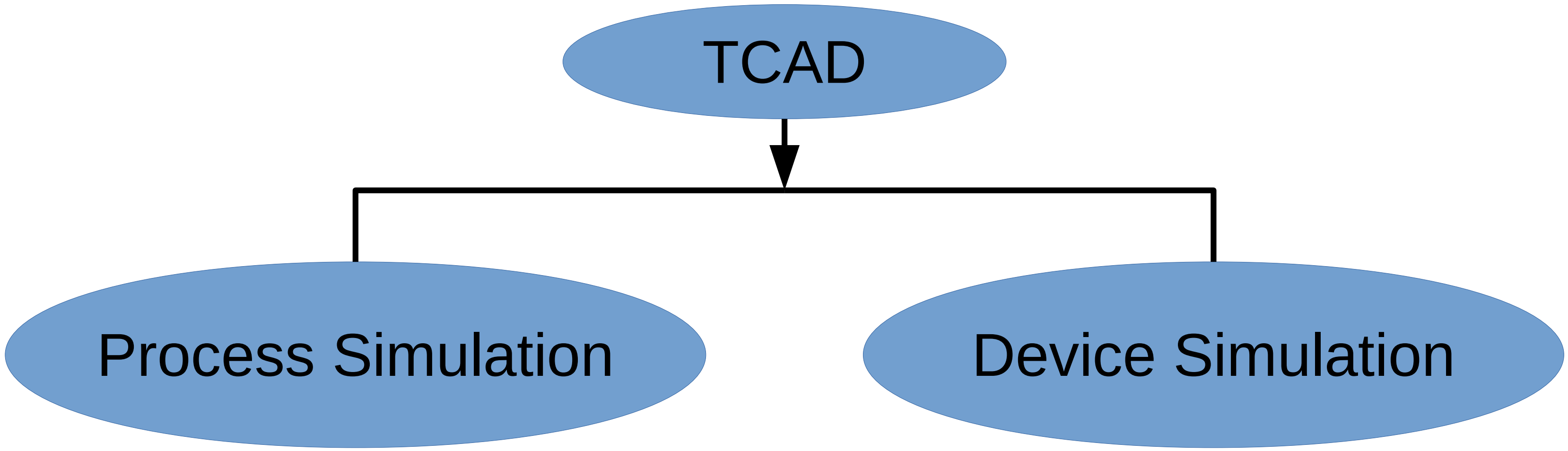
TCAD Tutorial

Introduction to TCAD

- Technology Computer-Aided Design (TCAD) refers to using computer simulations to develop and optimize semiconductor processing technologies and devices.
- TCAD simulation tools solve fundamental, physical, partial differential equations, such as diffusion and transport equations for discretized geometries, representing the silicon wafer or the layer system in a semiconductor device.

Introduction to TCAD



- **Process Simulation:** In process simulation, processing steps such as etching, deposition, ion implantation, thermal annealing, and oxidation are simulated based on physical equations, which govern the respective processing steps.
- **Device Simulation:** Device simulations can be thought of as virtual measurements of the electrical behavior of a semiconductor device, such as a transistor or diode.

TCAD Tools

(a) Sentaurus Workbench

(b) Sentaurus Process

(c) **Sentaurus Structure Editor**

(d) **Sentaurus Mesh**

(e) **Sentaurus Device**

(f) Sentaurus Device Electromagnetic Wave Solver

(g) Sentaurus Interconnect

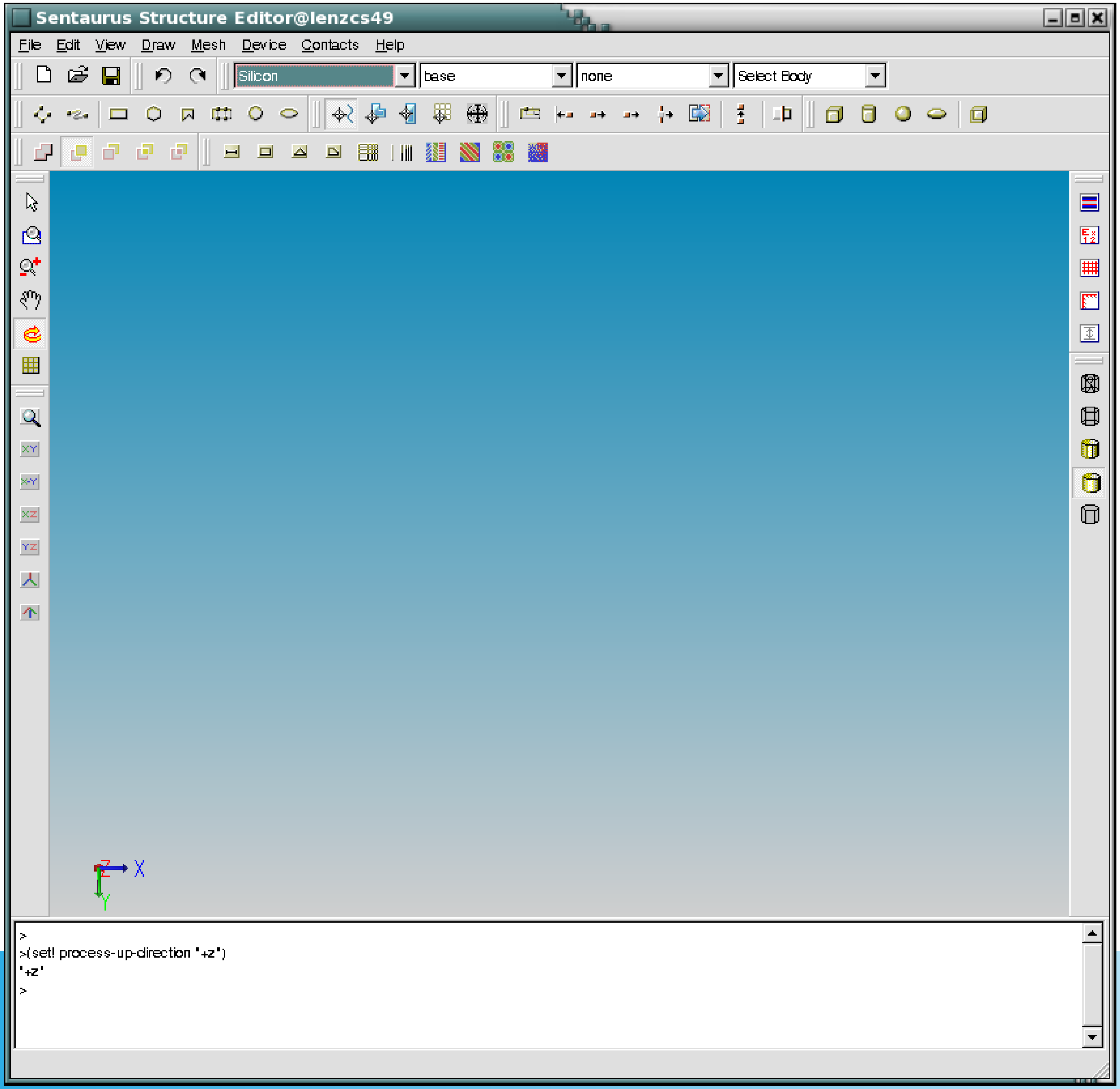
(h) **Sentaurus Visual** and Tecplot SV

(i) **Inspect**

Sentaurus Structure Editor

- To start Sentaurus Structure Editor, on the command line, type:

> sde

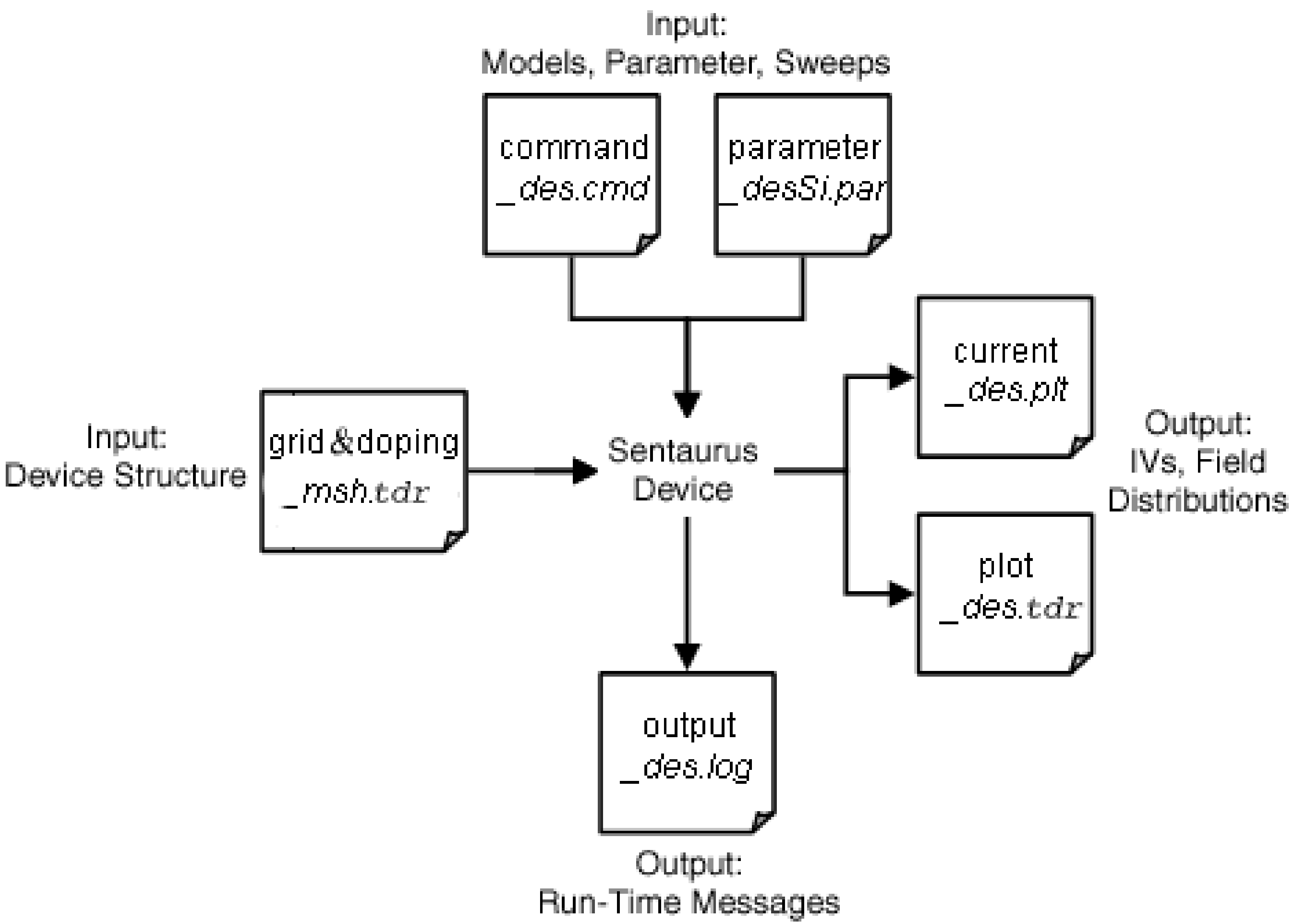


Input and Output File Types to Sentaurus Structure Editor

- **Scheme script file (.scm):**
  - This is a user-defined script file that contains Scheme script commands describing the steps to be executed by Sentaurus Structure Editor in creating a device structure.
- **TDR boundary file (_bnd.tdr):**
  - This is a boundary representation file written in the TDR format.
- **TDR Mesh file (_msh.tdr):**
  - This a file containing all the mesh information and this will be the input file for the simulation.

(Demo)

Sentaurus Device



Sentaurus Device Command File Sections

- **File section**
- **Electrode section**
- **Physics section**
- **Plot section**
- **Math section**
- **Solve section**

- **File section:** Defines the input and output files of the simulation, such as:

```
File {
  * Input Files
  Grid = "nmos_msh.tdr"
  Parameter = "nmos.par"
  * Output Files
  Current = "nmos"
  Plot = "nmos"
  Output = "nmos"
}
```

Sentaurus Device Command File Sections

- **Electrode section:** The electrical device contacts are declared in the Electrode section together with the initial boundary conditions (bias) and other optional specifications.

```
Electrode {
{ Name = "source"          Voltage=0.0 }
{ Name= "drain"            Voltage=0.0        Resistor=100 }
{ Name= "gate"             Voltage=0.0        Barrier=-0.55 }
{ Name = "base"            Voltage=0.0        Current=0. }
{ Name = "HEMTgate"        Voltage=0.0        Schottky Barrier=0.78 }
{ Name = "floating_gate"   Voltage=0.0        charge=0. }
}
```

Sentaurus Device Command File Sections

- **Physics section:** In the Physics section, you declare the physical models to be used in the simulation. The following example shows typical declarations of a Physics section for a MOSFET device simulation:

```
Physics {
  Mobility( DopingDep HighFieldSat Enormal )
  EffectiveIntrinsicDensity( OldSlotboom )
  Recombination( SRH Auger Avalanche )
}
```

Sentaurus Device Command File Sections

- **Plot section:** The Plot section is used to specify the variables to be saved in the Plot file (named in the File section):

  Plot {

  eDensity hDensity eCurrent hCurrent

  Potential SpaceCharge ElectricField

  eMobility hMobility eVelocity hVelocity

  Doping DonorConcentration AcceptorConcentration

  }

Sentaurus Device Command File Sections

- **Math section:** The Math section is used to control the simulator numerics. The following example illustrates typical controls of the Math section used for a 3D device transient simulation:

```
Math {
  Extrapolate        * switches on solution extrapolation along a bias ramp
  Derivatives        * considers mobility derivatives in Jacobian
  Iterations=8       * maximum-allowed number of Newton iterations (3D)
  RelErrControl      * switches on the relative error control for solution variables (on by default)
  Digits=5           * relative error control value. Iterations stop if dx/x < 10^(-Digits)
  Method=ILS         * use the iterative linear solver with default parameter
  NotDamped=100      * number of Newton iterations over which the RHS-norm is allowed to increase
  Transient=BE       * switches on BE transient method
}
```

Sentaurus Device Command File Sections

- **Solve section:** The Solve section consists of a series of simulation commands to be performed that are activated sequentially. The specified command sequence instructs the simulator as to which task must be solved and how:

```
Solve {
*- Buildup of initial solution:
  Coupled(Iterations=100){ Poisson }
  Coupled{ Poisson Electron Hole }
*- Bias drain to target bias
  Quasistationary(
    InitialStep=0.01 MinStep=1e-5 MaxStep=0.2
    Goal{ Name="drain" Voltage= 0.05 }
  ){ Coupled{ Poisson Electron Hole } }
*- Gate voltage sweep
  Quasistationary(
       InitialStep=1e-3  MinStep=1e-5  MaxStep=0.05
Increment=1.41 Decrement=2.
    Goal{ Name="gate" Voltage= 1.5 }
  ){ Coupled{ Poisson Electron Hole } }
}
```

Sentaurus Visual and Inspect

- **Sentaurus Visual:**
  - Sentaurus Visual is a plotting tool for visualizing data from TCAD simulations and experiments.
- **Inspect:**
  - Inspect is a plotting and analysis tool for xy data such as doping profiles and electrical characteristics of semiconductor devices.

Instructions for Login and TCAD Simulation

- First loginto the server using your user id (EE620_GroupNo) and password (EE620) (try for other server in case you could not login)
  - ssh -X EE620_20@10.107.106.XX (here XX is the server number)
  - binit@binit-HP-Notebook:~$ ssh -X EE620_TA@10.107.106.20
  - EE620_TA@10.107.106.20's password:
- List of some useful commands:
  - ls (show you the directory and files for you present directory)
  - pwd (show the current directory)
  - mkdir (make directory)
  - cd (change directory)
  - touch (create file)
  - geidt (edit a file using gedit)

Instructions for Login and TCAD Simulation

- `[EE620_TA@mcl20 ~]$ ls`
- `[EE620_TA@mcl20 ~]$ pwd`
- `/home/users/EE620_2019/EE620_TA`
- `[EE620_TA@mcl20 ~]$ mkdir MOSCAP`
- `[EE620_TA@mcl20 ~]$ cd MOSCAP`
- `[EE620_TA@mcl20 MOSCAP]$ touch moscap.scm`
- `[EE620_TA@mcl20 MOSCAP]$ ls`
- `moscap.scm`
- `[EE620_TA@mcl20 MOSCAP]$ gedit moscap.scm`
- Copy the code you are provided with and paste it within the .scm file. Then save and exit from gedit.

Instructions for Login and TCAD Simulation

- [EE620_TA@mcl20 MOSCAP]$ sde -l moscap.scm
- Wait for the message "Saving file moscap_msh.tdr...done" on terminal screen. After you see the message you may able to see the complete device structure on the Sentaurus Structure Editor window. Don't worry even if you cannot see the device structure on the Sentaurus Structure Editor window, if you can only see the above mentioned message on terminal window then please save the structure with a file extension of .scm but with a different name than the previous .scm file and exit from SDE. Alternatively you may not save the structure and exit from SDE because the "snmesh" command already generated the _msh.tdr file which we will use in the device simulation section.

Instructions for Login and TCAD Simulation

- [EE620_TA@mcl20 MOSCAP]$ touch HD_des.cmd
- [EE620_TA@mcl20 MOSCAP]$ gedit HD_des.cmd
- Copy the code you are provided with and paste it within the _des.cmd file. Then save and exit from gedit.
- [EE620_TA@mcl20 MOSCAP]$ sdevice HD_des.cmd
- This command will simulate the structure where _msh.tdr and param.par are the inputs to the HD_des.cmd and _des.tdr, _des.plt are the output from the simulation.
- Use svisual and inspect to analyse the simulation output.
- [EE620_TA@mcl20 MOSCAP]$ svisual moscap_des.tdr
- [EE620_TA@mcl20 MOSCAP]$ inspect moscap_des.plt