# Tools: Garfield and Maxwell

## —— Introduction and Application

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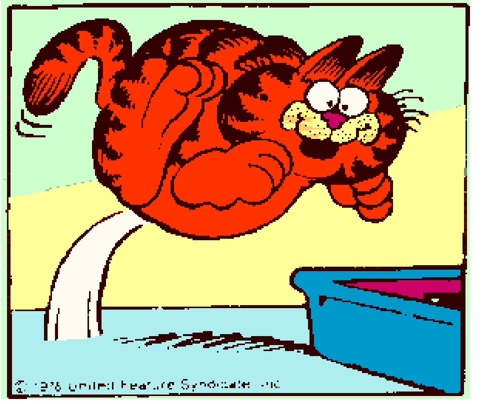
# Outline

- Some Simulation tools
- Introduction of Garfield
- Application of Garfield
- Introduction of Maxwell
- Application of Maxwell

# Some simulation tools

- ***Garfield***: main framework; electric field map…etc.
- ***Maxwell***: electric field map; magnetic field map…etc.
- ***Magboltz***: electron/ion drift velocity and diffusion coefficients
- ***Imonte***: Townsend and attachment coefficients for given gas mixture
- ***Heed***: energy loss by ionization in gas; cluster production

# Introduction of Garfield



- What's Garfield?

Garfield is a computer program for the detailed simulation of two- and three-dimensional drift chambers.

**Author**: Rob Veenhof (CERN)

**Latest Version**: 9.0

**Supporting OS**: Linux (Red Hat Enterprise Linux 3/4 )

You can get it freely:

**http://garfield.web.cern.ch/garfield/**

# Introduction of Garfield

- **Field**

Originally, the program was written for two-dimensional chambers made of wires and planes, such as drift chambers, TPCs and multiwire counters.

Garfield accepts two and three dimensional field maps computed by finite element programs such as Maxwell, Tosca, Quickfield and FEMLAB as basis for its caculations.

**Advantage**: The finite element technique can handle nearly arbitrary electrode shapes as well as dielectrics.

- **Transport and ionization in gas mixtures**

An interface to the Magboltz program and Heed program are provided the computation of electron transport properties in nearly arbitrary gas mixtures.

# Introduction of Garfield

- How to install Garfield?

1. Compile Garfield yourself (Not easy)

The main program files of Garfield, Heed and Magboltz are the same for all machines. But you need download the cradle files and make files according to your computer and OS.

2. Compressed ready to use executables files (Easy)

To decode the compressed files and set accurately your environment variables (For example: $LD_LIBRARY_PATH)

# Applications of Garfield

**The program can calculate for instance the following:**

- field maps, contour plots and 3-dimensional impressions;
- the wire sag that results from electrostatic and gravitational forces;
- optimum potential settings to achieve various conditions;
- plots of electron and ion drift lines;
- x(t)-relations, drift time tables and arrival time distributions;
- signals induced by charged particles traversing a chamber, taking both electron pulse and ion tail into account.

# Applications of Garfield

- How to run it?

  If you have installed garfield successfully in your OS, you can input garfield to run it.

  /home/user> garfield-9

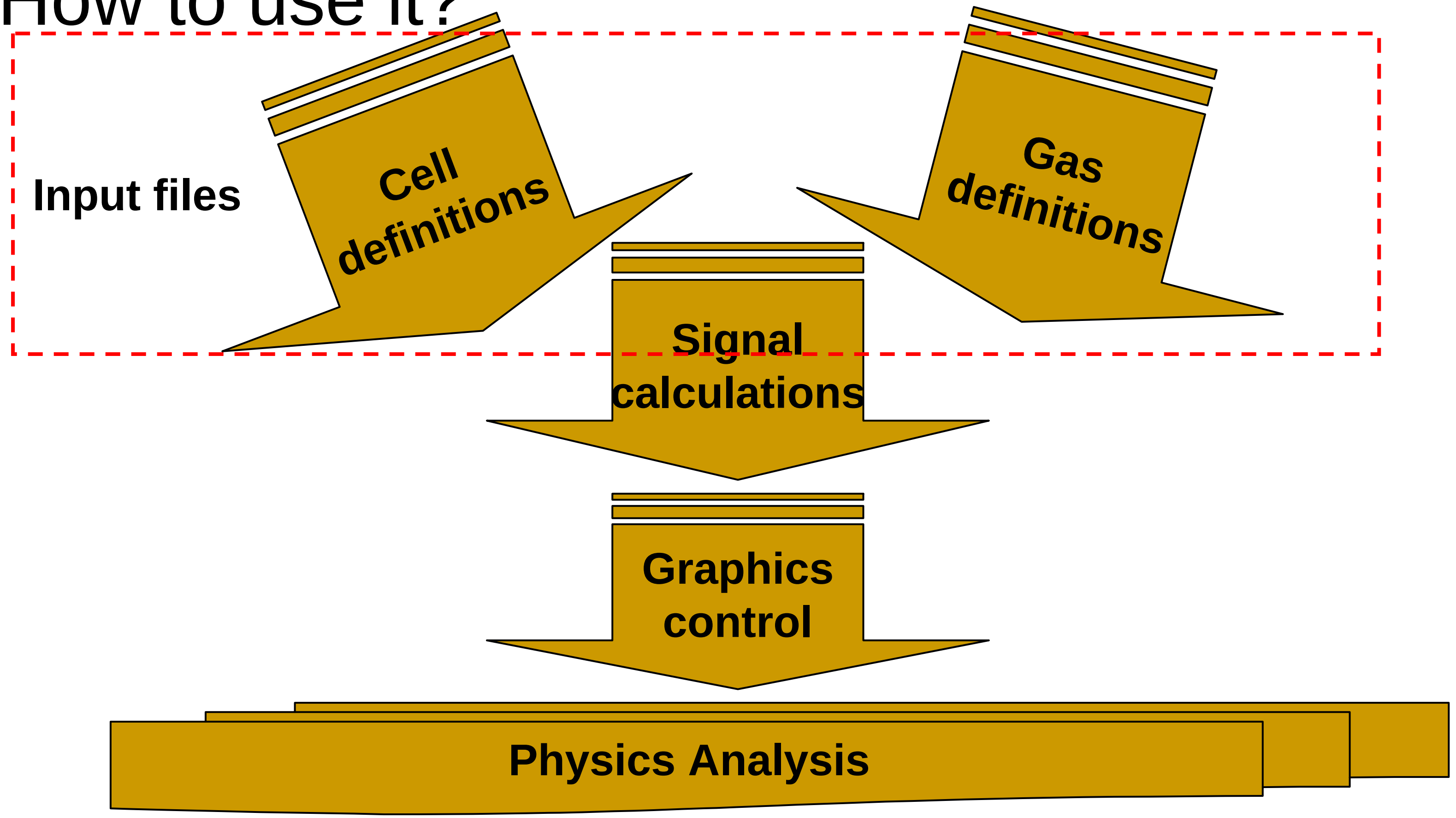
```
RANLUX DEFAULT INITIALIZATION:    314159265
RANLUX DEFAULT LUXURY LEVEL =   3      p = 223
RM48 INITIALIZED:  54217137          0         0
 ------ RNDINI MESSAGE : Random number generators have been called  14256
 times.
Version 1.29/04 of HIGZ started
Workstation type (?=HELP) <CR>=1 :
 Welcome, this is Garfield - version 7.13, updated until 22 Nov 2006

 Documentation is in http://cern.ch/garfield

 Main:
```

# Applications of Garfield

- How to use it?



# Applications of Garfield

## Global variables (Example)

- *------------------------------------------------------------------*
- * Garfield input file for generating r-t relations. *
- * (Adapted from a file from Werner Riegler.) *
- *------------------------------------------------------------------*
- Global tp = 0.025
- Global ex = 6
- Global ENC = 6650
- Global gain= 20
- Global volt= 3270
- Global num = 50
- Global rmsnoise = 250*ex**ex*exp(-ex)*ENC*1.609e-7
- Global thr1 = -5*rmsnoise
- Global pressure=3*760
- Global tau1 = 0.169
- Global tau2 = 0.10
- Global tau3 = 0.135
- Global tau4 = 0.054
- Global tau5 = 1.130
- Global tau6 = 0.706
- Global t1 = 0
- Global rmin=0.0501
- Global rmax=1.474
- Global nr=20

# Applications of Garfield

## Cell and Gas definitions (Example)

```
*---------------------------------------------------------------*
* Description of the tube and the magnetic field. *
*---------------------------------------------------------------*
& CELL
tube radius 1.475 voltage 0
rows
s 1 0.05 0 0 {volt}
*---------------------------------------------------------------*
* Description of the gas. *
*---------------------------------------------------------------*
& GAS
Global gas_file y    jd/public/Digit/mdtgas.py/string(pressure/760)
pressure {pressure}
Call inquire_file(gas_file,exist)
If exist Then
Say "Gas file {gas_file} exists, retrieving ..."
get {gas_file}
Else
opt gas-plot
Say "Gas file {gas_file} not found, generating ..."
magboltz Argon 91 Nitrogen 4 Methane 5 ...
low-precision ...
mobility 0.55e-6
parameter mean {40*pressure/760}
cluster function=35.909221/(n**2) overlap
0.0, 82.2, 3.1, 2.2, 1.4, 0.9, 0.7, 0.4, 0.3, 1.1, 1.7,
0.9, 0.5 , 0.5, 0.4, 0.4, 0.4, 0.4, 0.35,0.25,0.15
write {gas_file}
Endif
```

**Cell definitions**

**Gas definitions**

# Applications of Garfield

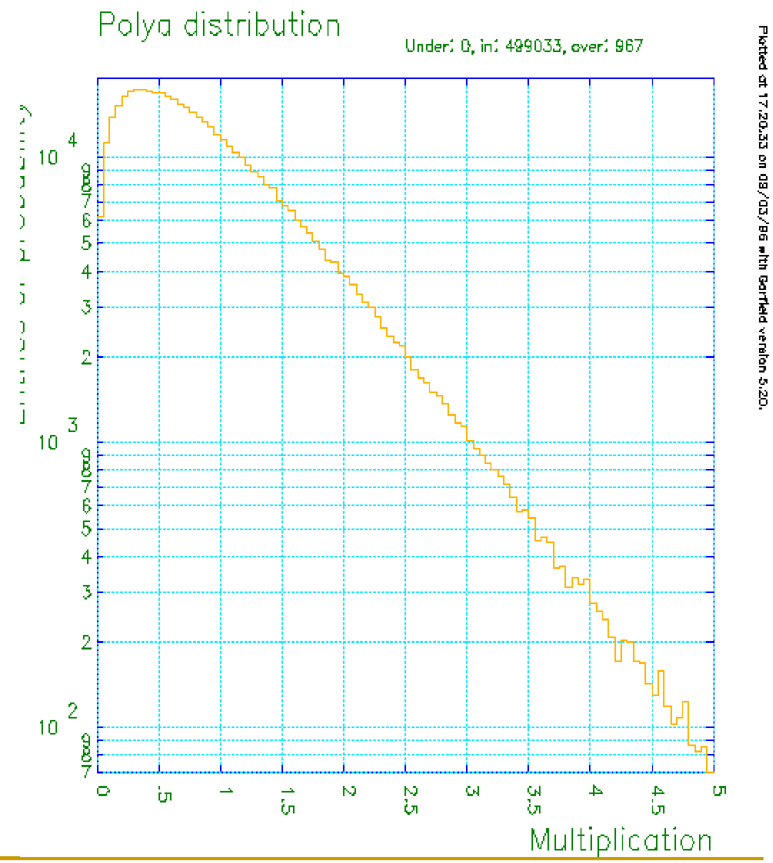
## Signal calculations (Example)

```
*----------------------------------------------------------------*
* Compute the signals, apply electronics and compute thresholds. *
*----------------------------------------------------------------*
& SIGNAL
opt nocluster-print nocluster-plot
avalanche polya-fixed {gain} 0.38
resolution 0.0 0.01
For ir from 1 Step 1 To nr Do
Global r=rmin*(rmax/rmin)**((ir-1)/(nr-1))
track {r} -1.5 {r} 1.5
prepare-track
call book_histogram(ref,50)
For i From 1 To num Do
signal avalanche diffusion ion-tail electron-pulse
add-noise noise-function=RND_GAUSS*6650*1.609e-4/3.6
convolute-signals ...
transfer-function 0.85*250*({ex}*t/{tp})**{ex}*exp(-{ex}*t/{tp})
convolute-signals ...
transfer-function (1/{tau3}-1/{tau4})*exp(-t/{tau4}) ...
add signal
convolute-signals ...
transfer-function (1/{tau5}-1/{tau6})*exp(-t/{tau6}) ...
add signal
Call threshold_crossing(1,thr1,yNOPLOT,FALLING,LINEARy,n,t1)
Call fill_histogram(ref,t1)
Enddo
Call fit_gaussian(ref,int,mean,sig,eint,emean,esig,yNOPLOTy)
Say "r={r}: t={mean} +/- {emean}, sigma_t={sig} +/- {esig} musec."
Call delete_histogram(ref)
Enddo
```

# Applications of Garfield

## A example of Garfield utilities

- *------------------------------------------------------------------------------------ *
- * Draw 500000 Polya distributed random numbers and plot *
- * the histogram on a log scale. *
- *------------------------------------------------------------------------------------ *
- Call book_histogram(ref,100,0.0,5.0)
- For i From 1 To 500000 Do
- Call fill_histogram(ref,rnd_polya(0.5))
- Enddo
- !opt log-y
- Call plot_histogram(ref,`Multiplication`,`Polya distribution`)
- Call plot_end



# Applications of Garfield

Here are some examples of gaseous detectors studies for which Garfield has been used. ( You can get the input files from web)

- Resolution and calibration of the Atlas muon tubes
- Wire movements in the Alice RICH
- Diffusion study for Micromegas
- CMS barrel muon drift tubes (containing comparisons of Magboltz gas data to measurements)
- Electrostatic study of a mini TPC for PEP2 commissioning
- Study of the drift properties in the HADES drift chamber prototype
- Effect of the water contents on the transport properties of a gas
- Calculation of the gain in straw tubes
- Micropattern detector simulation using finite element methods
- Avalanche simulation in a GEM foil
- The Sandglass detector

# Training of Garfield

- Run the example

1. You can input every line one by one.
2. You can write a file to input it.

```
&GAS
write 'Gas_p5.gas'
temperature 290 K
pressure 1 atm
magboltz CH4 5 Ar 95 electric-field-range 100 200
```

To start calculating the GAS section

Write files

Set temperature is standard temperature

Set gas pressure

Set electric field rang

Set gas mixtures

# Introduction of Maxwell

- What's Maxwell?

ANSOFT
PRODUCTS AT CERN

**Maxwell is a commercial software, Not Free!**

**Latest Version**: 11.1

**Supporting**: Windows

**Calculates <u>Electric</u> , <u>DC Magnetic</u>, and <u>AC Eddy Current fields</u> in the frequency domain using an advanced quasi-static solving engine**

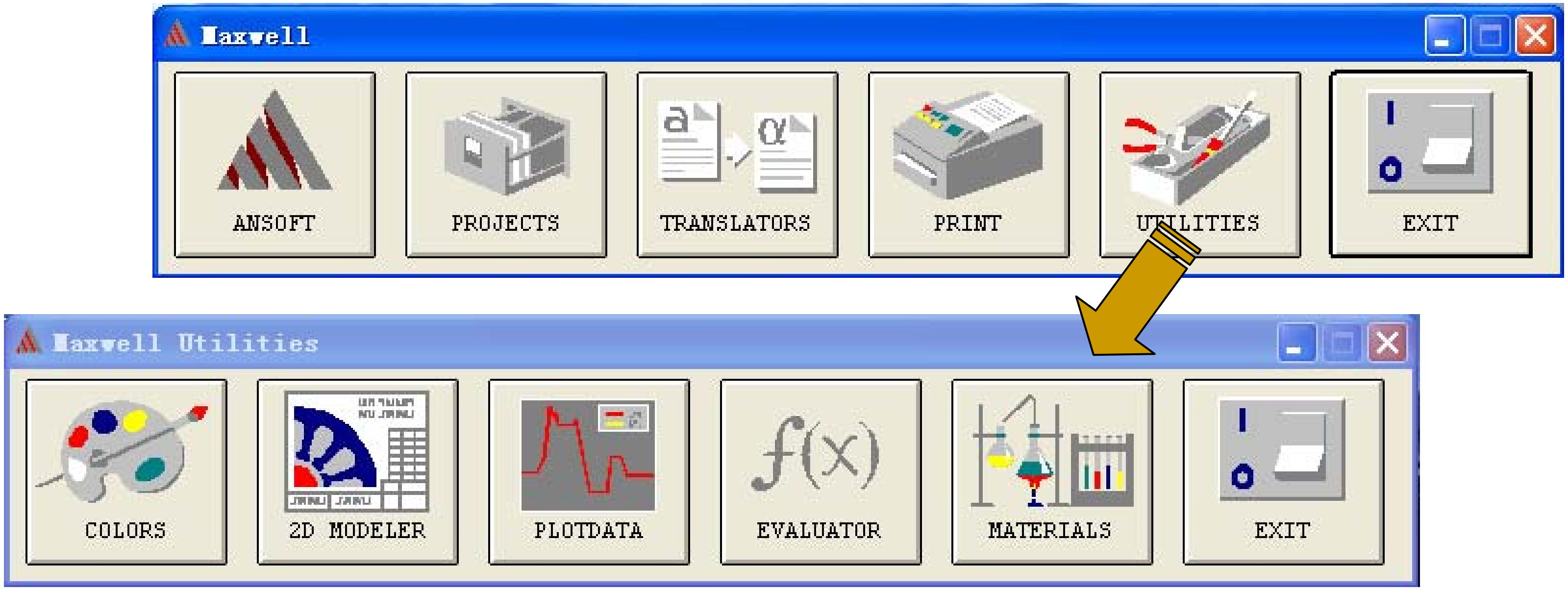
**Examples of applications:**

1、Detectors
2、Shielding
3、Voltage surge analysis
4、Cathode Ray Tube, etc

# Introduction of Maxwell

- How to run it?

In windows program, you can run maxwell.exe.



# Introduction of Maxwell

- Maxwell's equations (Theoretical Basic of Maxwell)

Maxwell's equations in differential form and integral form.

Differential form

$$\begin{cases} \nabla \cdot \vec{D} = \rho_f \\ \nabla \times \vec{E} = -\dfrac{\partial \vec{B}}{\partial t} \\ \nabla \cdot \vec{B} = 0 \\ \nabla \times \vec{H} = \vec{j}_f + \dfrac{\partial \vec{D}}{\partial t} \end{cases}$$

Integral form

$$\begin{cases} \oint_L \vec{E} \cdot d\vec{l} = -\dfrac{d}{dt} \iint_S \vec{B} \cdot d\vec{s} \\ \oint_L \vec{H} \cdot d\vec{l} = I_f + \dfrac{d}{dt} \iint_S \vec{D} \cdot d\vec{s} \\ \oiint_S \vec{D} \cdot d\vec{s} = Q_f \\ \oiint_S \vec{B} \cdot d\vec{s} = 0 \end{cases}$$

# Introduction of Maxwell

- Maxwell's equations' boundary condition

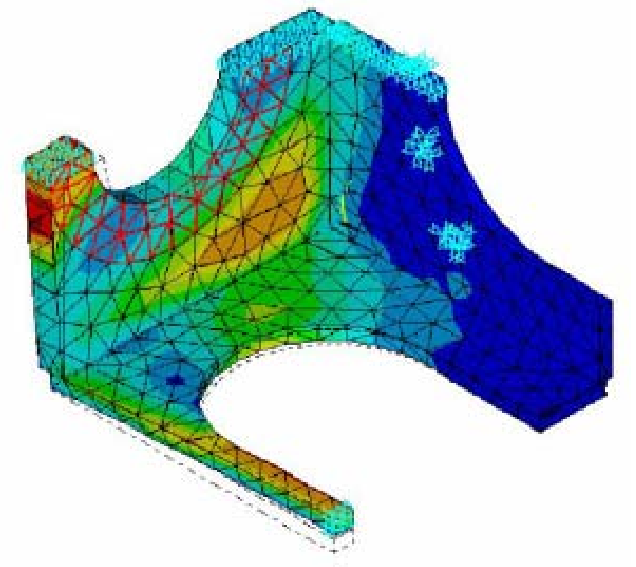
| | | |
|---|---|---|
| **General medium** | $\gamma \neq 0, \gamma \neq \infty$ | $H_{1t} - H_{2t} = J_s$ $E_{1t} = E_{2t}$<br>$B_{2n} = B_{1n}$ $D_{1n} - D_{2n} = \rho_s$ |
| **Perfect medium** | $\gamma = 0$ | $H_{1t} - H_{2t} = 0$ $E_{1t} = E_{2t}$<br>$B_{2n} = B_{1n}$ $D_{1n} - D_{2n} = 0$ |
| **Perfect conductor** | $\gamma \to \infty$ | $H_t = J_s$ $E_t = 0$<br>$B_n = 0$ $D_n = \rho_s$ |

# Introduction of Maxwell

- The Finite Element Method Defined (Calculated Method of Maxwell)

The Finite Element Method (FEM) is a weighted residual method that uses compactly-supported basis functions.

FEM consists of a computer model of a material or design that is stressed and analyzed for specific results.



# Introduction of Maxwell

- Overview of the Finite Element Method

$$(S) \Leftrightarrow (W) \approx (G) \Leftrightarrow (M)$$

| Strong form | Weak form | Galerkin approx. | Matrix form |
| --- | --- | --- | --- |

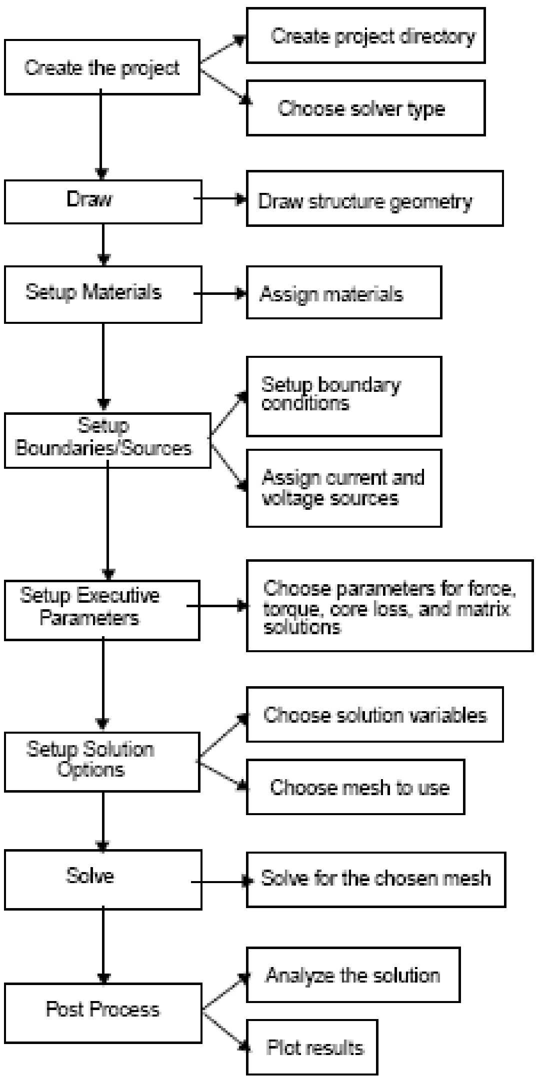
- FEM is a Key factors of the accuracy of final results by Maxwell

# Application of Maxwell

## General Procedure

- The general procedure for creating and analyzing a project is
- summarized in the following list and flowchart:

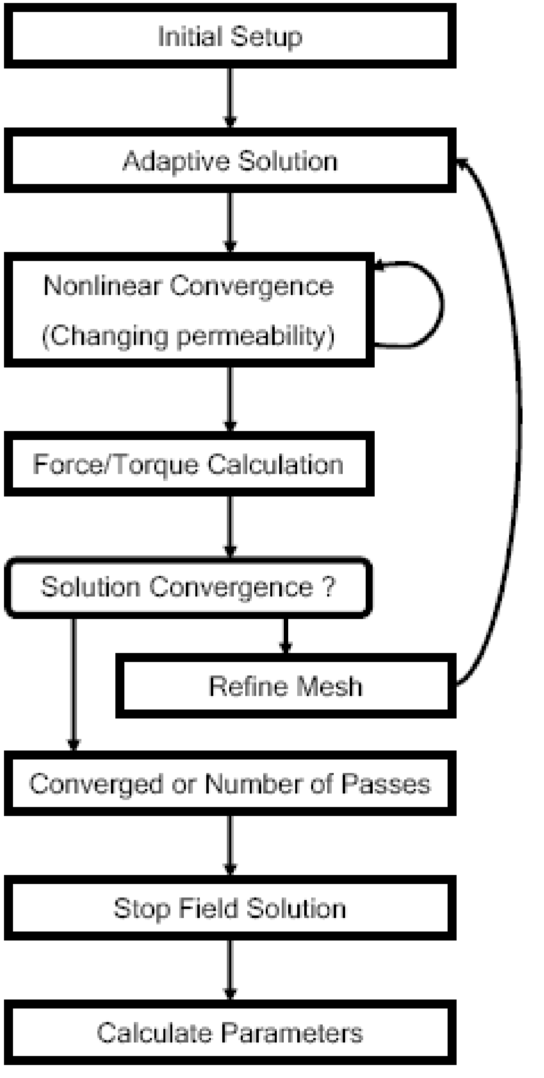
1. Create a project for Maxwell 3D.
2. Draw the model.
3. Set up the problem:
a. Assign materials to objects.
b. Set up boundary conditions.
c. Assign voltage and current sources.
4. Define problem parameters: forces, torques, or related values.
5. Setup the solution:
a. Choose meshing variables and the mesh for which you want to solve.
b. Specify how accurately (or how quickly) you want your problem to be solved.
6. Solve the problem. You can view solution information during and after the solution process.
7. Use the Post



# Application of Maxwell

- **Magnetostatic Solution Process**

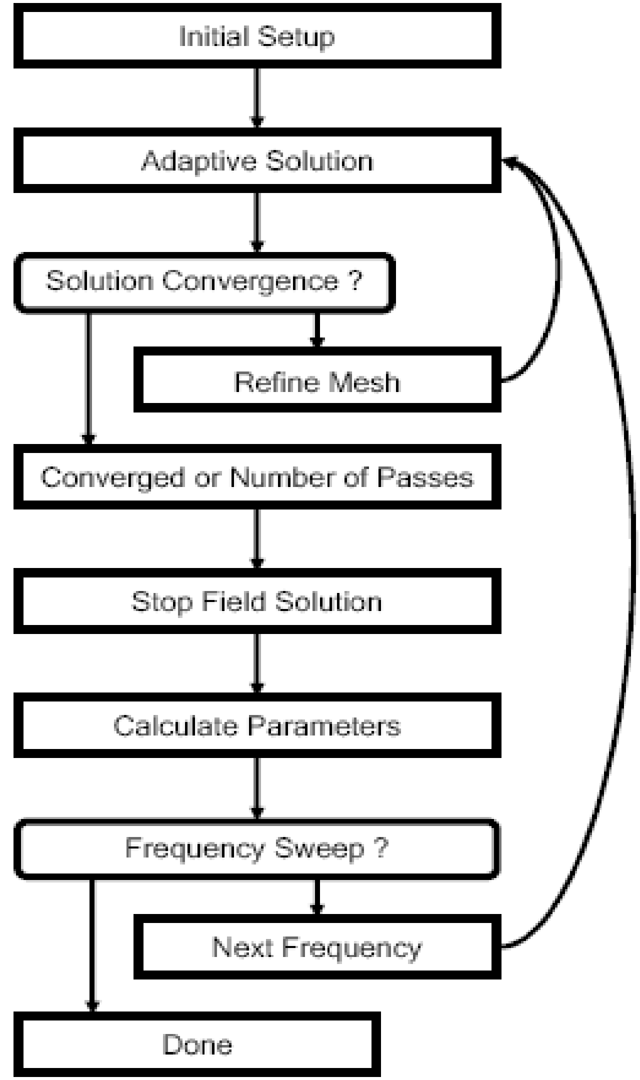
  Unlike pre-processing, the solution process is very automated. Once the problem has been defined properly, Maxwell will take over and step through several stages of the solution process. To start the solution process, right-click on Analysis in the Maxwell Project Tree and select Analyze.



# Application of Maxwell

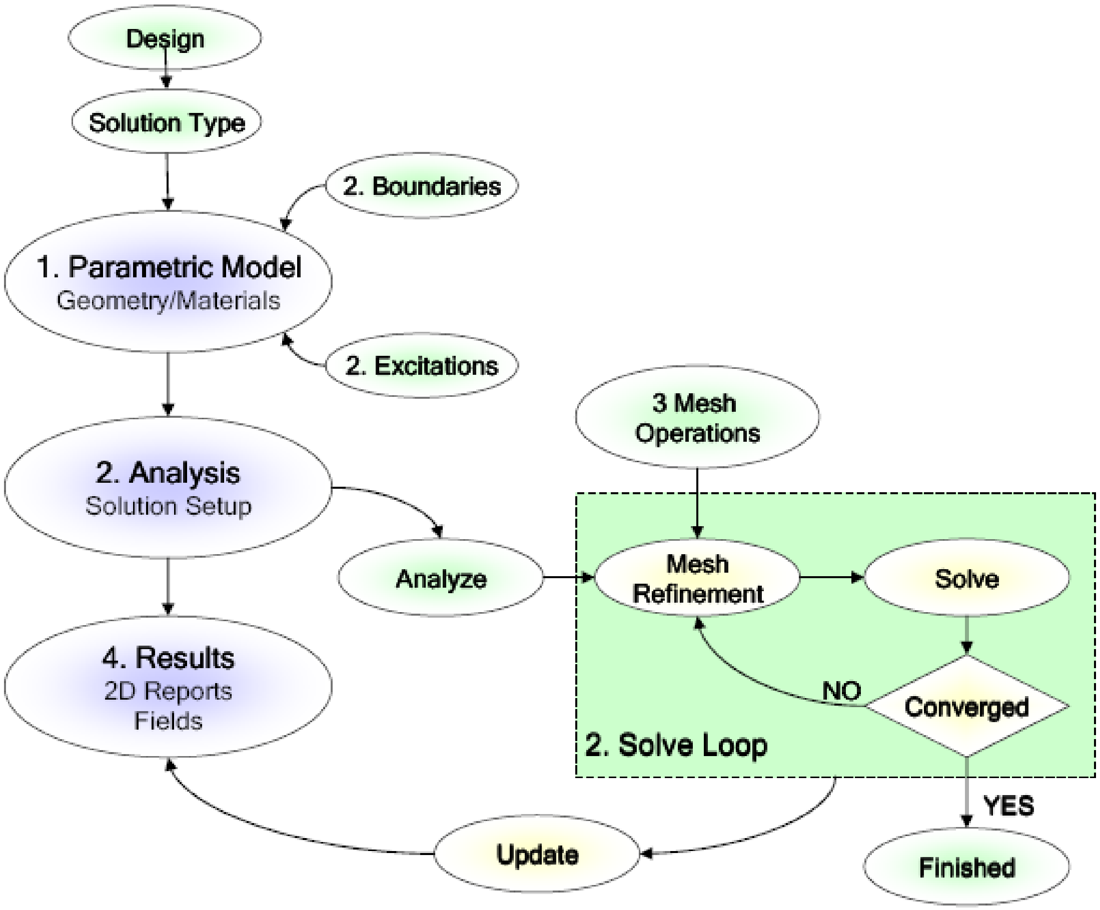
- **Eddy Current Solution Process**

  Unlike pre-processing, the solution process is very automated. Once the problem has been defined properly, Maxwell will take over and step through several stages of the solution process. To start the solution process, right-click on Analysis in the Maxwell Project Tree and select Analyze.



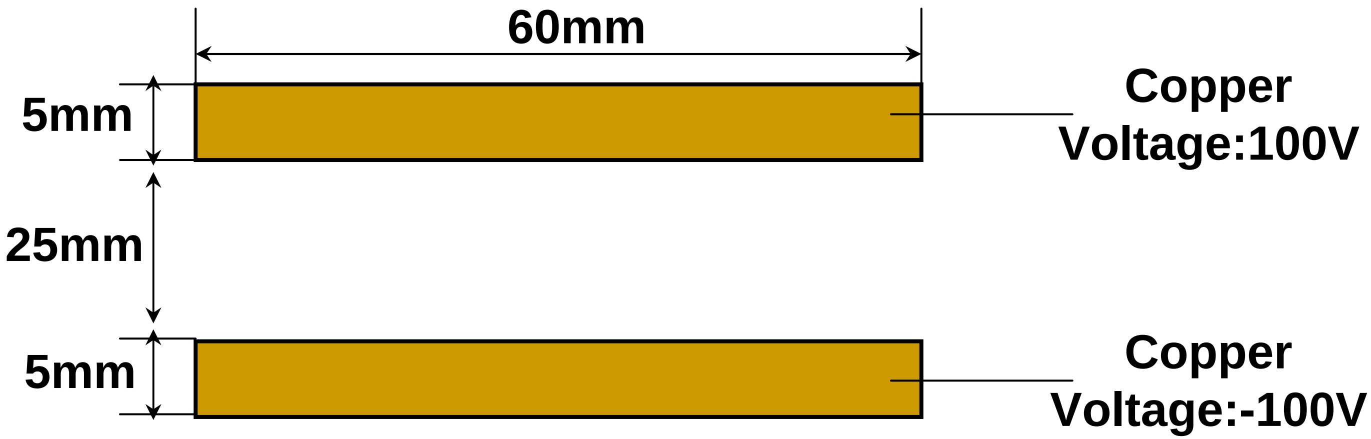
# Application of Maxwell

- **Parametric Model Generation** – creating the geometry, boundaries and excitations
- **Analysis Setup** – defining solution setup and frequency sweeps
- **Results** – creating 2D reports and field plots
- **Solve Loop** - the solution process is fully automated



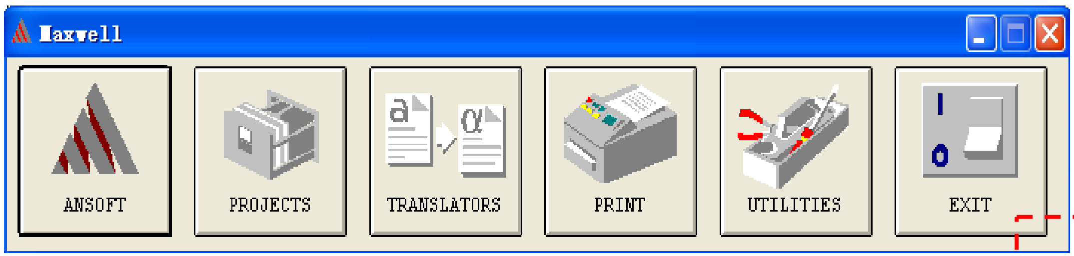
# Training of Maxwell

- Calculated the electric field of parallel plate capacitive

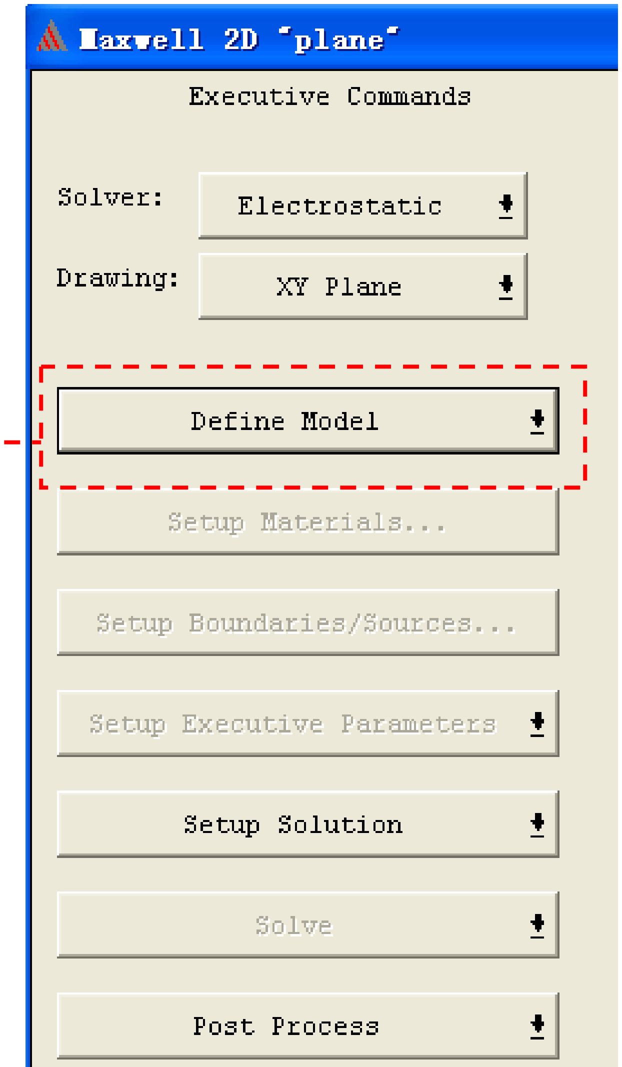


# Training of Maxwell

- 1、 Run maxwell.exe

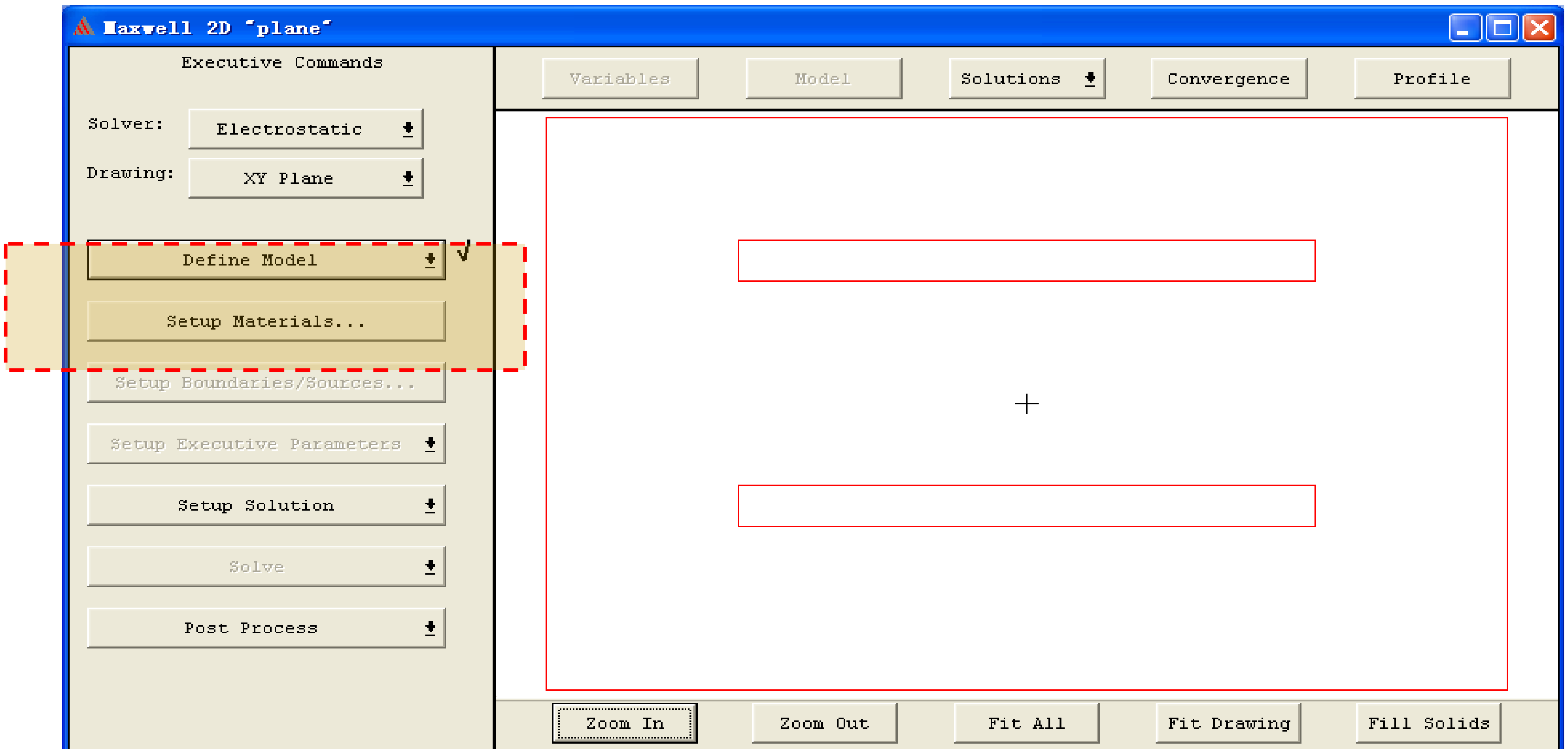



- 2、 Click “PROJECTS”, Created the 2D projects, Selected “Electrostatic”
- 3、 Draw the 2D model



# Training of Maxwell

- 4、Define Model is OK



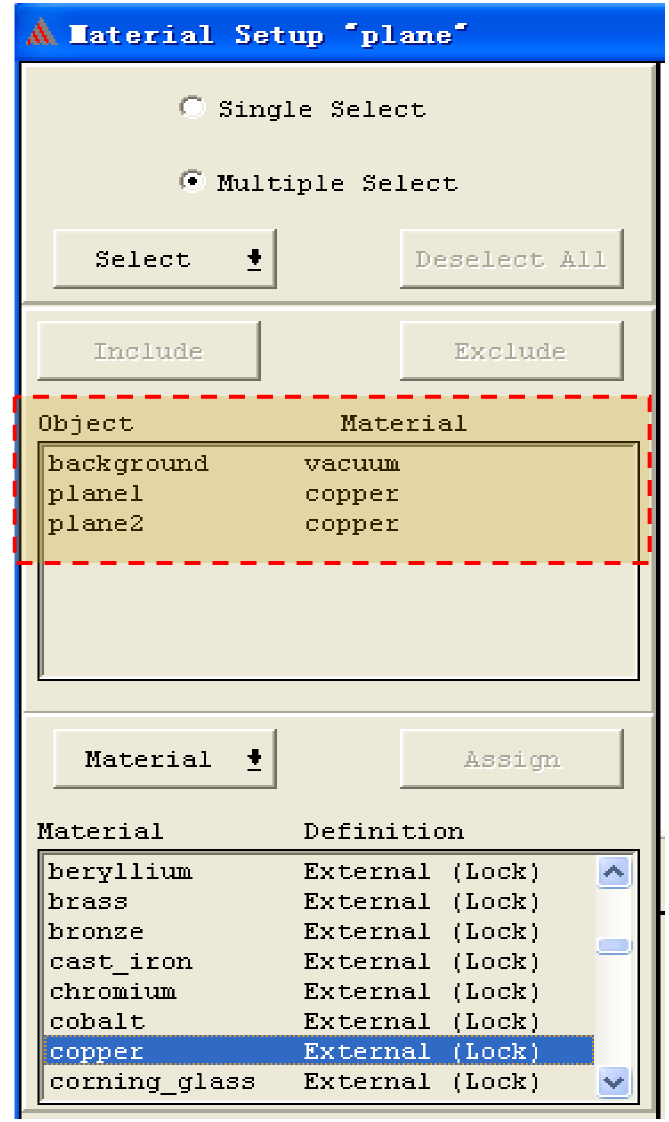
# Training of Maxwell

- 5、Set Material

  Background

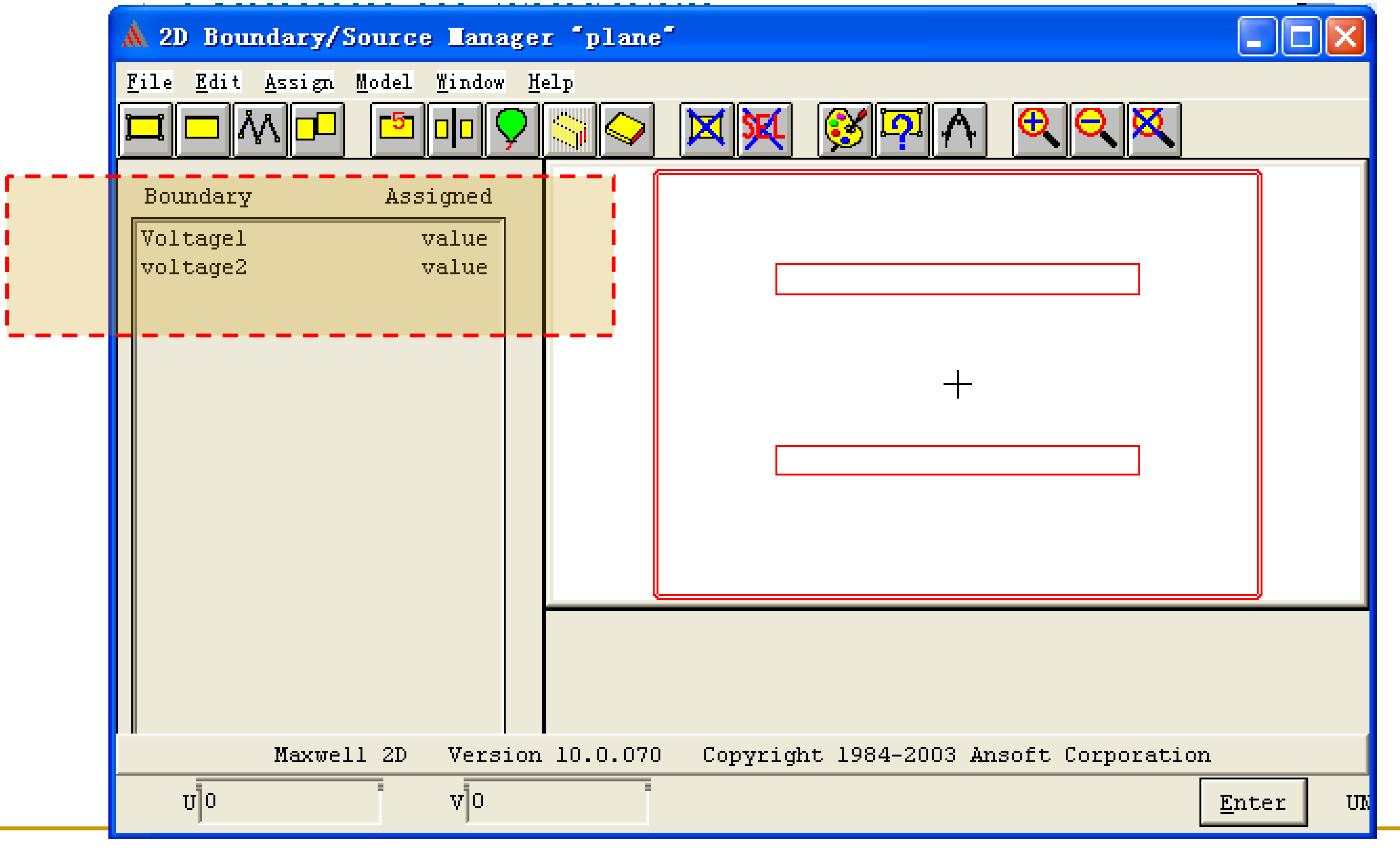
  plane1

  plane2



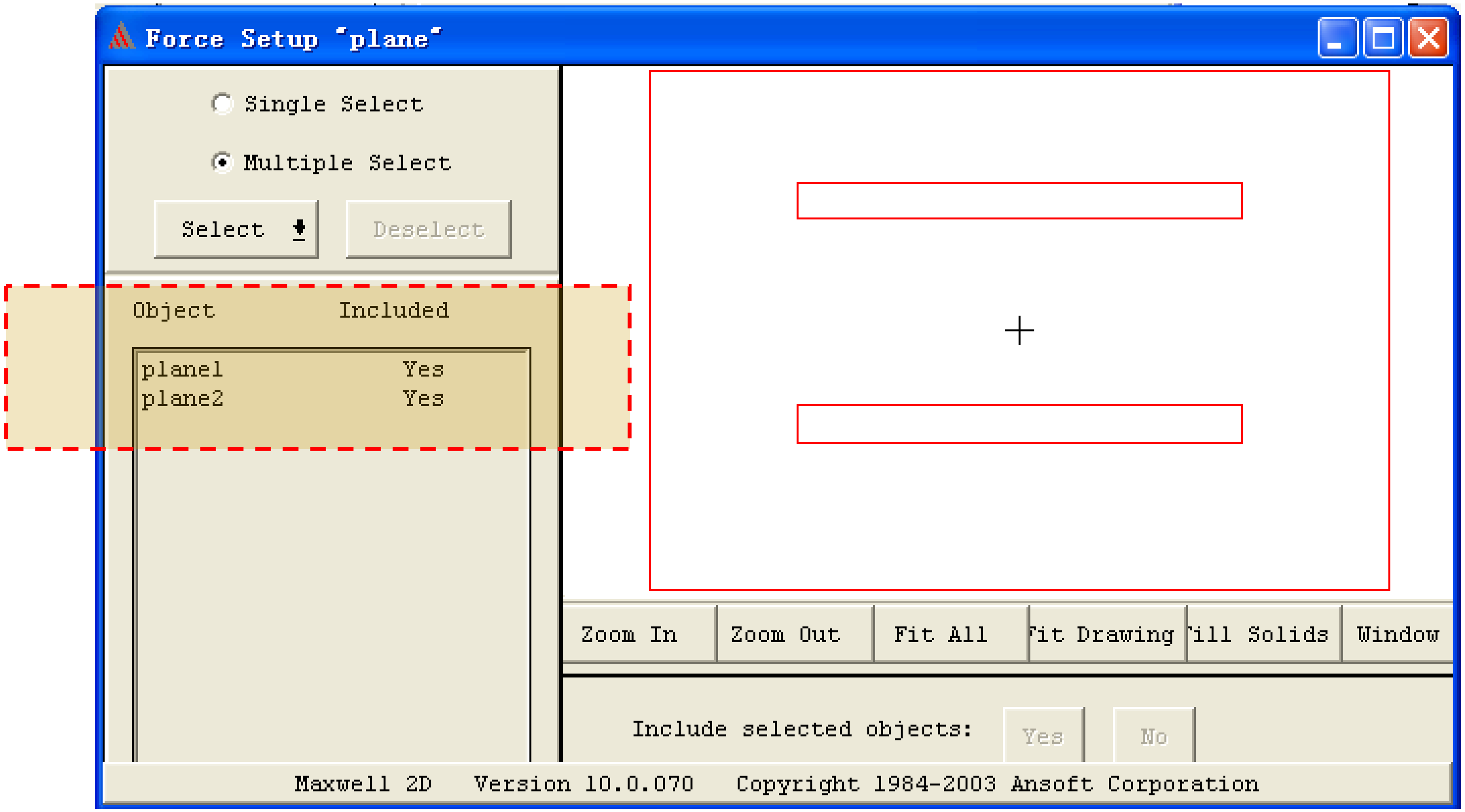
# Training of Maxwell

- 6、Set 2D Boundary/Source and set the Voltage



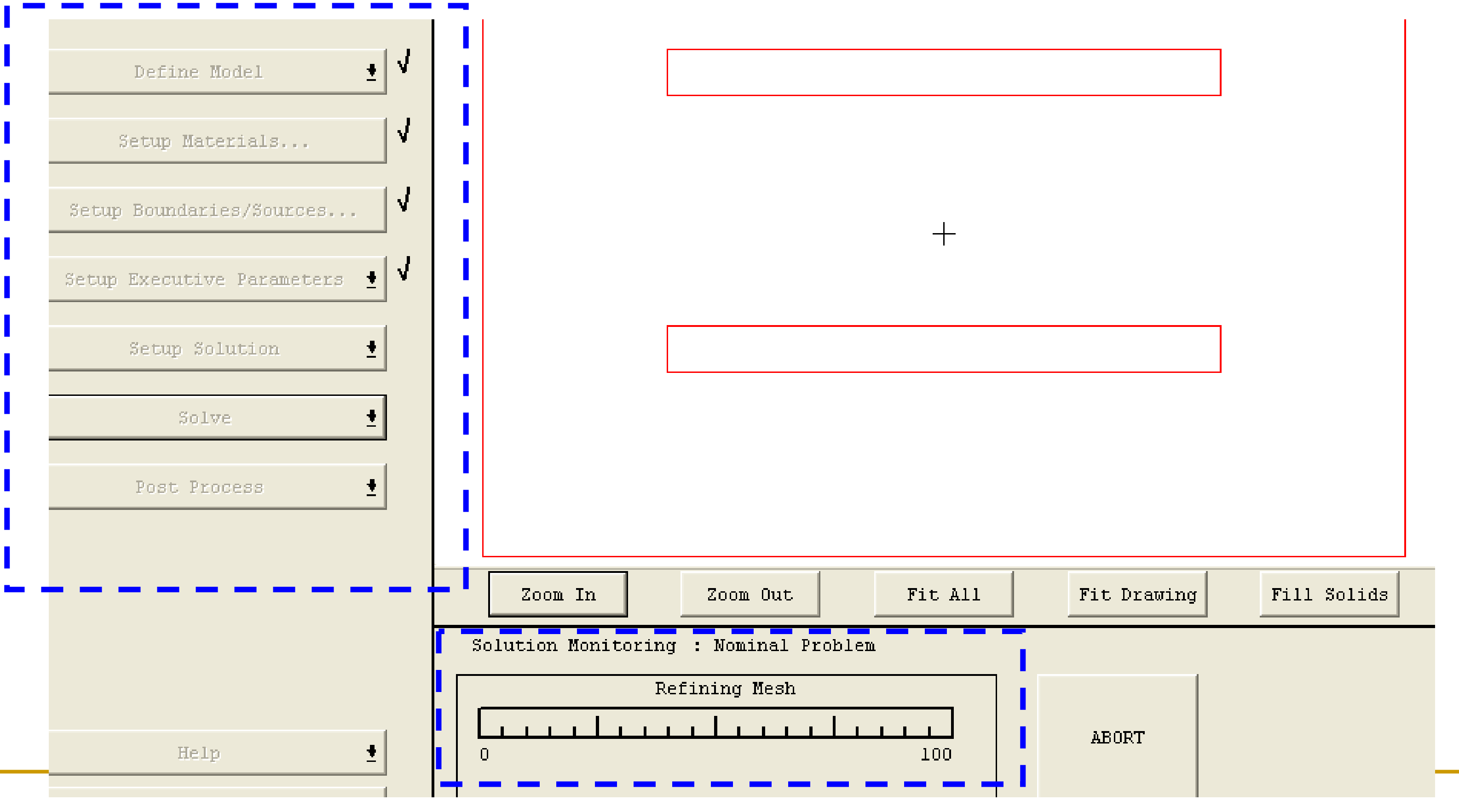
# Training of Maxwell

- 7、Force setup, selected the plane1 and plane2



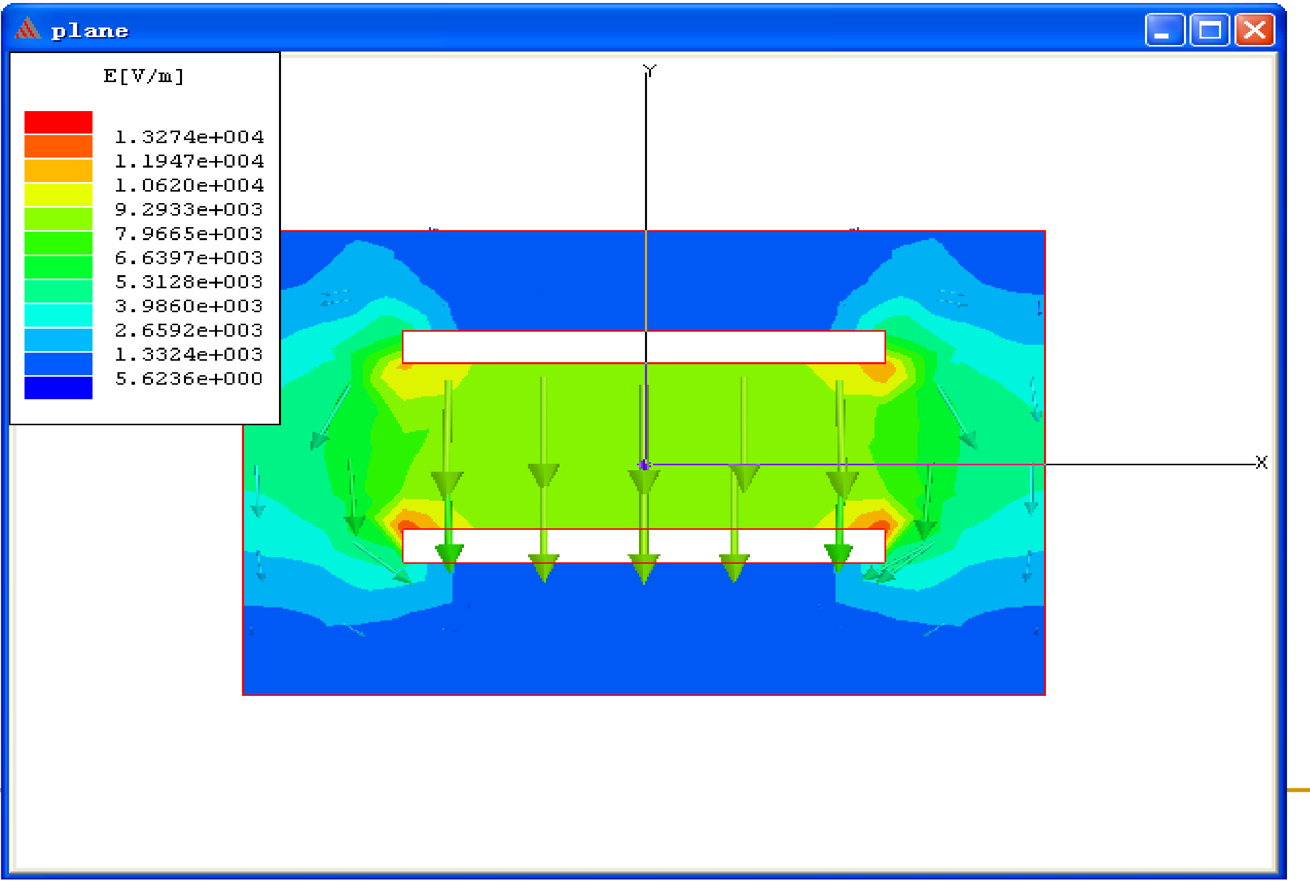
# Training of Maxwell

- 8、Setup solution and solve the model



# Training of Maxwell

- 9、 Open the 2D post processor and display the electric field and electric field vector



# Thank You All!

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