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PRESS RELEASE

Scientists recreate World Trade Centre horror

A computer simulation of the mass evacuation from World Trade Centre Building 1 (WTC1) has concluded that on 11 September 2001, everyone who could get out did get out prior to the building's collapse. Scientists at the University of Greenwich used their EXODUS evacuation simulation software to recreate the disaster as it unfolded in the building struck first in the terrorist attack. The impact of the aircraft severed the three emergency staircases, effectively dooming those caught above. The simulations reveal that had a single staircase survived linking the top of the building to ground level, it is likely those people surviving the crash would have successfully evacuated. However, it would have been a very different story had the buildings been fully occupied.

The advanced evacuation simulation software package buildingEXODUS, developed by the Fire Safety Engineering Group (FSEG) of the University of Greenwich, is being used to probe the tragic events of September 11 in which over 2,000 building occupants are thought to have perished - over 1,400 people in WTC1 alone.

The simulations of the WTC1 evacuation assumed that the approximately 7,000 people were uniformly distributed throughout the building. The floors above floor 91 were then severed from the remainder of the building, essentially dooming the 1434 occupants above. The simulation then progressed allowing the building occupants to evacuate via their nearest available staircase. The results suggest that the remaining 5,544 people were able to evacuate the building in **1 hour 32 minutes**. WTC1 collapsed after **1 hour 42 minutes.**

"The results were quite staggering – showing that the model we have constructed fits the available data very well, and suggesting that it is capable of reproducing the actual events with a reasonable degree of accuracy," says Professor Ed Galea, director of FSEG. "But what is more interesting is that the model allows us to explore 'what-if' scenarios to better understand the interaction between, building design, population behaviour and scenario evolution."

One such scenario the group has explored is what would have happened had at least one staircase survived the impact. Could the people above the impact zone have managed to escape before the building collapsed? The simulations suggest that all 6,696 impact survivors would have managed to escape with a total evacuation time of **1 hour 34 minutes.**

"These results suggest that had at least one staircase survived from top to bottom, it is possible that everyone that survived the initial trauma of the impact could have managed to safely escape," says Professor Galea. "This underlines the importance of staircase dispersal within buildings. We need to make it less likely that we can lose all means of escape in the event of a catastrophic incident, and that staircases are sufficiently hardened to withstand plausible threats."

Another scenario the group explored was what might have happened if the building had been fully occupied. The team repeated the simulations assuming that 24,924 people were in the building. Assuming that none of the 4,288 people above the 91st floor impact zone would have been able to escape, the simulation revealed that the rest of the building would have taken **2 hours 3 minutes** to evacuate, compared to the time available of **1 hour 42 minutes.** This means that at the time of the collapse of WTC1, **1,530 people** would have been on the stairs trying to get out, in addition to those caught above the 90th floor. If WTC1 had collapsed in the 56 minutes that were available to the occupants in WTC2, **13,373 people** – over 50% - would have died.

"One of the interesting things we have seen from these calculations is the massive congestion that can develop within the stairs, and the impact this has on individual travel speeds," says Professor Galea. "People are moving really quite slowly in some

places. Some from the upper floors can expend as much as 70% of their travel time caught in congestion. Clearly, procedures for a phased evacuation of part-of or an entire building must be developed to allow the people most at risk to expedite their evacuation."

Another scenario examined considered what would happen if a single staircase survived from top to bottom with an occupancy of 25,000. The results for this case are strongly dependent on which staircase survives. However, results suggest that in the worst case, the building requires **3 hours 2 minutes** to evacuate. What is more concerning is that after 56 minutes – the time that occupants of WTC2 had to evacuate – 13,385 people would still be on the stairs trying to get out of WTC1 and after 102 minutes – the time that occupants of WTC1 had to evacuate – 5,813 would still be trying to evacuate. In this case, the same total number of people would have perished regardless of whether a single staircase had survived or not.

"Calculations of this type are providing us with insight into building performance under extreme conditions," says Professor Galea. "We hope that what we learn from these calculations will assist us to build safer buildings, and develop procedures for existing buildings that will assist in maximising chances of survival in extreme events. It is important to note that these results are preliminary and that that the model, while providing a good representation of reality, is not perfect – yet. There are some factors that we have not considered, such as fatigue. On descending 110 floors the average person will tire and slow down; they may even stop for a rest. This was not taken into account in these simulations. We need to do much more research to collect data to improve the quality of our predictive models."

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NOTES FOR EDITORS

THE EXODUS WTC MODEL

In attempting to simulate the events of 911, members of FSEG have reconstructed an approximate representation of WTC1 in the EXODUS software. The geometry is an approximation to the actual building as many details of the structure were not available to FSEG. The model also assumes that there is no significant damage to the building below the impact floors but that the elevators are not available to assist in the evacuation. In addition, the model incorporates estimations to several key factors such as the number and location of people and essential parameters such as the occupant response time. This is the time that occupants spend between the event occurring i.e. aircraft smashing into one of the buildings and the time that occupants begin to purposely evacuate.

As an estimate of the number of people in the building at the time of impact, the FSEG team have taken as an upper estimate the numbers reported in ***USA Today*** of approximately 7,000 people. The model actually considered 6,978 people. Of these 1,434 were assumed trapped above the impact zone or were killed by the impact. In the simulations involving a surviving staircase, it is assumed that 282 people from four floors are killed by the impact and 6,696 people remain alive in the building, 1,152 above the impact zone. For the response time analysis, FSEG used data collected from accounts of survivors of 911 available in the media. They studied close to 300 accounts from survivors of the WTC disaster. Of these, 73 accounts were useful in providing good information upon which to base a response time distribution for WTC1. The analysis suggests that occupant response times in WTC1 could have been as long as 64 minutes.

THE EXODUS SUITE OF SOFTWARE

Developed by the University of Greenwich's Fire Safety Engineering Group (www.fseg.gre.ac.uk), the EXODUS suite of evacuation software uses complex interacting sub-models to predict evacuation behaviour during emergencies such as fires. The software's sophistication means that people are represented as individuals with real human behaviour, such as returning to their desk to collect a handbag or searching for a child. Simulated occupants even react to the heat, smoke and toxic gases generated by a fire. EXODUS simulations allow engineers to assess more

potential designs than conventional methods and are free of the potential danger and high cost of conventional human evacuation trials.

THE FIRE SAFETY ENGINEERING GROUP

Located in the School of Computing and Mathematical Sciences, The Fire Safety Engineering Group consists of a 30-strong multi-disciplinary team of mathematicians, behavioural psychologists, fire safety engineers and computer scientists. The group was established in 1986 and the modelling philosophy behind EXODUS has been developed and refined through 13 years of research into understanding and simulating evacuation, as well as the rigours of the peer review process in both academic journals and doctoral examination. The group has also produced the SMARTFIRE fire simulation software. The group has won a number of prestigious national and international awards for their work including the Queen's Anniversary Prize 2003 and the European IST Award 2004.

PROFESSOR GALEA

Professor Ed Galea is the founding director of the Fire Safety Engineering Group (FSEG) at the University of Greenwich, where he has worked in fire safety research since 1986. His work in fire safety engineering began after the tragic Manchester Boeing 737 fire, when he was commissioned by the UK Civil Aviation Authority to simulate the spread of fire and smoke in the disaster. Since then his research has expanded to include the modelling of evacuation, people movement, fire/smoke spread, combustion and fire suppression in the built environment, rail, marine and aviation environments. Professor Galea is the author of over 100 academic and professional publications related to fire. He serves on a number of national and international standards and safety committees concerned with fire and evacuation including BSI, ISO, IMO and SFPE. His research and consultancy activities have been supported by a wide range of European and North American organisations. His research group have developed the EXODUS suite of evacuation software and the SMARTFIRE fire simulation software.