Computer Models For Evacuation

Model Name:	maritimeEXODUS
Version:	4.1
Date:	1 August 2007
Classification:	Human behaviour/evacuation model
Very Short Description:	A PC based evacuation and pedestrian dynamics model that is capable of simulating individual people, behaviour and vessel details. The model includes aspects of people-people, people-structure and people-environment interaction. It is capable of simulating thousands of people in very large ship geometries and can incorporate interaction with fire hazard data such as smoke, heat and toxic gases and angle of heel.
Modeler(s), Organization(s):	EXODUS development Team, FSEG, The University of Greenwich, key members consist of Prof Ed Galea, Dr Peter Lawrence, Mr. Lazaros Filippidis, Mr. Darren Blackshields and Mr. David Cooney
User's Guide:	maritimeEXODUS V4.1 User Guide and Technical Manual, Doc Rev 4.1, June 2007.
Technical References:	maritimeEXODUS User Guide and Technical Manual "Recommendations on the Nature of the Passenger Response Time Distribution to be used in the MSC 1033 Assembly Time Analysis Based on Data Derived from Sea Trials.", Galea, E.R., Deere, S., Sharp, G., Filippidis, L., Lawrence, L., and Gwynne, S., International Journal of Maritime Engineering, Vol 149, Part A1, ISSN 1479-8751, pp 15-29, 2007. "The Impact of the passenger response time distribution on ship evacuation performance.", S. Deere, E.R. Galea, P.J. Lawrence and S. Gwynne, International Journal of Maritime Engineering, Vol 148, Part A1, ISSN 1479-8751, pp 35-44, 2006.

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Availability: Contact Professor E. Galea, FSEG, The University of Greenwich, 30 Park Row, Greenwich, UK SE10 9LS, e.r.galea@gre.ac.uk, http://fseg.gre.ac.uk/exodus/, phone: +44 (0)20 8331 8730

Price: Annual commercial licenses: Level 2: UK£6000, Level 1: UK£3000. Significant discounts available for: education, fire departments, government authorities, joint purchase with SMARTFIRE fire modeling software, multi-license and multi-year purchases.

Necessary Hardware:	PC/Workstations running Windows 32-bit or 64-bit editions.
Computer Language:	C++
Size:	Approximately 30MB for main application
Contact Information:	Prof Ed Galea FSEG, The University of Greenwich, 30 Park Row, Greenwich, UK SE10 9LS, exodus@gre.ac.uk +44 (0)20-8331-8730.

Detailed Description:

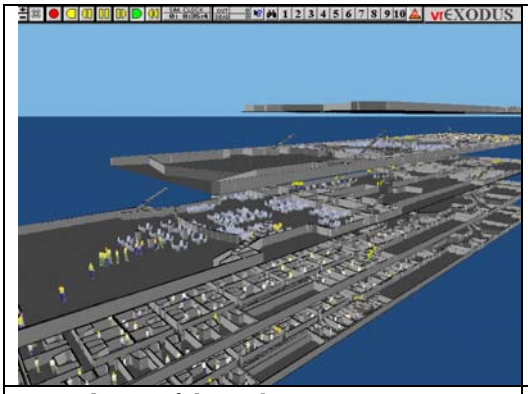
THE maritimeEXODUS SOFTWARE

The EXODUS software takes into consideration people-people, people-fire and people-structure interactions. The model tracks the path of each individual as they make their way to the muster location, or are overcome by fire hazards such as heat, smoke and toxic (narcotic and irritant) fire gases. EXODUS produces interactive two-dimensional graphics allowing the user to observe and interrogate the evacuation as it takes place. To aid in the interpretation of results, a post-processor virtual-reality graphics environment known as vrEXODUS (vrEXODUS available as part of Level 2 software) is provided which produces animated three-dimensional representations of the evacuation. More information about EXODUS can be found on our web pages at http://fseg.gre.ac.uk/exodus/. The following is a brief introduction into maritimeEXODUS.

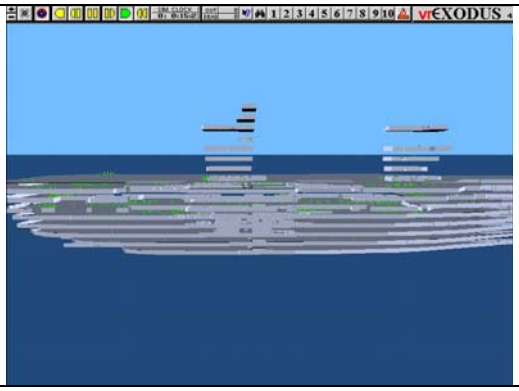
EXODUS is a suite of software tools designed to simulate both evacuation behaviours and pedestrian dynamics of large numbers of people within large complex enclosures. maritimeEXODUS is the ship version of the software. The maritimeEXODUS model comprises five core interacting sub-models, these are the ***Occupant, Movement, Behaviour, Toxicity and Hazard*** sub-models. The software, written in C++ using object orientated techniques, is rule-based, the progressive motion and behaviour of each individual being determined by a set of heuristics or rules.

The spatial and temporal dimensions within maritimeEXODUS are spanned by a two-dimensional spatial grid and a simulation clock (SC). The spatial grid maps out the geometry of the vessel, locating exits, internal compartments, obstacles, etc. Vessels with multiple decks can be made up of multiple grids connected by staircases or ladders, with each deck being allocated a separate window. The vessel layout can be specified using either a DXF file produced by a CAD package, or the interactive tools provided, and may then be stored in a vessel library for later use. The grid is made up of nodes and arcs with each node representing a small region of space and each arc representing the distance between each node. Individuals travel from node to node along the arcs.

The ***Occupant sub-model*** allows the nature of the passenger and crew population to be specified. The population can consist of a range of people with different movement abilities, reflecting age, gender and physical disabilities as well as different levels of knowledge of the enclosure's layout, response times etc. The population can be created manually by the user through a variety of "Population Panels" or dynamically at run time via the use of "Source Nodes".

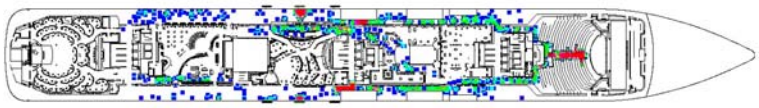


Simulation of the night mustering scenario for a large passenger ship using maritimeEXODUS V4.1



Simulation of abandonment process for a large aircraft carrier using maritimeEXODUS V4.1

Simulation of evacuation from HMS Victory using maritimeEXODUS V4.1



Simulation of non-emergency circulation scenario on board a large cruise ship using maritimeEXODUS V4.1 depicted in population density mode

Figure 1: Ship evacuation simulations produced using the maritimeEXODUS software

On the basis of an individual's personal attributes, the ***Behavior sub-model*** determines the occupant's response to the current situation, and passes its decision on to the ***Movement sub-model***. The Behavior sub-model functions on two levels, Global and Local. Global behavior involves implementing an escape strategy that may lead an occupant to exit via their nearest serviceable exit or most familiar exit. The desired global behavior is set by the user, but may be modified or overridden through the dictates of local behavior, which includes such considerations as determining the occupant's initial response, conflict resolution, overtaking, etc. In addition a number of localized decision-making processes are available to each individual according to the conditions in which they find themselves and the information available to them. This includes the ability to customize their egress route according to the levels of congestion around them, the environmental conditions and the social relationships within the population. It is also

possible to assign individuals with an itinerary of tasks – such as visit a pre-defined location - that must be completed prior to evacuation. To allow for dynamic paths to be adopted by the occupants these itinerary points could act as redirection nodes instructing the occupants to adopt alternative paths while evacuating or circulating. The occupants' behaviour can also be influenced by the presence of signage. Occupants can dynamically modify their egress routes through the detection of a wayfinding signage system. As certain behavior rules, such as conflict resolution, are probabilistic in nature, the model will not produce identical results if a simulation is repeated.

Another important aspect of human behaviour which is included in martimeEXODUS is the manner in which passengers react to ship orientation. Their movement rates in corridors on stairs and through doorways at various angles of heel is represented within model and based on data generated from large-scale trials. Naval vessel features such as watertight doors, vertical ladders, hatches and 60 degree stairs can also be represented within the model as can the performance of both naval personnel and civilians in the operation of these devices. In addition to simulating the mustering or assembly process, the abandonment system can also be explicitly represented within the model, enabling individual components of the abandonment system to be modelled individually.

The ***Toxicity sub-model*** (only available as part of Level 2 software) determines the physiological impact of the environment upon the occupant. To determine the effect of the fire hazards on occupants, EXODUS uses a Fractional Effective Dose (FED) toxicity model, this assumes that the effects of certain fire hazards are related to the *dose* received rather than the exposure *concentration*. The model calculates the ratio of the dose received over time to the effective dose that causes incapacitation or death, and sums these ratios during the exposure. When the total reaches unity, the toxic effect is predicted to occur. Within buildingEXODUS, as the FED approaches unity the occupant's mobility, agility, and travel rates can be reduced making it more difficult for the affected occupant to escape. The core toxicity model implemented within buildingEXODUS is the FED model of Purser. This model considers the toxic and physical hazards associated with elevated temperature, thermal radiation, HCN, CO, CO_2 and low O_2 and estimates the time to incapacitation. The model can also consider the impact of irritant fire gases such as HCl, HBr, HF, SO2 , NO2, Acrolein and Formaldehyde. In addition to this behaviour, the occupant is allowed to stagger through smoke filled environments and is slowed down according to the data of Jin. Occupants are also given the ability to select another exit path when faced with a smoke barrier based on their familiarity with the structure.

The thermal and toxic environment is determined by the ***Hazard sub-model*** (this capability only available as part of Level 2 software). This distributes hazards throughout the vessel as a function of time and location. maritimeEXODUS does not predict these hazards but can accept experimental data or numerical data from other models. A software link has been established between the maritimeEXODUS and the CFAST zone model and the SMARTFIRE field model. This allows CFAST (version 6.0) history files and SMARTFIRE output files to be automatically passed to the maritimeEXODUS model, thereby enabling the buildingEXODUS and CFAST/SMARTFIRE models to interact in a relatively straight forward manner.

The software has an intuitive user interface and includes editable toolbars, windows for navigation, status information and data output, pop up menus for all model elements (geometry elements, occupants etc). The software also automatically identifies areas in which significant congestion ($\geq$ 4 people/m^2) was experienced for greater than 10% of the total simulation time as required by IMO MSC 1033.