



buildingEXODUS The Evacuation Model for the Built Environment

buildingEXODUS is more than simply an evacuation model, it is a computer based laboratory for evaluating the emergency and non-emergency movement and behaviour of people.

Developed within the Fire Safety Engineering Group (FSEG) through pioneering research and development at the University of Greenwich, buildingEXODUS simulates **people-people**, **people-fire** and **people-structure** interactions. The model tracks the path of each individual as they make their way out of the enclosure, or are overcome by fire hazards such as heat, smoke and toxic gases.

High profile projects buildingEXODUS has been used on include:

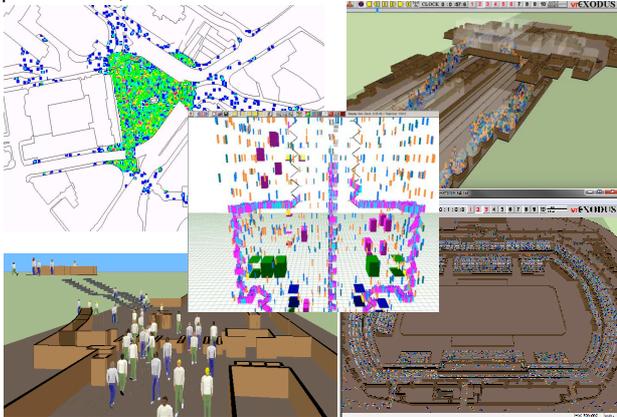
- **Pentagon US Dept Defence**
- **Statue of Liberty Redevelopment**
- **2nd Avenue Subway extension, New York**
- **San Francisco Subway**
- **London Millennium Dome**
- **Sydney Olympic Stadium**
- **World Trade Center 9/11 evacuation analysis**
- **Beijing Olympic Stadium**



buildingEXODUS applications

THE EXODUS MODEL

The software is written in C++ using Object Orientated techniques and utilises rule-based software technology to control the simulation. For additional flexibility these rules have been categorised into five interacting submodels known as the Occupant, Movement, Behaviour, Toxicity and Hazard models. These operate on a region of space defined by the geometry of the enclosure. Internally, the geometry is covered in a mesh of nodes. The nodes are linked by a system of arcs. Each node represents a region of space typically occupied by a single person. Lifts, escalators and stairs can be modelled.



Pedestrian dynamics for city centre concert, underground station fire and evacuation, station pedestrian circulation, stadium evacuation, building circulation using lifts

buildingEXODUS FEATURES

- buildingEXODUS is available for Windows including: XP, Vista, 7, 8 and 10, in both 32 and 64 bit versions
- Minimum PC spec required: P4 1.5 GHz, 1GB RAM.
- Multithreaded implementation, typical software performance:
 - 30,000 agents, 60,000m² enclosure, 5.9 min using 3.3GHz, 8Gb PC
 - 8,100 agents in 50 storey building, 25 min using 3.3GHz, 8Gb PC.
- Simulates evacuation/circulation pedestrian dynamics including lifts.
- Reads CAD, BIM, FDS and SMARTFIRE geometry files.
- Ability to distinguish emergency exits from normal exits and assign exit usage according to occupant familiarity.
- Simulates occupant interaction with lifts, escalators, stairs and signage
- Itinerary function enabling allocation of tasks
- Link to SMARTFIRE CFD fire simulation and CFAST
- Toxicity calculations determined using FED models.
- Occupant reaction to fire irritant gases
- Determines time spent in congestion for each occupant.
- Census nodes/lines allows flow statistics of any arbitrary point within the structure to be recorded.
- Interactive run-time 2D graphics allows occupant interrogation.
- Run-time 2D graphics can display:
 - individual occupants, - population densities,
 - smoke and temperature distribution.
- Run-time 3D graphics can display operation of lifts and movement of agents between floors in both population density and individual modes
- All new vrEXODUS post-proc Virtual Reality animation tool enables the rapid 3D visualisation of very large data sets and the creation of WMV movie files.
- askEXODUS is a tool designed to assist in the analysis of large data output files produced from multiple runs
- Batch Mode allows rapid execution of multiple runs.



Fire in train in tunnel. SMARTFIRE is used to predict the fire, smoke and toxic gas spread, buildingEXODUS is used for the evacuation analysis

NEW FEATURES SOON TO BE RELEASED/UNDER DEVELOPMENT

- Urban scale evacuation
- Parallel simulation capability
- Emotion modelling
- Development of hybrid version linking, coarse, fine and continuous representation within single model



EXODUS urban scale evacuation analysis, reads Open Street Map geometry, simulates 250,000 agent evacuation over 1.2km x 1.2km region



EXODUS hybrid model



Contact: Prof Ed Galea

e.r.galea@gre.ac.uk

<http://fseg.gre.ac.uk>

Phone: + 44 (0)208 331 8730



Fire Safety Engineering Group

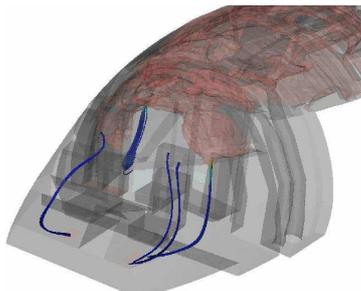
The University of Greenwich
London SE10 9LS



A WORLD LEADER IN COMPUTATIONAL FIRE ENGINEERING

The Fire Safety Engineering Group (FSEG) of the University of Greenwich was founded by Prof Galea in 1986. The research and consultancy interests of the 30 strong team are focused on the development and application of Computational Fire Engineering (CFE) tools for the simulation of evacuation, non-emergency circulation of people, combustion, fire/smoke spread, structural response to fire and fire suppression. High profile applications of FSEG skills and technology in the built environment, aerospace, marine and rail sectors include:

- **9/11 WTC** – evacuation analysis
- **Airbus A380 super jumbo** - evacuation analysis
- **SwissAir MD11 disaster inquiry** – fire analysis
- **New Royal Navy aircraft carrier (CVF)** – evacuation analysis
- **Ladbroke Grove rail disaster inquiry** – fire/evacuation analysis
- **Sydney Olympic Stadium** – evacuation analysis

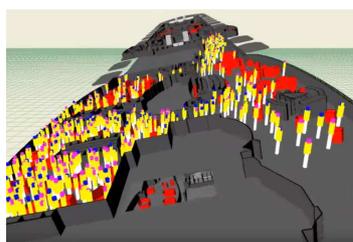
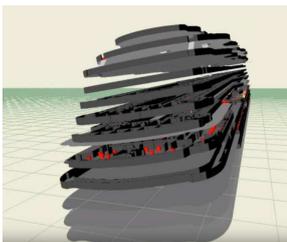


SMARTFIRE generated fire and smoke spread in above ceiling aircraft space

INTERNATIONAL RESEARCH AND CONSULTANCY

FSEG is one of Europe's leading centres of excellence in CFE. It is also one of the largest university-based groups dedicated to the modelling of fire and related phenomena in the world. FSEG has published over 330 academic and professional publications on fire and related topics. Since 2010 FSEG has generated over £10 million worth of research and consultancy funding and its research and consultancy activities have been supported by a client base including:

EADS, BAe Systems, BA, Buro Happold, BMT, Canary Wharf Management Ltd., EPSRC, EU, European Space Agency, Mitsubishi, LPC, MCA, NHS, Arup, RINA, Borealis, Rockwool, Thales, The Engineering Link, MOD, Lloyds Register, CAA, FAA, FRA, Boeing, NTSB, Bombardier, Canadian Dept of Trans, US Dept of Trans, Canadian Transportation Safety Board, US Federal Rail Administration.



maritimeEXODUS: Simulation of assembly while vessel is heeling

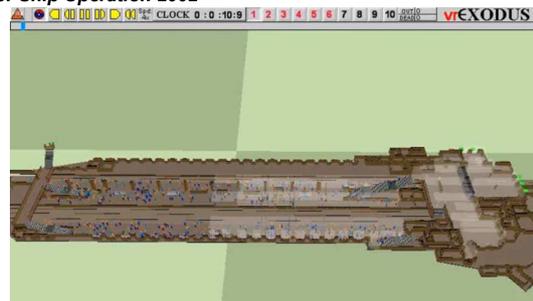
Examples of FSEG research and consultancy projects include:

- Analysis of naval/passenger ship design for evacuation
- Fire/smoke analysis for underground stations
- Evacuation analysis of high-rise buildings
- Fire/evacuation design and certification analyses for aircraft
- Circulation/evacuation analysis for airports and subways
- Analysis of evacuation provision for hospitals
- Prediction of toxic gas generation resulting from cable fires
- Full-scale and experimental scale evacuation trials in aircraft, buildings, ship and rail environments.

AWARD-WINNING SOFTWARE

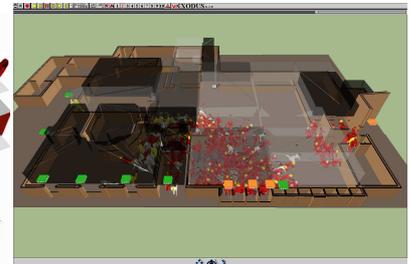
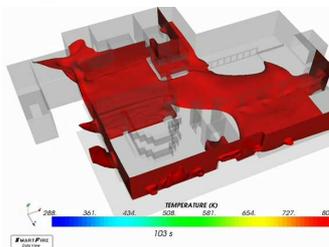
Research undertaken by FSEG has led to the development of the CFE software: SMARTFIRE, buildingEXODUS, airEXODUS, maritimeEXODUS and railEXODUS. These products are distributed world-wide by FSEG to customers in 35 countries. FSEG's innovation has been recognised through a number of prestigious awards:

- **International Journal of Maritime Engineering Medal of distinction 2014**
- **The Guardian University Award for Research Impact 2014**
- **SFPE Bono Award 2008**
- **Royal Aeronautical Society's Gold Award and George Taylor Prize 2006,**
- **IST prize 2004 awarded by the EU and the European Council of Applied Sciences, Technology and Engineering**
- **Queen's Anniversary Prize 2002**
- **British Computer Society IT Award, 2001**
- **Royal Institution of Naval Architecture/Lloyds Register Safer Ship Award 2001**
- **Communications & IT in Shipping Award for Innovation in IT for Ship Operation 2002**



buildingEXODUS: Occupant interaction with fire, smoke and toxic gases during evacuation from a station
KNOWLEDGE TRANSFER

Members of FSEG are actively involved in the supervision of doctoral and masters level research students concerned with fire safety and the development and delivery of fire safety engineering courses, including, short courses for industry, MSc by Research and Taught MSc programmes.



Linked SMARTFIRE and buildingEXODUS simulation of Rhode Island disco fire incorporating smoke, heat, toxic and irritant gases.

HELPING SET INTERNATIONAL STANDARDS

FSEG expertise is sought by standards bodies such as the BSI, ISO, IMO and SFPE and is used to set standards in life safety, fire safety engineering and the use and validation of CFE tools.



Evacuation Trials: FSEG conduct evacuation trials in a range of environments including hospitals, ships, underground stations and rail cars in order to collect human performance data



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