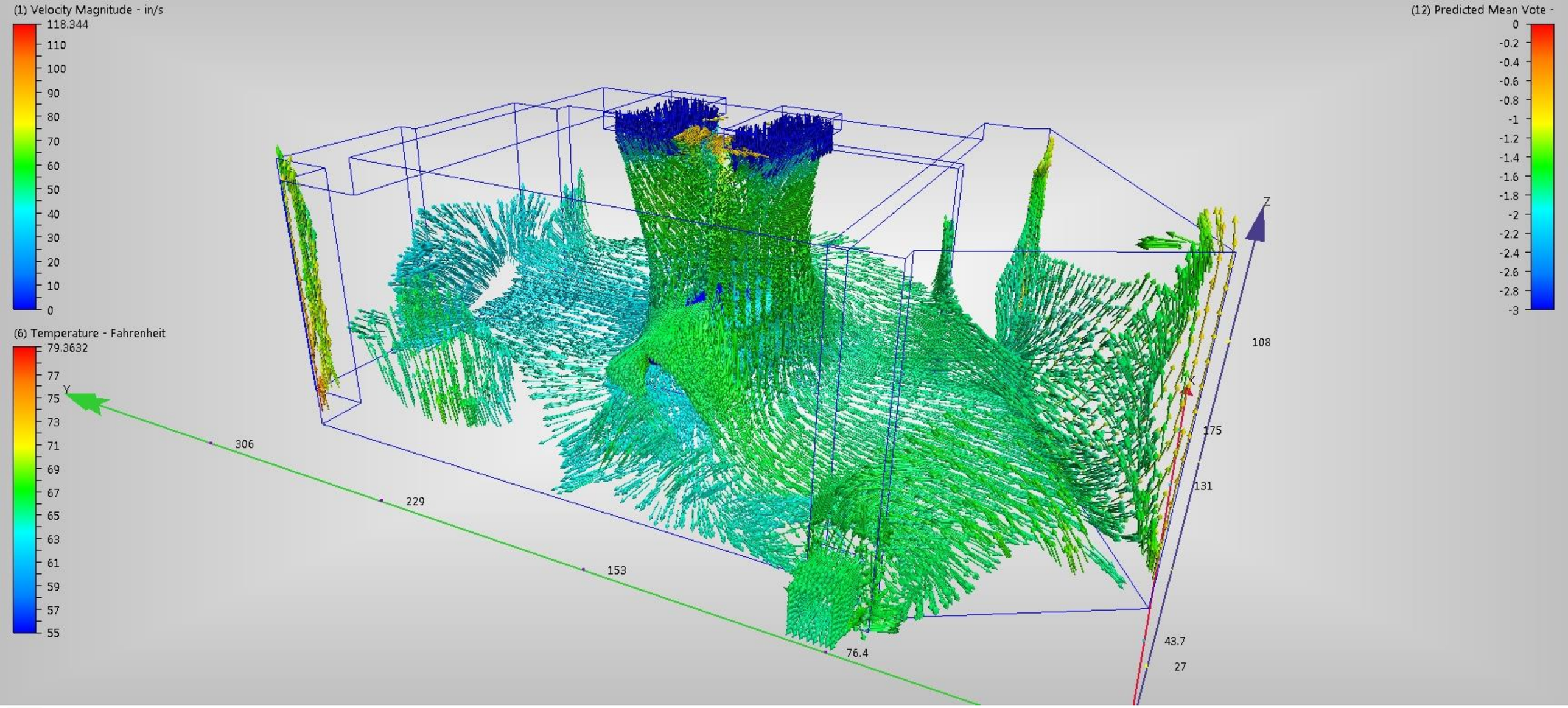
Single Patient Room – Boundary Conditions



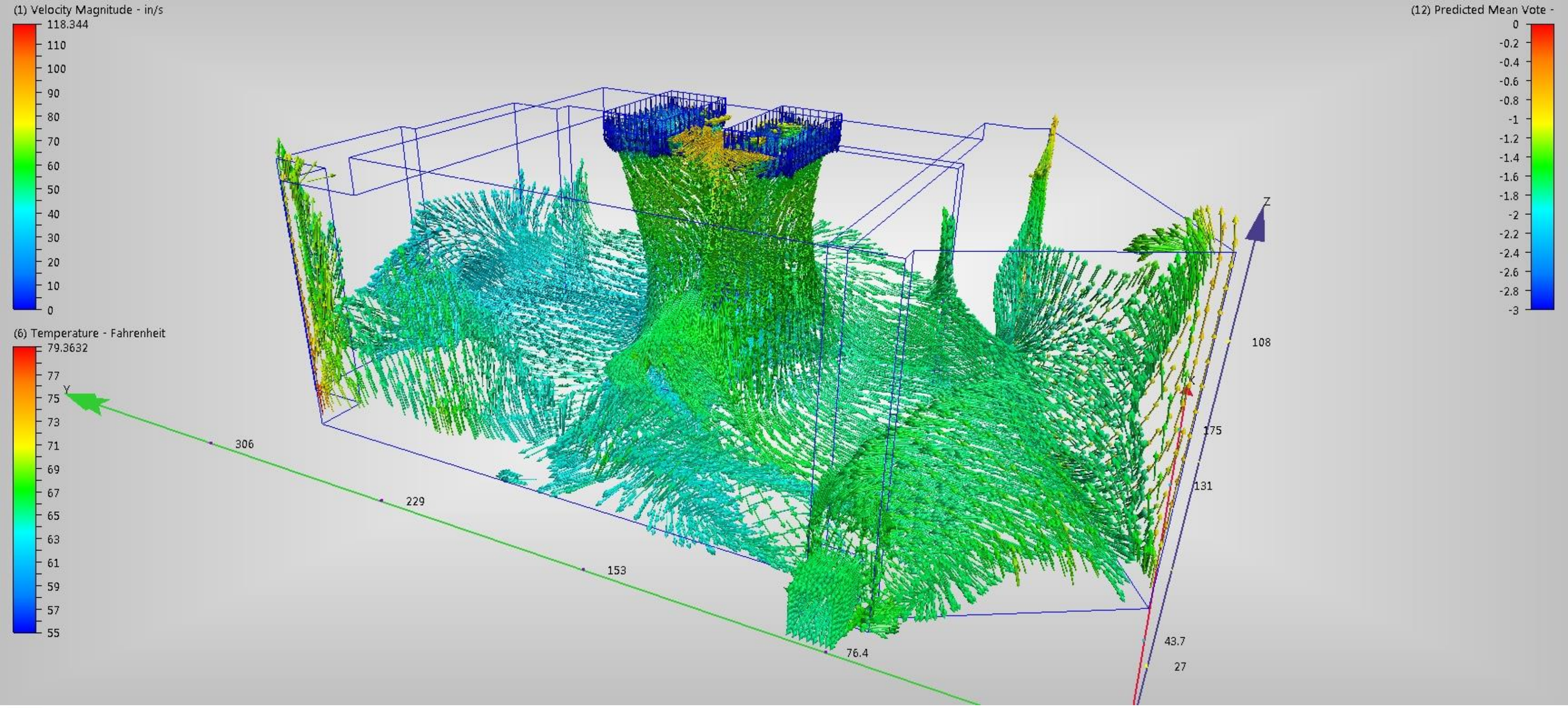
Boundary conditions applied:

- External Walls: Film Coefficient = 0.45 W/m2/K @ 27 degrees Celsius.
- Internal Walls: Film Coefficient = 0.45 W/m2/K @ 22 degrees Celsius
- External Glazing: Film Coefficient = 3.36 W/m2/K @ 27 degrees Celsius
- Supply Air: Velocity (normal) = 530 feet per minute (ft/min) @ 22 degrees Celsius
- Return Air: 0 Pressure
- Patient Bed: Slip Symmetry, This BC was applied in error.
- Human Avatar: No BC applied, this is also a mistake. A volumetric BC, Total Heat Generation, should have been applied at 60 watts

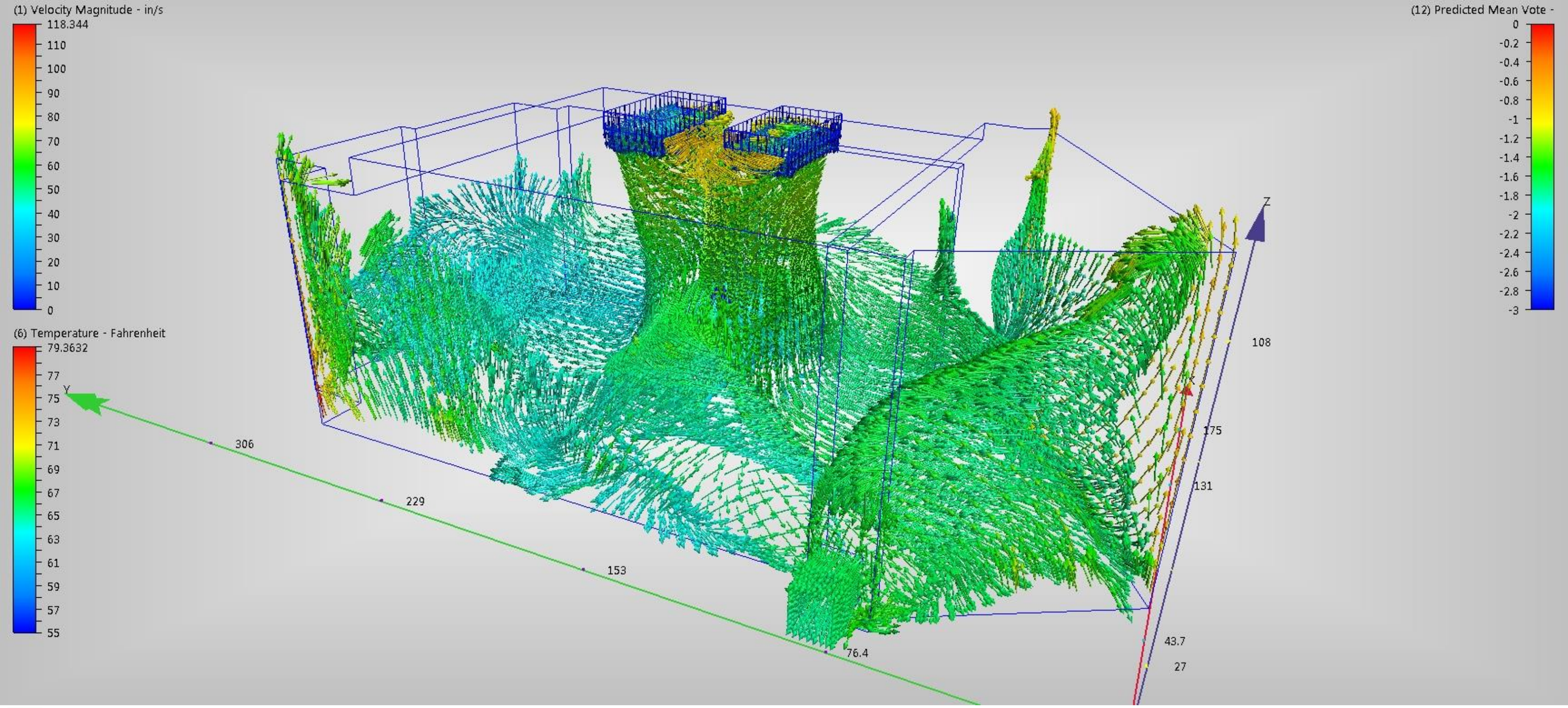
Single Patient Room – Results, Iso surface w/vectors



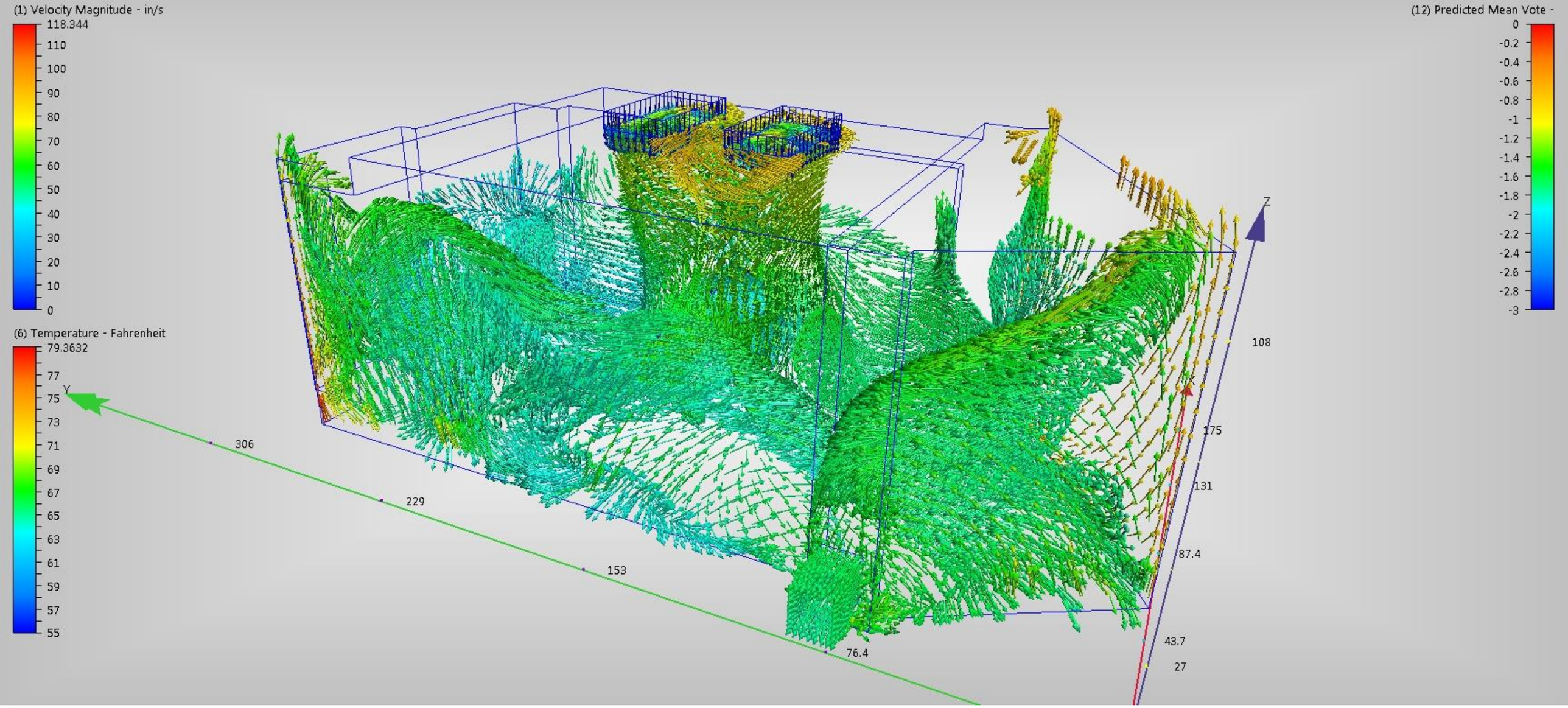
Single Patient Room – Results, Iso surface w/vectors



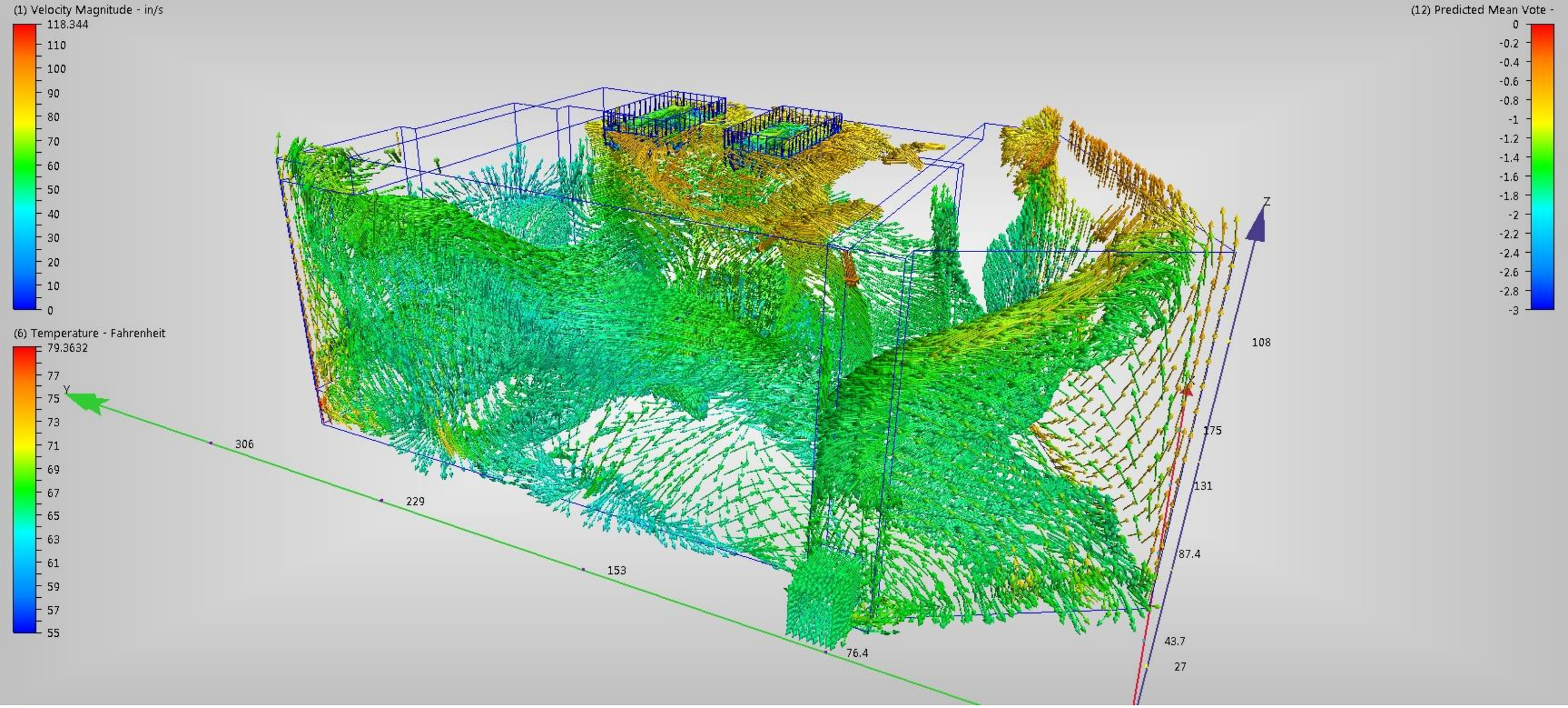
Single Patient Room – Results, Iso surface w/vectors



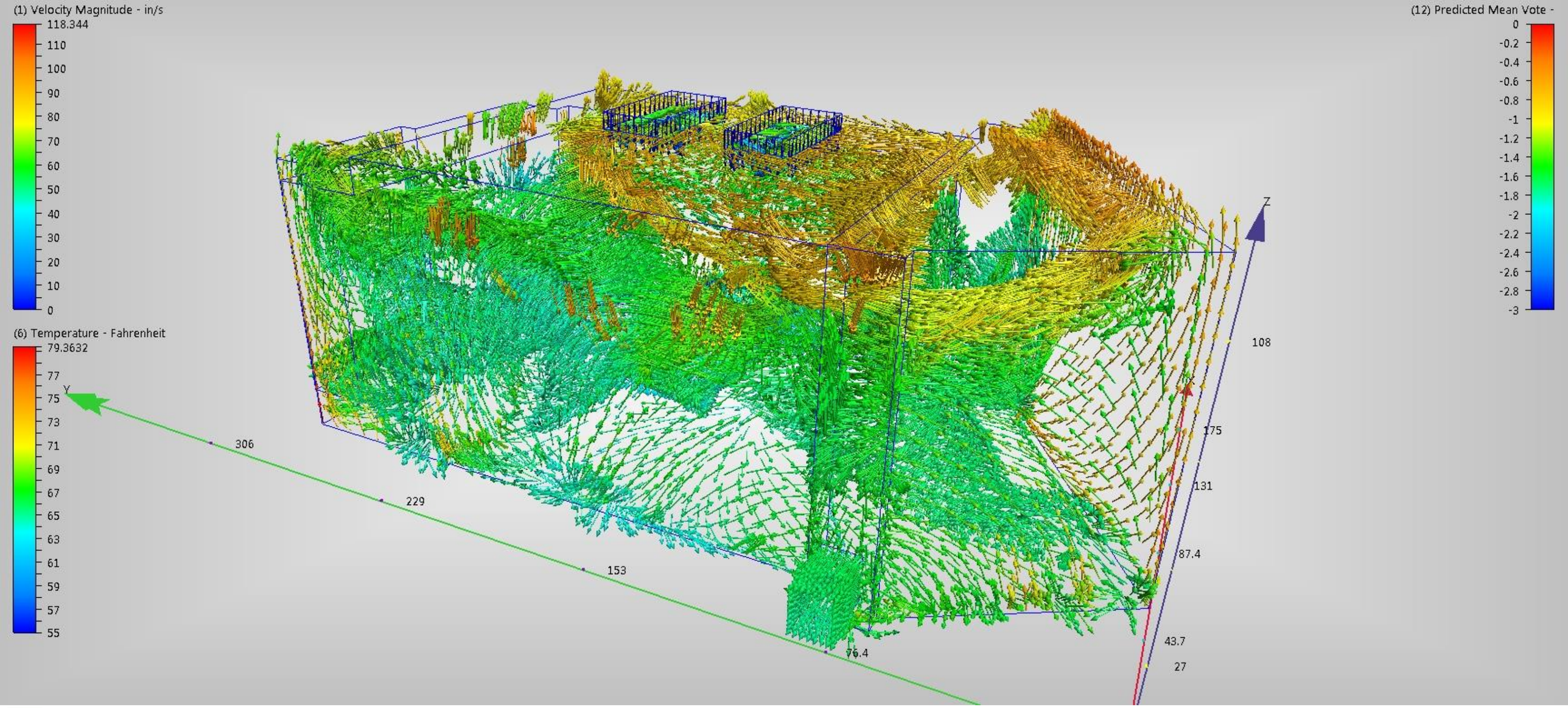
Single Patient Room – Results, Iso surface w/vectors



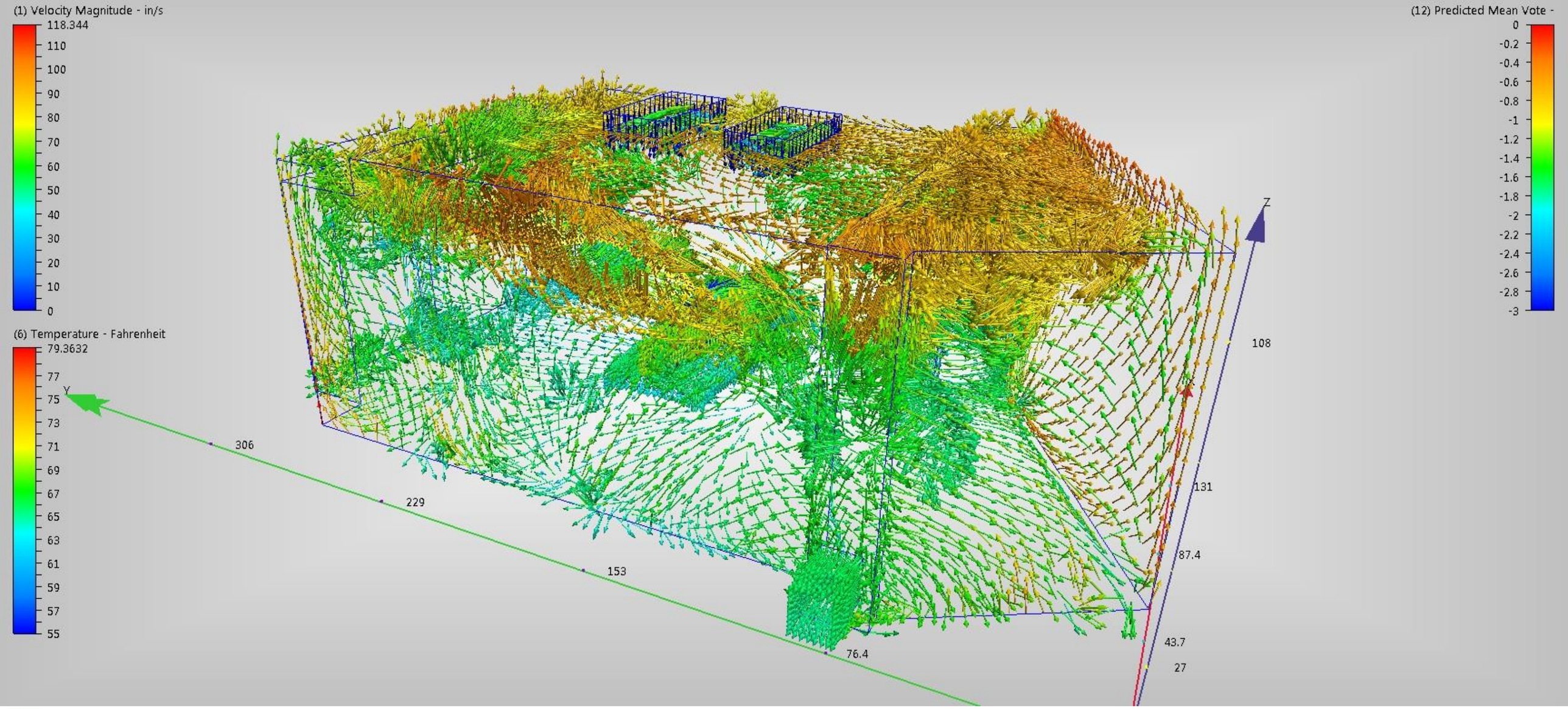
Single Patient Room – Results, Iso surface w/vectors



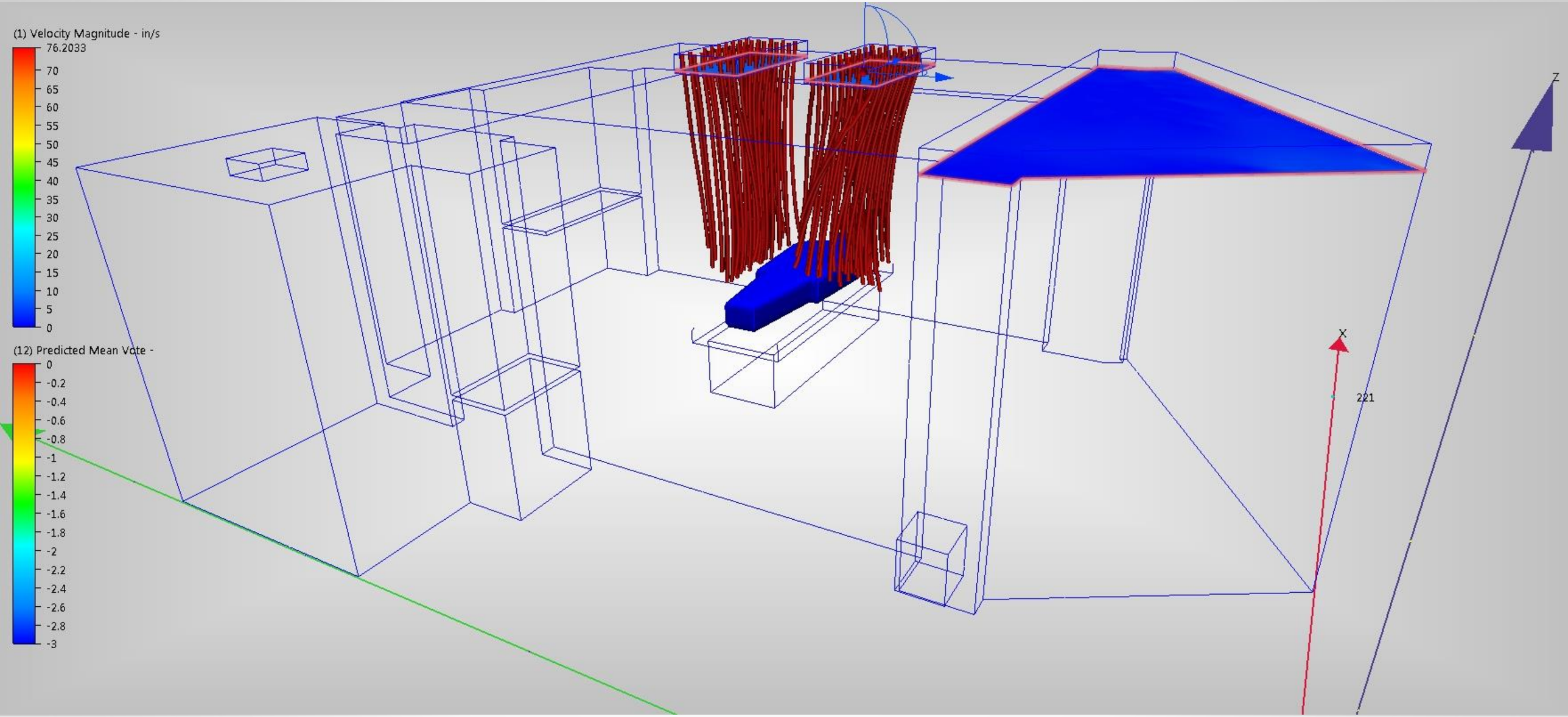
Single Patient Room – Results, Iso surface w/vectors



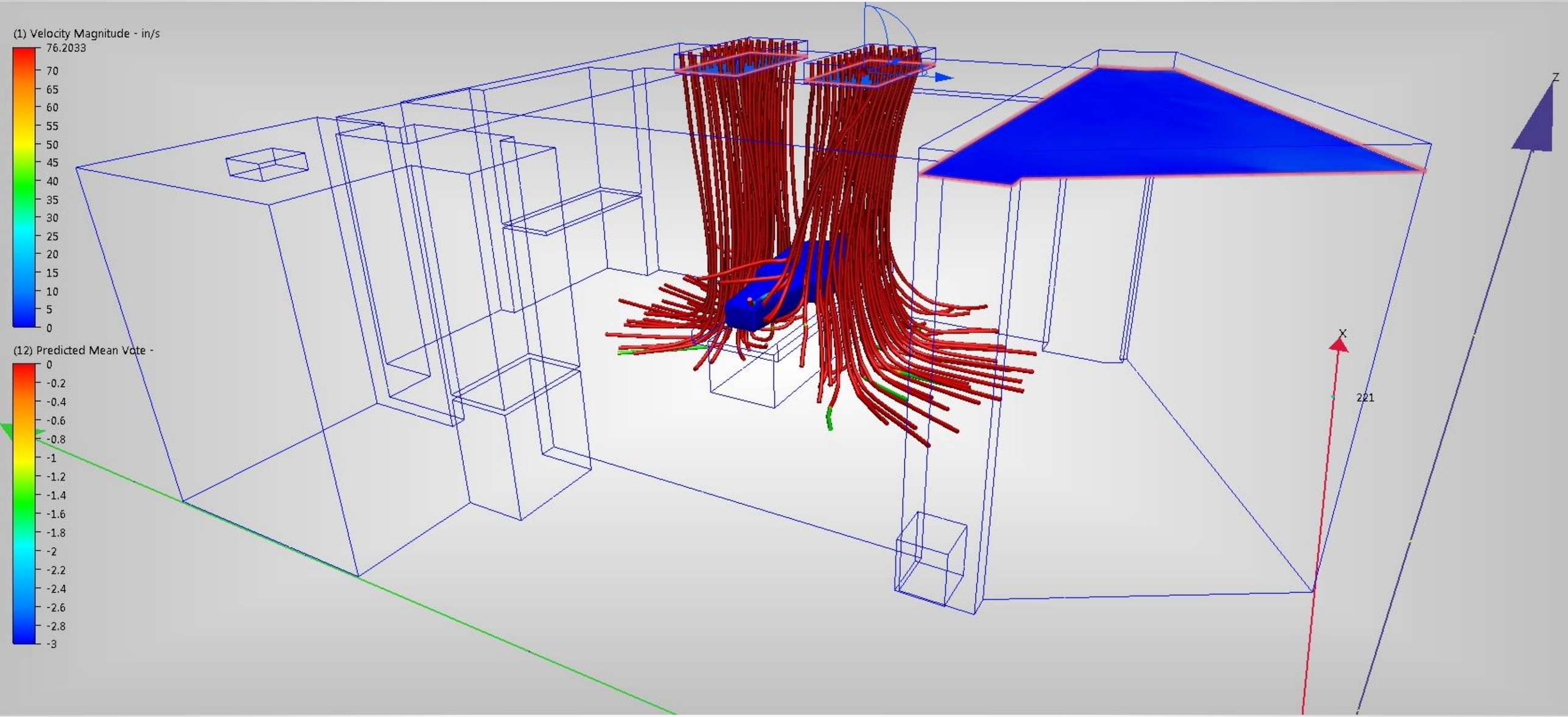
Single Patient Room – Results,Iso surface w/vectors



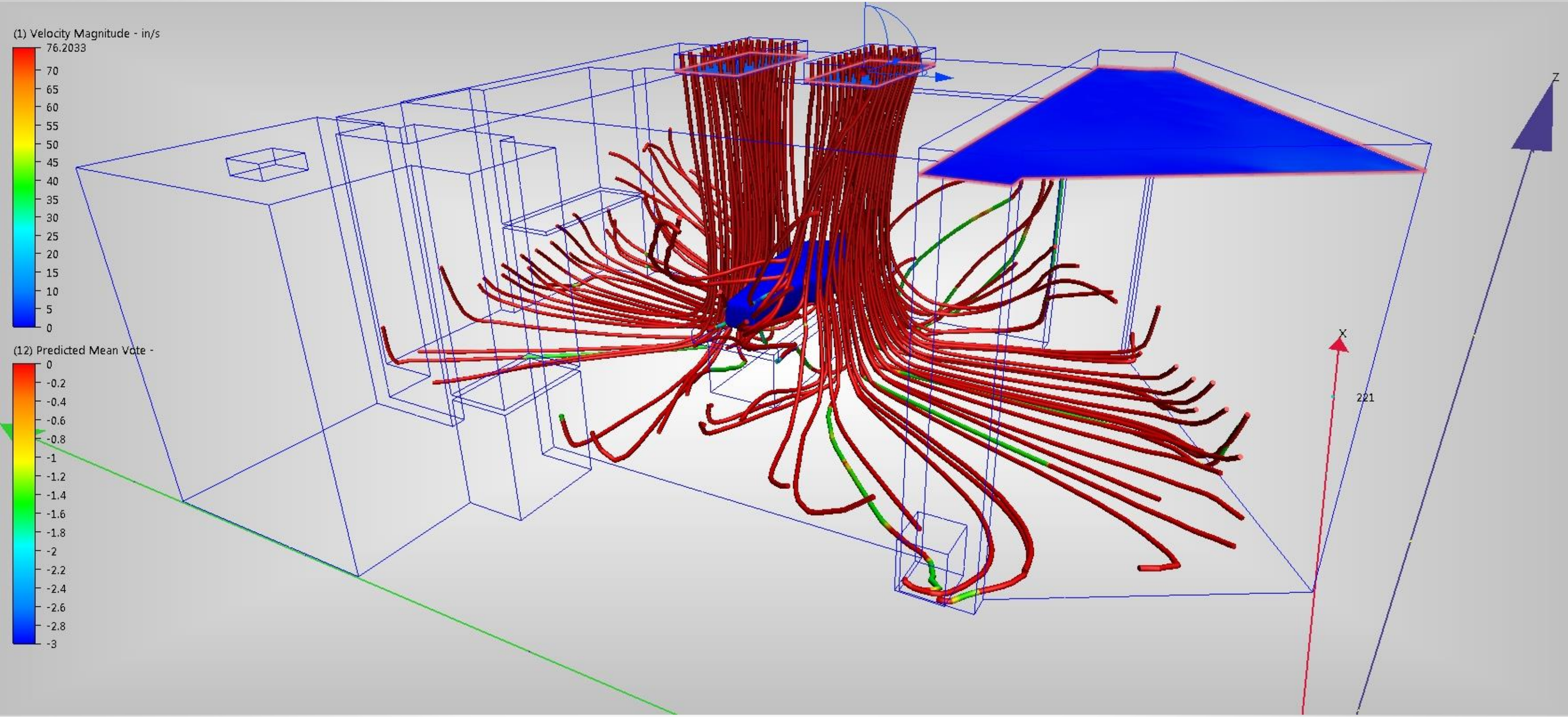
Single Patient Room – Results, Planes w/ Traces



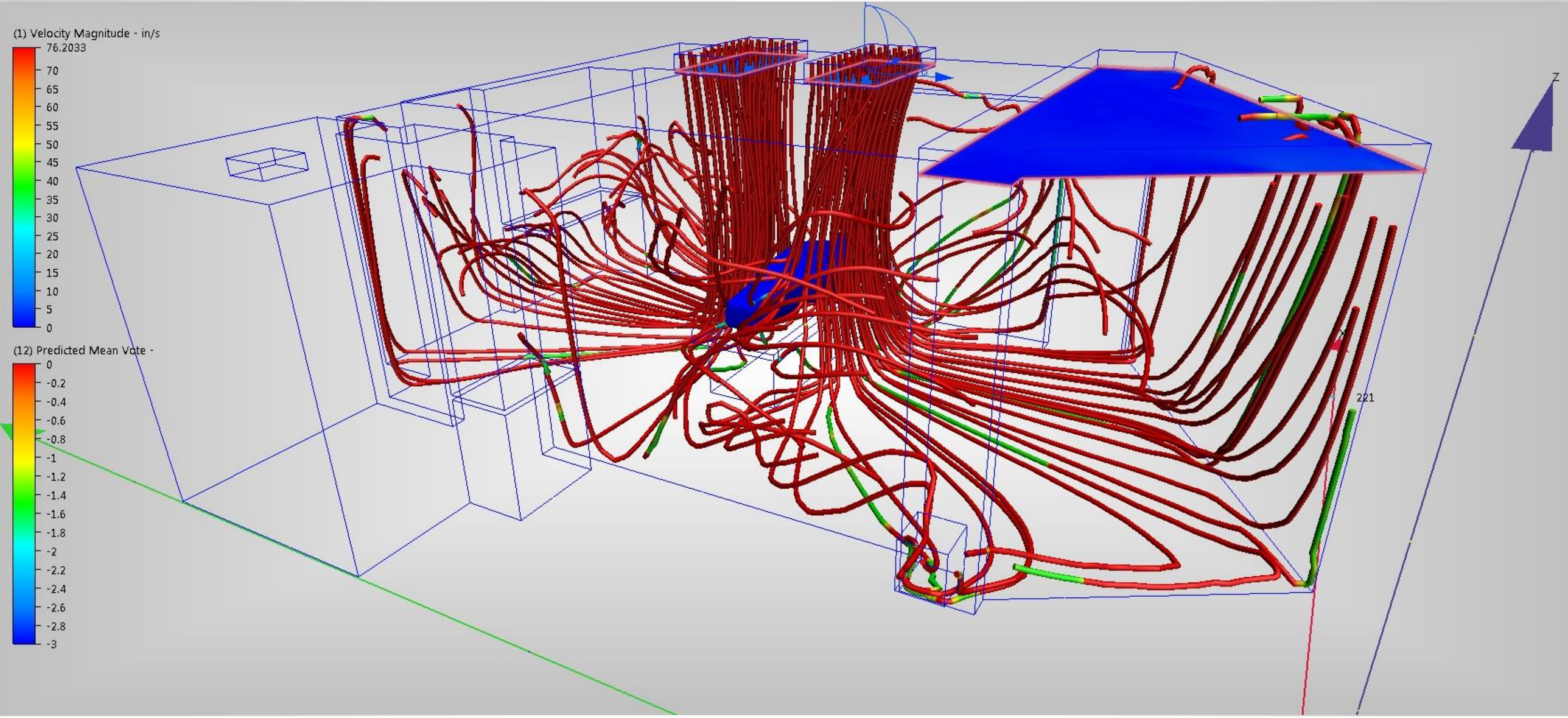
Single Patient Room – Results, Planes w/ Traces



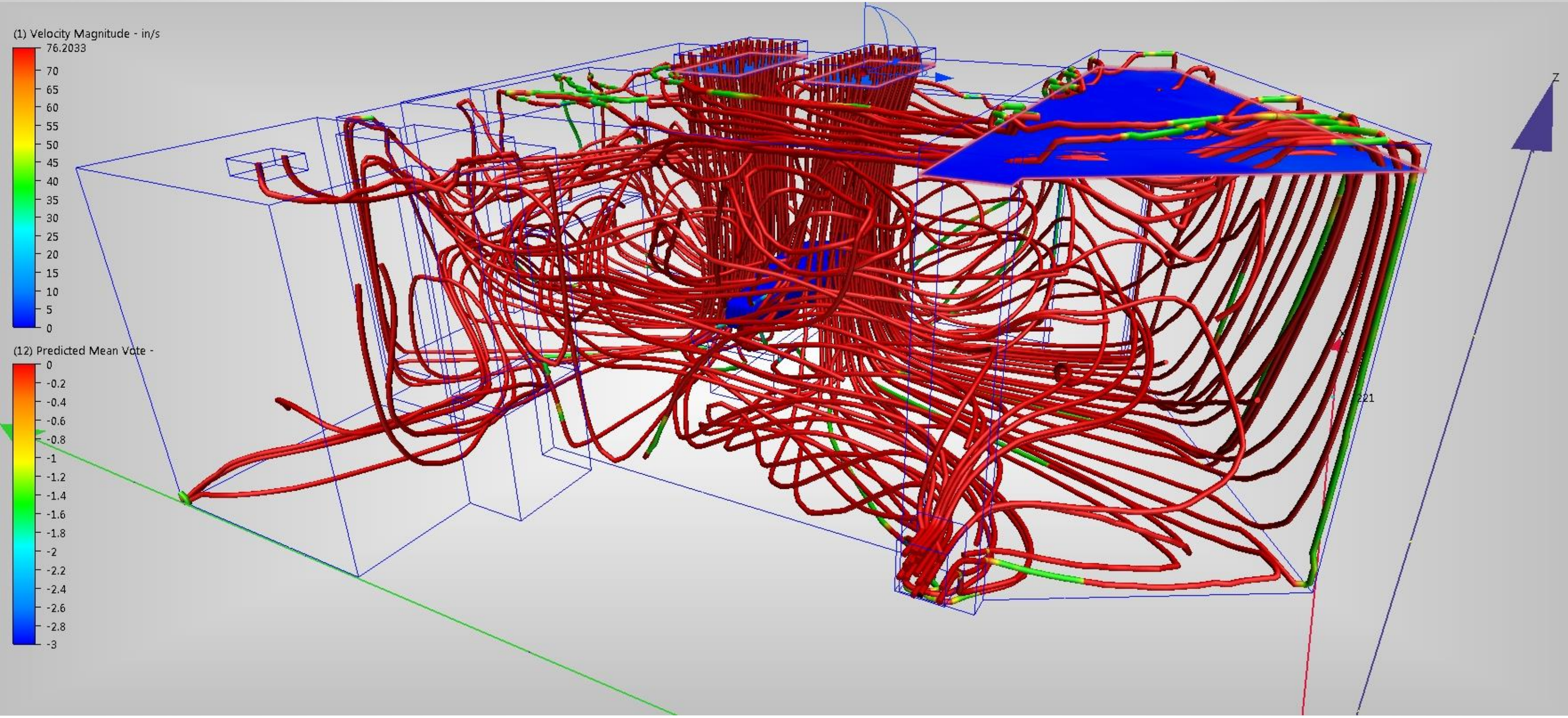
Single Patient Room – Results, Planes w/ Traces



Single Patient Room – Results, Planes w/ Traces

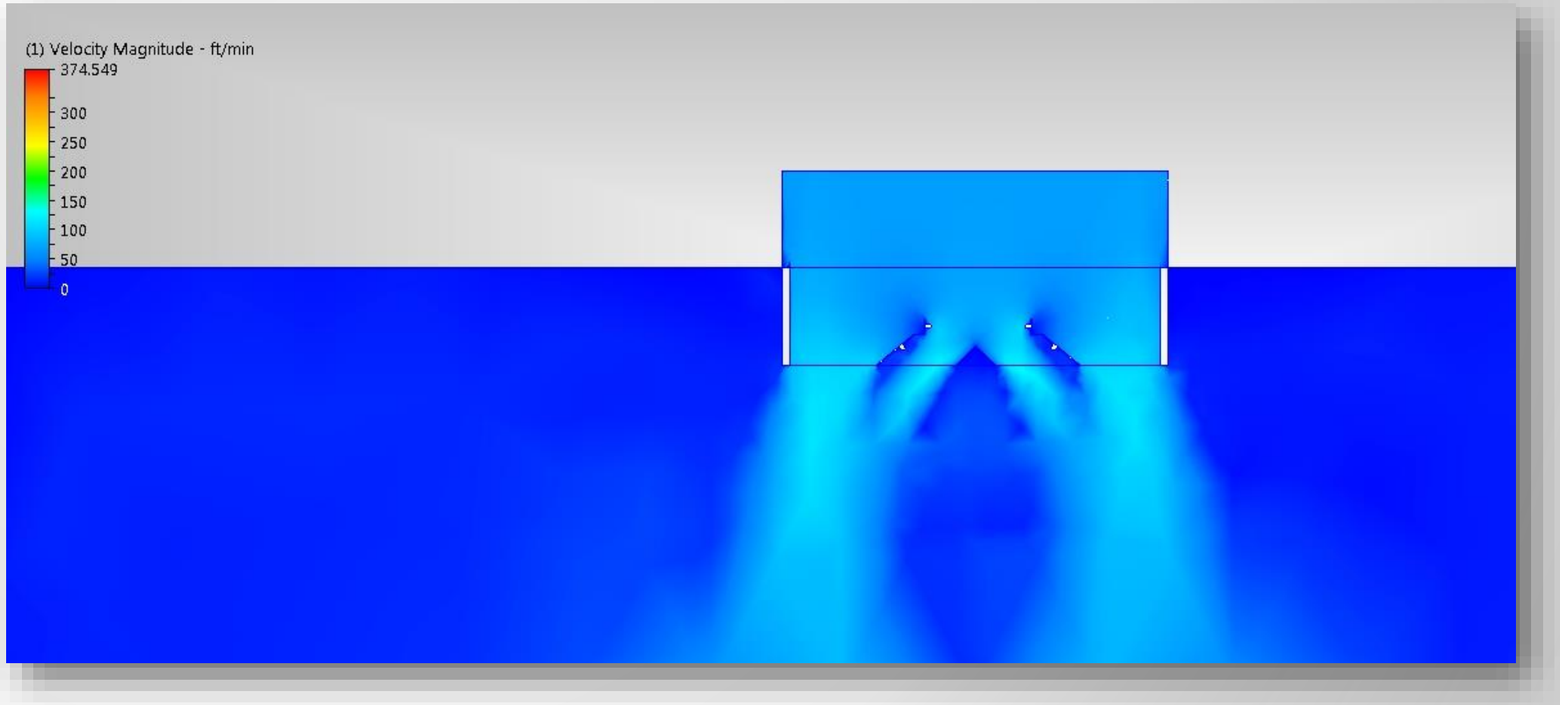


Single Patient Room – Results, Planes w/ Traces



Single Patient Room - Results

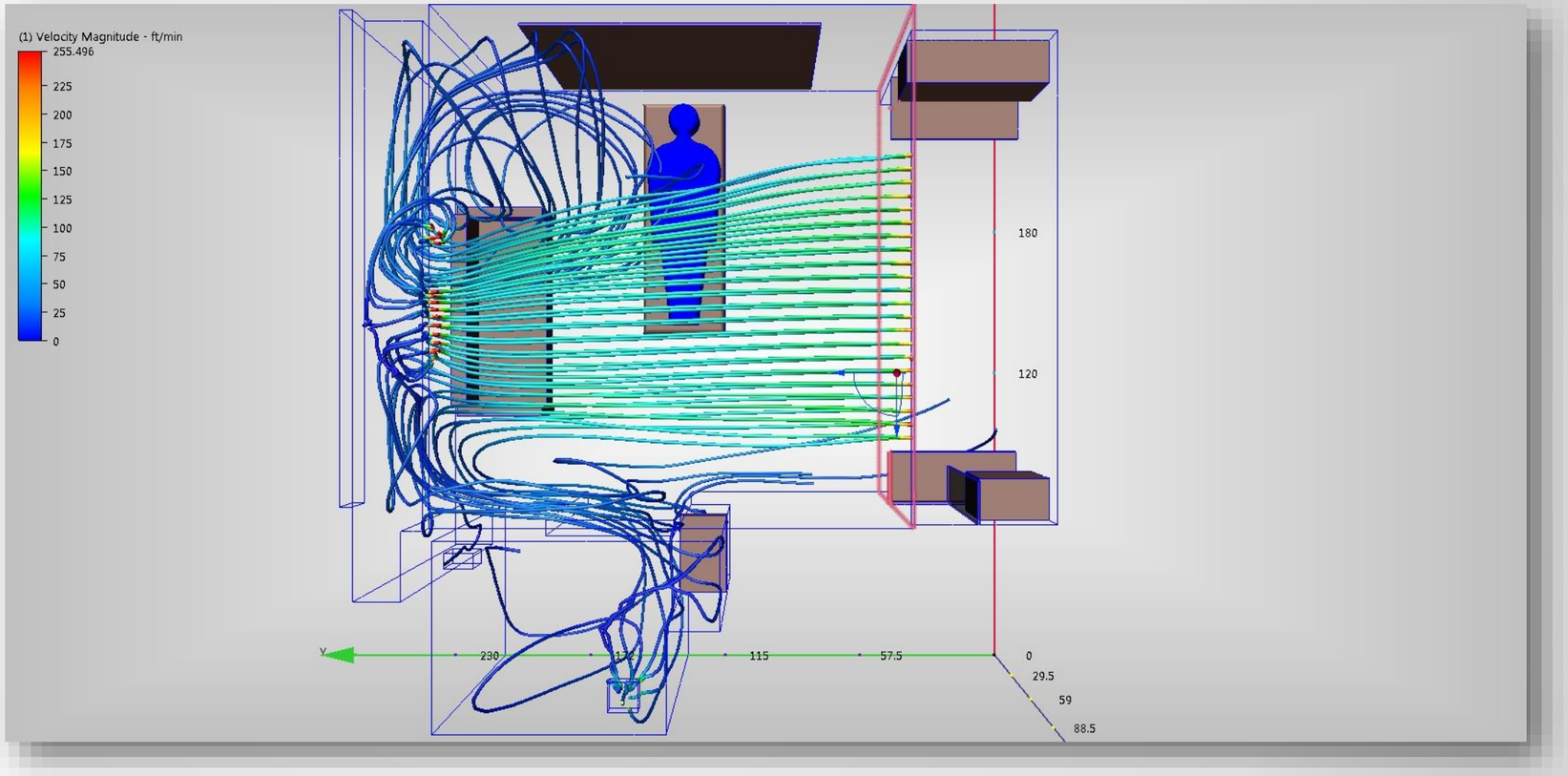
- Naïve
- Observational Results
- Learning – first steps
- Didn’t fully understand what we were testing
- Cumbersome to model
- Cumbersome to iterate
- Research in progress
- No solution



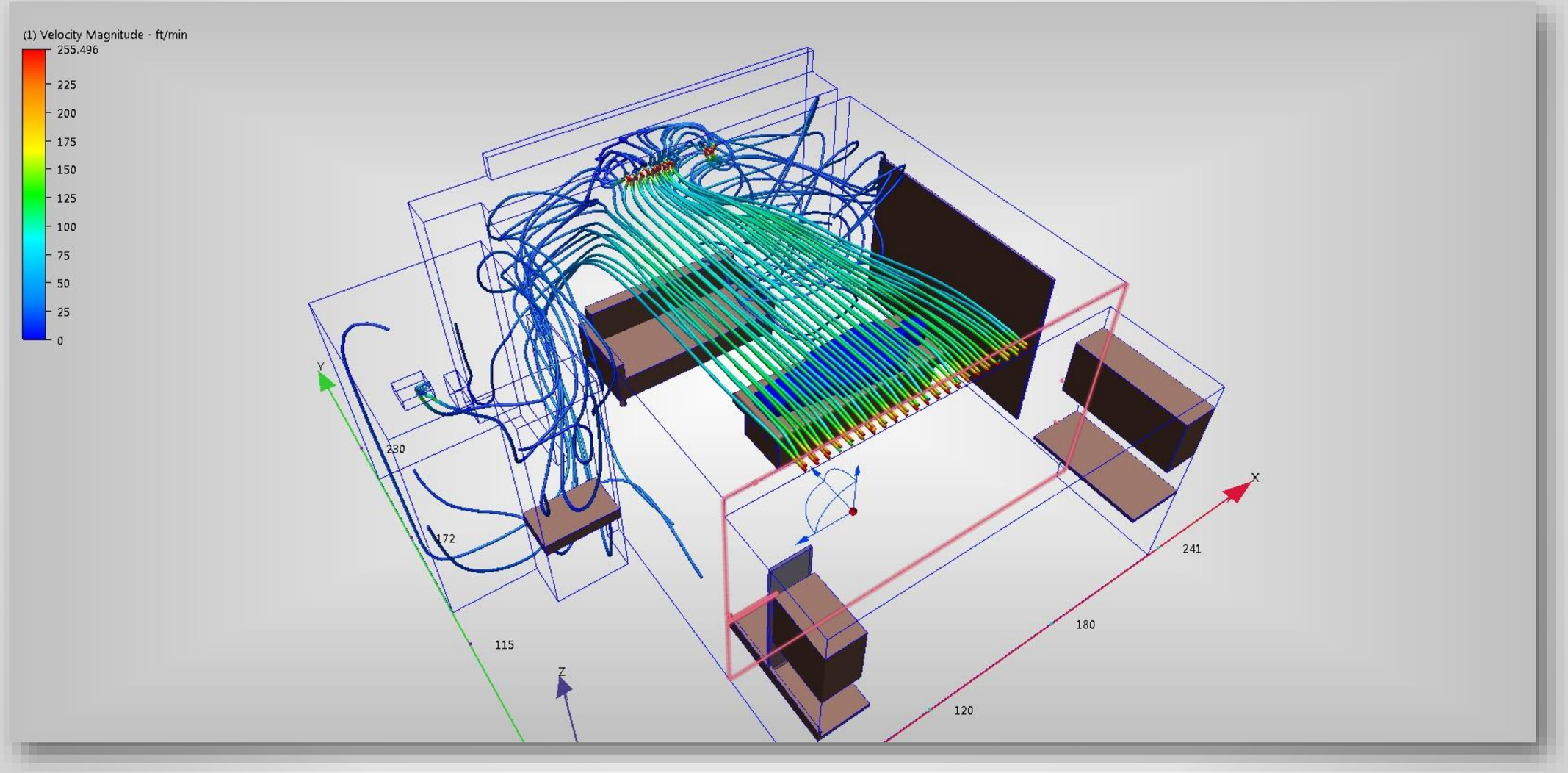
Single Patient Room - Lessons

- Need a more accurate model
- Need a more complete model
- Simplified setup is useful
- Observational results – help confirm data
- Need measureable data
- Need to know more – training
- Ham Fisted
- Didn’t understand PMV

Amateur 2


(1) Velocity Magnitude - ft/min
255.496
225
200
175
150
125
100
75
50
25
0
180
120
230
115
57.5
0
29.5
59
88.5

Single Patient Room 2



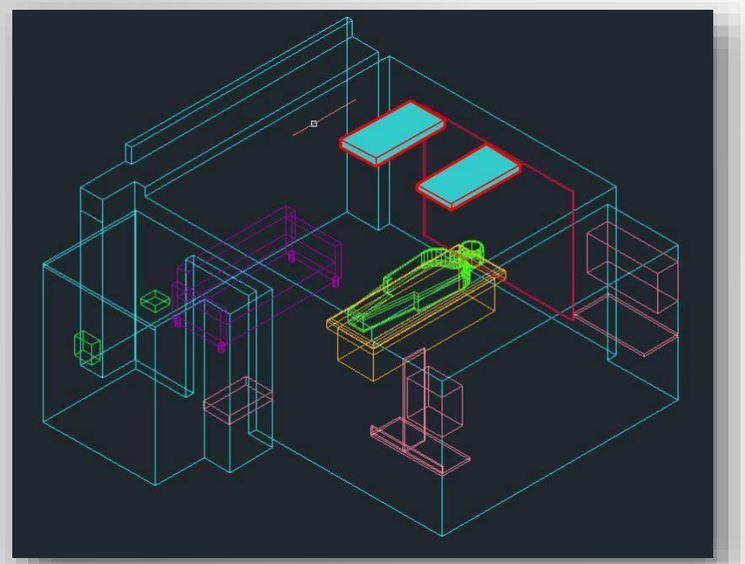
Single Patient Room 2 – Problem Statement

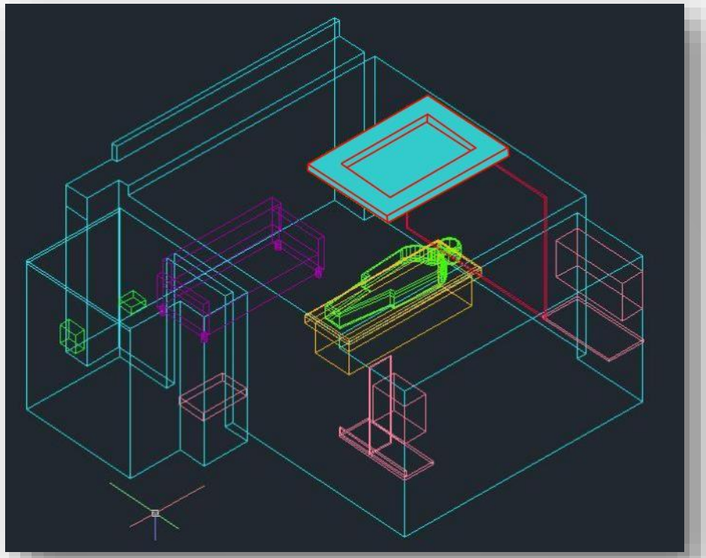
- Can a single patient room be set up to be multimodal?
- What is the best diffuser configuration for this need?
- Client request based on knowledge of existing research
- ASR paid for the software

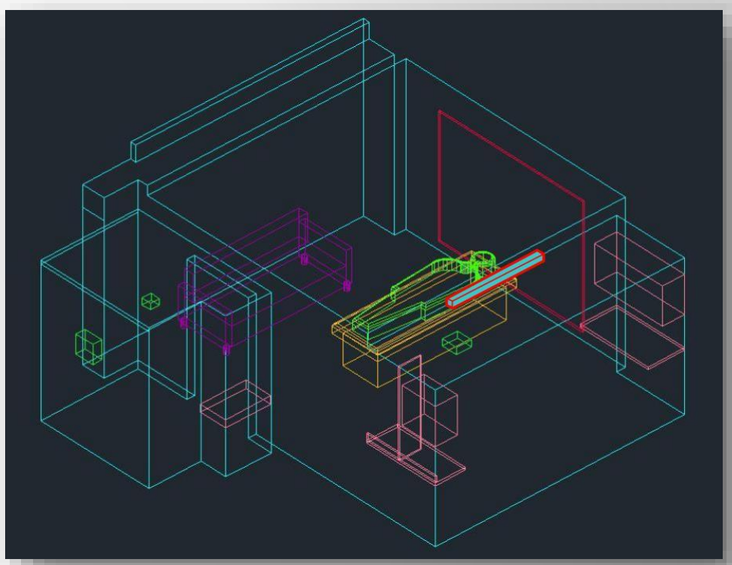
Single Patient Room 2 - Improvements

- Observational – w/Strict setup
- Trainer stayed with us
- Continued use = improvements
- Have specific questions
- Have inquiry process
- Smarter model setup

Single Patient Room 2 - Modeling







RANGE OF STUDY CONDITIONS

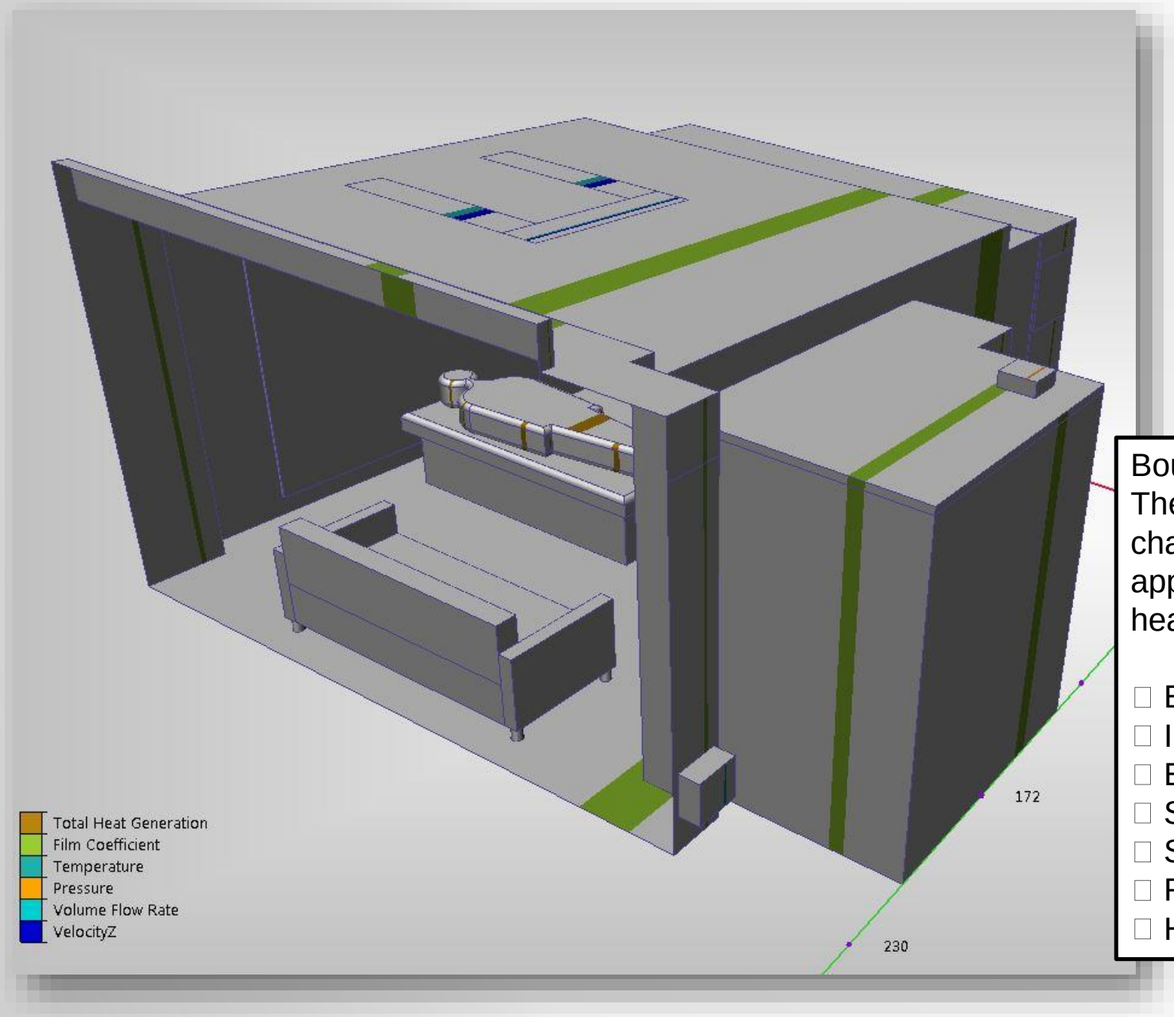
PATIENT ROOM AIR FLOW STUDY - LEVEL 6 ICU - HIGHER PROTECTION "PE" ROOMS

SCOPE OF STUDY VARIABLES

Diffuser Design	Baseline 2 Box Diffuser Design						4 Linear Diffuser Design						Typical 2 Linear Diffuser Design
Air Change Rates	6 ACH		9 ACH		12 ACH		6 ACH		9 ACH		12 ACH		12 ACH
Exhaust Design	1 exhaust	2 exhausts	1 exhaust	2 exhausts	1 exhaust	2 exhausts	1 exhaust	2 exhausts	1 exhaust	2 exhausts	1 exhaust	2 exhausts	High return + toilet rm
Outcomes					?		?				?		
Infection Control issues													
Patient Comfort													
	Note: All solutions assume that there a closed door												

Testing criteria was established prior to setting up the study. Multiple diffuser configurations were modeled and each configuration was set up with multiple scenarios wherein the air flow velocity was changed to show the 3 different ACH rates, 6,9,12

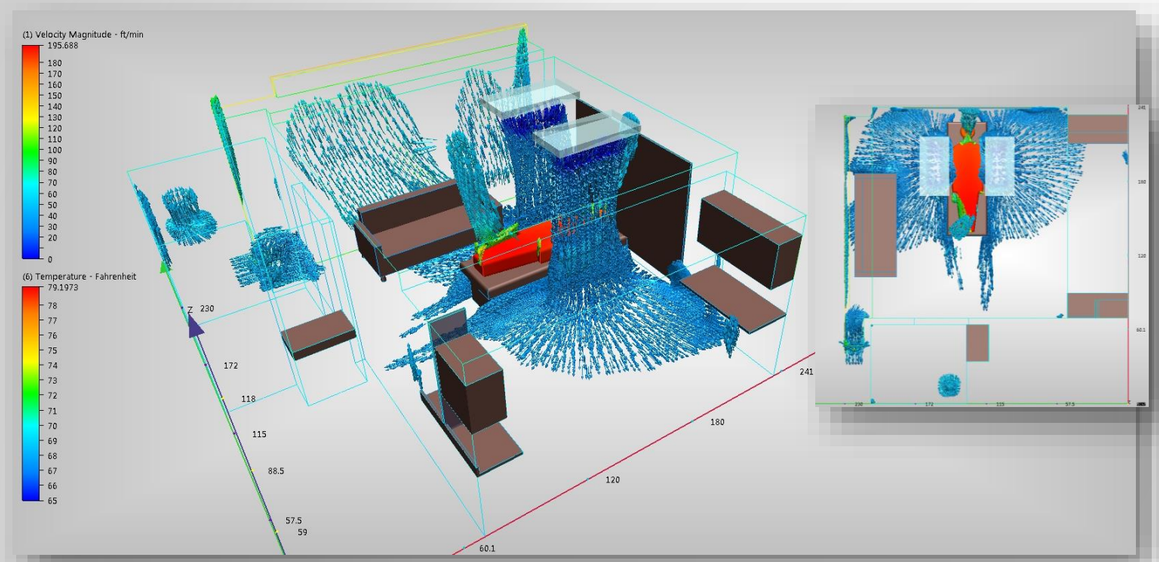
Single Patient Room 2 – Boundary Conditions

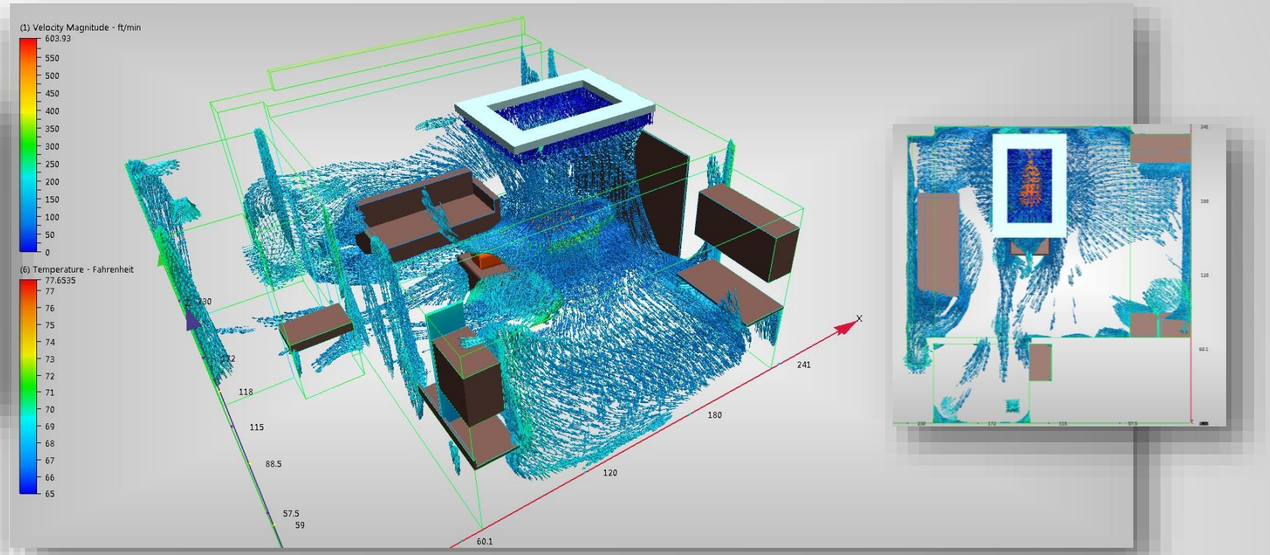


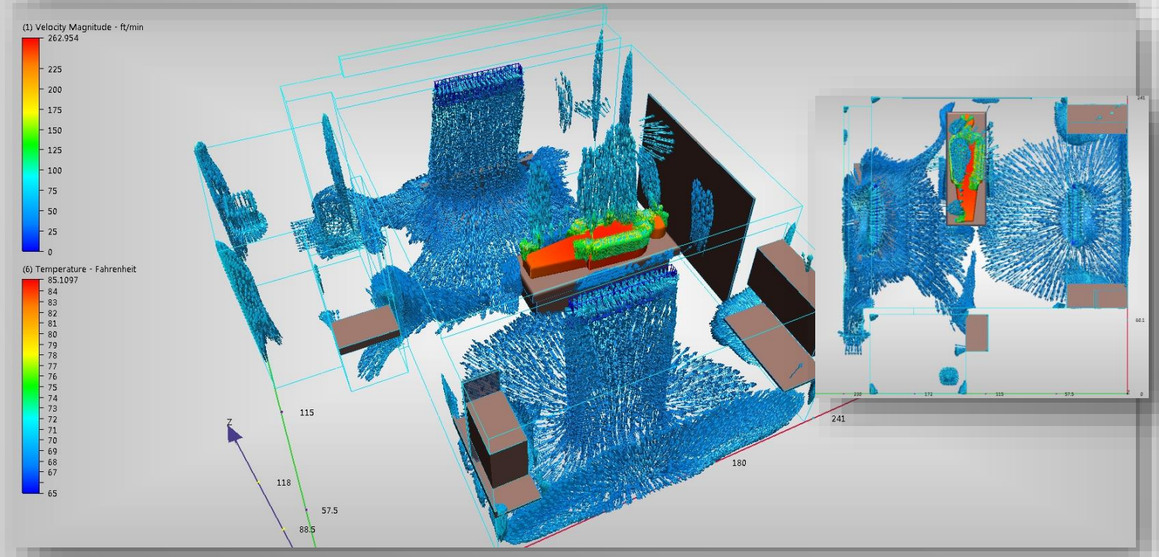
Boundary conditions applied:
The boundary conditions applied were similar to the previous study but some small changes were made. Primarily in the multi-scenario setup, different air flows, and proper application of BCs to human avatar. BCs were not applied to the casework, furniture and headwall.

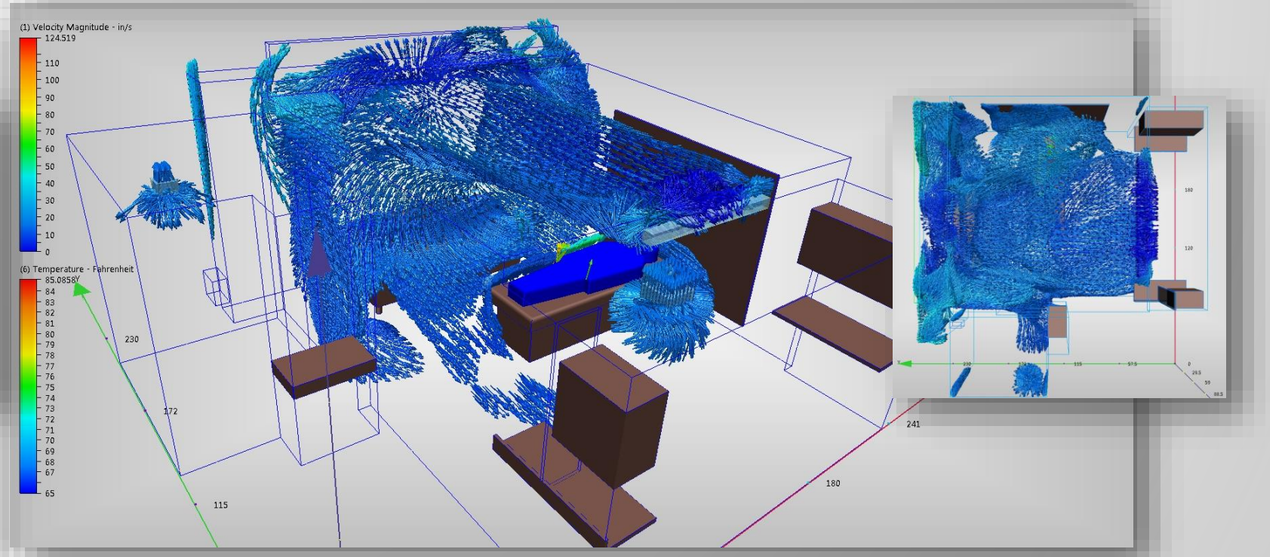
- External Walls: Film Coefficient = 0.45 W/m2/K @ 27 degrees Celsius.
- Internal Walls: Film Coefficient = 0.45 W/m2/K @ 22 degrees Celsius
- External Glazing: Film Coefficient = 3.36 W/m2/K @ 27 degrees Celsius
- Supply Air: Velocity (normal) = 530 CFM, 380 CFM, 265 CFM per scenario
- Supply Air: Temperature = 20 D C
- Return Air: 0 Pressure
- Human Avatar: Volumetric BC, Total Heat Generation, applied at 60 watts

Single Patient Room 2 - Results

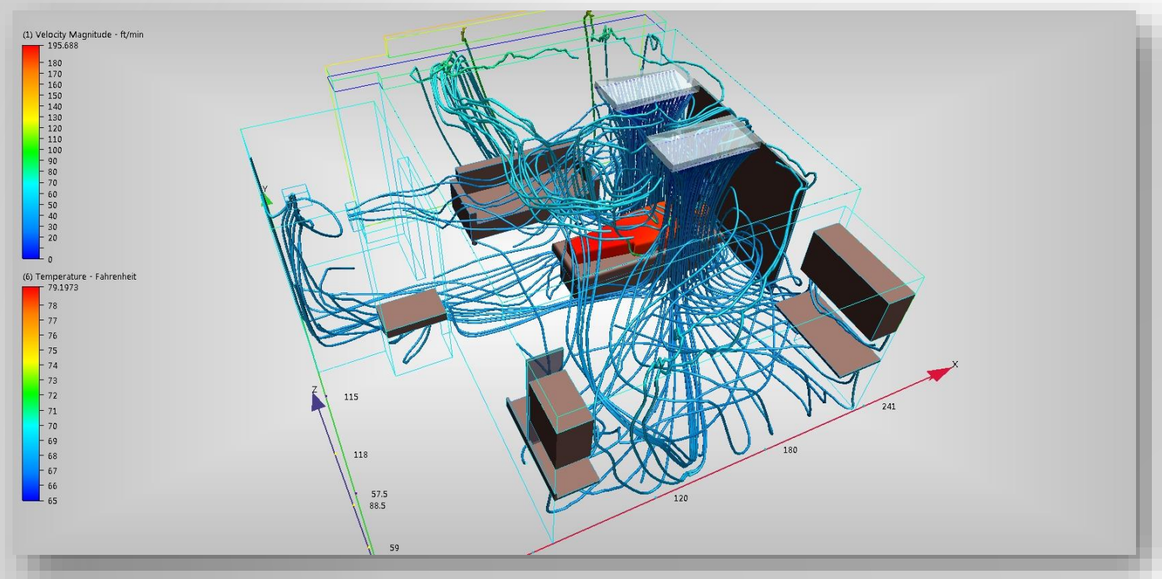


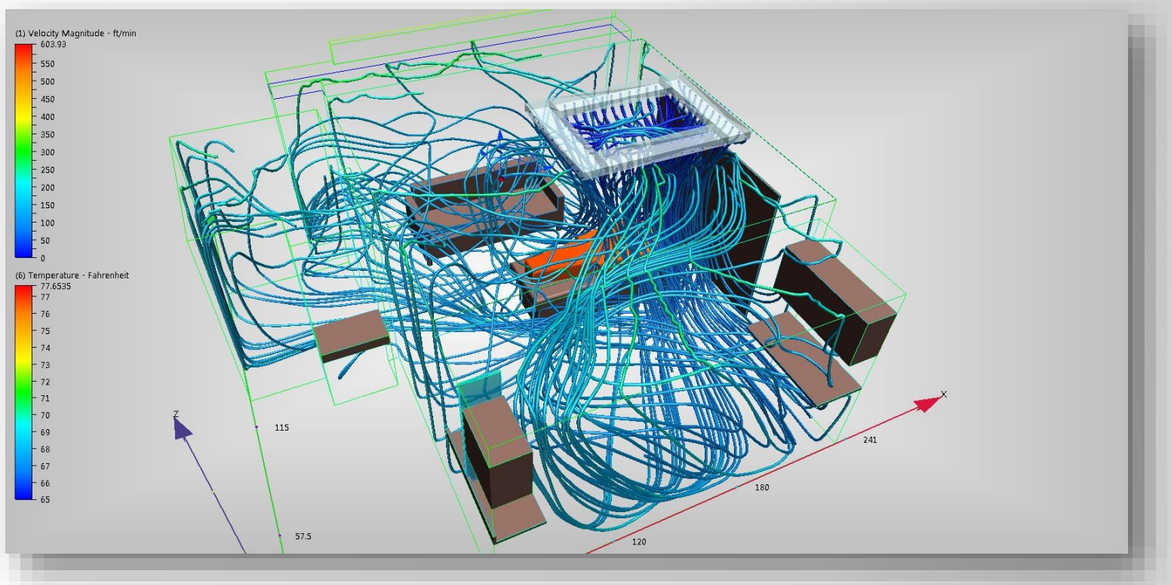


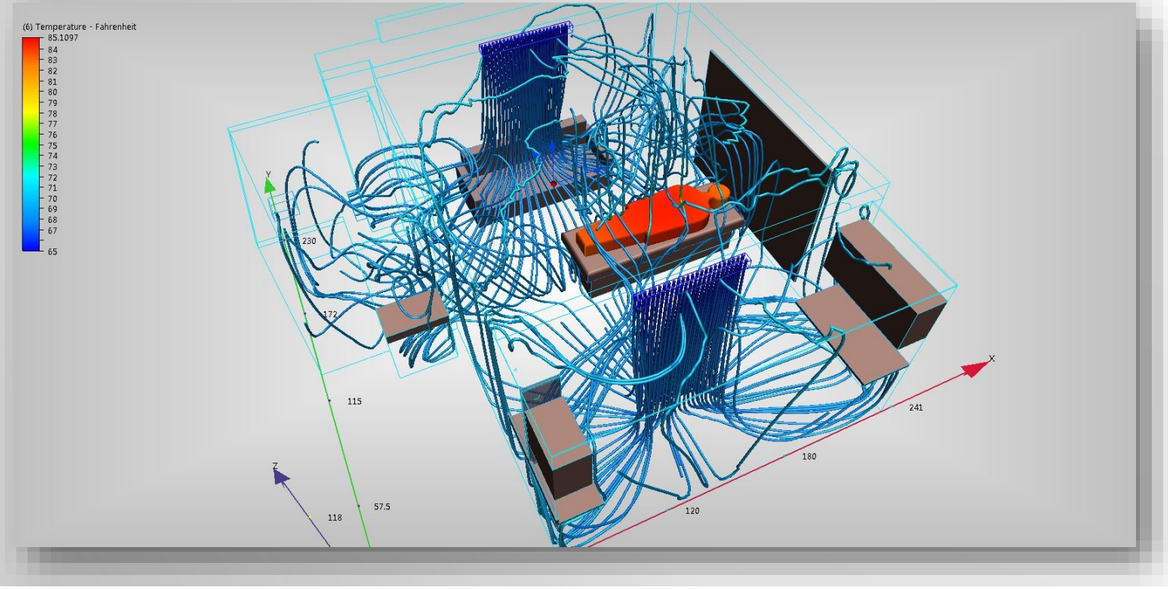


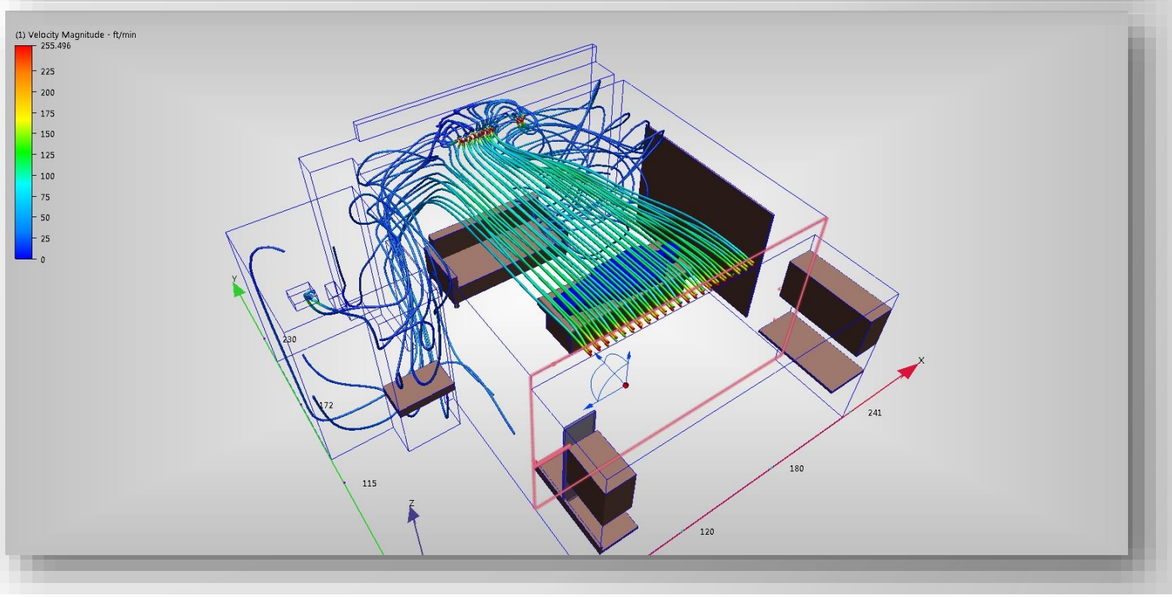


Single Patient Room 2 - Results

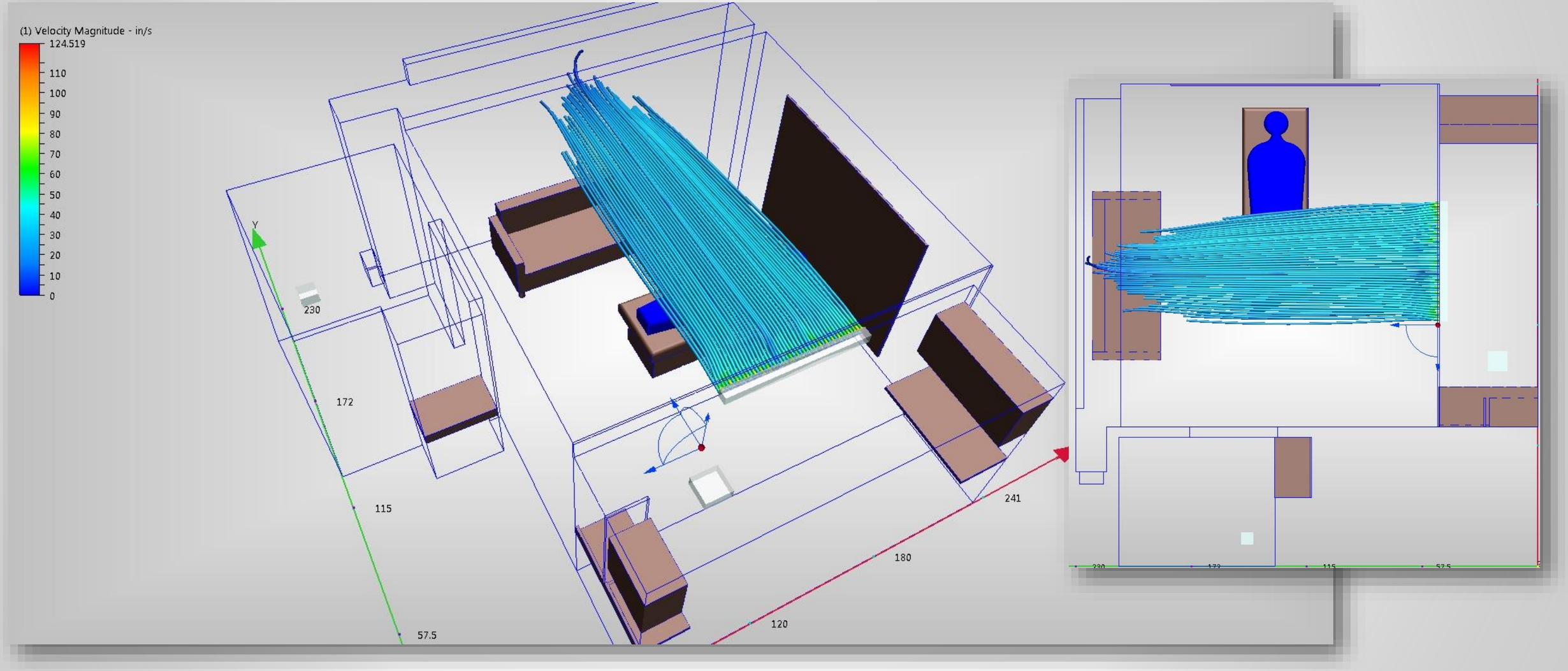




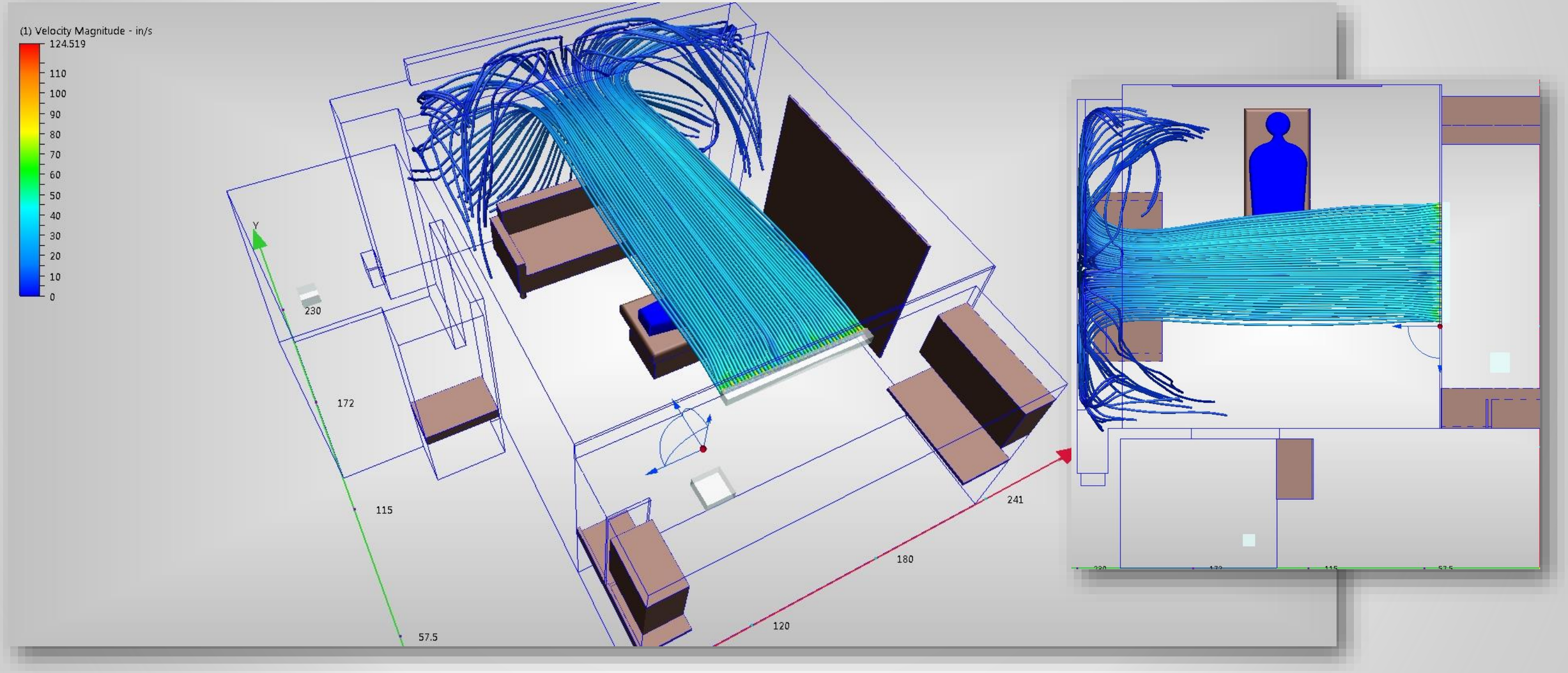




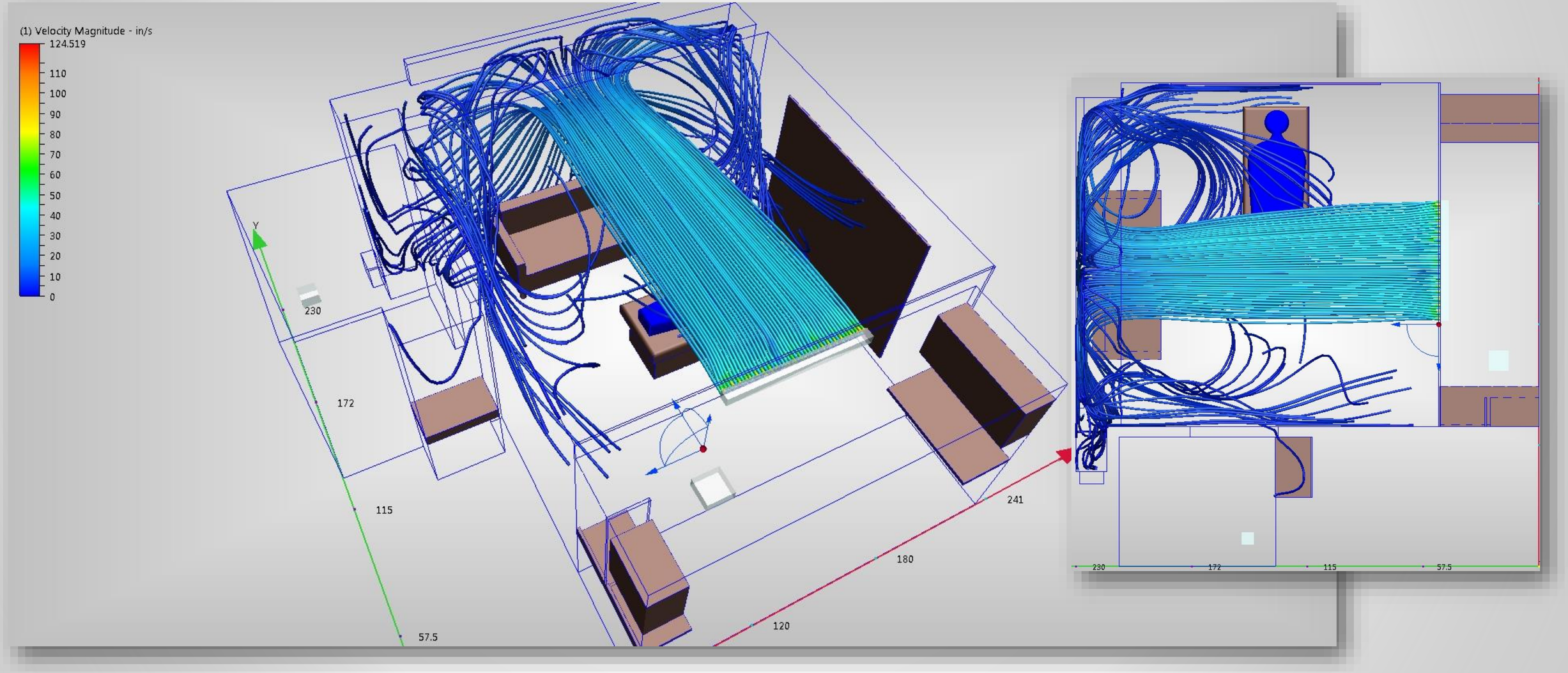
Single Patient Room 2 – Linear Diffuser w/Traces



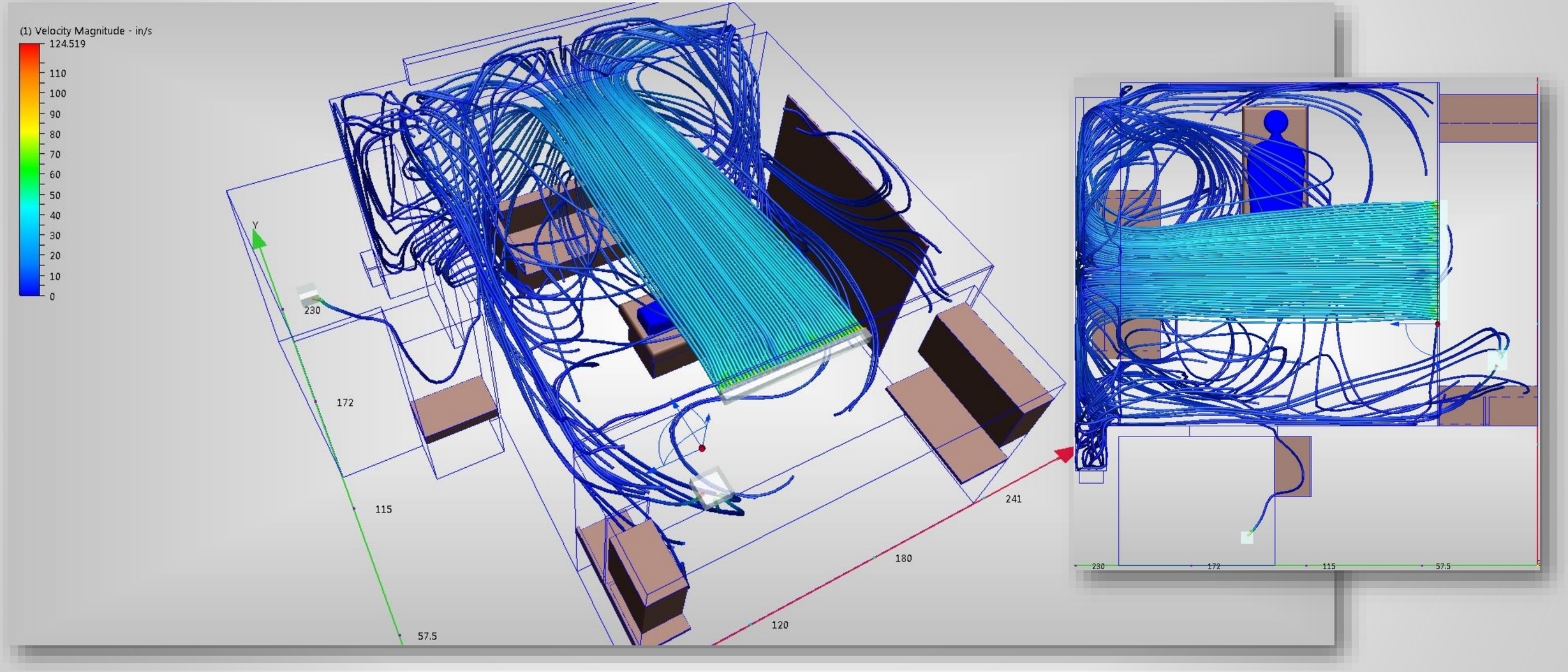
Single Patient Room 2 – Linear Diffuser w/Traces



Single Patient Room 2 – Linear Diffuser w/Traces



Single Patient Room 2 – Linear Diffuser w/Traces



Single Patient Room 2 - Results

- More confident in model
- More confident in setup
- Simplified setup
- Observation = Linear diffuser shows less re-entrainment
- Observation = Less turbulent at 6 ACHs
- How to represent equipment heat loads?
- Client reviewed results, still decided to build out room to 12 ACH

Single Patient Room 2 - Lessons

- Hard to update model
- Plan model and scenarios prior to modeling
- Work with proper flow loads
- How to represent equipment heat loads?
- How much to model?
- Need Data
- Still don’t understand PMV

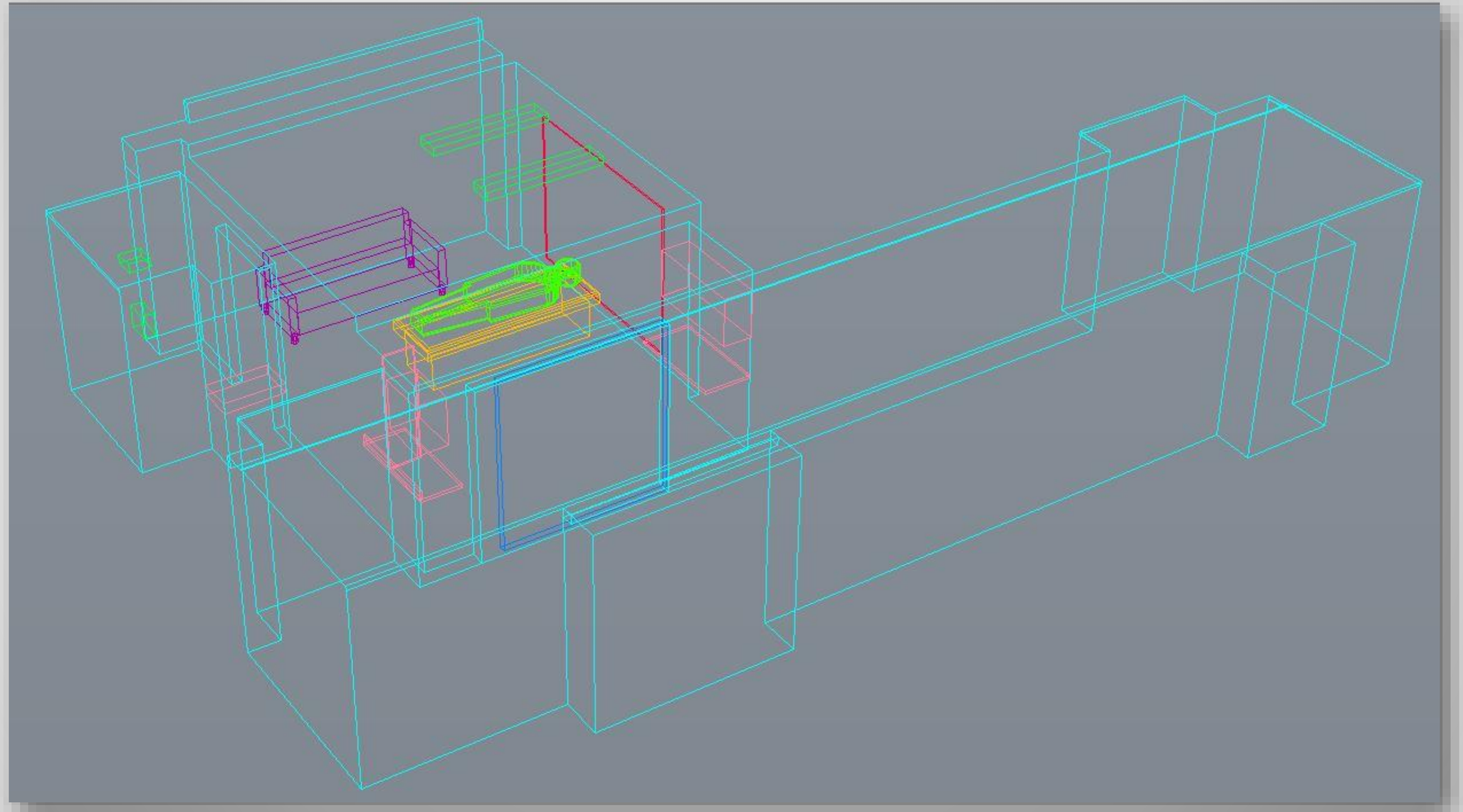
Infection Control

ICU Rooms and Infection Control

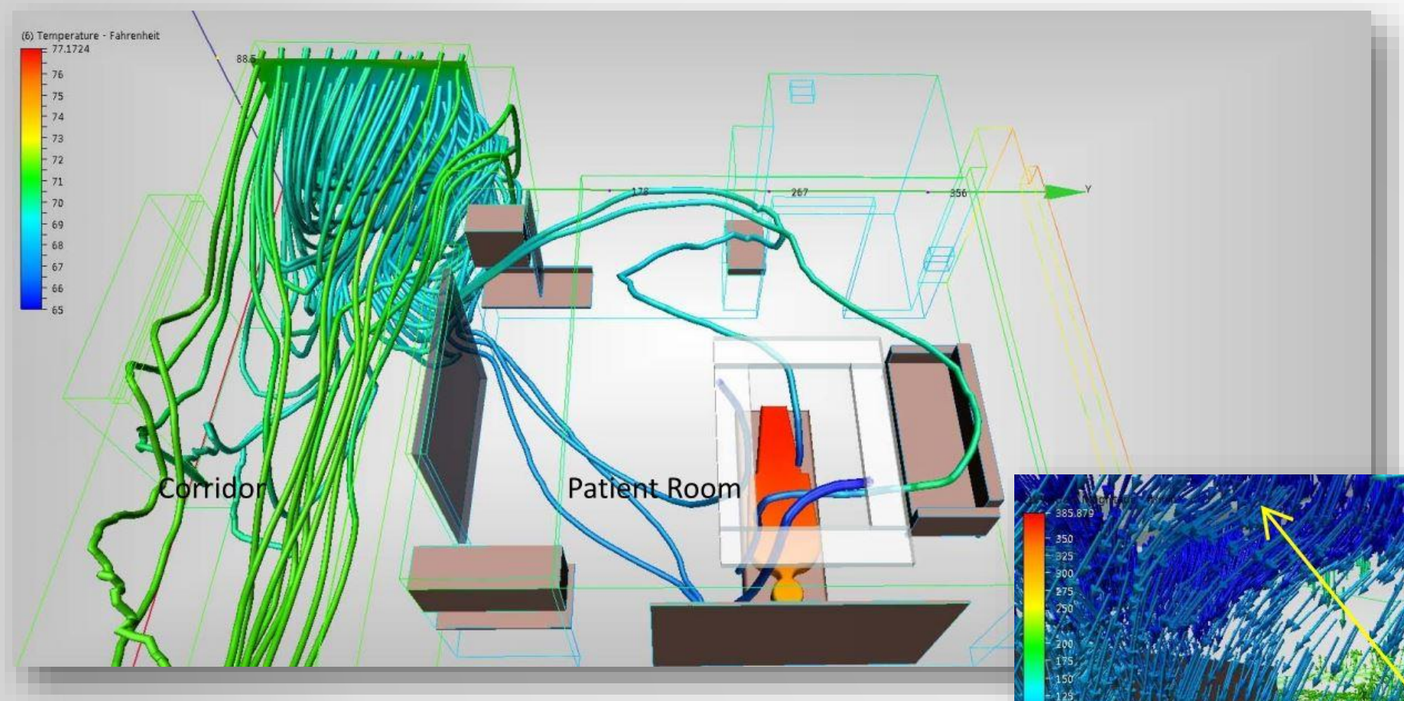
From the original diffuser study a secondary study emerged. It became clear that a common practice in the hospital was for ICU nurses to prop open the ICU door by 12” so they could “hear” any distress from their patients. Although done out of care and concern it may cause air infiltration and possible infection control issues.

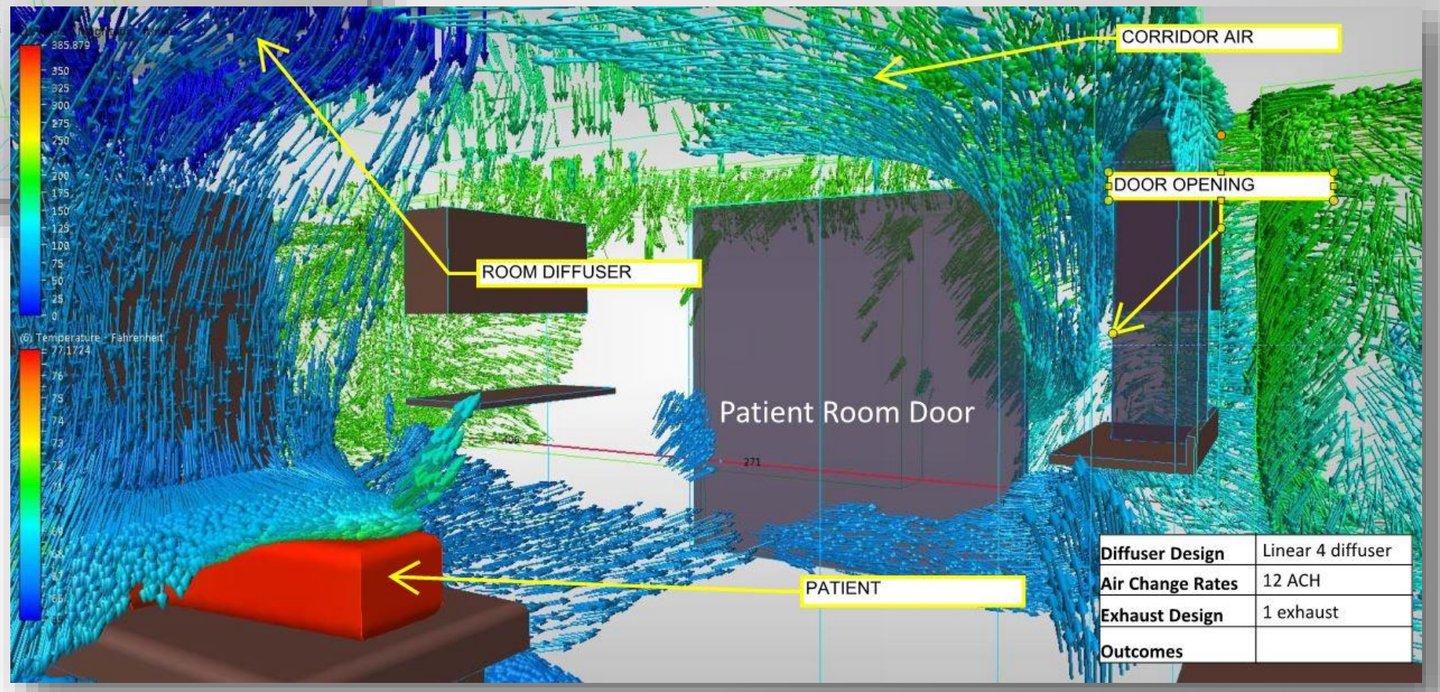
The model used for the second patient room study was altered to add the corridor and a door with a one foot wide opening the height of the door at the jamb. Each diffuser layout, with 3 different ACH rates, was used for this study. The boundary conditions used in the patient room study were used and an additional velocity was added to the corridor. All others are the same.

Infection Control - Model

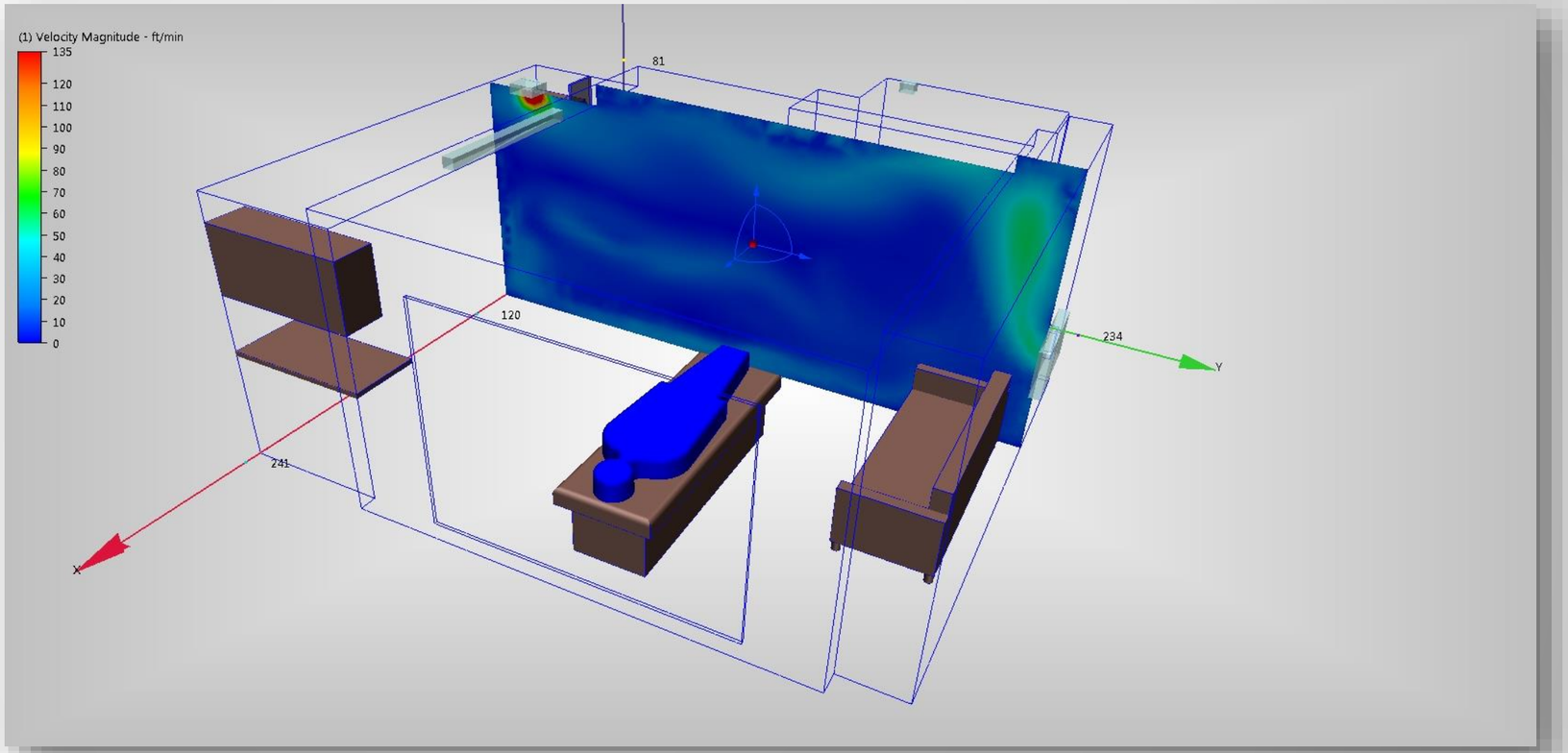


ICU Rooms and Infection Control





Novice

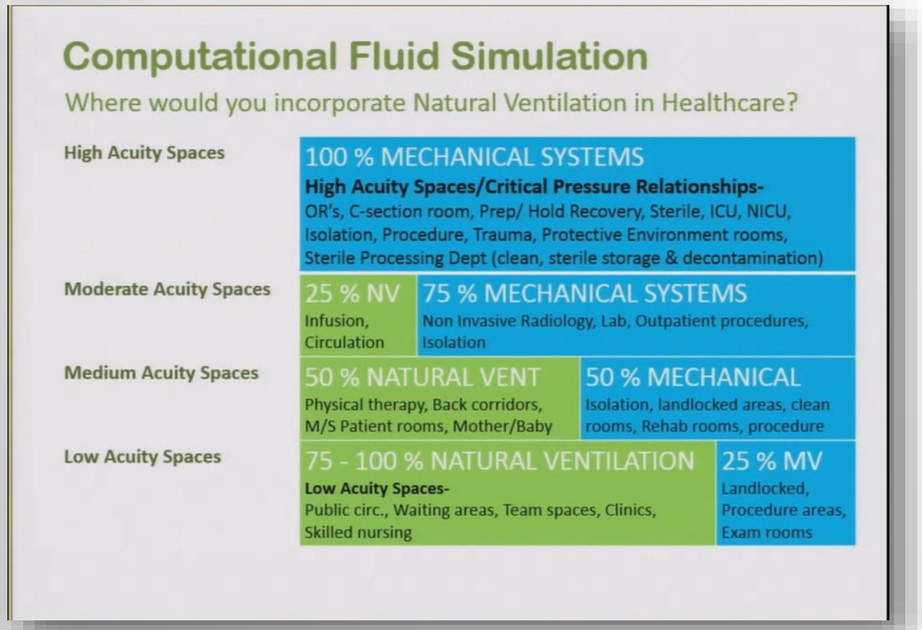

(1) Velocity Magnitude - ft/min
135
120
110
100
90
80
70
60
50
40
30
20
10
0
81
120
234
241
X
Y

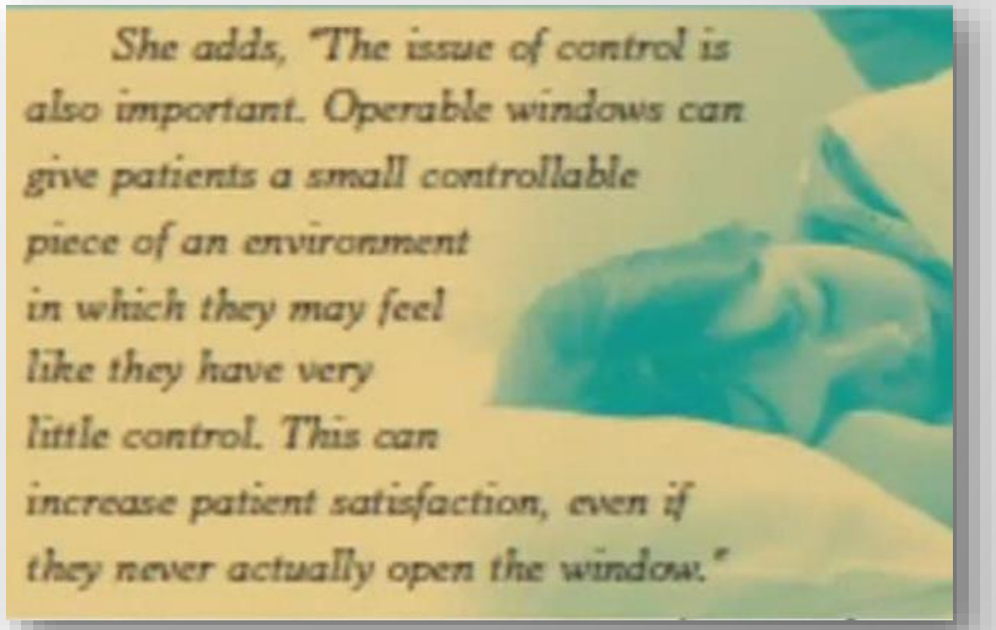
Natural Ventilation – Single Patient Room

- Is natural ventilation a possible strategy for hospital room design?
- What is the right mix of mechanical supply and return coupled with natural ventilation?
- Under what outdoor air conditions can the windows be opened and achieve thermally comfortable conditions, with code required and safe airflow outcomes?

Natural Ventilation – Single Patient Room

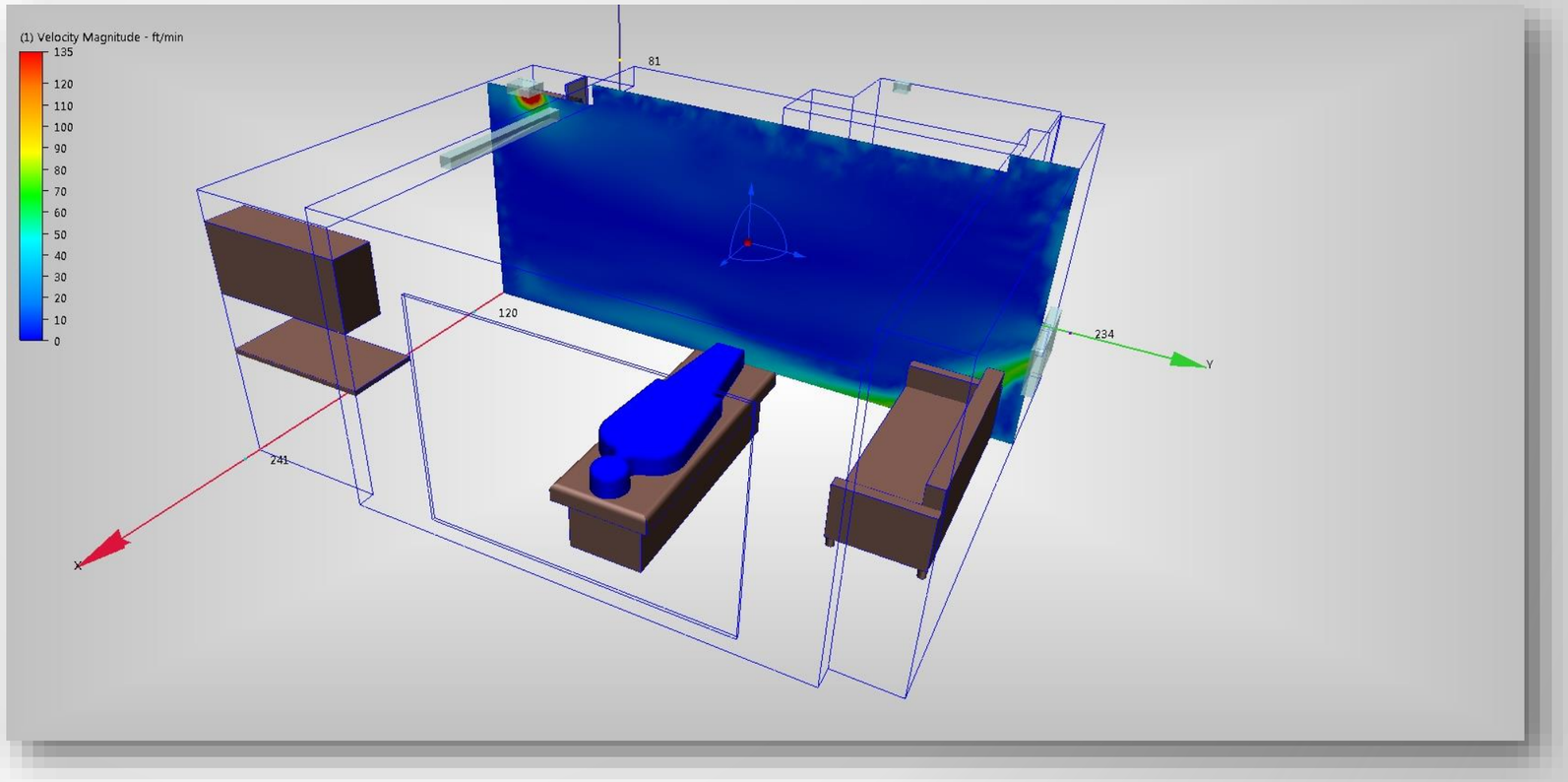
- Strategy
  - Test supply and return air velocities in conjunction with natural ventilation in a single patient room with a single operable window.
  - Test: 6,2,0 ACH with external temps ranging from 55D F and 75D F



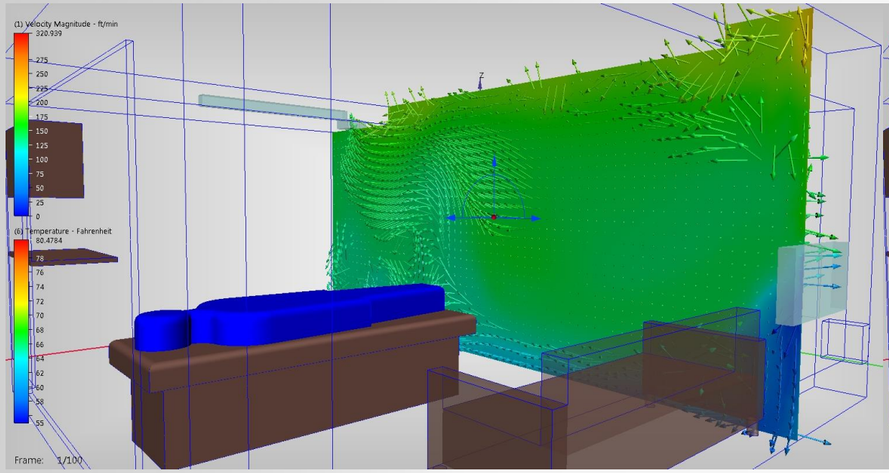


Natural Ventilation - Model

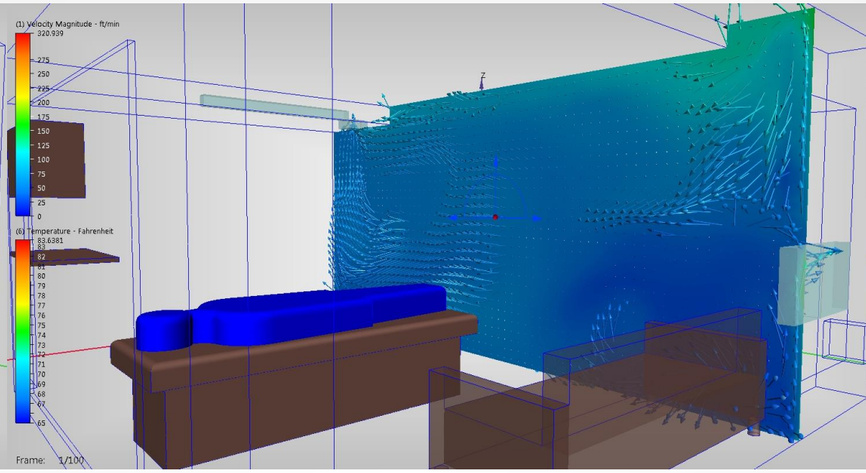
- The single patient room model was altered to add a operable window and the proper boundary conditions added. All other settings are the same as the single patient room study



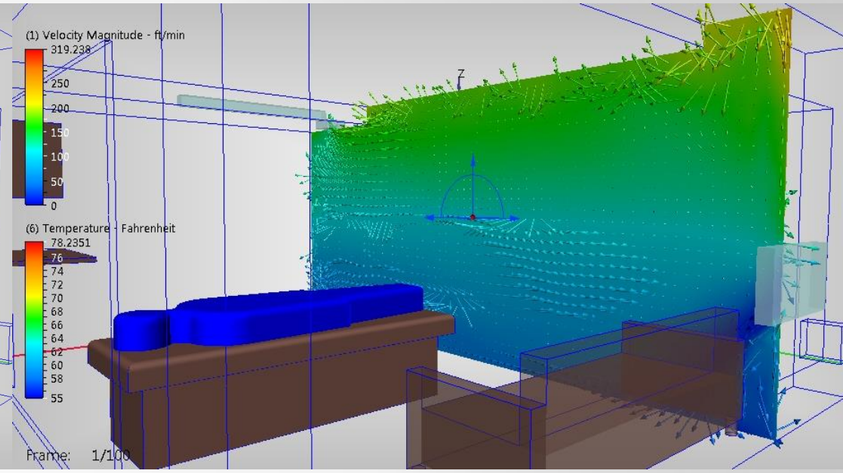
Natural Ventilation – Testing Results



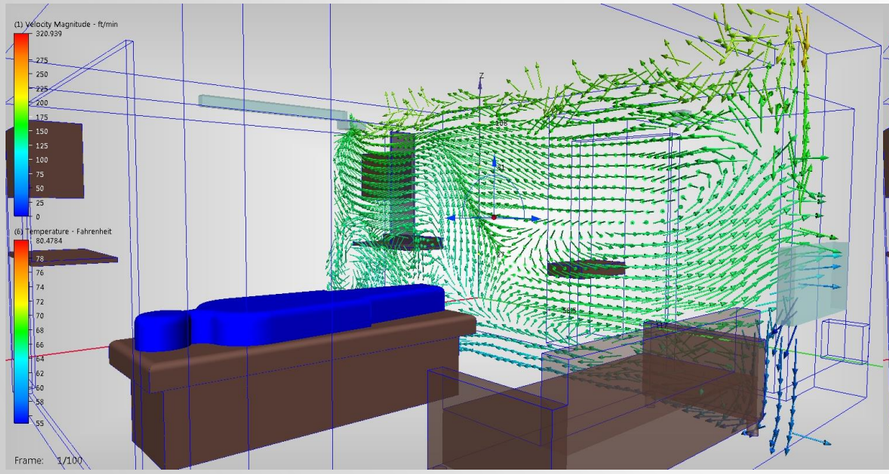
6 ACH Temp = 55D F

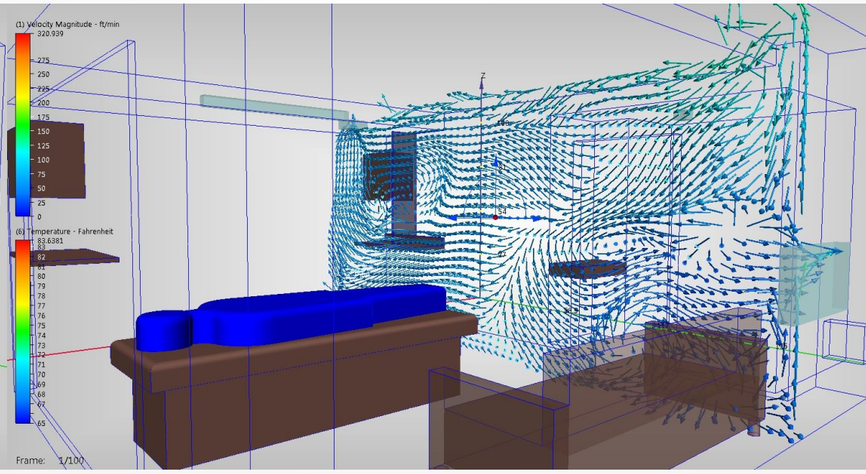


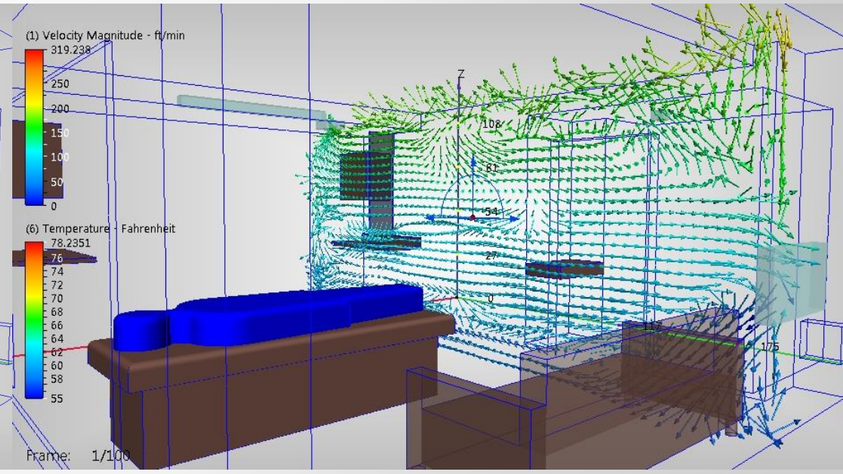
6 ACH Temp = 75D F



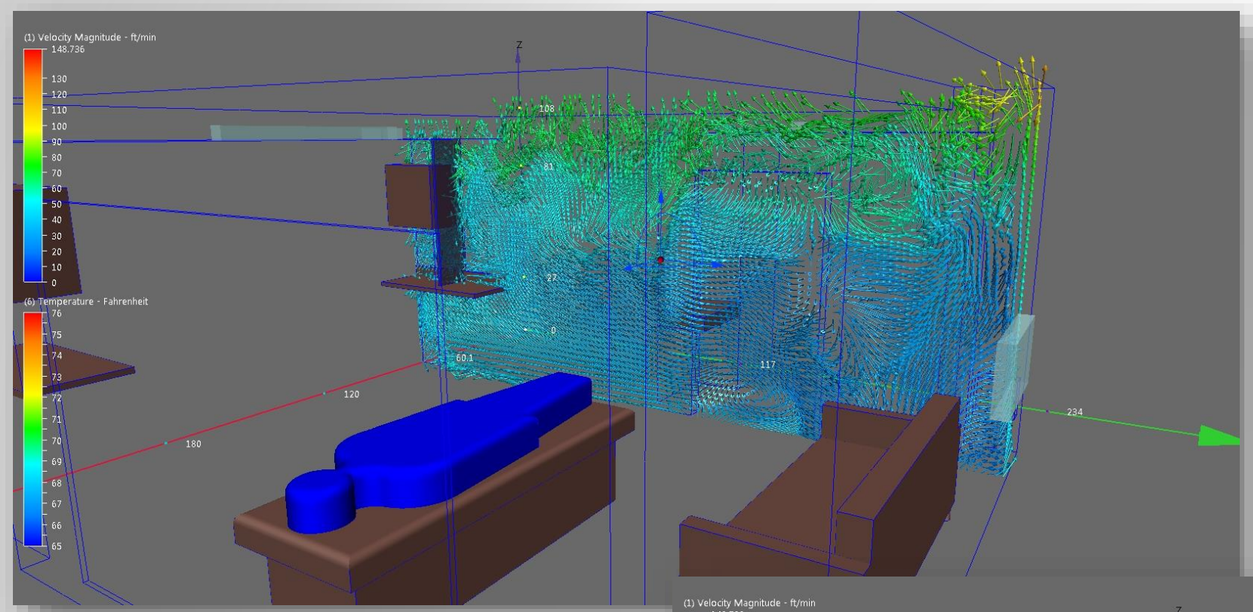
2 ACH Temp = 55D F



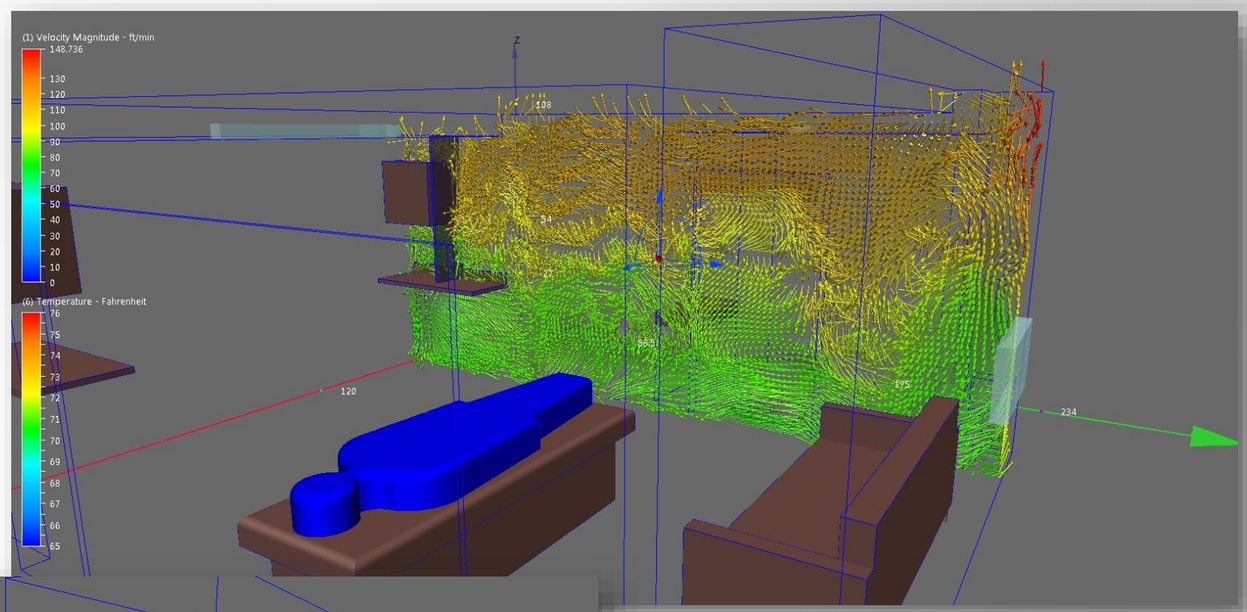




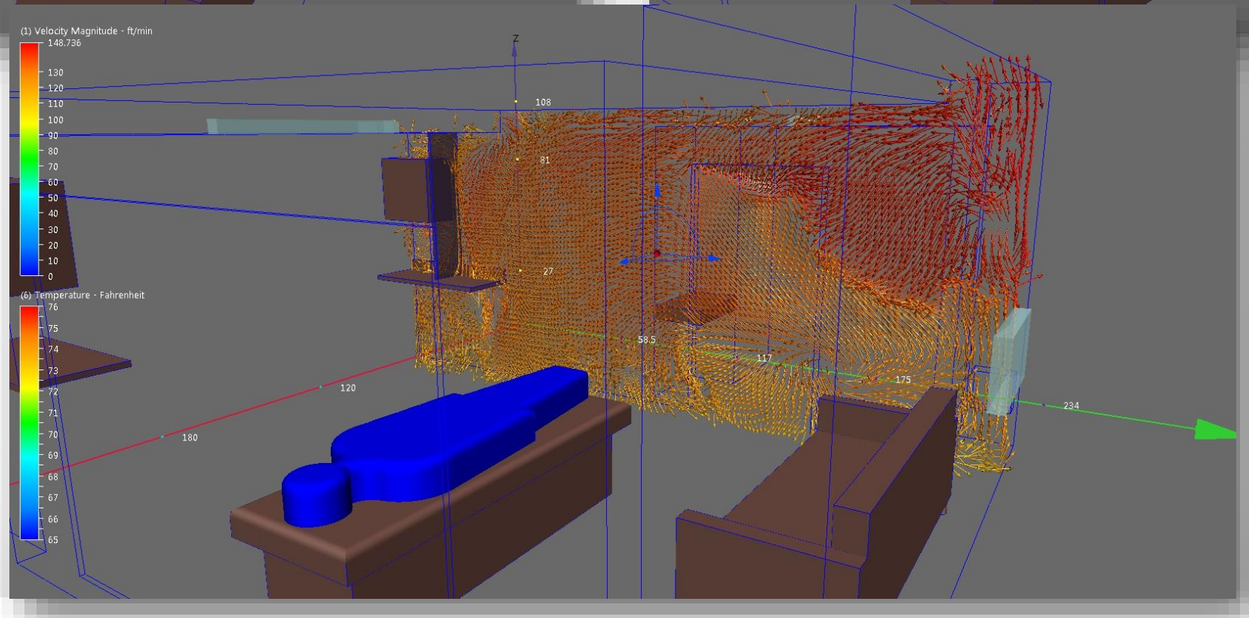
Natural Ventilation – Testing Results



6 ACH Temp = 75D F

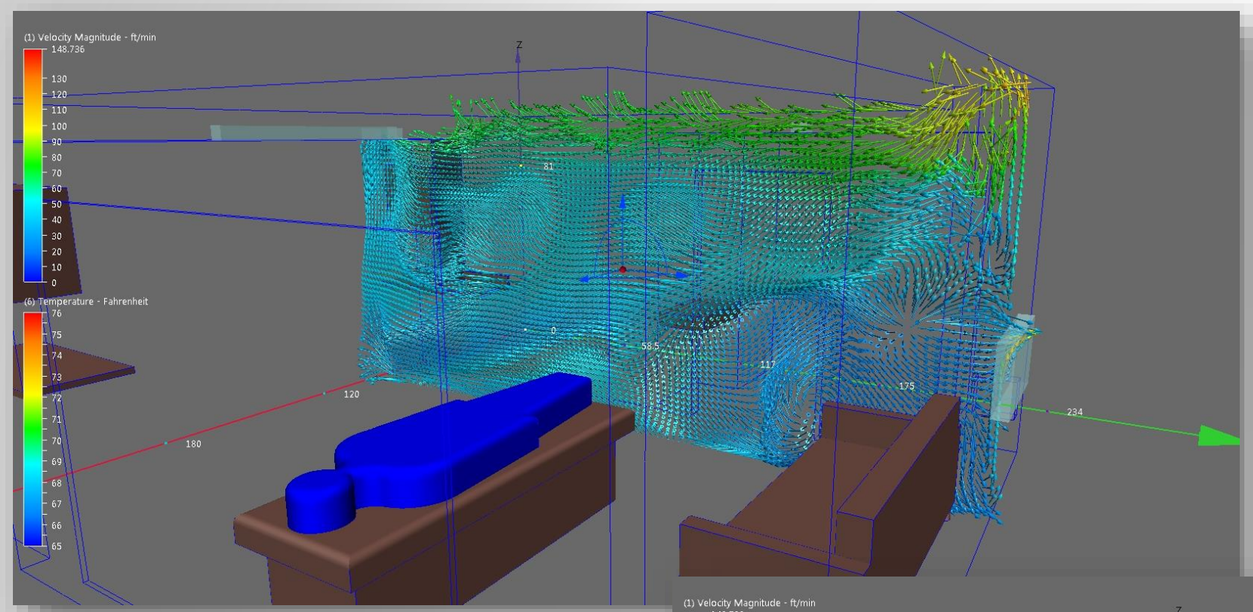


2 ACH Temp = 75D F

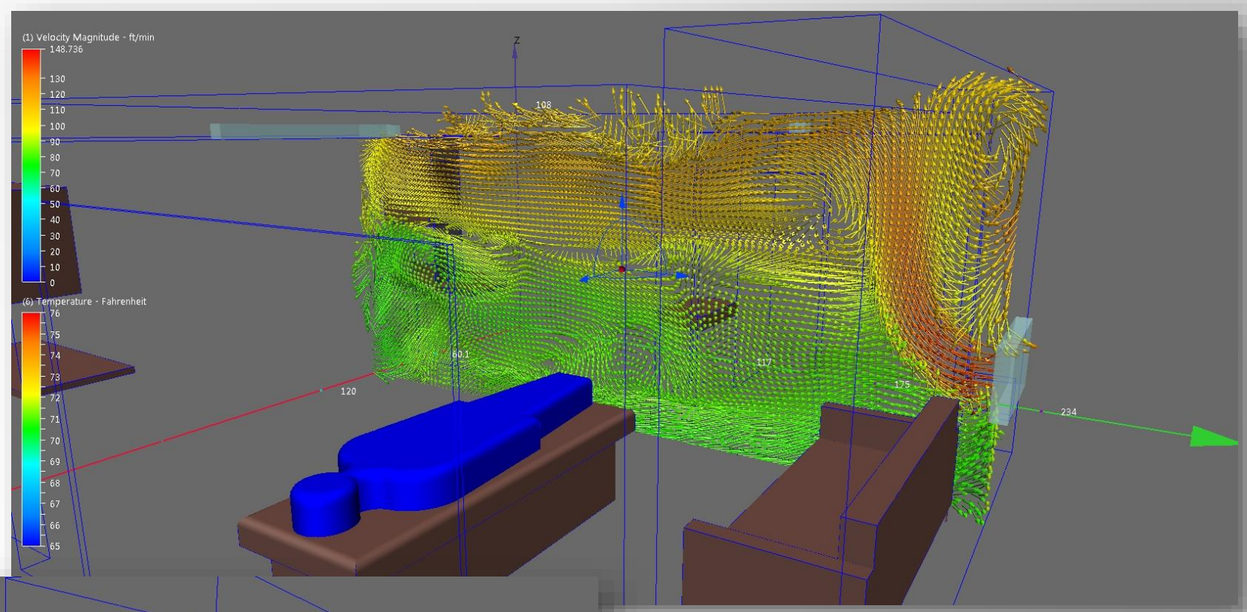


0 ACH Temp = 75D F

Natural Ventilation – Testing Results



6 ACH Temp = 75D F



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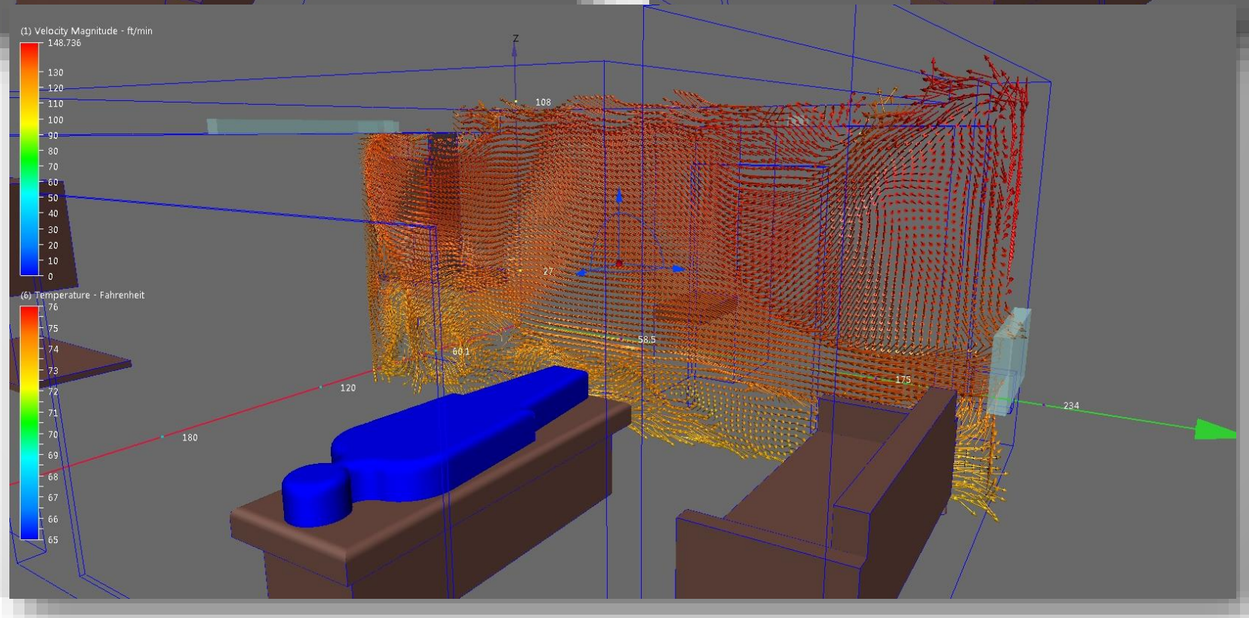
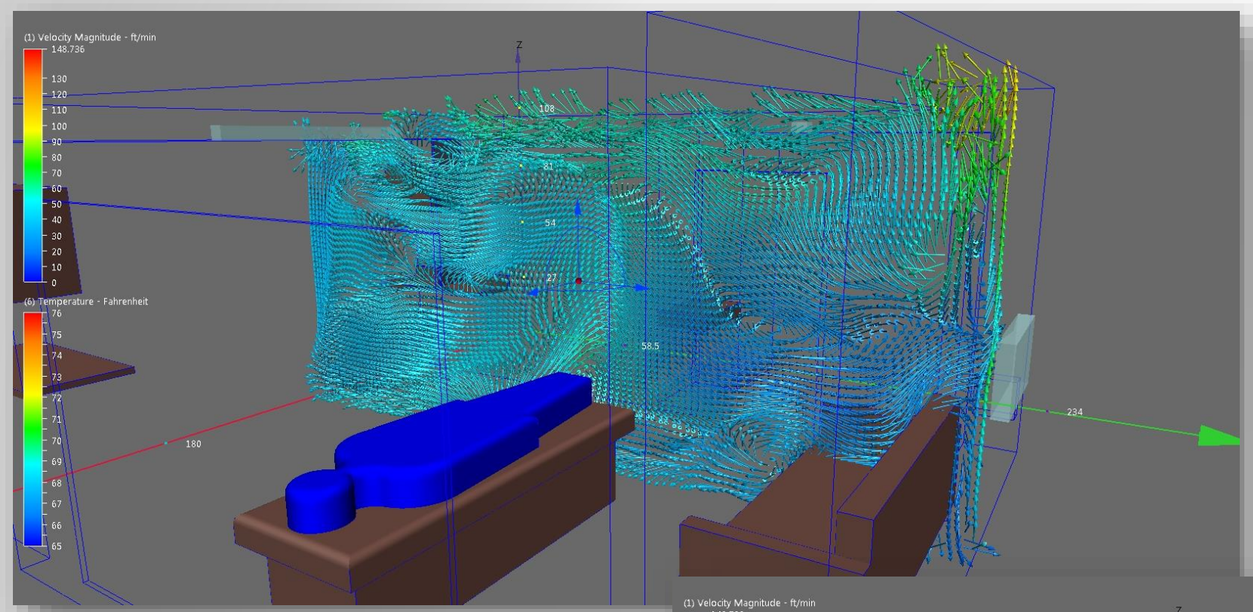


0 ACH Temp = 75D F

Natural Ventilation – Testing Results



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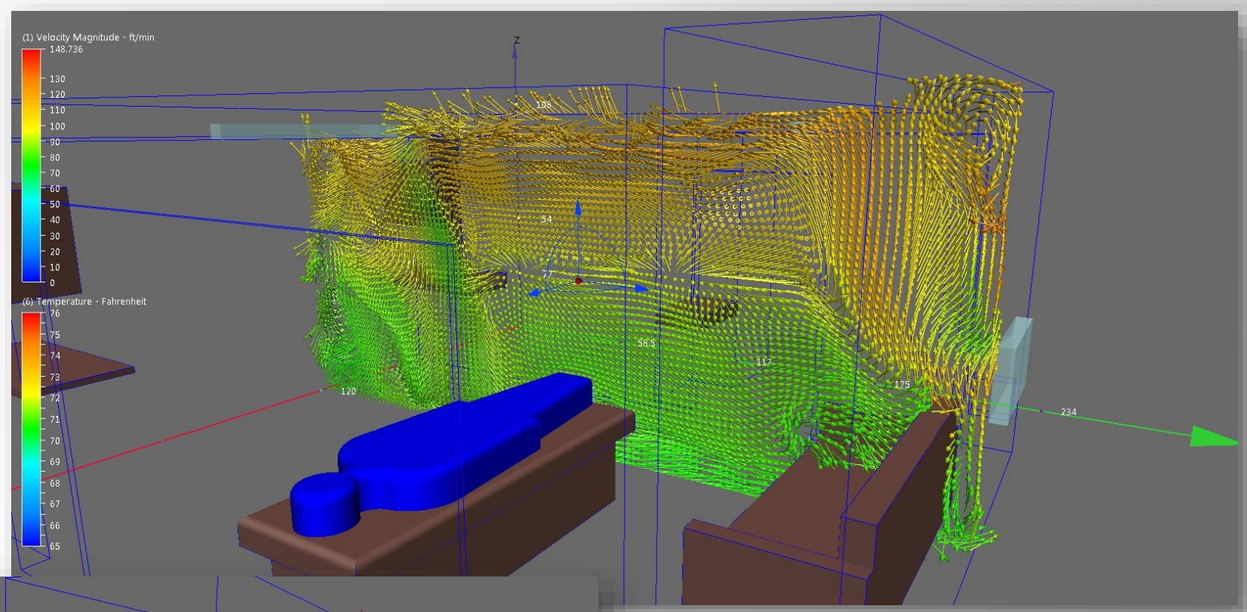

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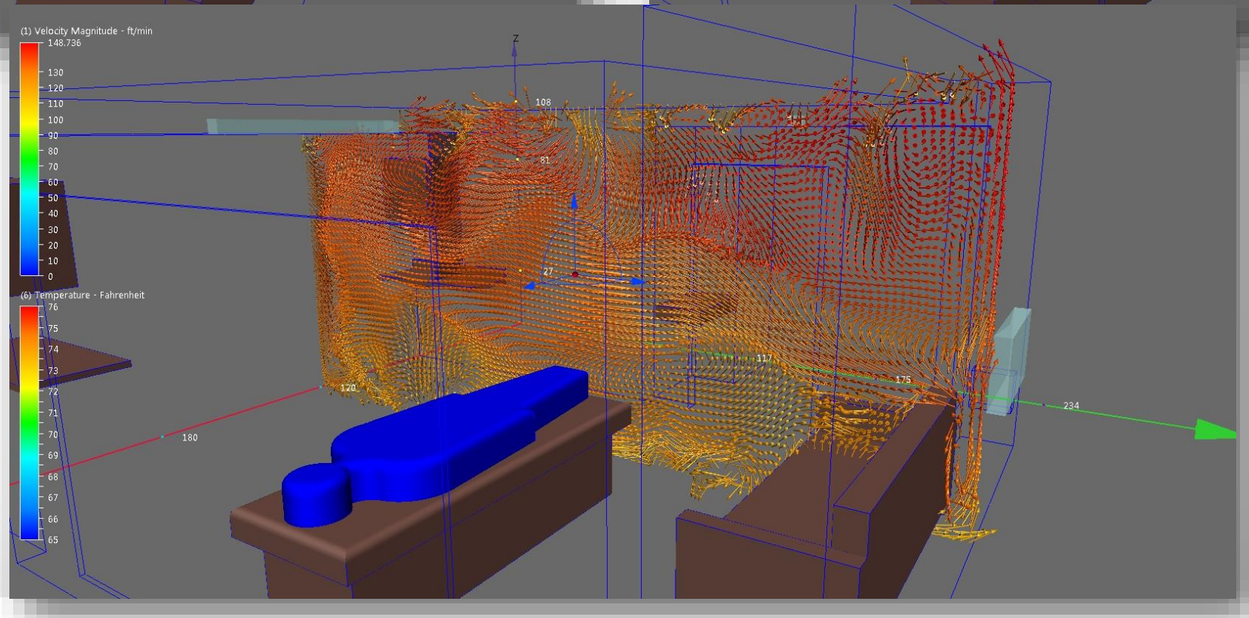
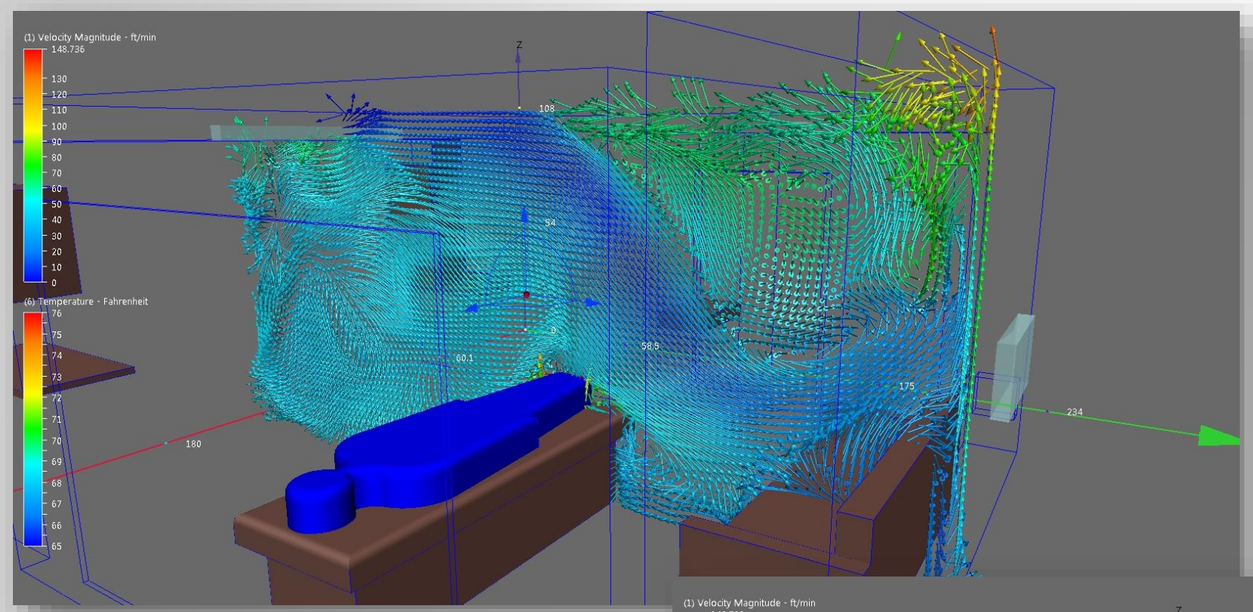
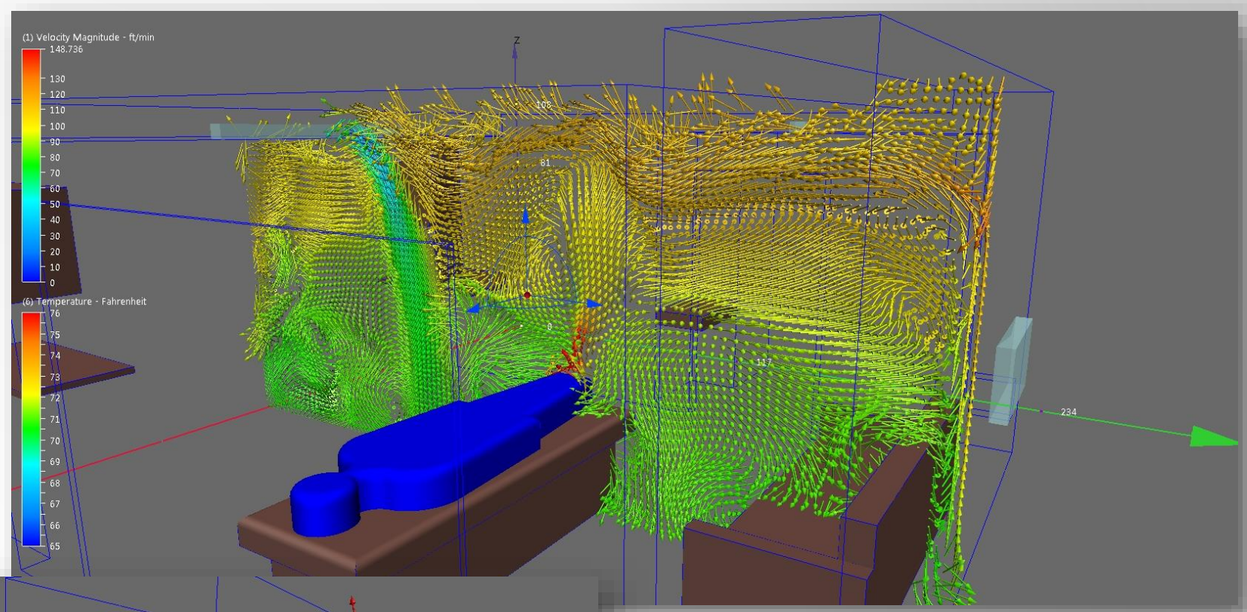


0 ACH Temp = 75D F

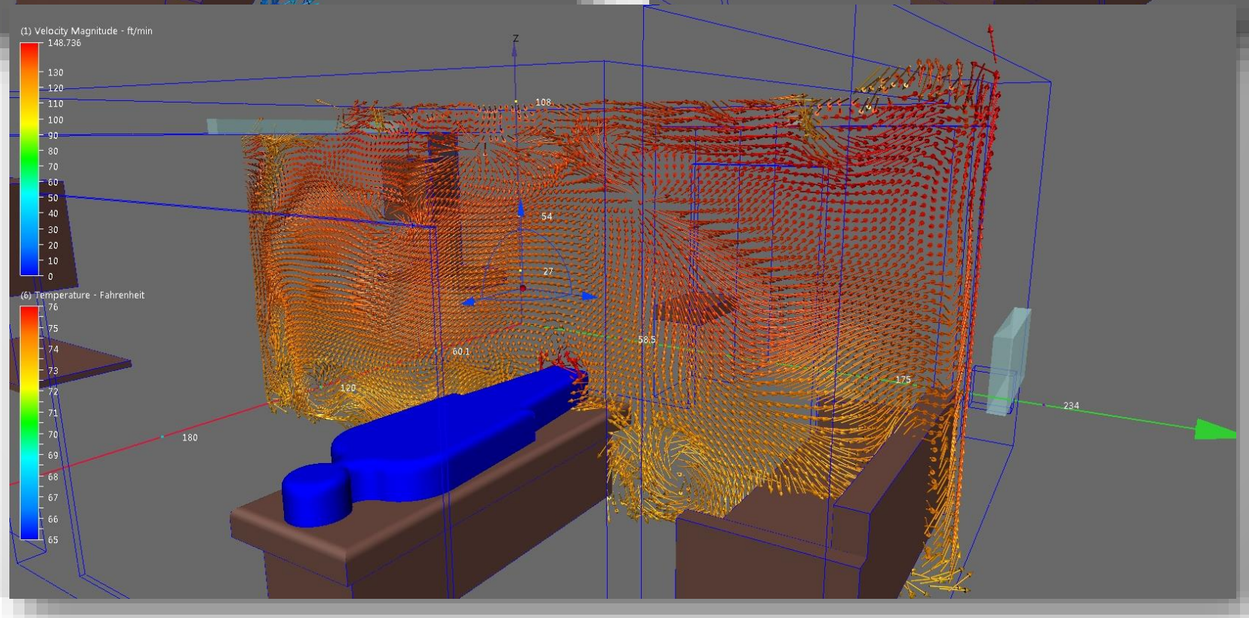
Natural Ventilation – Testing Results



6 ACH Temp = 75D F

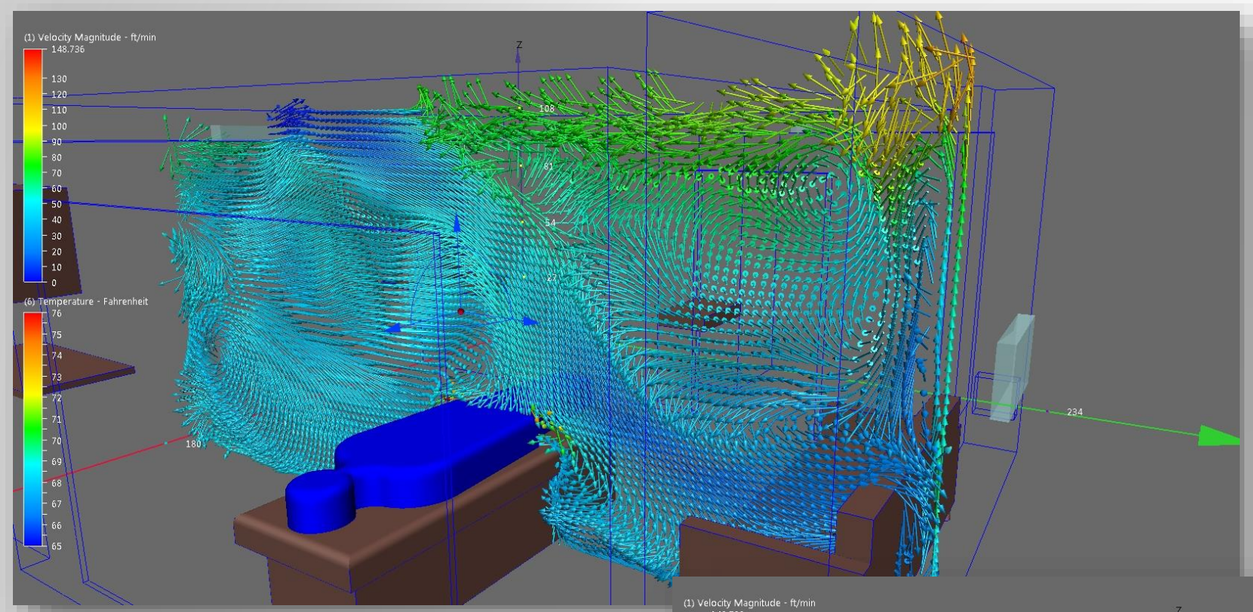


2 ACH Temp = 75D F



0 ACH Temp = 75D F

Natural Ventilation – Testing Results



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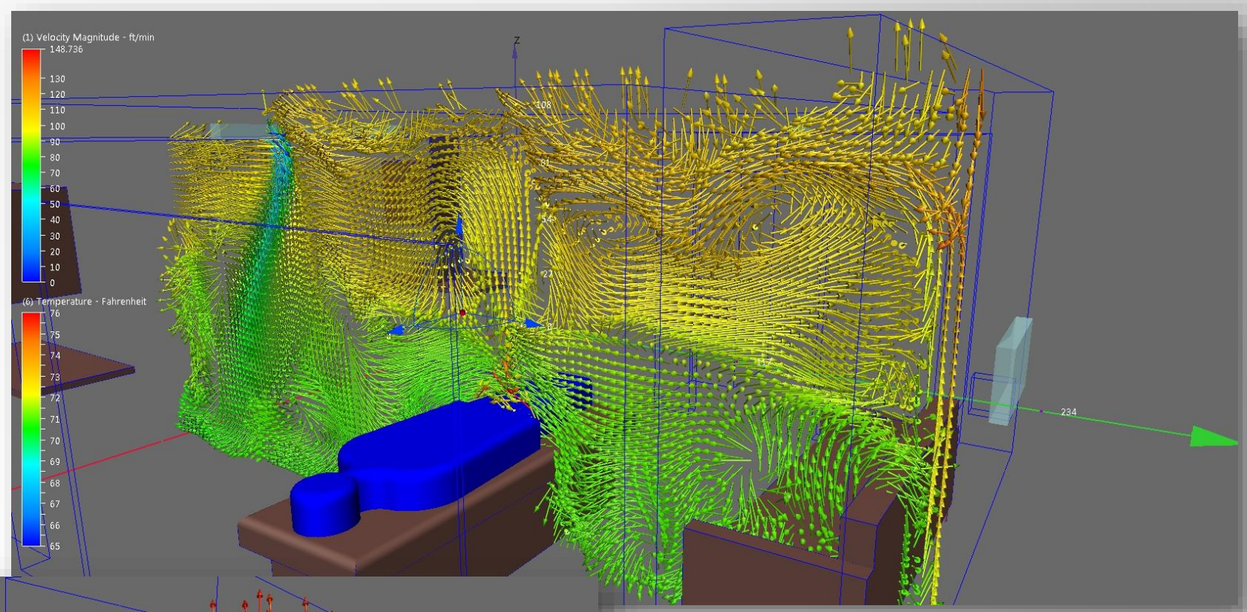

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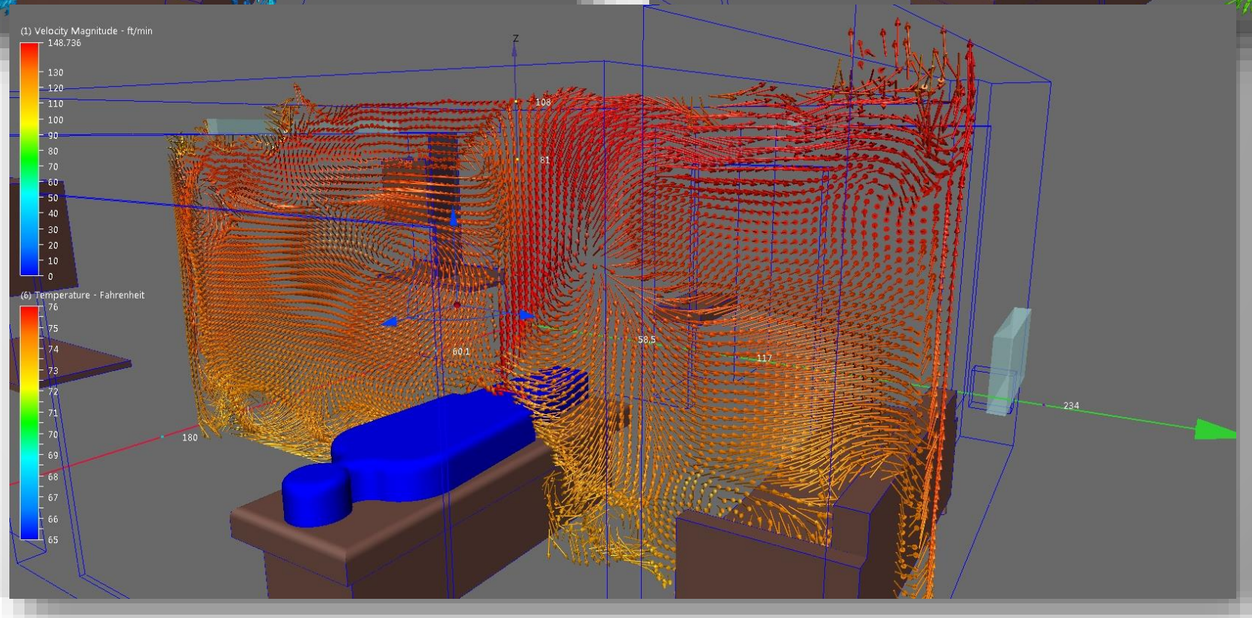
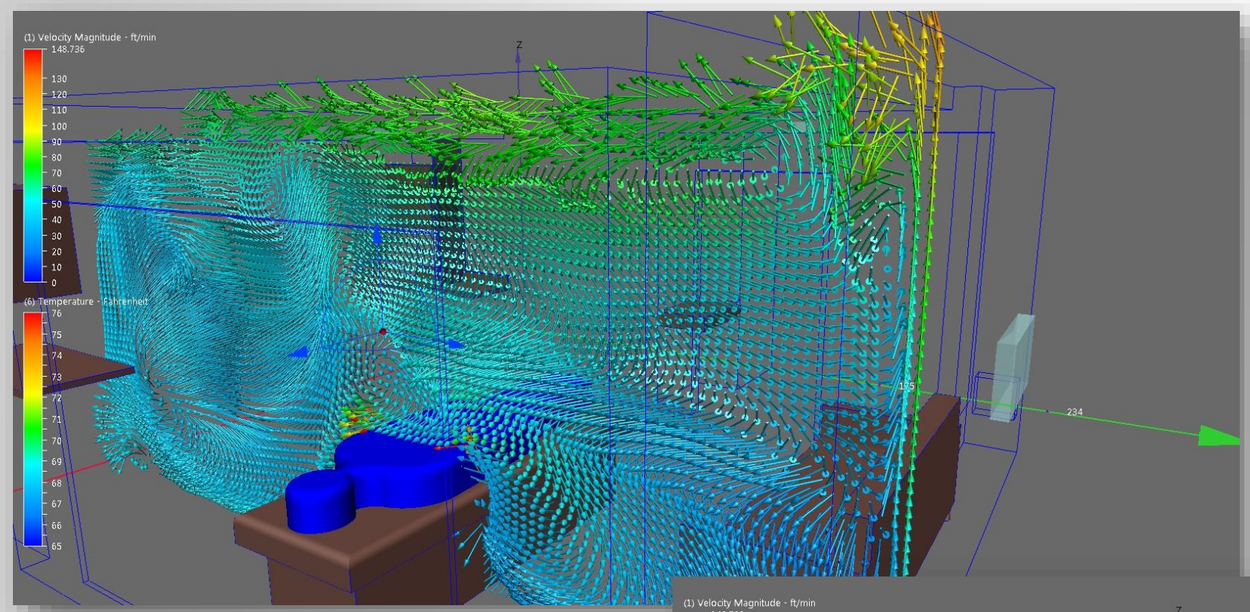
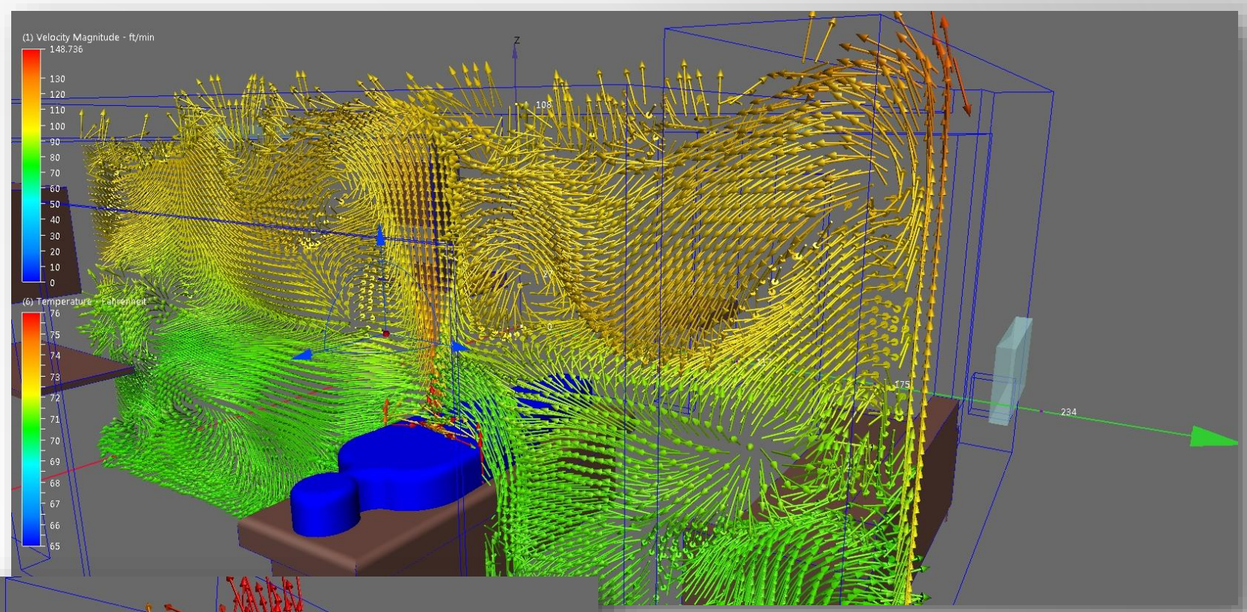


0 ACH Temp = 75D F

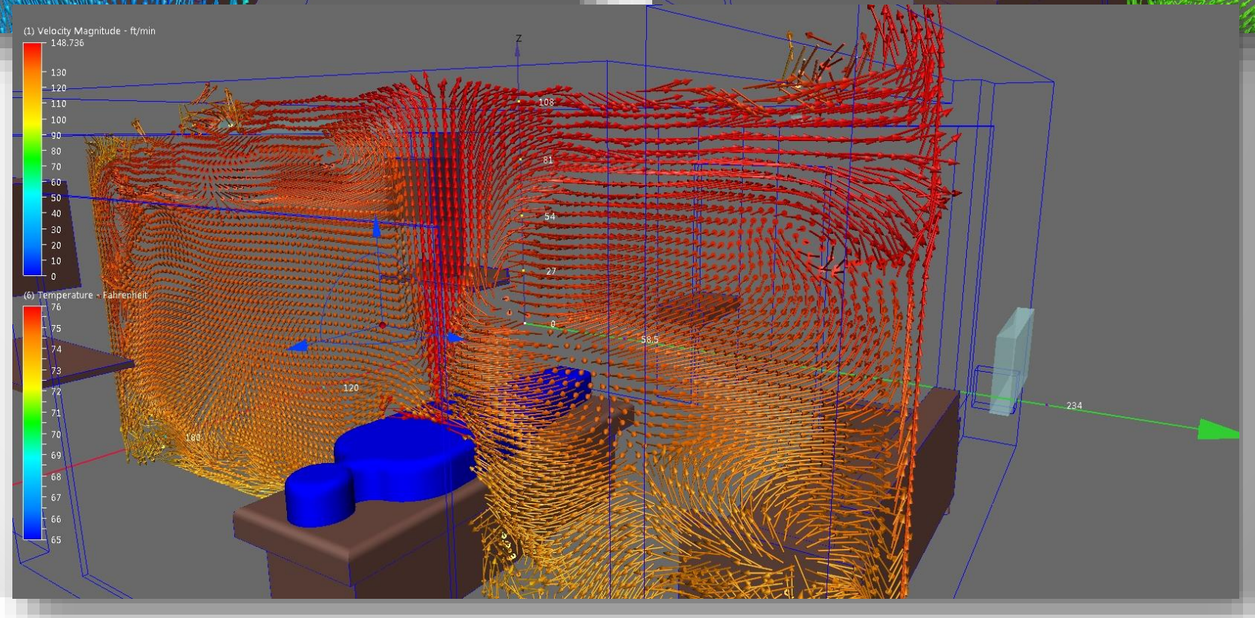
Natural Ventilation – Testing Results



6 ACH Temp = 75D F

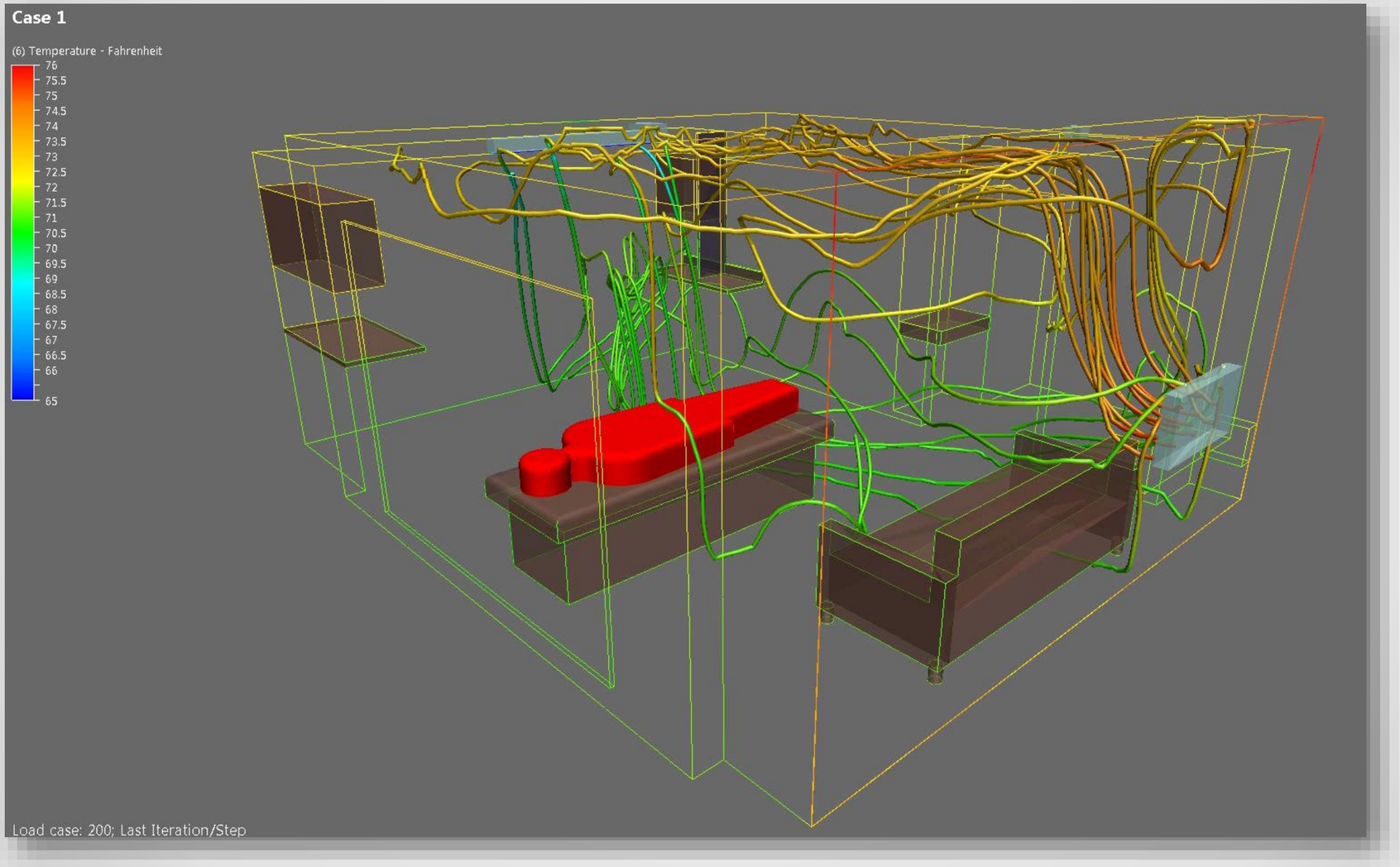


2 ACH Temp = 75D F



0 ACH Temp = 75D F

Natural Ventilation – Animation w/Traces



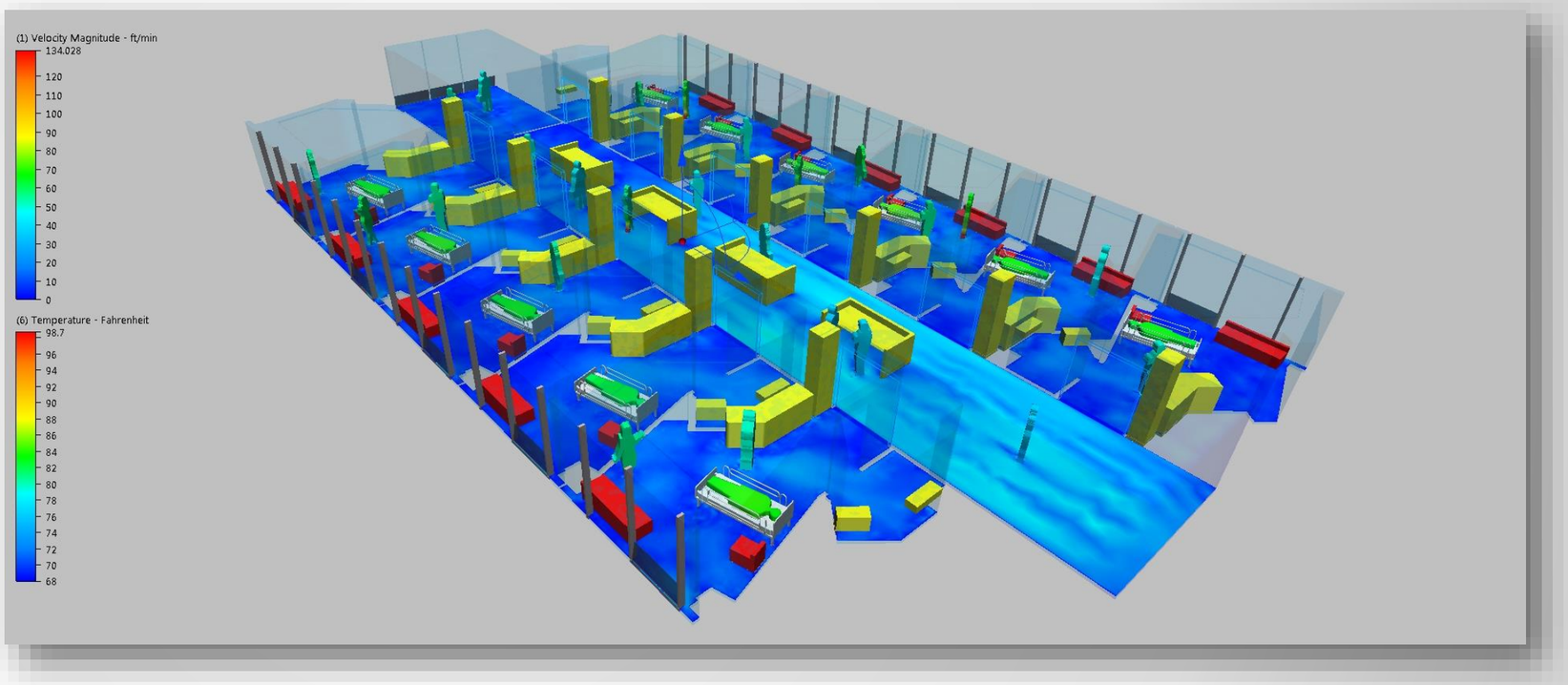
Natural Ventilation - Results

- Natural Ventilation is viable
- Hard to manage the multi-modal system
- Mixed mechanical supply and return plus natural ventilation is possible.
- Lower supply velocities and higher outdoor temperatures create the best system.
- Outdoor air moves into the space, even at high mechanically driven ACHs

Natural Ventilation - Lessons

- Model setup was easier – Grouping helped
- Boundary conditions are better but not perfect
- Data is key and helps confirm observational results
- PMV is still not understood at this point.

Advanced


(1) Velocity Magnitude - ft/min
134.028
120
110
100
90
80
70
60
50
40
30
20
10
0
(6) Temperature - Fahrenheit
98.7
96
94
92
90
88
86
84
82
80
78
76
74
72
70
68

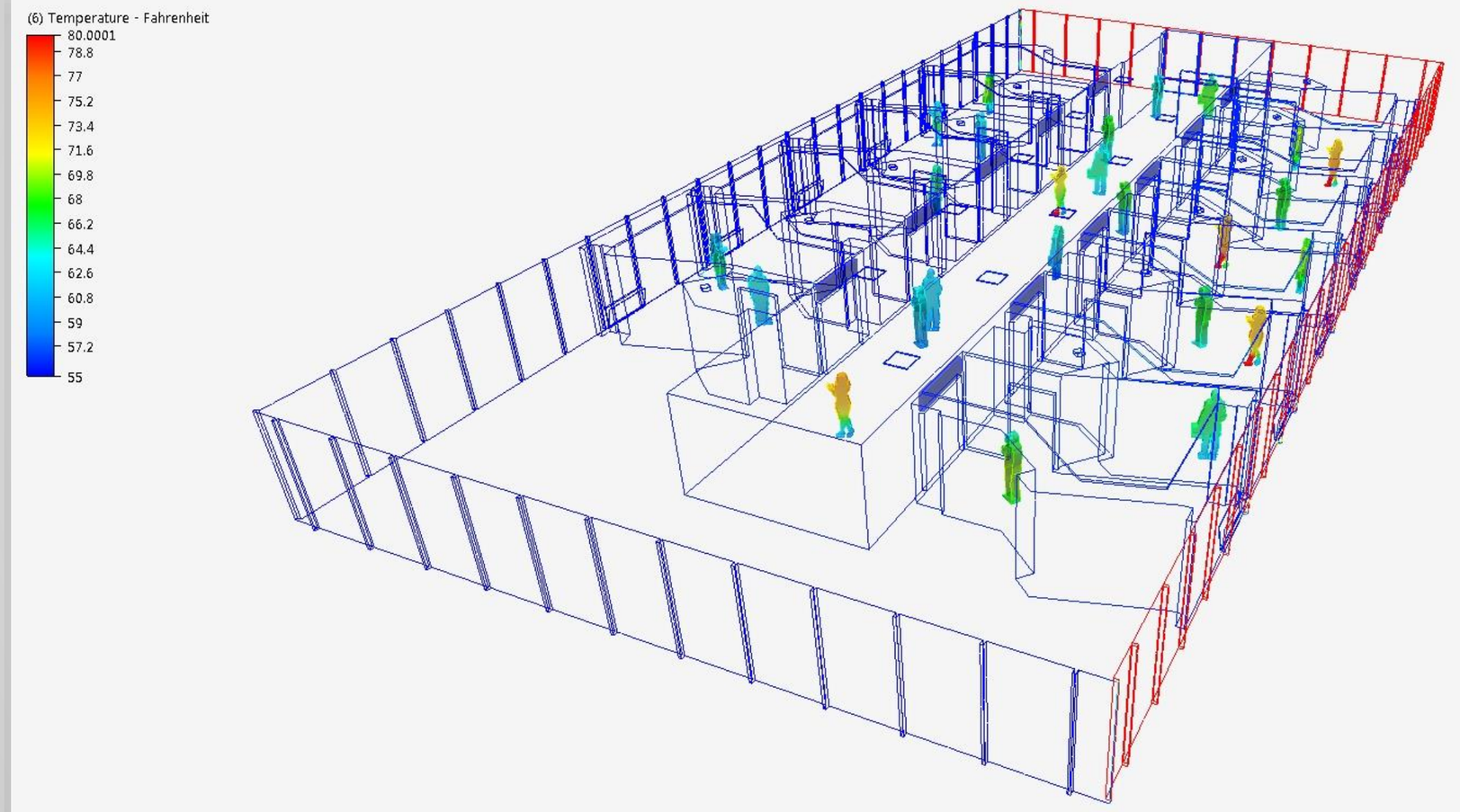
Natural Ventilation – multiple patient rooms

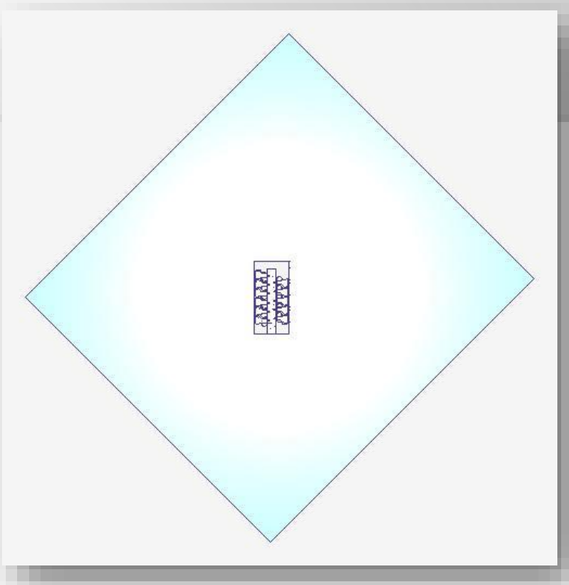
- Is natural ventilation a possible strategy for hospital room design?
- What is the right mix of mechanical supply and return coupled with natural ventilation?
- Can Natural Ventilation solutions serve Medical/Surgical bed units with a narrow core?
- Under what outdoor air conditions can the windows be opened and achieve thermally comfortable conditions, with code required and safe airflow outcomes?

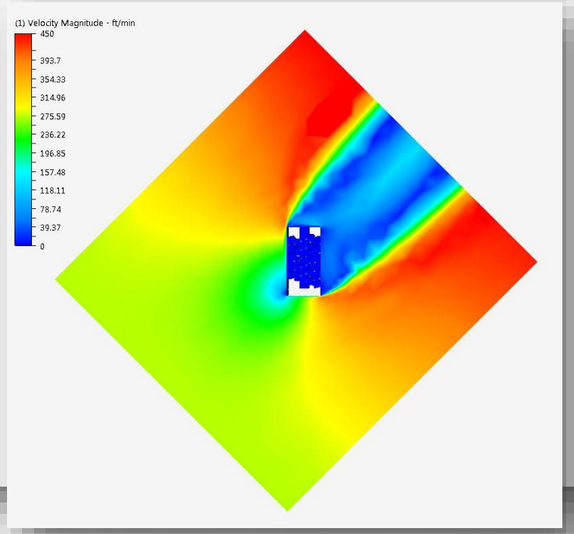
Natural Ventilation – multiple patient rooms

- Strategy: Model an entire patient wing of a hospital. This includes 13 patient rooms, the connecting corridor, the exterior skin, operable windows for each patient room and exterior end of the corridor. Patient room and corridor are connected via a transom (considered open) Mechanical returns are also located in the corridor.
- Model an representative “air domain” which surrounds the entire patient room, corridor, exterior shell.
- Introduce air flow velocity at the boundary edge of the air domain.
- Test multiple conditions varying
  - Air flow speed
  - Air Temp
  - Mechanical return rate
  - Both leeward and windward sides of the model

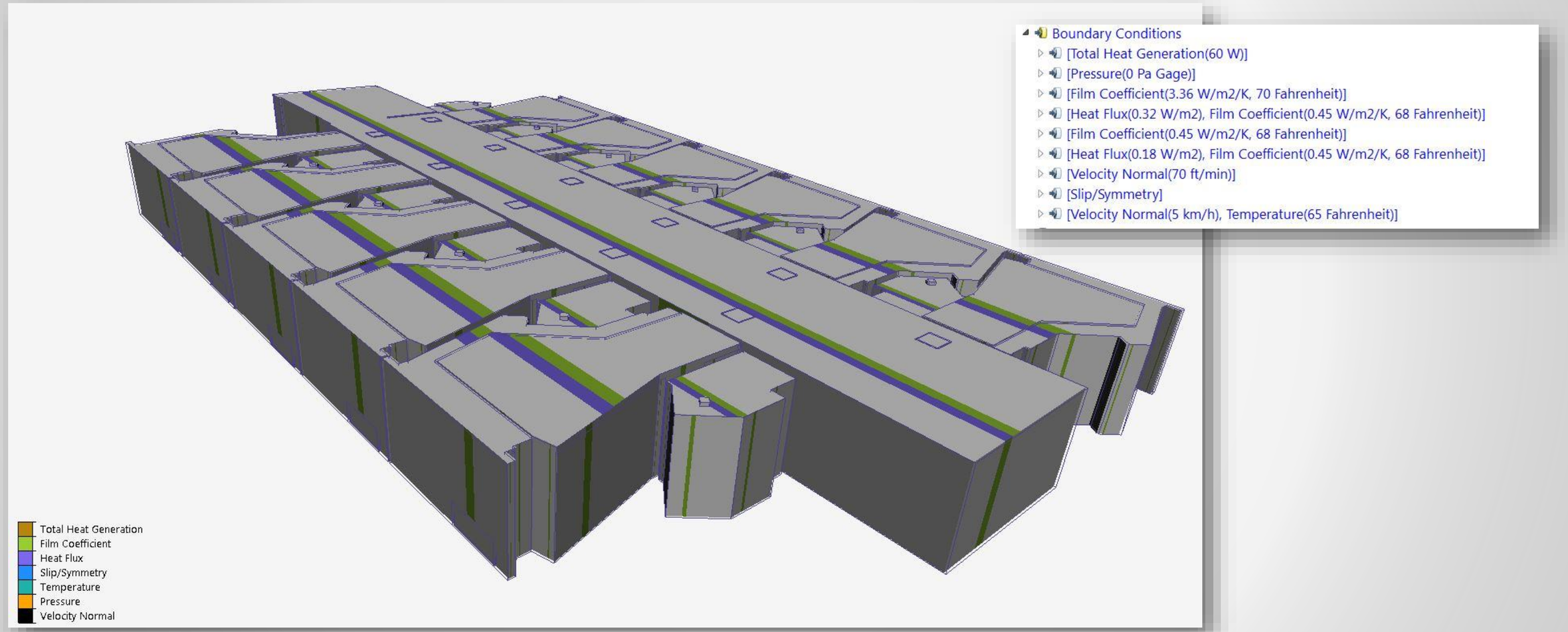
Natural Ventilation – multiple patient rooms - Model



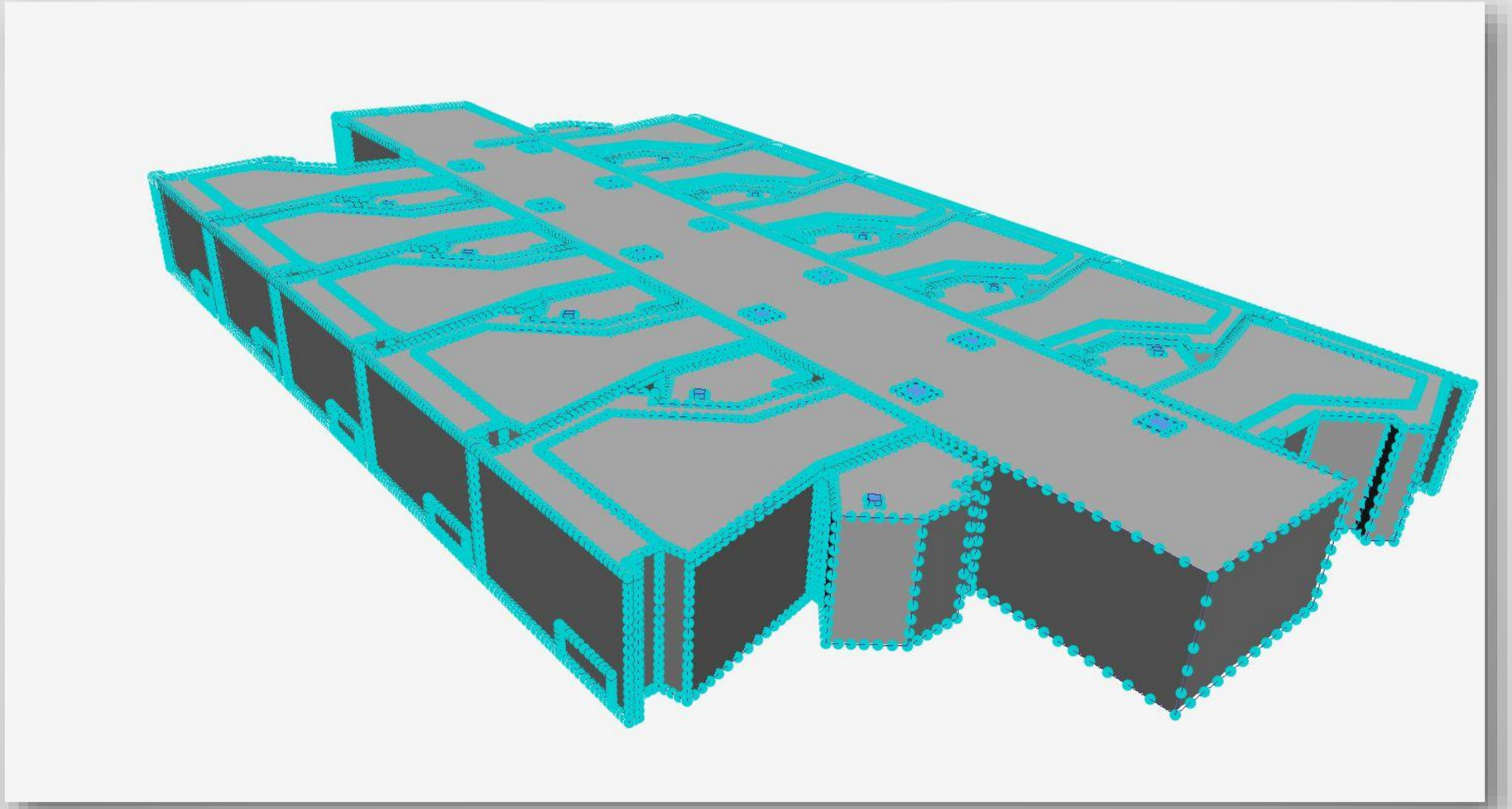




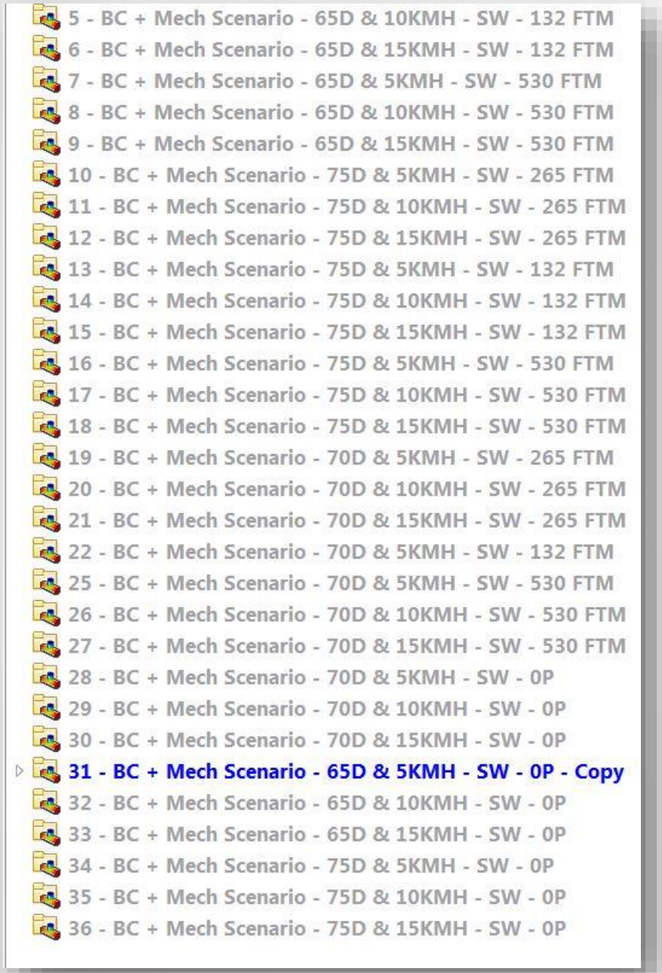
Natural Ventilation – multiple patient rooms - BCs



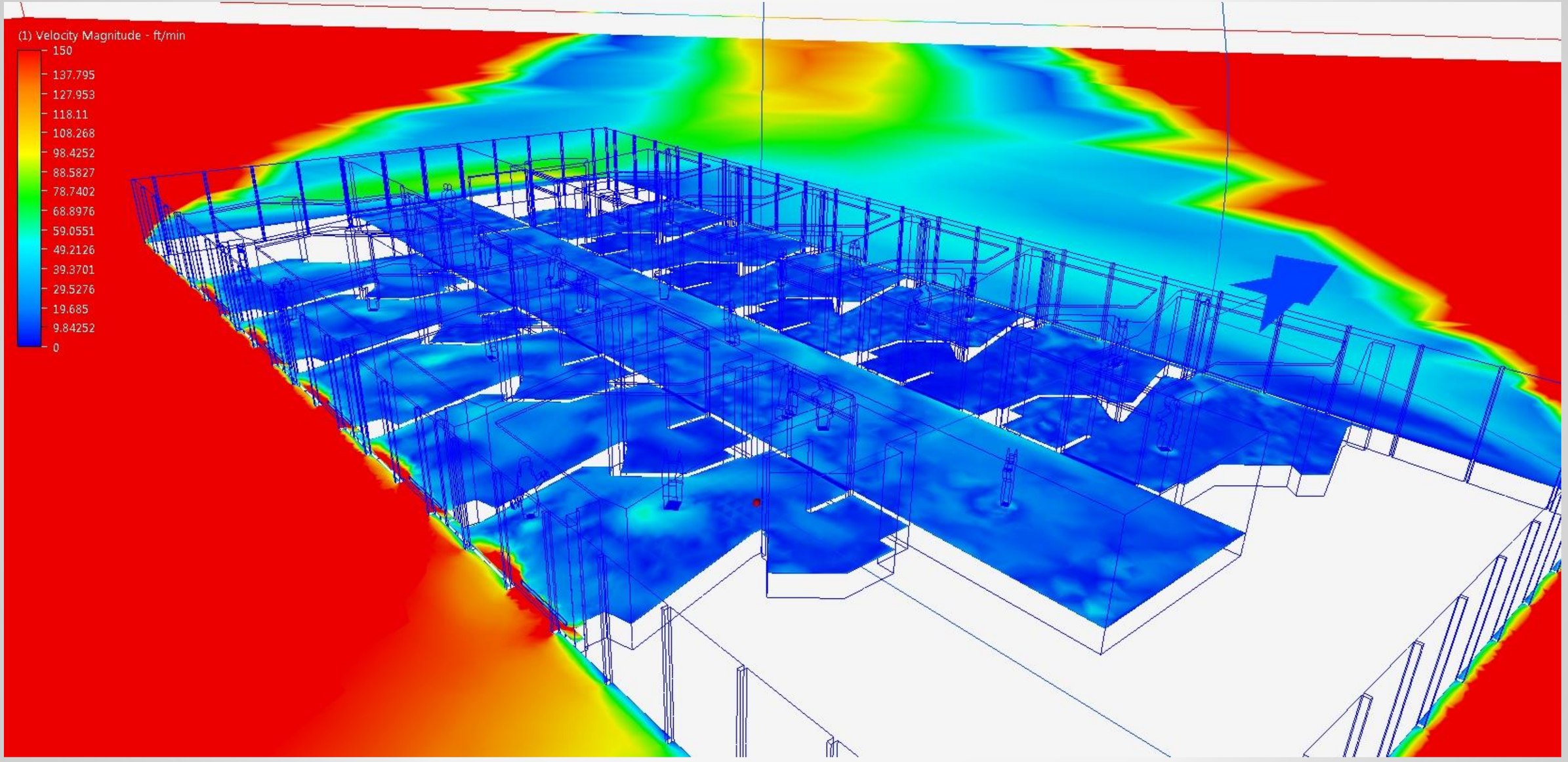
Natural Ventilation – multiple patient rooms - Mesh



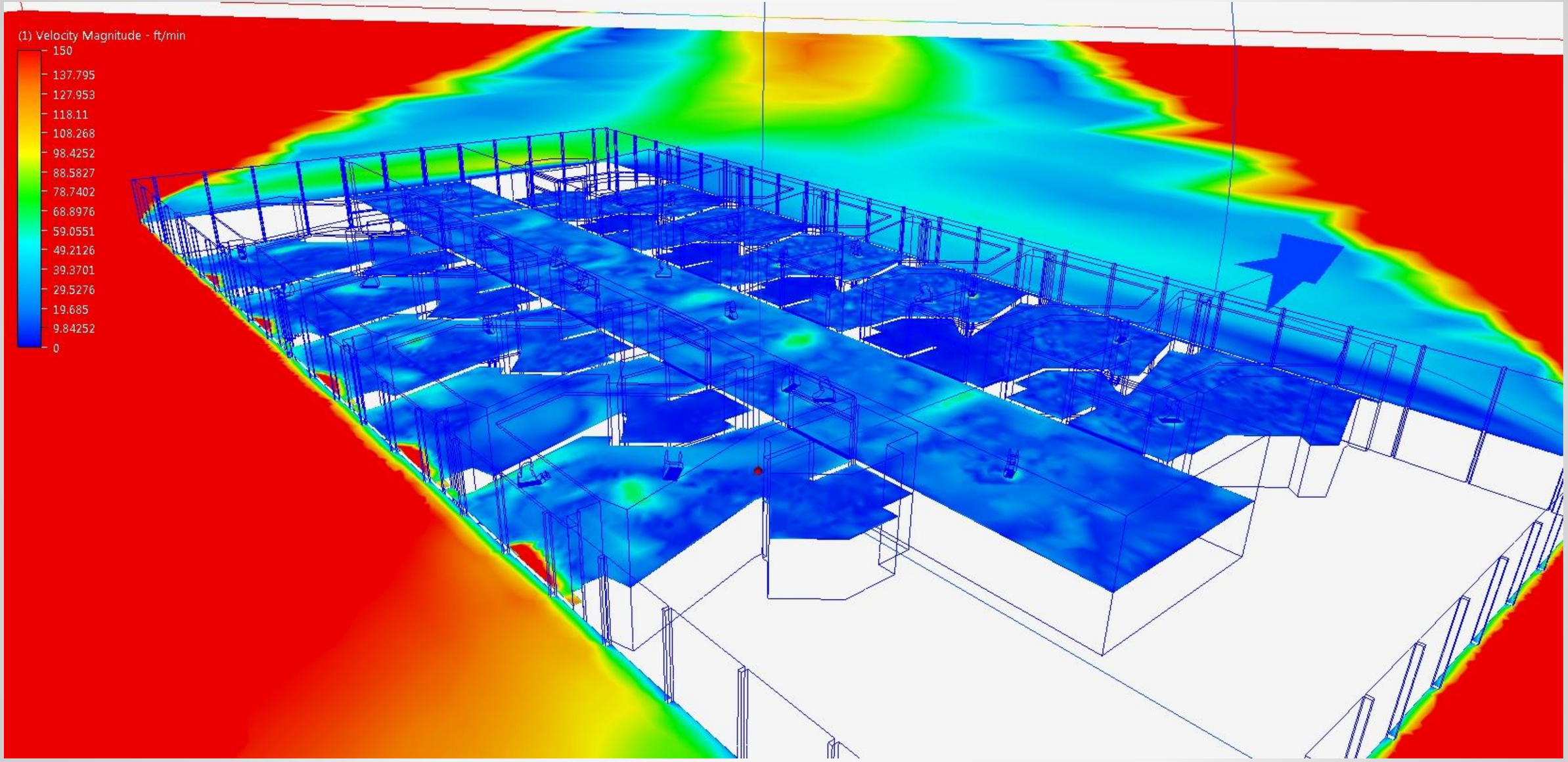
Natural Ventilation – multiple patient rooms - Setup



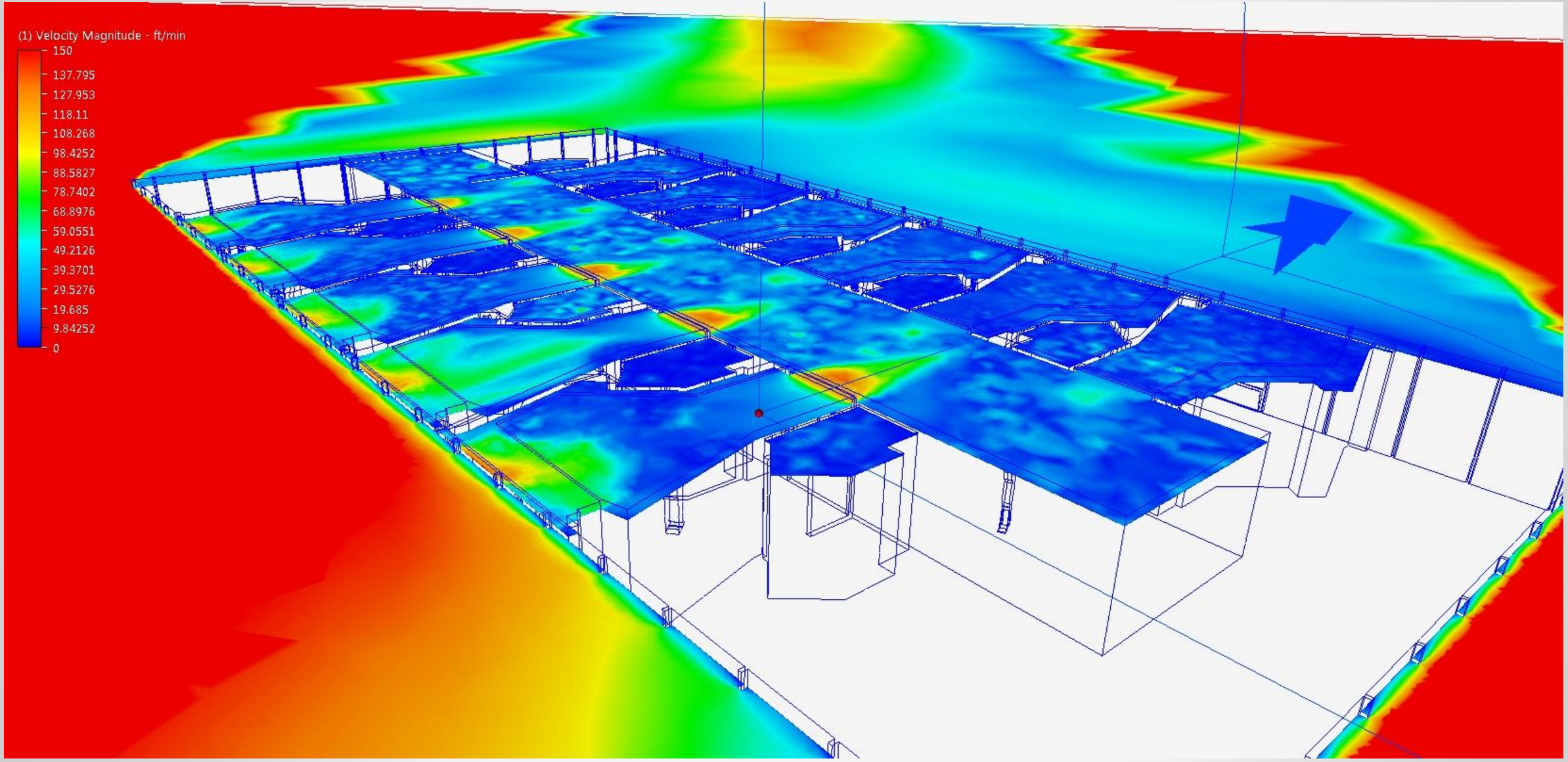
Natural Ventilation – multiple patient rooms - Results



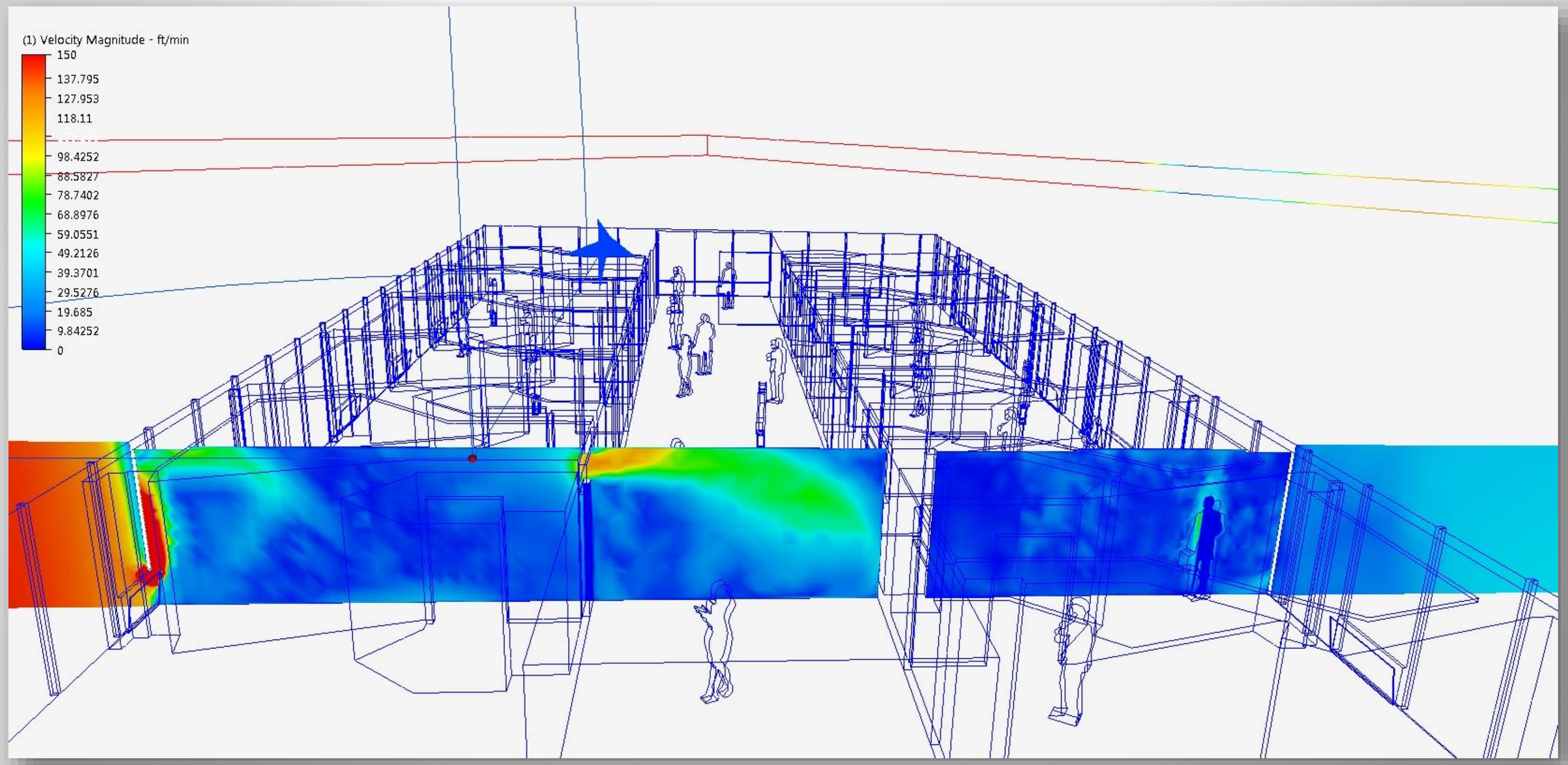
Natural Ventilation – multiple patient rooms - Results



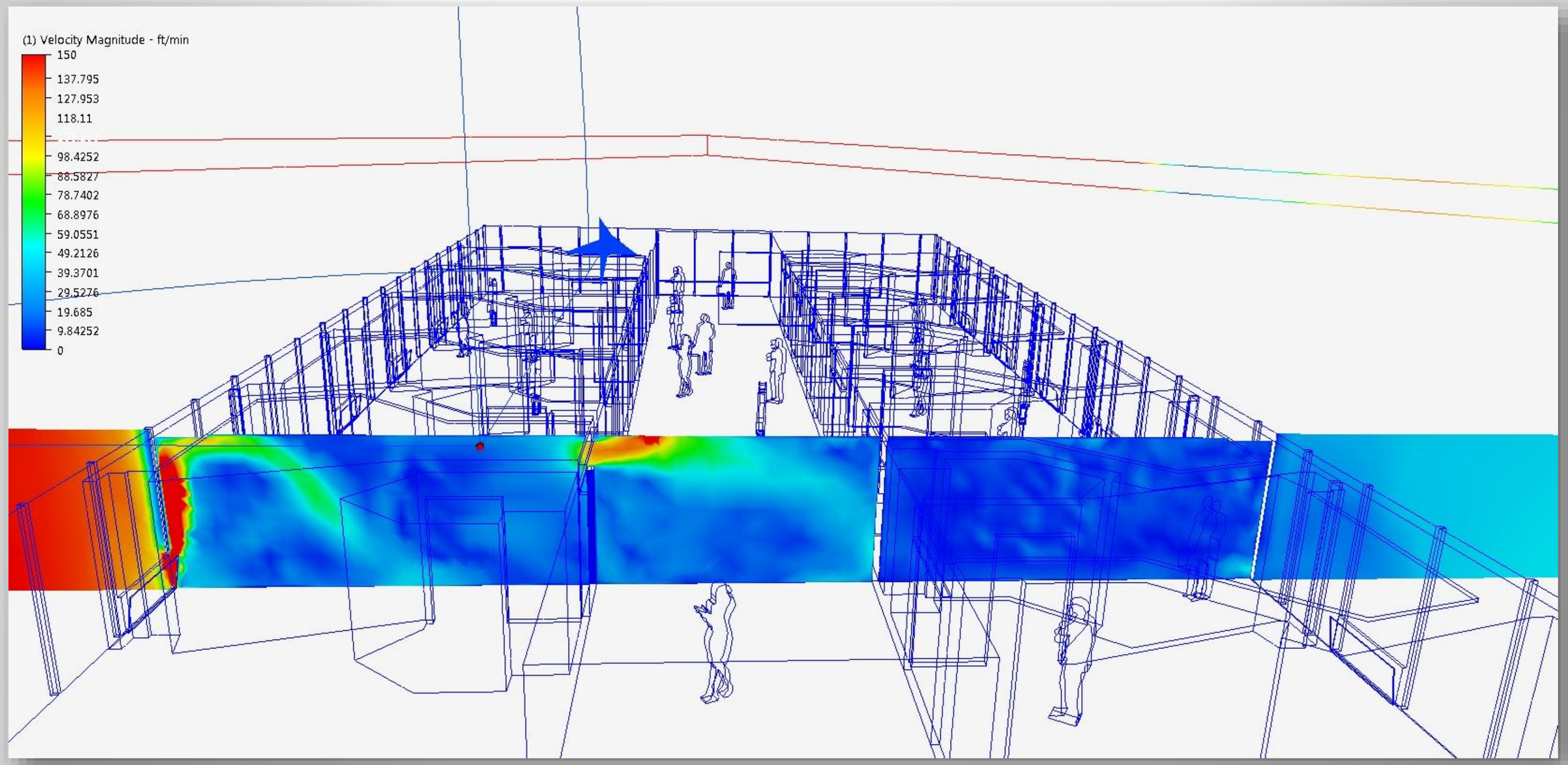
Natural Ventilation – multiple patient rooms - Results



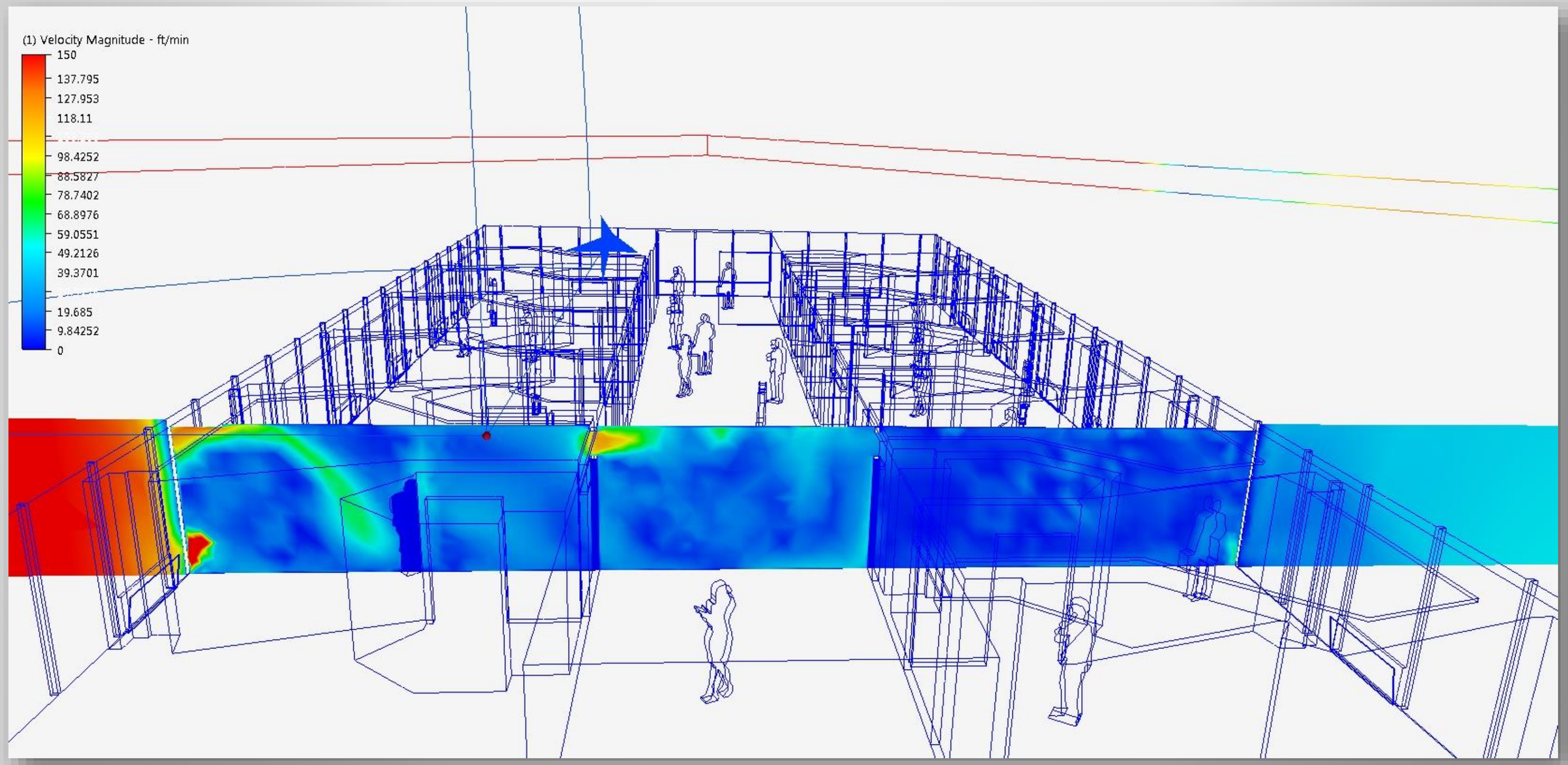
Natural Ventilation – multiple patient rooms - Results



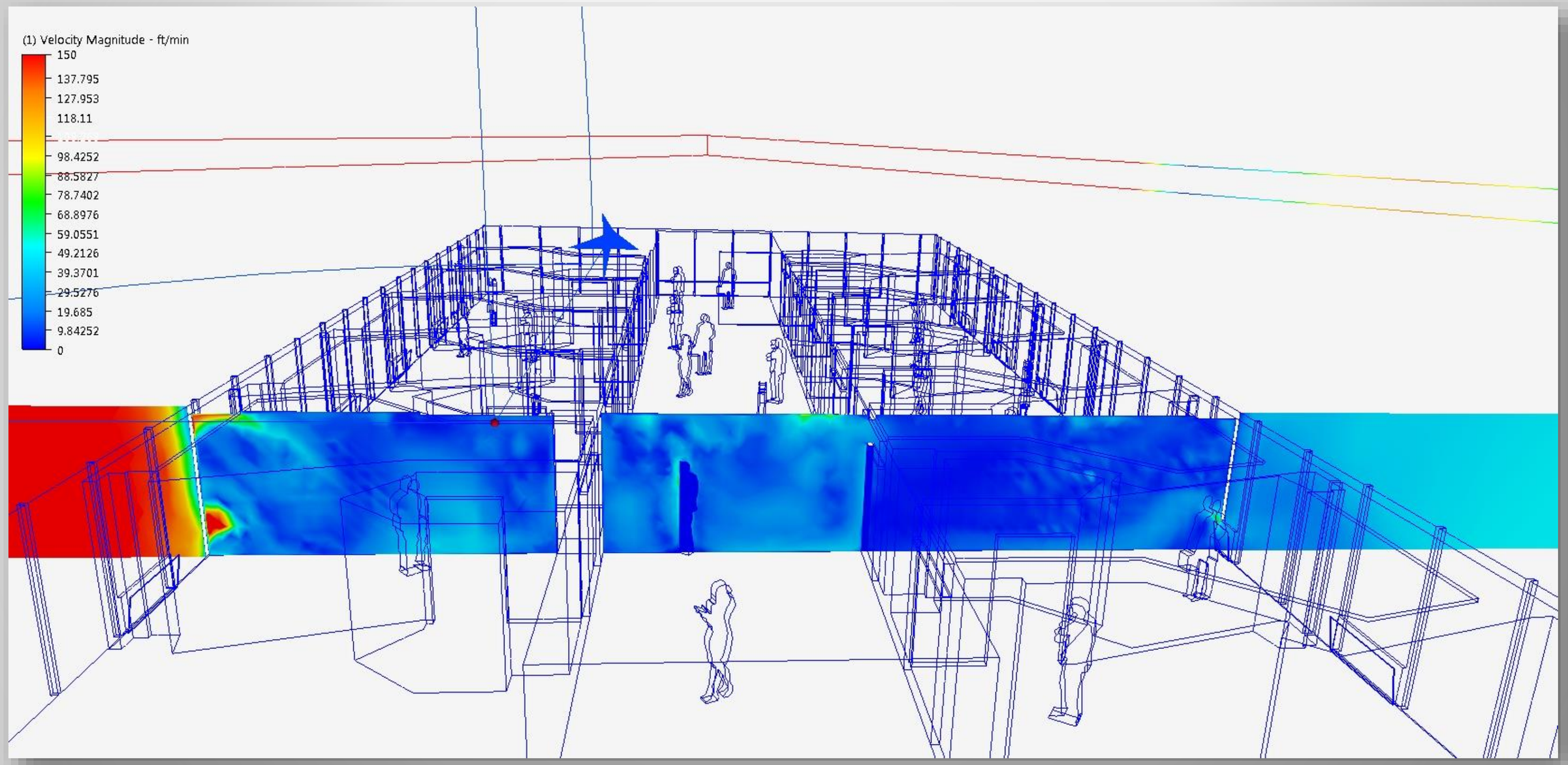
Natural Ventilation – multiple patient rooms - Results



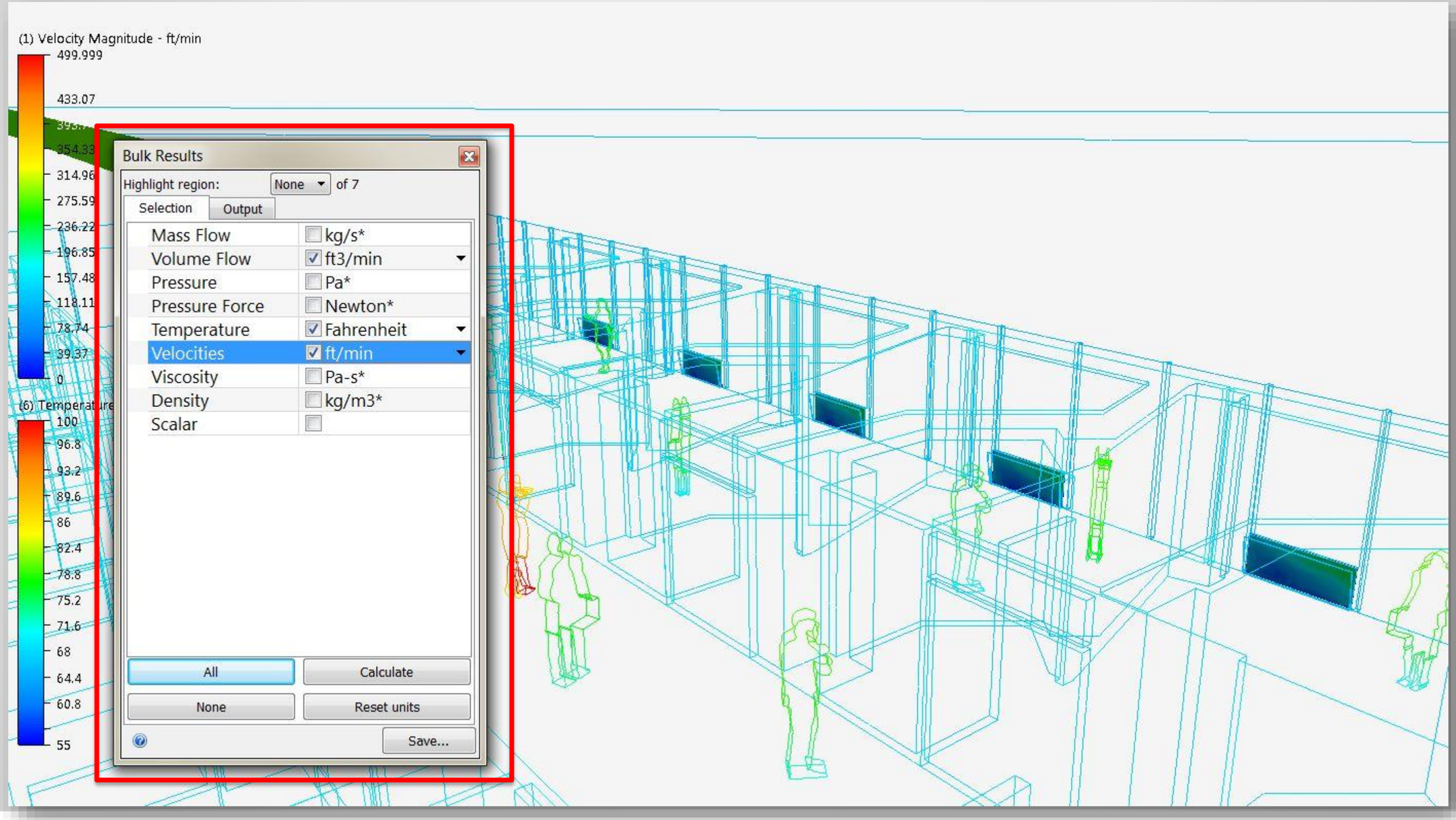
Natural Ventilation – multiple patient rooms - Results



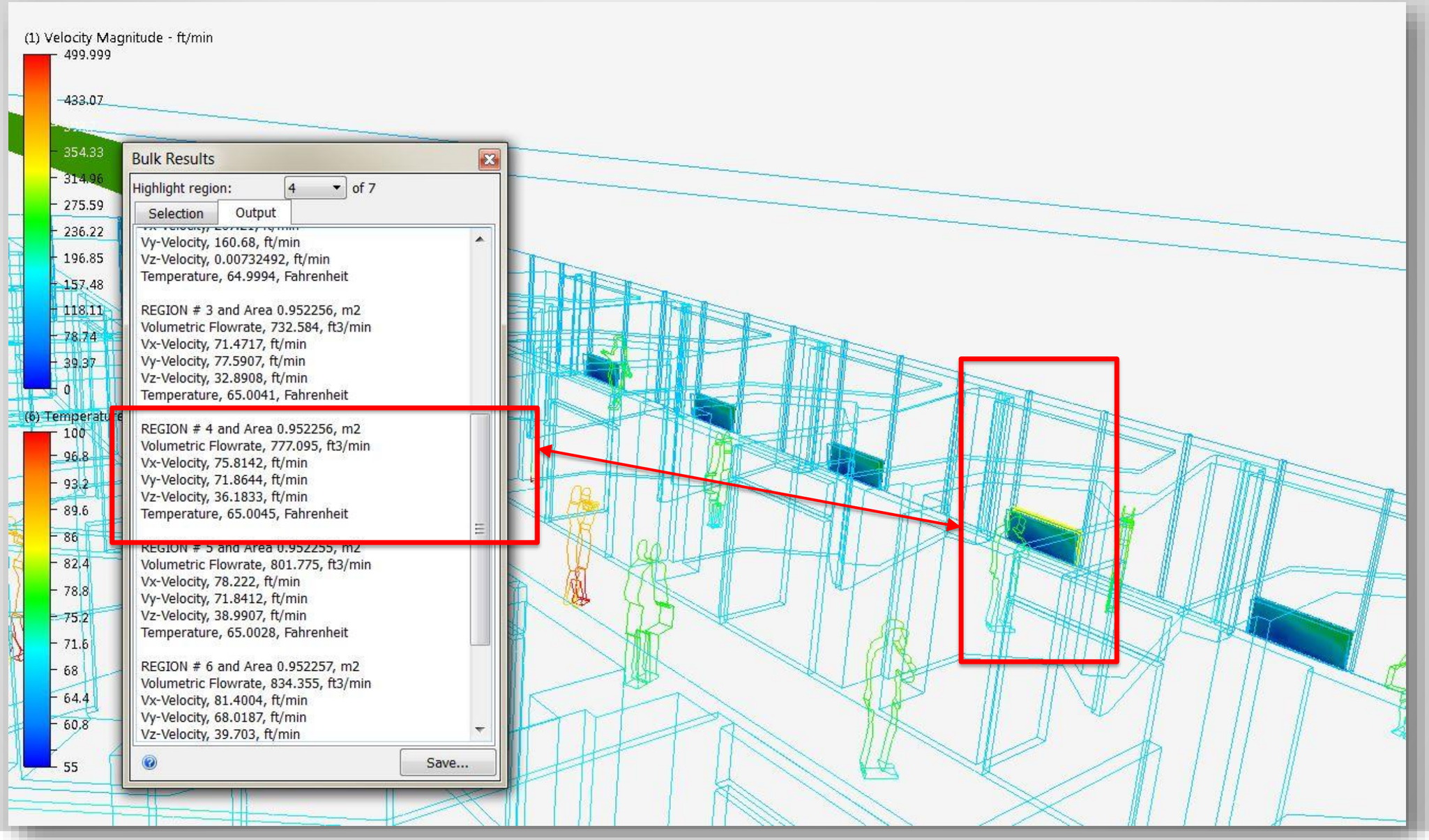
Natural Ventilation – multiple patient rooms - Results



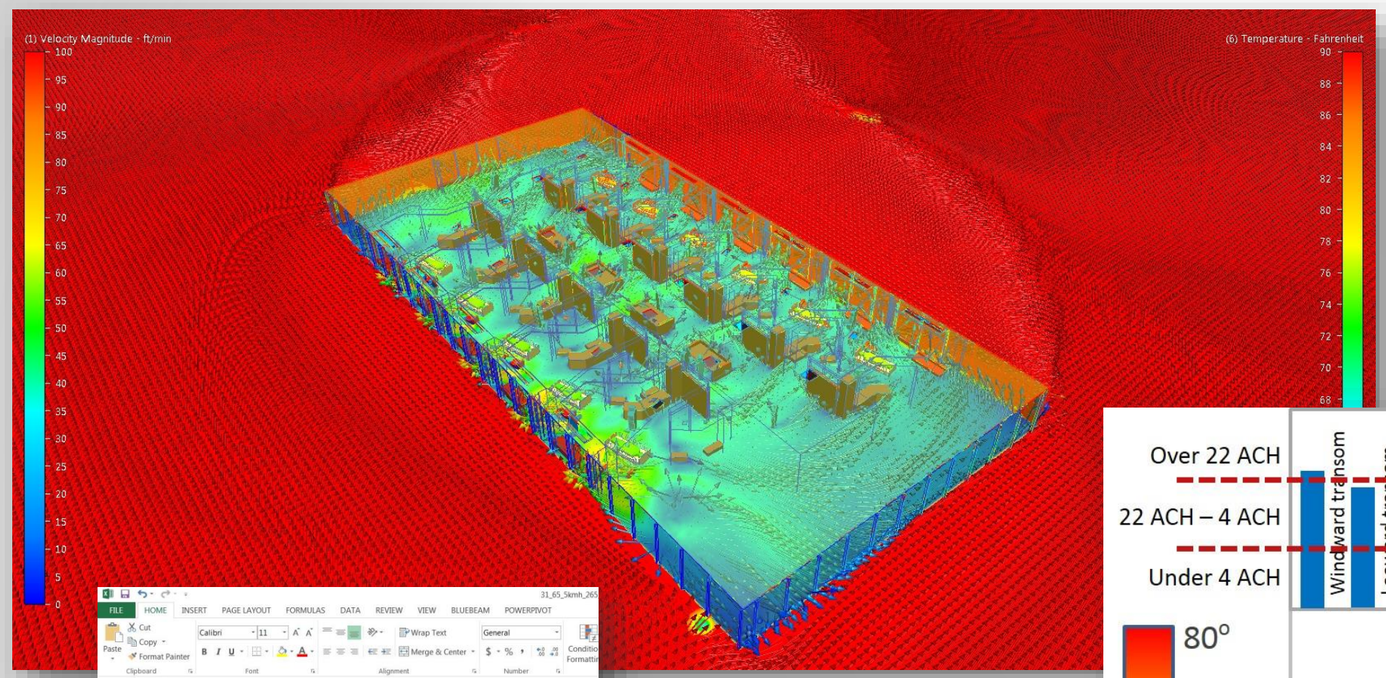
Natural Ventilation – multiple patient rooms - Method

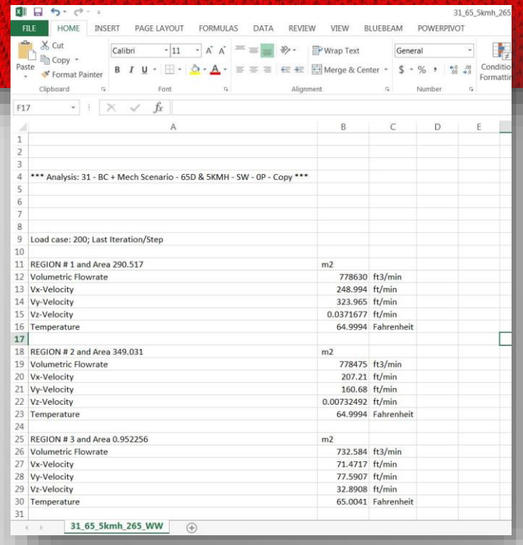


Natural Ventilation – multiple patient rooms - Method

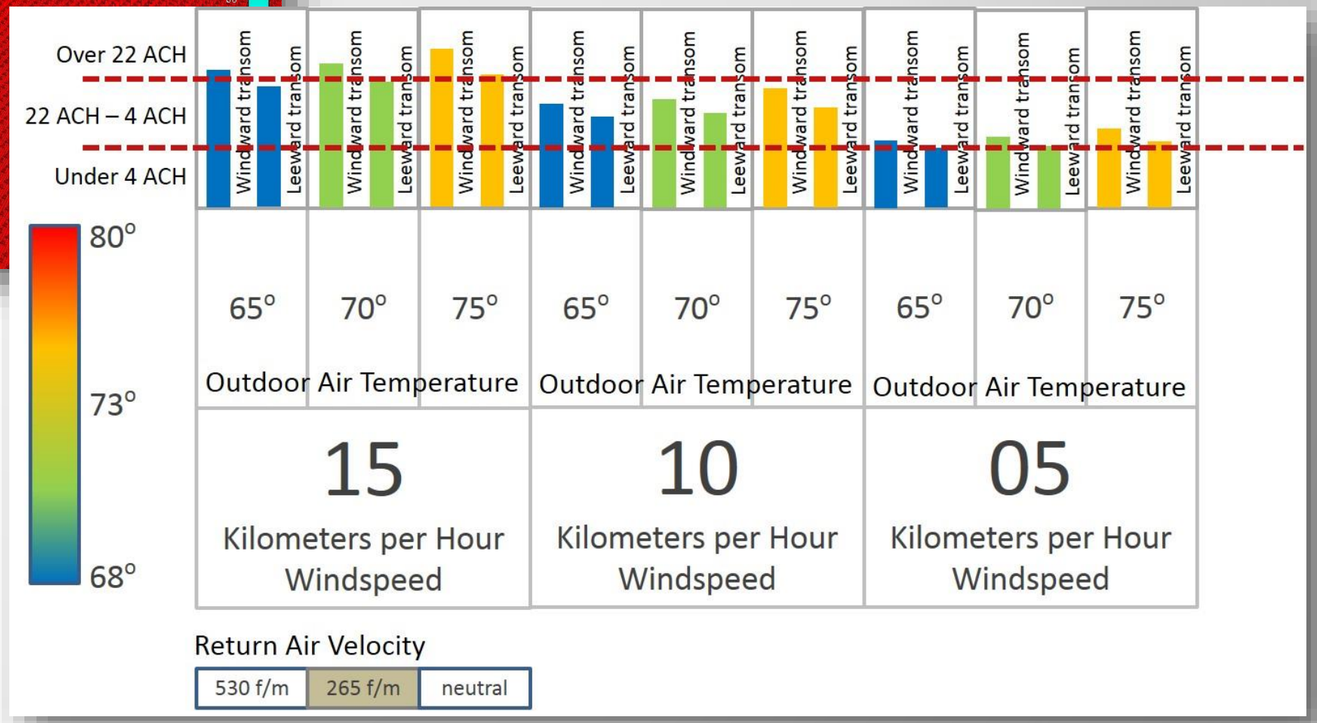


Natural Ventilation – multiple patient rooms - Method





*** Analysis: 31 - BC + Mech Scenario - 65D & 5KMH - SW - 0P - Copy ***	
Load case: 200; Last Iteration/Step	
REGION # 1 and Area 290.517	m2
Volumetric Flowrate	778630 ft3/min
Vx-Velocity	248.994 ft/min
Vy-Velocity	323.965 ft/min
Vz-Velocity	0.0371677 ft/min
Temperature	64.9994 Fahrenheit
REGION # 2 and Area 349.031	m2
Volumetric Flowrate	778475 ft3/min
Vx-Velocity	207.21 ft/min
Vy-Velocity	160.68 ft/min
Vz-Velocity	0.00732492 ft/min
Temperature	64.9994 Fahrenheit
REGION # 3 and Area 0.952256	m2
Volumetric Flowrate	732.584 ft3/min
Vx-Velocity	71.4717 ft/min
Vy-Velocity	77.5907 ft/min
Vz-Velocity	32.8908 ft/min
Temperature	65.0041 Fahrenheit



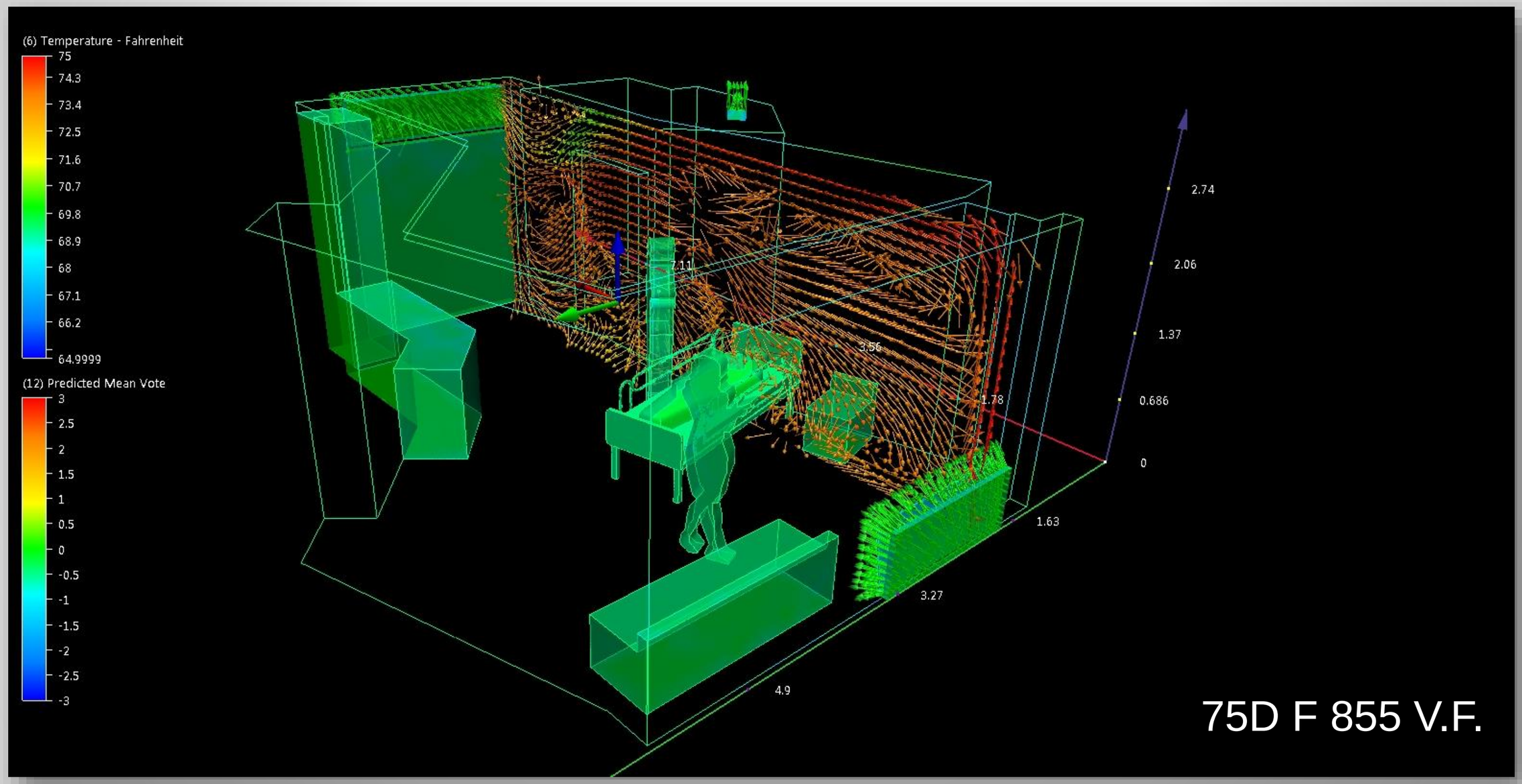
Natural Ventilation – multiple patient rooms - Results

- Natural Ventilation is possible
- The model is too cumbersome currently
- Need to re-purpose data to another model
- Bulks can be used to gather needed data
- Bulk results used as BC variables in new model
- PMV works but can’t be run on this model, new model should allow for PMV analysis

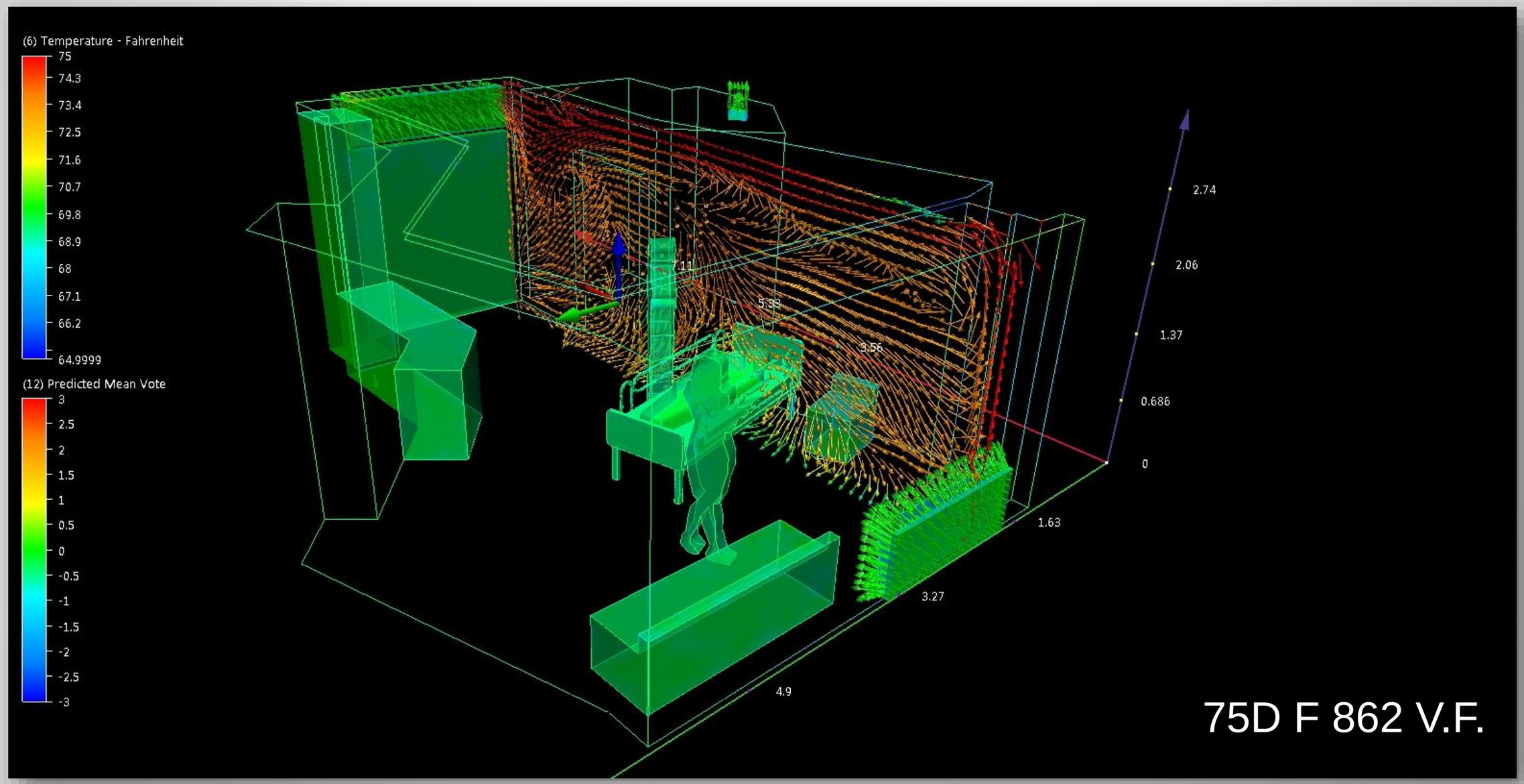
Natural Ventilation – Multiple Patient Rooms – Single Room Studies

- 4 solutions were selected from the bulk data of the previous 36 scenarios (1:9)
- That data was used as the BC variable for 8 new single patient room studies / scenarios
- Both leeward and windward patient rooms were studied
- The rest of the modeling and setup is consistent with the overall parent model.
- PMV and PPD (percent persons dissatisfied) were used to analyze the results

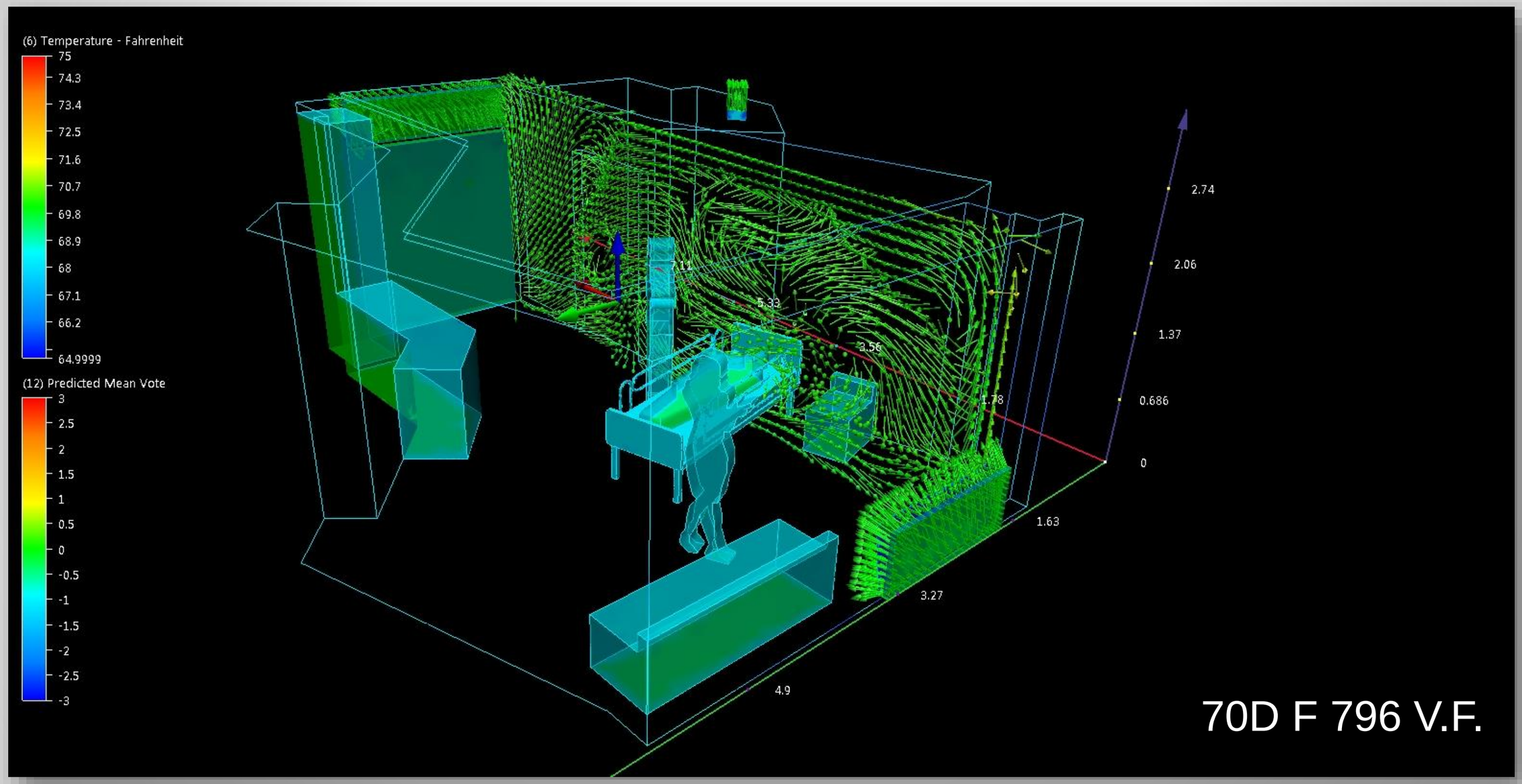
Windward Results - PMV



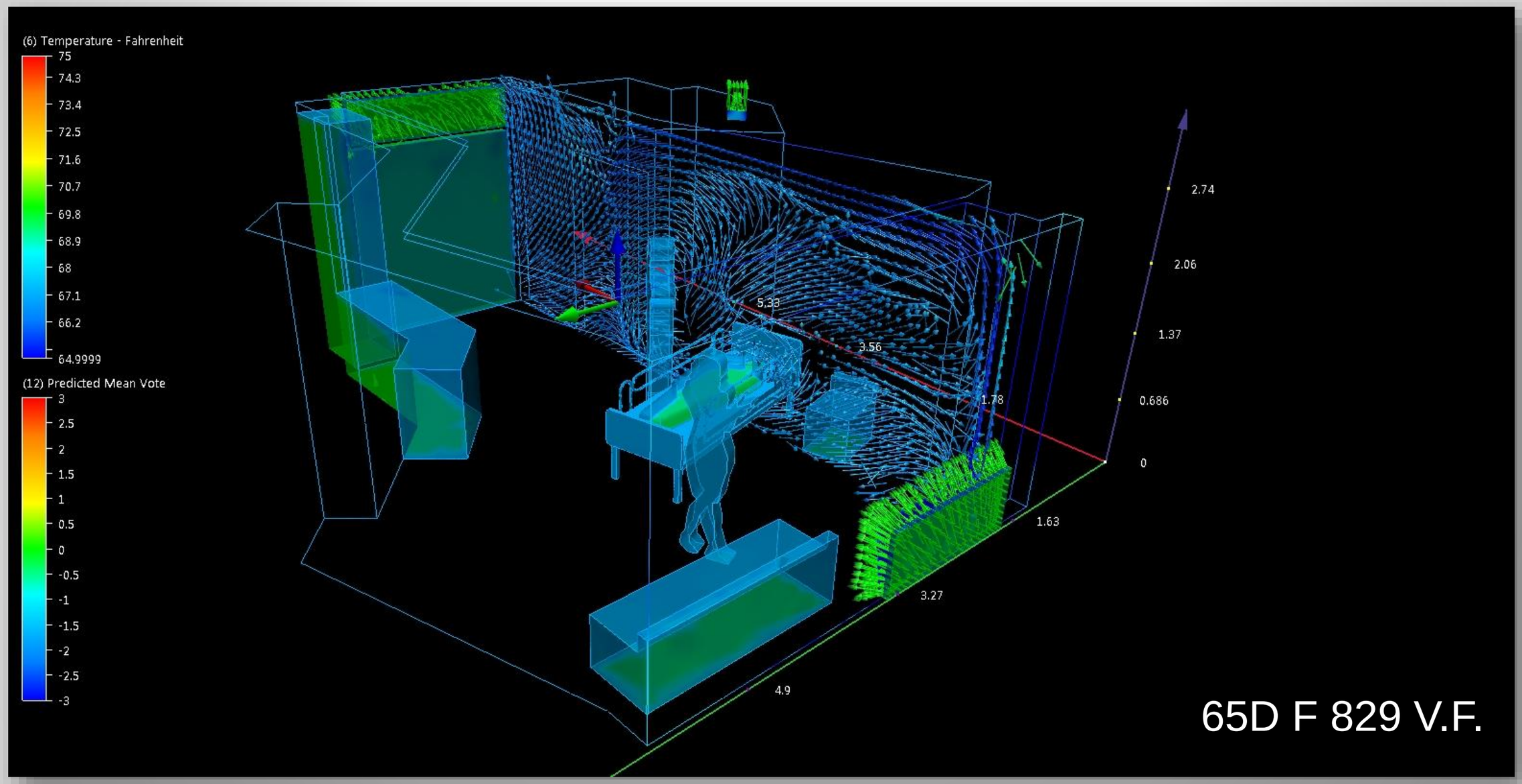
Windward Results - PMV



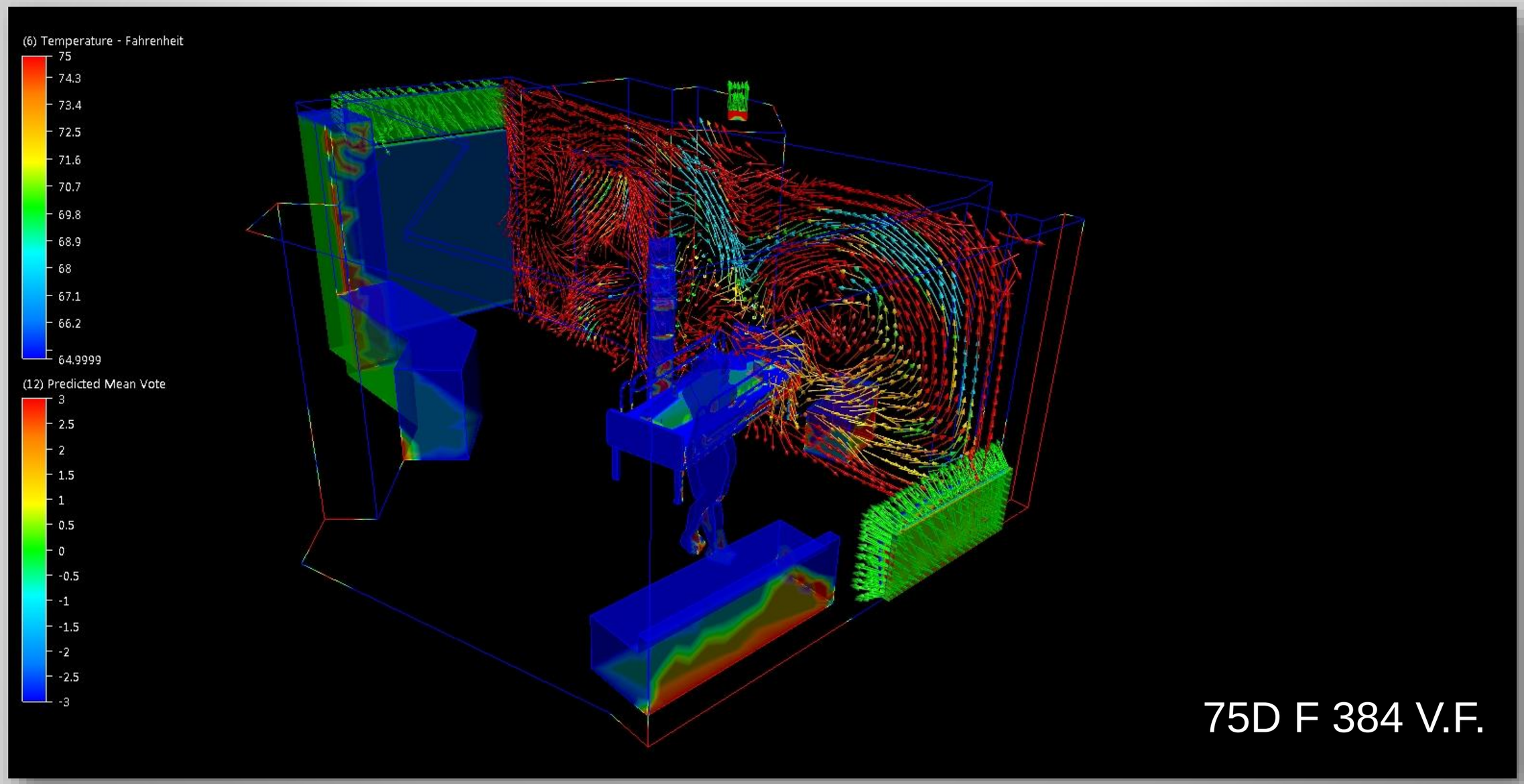
Windward Results - PMV



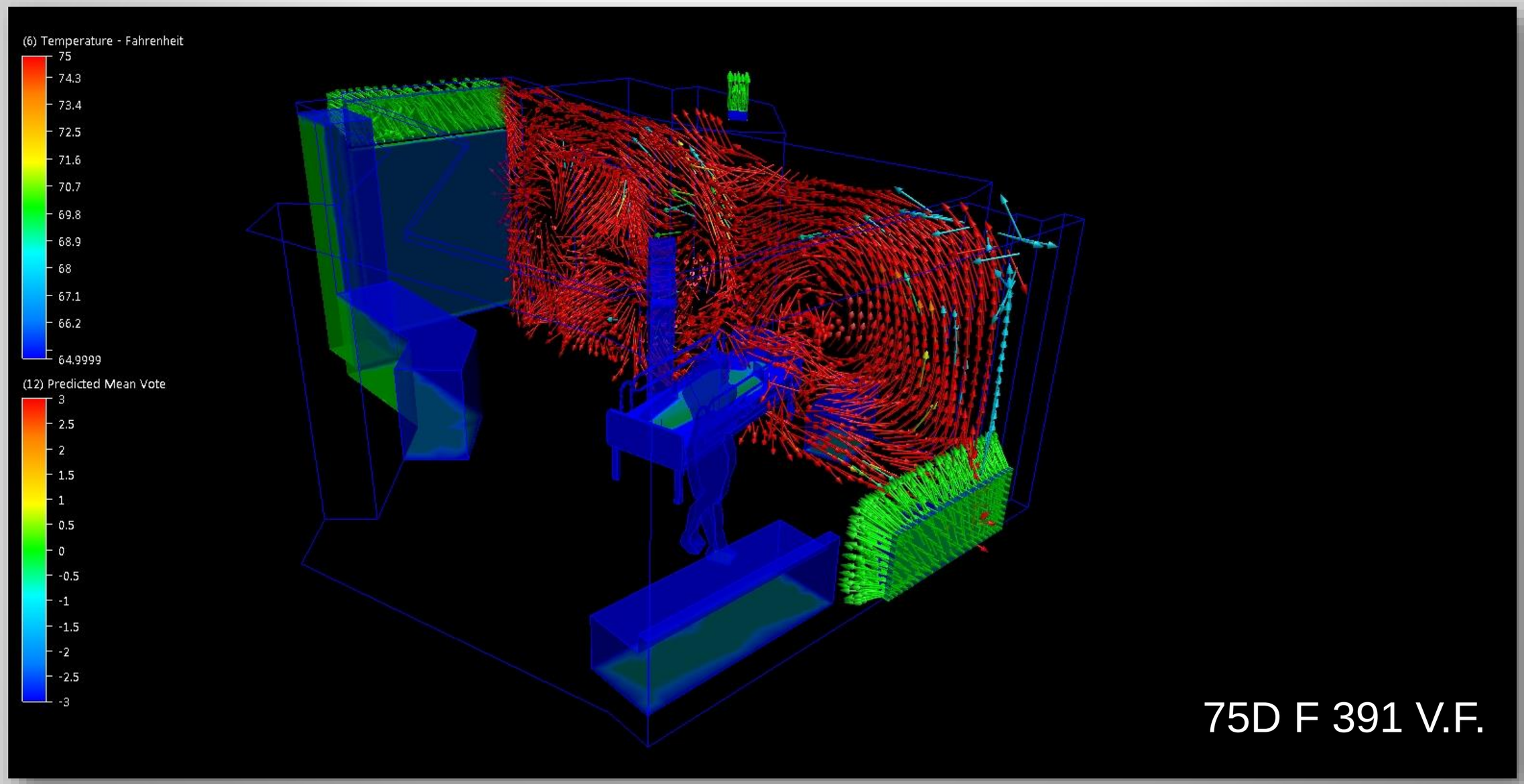
Windward Results - PMV



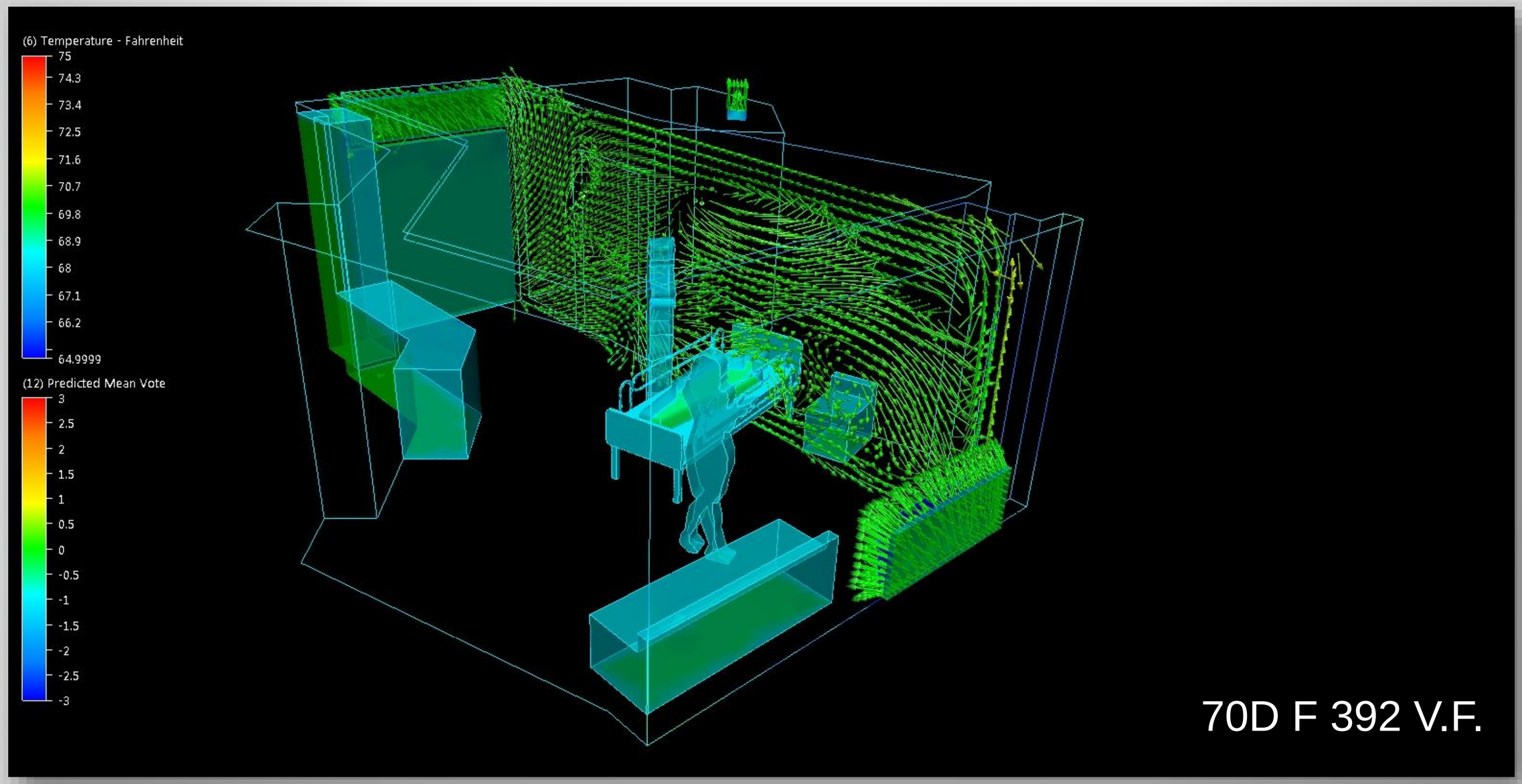
Leeward Results - PMV



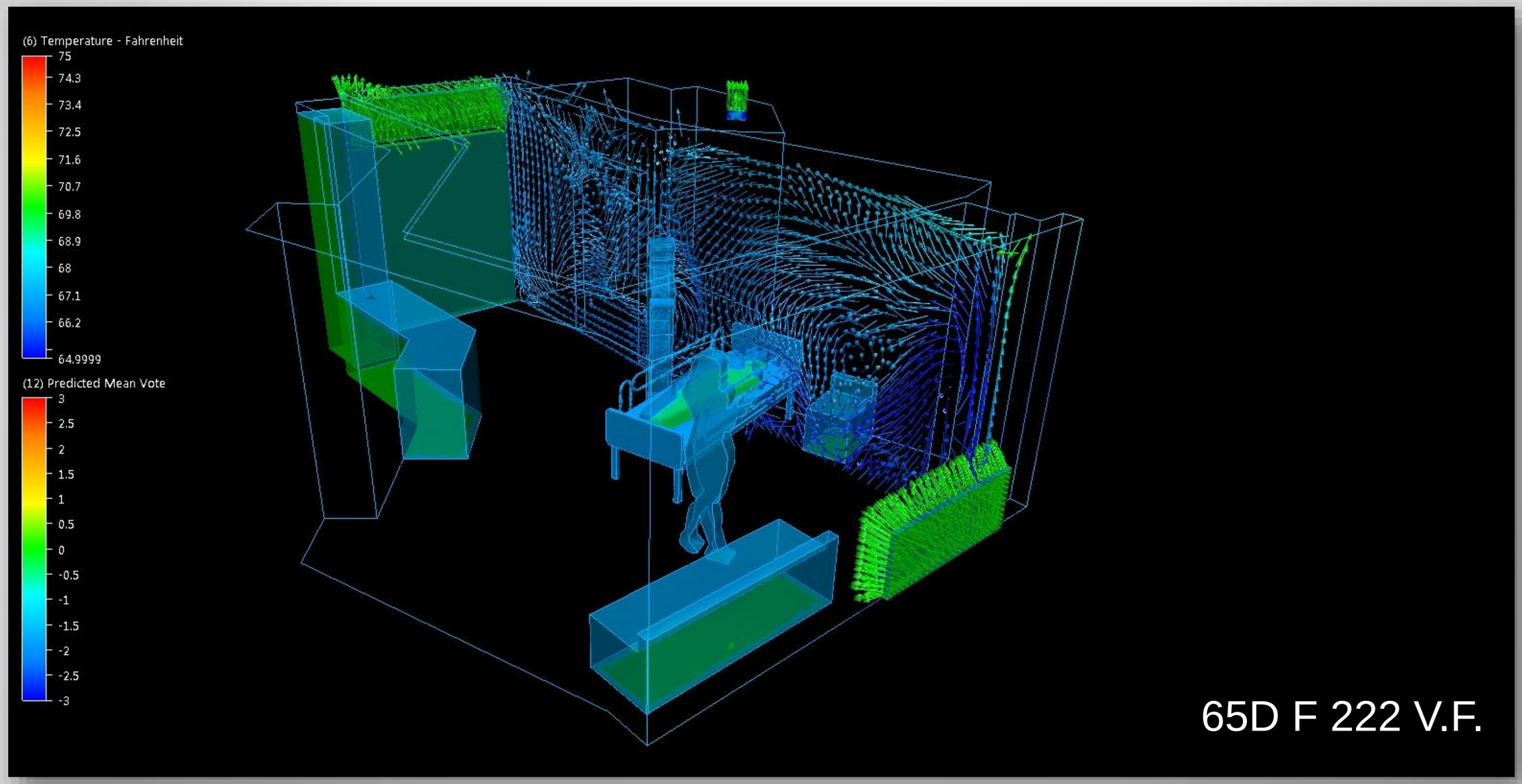
Leeward Results - PMV



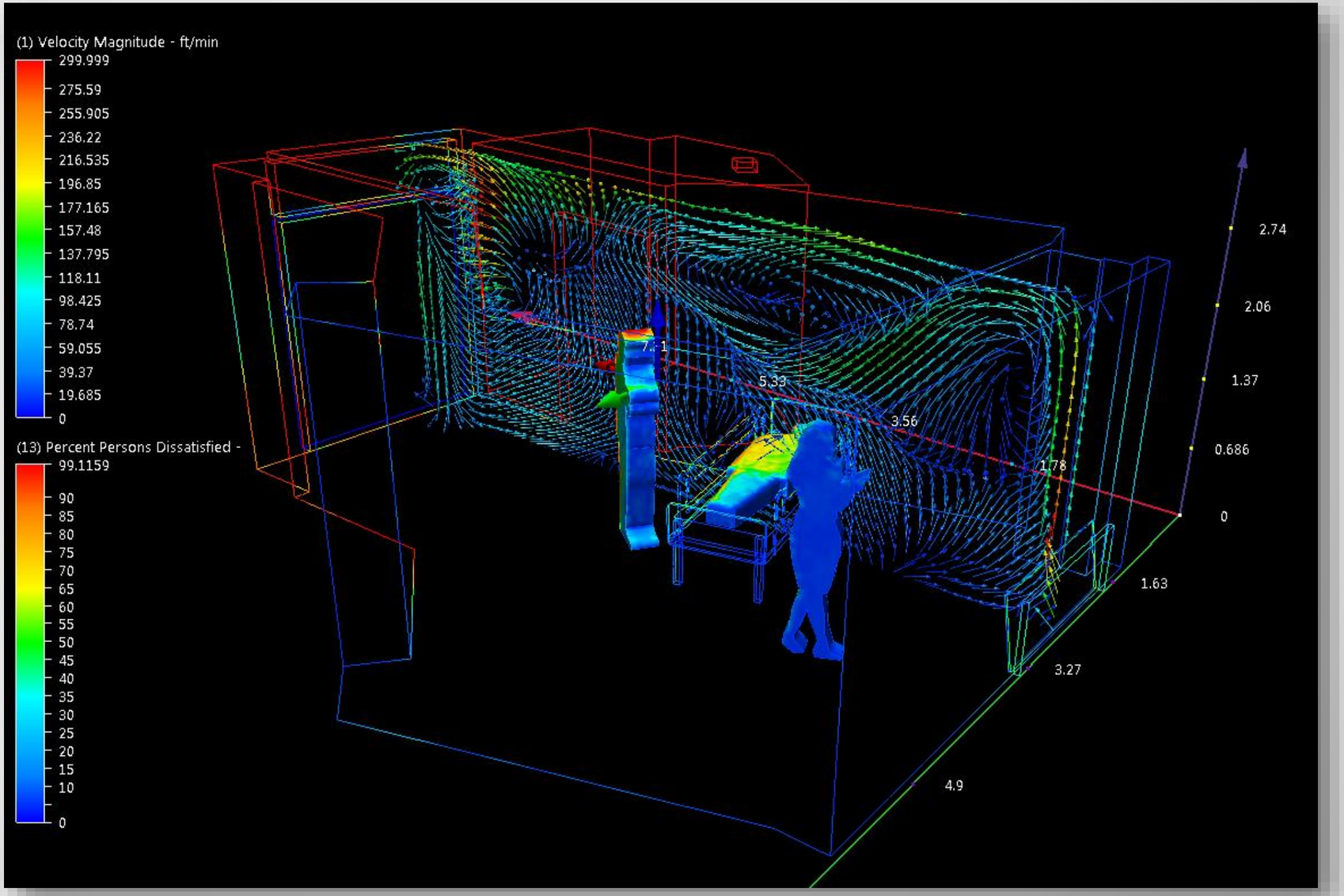
Leeward Results - PMV



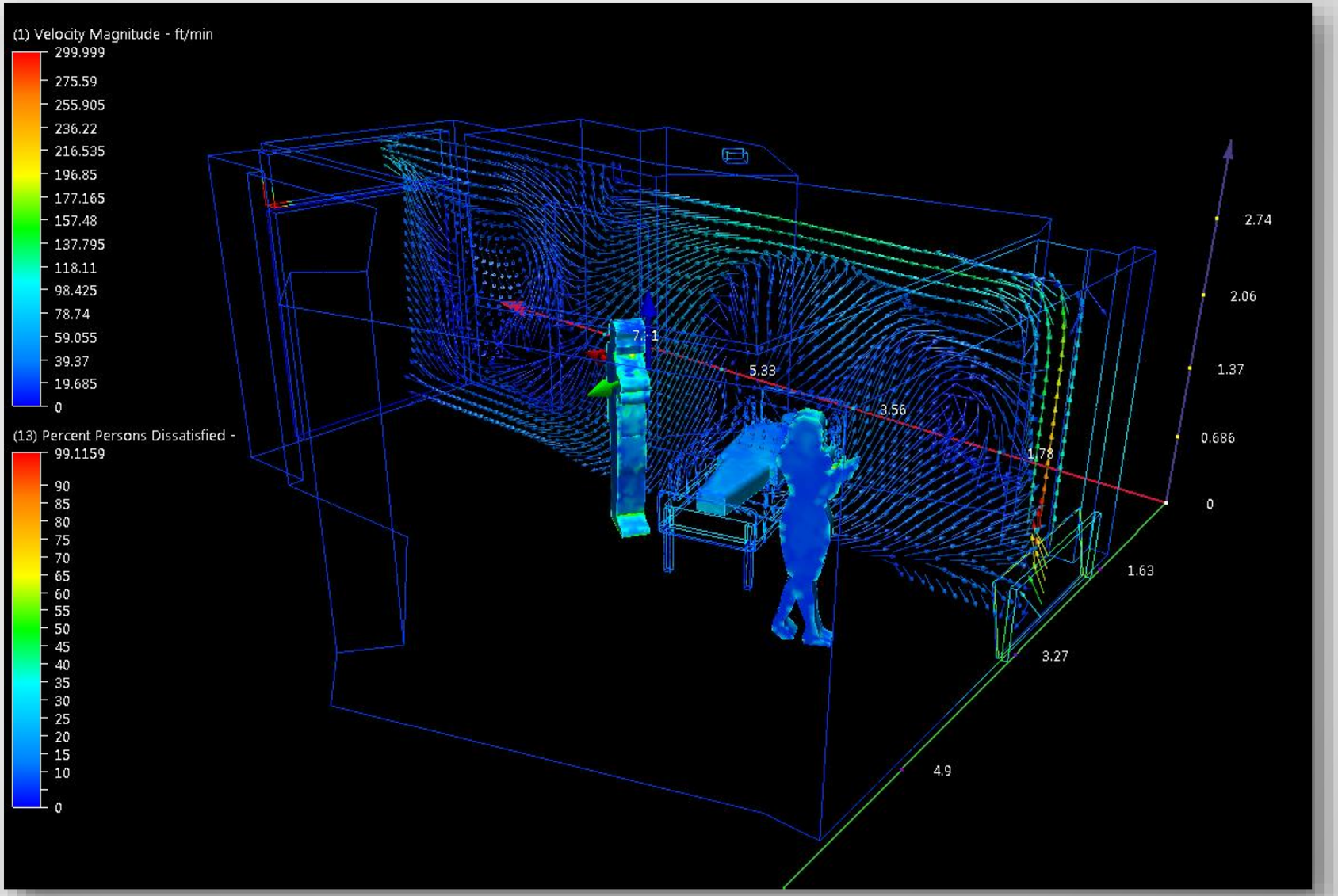
Leeward Results - PMV



Results - PPD


(1) Velocity Magnitude - ft/min
299.999
275.59
255.905
236.22
216.535
196.85
177.165
157.48
137.795
118.11
98.425
78.74
59.055
39.37
19.685
0
(13) Percent Persons Dissatisfied -
99.1159
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
0
7.1
5.33
3.56
1.78
0
1.63
3.27
4.9
2.74
2.06
1.37
0.686
0

Results - PPD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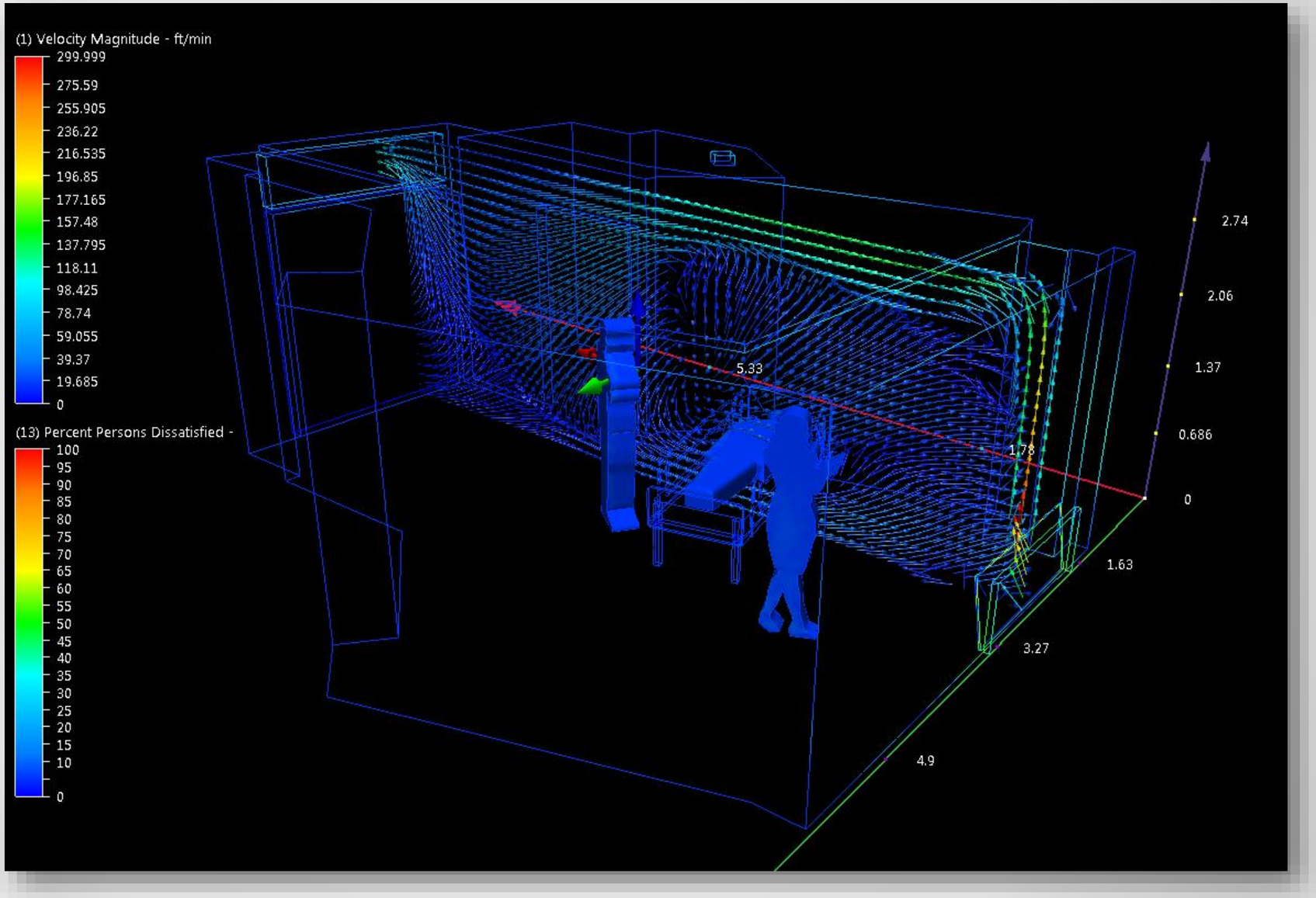
Results - PPD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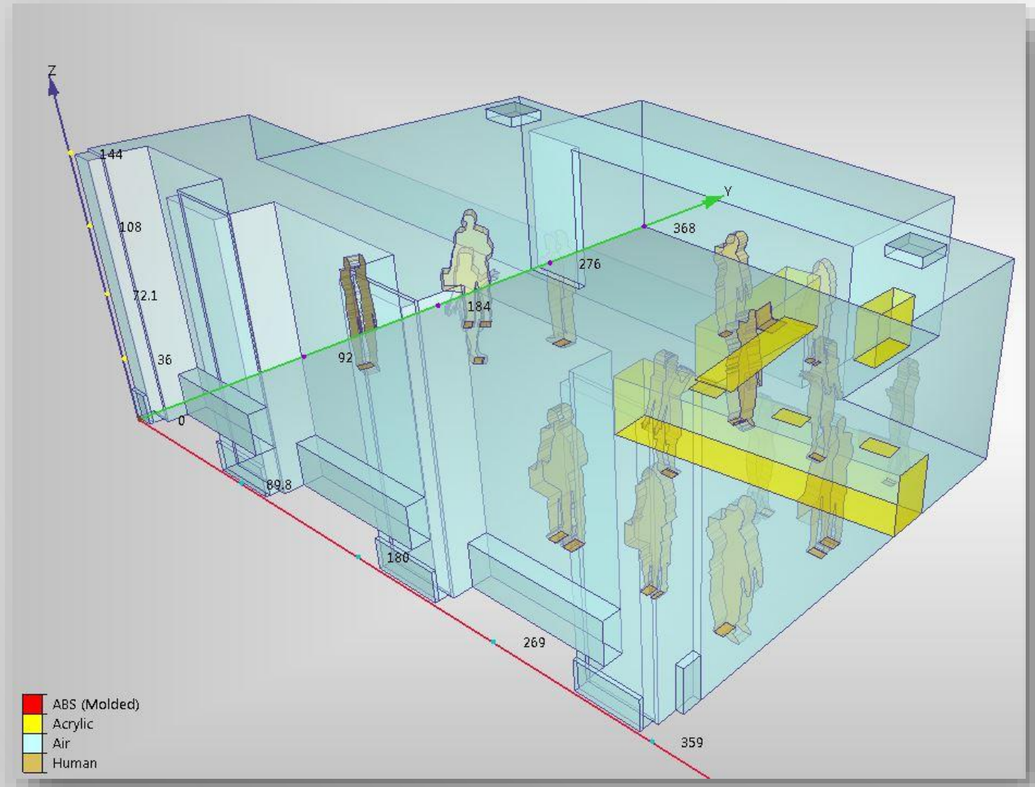
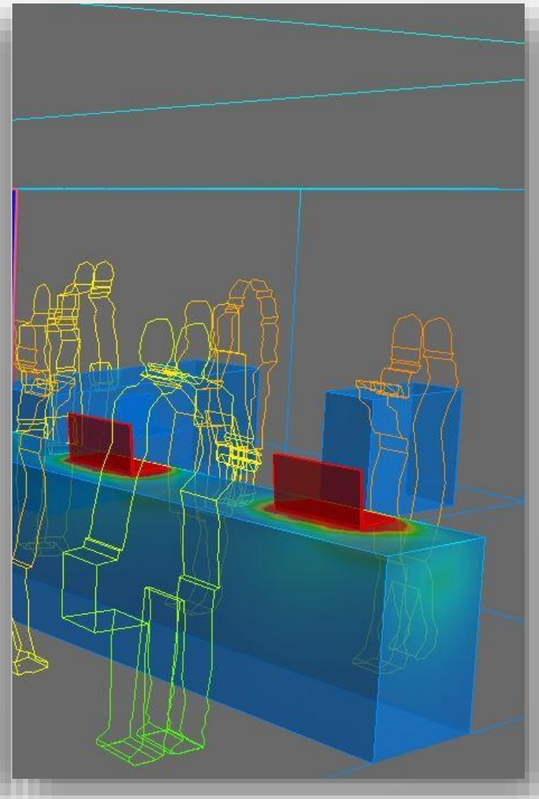
0
5.33
1.78
2.74
2.06
1.37
0.686
0
1.63
3.27
4.9

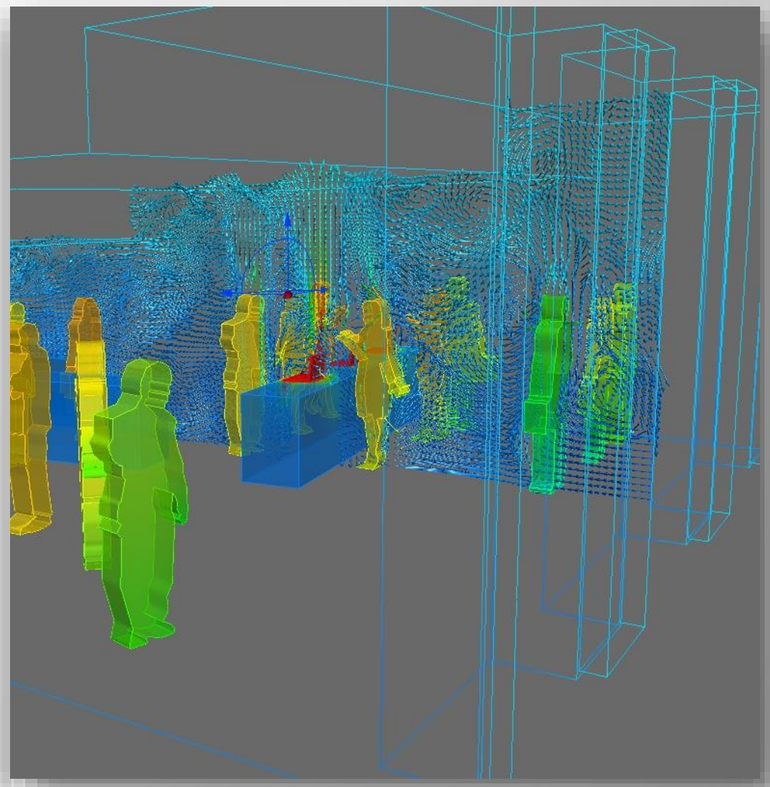
Additional Studies

Other Uses – Displacement Ventilation

- MCH – Low Income / No Budget
- Displacement ventilation as a low energy alternative to traditional heating and cooling

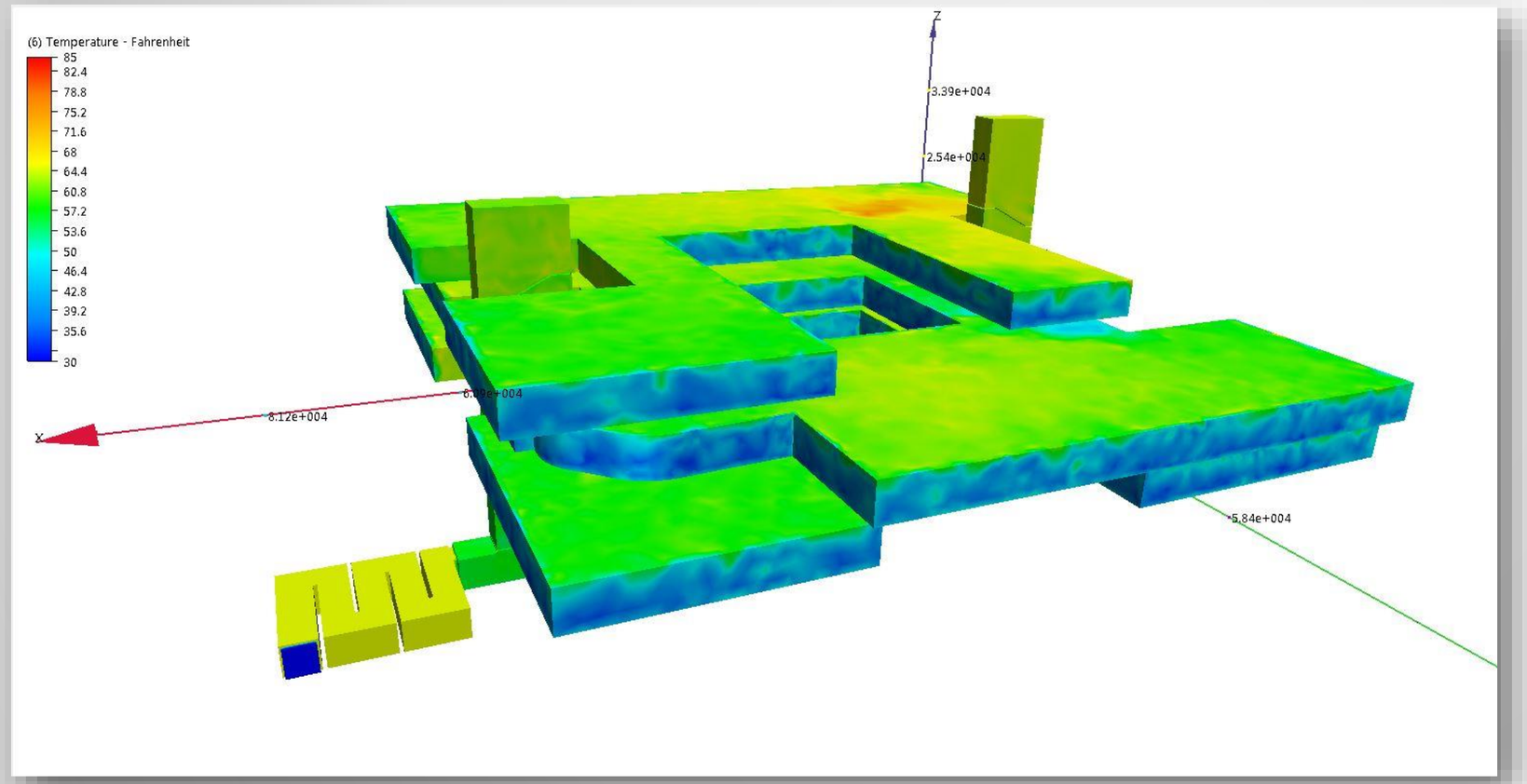


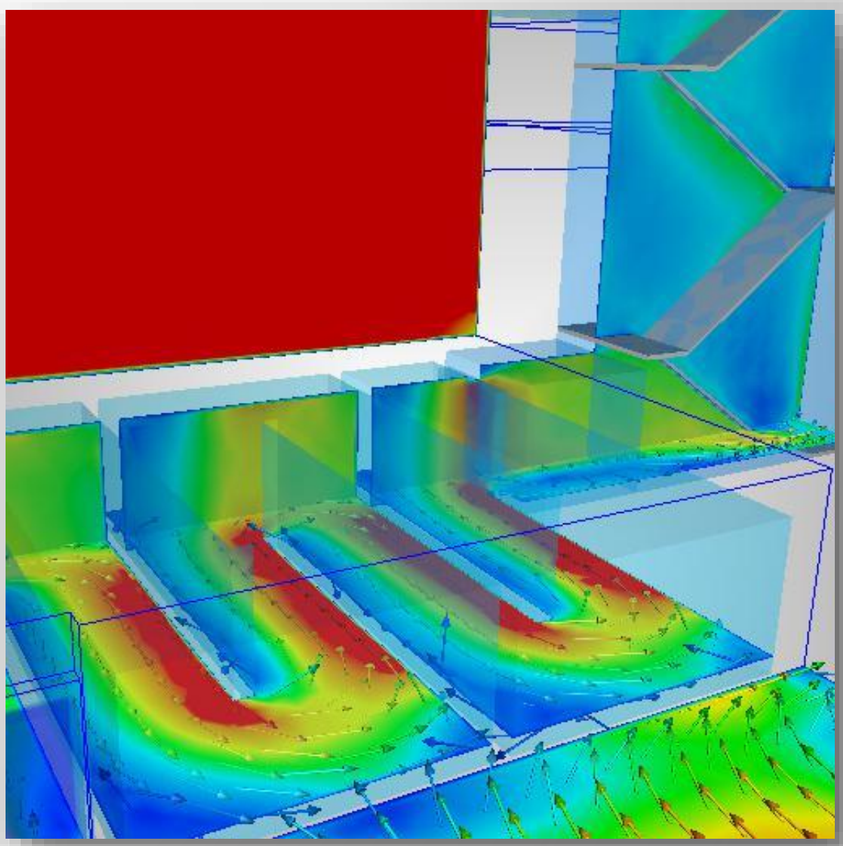




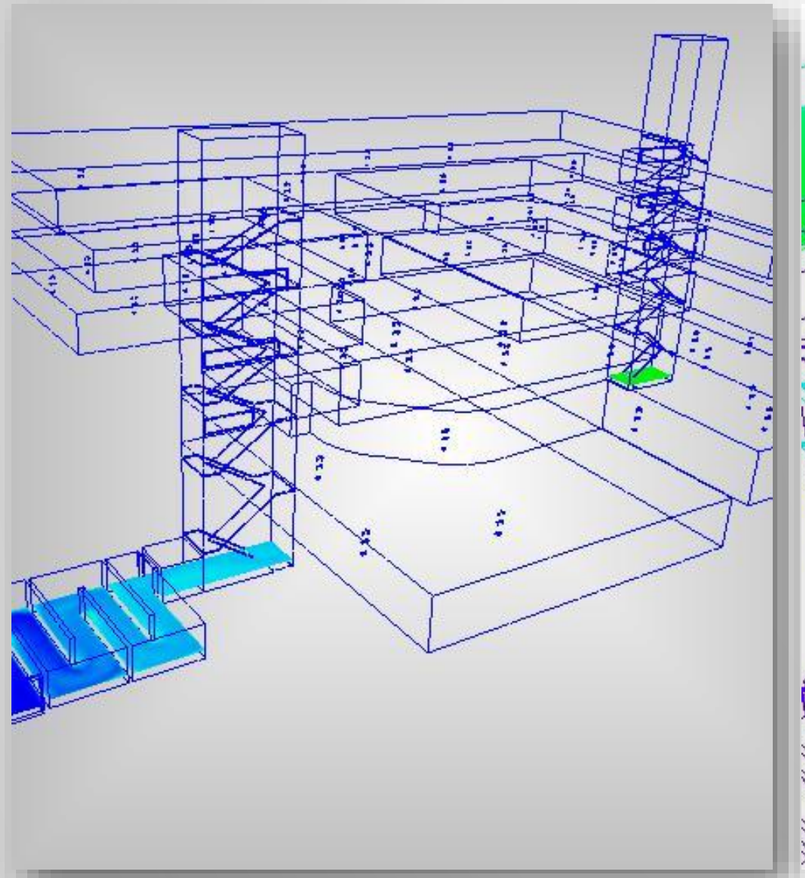
Other Uses – Sustainable solutions

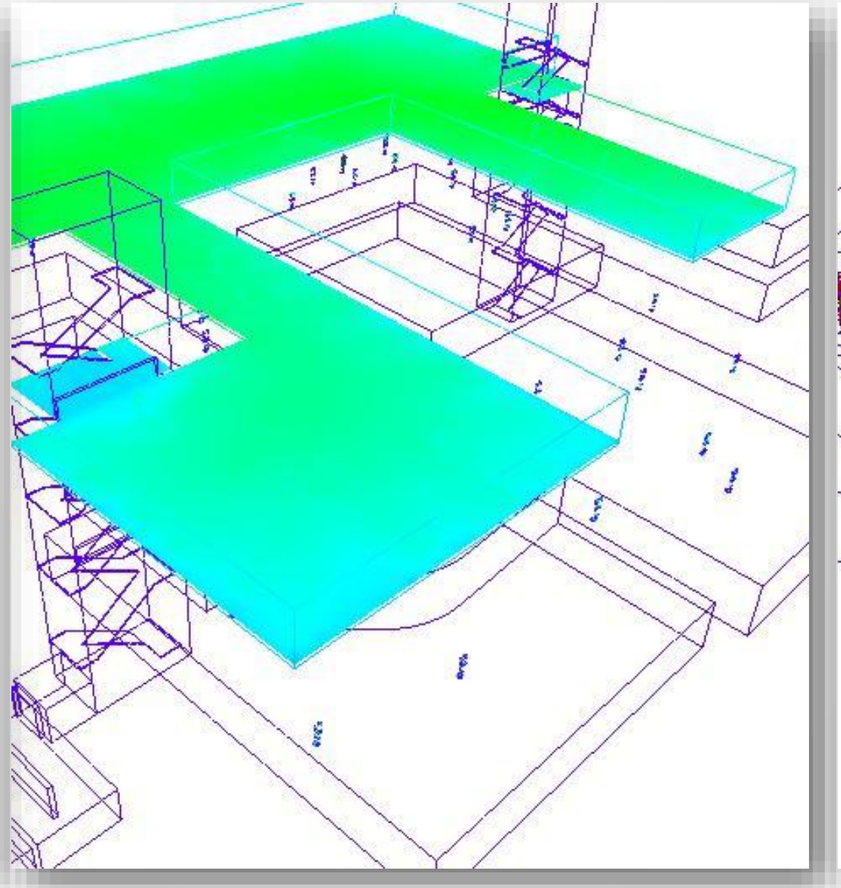
- University Library
- No environmental analysis options
- Propose a thermal labyrinth and natural ventilation.

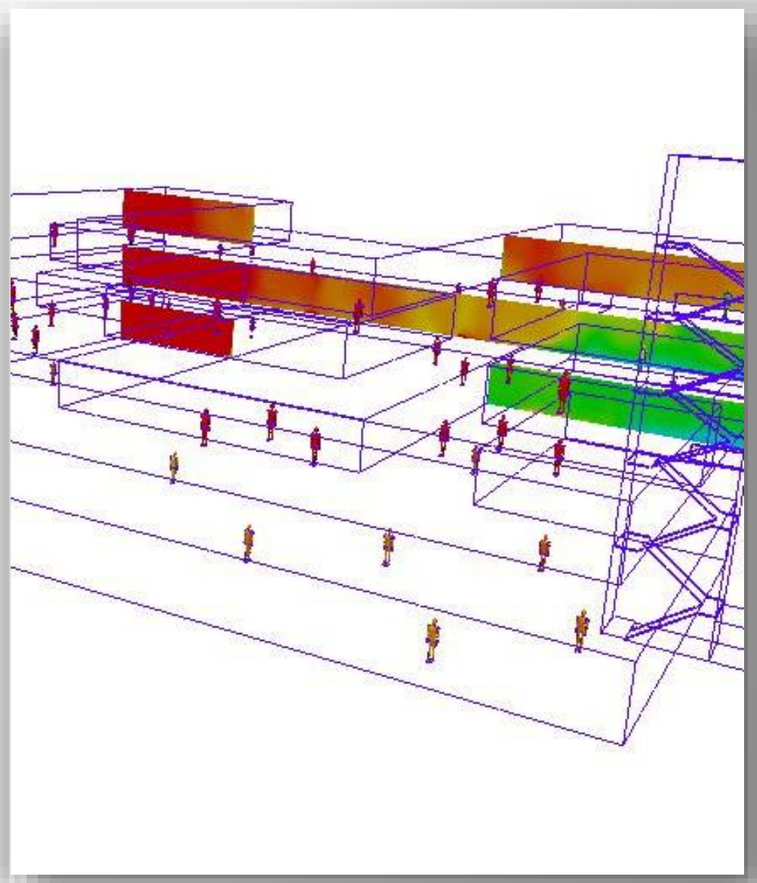




Other Uses – Sustainable solutions

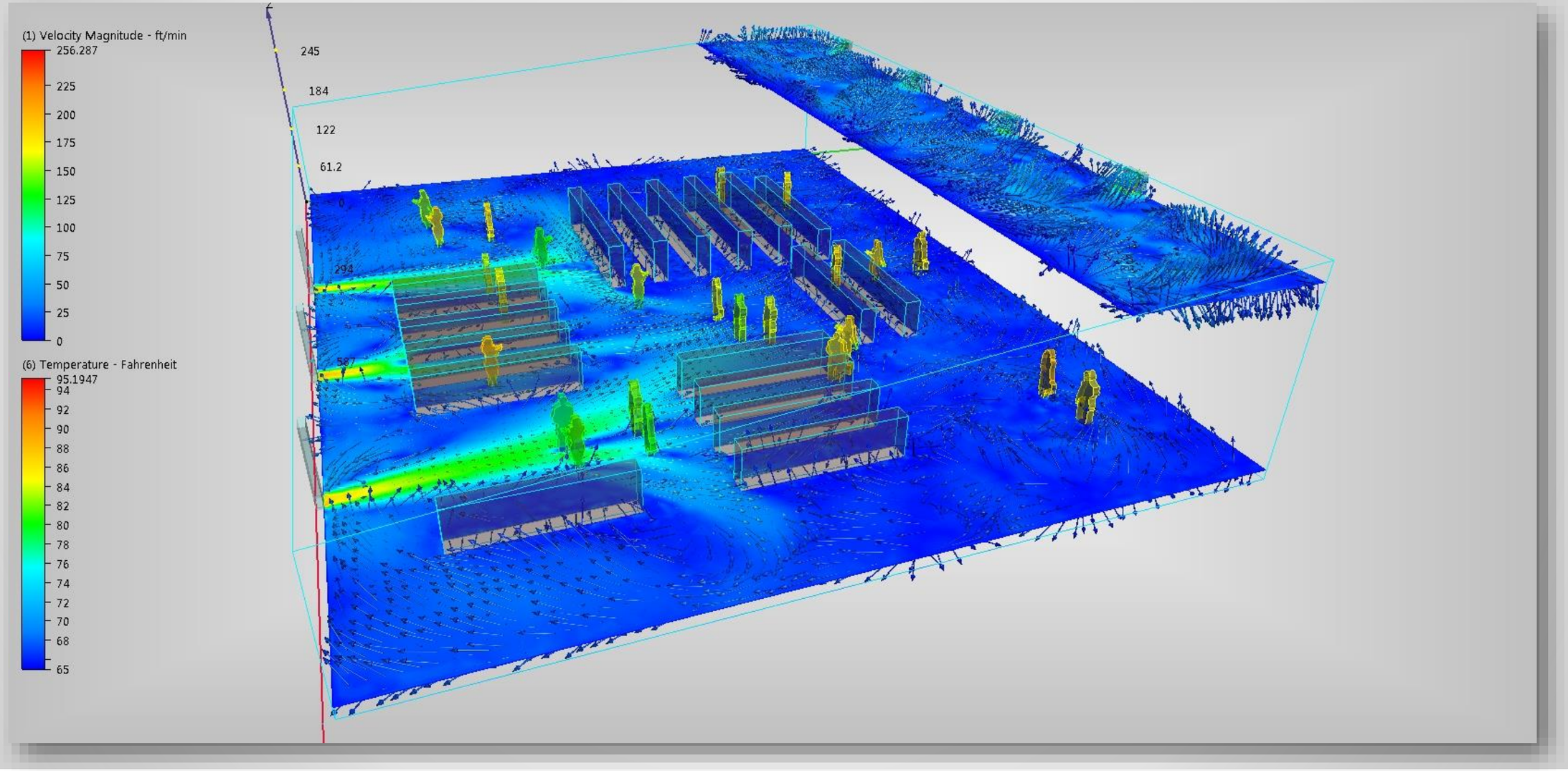






Others – Fast Studies

- WCL – Low budget (1 hr to do model)



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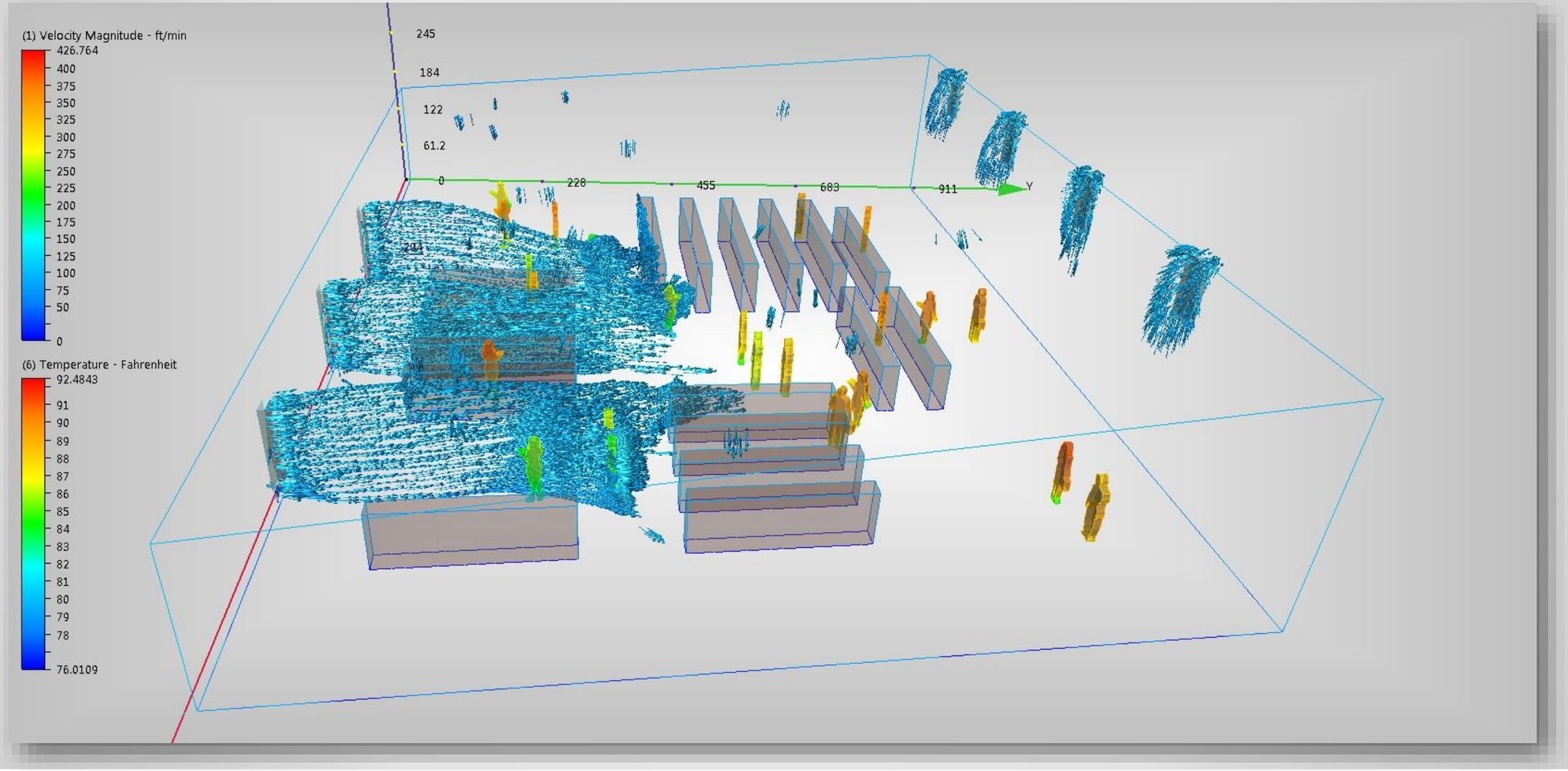

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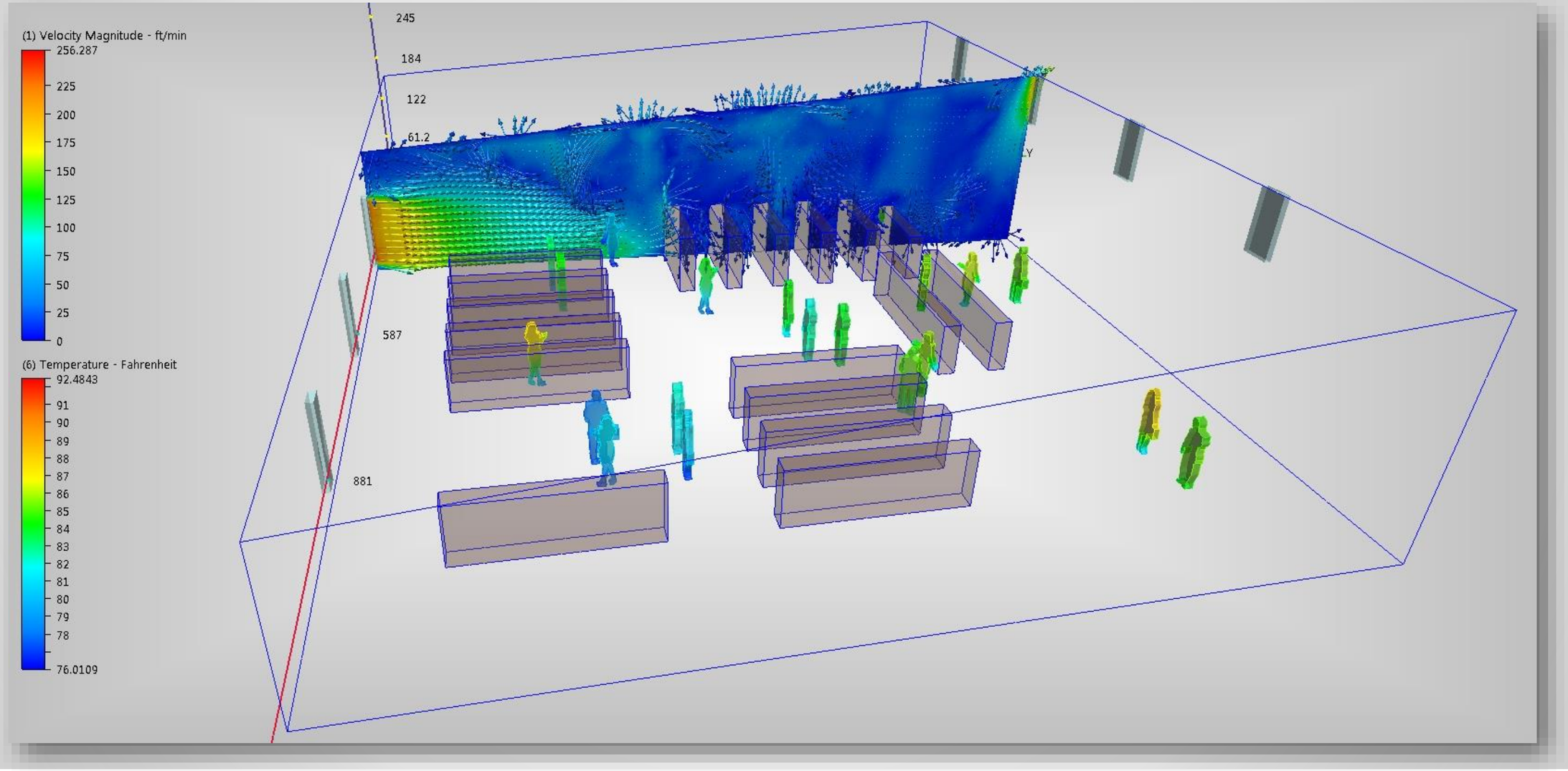

Future studies

- Sun path modeling
  - Model the area of solar influence
- Liquid studies
  - What do liquids do?
- Drainage patterns
  - Can we study drainage patterns in hardscape? Buildings?

Questions?

Session Feedback

- Via the Survey Stations, email or mobile device
- AU 2015 passes given out each day!
- Best to do it right after the session
- Instructors see results in real-time

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