

# Thermal Tutorial

2022/12/1

12/8/2022



# / Introduction

✂ We will be taking thermal through 6 sets of runs and analysis scripts:

✂ RHSC-ET 1<sup>st</sup> run scripts:

- **Thermal\_flow.tcl**: this script does the following:
  - ✓ Imports data
  - ✓ Performs 3DIC thermal assembly
  - ✓ Performs 3 static thermal analysis (4m16s, 5m21s, 10m2s)
  - ✓ Performs 1 transient thermal analysis (8m12s)
- Bring up RHSC-ET GUI to view results

✂ RHSC 2<sup>nd</sup> run scripts:

- **Electro\_Thermal\_flow.tcl**: this script does the following:
  - ✓ Imports data
  - ✓ Performs 3DIC thermal assembly
  - ✓ Performs 3 static electro thermal analysis
  - ✓ Performs 1 transient electro thermal analysis (30m2s)
- Bring up RHSC-ET GUI to view results

# / Introduction

## ⌘ RHSC-ET 3<sup>rd</sup> run scripts:

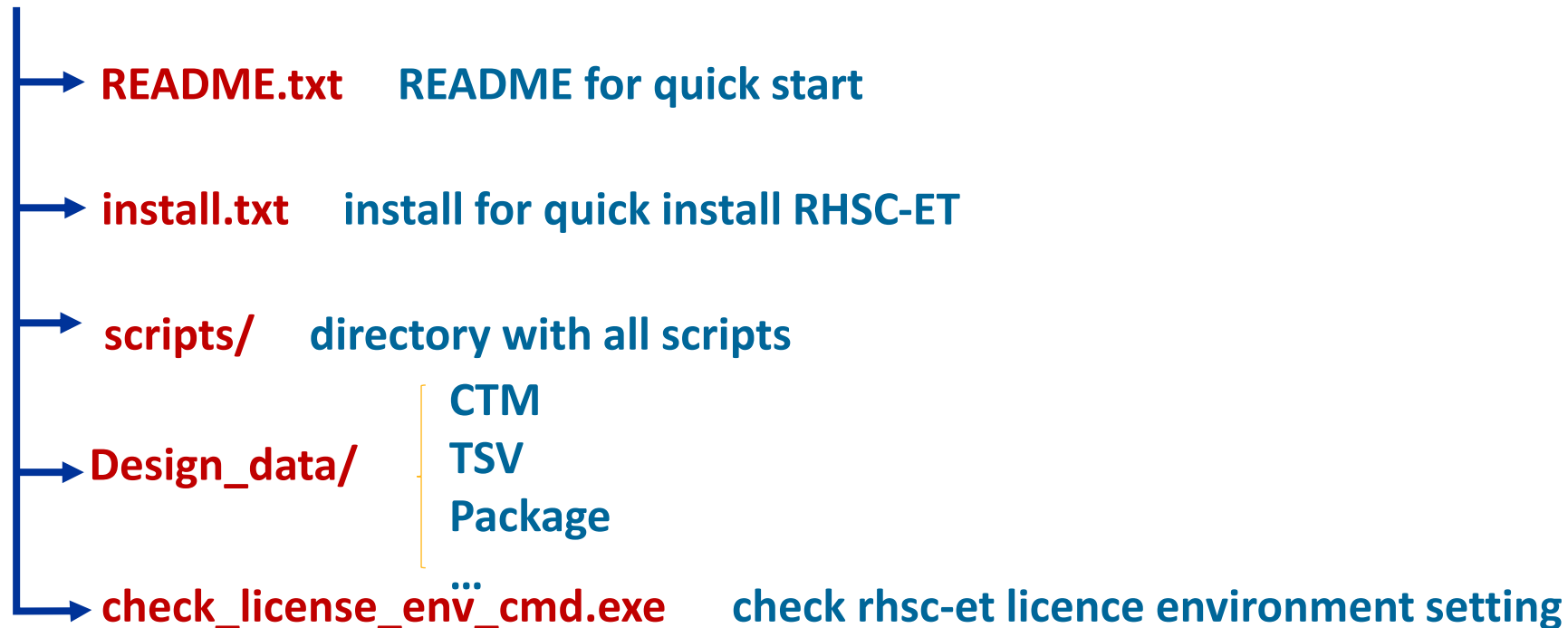
- **TI\_ComplexConnection.tcl**: this script does the following:
  - ✓ Imports data
  - ✓ Performs 3DIC thermal assembly
  - ✓ Performs 1 static thermal analysis (**Please note, it will take 6h17m23s**)
- Bring up RHSC-ET GUI to view results

## ⌘ RHSC 4<sup>th</sup> and 5<sup>th</sup> run scripts:

- **TI\_Hiera1.tcl, TI\_Ubump1.tcl, TI\_Ubump2.tcl**: these scripts do the following:
  - ✓ Imports data
  - ✓ Performs 3DIC thermal assembly
  - ✓ Performs 1 static thermal analysis
- Bring up RHSC-ET GUI to view results

# RHSC-ET Thermal Flow Directory Structure

## RHSC-ET Thermal Flow Training directory



# / Step I: RHSC-ET Install and Set License

## ❖ Set Redhawk-SC Electrothermal path and license :

- `setenv CPSROOT <choose the version installed on your server>`
- `set path = ( $CPSROOT/bin $path )`
- `setenv ANSYSLMD_LICENSE_FILE <To your redhawk_sc_electrothermal license>`

## ❖ To execute Redhawk-SC Electrothermal :

- 2D: `redhawk_sc_et&`
- 3D: `redhawk_sc_et -3dic`

## Step II: Running the script: Thermal\_flow.tcl

✂ First cd into the scripts directory

✂ To run the first script:

```
% cd scripts/  
% redhawk_sc_et -3dic -ng Thermal_flow.tcl
```

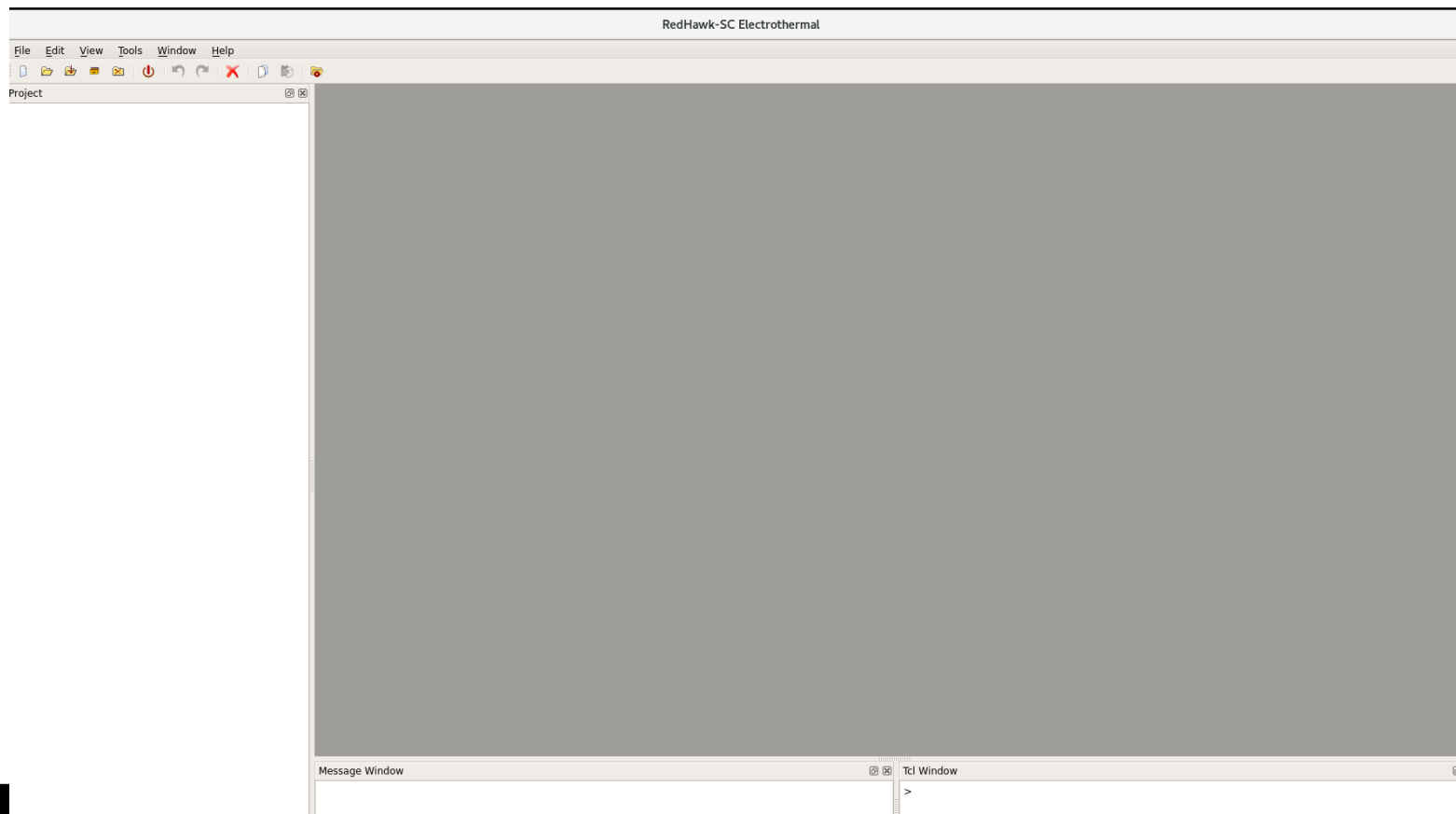
✂ What does Thermal\_flow.tcl do?

- ✓ Create the new project
- ✓ Import package, TSV and CTM, bump connection file.
- ✓ Perform 3DIC thermal assembly
- ✓ Perform 3DIC thermal analysis

# / Step III: Result Exploration using GUI

✧ View the results in RHSC-ET GUI

```
% redhawk_sc_et -3dic
```



# Step III: Result Exploration using GUI – Opening Case

```
% project open -name /home/user/project.cps
```

RedHawk-SC Electrothermal: /nfs/sjocpspe1.data/ssoqa/cps\_release/RH\_SC\_ET\_release\_2021R2.0/RedHawk-SC\_Electrothermal\_Package\_v2021R2.0/Training\_testcase/TI/scripts/Thermal\_flow/Thermal\_flow.cps - [Analysis Setup view: TI1\_ThermalOnly\_Static] x

File Edit View Tools Window Help

open project

Project

- Thermal\_flow
  - Physical Die
    - Die1
    - Interposer
  - Chip Model
    - CTM
      - Interposer\_Power
      - Die\_ConstantPower
      - Interposer\_Power\_Tran
      - DIE\_T-aware
      - Die\_Power\_Tran
  - Layout
    - substrate\_pkg
    - PCB
    - BGA
    - Die\_Bump
    - Interposer\_Bump
    - Molding
    - HeatSink
  - Off-Chip Model
  - Analysis
    - TI1\_ThermalOnly\_Static
    - TI1\_ThermalOnly\_Transient
    - TI1\_ThermalOnly\_Static\_IcepakBC
    - TI1\_ThermalStress
  - Report

check 3DIC assembly

Simulation

| Property                | Value                               |
|-------------------------|-------------------------------------|
| Solver                  | CTA                                 |
| Multiphysics Type       | Thermal                             |
| Simulation Type         | Static                              |
| Boundary Condition      | Edit...                             |
| Solver Type             | Auto                                |
| Cores[1~63]             | 10                                  |
| Power Ratio             | 0.05                                |
| Max Iteration           | 10                                  |
| Temperature Diff(C)     | 0.1                                 |
| Mesh Control            | Edit...                             |
| Fine Grid Control       | Edit...                             |
| Advance Mesh Set...     | Edit...                             |
| Dielectric Filling E... | 5                                   |
| Tech File               | Edit...                             |
| Sub Modeling            | Edit...                             |
| Dump NEU                | <input checked="" type="checkbox"/> |
| Model Only              | <input type="checkbox"/>            |
| GSR From User           | Edit...                             |

Simulation Simulation log

Result

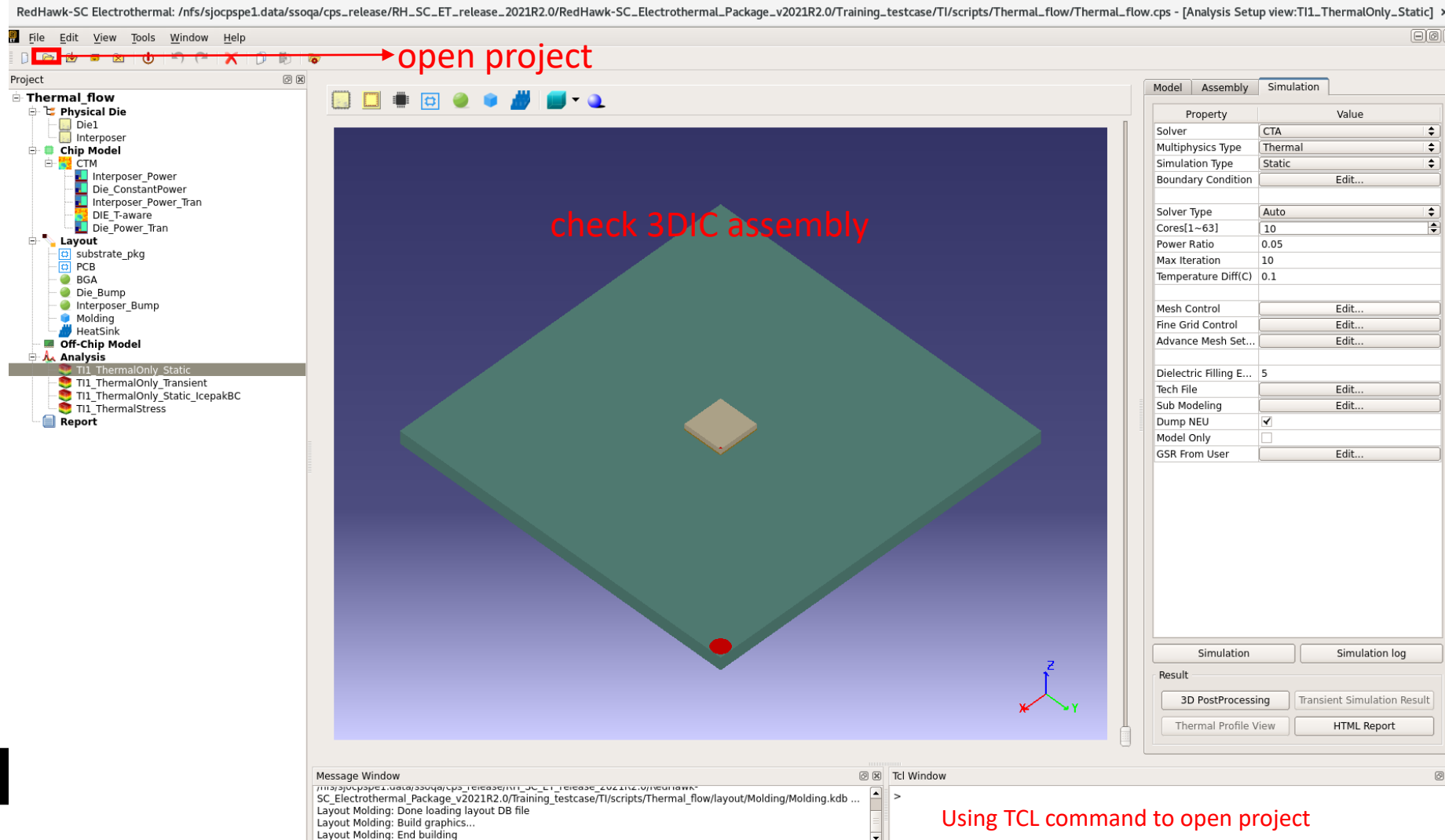
3D PostProcessing Transient Simulation Result

Thermal Profile View HTML Report

Message Window

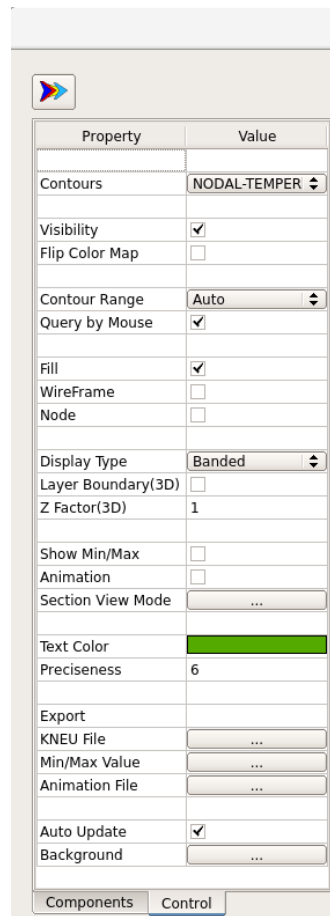
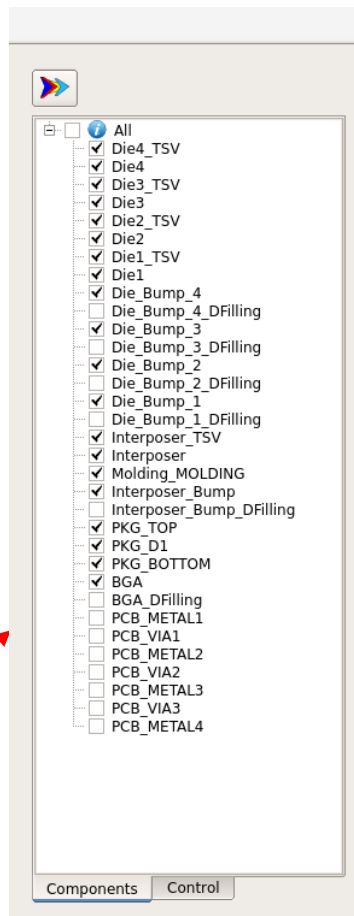
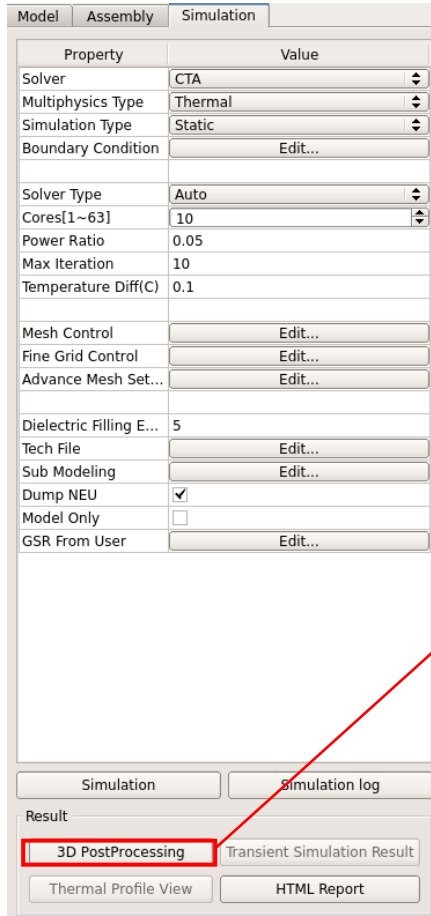
Tcl Window

Using TCL command to open project



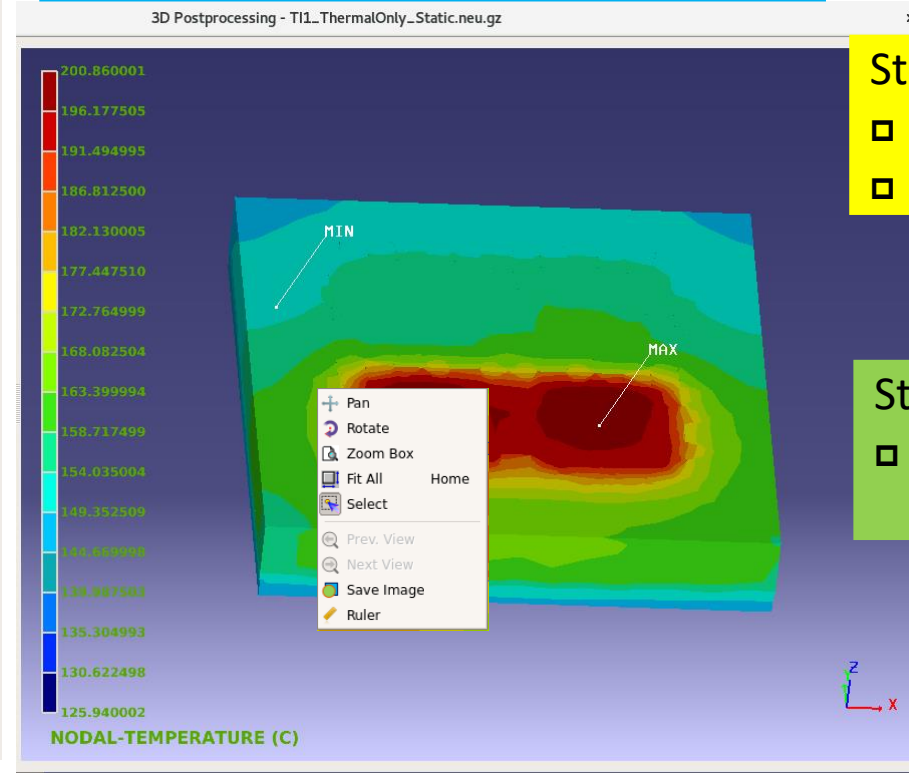


# Step III: Result Exploration using GUI – Viewing 3D Postprocess Results



## Step1:

- Go to Simulation tab
- Click 3D Postprocessing



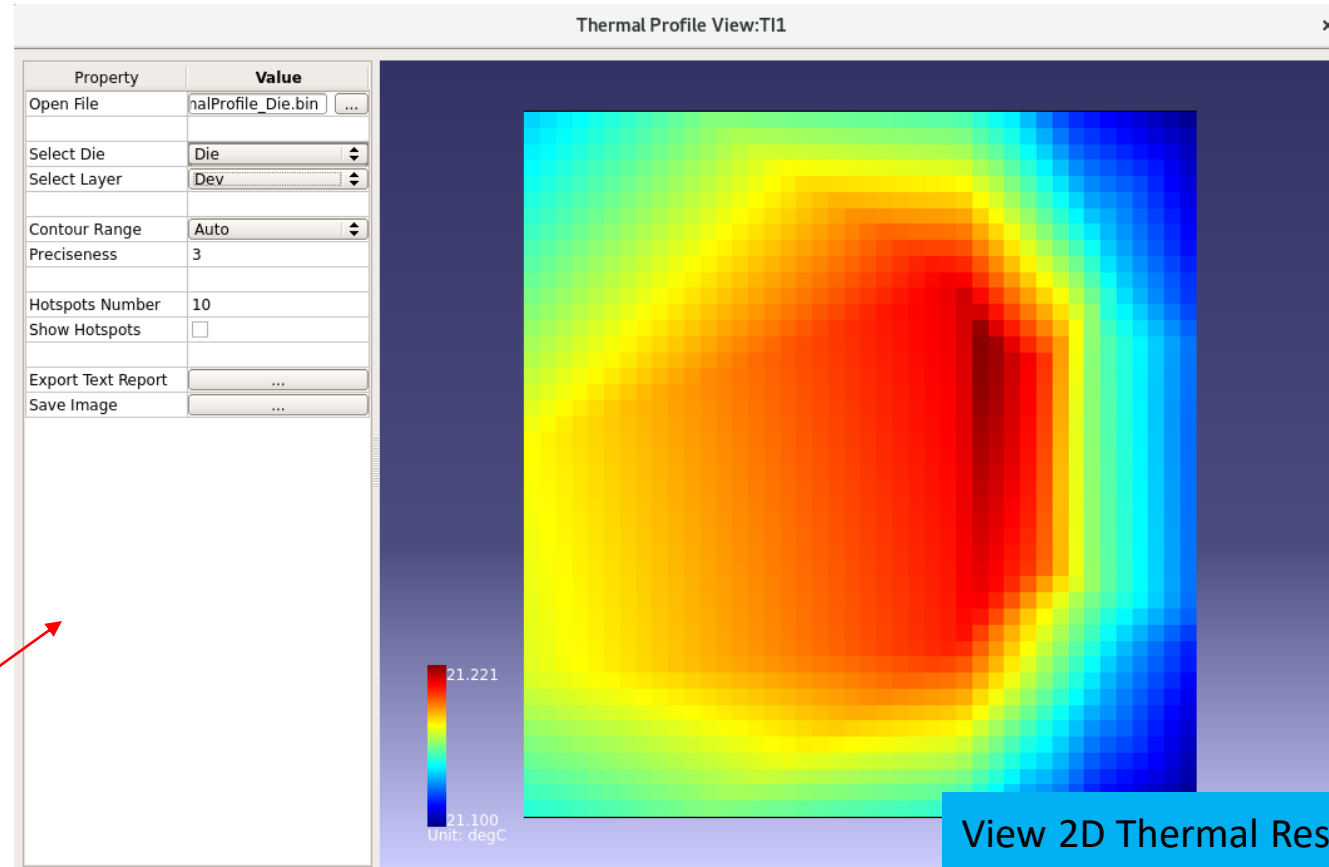
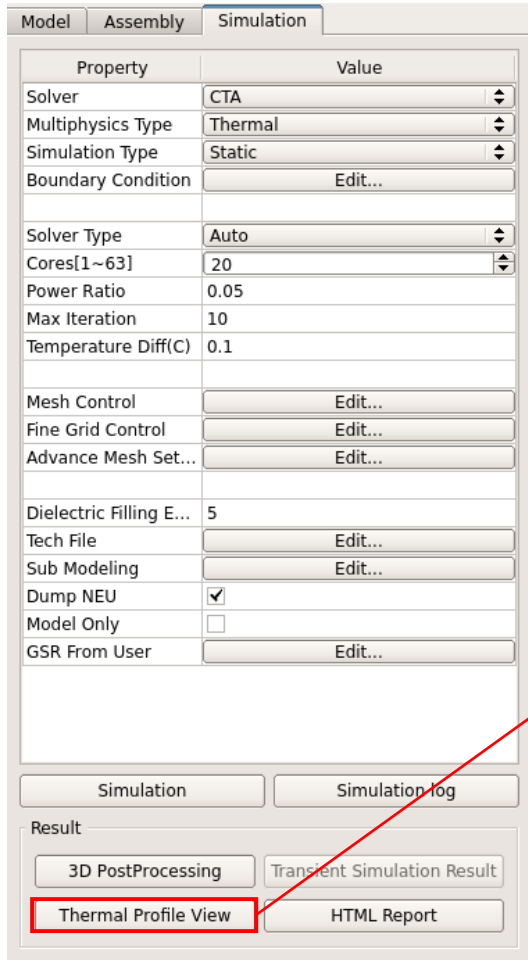
## Step2:

- Select Components
- Set control options

## Step3:

- Right-click to select Rotate or Fit All

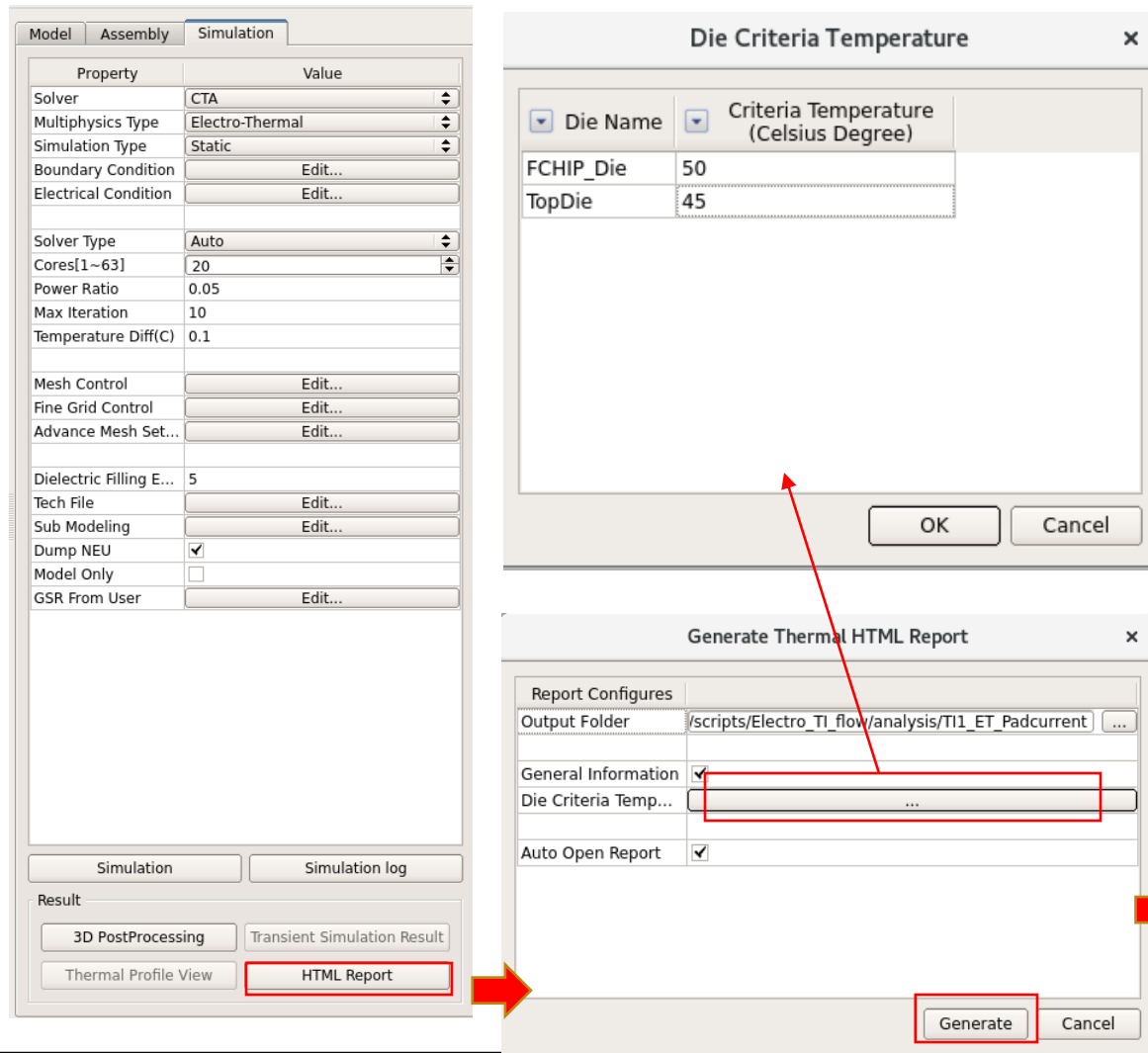
## Step III: Result Exploration using GUI – Viewing 2D Results



### View 2D Thermal Result

- ❑ Click Thermal Profile View
- ❑ View thermal result of each layer
- ❑ Please note, only there is CTM file, this feature would be available.

# Step III: Result Exploration using GUI – Generate HTML Report



Step1:

- ❑ Go to Simulation tab
- ❑ Click HTML Report

Step2:

- ❑ Define Output path
- ❑ Define Die criteria T

Step3:

- ❑ View thermal report

## Thermal Report of RHSC-ElectroThermal

### Contents

- [1 General Information](#)
- [2 Die Definitions](#)
- [3 Heat Sources](#)
- [4 Layout Models](#)
  - [4.1 TopDie\\_Bump](#)
  - [4.2 PCB](#)
  - [4.3 fccsp](#)
- [5 Analysis Definition](#)
  - [5.1 Models](#)

# Step III: Result Exploration using GUI – Viewing Transient Results

The screenshot displays the ANSYS GUI interface for viewing transient simulation results. The main window is titled "Transient Analysis Result: TI1\_ThermalOnly\_Transient". The "Simulation" tab is active, showing the "Property" and "Value" table. The "Result" section at the bottom has "Transient Simulation Result" highlighted with a red box. A blue callout box with the text "View Transient Result" and three bullet points is overlaid on the main window:

- Click Transient Simulation Result
- Define Probes
- View Transient Curves

The "Define Probes" dialog box is open, showing a 2D temperature distribution plot with a color scale from 158.21 degC to 158.75 degC. The "Probes" table lists 14 probes (P1 to P14) with their X and Y coordinates in micrometers (um). The "Transient Curve Viewer: TI1\_ThermalOnly\_Transient(Die1)" dialog box is also open, showing a graph of Temperature (degC) vs Time (s) for the selected probes. The graph shows a transient temperature response with a peak of 189.792 degC. The "Probes" list in the curve viewer shows the selected probes and their coordinates.

| Name         | State   | Duration(s) |
|--------------|---------|-------------|
| 1 Activity_1 | State_1 | 500         |
| 2 Activity_2 | NULL    | 100         |
| 3 Activity_3 | State_2 | 500         |

| Name   | X (um)   | Y (um)  |
|--------|----------|---------|
| 1 P1   | -1045.33 | 438.667 |
| 2 P2   | -1045.33 | 605.333 |
| 3 P3   | -1045.33 | 772     |
| 4 P4   | -1045.33 | 938.667 |
| 5 P5   | -1045.33 | 1105.33 |
| 6 P6   | -878.667 | 438.667 |
| 7 P7   | -878.667 | 605.333 |
| 8 P8   | -878.667 | 772     |
| 9 P9   | -878.667 | 938.667 |
| 10 P10 | -878.667 | 1105.33 |
| 11 P11 | -712     | 438.667 |
| 12 P12 | -712     | 605.333 |
| 13 P13 | -712     | 772     |
| 14 P14 | -712     | 938.667 |

| Probes                          | Selected |
|---------------------------------|----------|
| P14 (-712,938.667)(189.792)     | ✓        |
| P13 (-712,772)(189.285)         | ✓        |
| P8 (-878.667,772)(189.188)      | ✓        |
| P9 (-878.667,938.667)(188.982)  | ✓        |
| P15 (-712,1105.33)(188.906)     | ✓        |
| P19 (-545.333,938.667)(188.501) | ✓        |
| P10 (-878.667,1105.33)(188.478) | ✓        |
| P20 (-545.333,1105.33)(188.476) | ✓        |
| P18 (-545.333,772)(188.049)     | ✓        |
| P12 (-712,605.333)(187.753)     | ✓        |
| P4 (-1045.33,938.667)(187.526)  | ✓        |
| P3 (-1045.33,772)(187.513)      | ✓        |
| P7 (-878.667,605.333)(187.313)  | ✓        |
| P17 (-545.333,605.333)(187.312) | ✓        |
| P5 (-1045.33,1105.33)(187.171)  | ✓        |
| P25 (-378.667,1105.33)(186.994) | ✓        |
| P24 (-378.667,938.667)(186.822) | ✓        |
| P23 (-378.667,772)(186.551)     | ✓        |
| P2 (-1045.33,605.333)(186.504)  | ✓        |

## Step IV: Running the script: Electro\_Thermal\_flow.tcl

✧ To run the script:

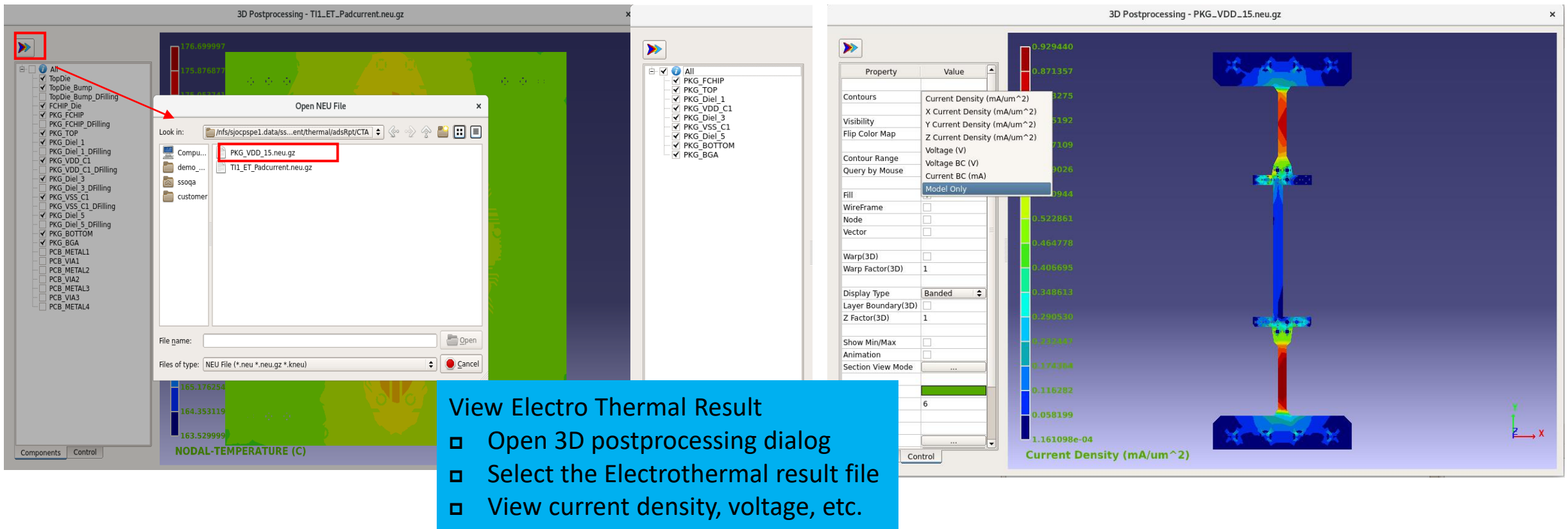
```
% cd scripts/  
% redhawk_sc_et -3dic -ng Electro_Thermal_flow.tcl
```

✧ What does Electro\_Thermal\_flow.tcl do?

- ✓ Create the new project
- ✓ Import package, TSV, CTM, bump connection file, etc.
- ✓ Perform 3DIC thermal assembly
- ✓ Perform 3DIC Electro-Thermal analysis

# Step V : Viewing Static Electrothermal Results

```
% redhawk_sc_et -3dic  
% open project
```

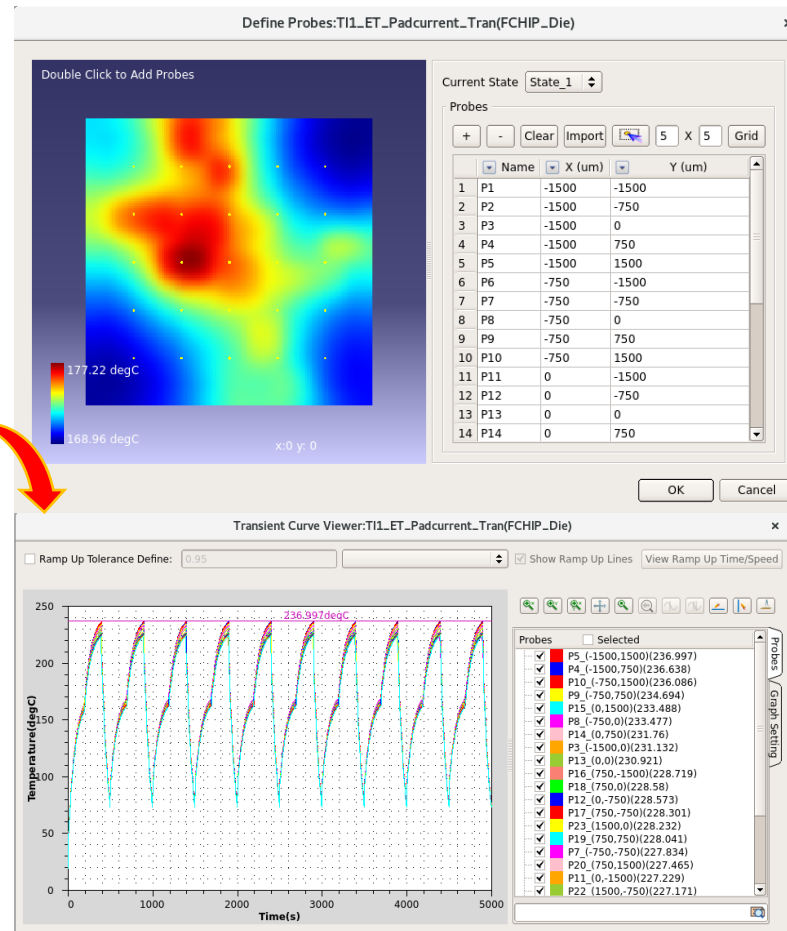


The screenshot displays the ANSYS 3D Postprocessing environment. On the left, a tree view lists components like TopDie, FCHIP, and various die layers. A red arrow points to the 'Open NEU File' dialog box, which is open and shows the file 'PKG\_VDD\_15.neu.gz' selected. The main window shows a 3D model of a package with a color map representing current density. A context menu is open over the model, listing properties such as Current Density, X Current Density, Y Current Density, Z Current Density, Voltage, and Current BC. The bottom right corner shows a color scale for Current Density (mA/um^2) ranging from 0.058199 to 1.161098e-04.

**View Electro Thermal Result**

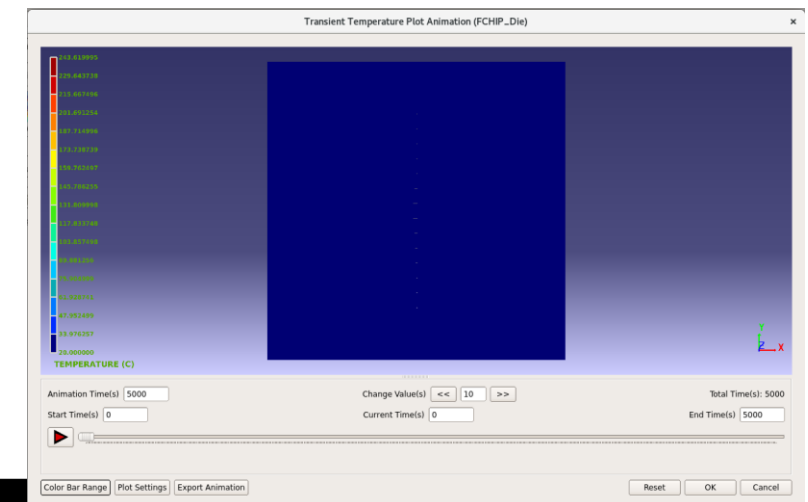
- ❑ Open 3D postprocessing dialog
- ❑ Select the Electrothermal result file
- ❑ View current density, voltage, etc.

# Step V : Viewing Transient Electrothermal Results



## View Transient Result

- Click Transient Simulation Result
- Define Probes
- View Transient Curves
- View Animation



## Step VI: Running the script: TI\_Hiera1.tcl.tcl

✧ To run the script:

```
% cd scripts/  
% redhawk_sc_et -3dic -ng TI_Hiera1.tcl
```

✧ What does Electro\_Thermal\_flow.tcl do?

- ✓ Create the new project
- ✓ Create Hierarchy CTM model.
- ✓ Perform 3DIC thermal assembly
- ✓ Perform 3DIC Electro-Thermal analysis



# Step VI : Viewing Transient Results – Activity Based

**Transient Analysis Result: T11**

Type: **Activity Based**

Activity Define

| Name         | State   | Duration(s) |
|--------------|---------|-------------|
| 1 Activity_1 | State_2 | 500         |
| 2 Activity_2 | State_1 | 1000        |
| 3 Activity_3 | State_3 | 500         |

Chiplet Group State

Current Die: **Die** ☐ Time Step(s)

**View Dynamic Result** **Define Probes**

**Dynamic result of die: Die**

| Chiplet Group | State   | Duration(s) |
|---------------|---------|-------------|
| Activity_1    | State_2 | 500         |
| group1        | sleep   |             |
| group2        | sleep   |             |
| group3        | sleep   |             |
| Activity_2    | State_1 | 1000        |
| group1        | 2.0g    |             |
| group2        | 2.0g    |             |
| group3        | 2.0g    |             |
| Activity_3    | State_3 | 500         |
| group1        | 3.0g    |             |
| group2        | 3.0g    |             |
| group3        | 3.0g    |             |

**Transient Curve Viewer: T11(Die)**

Temperature (degC) vs Time (s)

Probes: P13 (0.0)(123.757), P18 (1666.67)(123.379), P22 (3333.33)(122.917), P8 (-1666.67)(122.816), P17 (1666.67)(122.799), P23 (3333.33)(122.669), P12 (0.5000)(122.569), P7 (-1666.67)(122.34), P3 (-3333.33)(122.145), P2 (-3333.33)(121.955), P21 (3333.33)(121.858), P9 (-1666.67)(121.794), P14 (0.5000)(121.704), P16 (1666.67)(121.686), P4 (-3333.33)(121.667), P19 (1666.67)(121.456), P11 (0.10000)(121.417), P24 (3333.33)(121.302), P6 (-1666.67)(121.208)

## Step1:

- Open Transient Analysis Result dialog
- Define probes

## Step2:

- View dynamic result
- Show transient curves

## Step3:

- View ramp up time/speed

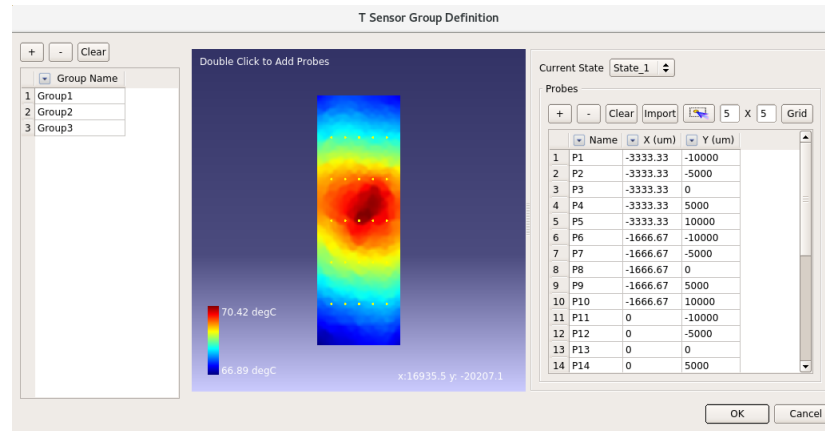
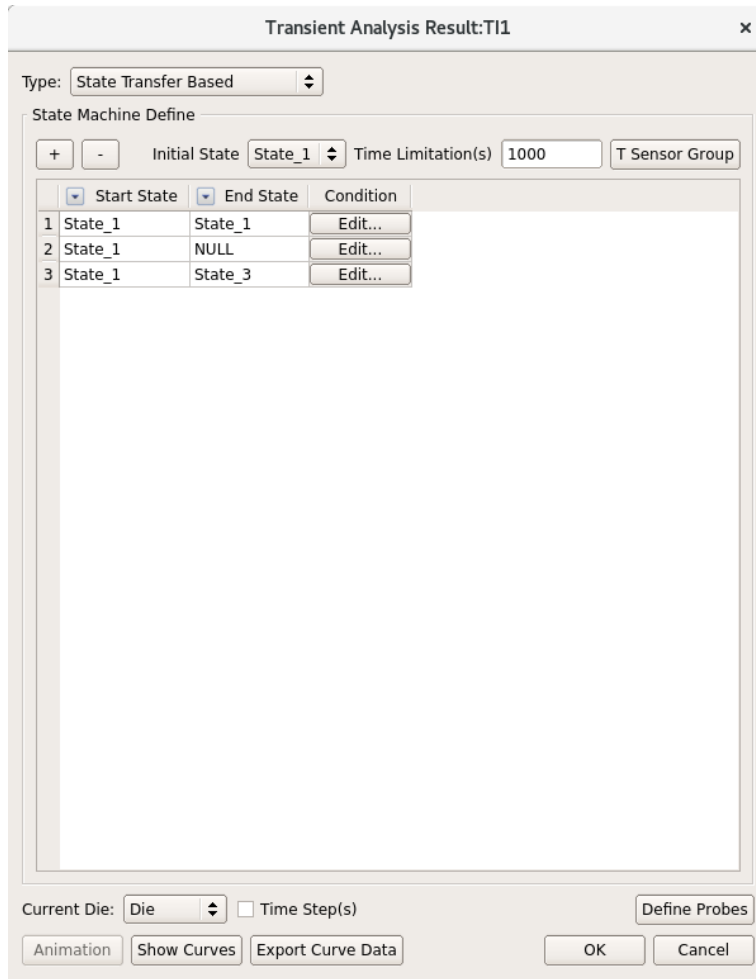
**Ramp Up**

Search

☐ Load changes automatically

#Ramp Up Time and Speed  
#Cycle Activity: (start time) (duration) (start temperature) (end temperature) (speed)  
P13(0.0)  
Cycle1 Activity\_1: 0s 350s 20C 22.4274C 0.00693549C/s  
Cycle1 Activity\_2: 500s 383.333s 22.57C 67.6962C 0.117721C/s  
Cycle1 Activity\_3: 1516.67s 350s 85.3545C 121.273C 0.102624C/s  
Cycle2 Activity\_1: 2500s 0s 24.2293C 24.2293C nanC/s  
Cycle2 Activity\_2: 2516.67s 400s 37.1088C 68.349C 0.0781003C/s  
Cycle2 Activity\_3: 3500s 350s 70.2496C 120.789C 0.144399C/s  
Cycle3 Activity\_1: 4500s 0s 24.2293C 24.2293C nanC/s  
Cycle3 Activity\_2: 4516.67s 400s 37.1088C 68.349C 0.0781003C/s  
Cycle3 Activity\_3: 5516.67s 366.667s 85.3545C 121.705C 0.0991378C/s  
Cycle4 Activity\_1: 6483.33s 0s 24.6235C 24.6235C nanC/s  
Cycle4 Activity\_2: 6500s 383.333s 24.2293C 67.6962C 0.113392C/s  
Cycle4 Activity\_3: 7500s 350s 70.2496C 120.789C 0.144399C/s  
Cycle5 Activity\_1: 8500s 0s 24.2293C 24.2293C nanC/s  
Cycle5 Activity\_2: 8516.67s 400s 37.1088C 68.349C 0.0781003C/s  
Cycle5 Activity\_3: 9516.67s 366.667s 85.3545C 121.705C 0.0991378C/s  
Cycle6 Activity\_1: 10500s 0s 24.2293C 24.2293C nanC/s  
Cycle6 Activity\_2: 10516.67s 400s 37.1088C 68.349C 0.0781003C/s

# Step VI : Viewing Transient Results – State Transfer Based



## Step1:

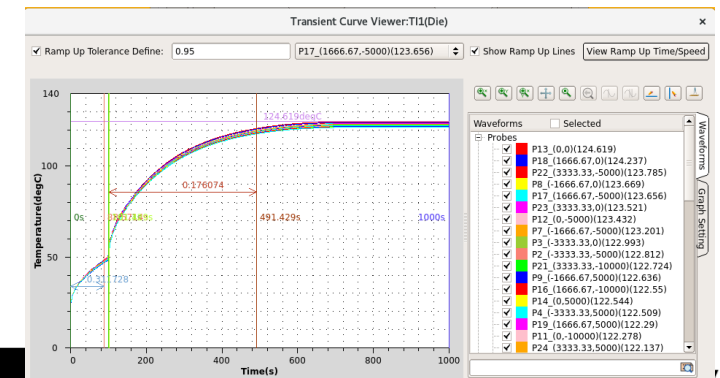
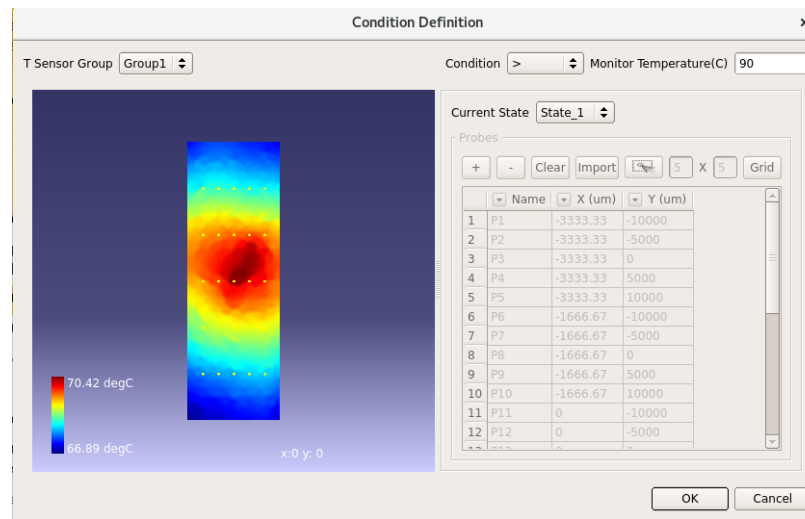
- ❑ Select State Transfer Based
- ❑ Define State

## Step2:

- ❑ Initial state
- ❑ Define T Sensor Group

## Step3:

- ❑ View curves



# Step VII : TI\_Ubump1.tcl

❖ To run the script:

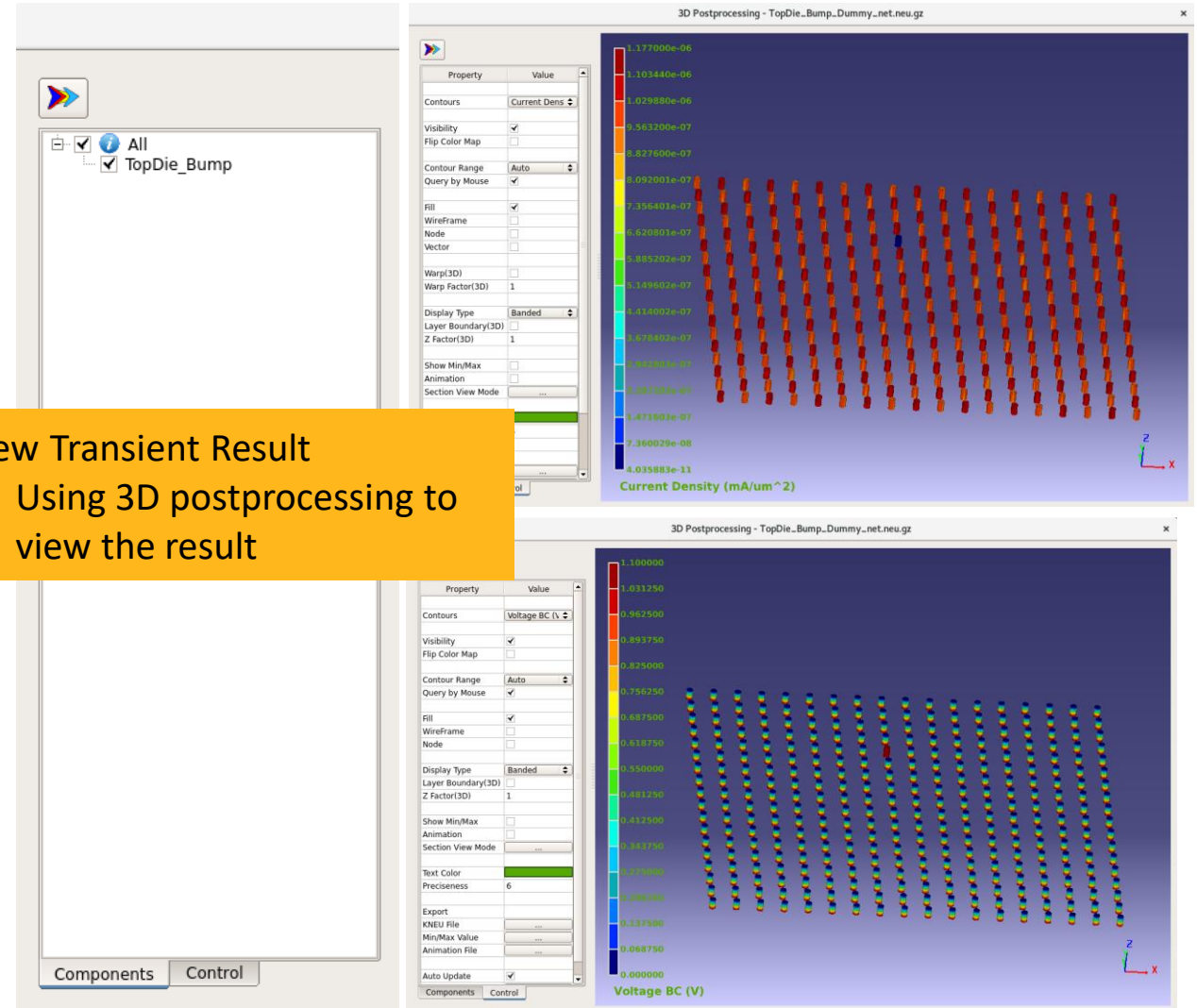
```
% cd scripts/  
% redhawk_sc_et -3dic -ng TI_Ubump1.tcl
```

❖ What does Electro\_Thermal\_flow.tcl do?

- ✓ Create the new project
- ✓ Import package and CPM file
- ✓ Perform 3DIC thermal assembly
- ✓ Perform 3DIC Electro-Thermal analysis to ubump

View Transient Result

- ❑ Using 3D postprocessing to view the result



# Step VIII : TI\_Ubump2.tcl

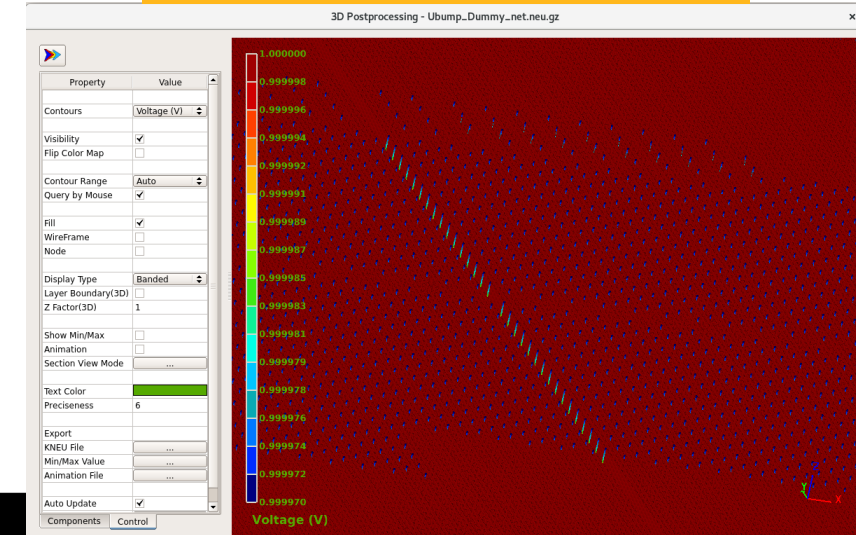
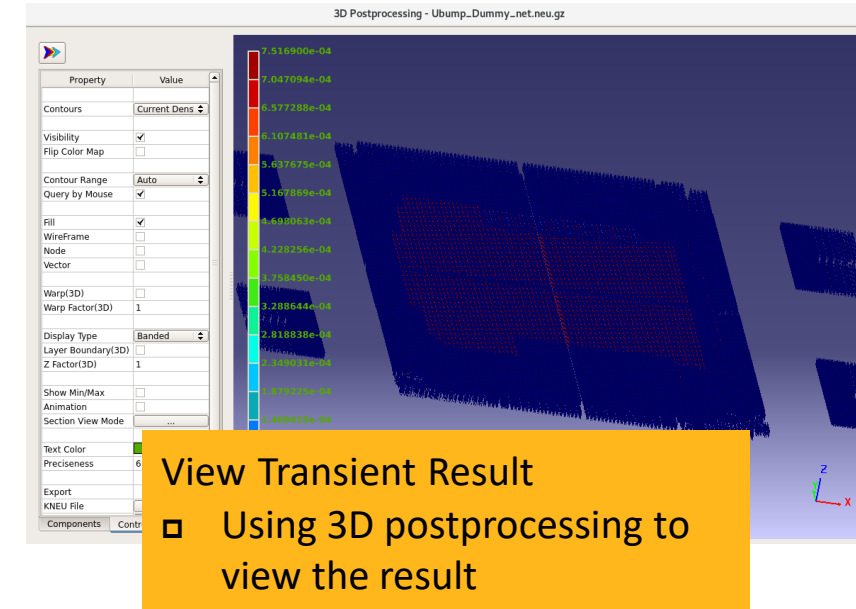
✂ To run the script:

```
% cd scripts/  
% redhawk_sc_et -ng TI_Ubump2.tcl
```

✂ What does Electro\_Thermal\_flow.tcl do?

- ✓ Create the new project
- ✓ Import Interposer Ubump file and CPM file
- ✓ Perform 3DIC Electro-Thermal analysis

✂ In this case, it's used to run Electro Thermal analysis on Ubump.



# Step IX : TI\_ComplexConnection.tcl

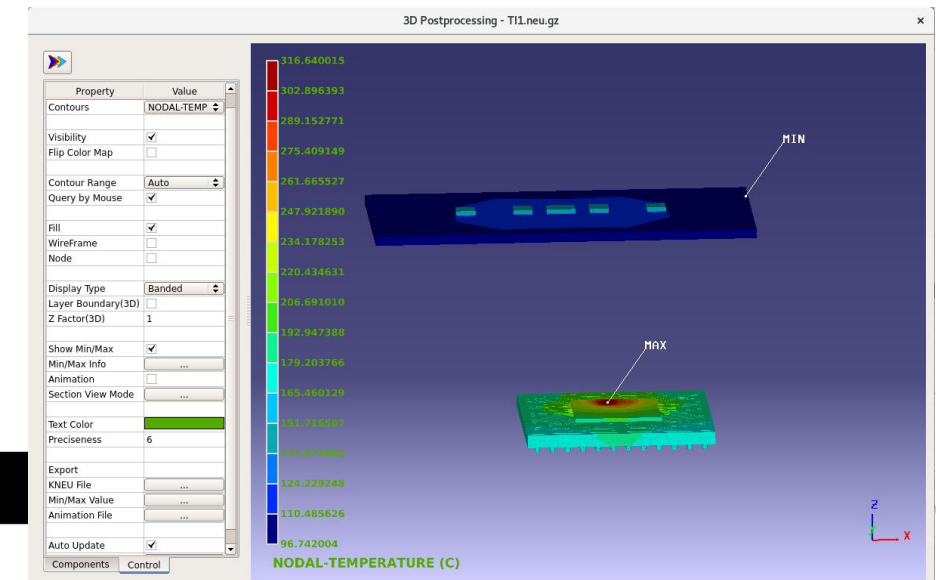
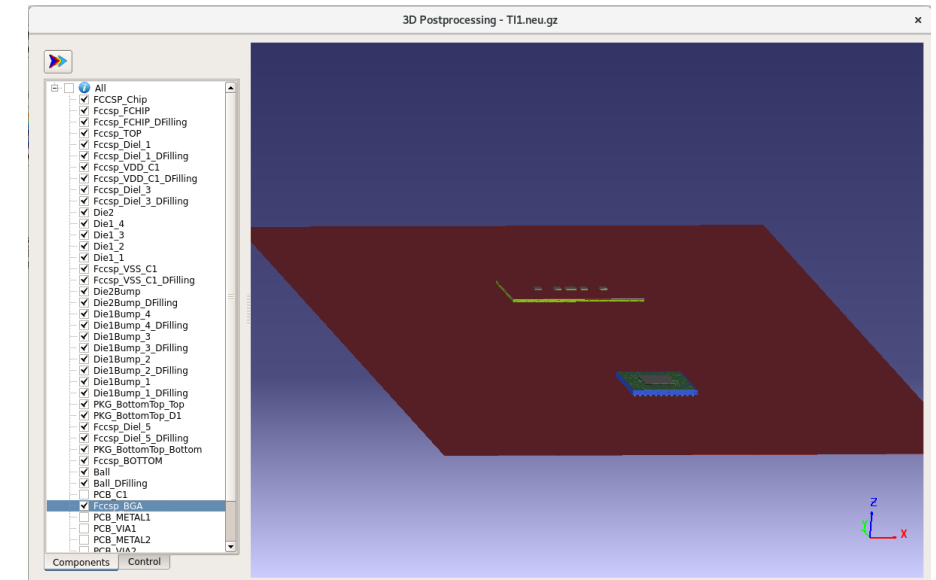
❖ To run the script:

```
% cd scripts/  
% redhawk_sc_et -3dic -ng TI_ComplexConnection.tcl
```

❖ What does TI\_ComplexConnection.tcl do?

- ✓ Create the new project
- ✓ Import package and CTM file
- ✓ Perform 3DIC static thermal analysis

❖ This case, it connects to two package file, one is fccsp, the other is prototype package. There are 5 dies on prototype package, 1 die on fccsp package.



 **Ansys**

