RISK ENVIRONMENT: TENABILITY OF THE FIRE FLOOR

Policy makers have long lacked studies that quantify changes in fireground performance based on apparatus crew size and on-scene arrival time intervals. The NIST high-rise experiments were designed to observe the effect of these variables including company crew size, apparatus deployment (alarm size), the availability of stairs and elevators, and automatic sprinkler protection on the time it takes to execute essential fireground tasks and on the tenability inside a high-rise building, particularly on the fire floor and floor above the fire.

Computer modeling was used to estimate the tenability conditions inside the high-rise building as a function of the firefighter activities measured in the firefighter time-to-task portion of the study.

Research Question: How do crew size, alarm size, vertical ascent, and fixed fire sprinklers affect the resulting interior tenability on the fire floor?

Primary Funding: Larger fires produce more risk exposure for building occupants. In general, occupants being rescued by smaller crew sizes and by crews that use the stairs rather than elevators were exposed to significantly greater doses of toxins from the fire. While the exact risk exposure for an occupant will depend on the fire growth rate, their proximity to the fire, and the floor on which the fire is located, it is clear that on scene deployment decisions can have a dramatic impact in determining the fate of building occupants.

Tenability Due to Fire Gases

Fire simulation is used to calculate the change in interior conditions (spatially and temporally) of the high-rise due to the presence of fire. This analysis focused on the tenability (the likelihood that persons exposed to a specific dose of toxic products will be capable of escaping) of the fire floor. To characterize the accumulated hazard associated with inhalation of gases typical of combustion products, a time-integrated value known as the fractional effective dose (FED) is used. FED is an international standard, maintained by the International Standards Organization (ISO) and documented in ISO document 13571. FED is a probabilistic quantity used to estimate the impact of toxic gases on humans (ISO 2007). For this study, FED includes the impact of excess carbon monoxide and carbon dioxide inhalation and oxygen depletion. Additional gases such as cyanide, nitric oxide and irritants were not included in the calculation of the FED value as they tend to be of secondary importance compared to carbon monoxide, carbon dioxide, and oxygen. Depending on the fuels present, neglecting these species may affect the FED for occupants, potentially raising the FED value. Additionally, smoke density is a commonly used tenability criteria, since it may limit the ability of an occupant to find their way to an exit. However, it is assumed for this analysis that occupants are in a single fixed location for the duration of the fire event; therefore, smoke density is neglected. FED values are generally divided by three thresholds as they relate to the potential for certain portions of the population to become incapacitated.

Incapacitation is defined to be the point at which a person can no longer escape the hazardous area on his/her own.

The lowest FED threshold is 0.3, which typically relates to the most sensitive populations: elderly, young, or those with compromised immune systems. The lowest threshold group encompasses approximately 11 % of the population.

The second threshold occurs at an FED value of 1.0, which represents the level at which the median or 50 % of the population is likely to become incapacitated.

An FED value of 3.0 represents the upper threshold for tolerance to combustion gas inhalation where it is estimated that 89%+ of the population would likely become incapacitated. This formulation of FED assumes that the potential victim remains stationary over the course of the simulation. The table below shows the four bins created by the three threshold limits and the percentage of the population likely to become incapacitated.

FED Value Range	Estimated Population Range of Incapacitation	FDS-Smokeview Coloring
$0.0 < FED \leq 0.3$	$0.0 < \% \leq 11$	
$0.3 < FED \leq 1.0$	$11 < \% \leq 50$	
$1.0 < FED \leq 3.0$	$50 < \% \leq 89$	
$FED > 3.0$	$\% > 89$	

Tenability Results for CO, O2, CO2

On the fire floor, the victim was located in the cubicle at button 18 in the figures below. The local fractional effective dose (FED) of toxic gases experienced by the victim during the hypothetical high-rise fires can be calculated based on the average time at which button 18 was pressed during experiments. In order to study the effects of crew size and ascent method, data from high and low deployments were combined.

The time-to-task experiments used a pre-determined, fixed victim location in order to ensure repeatability and to evaluate the impact of the three main study variables. In reality, a victim can be located in any of the cubicles. It is therefore important to know how FED evolves throughout the entire fire floor as a function of time.

Victims may be situated anywhere on the fire floor. Therefore, in order to generalize the determination of FED at the time of rescue to victims in places other than the cubicle marked by button 18, the non-uniform contours of FED on the fire floor can be combined with the experimental time-to-task data by calculating FED values at the time and location of button press for each experimental configuration. Figure 1through Figure 4 below show the FED values on the fire floor at the time of the average button press (representing finding a victim in that location) as a function of crew size using the stairs.

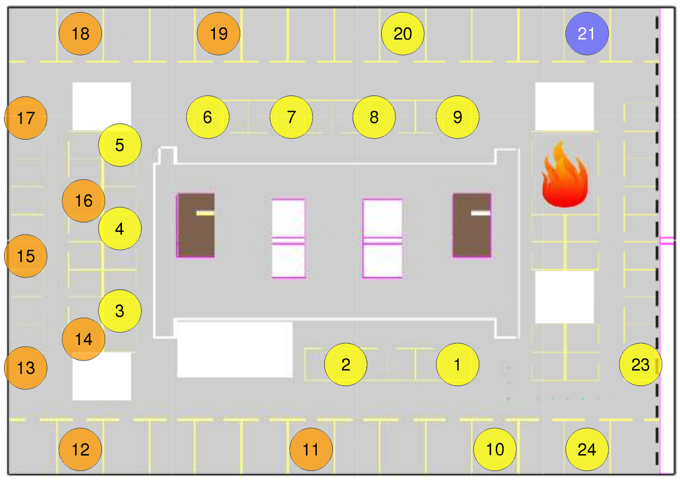

Figure 1: Crew size of 3 using stairs

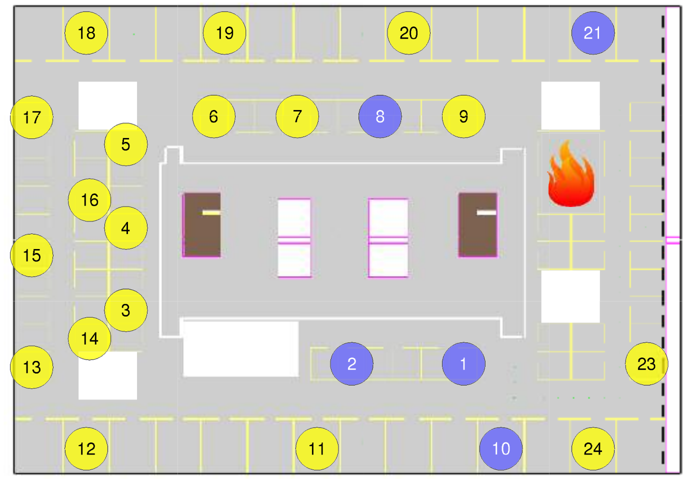

Figure 2: Crew size of 4 using stairs

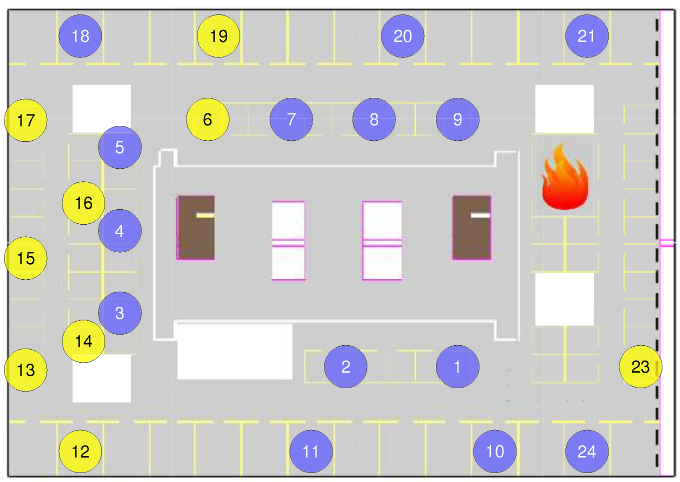

Figure 3: Crew size of 5 using stairs

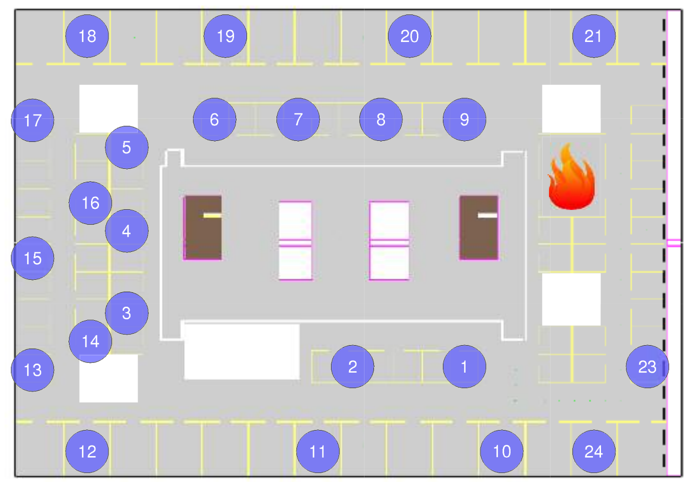

Figure 4: Crew size of 6 using stairs