Fire Dynamics Simulator

Wolfram Jahn

Lulea, 13^{th}–15^{th} of March 2014

About FDS

Developed by Kevin McGrattan at NIST for examining fire and smoke movement in enclosed spaces such as atria, exhibition halls, warehouses, tunnels, etc

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- Radiation Model

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FDS consists of:

- Navier-Stokes solver
- Turbulence Model
- Combustion Model
- Radiation Model
- Boundary heat transfer

About FDS

Navier-Stokes:

Mass Conservation

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \rho \mathbf{u} = \dot{m}_b'''$$

Change of mass in Control Volume

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Incoming/Outgoing mass

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Produced mass

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Momentum Conservation

$$\frac{\partial}{\partial t}(\rho \boldsymbol{u}) + \nabla \cdot \rho \boldsymbol{u}\boldsymbol{u} + \nabla p = \rho \boldsymbol{g} + \boldsymbol{f}_b + \nabla \cdot \boldsymbol{\tau}_{ij}$$

Change of momentum
in Control Volume

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Inertia

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Pressure difference
(external force)

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Gravity

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Some external force

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Shear forces

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Energy Conservation

$$\frac{\partial}{\partial t}(\rho h) + \nabla \cdot \rho h \boldsymbol{u} = \frac{Dp}{Dt} + \dot{q}''' - \nabla \cdot \dot{\boldsymbol{q}}''$$

Change of energy in
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energy by convection

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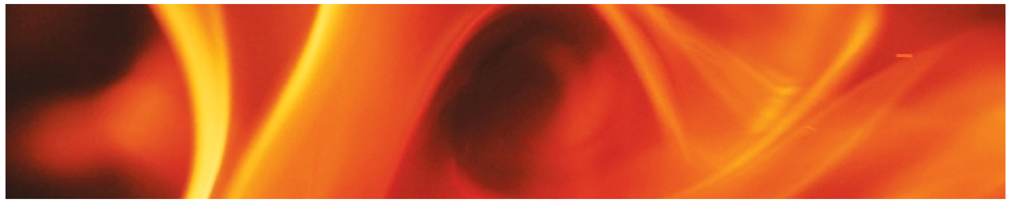
Energy production



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Gas Equation (for closure)

$$p = \rho \mathcal{R}_{\text{spec}} T$$

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- Two approaches to model a fire:
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  → "Fire spread".

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  → e.g. Sprinkler - Fire interaction DOES NOT WORK!!

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- Non-physical phenomena are common, but are often not recognized.
  → Example: Burning at openings.

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General Rule: **GIGO**!

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Garbage In – Garbage Out

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How does **FDS** work?

FDS

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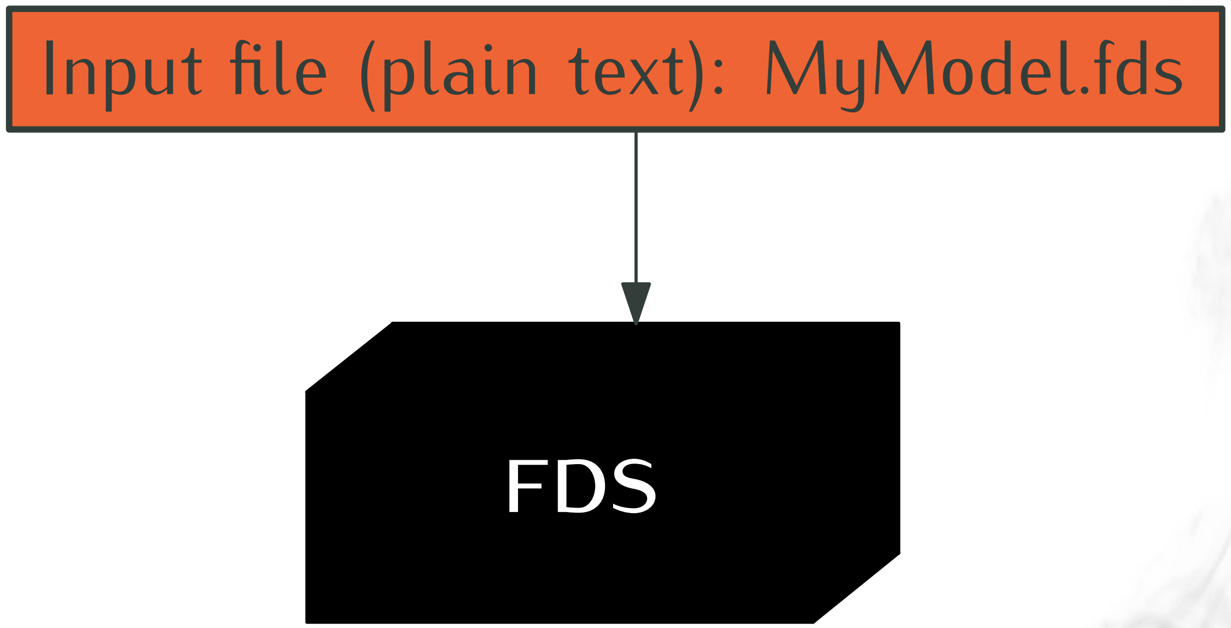
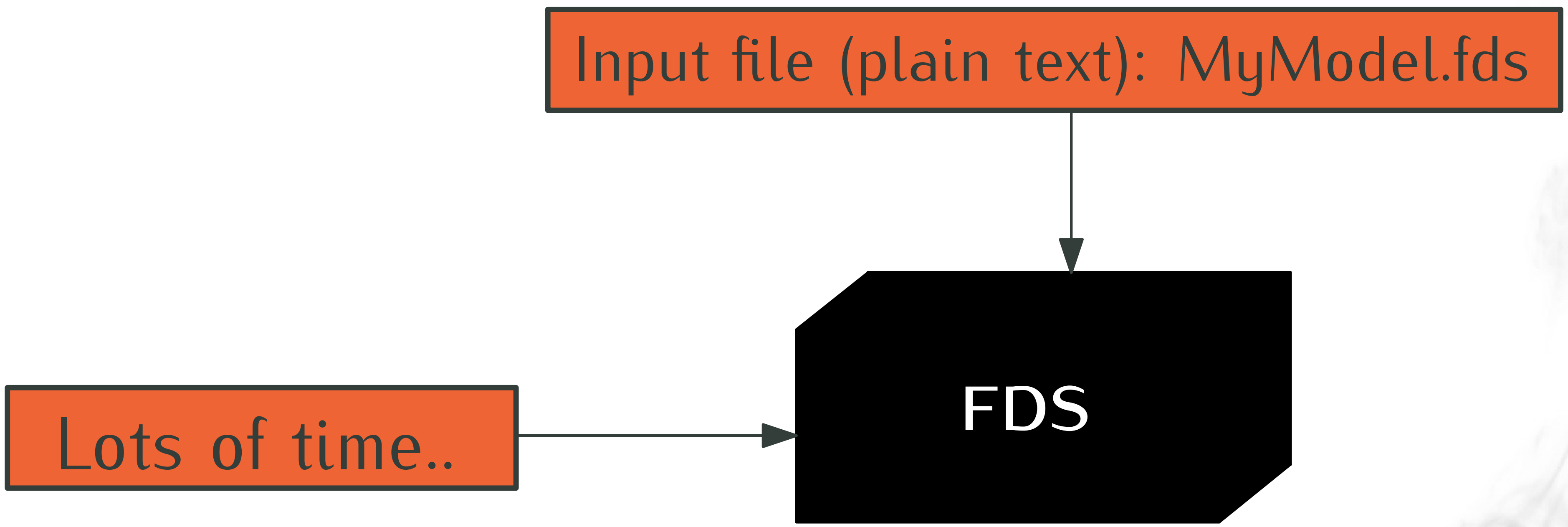


How does **FDS** work?



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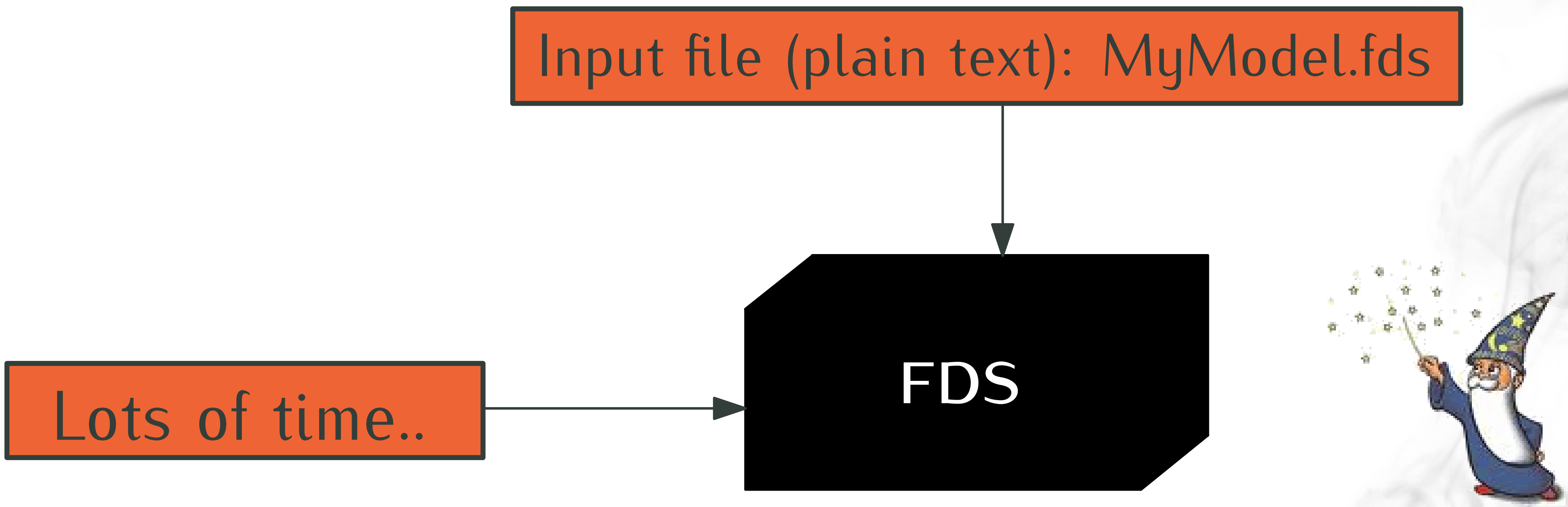

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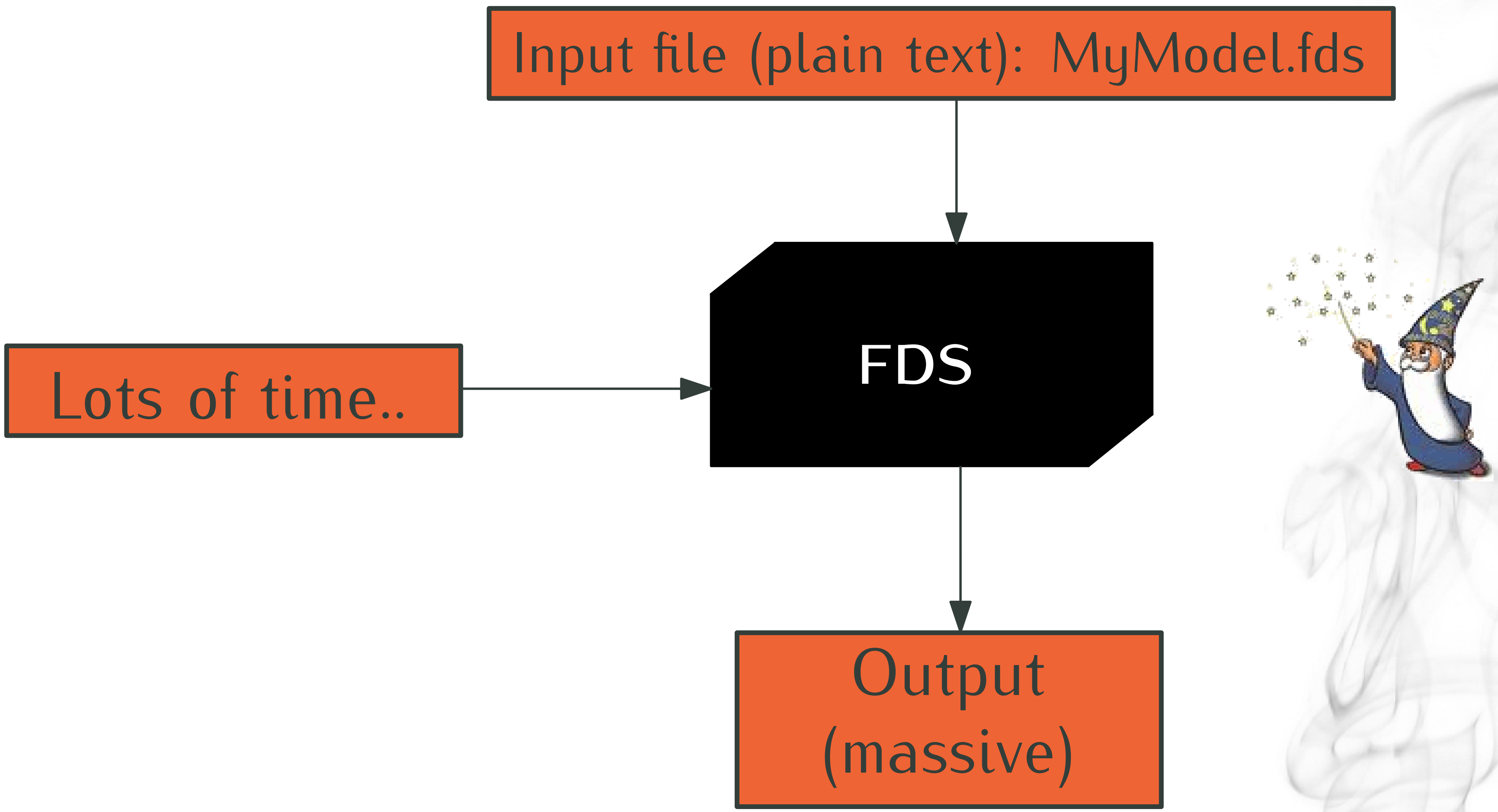

Creating an Input File

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- A valid line has to finish with a '\'.

Creating an Input File

CHID – Naming the input file:

```
// Setup of FDS file
&HEAD CHID='First Example', TITLE='First Try' /
```

Creating an Input File

The computational domain and grid:

```
// Setup of FDS file
&HEAD CHID='First Example', TITLE='First Try' /

// Grid spacing
&MESH IJK=120,192,40, XB=0.0,12.0,0.0,19.0,0.0,4.0 /
```

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// Setup of FDS file
&HEAD CHID='First Example', TITLE='First Try' /

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&MESH IJK=120,192,40, XB=0.0,12.0,0.0,19.0,0.0,4.0 /
```

$XB = x_i, x_f, y_i, y_f, z_i, z_f$

Creating an Input File

Simulation time:

```
// Setup of FDS file
&HEAD CHID='First Example', TITLE='First Try' /

// Grid spacing
&MESH IJK=120,192,40, XB=0.0,12.0,0.0,19.0,0.0,4.0 /

// Simulation time
&TIME T_END=10. /
```

Creating an Input File

RAINDANCE SCIENCE INTERNATIONAL

Simulation time:

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&HEAD CHID='First Example', TITLE='First Try' /

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&MESH IJK=120,192,40, XB=0.0,12.0,0.0,19.0,0.0,4.0 /

// Simulation time
&TIME T_END=10. /
```

if set to 0, only geometry is checked.

Creating an Input File

Miscellaneous:

```
// General Parameters
&MISC SURF_DEFAULT='CONCRETE', RADIATION=.FALSE.,TMPA=25.,
                    RESTART=.TRUE. /
```

Creating an Input File

Control:

```
// General Parameters
&MISC SURF_DEFAULT='CONCRETE', RADIATION=.FALSE.,TMPA=25.,
                    RESTART=.TRUE. /

// Control Parameters
&DUMP DT_RESTART=100.,NFRAMES=1800 /
```

Creating an Input File

Control:

```
// General Parameters
&MISC SURF_DEFAULT='CONCRETE', RADIATION=.FALSE.,TMPA=25.,
                    RESTART=.TRUE. /

// Control Parameters
&DUMP DT_RESTART=100.,DT_DEVC=5.,DT_SLCF=10. /
```

Defining the Geometry

Obstacles:
Walls, furniture, doors etc. are all defined using rectangle blockages

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// Creating obstacles
&OBST XB=6.2,6.4,1.6,6.6,0.0,2.4 /
```

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```

from x to x

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```

from y (1.6) to y (6.6)

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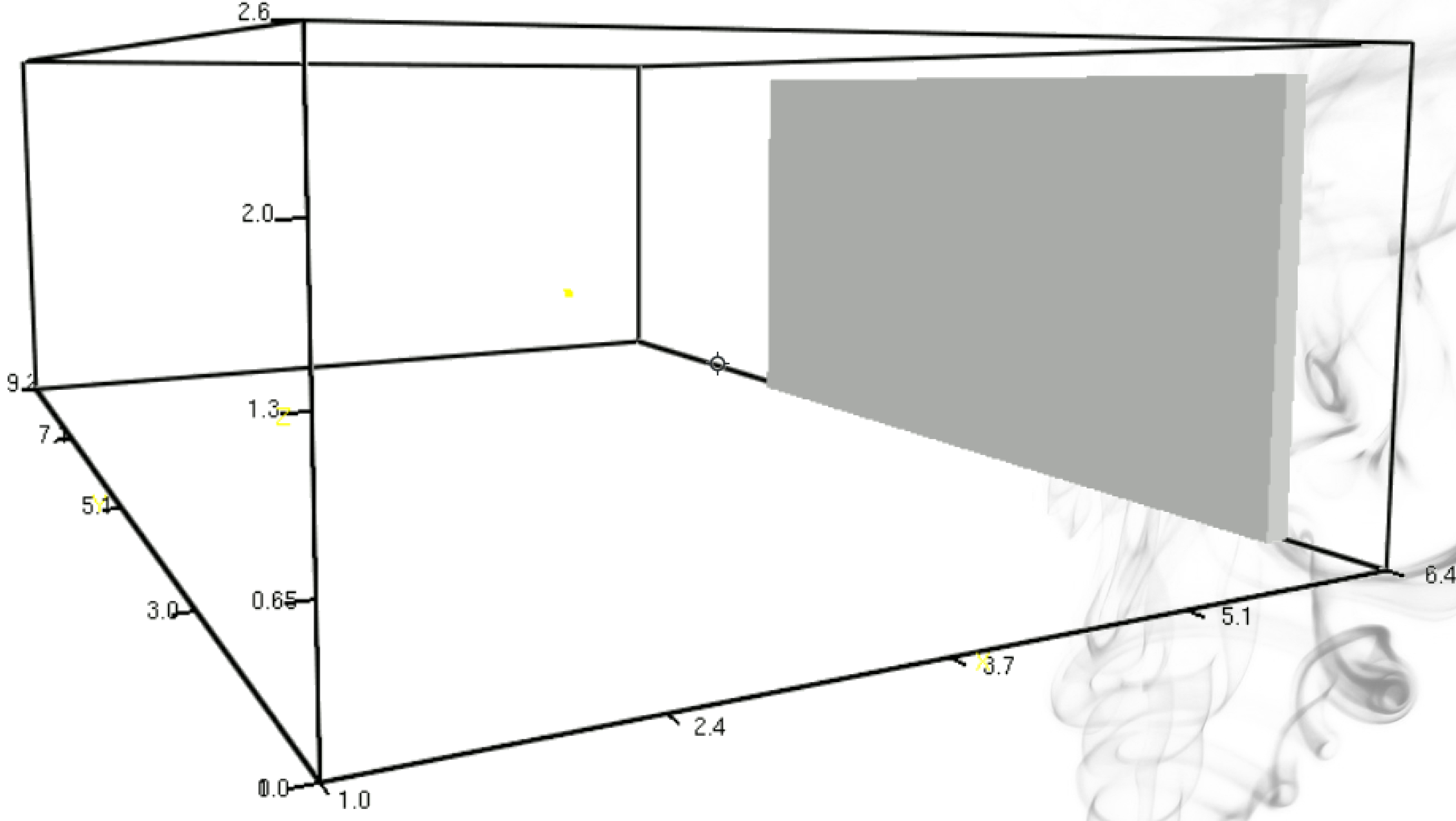
&OBST XB=6.2,6.4,1.6,6.6,0.0,2.4 /
```

from z (0.0) to z (2.4)

Defining the Geometry



Boundary Conditions

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- What about thermal boundary conditions (to calculate heat fluxes, wall temperatures)?

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Surfaces and Materials

```
&SURF ID='Wall',MATL_ID='Paper','Concrete',
         THICKNESS=0.001,0.3,BACKING='EXPOSED'/
```

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```
&SURF ID='Wall',MATL_ID='Paper','Concrete',
         THICKNESS=0.001,0.3,BACKING='EXPOSED'/
&MATL ID='Paper',CONDUCTIVITY=0.12,
         SPECIFIC_HEAT=1.172,DENSITY=128./
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Surfaces and Materials

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&SURF ID='Wall',MATL_ID='Paper','Concrete',
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&MATL ID='Paper',CONDUCTIVITY=0.12,
         SPECIFIC_HEAT=1.172,DENSITY=128./
&MATL ID='Concrete',CONDUCTIVITY=1.7,
         SPECIFIC_HEAT=0.75,DENSITY=2400./
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Boundary Conditions

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→ `&VENT XB=6.2,6.2,1.6,6.6,0.0,2.4,SURF_ID='WOOD'\`

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- The BCs of the Computational domain have to defined:

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  → `&VENT XB=6.2,6.2,1.6,6.6,0.0,2.4,SURF_ID='WOOD'\`
- The BCs of the Computational domain have to defined:

```
 //  All domain boundaries initially exposed
&VENT MB='XMIN',SURF_ID='OPEN'/
&VENT MB='XMAX',SURF_ID='OPEN'/
```

The Fire

- Special case of Boundary Condition

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↓

SURF ID

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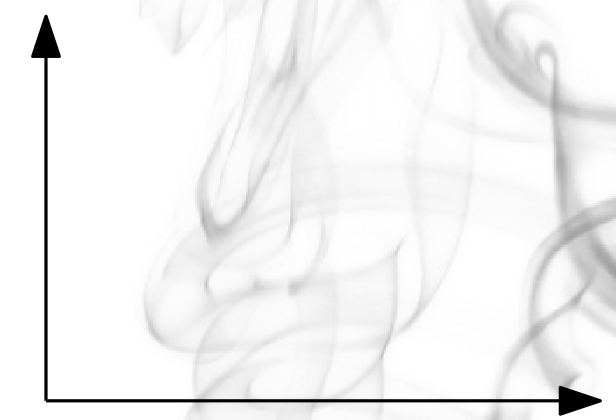
SURF ID

- HRRPUA, RAMP

```
&SURF ID='MyFire',HRRPUA=700,RAMP_Q='MyRamp'\
```



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```
&SURF ID='MyFire',HRRPUA=700,RAMP_Q='MyRamp'\

&RAMP ID='MyRamp',T=0,F=0.0/
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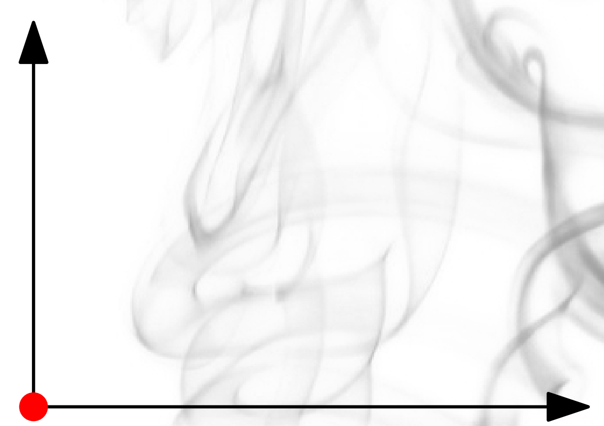

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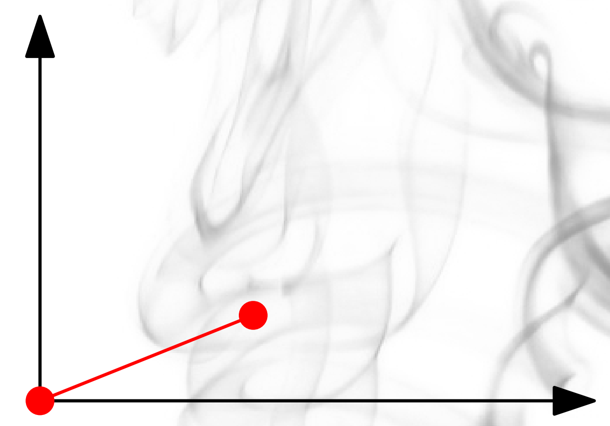
&SURF ID='MyFire',HRRPUA=700,RAMP_Q='MyRamp'\

&RAMP ID='MyRamp',T=0,F=0.0/
&RAMP ID='MyRamp',T=80,F=0.2/
```



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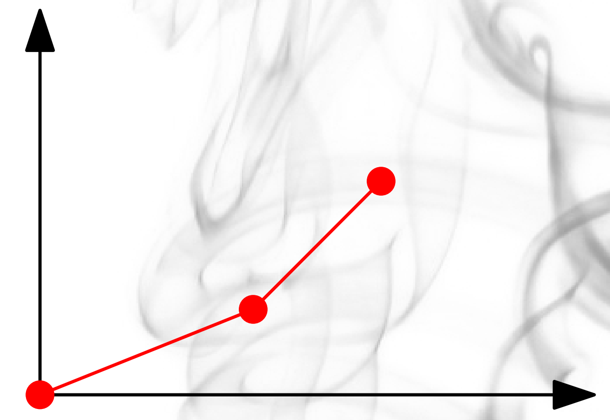
&RAMP ID='MyRamp',T=80,F=0.2/
&RAMP ID='MyRamp',T=120,F=0.5/
```



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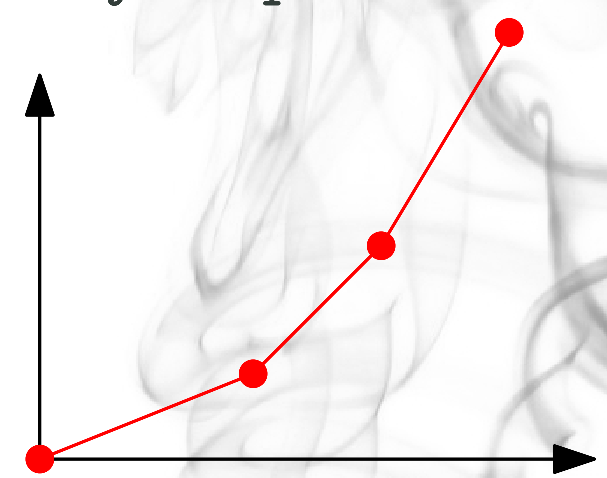
&RAMP ID='MyRamp',T=0,F=0.0/
&RAMP ID='MyRamp',T=80,F=0.2/
&RAMP ID='MyRamp',T=120,F=0.5/
&RAMP ID='MyRamp',T=150,F=1.0/
```



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&VENT XB=0.0,5.0,1.5,9.5,0.0,0.0,SURF_ID='FIRE',
         XYZ=1.5,4.0,0.0,SPREAD_RATE=0.03/
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- You can also define pyrolysis parameters and get FDS to mimic a "real" fire.→VERY Carful with that!

Other BCs

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Air supply:

```
&SURF ID='SUPPLY', VEL=-1.2, COLOR='BLUE' /
&VENT XB=5.0,5.0,1.0,1.4,2.0,2.4, SURF_ID='SUPPLY' /
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&VENT XB=5.0,5.0,1.0,1.4,2.0,2.4, SURF_ID='SUPPLY' /
```

Exhaust:

```
&SURF ID='EXHAUST', VEL=1.2, COLOR='RED' /
&VENT XB=5.0,5.0,1.8,3.3,2.0,2.4, SURF_ID='EXHAUST' /
```

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- Add `SETPOINT` to `DEVC` line:

```
&DEVC XYZ=0,0,0,ID='Clock',QUANTITY='TIME',SETPOINT=30.,INITIAL_STATE=.TRUE./
```

Manage the Output

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  → `&DEVC XYZ=2.0,6.4,0.0,QUANTITY='TEMPERATURE'/`
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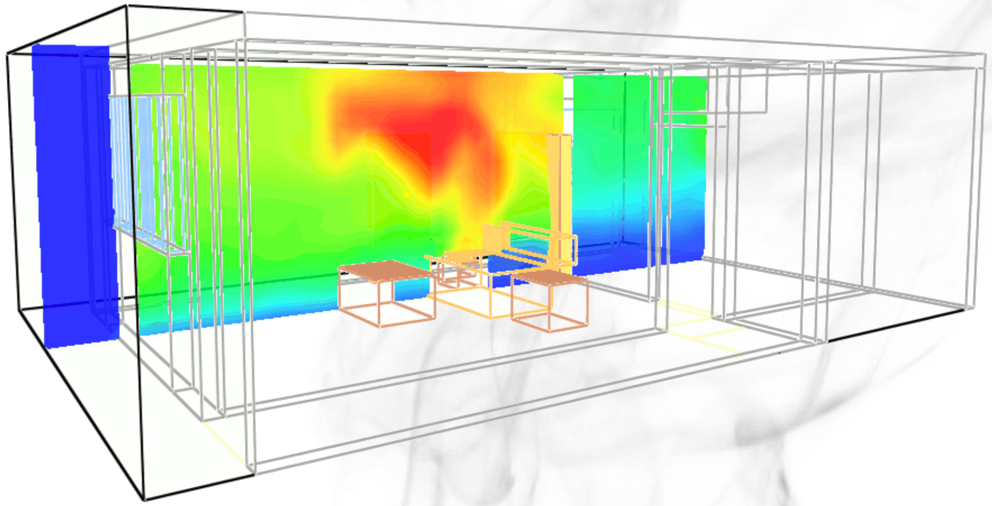
- Devices (`DEVC`) can also be used to control actions:
  → Smoke detectors, Sprinklers etc.

- Add `SETPOINT` to `DEVC` line and link it to other item:

```
&DEVC XYZ=0,0,0,ID='Clock',QUANTITY='TIME',SETPOINT=30.,INITIAL_STATE=.TRUE./
&OBST XB=...,SURF_ID='...',DEVC_ID='Clock'/
```

Manage the Output

- Slice Files:



Manage the Output

- Slice Files:

→ `&SLCF PBZ=0.45,QUANTITY='TEMPERATURE',VECTOR=.TRUE./`

Plane parallel to $z = 0.45$

Manage the Output

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- Boundary Files:

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Manage the Output

- Slice Files:
  → `&SLCF PBZ=0.45,QUANTITY='TEMPERATURE',VECTOR=.TRUE./`

- Boundary Files:
  → `&BNDF QUANTITY='TEMPERATURE'/`

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  → Define `BNDF_OBST=.TRUE.` on an `OBST` line you want to see.

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- Information contained in the slice files can be exported into spreadsheet format if required (using `fds2ascii`, which can be downloaded from the FDS website).

Finally...

- The last line in an FDSv5 input file is '`&TAIL/`':

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```
&OBST XB=5.6,6.2,5.8,6.6,0.0,2.0,SURF_ID='WALL'/
&OBST XB=5.4,6.2,1.6,5.8,0.0,2.0,SURF_ID='WALL'/

&SURF ID='WALL', MATL_ID='...'.../

&MATL ID='...'..../
&SLCF PBZ=0.45,QUANTITY='TEMPERATURE',VECTOR=.TRUE./

&TAIL/
```

How to run **FDS**?

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- Once in your working directory run **FDS** by typing:

```
fds5 inputfile.fds
```

Let's try...