Computer Models For Fire and Smoke

Model Name:	***SMARTFIRE***
Version:	4.1
Date:	1st August 2007
Classification:	Fire Field Modelling Environment using CFD.
Very Short Description:	A PC or Cluster based fire field model with automated mesh generation and interactive graphical interface providing dynamic control of the CFD software. Simulates fire, smoke, thermal radiation and toxicity within whole complex structures such as buildings, aircraft, ship and rail environments.
Modeler(s), Organization(s):	***SMARTFIRE*** Development Team, Fire Safety Engineering Group (FSEG), The University of Greenwich, Prof Ed Galea, Dr Mayur Patel, Dr John Ewer, Dr Fuchen Jia, Dr Angus Grandison.
User's Guide:	***SMARTFIRE*** V4.1 User Guide and Technical Manual, Doc Rev 1.0, July 2007.
Technical References:	"Parallel CFD fire modelling on office PCs with dynamic load balancing", Grandison A.J., Galea E.R., Patel M.K., Ewer J., International Journal for Numerical Methods in Fluids (in press 2007), DOI: 10.1002/fld.1278 "Predicting HCl concentrations in fire enclosures using an HCl decay model coupled to a CFD-based fire field model." Wang, Z, Jia, J., Galea, E.R., Patel, M.K., Ewer, J., Fire and Materials, (in press 2007) DOI 0.1002/fam.942 "Predicting toxic gas concentrations resulting from enclosure fires using local equivalence ratio concept linked to fire field models". Galea E.R., Jia F., and Wang Z., Fire and Materials, Vol 31, Issue 1 pp 27-51 Jan/Feb 2007. "CFD Fire Simulation of the Swissair Flight 111 In-Flight Fire – Part 1: Prediction of the Pre-Fire Air Flow within the Cockpit and Surrounding Area", Jia F., Patel M., Galea E.R., Grandison A., Ewer J., The Aeronautical Journal. Vol 110, Number 1103, pp 41-52, 2006.

“CFD Fire Simulation of the Swissair Flight 111 In-Flight Fire – Part 2: Fire Spread analysis”, Jia F., Patel M., Galea E., Grandison A., Ewer J., The Aeronautical Journal. Vol 110, Number 1107, pp 303-314, 2006.

“The Development of Parallel Implementation for a CFD based fire field model utilising conventional office based PCs.”. Grandison A.J., Galea E.R., Patel M.K., Ewer J. Journal of Applied Fire Science, Vol 12(2) 137-157, 2003-2004.

"The Simulation of Fire and Evacuation at Sea". Galea E.R.,, Grandison A., Filippidis L., Gwynne S., Ewer J., Lawrence P., Proceedings of the 10th International Interflam Conference, Edinburgh, 5-7 July 2004, Vol. 1, pp 755-760; ISBN 0 9541216 4 3.

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"Predicting Hydrogen Chloride Concentrations in Fire Enclosures using a Deposition Model Linked to Field Fire Models". Wang Z., Jia F., Galea E.R., Ewer J., Proceedings of the 10th International Interflam Conference, Edinburgh, 5-7 July 2004, Vol. 1, pp 665-670; ISBN 0 9541216 4 3.

"A New Approach to the Simulation of Gaseous Combustion and its Application to Several Test Fire Scenarios". Zhang J., Jia F., Galea E.R., Ewer J., Proceedings of the 10th International Interflam Conference, Edinburgh, 5-7 July 2004, Vol. 1, pp 1293-1304; ISBN 0 9541216 4 3.

"Applying the Local Equivalence Ratio Concept to Fire Field Models", Authors: Wang Z., Jia F., and Galea E.R., Proceedings of the 9th International Fire Science and Engineering Conference: Interflam '01, Vol. 2, pp 1409-1414, Edinburgh, Scotland, Sept 17-19 2001, published by Interscience Communications Ltd, London, UK, 2001. ISBN 0 95323129 1 (vol2).

	"A semi-automated approach to CAD input into Field Based Fire Modelling Tools", Authors: Frost I., Patel M.K., Galea E.R., Rymacrzyk P., and Mawhinney R.N., Proceedings of the 9th International Fire Science and Engineering Conference: Interflam '01, Vol. 2, pp 1421-1426, Edinburgh,Scotland, Sept 17-19 2001, published by Interscience Communications Ltd, London, UK, 2001. ISBN 0 95323129 1 (vol2).
Validation References:	"SMARTFIRE Verification and Validation Report", Report Version 4.1.1, Report Revision Date 05/2007, CMS, University of Greenwich.
	"Development of Standards for Fire Field Models. Report on Phase 1 Simulations", Grandison, A.J., Galea E.R., Patel, M.K., Office of the Deputy Prime Minister, Fire Research Division, Fire Research Division, Research Report 2/2003, 2003
	"Development of Standards for Fire Field Models. Report on SMARTFIRE Phase 2 Simulations", Grandison, A.J., Galea E.R., Patel, M.K., Office of the Deputy Prime Minister, Fire Research Division, Fire Research Division, Research Report 1/2003, 2003
	"Simulating one of the CIB W14 round robin test cases using the SMARTFIRE fire field model", Wang, Z., Jia, F., Galea, E.R., Patel, M.K., Ewer, J. Fire Safety Journal, 36, pp661-677, 2001.
Availability:	Contact Professor E. Galea, FSEG, The University of Greenwich, Park Row, Greenwich, UK SE10 9LS, e.r.galea@gre.ac.uk, http://fseg.gre.ac.uk/smartfire/, phone: +44 (0)20-8331-8730.
Price:	UK£3000 annual commercial license, significant discounts available for: education, fire departments, government authorities, joint purchase with EXODUS evacuation modeling software, multi-license and multi-year purchases.
Necessary Hardware:	PC/Workstations running Windows 32-bit or 64-bit editions and Windows based clusters with MPI.
Computer Language:	C++

Size: Approximately 65 MB on hard disk (excluding work cases).

Contact Information: Dr J. Ewer FSEG, The University of Greenwich, Park Row, Greenwich, UK SE10 9LS, smartfire@gre.ac.uk +44 (0)20-8331-8658.

Detailed Description:
SMARTFIRE is an integrated fire simulation environment ideal for both novice and expert user. The ***SMARTFIRE*** environment provides complete support of the modelling cycle, from specification of the fire modelling problem, mesh generation, model configuration, processing, run-time data analysis and visualisation; and post-processing data analysis and visualisation (see Figure 1).

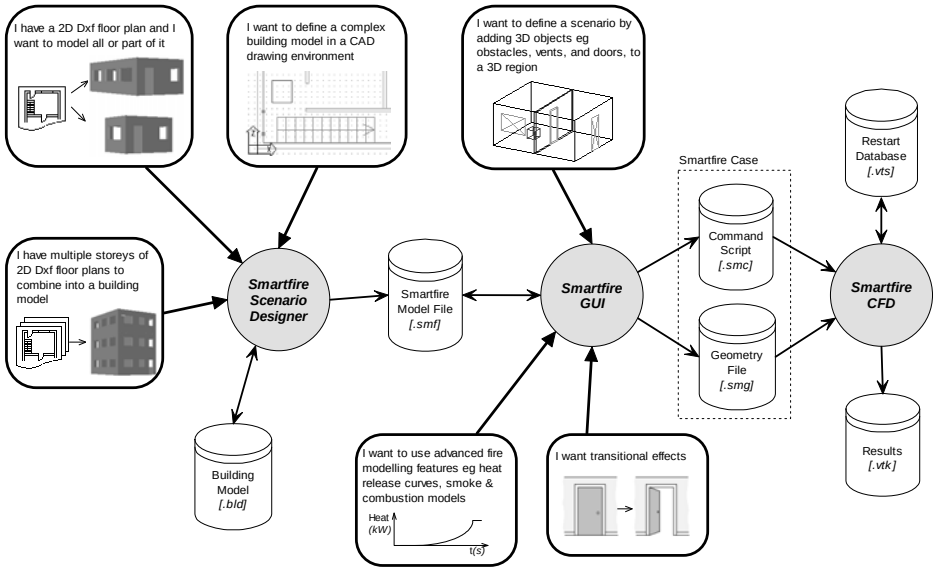


Figure 1: Using the *SMARTFIRE* Environment.

SMARTFIRE V4.1 provides a host of features that make it a unique fire modelling environment. ***SMARTFIRE V4.1*** consists of four main components (see Figure 2):

- **SCENARIO DESIGNER**: CAD-like design tool allows specification of building geometry using a 2D CAD or bitmap floor plan or by simply drawing 2D objects on the building floor plan. Includes semi-automated search for rooms and doors. There are object tools to add objects to the scenario such as rooms, ceiling apertures, doors, windows, obstacles, stairs, fans, inlets, outlets or fires. Supports multiple storey layer design for tall buildings (including layer cloning). Composite object creation helps with the design of complex scenarios with repetitive features. A VR display mode supports scenario checking.
- **CASE SPECIFICATION ENVIRONMENT:** Provides a 3D environment to build models and provides full configuration of the physics (sub-model activation) and the

numerical options/parameters of a scenario in a 3D graphical User Interface. Supports configuration of optimizations, output control and other scenario details.

- **AUTOMATED MESHING TOOL:** Knowledge based tool uses geometry recognition and multiple meshing libraries to give an appropriate structured mesh solution. Supports iterative mesh refinement based on mesh quality metrics for the aspect ratio of cells and the ratio of lengths of adjacent cells. Unstructured meshing currently requires third party meshing systems.

- **CFD ENGINE:** Performs the CFD calculations and includes many run-time data analysis tools as well as comprehensive control of the CFD solution process. The ***SMARTFIRE*** CFD Engine is a fully unstructured 3D mesh code using Control Volume methods. Simulation involves the solution of the Navier Stokes equations for compressible flow and heat transfer including the two equation k-e turbulence model. Both the SIMPLE and SIMPLEC solution procedures are available. There are a number of iterative solvers including Jacobi, Gauss SOR and BiCG. Combustion is modelled using the Simple Chemical Reaction Scheme (SCRS) using either diffusion- or eddy dissipation- controlled reaction. Combustion is sensitive to the local oxygen concentrations. Thermal radiation can be modelled using Radiosity-, Six-Flux- or a Multi-Ray- radiation model. Volumetric and Face Porosities are supported to provide flow restrictions where the restricting objects can not be meshed due to their small scale (compared to the scale of the rest of the scenario). An integral restart database management system is included in the User Interface. The database uses file compression to minimise the storage requirements and keeps the restart data sets separate from the case and results files. Interactive and graphical tool that performs the numerical simulation. Toxicity (CO_2 and CO) and HCl sub-models allow the calculation of more of the fire effluents to be calculated. Provides the ability to see contextual planar visualisations of field variables and flows and allows rotate/zoom and panning. Visualization of 2D slice interactive ray traced visibility distance (through smoke) from a chosen view point. Extensive data gathering facilities using line plots, graphs of residuals and monitor values. Supports SMART and MUSCL higher order difference schemes. A prototype water mist/sprinkler model with nozzles providing water droplets to a fire modelling scenario included.

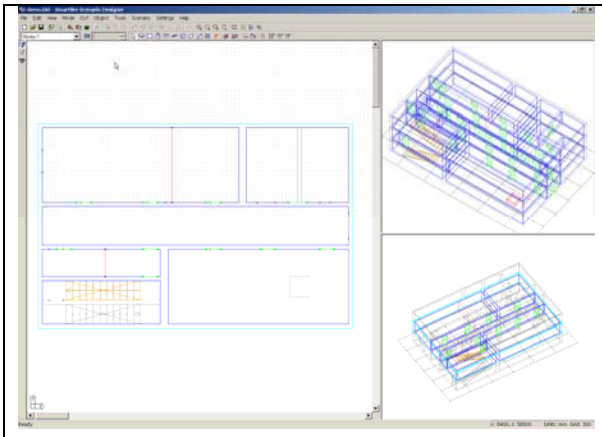
Other ***SMARTFIRE V4.1*** features include:

- **SMARTFIRE Mesh Morphing Utility:** Provides limited re-shaping functionality to change a structured mesh into a BFC-like mesh. Mesh node selection using logical points range. Allows simple configuration of pitched roofs. “Bend” function allows mesh to be bent by a set angle around one of the coordinate axes. “Move Object” functionality, allows a chosen object (e.g. a fire) to be moved to a new location.

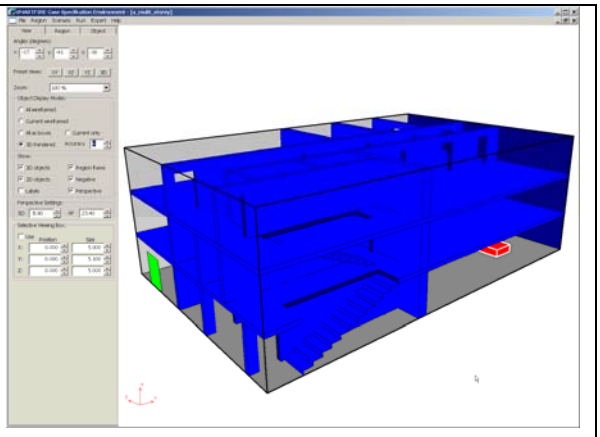
- **Parallel Computing Capability:** Harnesses office based networked Windows PCs or dedicated PC clusters to solve large fire simulation problems must faster than on a single PC.

- **Direct Linkage to EXODUS Evacuation software:** Allows the export of zone averaged hazard data to the EXODUS suite of evacuation software. Zones are automatically created for room blocks in the Scenario Designer.

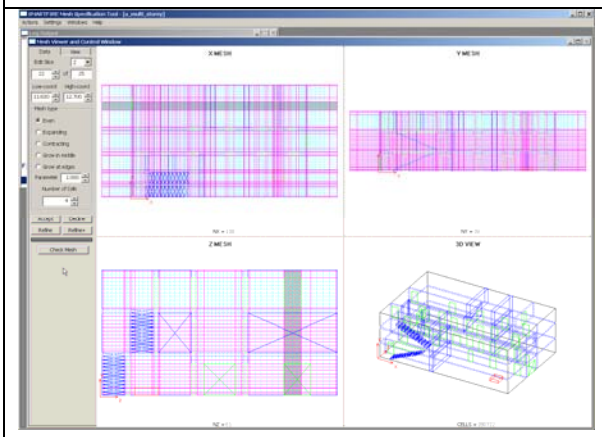
- **Data Output Options:** Many additional post processing output formats to allow the use of third party post processing software.
- **Trigged Secondary Events:** Allows the ignition of secondary fires or changes to geometry features (e.g. breaking windows and/or opening doors) using triggered events. Delayed triggering is also possible. Multiple trigger factors and multiple triggered objects are fully supported. Critical change handling allows the user to set prescribed mitigation using reduced time step sizes for sudden changes that could break the solution.
- **Data View Post Processing System:** Allows 3D display of all of the simulation data including scalars, vectors, streamlines, volumetric smoke, data graphs (which can also be animated with time).



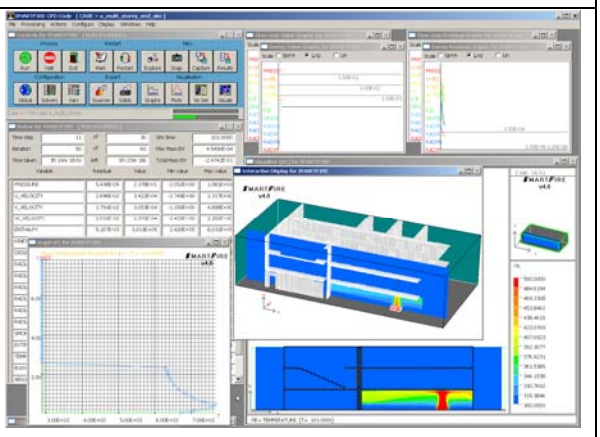
SMARTFIRE **Scenario Designer : CAD Import**



SMARTFIRE **Case Specification Environment**



SMARTFIRE **Automated Meshing System**



SMARTFIRE **CFD Engine**

Figure 2: Components of the SMARTFIRE environment.

SMARTFIRE FEATURES CURRENTLY UNDER DEVELOPMENT

The ***SMARTFIRE*** development team are working on a range of new and enhanced features to be released in future versions of ***SMARTFIRE***. These include:

- 64 Bit processing support to go beyond the 2 GB memory limitation imposed by 32 bit Windows OS.
- Multi-threading to use the power of dual and quad core processors.
- Experiment Engine to give fully automated support and control of the case set-up including meshing, solution control, monitoring and error handling,
- Unstructured mesh generation using tetrahedral meshes.
- Unstructured meshing using BFC meshing with mesh smoothing,
- Solid fuel combustion (by pyrolysis),
- Enhanced oxygen/fuel/temperature sensitivity for the Combustion model,
- More coupling between the sprinkler modelling and other physics,
- LES turbulence modelling,
- Automated optimisation strategies to limit unnecessary processing,
- Enhanced linkage with the ***EXODUS*** evacuation model for hazard modelling with zone independent coupling and two way interactive coupling.