SOFTWARE TOOLS FOR FIRE ENGINEERING

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ABSTRAKT

Článek se věnuje popisu softwarových nástrojů pro analýzu a algoritmizaci modelů požáru a jejich využití v požárním inženýrství. S ohledem na komplikovaný proces získání výsledných průběhů teplot ze sofistikovaných modelů požáru, jako jsou zónové modely, zastoupené např. programem CFAST, a dynamické modely kapalin a plynů, zastoupené např. programem FDS, byl vytvořen program DataPlot. Tento nástroj slouží ke zpracování, zobrazení a porovnání výsledných hodnot průběhů teplot. V literatuře je popsáno velké množství zjednodušených modelů požáru. Pro usnadnění práce s těmito modely byl vytvořen program FMC (Fire Models Calculator). Tento program obsahuje vybrané zjednodušené modely požáru, se kterými lze efektivně pracovat. Oba softwarové nástroje jsou vytvořeny v prostředí programovacího jazyka MATLAB a mají podobu samostatně spustitelných aplikací.

KLÍČOVÁ SLOVA

Požární inženýrství • Modely požáru • MATLAB • FDS • CFAST

ABSTRACT

This paper is focused on the analysis and algorithmization of fire models for fire engineering. Because of the complicated process of obtaining results from the sophisticated fire models – zone models (e. g. software CFAST – Consolidated Fire and Smoke Transport Model) and Computational Fluid Dynamics models (e. g. software FDS – Fire Dynamics Software), a soft-ware tool DataPlot was developed. This tool serves for elaboration, display, and comparison of the resulting values of the temperature curves. In literature, there are available many simplified fire models. In order to simplify the usage of these models, a software tool FMC (Fire Models Calculator) was developed. This software tool contains selected simplified fire models. The software tools are developed in the MATLAB environment and they work as standalone applications.

KEYWORDS

Fire Engineering • Fire Models • MATLAB • FDS • CFAST

1. INTRODUCTION

Fire was a significant phenomenon in the past and is still an important scientific branch. With extending knowledge, scientists and researchers in fire safety engineering, can leave standard approaches and can apply advanced methods. A typical fire has four stages. Each stage can be investigated separately (Pokorný 2018).

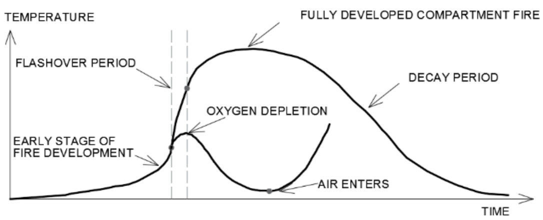

Fig. 1: *Phases of fire.* (Karlsson 2000)

Fire can be described by the models of fire. They can be deterministic (Benýšek et al. 2018) or probabilistic (Benýšek et al. 2019). This paper is mainly focused on the algorithmization of the deterministic fire models. These models can be simplified, e. g. nominal temperature-time curves (standard temperature-time curve, external fire, etc.), parametric temperature-time curves, or advanced, e. g. zone and CFD (Computational Fluid Dynamics) models, see Fig.2.

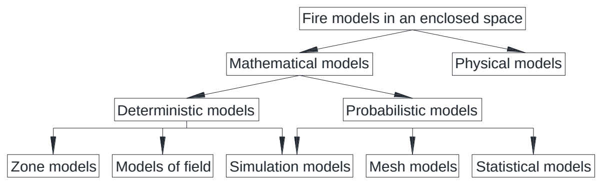

Fig. 2: *Types of fire models.* (Kučera 2010)

Currently, there is a tendency to use advanced fire models with sophisticated models for assessment of the fire resistance of structures for complicated buildings. However, this process is time-dependent so that there is a tendency to speed up it by automatization. That is the reason why two software tools were developed in MATLAB environment – DataPlot – tool for visualization of csv data (Štefan, Benýšek 2017) and FMC – Fire Models Calculator (Benýšek, Štefan 2018).

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2. SOFTWARE FMC

This program, see Fig. 3, was developed in MATLAB R2015b under the Czech Technical University academic license. It contains simplified and frequently used fire models. The main window of the programme is shown below.

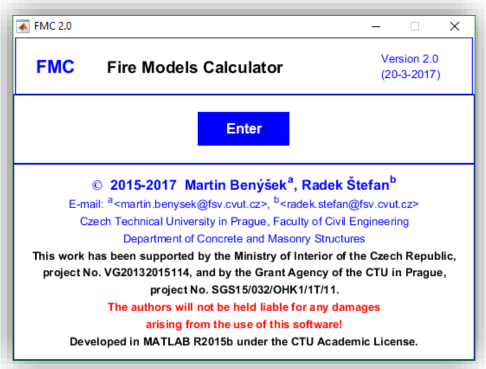

Fig. 3: *FMC.* (Benýšek, Štefan 2018)

FMC is divided into four main parts – type of model, see Fig. 4:

- Flashover
- Nominal temperature-time curves
- Natural fire models
- Equivalent time of fire exposure

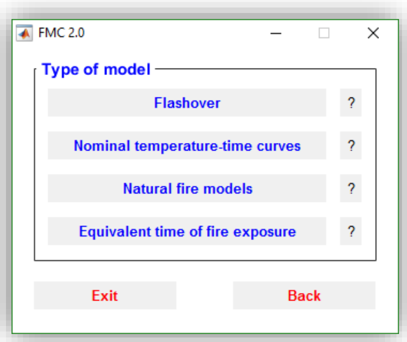

Fig. 4: *FMC- Type of Model.* (Benýšek, Štefan 2018)

2.1. FMC - Flashover

The flashover effect can be determined by the empirical equations according to three models (Babrauskas, Thomas, McCaffrey et.al.). In this section of FMC, according to inputs, the program can determine the value of the heat release rate (HRR or RHR) which is required for the flashover effect. It also allows plotting a graph of the required HRR for the flashover effect at given time according to McCaffrey et.al., see Fig. 5.

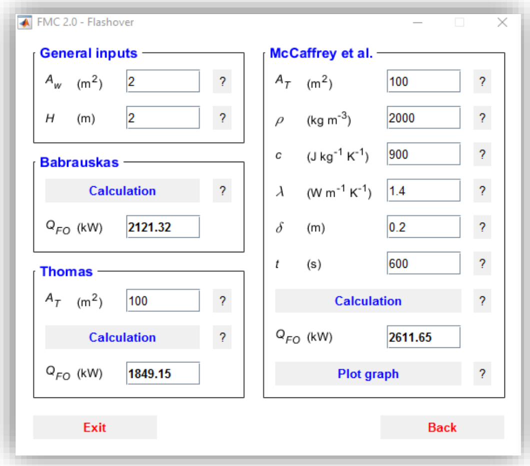

Fig. 5: *FMC - Flashover.* (Benýšek, Štefan 2018)

FMC is equipped with input control. Limits of fire models and formats of inputs are checked. In case that the input is incorrect, the input window becomes red, see Fig. 6. This is set up in the whole FMC software.

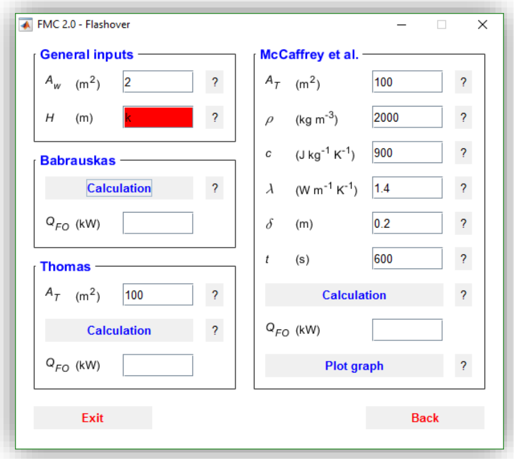

Fig. 6: *FMC – input control.* (Benýšek, Štefan 2018)

2.2. FMC – Nominal temperature-time curves

The program in this section allows plot up to eight nominal temperature-time curves. The plot is made according to the checkboxes for a given time. With regard to the possible comparison of the temperature-time curves with the temperature processes from sophisticated programs (e.g. CFD fire models, zone fire models) or fire experiments, it is available to load variable temperature curve(s) in .xls format, see Fig. 7. The loaded temperature curve(s) must have only one time-vector and a variable amount of temperature-vectors. The loaded curve(s) can be compared with the variable numbers of the nominal temperature-time curves. Nominal temperature-time curves could be also exported to a .xls format.

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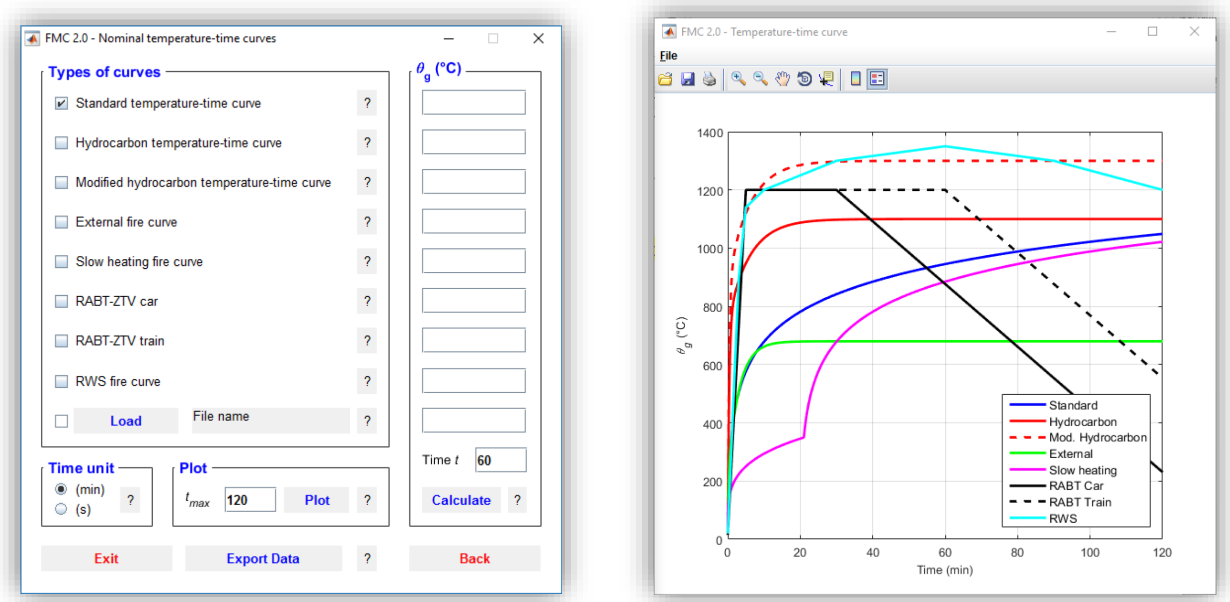

(a) (b)

Fig. 7: *FMC – (a) Nominal temperature-time curves, (b) graph of the temperature-time curves.* (Benýšek, Štefan 2018)

2.3. FMC – Natural Fire Models

Section Natural fire models is divided into five sub-programs, see Fig. 8:

- Heat Release Rate (HRR or RHR)
- HRR with activation of sprinkler nozzle
- HRR of flammable liquids
- Parametric temperature-time curve (EN 1991-1-2, Annex A)
- Localised Fires

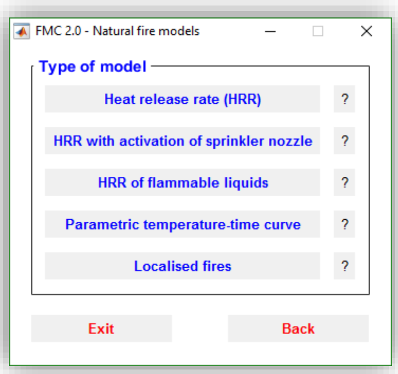

Fig. 8: *FMC – Natural Fire Models. (Benýšek, Štefan 2018)*

FMC can calculate the maximum value and plot the graph of the heat release rate. The program allows the export of the data in .xls format for the following applications (e.g. for CFD models of fire), see Fig 9.

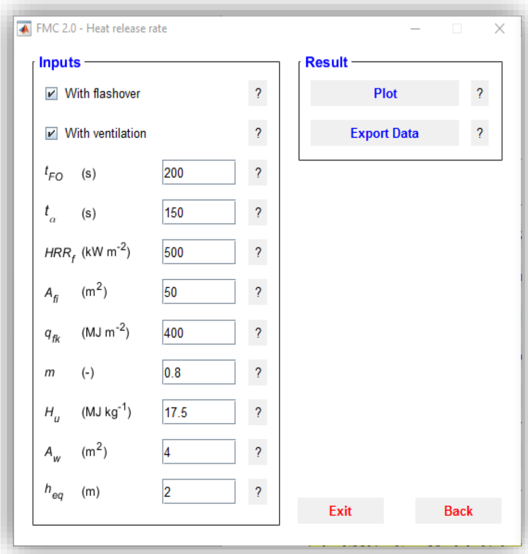

Fig. 9: *FMC – Natural Fire Models – HRR.* (Benýšek, Štefan 2018)

Program FMC can automatically determine the type of the HRR according to inputs (fuel-controlled fire, ventilation-controlled fire, fuel-controlled fire with flashover, ventilation-controlled fire with flashover).

The HRR with activation of a sprinkler nozzle, see Fig. 10, can calculate both models (Madrzykowski, D., & Vettori, R. L. (1992); Evans (1993)). The result of this fire model is a graph with a given maximum value of the HRR.

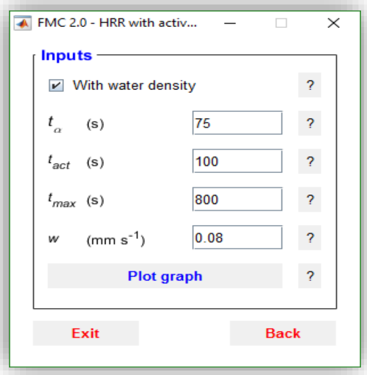

Fig. 10: *FMC – Natural Fire Models – HRR with activation of sprinkler nozzle.* (Benýšek, Štefan 2018)

The HRR of flammable liquids can determine the maximum value of the HRR based on the inputs. The calculation works for two different shapes (square and circle) where flammable liquids are located. FMC contains several input values, see Fig. 11.

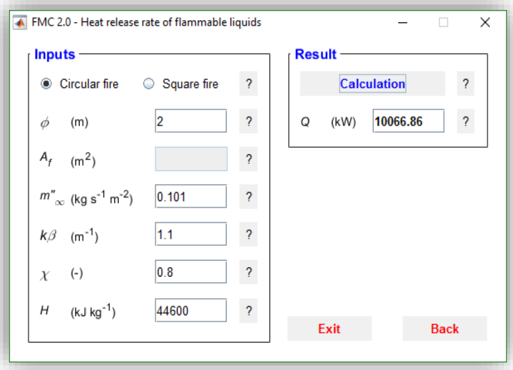

Fig. 11: *FMC – Natural Fire Models – HRR of flammable liquids.* (Benýšek, Štefan 2018)

The parametric fire curve is also included (EN 1991-1-2). FMC can plot the graph of this curve, calculate the temperature in variable time and export data in .xls format, see Fig. 12.

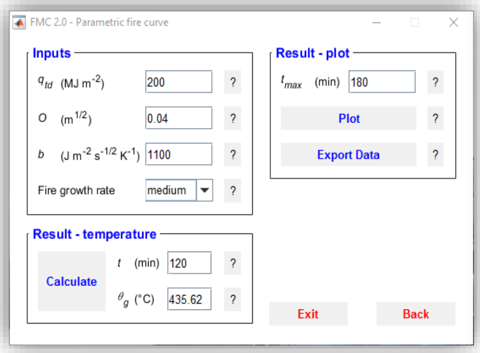

Fig. 12: *FMC – Natural Fire Models – Parametric temperature-time curve.* (Benýšek, Štefan 2018)

The next fire model is localised fire according to EN 1991-1-2. FMC contains both models (the flame is impacting the ceiling; the flame is not impacting the ceiling). According to the inputs, FMC determines the shapes of the flame and the heat flux from localised fire, see Fig. 13.

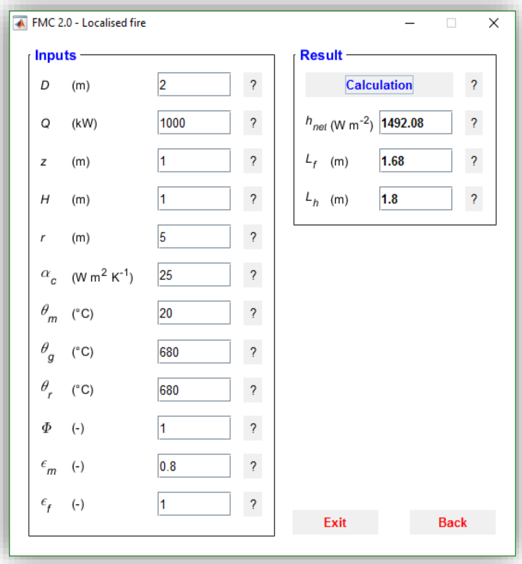

Fig. 13: *FMC – Natural Fire Models – Localised fire.* (Benýšek, Štefan 2018)

2.4. FMC – Equivalent Time of Fire Exposure

The last section of the FMC serves for determination of the Equivalent time of fire exposure, see Fig. 14. The program according to the inputs can assess the condition if the equivalent time of fire exposure is larger or smaller than the equivalent time of ISO-fire exposure assessed according to Eurocodes.

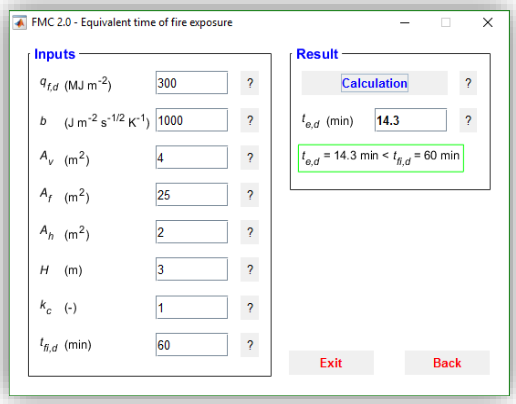

Fig. 14: *FMC – Equivalent time of fire exposure.* (Benýšek, Štefan 2018)

3. SOFTWARE DATAPLOT – TOOL FOR VISUALIZATION OF CSV DATA

Software DataPlot – tool for visualization of csv data (csv = Comma-Separated Values) is a simple tool for reformatting of the csv files into user-friendly xls files and, of course, it is for creating graphs. It is mainly created for support of the output files of the FDS and CFAST software. The main window is shown in Fig. 15.

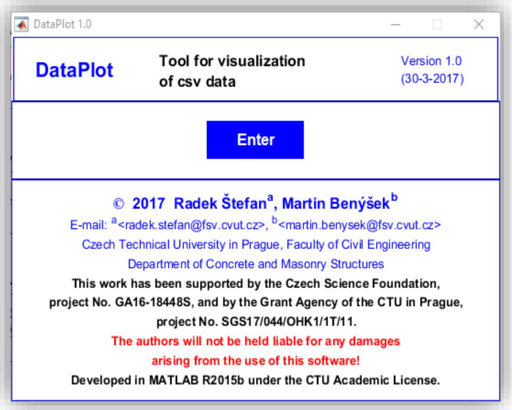

Fig. 15: *DataPlot.* (Štefan, Benýšek 2017)

This program was also developed in MATLAB R2015b under the Czech Technical University academic license. After the main window of the program, there is a prime window, see Fig. 16. This window is separated into two main parts – Input and Results.

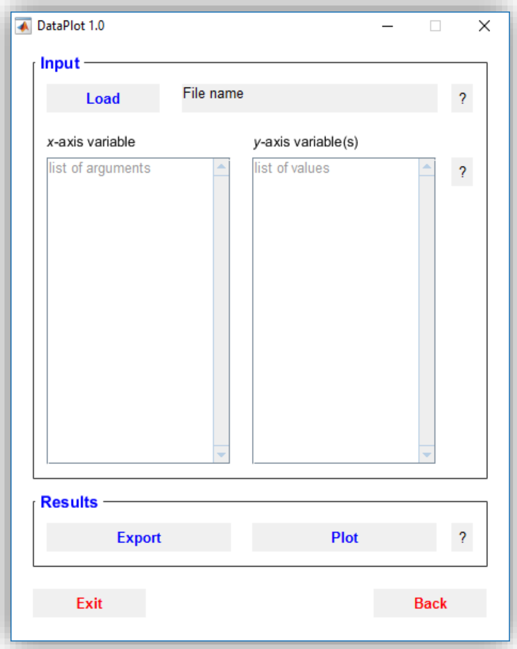

Fig. 15: *DataPlot – main window.* (Štefan, Benýšek 2017)

Load the data (e. g. the output from the Fire Dynamics Simulator) respecting the following rules:

- the input file must be in .csv format (the first sheet is assumed for the calculation),
- the first row must contain the units of variables separated by "comma",
- the second row must contain the names of variables separated by "comma",
- the third and the others must contain the variables data.

DataPlot contains input control and helps as well as FMC. Using the button "Load", it is available to load a random .csv file (output from FDS software). DataPlot loads all the data to columns (in DataPlot marked as x-axis variable and y-axis variable(s)), see Fig. 16, where the user can choose the axis "x" and the axis "y" for a graph. It can be marked only one value for the axis x and a variable amount of values for the axis y. Then the program DataPlot can plot the required graph.

DataPlot can also export the data to .xls file. This exported .xls file can be loaded in FMC software. This connection of FMC and DataPlot is appropriate for comparison, for example, the temperatures from FDS software with nominal temperature-time curves.

4. CONCLUSIONS

Modelling of fire is a complicated process. There are simplified models (e. g. nominal temperature-time curves, parametric temperature-time curves, localised fires, etc.), and advanced fire models (zone models and CFD models). For complicated buildings and for the economic design of the structure and fire safety design, there is a tendency to apply an advanced approach.

Two software tools have been developed: FMC – Fire Models Calculator and DataPlot – tool for visualization of csv data. FMC contains simplified and frequently used fire models. DataPlot is a simple tool for reformatting of the csv files into user-friendly xls files and, of course, it is for creating graphs.

Both software tools were developed in MATLAB R2015b under the Czech Technical University academic license.

FMC and DataPlot are useful in engineering practise and for future scientific purposes.

ACKNOWLEDGEMENTS

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References

Benýšek, M., Štefan, R. & Procházka, J. Analysis of fire resistance of concrete structural members based on different fire models: An illustrative example of the slab panel assessment. In 25th Concrete Days 2018, volume 292 of Solid State Phenomena, pages 173–182. Trans Tech Publications, 7 2019. (Benýšek et al. 2018)

Benýšek, M., Štefan, R. & Procházka, J. Effect of Fire Model Parameter Variability on Determination of Fire Resistance of Concrete Structural Members. In 26th Concrete Days 2019, Accepted. (Benýšek et al. 2019)

Karlsson, B., Quintiere, J. G. Enclosure fire dynamics. Boca Raton, FL: CRC Press, 2000. ISBN 0849313007. (Karlsson 2000)

EN 1991-1-2. Eurocode 1: Actions on structures – Part 1-2: General actions – Actions on structures exposed to fire. CEN, 2002. (EN 1991-1-2)

Štefan, R.; Benýšek, M. DataPlot - Tool for visualization of csv data [Software]. CTU in Prague 2017. (Štefan, Benýšek 2017)

Benýšek, M.; Štefan, R. FMC - Fire Models Calculator ver. 2.0 [Software]. CTU in Prague 2018. (Benýšek, Štefan 2018)

Pokorný, J.; Pavlík, T. Hodnocení rozvoje požáru při posuzování požární bezpečnosti staveb v České republice. V Ostravě: Sdružení požárního a bezpečnostního inženýrství, 2018. Spektrum (Sdružení požárního a bezpečnostního inženýrství). ISBN 978-80-7385-208-5. (Pokorný 2018)

Kučera, P. & Pezdová, Z. (2010), *Základy matematického modelování požáru*. Ostrava : Edice SPBI spektrum, ISBN: 978-80-7385-095-1. (Kučera 2010)

Madrzykowski, D., Vettori, R. L., A Sprinkler Fire Suppression Algorithm for the GSA Engineering Fire Assessment System, U.S. Dept. of Commerce, National Institute of Standards and Technology, Building and Fire Research Laboratory, Gaithersburg, MD, 1992.

Evans, D. D., Sprinkler Fire Suppression Algorithm for Hazard, Building and Fire Research Laboratory, National Institute of Standards and Technology, 1993