CBR MODELING AND SIMULATION TOOL (CBRSim)

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CBR Modeling Simulation Tool (CBRSIM)

- Software tool for modeling and simulating contamination infiltrating buildings from external release of chemical, biological and radiological (CBR) agents has been developed.

- Incorporates source terms for 23 weaponized agents (e.g., anthrax and sarin) from the

- Defense Threat Reduction Agency (DTRA) Hazardous Prediction and Assessment Capability (HPAC)

- 36 Toxic Industrial Chemicals (TICs) were added to HPACs existing data base from DOE's Chemical Accident Statistical Risk Assessment Model (CASRAM)

Background-
Fort Future

- Developed to provide installation planners with knowledge to make strategic decisions by visualizing results of many different scenarios.
- A system-of-systems that unites existing and new computer models to form a virtual installation.
- Uses modeling and simulation to help decision-makers explore potential consequences of their decisions.
- Integrated, web-based M&S tools for deployment, facility, encroachment, sustainability and force protection planning and forecasting

Background

- Fort Future suite of modeling and simulation software tools
- CBRSim Simulation CBR attack on military installation
  - Reaction of personnel
  - During normal operations
  - During deployment
- Detect
- Assess
- Warn
- Defend
- Recover

CBR Modeling & Simulation Tool

– Uses DTRA developed HPAC 4.0.3 Secondary Closure Integrated Puff Models (SCIPUFF) simulates transport of the CBR contaminant into the buildings

– User Interface for Weather

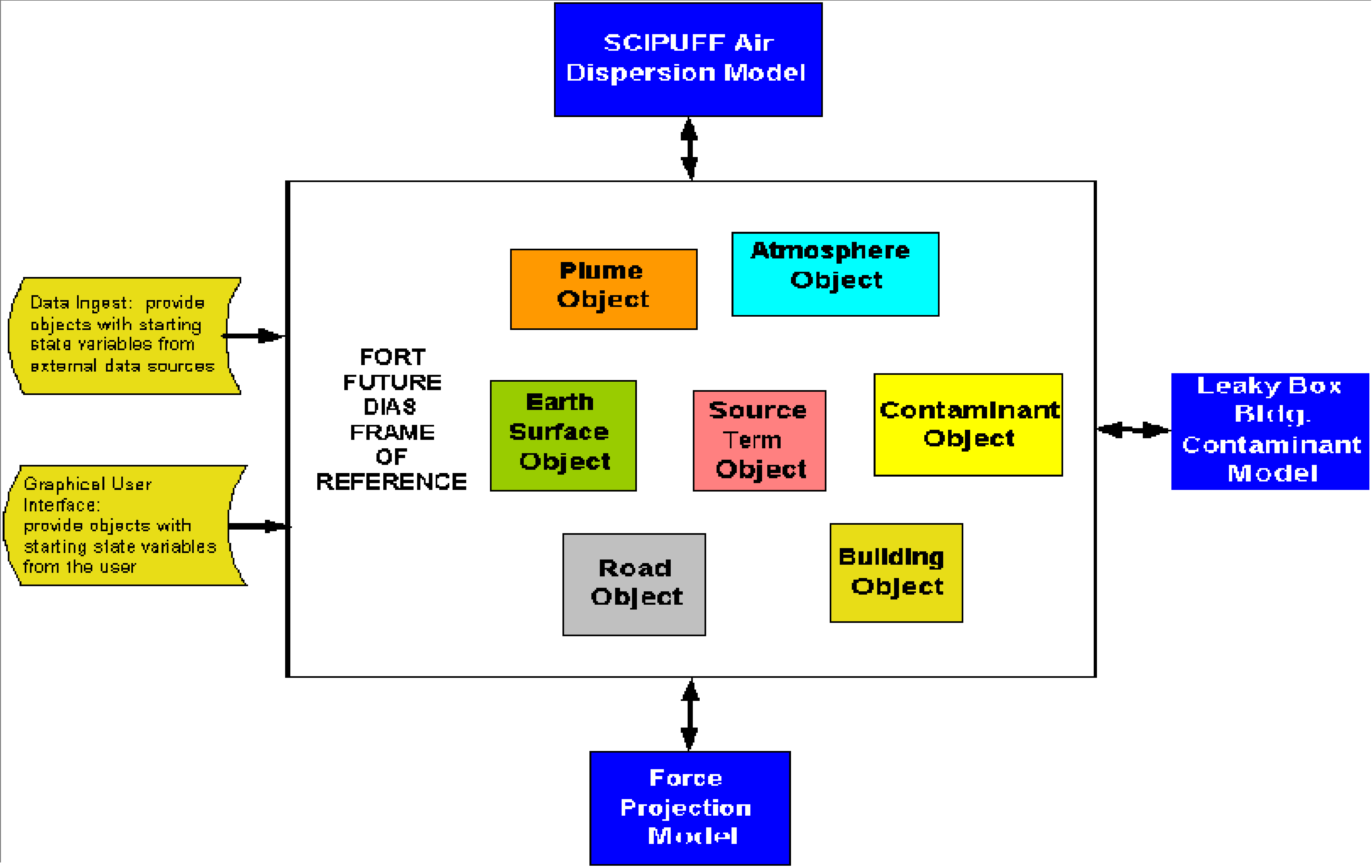
– Includes advanced visualization using JeoViewer

– Leaky Box Model for modeling concentration of agents within facilities as a function of time

CBRSim

- The simulation runs in the Dynamic Information Architecture System (DIAS)
- Source terms, buildings, the atmosphere etc. are modeled as “objects”
- State variables are updated at 15 minute intervals by SCIPUFF and the leaky box model
- Data from external sources:
  – User input provides initial state variables, such as amount of hazardous material released, release rate, location, duration of the release event, and local meteorological information.

CBR Modeling Simulation Tool



External Release Modes

- Chem/Bio Facility
- Air Drop Weaponized Agent
- Industrial Accident
- Aerial Spray
  - Any chemical can be spray-released
  - *Solids* can only be *spray-released* (not transport-released). SCIPUFF for is used for the transport model.
  - Aerial (spray) releases are modeled as a Moving release with a heading and duration.

Input Required

- Default values for HVAC and leakage air exchange rates are specified in the input scenario.xml file

- These values are used for all facilities on the installation if there is no data within the Facility ESRI Shapefile. The elements look like this in the file:
- <HVACField default="2.0"/>
- <LeakageOpenField default="8.0"/>
- <LeakageClosedField default="1.0"/>
- When specified this way, these values are used for ALL facilities by default.

- The facility shapefile is read in for an installation, the fieldNames above are read in from the corresponding .DBF file

Leaky Box Model Assumptions

- (1) a uniform concentration of contaminants in the building,
- (2) a constant air exchange rate with the outdoors,
- (3) building air exchange rate is the sum of heating ventilation and air conditioning (HVAC) and building leakage exchange rates.

Mathematical Description of Leaky Box Model Assumptions

$$C_{in} = \int_{t=0}^{t=\infty} C_{out}(\tau)\{1\text{-}\exp[A_c\,(t-\tau)]\}d\tau$$

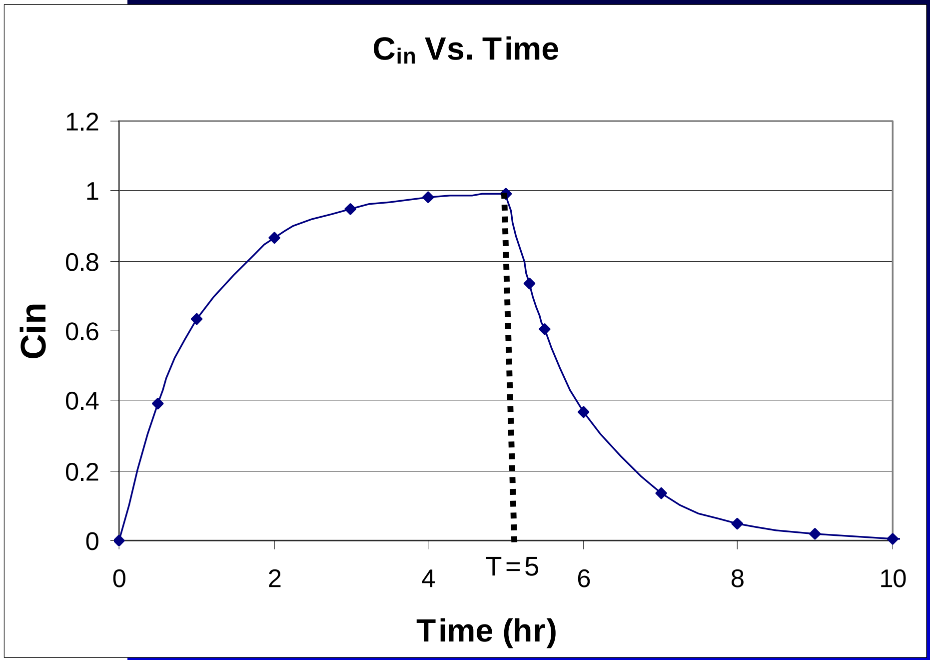
Where:

C_{out} and C_{in} = outdoor and indoor concentrations, respectively,
t = time,
Ac = building ventilation rate.

For a constant outdoor concentration of C_{out} between $t = 0$ and $t = T$, the equation reduces to:

$$C_{in} = C_{out}\{1\text{-}\exp[A_c t)]\} \quad \text{for } 0 < t < T$$

$$C_{in} = C_{out}\{\exp[A_c(t-T)]\} \quad \text{for } t > T$$



References
(1) D.F. Brown, W.E. Dunn,* and A.J. Policastro "ANL/DIS-01: A National Risk Assessment for Selected Hazardous Materials in Transportation," Argonne National Laboratory, pp. 40-44

Leaky Box Model Air Exchange Rates

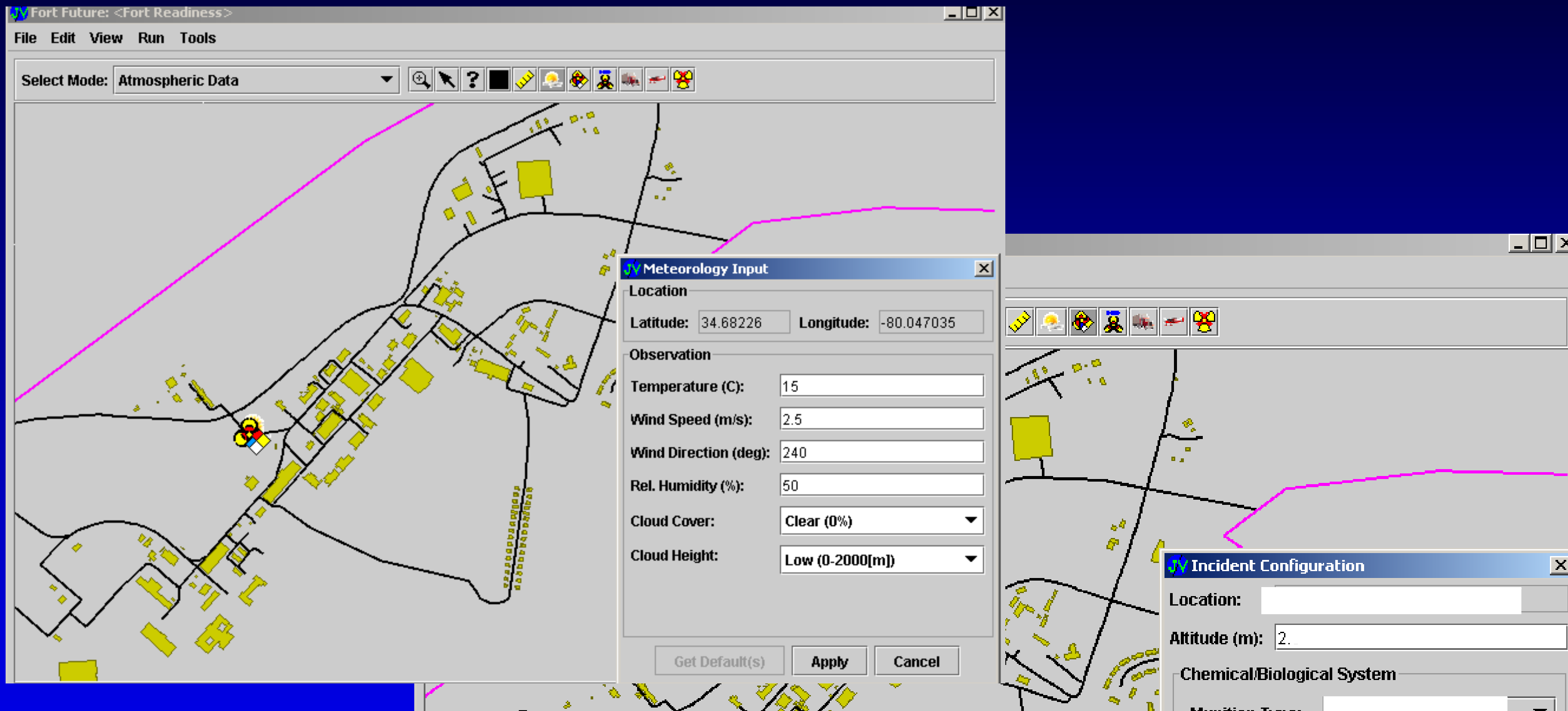
- Air exchange rates (AER) are specified and used to describe 4 different states that can characterize the building exchange.

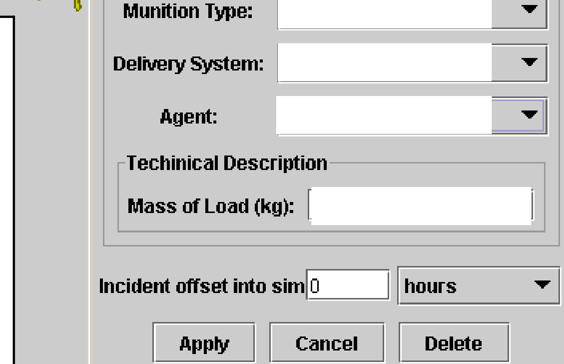
- The 4 possible building states are:
  - (a) HVAC on, windows and doors closed (AER =2),
  - (b) HVAC on, windows and doors open (AER =8),
  - (c) HVAC off, windows and doors closed (AER=1),
  - (d) HVAC off, windows and doors open (AER=8).

Leaky Box Model States

- Only two of these are actually used, because it is assumed that a release would be detected
- HVAC would be shut off and windows and doors closed during the plume passage to minimize the air exchange rate (AER=1).
- When the plume has passed, the HVAC comes on and the doors and windows are opened to maximize the air exchange rate (AER=8).

CBR Modeling Simulation Incidence Setup

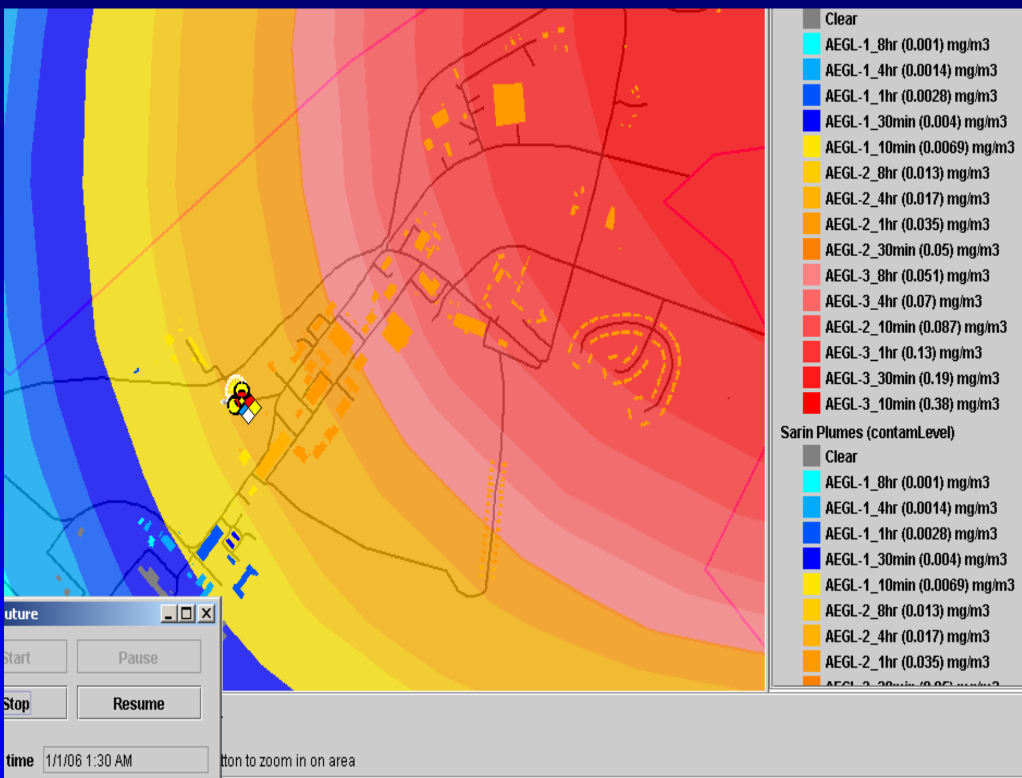


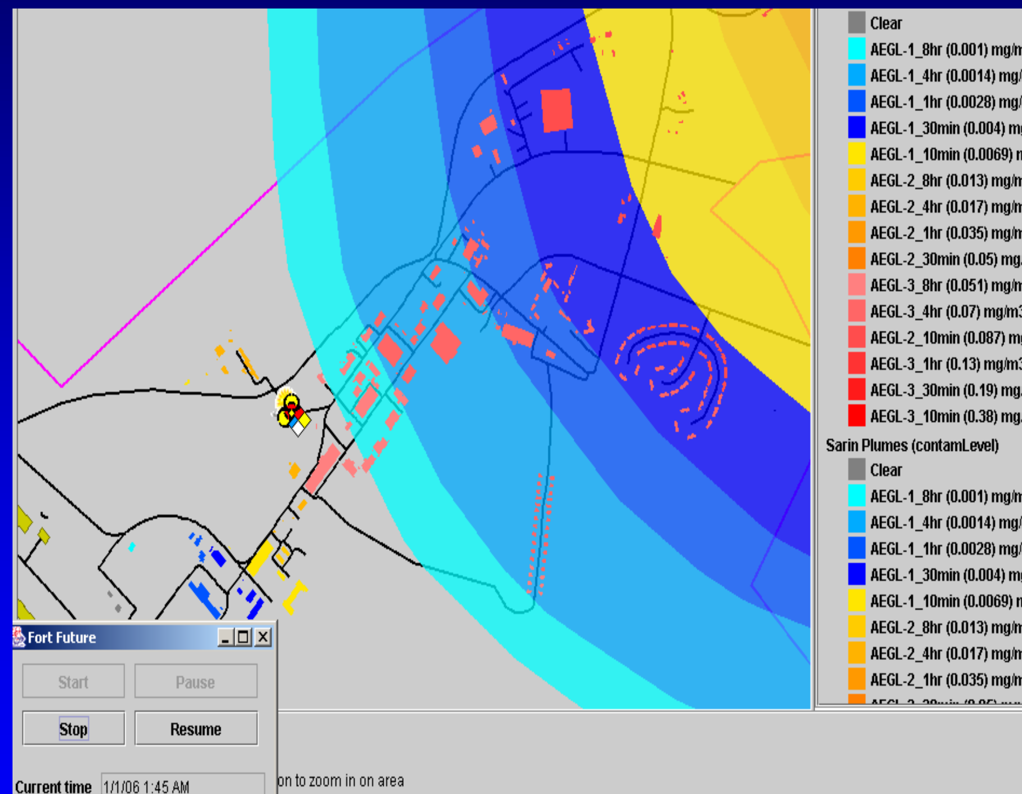


User selects:

- Release Location(s)
- CBR information

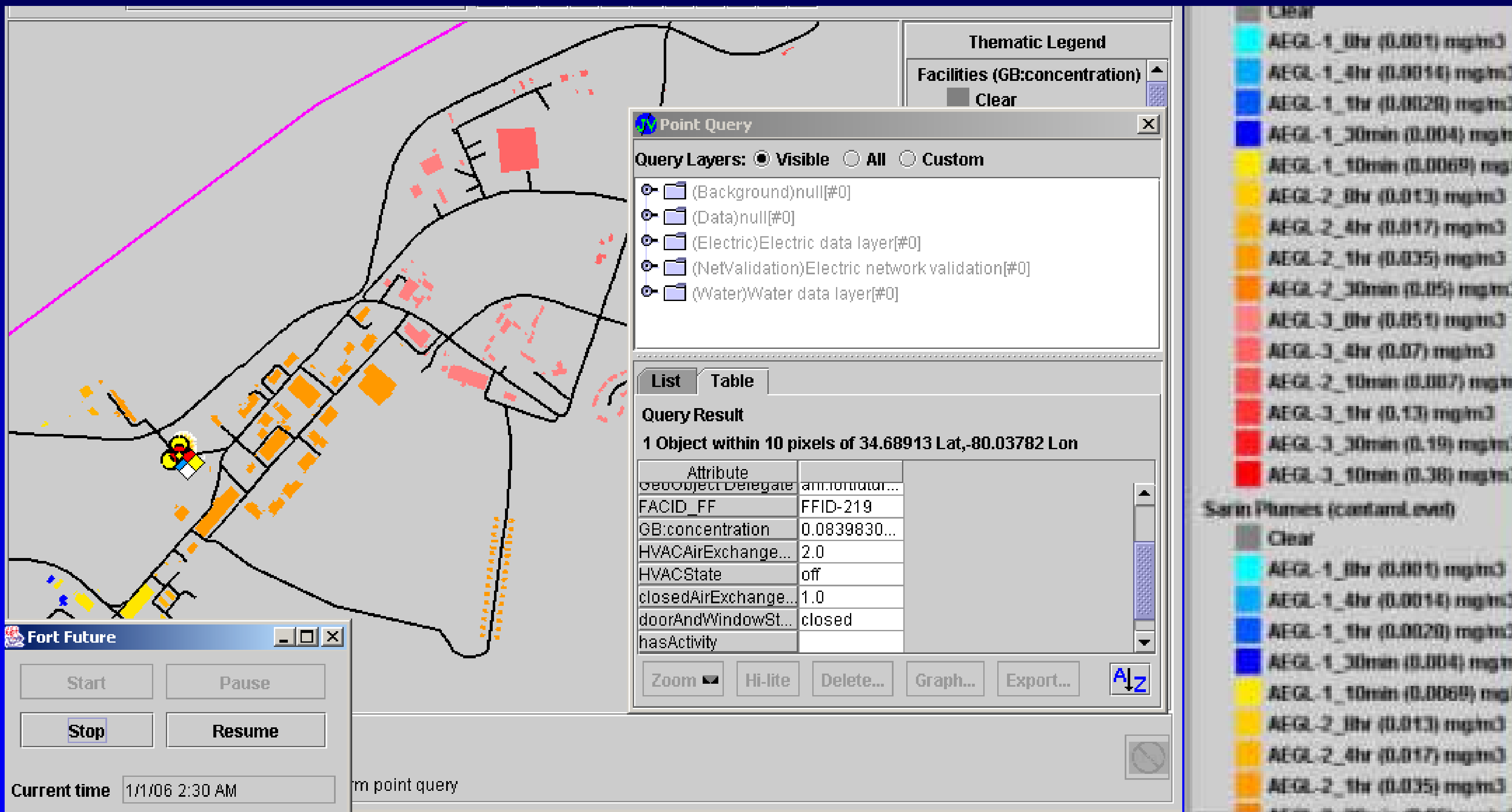
CBRSim simulates dispersion of CBR agents and TICs across the installation “Ft. Readiness”





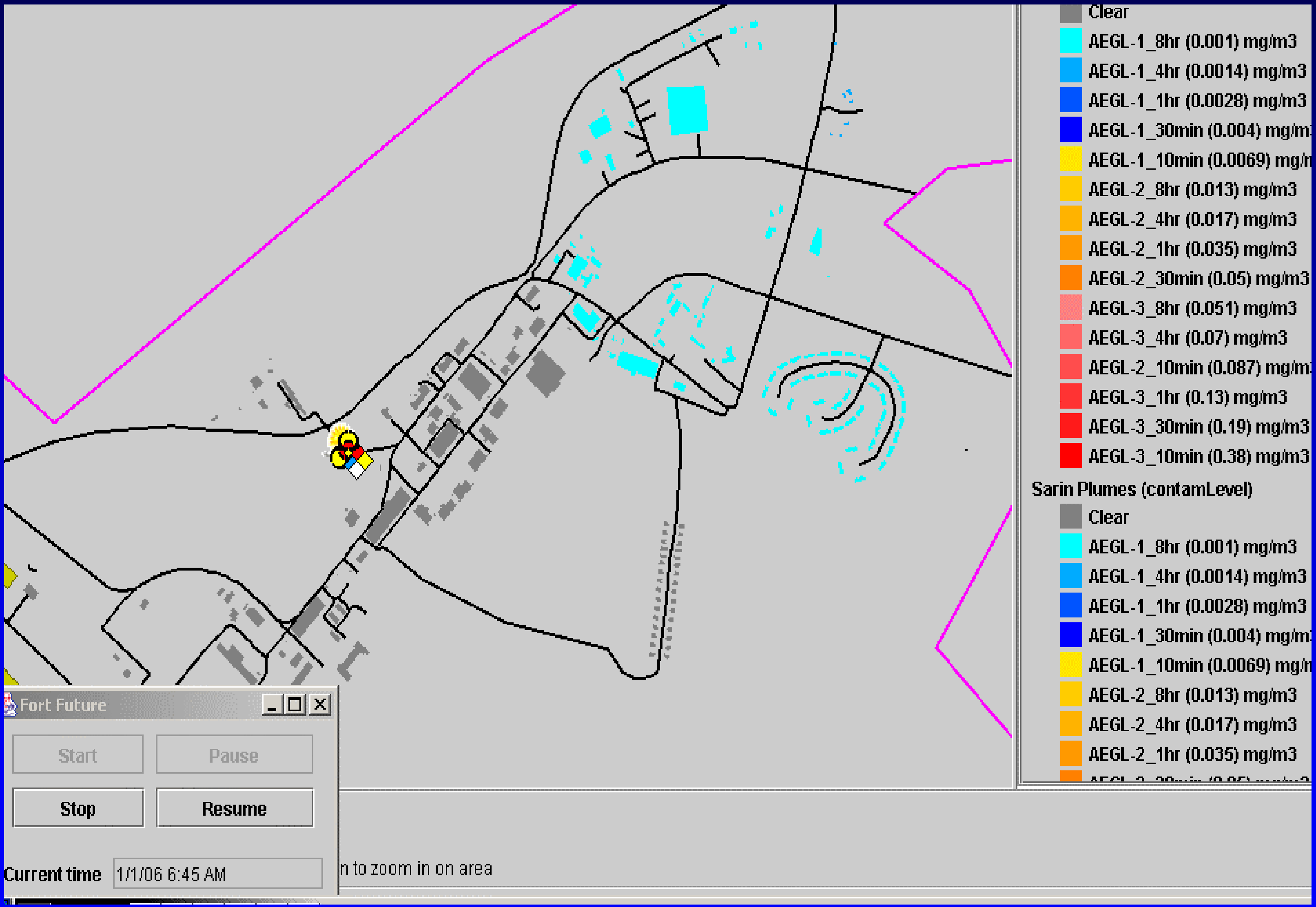
Leaky Box Model for Buildings

Facility concentration values are used within the Fort Future projection model to alter the flow of deployment through the installation based upon facilities being unavailable due to release of CBR agent.



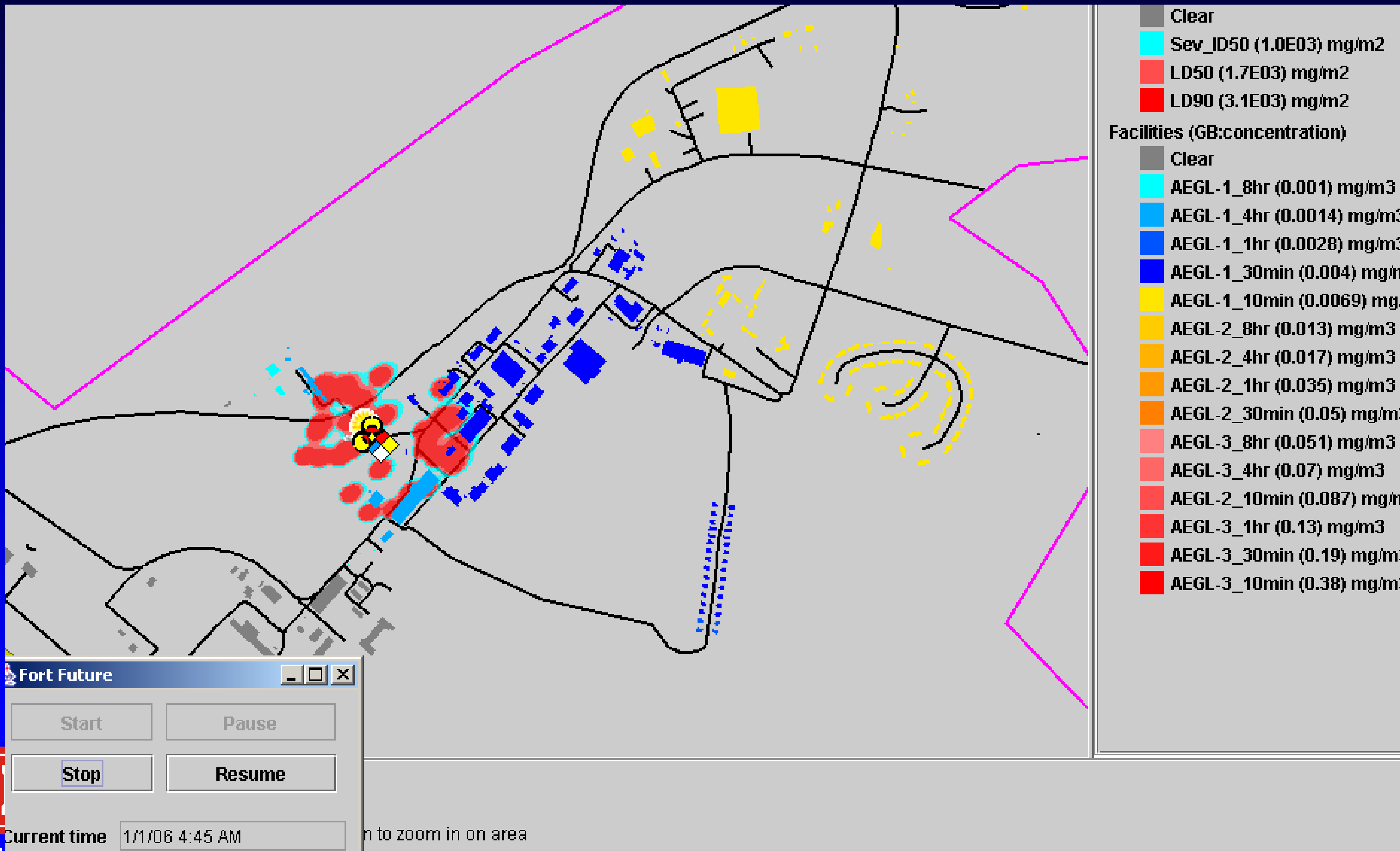
Facility icon will change color based upon concentration levels. Querying on a specific facility will allow the user to follow concentration at any time-step of the model.

Color-coding shows the persistence of agents within buildings. Several hours after the plume has passed most facilities are clear of the agent and can be used again.

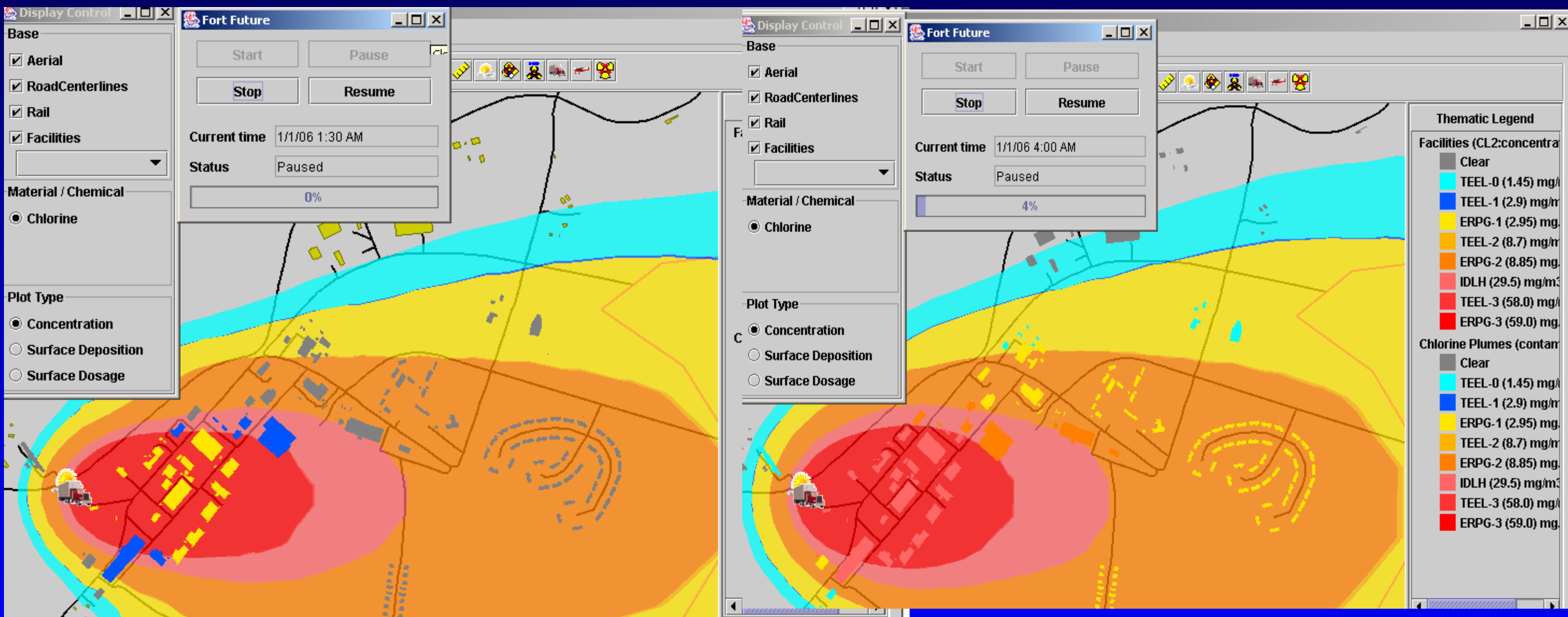


Dosage contours can be displayed at given time intervals

Deposition contours can also be displayed at given time intervals



Industrial Accident Chlorine Release from 20000 gal Tanker



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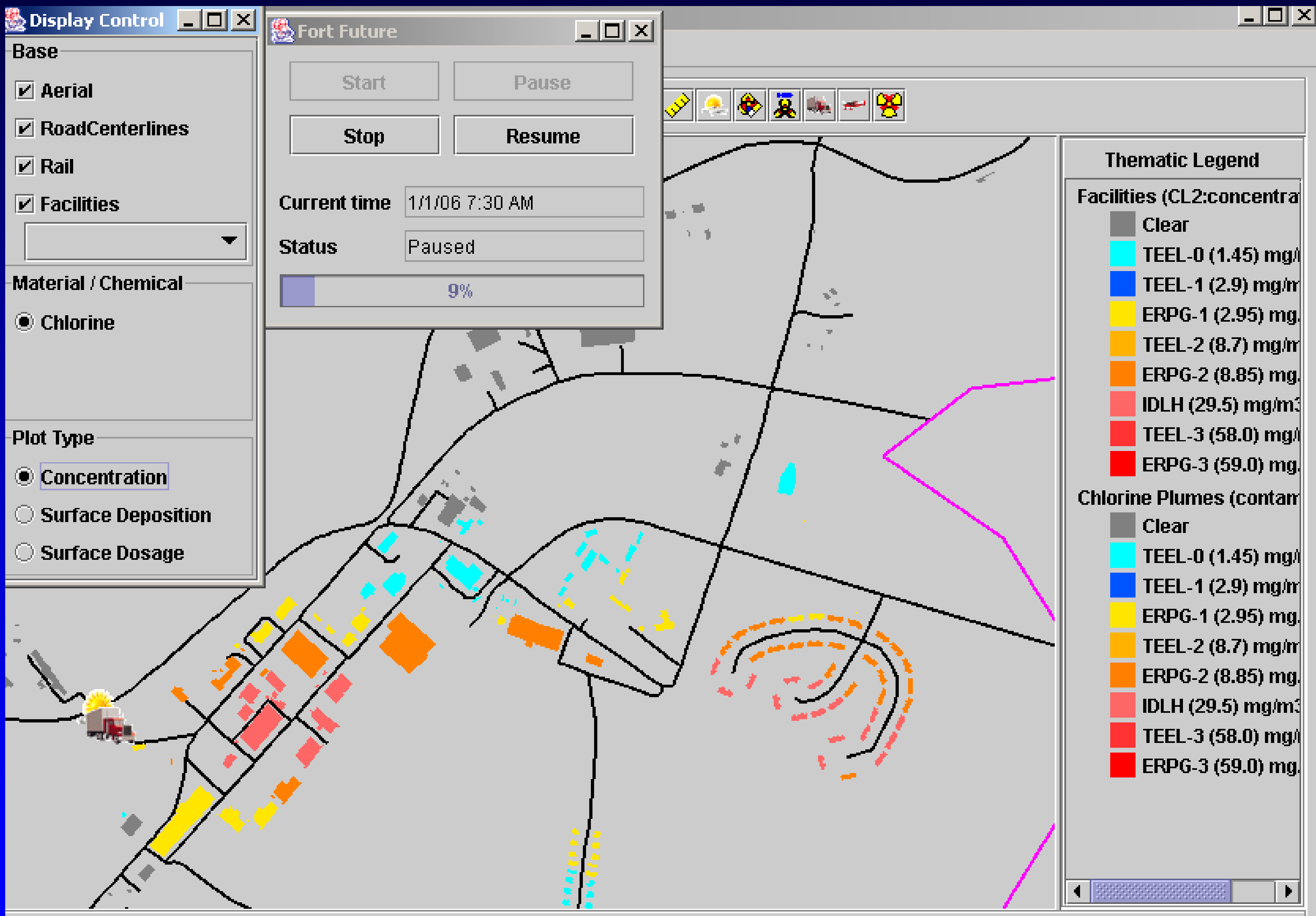
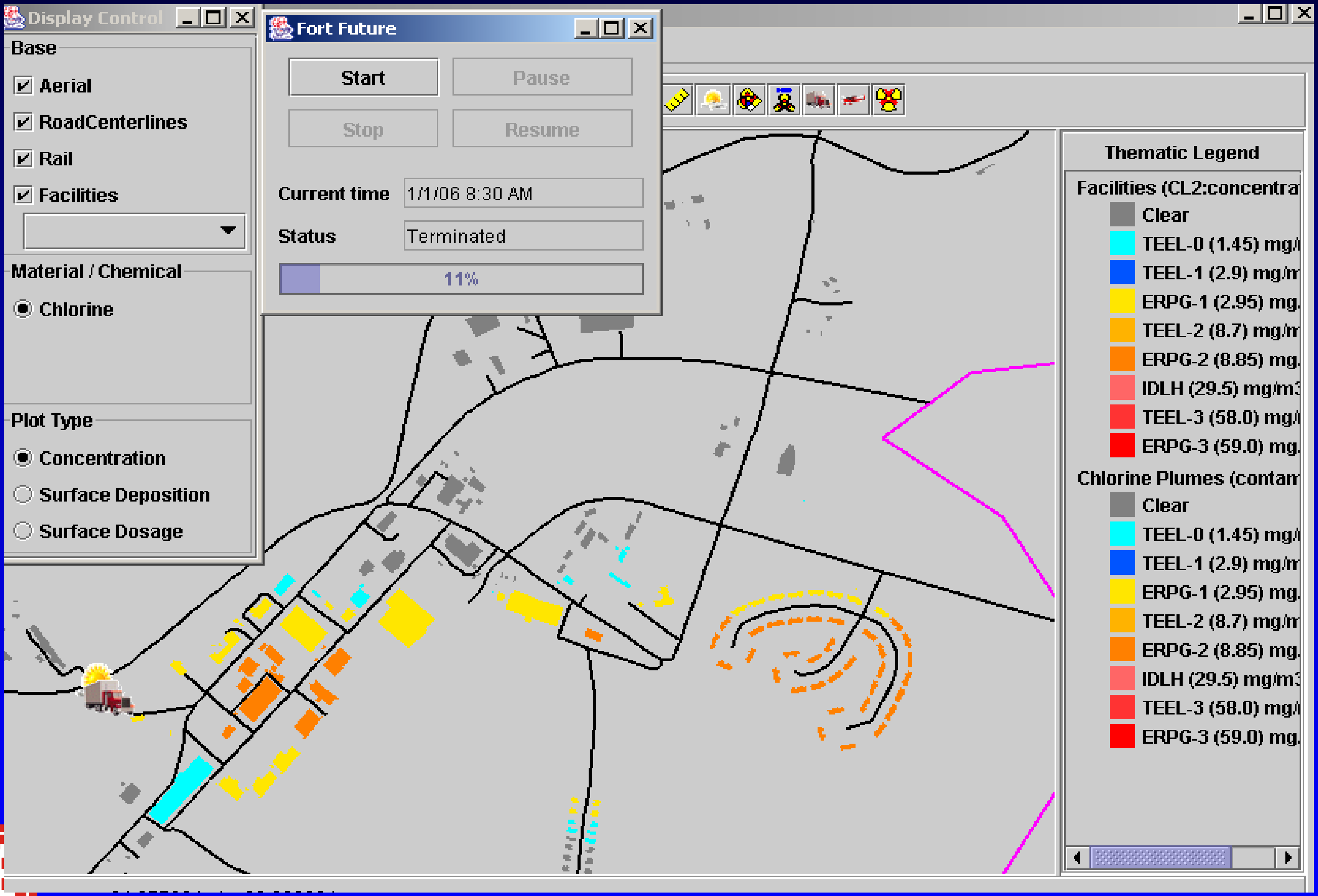
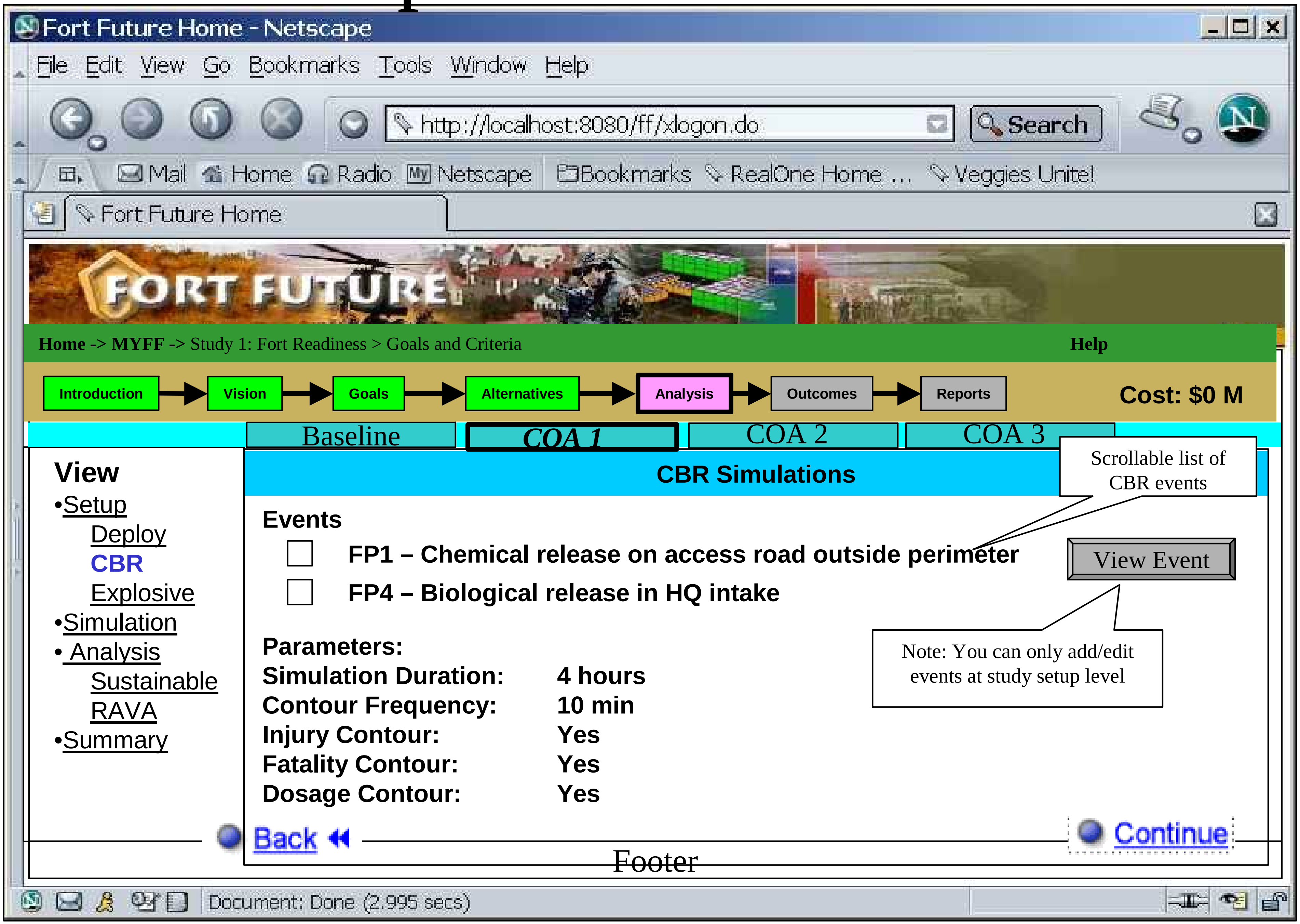


Industrial Accident Chlorine Release from 20000 gal Tanker



Setup CBR Simulation



Evolving Requirements for Facility CB Protection

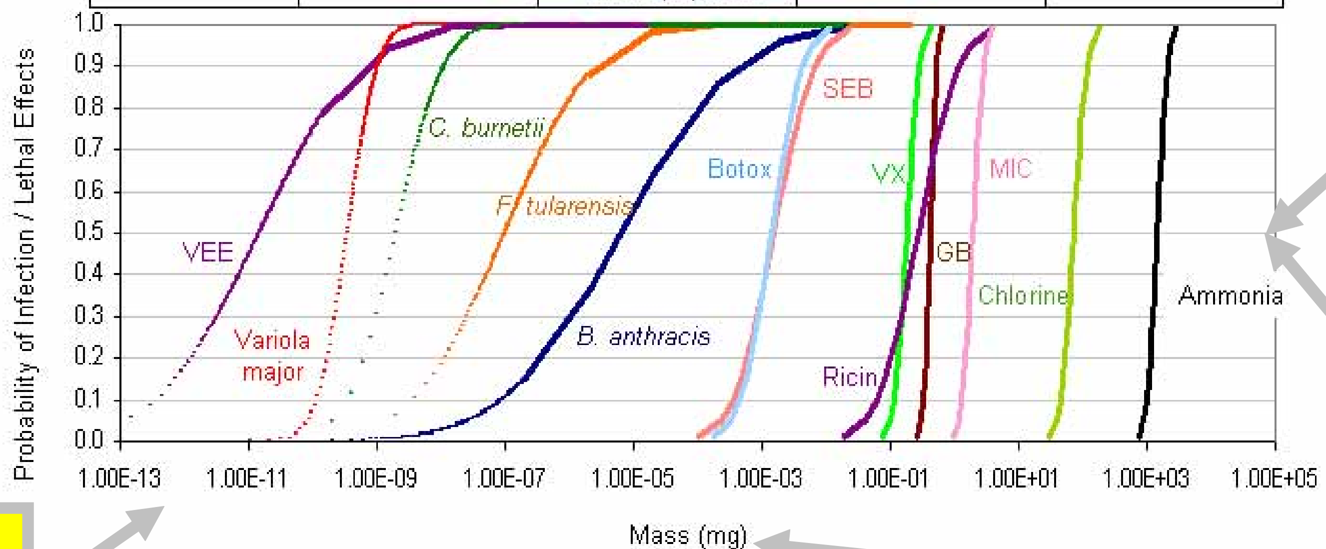
- Internal release vs external release
  - Historical emphasis on external release
  - Smaller quantities needed to inflict deleterious effects via internal release
  - Recent incidents (anthrax letters and ricin) have been internal releases

Overview of Threat Spectrum for CB Protection

Threat Spectrum

Special Projects Office

Viruses	Bacteria	Toxins and Bioregulators	Chemical Agents	TICs
▪ DNA Viruses ▪ RNA Viruses	▪ Vegetative cells ▪ Spores	▪ Neurotoxins ▪ Cytotoxins ▪ Enterotoxins ▪ Mycotoxins ▪ Neuropeptides	▪ Nerve Agents ▪ Blister Agents ▪ Blood Agents ▪ Choking Agents	▪ thousands of substances with characteristics



LD_{50} (Chemical)

ID_{50} (Biological)

Extremely Small Quantities

Mass (mg)

Based on Unclassified Sources

Lower Probability of Infectious/Lethal Effects → Lower Mass

Evolving need for more accurate determination of the CB contaminant levels

- **Trend of acceptable exposure levels is lower**
  - **Acceptable chemical exposure limits tending lower as other populations are considered**
    - **Military personnel**
    - **DoD worker occupational health**
    - **General civilian population**
  - **Uncertainty in infectious levels for biological agents**
    - **Anthrax death with no measurable exposure**
    - **Can one spore cause infection?**

- **Lower acceptable exposure levels translate into lower concentration levels and/or shorter exposure times**

Comparison of Muulti-Zonal (MZ) and Computational Fluid Dynamics (CFD) Results

Continuous flow of contaminant at entrance to a four room complex with open doors.

Multi-Zone Model

Uniform mixing/dispersion in each zone

CONTAM 2.1 calculations

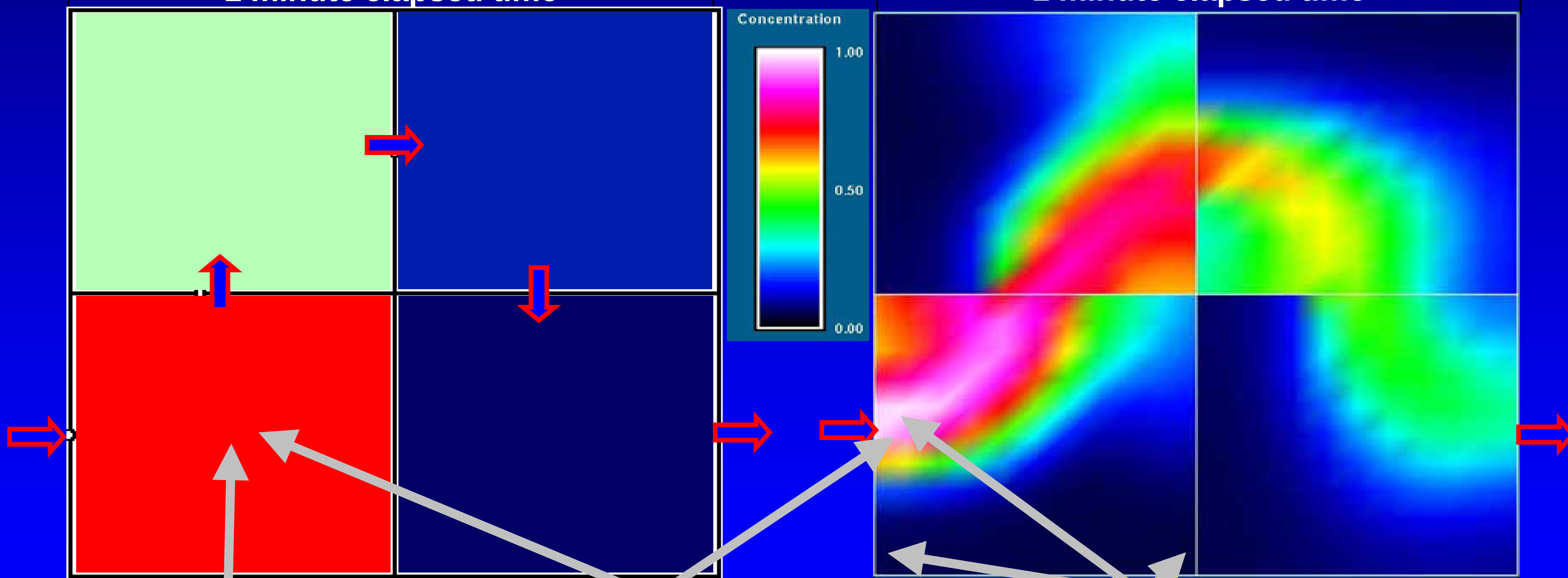
1 minute elapsed time

Computational Fluid Dynamics

Detailed contaminant transport

PAR3D calculations

1 minute elapsed time

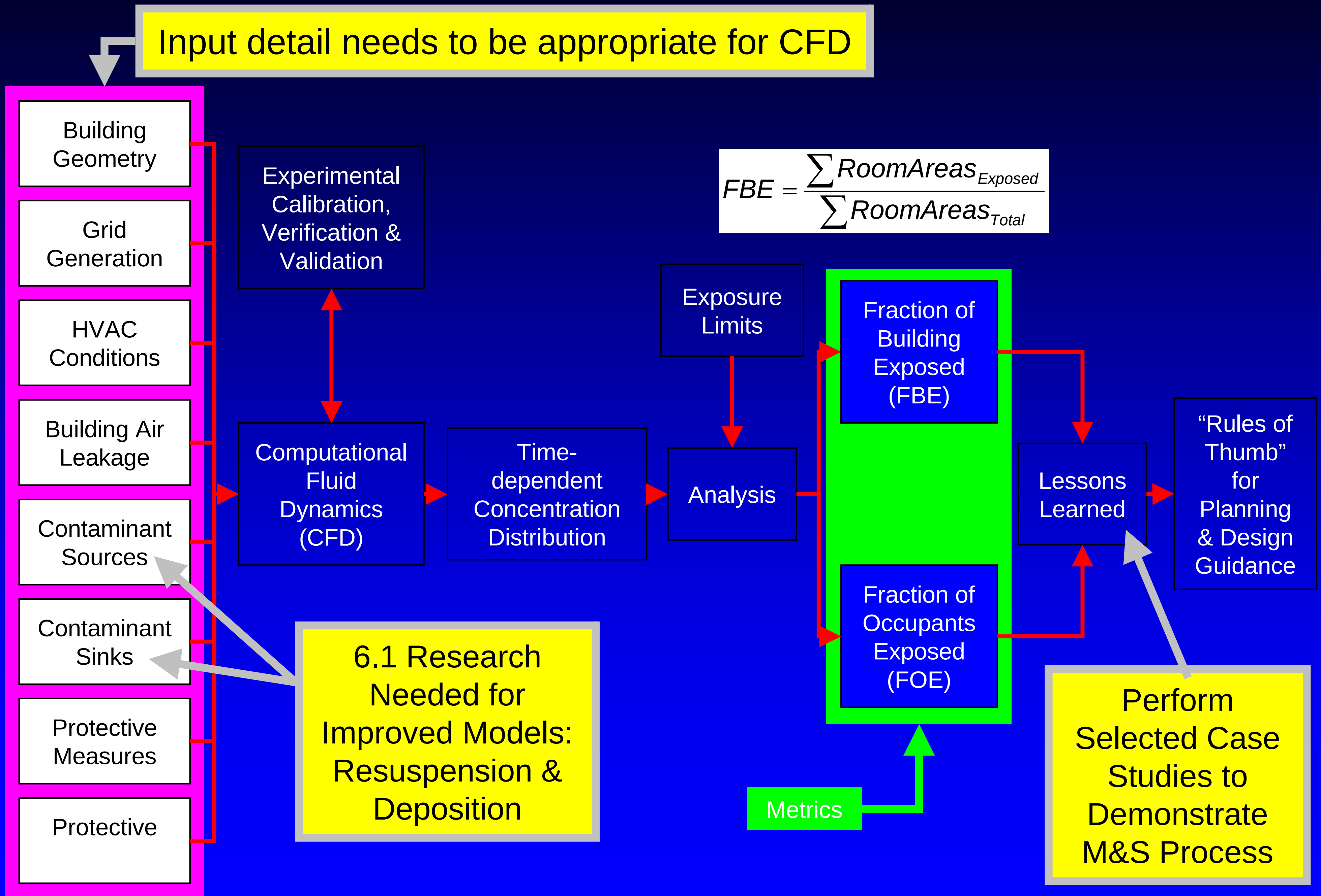


Uniform concentration in room (zone)

MZ results do not show maximum concentration

CFD results show orders of magnitude difference in concentration within room

M&S Process for Facility CB Protection

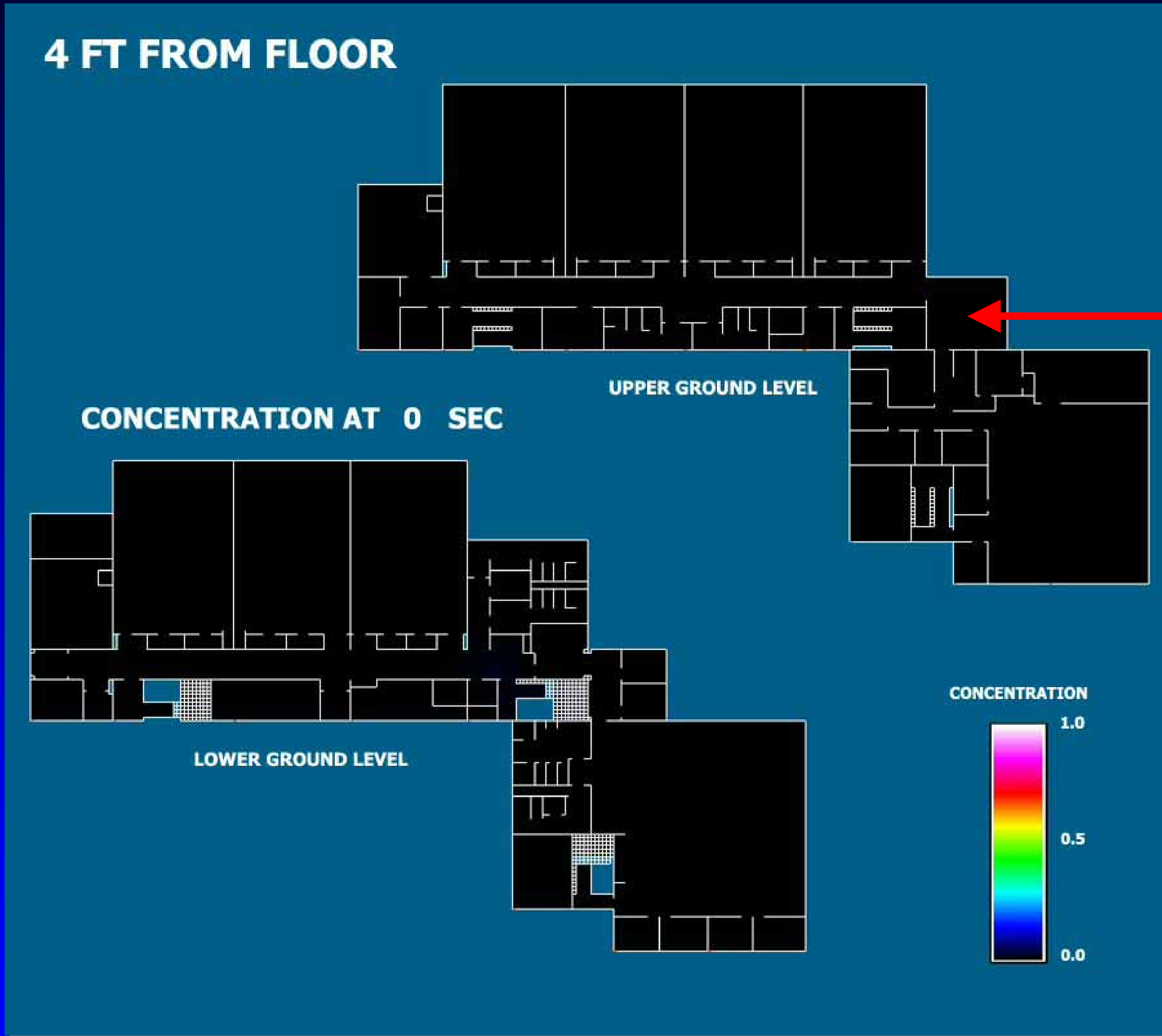


Example Qualitative CFD Simulation

Upper Level

Time Step (variable)

Lower Level



Source

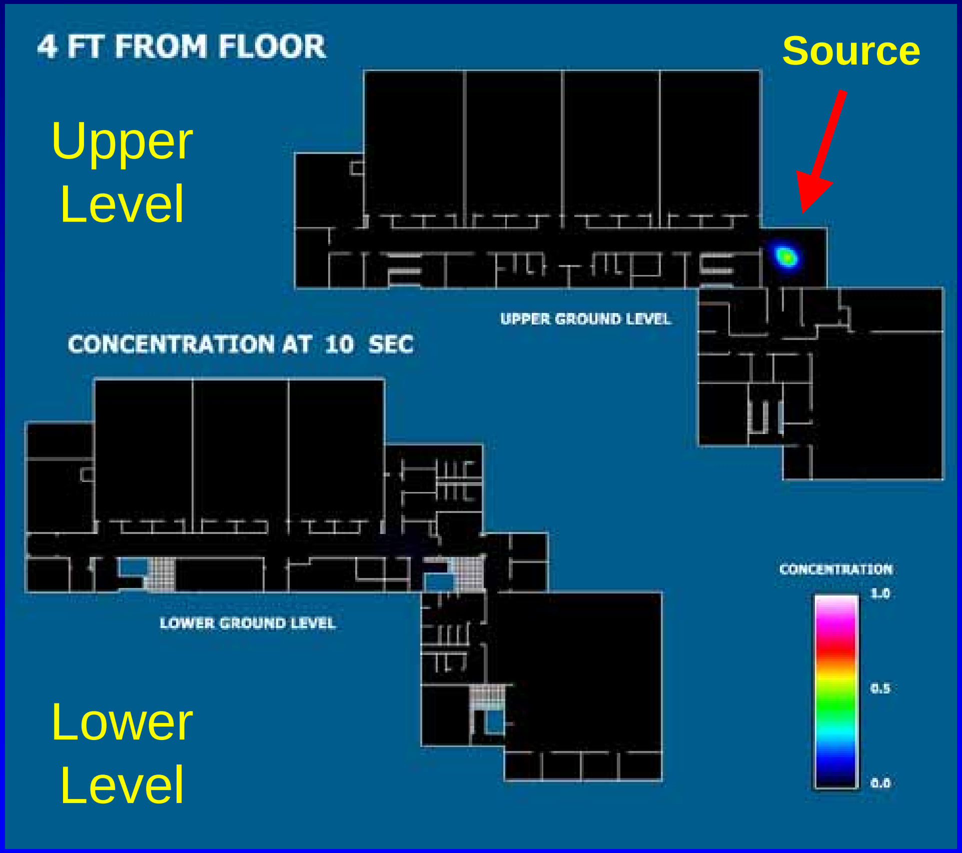
Results of CFD calculations yield insights into dynamic CB transport

Example Qualitative CFD Simulation

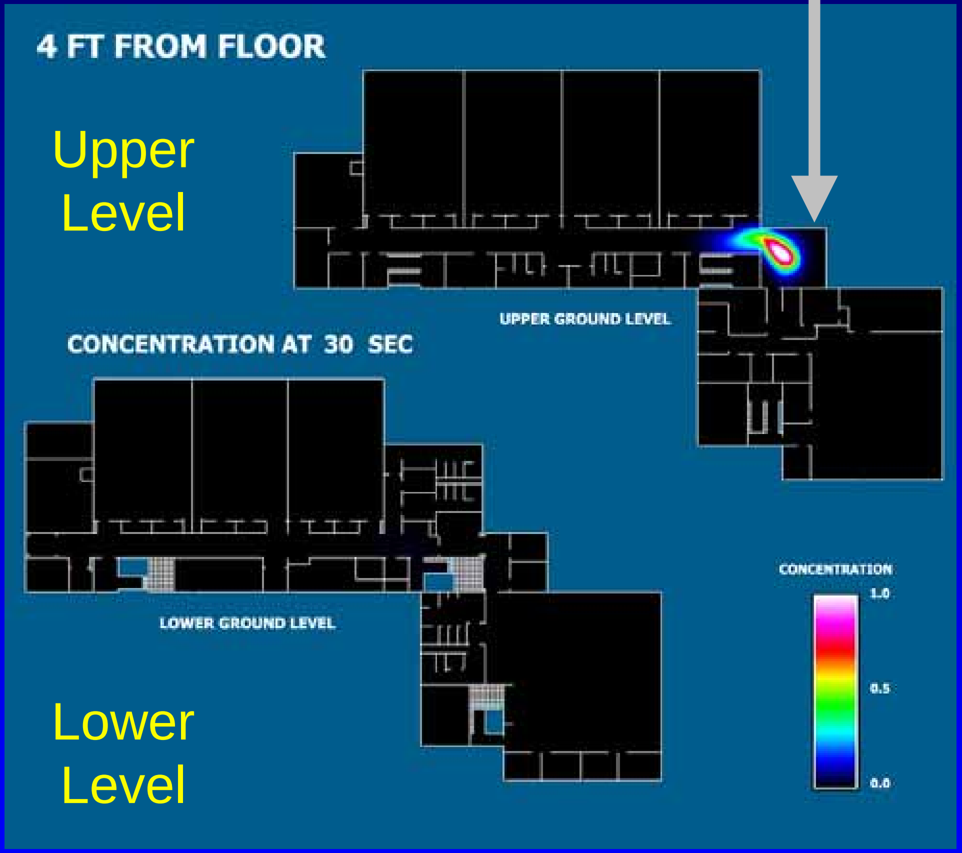
Continuous release of neutrally buoyant contaminant at 1-foot level in lobby of upper level of a two-level building with plenum HVAC return

(all interior doors open)

Nonuniform Concentration



Contaminant distribution at 10 seconds



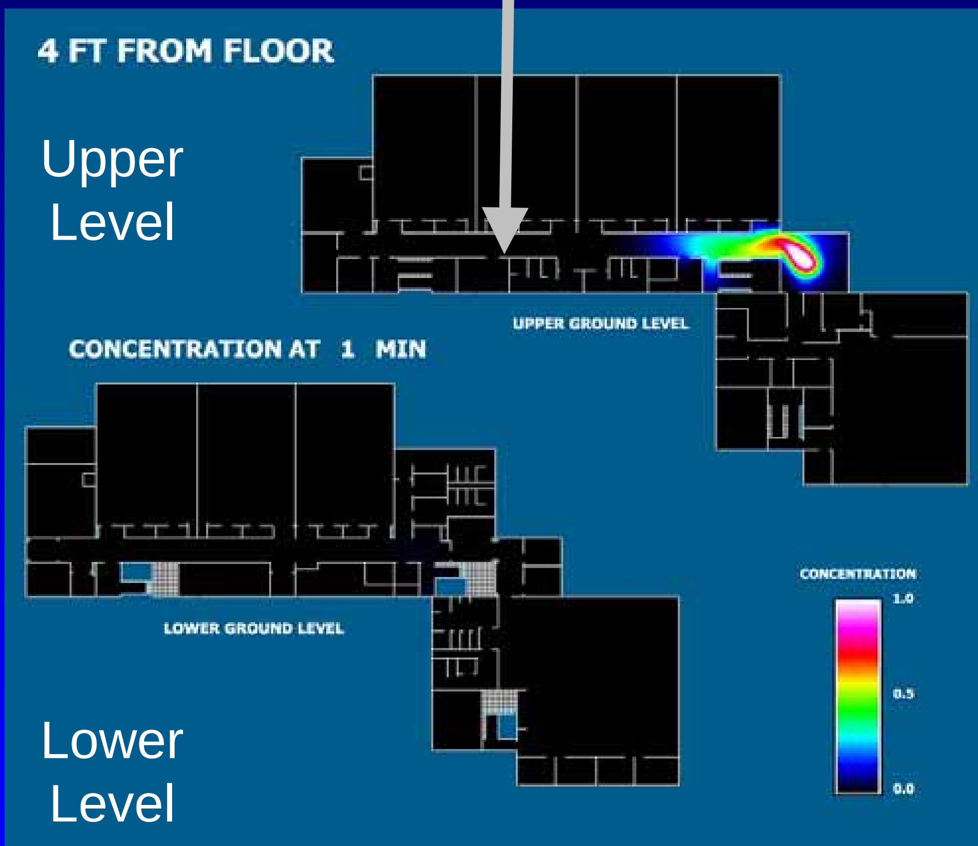
Contaminant distribution at 30 seconds

Example Qualitative CFD Simulation

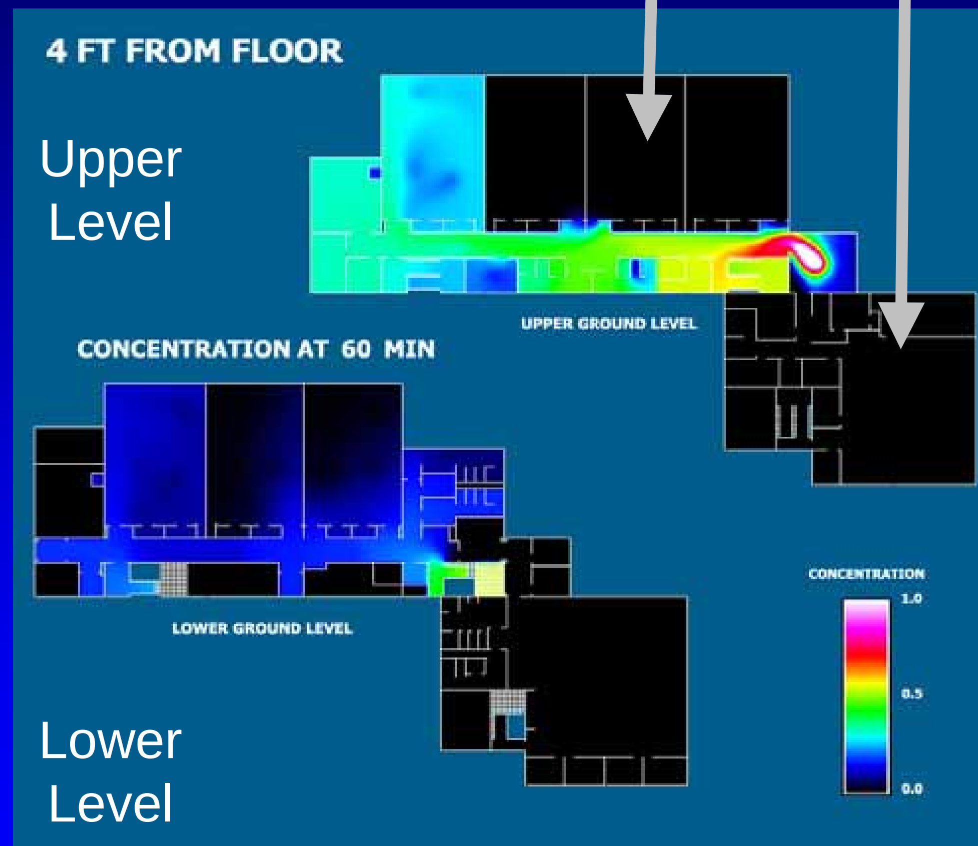
(Continued)

Contaminant Transport in Hallway

No Contaminant



Contaminant distribution at 1 minute



Contaminant distribution at 60 minutes

SUMMARY

- CBRSim software tool for modeling and simulating contamination infiltrating buildings from external release of chemical, biological and radiological (CBR) agents

- CBRSIM can be used by:
  - building planners
  - mission planners
  - mobilization, and emergency responders to determine when buildings are safe again for occupancy.

SUMMARY

- CFD modeling provides more accurate assessment of fate and transport of CB agents in HVAC systems
  - Allows exploration of alternative building designs
  - Better planning of escape routes
  - Optimum placement of sensors