2009 BFRL Project Description

Project Title: Safety of Building Occupants

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Principal Investigator: Jason Averill

Co-Investigators: Erica Kuligowski, Richard Peacock, and Paul Reneke

BFRL Program: Reduced Risk of Fire Spread in Buildings

Objective: To develop the technical foundation for best practices in the design and performance prediction of building evacuation and emergency access systems by developing and applying new measurement science in human behavior, movement of people, and related building systems and technologies.

Problem:

What is the problem? Currently, systems are designed around an antiquated concept of providing stair capacity for the largest occupant load floor in the building with little or no consideration of occupant behavior, needs of emergency responders, or evolving technologies. The NIST World Trade Center Investigation[1] clearly demonstrated a need for the engineering and architecture communities to ensure timely and reliable means for full building evacuation, consideration of available evacuation technologies (including use of elevators), accounting for occupants with mobility impairments,[2] and provisions for timely and reliable access for first responders. While numerous numerical models are available for egress analysis, the dearth of usable input or validation data renders model output highly uncertain. The need for validated models and data is seen as a significant measurement need for technological innovation in building construction in the NIST Assessment of the United States Measurement System (SP 1048) and in recent workshops on evacuation.[3]

Why is it hard to solve? A substantial leadership vacuum within the research arena of building egress in North America has exacerbated the growing problems. These problems include the inherent variability of human responses, obtaining access to buildings and populations during an evacuation for data collection, and the difficulty of collecting real-time building evacuation data during significant building emergencies.

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[1] *NIST NCSTAR 1, Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Final Report of the National Construction Safety Team on the Collapses of the World Trade Center Towers.* 2005.

[2] The NIST WTC Investigation estimated that 6 percent of the population who evacuated on September 11, 2001 had a mobility impairment.

[3] June 2004 at NIST, February 2008 *Pedestrian and Evacuation Dynamics Conference* in Wuppertal, Germany, and April 2008 *Rethinking Egress Workshop* in Warrenton, Virginia.

How is it solved today, and by whom? The current approach adopted by the evacuation community focuses on deterministic solutions using physics-based modeling analogues (such as fluid or electron flows). While appealing from a computational and theoretical perspective, evacuation is more stochastic than deterministic and there are no models that approach the complexity of human behavior. There is limited data on which to base such models. Only one group besides NIST is collecting building evacuation data, which is kept largely proprietary. Further, there is reason to question much of the available data due to changing occupant demographics in the United States and building design.

Why NIST? Concerted efforts in the last year have led to BFRL as a leading organization providing occupant movement and behavior data for building egress standards and performance-based design. Realistic prediction of occupant movement in buildings is key to performance-based standards for egress systems.

Approach:

What is the new technical idea? This approach will integrate multiple research areas into a comprehensive project. Critical to this understanding are several research areas: fundamentals of human behavior, people movement, enabling technological innovation, predictive model development and leadership in the stakeholder communities. BFRL will primarily focus on two of these areas in the short term: movement of people in stairwell evacuations and human behavior during fire emergencies. In people movement, analysis of newly collected evacuation data will provide a quantitative base for egress models. In human behavior, combining the vast body of knowledge in disciplines outside of the fire community with the extensive data set from the face-to-face interviews of the World Trade Center evacuation of 2001 will establish a foundation for explaining pre-evacuation behaviors of occupants, which will improve the predictive capability in future fire evacuations from buildings.

Why can we succeed now? Over the past several years, NIST has established partnerships with developers, other government agencies, researchers, and the fire service which can only now be leveraged. NIST has established a leadership position in the field of egress research through the WTC Investigation, recent research activities, and the Rethinking Egress workshop. The technical credibility, objectivity, and existing governmental and industrial partnerships enable NIST to bring disparate perspectives together to accomplish the long-term objectives.

What is the research plan? One of our areas of research includes people movement; specifically the collection and analysis of people movement data. Dependent upon negotiating access, it is expected that additional building observations will be conducted to further a study of the key parameters for stairwell movement. These key parameters include the density of the stair, stairwell width, first-responder counterflow, and building height. Also we will analyze egress data already collected. Presently, data from 6 building evacuations have been collected in buildings ranging from 6 to 62 stories. These data will be analyzed to obtain movement speeds of people down stairs as a function of occupant density, travel distance, merging behavior, delay time, and door size. Secondary analysis characteristics include handrail usage, occupant stagger geometry, body sway, body size, and counter-flow frequency (if any). In human behavior, BFRL will build upon a conceptual model of human behavior during the pre-evacuation phase that is based on comparison of the literature from disaster theory on collective behavior during crisis

and decision theory during uncertainty to fire evacuations. BFRL will begin to convert these conceptual findings to computer modeling input to simulate human behaviors in egress models, including submodels for elevator evacuation leveraging the existing work of Klote, et al. Finally, NIST will convene a workshop to follow-up on the results of the "Rethinking Egress" workshop. The objective of the workshop will be to develop a long-term R&D agenda for building egress and firefighter access.

Recent Results:

Outputs:

- Presentations on stairwell evacuation data, pre-evacuation behaviors, and storage and use of egress data at Pedestrian and Evacuation Dynamics Conference in Wuppertal Germany (2/2008).
- Presentation of egress modeling methods at SFPE Performance-based Deign Conference in Auckland, New Zealand (4/2008).
- Video-based observation of six fire drill evacuations have been completed with analysis published for three[4]. Additional analysis and publications are pending.
- NIST held a significant workshop ("Rethinking Egress") in 2008 which brought thought leaders from over 20 disciplines together in order to brainstorm new approaches to building evacuation. Over 400 solutions were posited. Publication pending.

Impact:

- Protected elevators for egress during fire, which explicitly credit NIST/ASME activity, are being included as design features in several buildings worldwide, including the Burj Dubai tower in United Arab Emirates, several in London by Arup Fire, in the Petronas Towers (Kuala Lumpur), and in Taipei 101.

Standards and Codes: Project staff serves on the ICC Means of Egress committee and the NFPA 101 Life Safety Code committee in order to ensure transfer of research findings to building codes. Recently, requirements for protected elevators for first-responder access were approved for adoption in the ICC and NFPA building codes.[5] A similar proposal to that submitted to ICC was accepted by NFPA 101/5000 addressing protected elevators for evacuation prior to Phase I for the 2009 edition.

[4] Averill, J. D. and Peacock, R. D., "The Influence of Stair Width on Descending Pedestrian Evacuation," Fourth International Conference on Pedestrian and Evacuation Dynamics, Wuppertal Germany, February 2008 (Proceedings forthcoming).
[5] International Building, 2008 Interim Edition and NFPA 101/500, 2009 Edition (Publication pending)