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## **Coupled Model for Simulation of Indoor Airflow and Pollutant Transport**

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## **Coupled Model for Simulation of Indoor Airflow and Pollutant Transport**

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Understanding airflow in buildings is essential for improving energy efficiency, controlling airborne pollutants, and maintaining occupant comfort. Recent research on whole-building airflow simulation has turned toward protecting occupants from threats of chemical or biological agents. Sample applications include helping design systems to reduce exposure, and selecting optimal sensor locations.

Multizone models [1] and computational fluid dynamics (CFD) provide complementary approaches to predicting airflows in buildings. Multizone models treat a building as a collection of well-mixed zones, connected by flow paths such as doors, windows, etc. These zone-to-zone airflows carry contaminants around the building. However, the multizone formulation assumes that pollutants mix perfectly and instantaneously within each zone. For large spaces that take a long time to mix, these models cannot assess occupant exposures, or guide decisions about sensor placement or ventilation strategy. Furthermore, since the airflow in most large spaces couples tightly to the rest of the building (through doors and ventilation systems), errors due to neglecting the room details eventually propagate to the rest of the solution.

CFD, on the other hand, resolves spatial details of the flow in a given space. Unfortunately, a CFD model of an entire building would prove prohibitively expensive to define and solve, especially in the context of a design exercise.

Coupling CFD to a multizone model overcomes the limitations of both models for predicting whole-building airflows and pollutant concentrations in the presence of large spaces. We present results from a numerical coupling between two such models. STAR-CD finds the detailed airflow and pollutant transport in the large

space, while the COMIS multizone model [2] handles the rest of the building and its surroundings.

To enforce consistency between the CFD and multizone codes, a supervisory program runs the domain-specific solutions iteratively, going back and forth between them until the state variables at the domain interfaces match to within user-specified tolerances. At each iteration of the airflow solution, the supervisory program extracts pertinent boundary conditions from the multizone solution for use with CFD, and from the resulting CFD solution for use with COMIS. After finding a consistent set of steady-state airflows, the supervisor solves for the transient pollutant concentrations. At each time step, the programs iterate until they match concentration boundary conditions.

We tested the coupling algorithm on a sample two-dimensional building [Fig 1] comprising one large “CFD-zone” (zone 1), and six “simple zones.” The CFD-zone connects to the simple zones, and to the outside, via doors, which may be open or closed. Wind from the south drives the main whole-building flows. In addition, a fan forces air from the CFD-zone into zone 4, forcing recirculation between the modeling domains (this fan was added to challenge the solution algorithms; it does not correspond to a likely feature of a real building). Finally, a small fan exhausts air from zone 7 to the roof.

Figure [2] compares fully-developed concentrations predicted by the coupled programs to those from a stand-alone multizone model, for a continuous release of a massless tracer in zone 3. The figure shows that CFD predicts concentration details in the large space, while the uncoupled multizone program yields a uniform concentration in that same space. Furthermore, calculating detailed concentrations for the CFD-zone changes the predictions for the smaller zones of the building.

Table [1] compares exposure estimates from the two models. Each simulated a six-minute release, at 1 g/sec, in zone 3. The table shows the occupant exposure, in g-sec/m<sup>3</sup> after 30 minutes. In the coupled case, the estimate for the CFD-zone uses a spatial average; exposure differences at specific points can be much larger.

	Zone1	Zone2	Zone3	Zone4	Zone5	Zone6	Zone7
COMIS only	101	0	249	55	102	102	96
Coupled	61	0	283	88	58	81	55

**Table 1: Exposure due to 6-minute release in Zone 3**

The differences in Table 1 reflect differences between the models' predicted transient fill-in of pollutant, as well as the different spatial results shown in Figure 2. Accounting for the flow details in the large CFD-zone affects the predicted timing, as well as the pollutant mass ultimately delivered to each zone of the building.

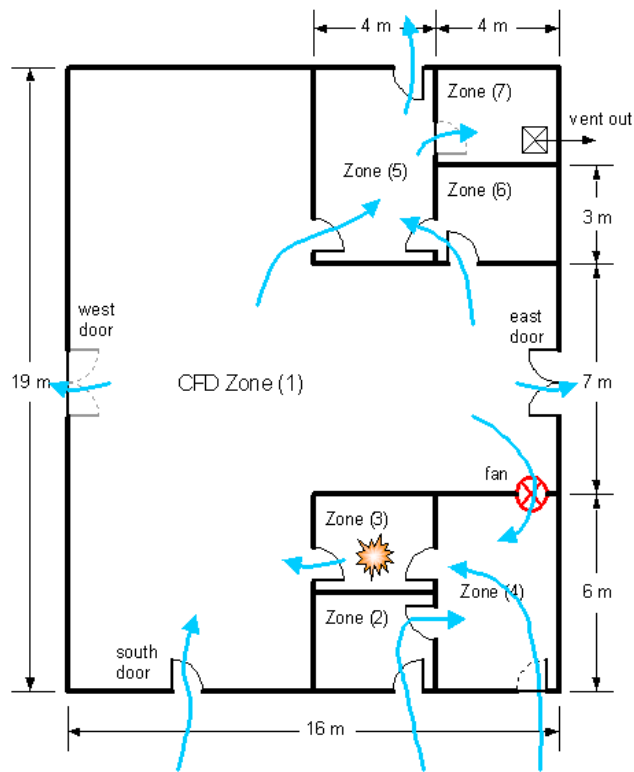
This preliminary study shows that coupling CFD to a multizone model results in more realistic predictions of airflow and pollutant transport in buildings with large spaces. Future efforts will extend the algorithm to 3-dimensional models, and will compare model predictions to experimental data.

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**References:**

1. D.M. Lorenzetti, Computational aspects of nodal multizone airflow systems, Building and Environment, v.37 (2002), pp.1083-1090.
2. H.E. Feustel, COMIS – An international multizone air-flow and contaminant transport model, Energy and Buildings, v.30 (1999), pp.3-18.



**Figure 2: Test building**

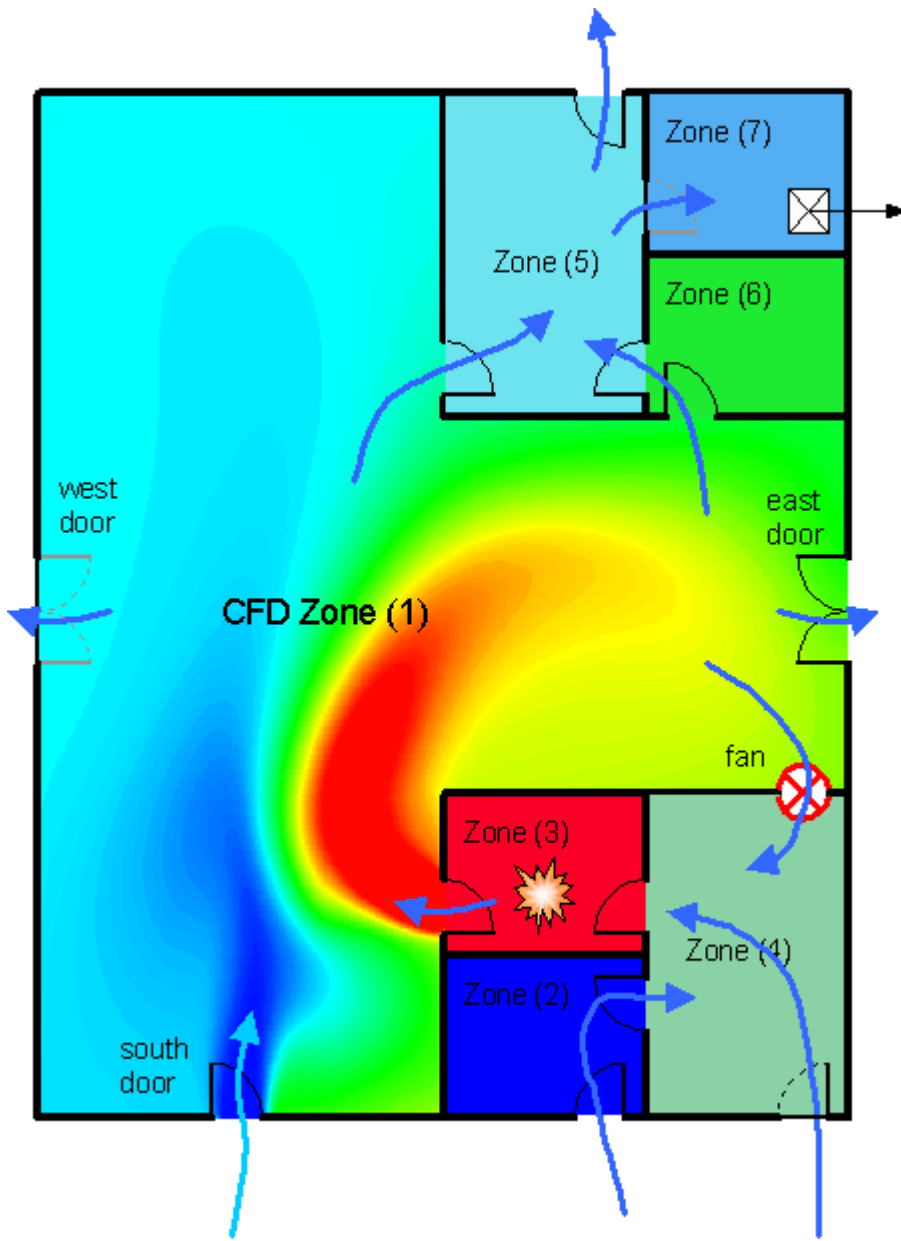


Figure 2: CFD + COMIS

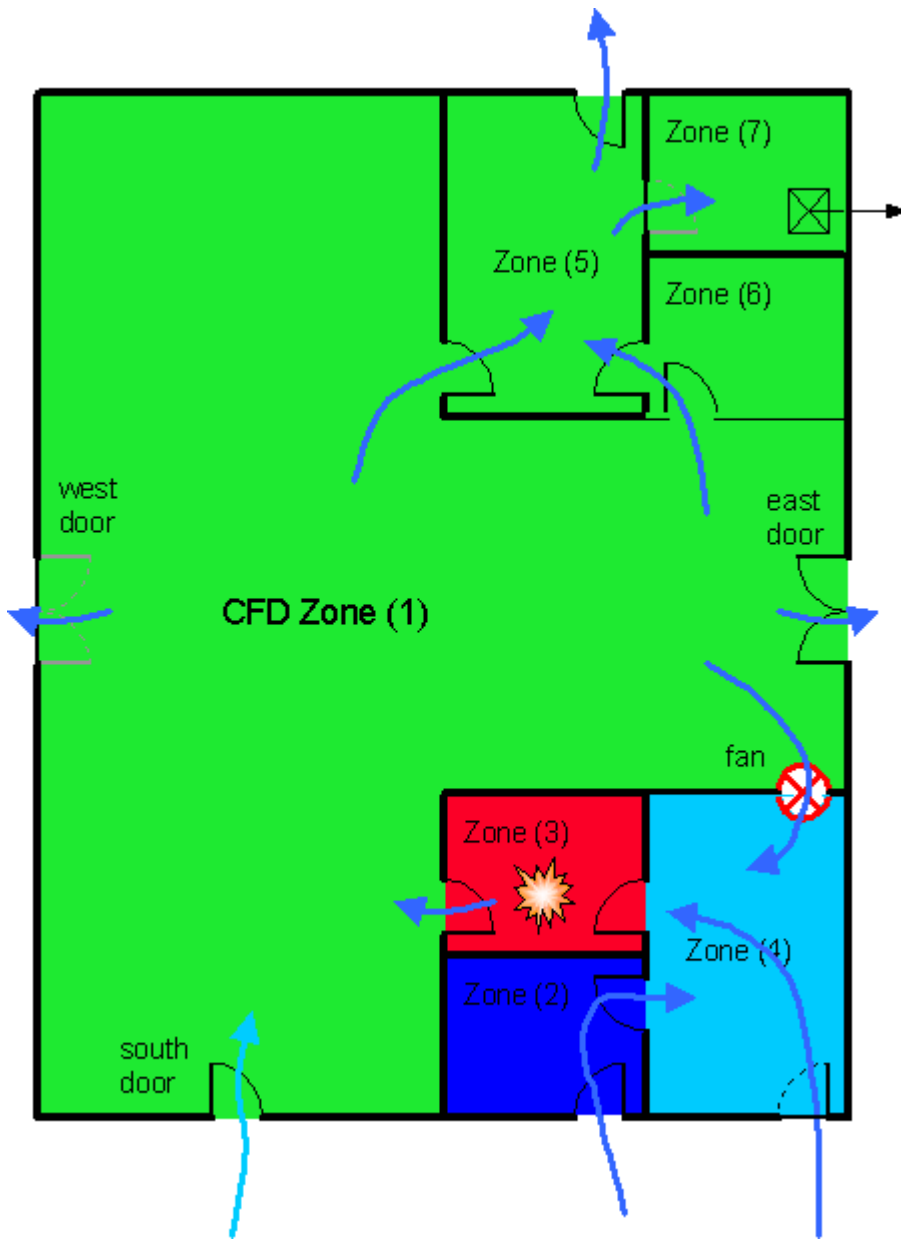


Figure 2: COMIS only