# PROGRESS REPORT

**CONTRACT N° :** IST-2000-29266

**PROJECT N° :**

**ACRONYM :** VIRTUALFIRES

**TITLE :** Virtual Real Time Fire Emergency Simulator

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# 2 Executive publishable summary

A Virtual Reality Real Time Fire Emergency Simulator (VIRTUALFIRES) will be developed using techniques of virtual reality. In the simulator, the observer will be able to visualise the fire and smoke development and the transport of heat and toxic combustion products inside a tunnel and walk or run through the virtual structure in the same way as through a real tunnel. The simulator will use and access a data base, which contains the results of three-dimensional transient combustion (Computational Fluid Dynamics - CFD) simulations for particular tunnel geometries with associated safety installations, particular fire hazard scenarios, etc.

It is planned to develop the system as a fixed installation in a CAVE virtual environment and as a portable installation using a PC and a head-mounted display (HMD). Two systems are planned: one where the CFD simulation is pre-calculated, stored into a data base and then displayed another where it is carried out in parallel to the visualisation. In the first system the user will be able to move through the data but will not be able to change the characteristics of the simulation, for example the ventilation characteristics. In the second system the user may change the properties of the simulation while the data are displayed.

The VIRTUALFIRES system will be a unique system that can be used for assessing the fire safety of tunnels and aircraft, for training of rescue personnel and for planning rescue scenarios and will be able to replace or supplement real fire tests. The end users of this system will be rescue organisations such as the fire brigade and police, tunnel operators and government organisations concerned about tunnel safety. The system can be used for making an objective assessment of the fire safety of existing European tunnels. It can also be used for training drivers on how to behave in the case of a fire emergency in a tunnel.

# 3 Objectives and strategic aspects

We propose, to apply the method of virtual reality to develop a simulator for assessing the fire safety of tunnels and for training rescue personel. In a virtual computer-simulation-based environment all data about the structure, the safety equipment, ventilation, the fire and smoke development and vehicles/passengers exist in computer memory only. These data are displayed in such a way that the user has the possibility to study all the hazardous effects of a real fire emergency. The project therefore aims to contribute to efforts by the Community to increase the fire safety of European tunnels. It also aims to extend the range of application of virtual reality techniques.

The objective is to develop and implement a Virtual Reality Real Time Fire Emergency Simulator (VIRTUALFIRES). In the simulator, the observer will be able to visualise the fire and smoke development and the transport of heat and toxic combustion products inside a tunnel and walk or run through the virtual structure in the same way as through a real tunnel.

By the end of this project a prototype of the VIRTUALFIRES simulator will have been developed which can be used by government authorities, tunnel operators and rescue personal. Currently the only method available to assess the fire safety of tunnels is to perform real fire tests. The advantages of virtual reality based simulations are that they offer virtually unlimited scope, are economical (the only expense being the computer time) and are environmentally friendly because no toxic waste is produced. As a result of the project's activity, through the availability of VIRTUALFIRES, the fire safety of tunnels will be increased because all European tunnels can be tested for fire safety and virtual fire tests can be made obligatory for new tunnels.

The work plan is to develop computer software, which together with specialised hardware can be used to display in a virtual reality environment the geometry of a tunnel with all its structural elements and safety installations together with the results of computer simulations of fires. The simulator will use and access a data base, which contains the results of three-dimensional transient combustion (Computational Fluid Dynamics - CFD) simulations for particular geometries, hazard scenarios, etc. It is planned to develop the system as a fixed installation in a CAVE virtual environment and as a portable installation using a PC and a head-mounted display (HMD) although emphasis will be placed on the development of the CAVE installation.

The applications include:

**Training of rescue personnel**. Currently this can be only done with real fire test which are expensive and produce toxic material.

**Objective assessment of the fire safety of tunnels**. This is currently either done using a list of rather arbitrary rules or by performing real fire/smoke tests (i.e. Mont Blanc Tunnel).

**Training of drivers.** Using the simulator truck and other drivers can be trained on how to behave in a case of a fire accident. Wrong driver behaviour has been determined as one of the main causes for fatalities in the Tauern tunnel.

**Intervention management.** The tunnel operators will be able to train the intervention procedures in order to mitigate the effects of a fire emergency. Wrong intervention management has been determined to be a major cause of fatalities in the Mont Blanc tunnel.

# 4 Scientific and technical performance

## *4.1 Objective summary*

The main objective of the first 6 months of the project was to select suitable developer tools, an existing VR system to be used for further development and the hardware in order to achieve the aims of the project. In addition a detailed specification of the system capabilities was worked out in consultation between the developers and end users. This is a crucial part of the development because the success of the project will depend on a good selection of the software platform to be used and the detail and quality of the system specification. A selection of an existing state of the art VR system will also help avoid duplication of software development.

Another objective of the first 6 month's work was to demonstrate current capabilities of CFD simulation software by performing calculations for some recent well known tunnel fire incidents (Mont Blanc and Gleinalm tunnels) and to investigate the feasibility of concurrent simulations. The objectives of the different work packages are reviewed next.

### 4.1.1 Workpackage 2

FIGD[+] was the workpackage leader of WP2. The task of this workpackage was the system specification and the selection of the developer tools. Several sub workpackages had to be synchronized and controlled. The other project partners contributed their knowledge and reports for the delivery reports of the sub workpackages, which were summarized and completed by FIGD. Additionally FIGD prepared the basic system layout for its part of the software, which is going to be developed within the project, and started the basic prototype design and realization. Different aspects of program design, parallelization and visualization had to be investigated and researched.

### 4.1.2 Workpackage 3

The objective is to specify the database for geometrical input data for the VR-System and the CFD-Calculation, which should be done in Task 1. The work of task 2 is to specify the format of data which are necessary for visualisation (i.e. display of smoke and fire). In task 3 the existing data compression and optimisation techniques are evaluated to provide a real time visualisation with a given I/O rate. After specification the work must be done in task 4 and be tested in task 5. Task 6 closes WP3 by writing the documentation.

### 4.1.3 Workpackage 4

The objective is to implement the VIRTUALFIRES functionality specified in WP2 in the VR environment. The same software will run both in the CAVE environment and in a Head Mounted Display (HMD) system with some modifications. The HMD-version of VIRTUALFIRES is designed to run on a well-equipped graphics workstation or PC. To display CFD data requires many optimisations because of the size of the data and is also demanding from a user interface perspective. The coupling of real-time generation of CFD-data to the VR-environment is highly innovative and rises many unsolved problems.

[+] see Glossary for the meaning aof abreviations

### 4.1.4 Workpackage 5

The objective was to perform sample analysis for the a-priori generation of CFD data and to investigate the feasibility of CFD simulations in real time.

## *4.2 Technical progress*

All the planned objectives were achieved. The work done will form a solid basis for the development of the VIRTUALFIRES system. The technical progress in the various work packages is reviewed next.

### 4.2.1 Workpackage 1

#### *4.2.1.1 WP 1.3: Setup and adaptation of Virtualfires Web server and mailing list*

A Linux-Server with Apache Web server has been installed and the Web-portal nuke has been adapted for the requirements of the project.

### 4.2.2 Workpackage 2

The technical progress, which is a main part for the development preparation in this project, was achieved regarding the following sub workpackages. Subsequently a short overview about the prototype development at FIGD is given.

#### *4.2.2.1 WP 2.1: "Report on available developer tools"*

The idea of this part of WP 2 was to give an overview of the existing developers tools and their relevance to the Virtualfires project. Every software developing partner gave introduction to the main tools important in his area of software development and usage. The outcome of WP 2.1 is documented in the delivery report for WP 2.1 and WP 2.3.

#### *4.2.2.2 WP 2.2: "Selection of developer tools"*

In this sub workpackage all software developing partners decided which developer tools should be chosen to implement her part of the system. The advantages and disadvantages were compared and based on this fundament the decisions were made. The result of WP 2.2 is available in the delivery report for WP 2.2 and WP 2.4.

#### *4.2.2.3 WP 2.3: "Report on available system capabilities (hardware)"*

The aim of WP 2.3 was to present the available hardware capabilities that each project partner is able to bring into the project. Every useful system for Virtualfires located at the project partners institutions was introduced. The written version of the results of WP 2.3 is available in the delivery report for WP 2.1 and WP 2.3.

#### *4.2.2.4 WP 2.4: "Specification of planned system capabilities (software)"*

WP 2.4 is responsible for the specification of the planned system software capabilities which are going to be developed within the project. Here the end users defined what they expect from the final system in terms of performance, processing capacities and visualization. They also defined which parameters are important for them and what they require as input or start parameters to influence on the simulation. The software developing project partners define in this workpackage the planned system layout and the necessary interfaces between the several software parts. After the completion of this Workpackages every software developing partner should know what his specific task is and what parts of the whole system he has to implement and realize. The outcome of this Workpackage will be available in the delivery report for WP 2.2 and WP 2.4.

#### *4.2.2.5 WP 2.5: "Review of existing VR systems, Adaptability to VIRTUALFIRES"*

In this sub workpackage the existing VR systems at the project partners institutions where introduced and their features were listed. WP 2.5. serves as a basis for WP 2.6. The result of this WP is documented in the delivery report for WP 2.5.

#### *4.2.2.6 WP 2.6: "Specification of selected VR system & required extensions"*

WP 2.6 was responsible for the selection of the VR system(s) which is going to be used in the Virtualfires project. The project members involved in the visualization part of Virtualfires had to decide whether they all want/are able to use the same VR system to realize their parts of the project or if they have to use several systems, e.g. for licensing, platform or performance reasons. The result of this project is documented in the delivery report for WP 2.6.

#### *4.2.2.7 Regarding the research and implementation work at FIGD*

FIGD investigated the important visualization techniques needed within the Virtualfires project for the scientific and for the realistic visualization of the simulation output. Several basic visualization methods were analyzed and implemented as prototypes. These are shown in Appendix I.

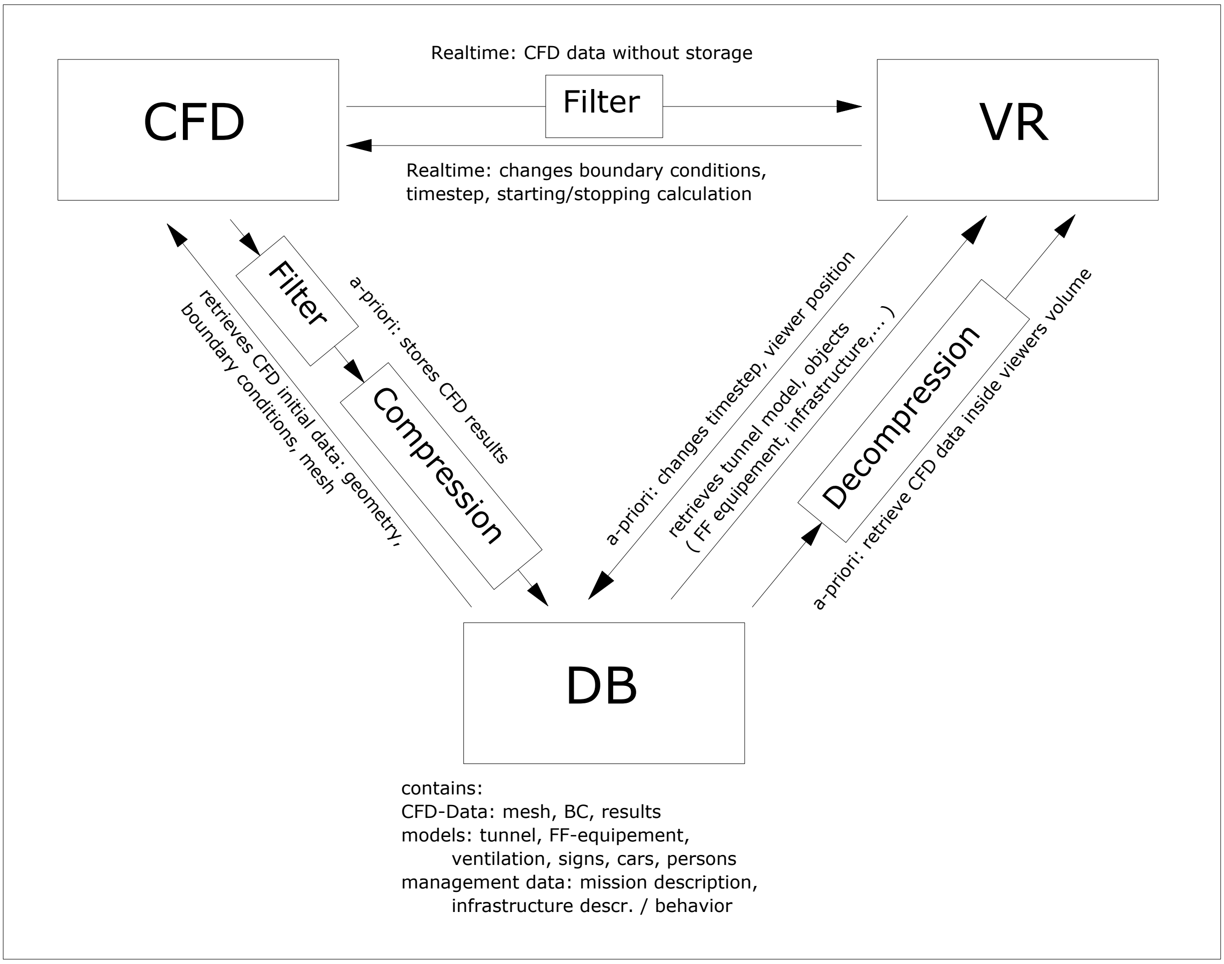



Fig.1: Interaction between CFD simulation, VR system and data base (DB)

### 4.2.3 Workpackage 3

SiTu gathered all necessary information to specify the database for data storage for the simulator and is working on a detailed description of the logical interconnections of the database items. The interaction of data between CFD-Calculation, VR-System and a-priori simulation is shown in Fig.1. The database must be designed to guarantee the required dataflow for real time simulation as well as for a-priori simulation.

#### *4.2.3.1 WP 3.1 / 3.2: Specification of geometrical database / Specification of CFD database*

A number of file formats for post-processing of flow data have been reviewed. These included:

- AVS
- Data Explorer
- EnSight
- FAST
- FIELDVIEW
- I-DEAS
- NASTRAN
- PATRAN
- Tecplot
- CGNS

All of the above have been analysed with respect to available documentation, file sizes, access speeds, etc.

Finally it was decided to use CGNS as interface between the flow solver and the VR-environment due to the following reasons:

- It is well documented.
- It is likely to become the common file format for all major CFD codes.
- I/O-libraries for C++ and Fortran are already available.
- It is attempted to establish CGNS as an ISO standard.

Some of the partners (CETU, AlpeTunnel, EUVE) are supplying examples of CAD files of tunnel geometry, tunnel equipment and infrastructure. Collection of data of fire fighting equipment and definition of fire fighting missions was done by of FDDo in workpackage 2 Task 4, which is the basis for the definition of the mission planning for the simulator.

The file formats for the CFD Simulation are defined and a test run of a part of the Mont Blanc tunnel was made be CD, which is part of workpackage 5, to find out how much data will be produced and to test if CGNS format is suitable for data storage of CFD calculation.

After workpackage 3 meeting in Stockholm a general concept has been developed, which is the basis for deliverable 3.1 and 3.2

#### *4.2.3.2 WP 3.3: Data compression and optimisation techniques*

Data compression and optimisation techniques will be worked out, when all data format files are specified.

#### *4.2.3.3 WP 3.5: Beta testing of system with real data*

A first set of CFD data was generated for a hazard scenario set-up within a portion of the Mont Blanc tunnel geometry. Results of the simulation have been made available via the VR-Server to the consortium members.

### 4.2.4 Workpackage 4

#### *4.2.4.1 WP 4.1: Selection and integration of hardware for HMD system*

A proper HMD was selected and evaluated with some OpenGL test programs in stereo mode

### 4.2.5 Workpackage 5

#### *4.2.5.1 Task 3.5: Beta testing of system with real data*

A first set of CFD data was generated for a hazard scenario set-up within a portion of the Mont Blanc tunnel geometry. Results of the simulation have been made available via the VIRTUALFIRES-Server to the consortium members.

#### *4.2.5.2 Task 5.1: A-priori generation of CFD data*

Two sections of tunnels with different ventilation systems have been considered for the a-priori CFD calculation. Both tunnels are operated using full transverse ventilation systems, but with significant differences concerning fresh air inlets and exhaust air outlets.

Sample results for a series of time steps are available in the download section of the project's homepage. The file size for a data set containing velocities, temperature and pressure is about 15 [MB] for one single time step and 130.000 cells. If only a single scalar variable (e.g. temperature) is used for visualisation, the file size can be reduced to about 3 [MB] for the aforementioned number of cells.

Examples of analysis of the Mont Blanc and the Gleinalm Tunnels are shown in Appendix II.

#### *4.2.5.3 Task 5.2: CFD simulations in real time*

Feasibility of real time simulations

An existing Lattice-Boltzmann code for two-dimensional calculations is extended to three dimensions. A number of two-dimensional studies have been carried out to test various turbulence and combustion models. As proposed, a Smagorinsky-type turbulence model [1] turned out to be most economical and hence will be used for all real-time simulations. For the combustion simulation a simple flame spread model is under development. It assumes a simplified one step reaction. The combustion process is controlled by turbulent mixing, i.e. chemical kinetics are assumed to be infinitely fast ("Mixed is burnt"). Details of the model can be found in Annex IV of the proposal.

Furthermore a concept for the domain decomposition and solver parallellisation has been developed. The method of choice is a recursive bisection algorithm (e.g. Cartesian coordinate, spectral, centre of gravity, etc.). The implementation of the domain decomposition method has been already started.

Concerning the feasibility of real time simulations as addressed in Annex 2 of the contract several benchmark test have been carried out with a prototype version of the three dimensional code. For a pure flow simulation without considering passively transported quantities (e.g. temperature, smoke) an update rate of about 1 million cells per second on a DEC Alpha DS 20 (theoretical peak performance of 1 GFLOP) was reached. The sustained performance of the prototype version on the DEC Alpha DS 20 turned out to be about 200 MFLOP. It is expected that the final 3D code including the combustion model will show a performance decrease of approximately 30 percent when compared to these figures.

On the basis of a conservative estimate this means that the 3D Virtualfires simulator on the DEC Alpha DS 20 for a problem containing 100.000 grid points 5 time steps per second are feasible. However for real time simulations at least 25 time steps per second are required. Hence a sustained performance of 1 GFLOP is necessary. Expecting that the Strindberg system at KTH, which has got a theoretical peak performance of about 200 GFLOP, also reaches a sustained performance of about 20 percent of the peak performance (i.e. 40 GFLOP) it is obvious that a real time simulation containing 100.000 grid points is feasible. A summary of the required CPU performance for performing real time simulations is given in table 1.

| **Smoke propagation speed** | **Spatial resolution** | **Computational time step** | **Time steps per second** | **Required sustained performance** |
|---|---|---|---|---|
| 100 [m/sec] | 0.1 [m] | 0.001 [sec] | 1000 | 200 [GFLOP] |
| 20[m/sec] | 0.1 [m] | 0.005 [sec] | 200 | 40 [GFLOP] |
| 5 [m/sec] | 0.1 [m] | 0.020 [sec] | 50 | 10 [GFLOP] |

***Table 1:*** Required sustained CPU performance for real-time combustion simulations

The simulations performed so far, resulted in smoke propagation speed of about 5 [m/sec], which is in good agreement with available measured data. This in turn means that according to the above table a much greater time step as initially assumed (in the proposal writing stage) can be used.

*4.2.5.4 Assessment of combustion model*

First results of a 2D-version of the Lattice-Boltzmann server including the above mentioned combustion model are shown in Appendix II

## *4.3 Comparison planned activities and actual work*

### 4.3.1 Reports

A number of deliverable reports were produced, which are listed in Table 2. In general all the planned activities were carried out successfully. The completion of some reports was delayed for a short time because information was not available in time.

| Work package | Title | Planned Closing date | Achieved closing date | Reason for delay |
|---|---|---|---|---|
| WP 2.1 | Report on available developer tools | 30.11.2001 | 11.12.2001 | • Missing text input from several project partners |
| WP 2.2 | Selection of developer tools | 14.12.2001 | 28.01.2002 | • Missing text input from several project partners |
| WP 2.3 | Report on available system capabilities (hardware) | 30.11.2001 | 11.12.2001 | • Missing text input from several project partners |
| WP 2.4 | Specification of planned system capabilities (software) | 14.12.2001 | 12.05.2002 | • Missing text input from several project partners<br>• Extension of included information and specification<br>• Required meeting to complete (Stockholm 12.05.2002) |
| WP 2.5 | Review of existing VR systems, Adaptability to VIRTUALFIRES | 15.01.2002 | 28.01.2002 | • Missing text input from several project partners |
| WP 2.6 | Specification of selected VR system & required extensions | 31.01.2002 | 12.05.2002 | • Required meeting to complete (Stockholm 12.05.2002) |
| WP 3.1 | Report on Specification of geometrical database | 30.03.2002 | 30.05.2002 | • Report WP 2.4 was not completed in time |
| WP 3.2 | Report on Specification of CFD database | 30.03.2002 | 30.05.2002 | • Report WP 2.4 was not completed in time |
| WP 3.3 | Report on Data compression and optimisation techniques | 30.5.2002 | 30.06.2002 | • Compression and optimisation will be selected depending on necessity |

***Table 2:*** Planned activities and actual work done

### 4.3.2 Software development

The planned tasks for the prototype implementation by FIGD were realized in time. Several implementations for visualization methods have been investigated and realized. The basic ideas for the parallel visualization system had been developed. The next step will be the concrete implementation of the post visualization system for Virtualfires.

## *4.4 State of the art review*

Computational Fluid Dynamics (CFD) calculations today result in data sets of around 1 GB (32 million nodes). It is common to generate hundreds or thousands of time steps as the result of unsteady simulation (on the same grids), leading quickly to TB-scale data sets.

Typically these huge data sets are not analysed while the supercomputer generates them (it is generally not cost-effective to use supercomputer cycles for human interaction). Rather, data sets are *post-processe*d: The supercomputer completes its simulation, and writes data to mass storage. Typically the data is copied to the high-end workstation's own disk or a database using an appropriate compress/transform algorithm. In our case the high-end graphics workstation is a CAVE computer system or a PC with an attached HMD. The workstation then performs the generation of geometry and rendering.

Currently several post-processing CFD visualisation techniques like Colour Mapping, Contour Lines, Iso-surfaces and Cutting Planes, Data Probes, Glyphs, Streamlines, Pathlines, Streaklines, Timelines and variations/combinations of them have established. It has been investigated, which of them serves the needs of VIRTUALFIRES and therefore will be implemented and/or further enhanced for example by parallelizing it. Besides of the mentioned already known visualisation techniques there is a wide field for innovations. If necessary, new techniques have to be developed with respect to the end users needs.

Additionally the processing and render calculation based on the geometry and CFD data base has to be parallelized as well as the access to the database itself. Finally the display of the scene is filled in several render pipelines simultaneously according to the multiple walls of a CAVE for example which is another parallelization step handled by the VR System.

**A priori fire simulations**

The results of 3-D transient combustion (Computational Fluid Dynamics- CFD) simulations are typically in the form of one-dimensional arrays of several values per location. For unsteady flows (such as tunnel fire propagation) each time step of the simulation creates another set of solution arrays. In continuous (differential equations and mesh based) implicit solution methods, from now on referred to as "Classical CFD (C-CFD)", additionally the geometric locations of the nodes corresponding to array values are stored in a three dimensional (co-ordinate) array. A standard solution file therefore contains a minimum of two scalars (pressure and temperature) and one three dimensional vector (velocities) per cell, all floating point values. Post processing frequently computes additional scalar and vector fields from these initial values, and while they may not require long term storage they take workstation memory while being rendered.

Furthermore each node is linked via corresponding addressing arrays to the adjacent neighbour nodes. If the connectivity defines for example a grid of distorted hexahedral cells this means that a minimum of 6 additional integer arrays is needed. This collection of cells normally is termed an unstructured grid of topologically hexahedral cells.

Efficient direct volume rendering techniques have been developed to operate on scalar data sampled or calculated on a grid of points arranged in a regular, rectangular pattern which we will call a regular grid. C-CFD grids fail to meet this specification in several ways. The grids are designed to fit the volume of space adjacent to objects in the flow; these objects in the current case might be car bodies, traffic signs, etc. and therefore subtly or strongly curved. As a result the size of the cells and the spacing between points is varying. Furthermore such type of grids can not be indexed in a rectangular manner (often referred to as "I-J-K-Addressing"). Unconstrained grids lack even the topological similarity to regular grids. Therefore coupling C-CFD methods and real time visualisation in a concurrent fashion giving today's computing resources neither seems feasible nor attractive.

To overcome these problems the following highly innovative approach is suggested:

1. Solve only for the fluid mechanics in those regions where user interaction takes place.
2. Consider the flow regions in front and behind the active region in a one-dimensional fashion as mentioned above and with proper coupling to an already existing Lattice-Boltzmann Code which will be used for the flow/combustion simulation in the region of user interaction.
3. Parallelise the LB-Code on an equidistant rectilinear grid for optimum performance.
4. Integrate the complete flow solver package (1D and 3D solver) into the VR environments for real time simulation and visualisation of tunnel fires in a concurrent fashion.

**Data input and compression**

From the previous remarks it is obvious that a critical issue in designing a concurrent CFD/VR system is the volume of data that can be handled. There are two types of data which need to be input static data that describe the geometry of the tunnel or aircraft including safety installations and dynamic data which describe the flame and smoke spread, pressure and the distribution of temperature. The handling of static input data poses no problems. The handling of dynamic data however requires special attention. As outlined above a large amount of data are generated for a given time period. Data have to be continuously updated to reflect the current situation. To ensure realistic and smooth display the intervals between updates have to be short. Obviously there will be a compromise between quality of the display and the speed in which data can be read into the system. In any case, special techniques will be required to handle the large data sets and this will be an innovative aspect of the project.

**Display methods**

Two partners of the consortium currently operate state of the art virtual reality systems in a CAVE environment. These systems allow volume rendering at a speed of up to 12 million triangles per second. The results of CFD calculations are displayed either as contours on selected planes or on object surfaces, as iso-surfaces, as data probes or glyphs or as streamlines. Since VIRTUALFIRES should allow the user to actually "walk through" the data an additional display method has to be implemented. The selected system (see deliverable report WP 2.6) fulfils all the requirements and in addition is cost-effective.

## *4.5 Planned activities for the next period*

The next six months period will see the start of the development of the VIRTUALFIRES system. This includes work on the data base, user interface, data compression, extension of the chosen VR system, CFD simulations, feasibility studies on concurrent CFD simulations etc. The planned activities in the various WP are reviewed next.

### 4.5.1 Workpackage 2

Workpackage 2 closed successfully. The specifications and extensions to the defined and selected system layout, developer tools and the VR system will be redefined if needed

### 4.5.2 Workpackage 3

#### *4.5.2.1 WP 3.1 / 3.2 : Specification of geometrical database / Specification of CFD database*

Reports will be finished.

#### *4.5.2.2 WP 3.3: Data compression / optimisation techniques*

Depending on necessity and type of data compression and optimisation, it will be selected and implemented for the first prototype.

#### *4.5.2.3 WP 3.4. Implementation of data generation/compression software*

Implementation of Database for the first prototype of the simulator

#### *4.5.2.4 Task 3.5: Beta testing of the system with real data*

All simulation data necessary for testing the data processing and compression algorithms in the VR system will be supplied.

### 4.5.3 Workpackage 4

#### *4.5.3.1 WP 4.1: Selection and integration of hardware for HMD system*

The hardware for the HMD is already selected. The chosen VR-software Covise and OpenSG will be installed and integrated with the HMD for the first prototype. Responsible partner: SITU.

#### *4.5.3.2 WP 4.2: Implementation display of geometric data*

Modelling of a tunnel for display in the VR-system and interfacing with the database. Responsible partner: KTH

#### *4.5.3.3 WP 4.3: Implementation of displaying CFD data*

The CFD data consist of many different variables, which can be displayed, in many formats. The user should easily be able to switch between different variables and views. Important variables to display are for example the velocity vector field, and scalar fields as temperature and the concentration of smoke and toxic gasses. The implementation will initially use the standard procedures of Covise but may later be optimized to run in parallel. Responsible partner: FIGD.

#### *4.5.3.4 WP 4.4: Implementation of user interactions*

A user interface for the entire system will be implemented. Many parts of the user interface will be common between the CAVE and HMD version and also on PC-screen but some parts have to be adapted to the different environments.

#### *4.5.3.5 WP 4.8: Testing of system with real data*

The entire data necessary for testing the virtual reality system will be supplied. Responsibility of all partners.

### 4.5.4 Workpackage 5

#### *4.5.4.1 Task 5.1: A-priori generation of CFD data*

Based on the already available simulation results the a-priori generation of CFD data will be continued and completed (Deliverable 5.1 & Milestone 5.1).

The results of the a-priori CFD calculations furthermore will be used to test and tune the combustion and turbulence models within the 3D Lattice-Boltzmann code to be used for the real time simulation.

#### *4.5.4.2 Task 5.2: CFD simulation in real time*

Task 5.2.1: Feasibility study concerning CFD simulations in real time

A beta version of the Lattice Boltzmann solver will be used to analyse the bottlenecks between the display hardware (CAVE & HMD), virtual reality system and the compute server “Strindberg”. This work will be performed in close cooperation between CD and KTH.

Research will be performed by KTH about coupling of a full 3D Lattice Bolzmann simulation with zone models and one-dimensional models. The idea is to simulate the actual fire in larger detail and in full 3D while areas of the tunnel far from the fire can be treated as 2D zone models or even in one dimension.

Task 5.2.2: Solver parallelisation

The implementation of the domain decomposition algorithms will be completed. Afterwards the parallelisation of the three-dimensional flow solver will be started.

# 5 List of deliverables

| No. | Deliverable (D) or Milestone (M) name | WP no. | Lead Participant | Estimated person-months | Del. type* | Sec.** | Delivery (proj. month) | Delivered (proj. month) |
|---|---|---|---|---|---|---|---|---|
| D2.1 | Report on available developer tools | 2 | FIGD | 1,5 | Report | Int. | 2 | 2,5 |
| D2.2 | Selection of developer tools | 2 | FIGD | 1,4 | Spec. | Int. | 2,5 | 3,5 |
| D2.3 | Report on available system capabilities (hardware) | 2 | FIGD | 1,8 | Report | Int. | 2 | 2,5 |
| D2.4 | Specification of planed system capabilities (software) | 2 | FIGD | 7,5 | Spec. | Int. | 2,5 | 6,5 |
| D2.5 | Report on existing VR-systems, Adaptability to VIRTUALFIRES | 2 | FIGD | 1,6 | Report | Int. | 3 | 3,5 |
| D2.6 | Specification of selected VR System & required extensions | 2 | FIGD | 2,2 | Spec. | Int. | 4 | 6,5 |
| D1 | Project presentation | 1 | SITU | | Publicity | Ext. | 3 | 1 |
| D3.1 | Report on geometrical data base | 3 | SITU | 3 | Report | Rest. | 5 | 7 |
| D3.2 | Report on CFD data base | 3 | SITU | 2,5 | Report | Rest. | 5 | 7 |
| D2 | Dissemination and Use plan | 7 | METL | | Report | IST | 6 | 7 |
| M1 | CFD computation of fire reference simulations completed | 1-5 | CD | 2 | Demonstration | IST | 6 | 6 |

* A short, self-evident description e.g. report, demonstration, conference, specification.

** Int. Internal circulation within project (and Commission Project Officer if requested)

Rest. Restricted circulation list (specify in footnote) and Commission PO only

IST Circulation within IST Program participants

# 6 Exploitation and dissemination of results

Since all deliverable reports produced in the first 6 month period are marked *internal* no results could be exploited or disseminated to the public. CD however delivered a milestone (M1) which was the demonstration of CFD simulations carried out for the fires in the Mont Blanc and Gleinalm tunnels.

The main activities were carried out to disseminate the project aims and publicise its existence were: A kick-off meeting was organized in a hotel in Graz, Austria and the press, TV and local fire brigades and tunnel operators were invited to attend. A half page article appeared in the local press. A web page was established (www.virtualfires.org) which serves for external as well as internal communication. On this web page major milestones will be published. The coordination project also maintains a data base of those who may be interested in the outcomes of the project (Tunnel operators, consultants, manufacturers of safety equipment, the press and television etc.). As soon as the first prototype will be available it is planned to organise a workshop where representatives of the commission and all interested will be invited.

The "Sudwestrundfunk (SWR)" arranged an TV interview with Dr.-Ing. Volker Luckas from FIGD on 11.12.2001 about VIRTUALFIRES. It was broadcasted in German TV in the scientific magazine called "Sonde" on the 10.01.2002 from 21:45 to 22:15 which was specialized on fire in tunnels and their prevention /analysis. The video stream of the interview is available for download on the WebPage of IGD for Virtualfires on http://www.igd.fhg.de/igd-a3. Furthermore the project was presented by the project coordinator Gernot Beer at the recent “Tunnel safety and Ventilation” Conference in Graz (see Appendix III) and at a FIT (Fire in Tunnels) network meeting in Malmö.

# 7 Management and coordination aspects

So far the project has been running smoothly with very little intervention required by the coordinator. This was because a very comprehensive project handbook, with all information required and the rules of cooperation clearly spelled out, was produced by the coordinator. A consortium agreement was signed by all partners prior to the commencement of the project.

A web page was set up by the coordinating institution about 2 months after the commencement of the project which allowed all partners to communicate via discussion forums. For this reason only one work package meeting and one PCC/TCC was required within the first 6 months after the kick-off meeting. The web page is also used to disseminate the results of the project.

The management of the workpackages was put in charge of the workpackage leaders with the coordinator reviewing the draft reports produced and only becoming active if necessary. The first 6 month period was mainly concerned with defining the specifications of the system and with the selection of the VR system to be used as a starting platform. As all will agree this is one of the most crucial items of the project as a wrong decision here could result in insurmountable problems further on. Therefore more time than originally planned was needed for some important items.

Some industrial partners were found slow to respond to request for information, specifically with respect to the user expectations. At the last PCC meeting it was agreed that in a case, where important information is not supplied by a partner after several requests, a WP meeting will be called. One partner (Alpetunnel) which was concerned with the planning of the Lyon-Turin tunnel project will be renamed and put in charge of carrying out the construction of the project.

# 8 Glossary

SiTu Institute for structural analysis, Graz University of Technology, Austria

CD Christian-Doppler-Laboratory for Applied Computational Thermofluiddynamics, Austria

FIGD Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung, Germany

KTH Kungl. Tekniska Högskolan, Sweden

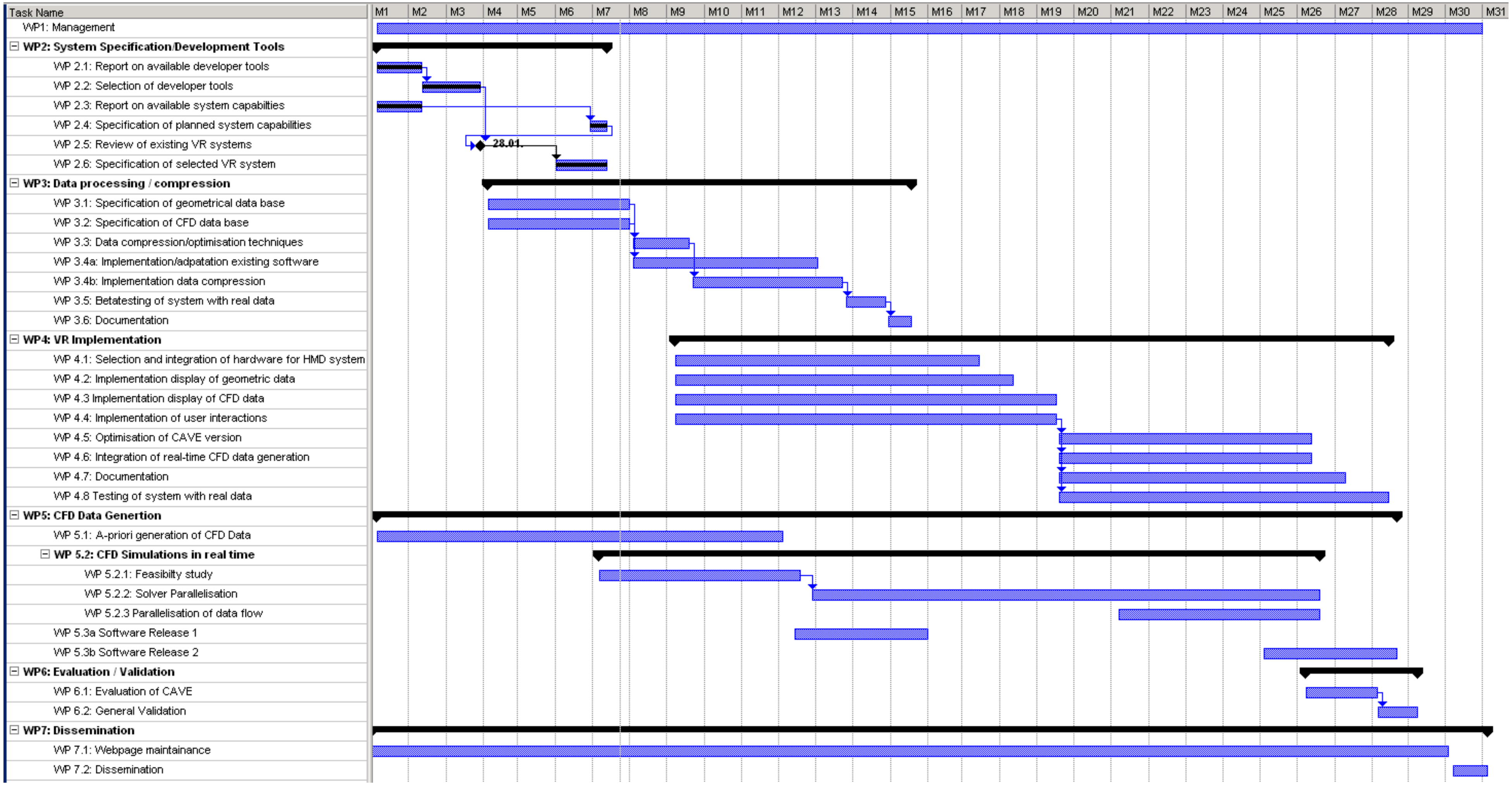
METL Ministere del'Equipment des Transport et du Logement, Centre d'Etudes de Tunnel, France

FDDO Stadt Dortmund, Feuerwehr (fire brigade), Germany

EUVE European virtual engineering, Spain

# 9 Annexes

## Table 2




Note : Only totals are required for the group of minor participants in Thematic Networks/Concerted Actions

# Literature/Links

[1] Smagorinsky J., B. Galperin and S.A. Orszag, Eds. “Some Historical Remarks on the Use of Non-linear Viscosities. In Large Eddy Simulation of Complex Engineering and Geophysical Flows.”, Cambridge University Press, 3-36