SYNTHESIS REPORT

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1. SUMMARY PAGE

Keywords: FIRE, SUPPRESSION, DETECTION, NUMERICAL MODEL, CFD

The overall objective of the FIREDASS programme was to develop new, sophisticated modelling techniques, which can then be used by industry to optimise fire detection and suppression/extinguishing systems. For industry, the development of these techniques would provide the following capabilities and benefits:

- The ability to model the effect of different fire scenarios, fire positions and different physical configurations of aircraft, ships, vehicles and buildings, and to generate data to allow the assessment of fire proofing of these enclosures.
- The ability to model fire detection/activation systems and water mist suppression/extinguishing systems to allow their performance (detection,

suppression and extinguishment) to be assessed and optimised without conducting fire tests.

- Reduction in the development time and number of fire tests necessary for system certification.
- The replacement of synthetic extinguishing media that damage the environment.

The primary aim of the project was to generate and validate a number of modules which, when integrated with the Computational Fluid Dynamics (CFD) engine, would allow the modelling of the interaction of fire, water mist and radiation. The combined software product is referred to as the FIREDASS Package. The separate computer models developed as part of this programme included the, fire sub-model, fire suppression sub-model, mist sub-model, the radiation sub-model and the detector / activation sub-model.

Within the FIREDASS Package the fire is specified as a combination of prescribed release rates. Thus, for a given set of hazard release rates, the FIREDASS model can determine the hazard (e.g. temperature, CO, etc.) history and distribution within the compartment. The effect upon this of the activation and deactivation times of the nozzles, the number of nozzles used, the mist characteristics etc. can then be determined. The FIREDASS model is therefore capable of assisting in the optimisation of the detection and suppression systems. Since the aim of the model development part of the project was to develop a tool capable of performing this function it is concluded that this part of the project has been successfully completed. It should be emphasised that the current model has considerable computational overheads. Furthermore, to be considered a practical tool, the FIREDASS model requires accurate release rate and boundary data and a sufficiently powerful computer. The model can then be used to better target the testing necessary for development and approval of the detection and water mist system. However, the model can be significantly improved in a number of areas concerned with how the fire is represented, how the fire spreads, how surfaces are “wetted”, how smoke is treated, etc.

The validation of the various models and the FIREDASS Package has been accomplished using data generated from the full-scale experimental programme undertaken as part of the FIREDASS project. This experimental programme involved the construction of an A340 cargo compartment which can be used for further fire research activities.

Another of the objectives of the FIREDASS programme was to address the replacement of synthetic extinguishing media that damage the environment and to provide an improved fire detection system and an acceptable halon replacement suppressant in the form of water. Testing and development during the FIREDASS programme has shown that the fire suppression and detection system developed as part of this programme controlled all the fire loads tested and is worth further investigation. Further testing is necessary and urgently required on the water mist system and this should be explored within Framework V.

While the FIREDASS programme has achieved much in leading to a better understanding of how water mist systems operate and how they may be efficiently employed in aviation applications, the industry as a whole has not established an agreed Minimum Performance Specification (MPS) for a non-halon system. This is considered to be a major disincentive to the development of water misting systems as a replacement for halon. Experience of the FIREDASS test campaign would suggest that any MPS for non-halon systems should include the performance of the detection systems. Work arising from the FIREDASS project has significantly contributed to the establishment of not only a possible MPS but has also provided input to the International Halon Replacement Working Group (IHRWG). As the most significant work contributing to this area has been undertaken in the FIREDASS programme, it is considered that Europe should take a proactive lead in resolving this situation.

2. CONSORTIUM

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2.2 Consortium description

A summary of the Partners and their function in this project is shown below:

Organisation name	Business	Function
Marconi Avionics	Avionics	Fire suppression developer - aircraft applications
Siemens Cerberus	Fire detection	Developer of fire detection systems
SINTEF	Research establishment	Fire test facility
DLR	Research establishment	Fire test facility
University of Greenwich	University	Fire and water mist modelling, software developer
National Technical University of Athens	University	Radiation modelling, software developer
CAA, Safety Regulation Group	Regulatory Authority	UK Aviation Safety Regulation

3. TECHNICAL ACHIEVMENTS

The aim of the Fire Detection and Suppression Simulation Programme (FIREDASS) is to develop computer modelling techniques which will aid the design of fire detection and non-halon suppression/extinguishing systems. This study is sponsored by the European Commission under the Brite/EuRam Programme (Contract No. BRPR-CT95-0040).

3.1 Scope

The report documents the progress achieved in the FIREDASS programme.

3.2 Industrial objectives and strategic aspects

The overall objective of the FIREDASS programme was to develop new sophisticated modelling techniques, which can then be used by industry to optimise fire detection and suppression/extinguishing systems. For industry, the development of these techniques would provide the following capabilities and benefits:

- The ability to model the effect of different fire scenarios, fire positions and different physical configurations of aircraft, ships, vehicles and buildings, and to generate data to allow the assessment of fire proofing of these enclosures.
- The ability to model fire detection/activation systems and water mist suppression/extinguishing systems to allow their performance (detection, suppression and extinguishment) to be assessed and optimised without conducting fire tests.
- Reduction in the development time and number of fire tests necessary for system certification.
- The replacement of synthetic extinguishing media that damage the environment.

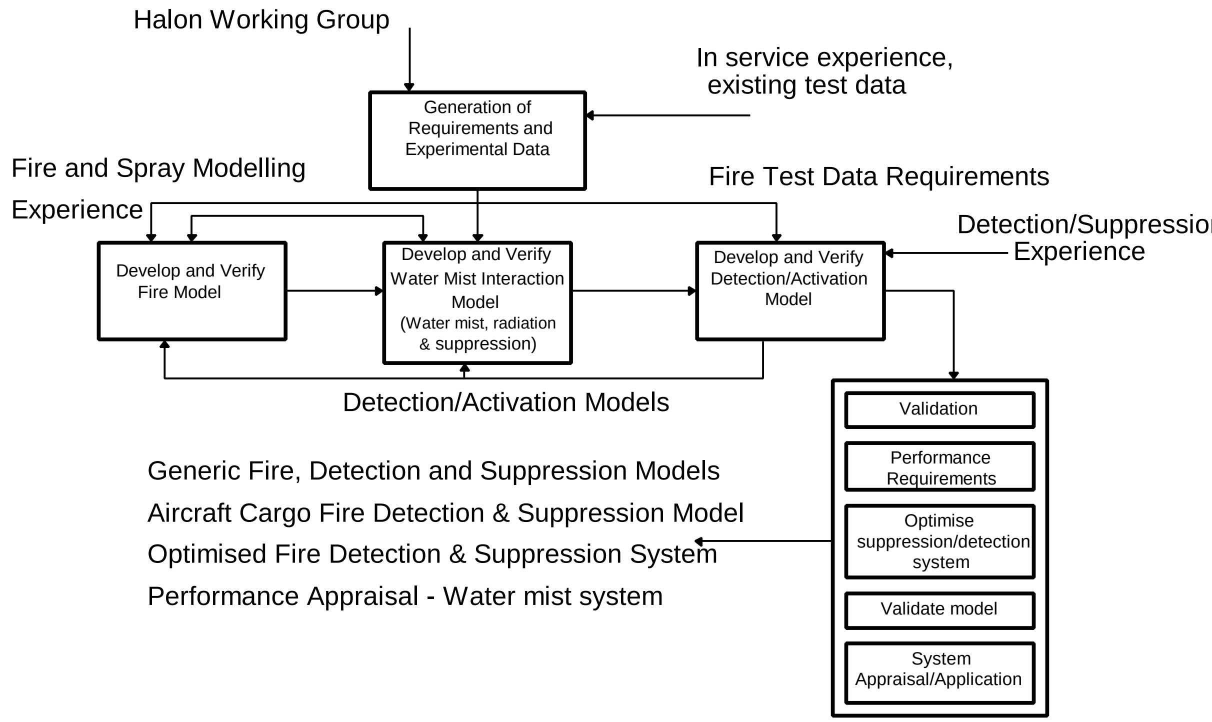
The software models to be developed and validated will comprise the following:

- A fire model capable of predicting the spread of fire hazards throughout the atmosphere of a forced ventilated enclosure, subject to a fire of prescribed characteristics.
- A model which predicts the activation of fire sensors within a forced ventilated enclosure.
- A water mist/fire atmosphere interaction model.
- A fire suppression model.

There is an immediate need to improve the performance of fire detection systems and with the increasing cost and depleting stocks of halon, the demand for a halon replacement suppression medium is increasing. By the end of the programme, the Consortium will be in a position to provide an improved fire detection system and an acceptable halon replacement suppressant in the form of water mist. This time frame, the Consortium believes, will be commensurate with market demand within the airline industry.

3.3 Work programme

The programme flow is shown below and the primary activities to achieve the objectives involved:



- Generation of requirement specifications for the generic and specific models, performance requirements specification for the suppression/detection system and experimental data to develop and verify the models.
- Design and development of physical models which will allow the simulation of various fire locations, fire growth, and the interaction of the fire suppression system and the fire detection system.
- Validation of the software models. The models will be used to optimise a fire suppression and detection system against a specified fire scenario. A hardware and software demonstrator of the optimised system will be developed and fire trials conducted to verify the performance of the models and the system.

3.4 Computer models

The primary aim of the project was to generate and validate a number of modules which, when integrated with the Computational Fluid Dynamics (CFD) engine, would allow the modelling of the interaction of fire, mist and radiation. The combined software product is referred to as the FIREDASS Package. The separate computer models developed as part of this programme included the, fire sub-model, fire suppression sub-model, mist sub-model, radiation sub-model (two-phase) and detector / activation sub-model. The interactions between these models are illustrated in Figure 3-1.

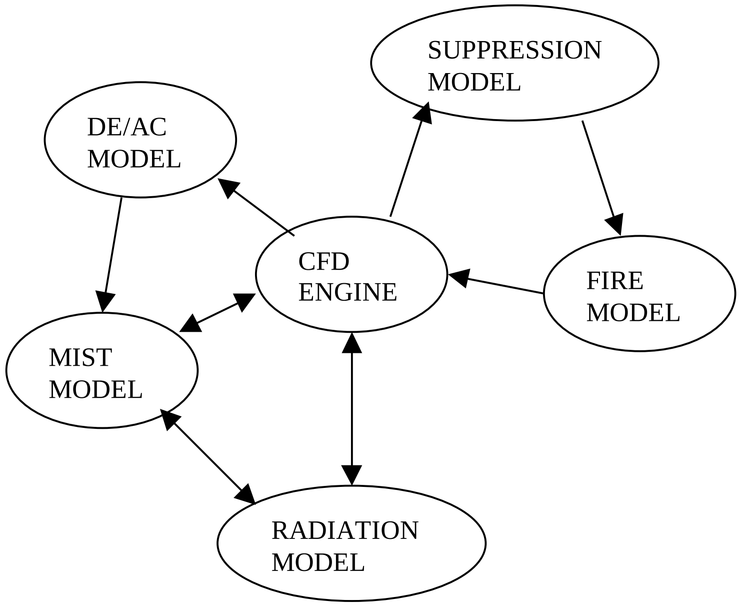


Figure 3-1. Interactions between the FIREDASS sub-models.

The whole code is built on the commercial CFD code CFX 4.1 using the interfaces provided by the USRXXX subroutines to implement the interactions between the models and the CFD engine.

3.4.1 The fire model.

This was successfully developed. It models the fire by prescribing the release rates, as a function of time, into the compartment of the main products of combustion, viz. heat, oxygen, carbon monoxide, carbon dioxide, water vapour and smoke. The CFD engine then transports these components around the compartment and predicts their distribution in space and time. However, as combustion is not modelled the release rates need to be specified in advance, i.e. obtained from experiment. Hence, the results produced by the fire model can only be considered to be as good as the experimental data defining the release rates. This is in line with the original FIREDASS objectives. The model has been successfully verified and validated and reports are available documenting the results.

3.4.2 The suppression model.

This was successfully developed. The model uses a set of criteria (developed by SINTEF and implemented by UoG) based upon the temperature and oxygen concentration in the vicinity of the fire to determine whether conditions are such that the fire would be extinguished. If they are then the release rates from the fire can be either set to zero or linearly decreased to zero over a time span set through the input files. The model is simple and empirical and has been verified within the limitations of the test data generated in this project. This is in line with the original FIREDASS objectives. A report is available on the development of, and rationale behind, the approach to suppression adopted.

3.4.3 Interaction model.

3.4.3.1 The mist model.

This was successfully developed. It models the effect of the mist upon the fire atmosphere by considering the momentum, heat and mass transfers between them. It also models the effect of the mist upon the radiation field by providing averages of droplet surface area and temperature to the radiation model for inclusion in the calculation of the opacity of the atmosphere to the radiation field. It takes the state of the mist at the nozzle as a boundary condition so this has to be supplied as experimental data. This is in line with the original FIREDASS objectives. The model has been verified and validated and results of these activities have been documented.

3.4.3.2 The radiation model.

This was successfully developed. It uses a six flux model to transport radiation from the fire and hot surfaces around the compartment. It uses a summed and averaged surface area and temperature for the mist in each computational cell to determine the loss of radiation enthalpy to the mist as well as calculating the enthalpy gained and lost to the radiation field due to the air and smoke. The enthalpy lost to the mist is passed to the mist model which distributes it between the droplets. The enthalpy lost to the air is passed to the CFD engine which transports it around the compartment. This is in line with the original FIREDASS objectives. The model has been verified and validated and results of these activities have been documented.

3.4.4 The detector / activation model.

This was successfully developed. It simulates the response of the smoke and heat detectors to their environment and predicts their signal output. This predicted signal output goes to the same software as the actual output will go to in the installed system. This software determines which nozzles to activate and when. This information is passed to the mist model which activates and deactivates the appropriate nozzles at the appropriate times. This is in line with the original FIREDASS objectives. The model has been verified and validated and results of these activities have been documented.

3.4.5 Conclusions.

The overall objective of the FIREDASS programme was to develop new sophisticated modelling techniques, which can then be used by industry to optimise fire detection and suppression/extinguishing systems.

A primary aim of the project was to generate and validate a number of modules which, when integrated with the CFD engine, would allow the modelling of the interaction of fire, mist and radiation. This has been done with the following restrictions.

To predict the generation of hazards within a fire compartment in a *fundamental* manner requires the incorporation of a combustion model to predict the hazard release rates. This was excluded from the project from the outset due to the complexity of the task. At the current state of development of fire modelling it is not possible to achieve this for arbitrary fuel types and fuel loads. Within the current model this problem is overcome through the imposition of prescribed release rates. Thus, for a given set of hazard release rates, the FIREDASS model can determine the hazard (e.g. temperature, CO, etc) history and distribution within the compartment. The effect upon this of the activation and deactivation times of the nozzles, the number of nozzles used, the mist characteristics etc. can then be determined. The FIREDASS model is therefore capable of assisting in the optimisation of the detection and suppression systems. Since the aim of the model development part of the project was to develop a modelling tool capable of performing this function it is concluded that this part of the project has been successfully completed.

A limitation of the model concerns the computational requirements necessary to perform a simulation. The computer hardware (i.e. DEC Alpha Workstation) used in the project is several years old, current technology could reduce run times by a factor of two. This would result in run times of typically 50 hours. If several such workstations or more powerful currently available computers are used this approaches practical turn around levels.

Given the assumptions of the model, to be considered a practical tool, the FIREDASS model requires accurate release rate and boundary data and a sufficiently powerful computer. If these conditions are met, the model can be used to better target the testing necessary for development and approval of the detection and water mist system.

The interaction model was applied to three applications during the programme:

1. Narrow bodied cargo compartment
2. Wide bodied cargo compartment
3. Ship turbine room

The validation of the various models and the FIREDASS Package has been accomplished using data generated from the full-scale experimental programme undertaken as part of the FIREDASS project. This environmental programme involved the construction of a A340 cargo compartment (section 3.5) which can be used for further fire research activities.

3.5 Demonstrator

Another of the objectives of the FIREDASS programme was to address the replacement of synthetic extinguishing media that damage the environment and to provide an improved fire detection system and an acceptable halon replacement suppressant in the form of water. The cargo suppression system demonstrator that was built during the programme consists of four major systems:

- fire detection and activation system;
- water mist fire suppression system;
- test rig;
- performance instrumentation system.

The test rig is a full scale steel mock-up of the lower part of an AIRBUS A340 fuselage section covering the front cargo compartment. Its overall length is 15m with a width of 5.540m and a height of 2.720m. The cargo compartment with the installation of the water mist system nozzles, the detection system sensors and the performance instrumentation has a length of 14.80m, a width of 4.20m and a height of 1.72m. It is covered by original cargo liner.

Figure 3-2. View of the test rig and inside the cargo compartment.

Testing and development during the FIREDASS programme has shown that the fire suppression and detection system developed as part of this programme controlled all the fire loads tested and is worth further investigation.

Further testing is necessary and urgently required on the water mist system and this should be explored within Framework V.

3.6 Minimum performance specification

While the FIREDASS programme has achieved much in leading to a better understanding of how water mist systems operate and how they may be efficiently employed in aviation applications, the industry as a whole has not established an agreed Minimum Performance Specification (MPS) for a non-halon system. This is considered to be a major disincentive to the development of water misting systems as a replacement for halon. Experience of the FIREDASS test campaign would suggest that any MPS for non-halon systems should include the performance of the detection systems. Work arising from the FIREDASS project has significantly contributed to the establishment of not only a possible MPS but has also provided input to the International Halon Replacement Working Group (IHRWG). As the most significant work contributing to this area has been undertaken in the FIREDASS programme, it is considered that Europe should take a proactive lead in resolving this situation.

4. EXPLOITATION AND MARKETING PLAN

4.1 University of Greenwich

The objective of the University of Greenwich is to develop - and wherever possible directly exploit - sophisticated fire safety software that can be used by fire safety engineers to aid in the development of a safer environment. In so doing, the fire safety engineering profession benefits from using tools that make their jobs easier and more efficient, the public benefits from a safer environment and the university benefits from fulfilment of its mission statement, enhanced reputation, and financially from the returns on licensed software. Past examples of this process include the development of the EXODUS evacuation software and the SMARTFIRE fire field model.

Thus the objective of the UoG is to partner consortium members and/or third parties – with the consent of the consortium - in order to make the FIREDASS package (i.e all the component modules working in unison) a useful tool for aviation applications. The UoG is also interested in partnering other organisations to adapt and further develop the various individual models or the FIREDASS package as a whole – with the consent of the consortium - for applications outside the interests of the consortium e.g. applications within the built environment, rail and chemical industries.

4.2 Marconi Avionics

The primary objective for MAv concerning the potential exploitation of the water mist technology is to ascertain whether a partnership could be created to take the water mist technology into the aerospace environment.

The possible strategies for Marconi Avionics are as follows:

- Conduct exploratory talks with potential partners (e.g. Cerberus (FIREDASS partner) and DASA (third party) to ascertain whether there is a viable development-exploitation route for the water mist technology.

The work required before formal exploitation of the technology can be conducted is summarised as follows:

- If we can not rely on the IHRWG to agree the minimum performance specification then Europe needs to define and agree a specification as per the original Framework IV DG VII programme.
- Water mist system and other halon replacement agents need to be tested against an agreed Minimum Performance Specification and compared against halon (and other agents). FIREDASS DLR A340 test rig could be used for such a programme under CEC funding.
- Test data from above could be used to further improve and refine the FIREDASS computer models.

4.3 Cerberus SA

The primary objective for Cerberus concerning the potential exploitation of the improved detection/activation systems technology is to involve market decision makers such as airframers and airworthiness authorities through a dedicated, European partnership in order to set the standards and define the design requirements for the next generation fire detection systems.

A strictly European partnership should indeed be sought to counter or lead international research that is undertaken in the field of aerospace fire safety thus allowing the European industry to shape the requirements and contribute to setting the standards.

Indeed, US lead research organisation including US manufacturers are actively involved in establishing the specifications for new fire protection systems which could later become an international standard. European active contribution to defining such standards will provide the European industry equal market opportunity.

4.4 DLR test rig

The test rig build as part of the FIREDASS fire detection and suppression system demonstrator provides a unique capability to investigate advanced technologies in the scope of fire detection and suppression systems and to verify the compliance of developed systems with certification requirements. The DLR will offer the use of this capability as a service provider for future research activities in the area of aircraft fire safety as well as fire detection and suppression system development and certification. By this European organisations and companies such as aircraft manufacturers, suppliers, airliners and research organisations will have access to a full scale-test facility within Europe that allows them to optimise and verify the quality and performance of advanced system developments.

4.5 SINTEF

SINTEF NBL is as a test house involved in the development of standards and test methods. The general knowledge about the suppression mechanisms using water mist gained through the FIREDASS programme, will be used in the development of new standards. The first step will be taken in CEN TC 191 – Fixed Fire Fighting Systems, WG5 – Sprinklers and water spray systems. A new task group on Water Mist Systems was formed in 1998, and the work is scheduled to start in 1999. The knowledge will be used to simplify tests procedures and minimise the number of tests needed for approval of water mist fire suppression systems.

4.6 CAA

Whilst maintaining the necessary confidentiality embodied in the Consortium Agreement, the CAA will use the knowledge gained as a FIREDASS partner in its contributions to any regulatory debate within the JAA or the JAA/FAA harmonisation process. If thought appropriate, FIREDASS partners might be supported by CAA as experts in the debate within bodies such as International Halon Replacement Working Group (IHRWG).