PSD™- User Manual

Passive Shipper Design for cold chain

Version 1.03

MCR Version: R2019b (9.7)

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Contents

1. Introduction

PSD™ is built to:

- Automatically determine the optimized shipping design
- Simulate a user-defined packaging configuration
- Minimize user input

PSD™ contains capabilities to:

- Automatically create a suitable design that satisfies the requirements and provide the user with dimensions and simulated results of the design.
- Simulate the design under fixed/user-defined/forecasted temperature profiles
- Easily create conceptual designs and show previews of the designs
- Simulate multiple designs simultaneously
- Produce PDF report summary with heatmaps, tables, and temperature plots
- Select from SI/US Units

1.1. Nomenclature

EPS	Expanded Polystyrene
VIP	Vacuum Insulated Panel.
PCM	Phase Changing Material

1.2. Main User Interface

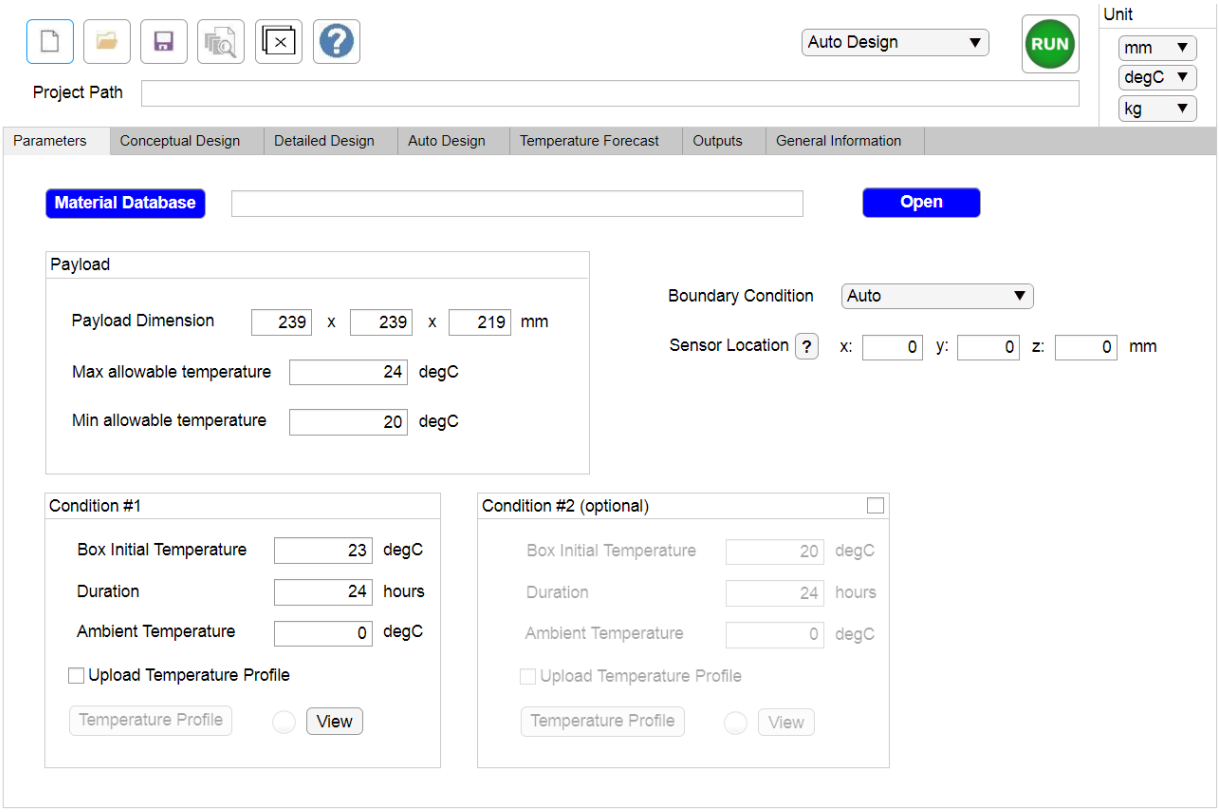


Figure 1 - Main User Interface

Figure 2 - Main User Interface (top)

New: Start a new project

Open: Open an existing project

 **Save**: Save the project

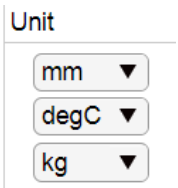
 **Open**: Open an existing project

 **Close Figures**: Close all the plots and heat map figures

 **Help**: Open this User Guide

Run: Run the simulation

- **Auto Design**: Program automatically determines required number of layers of insulation and material to satisfy design requirements.
- **Manual Design**: Simulate user defined design configurations



- **Unit**: Units of the user inputs. Unless otherwise specified, inputs in the GUI are assumed to be in these units. For example, if mm is selected, then all length inputs in the GUI will be in mm.

Figure 2 - Main User Interface (tabs)

- **Parameters**: Payload dimension and requirement, ambient temperature profile (only if temperature forecast data is not used).
- **Conceptual Design**: Defining the design layout for manual design
- **Detailed Design**: Detailed parameters for manual design, including the selection of material for each layer and their respective thickness
- **Auto Design**: Parameters for automated design
- **Temperature Forecast**: Simulate the design based on temperature forecast (a maximum of 30 days in advance)
- **Outputs**: Display the result plots, heat maps, and tables
- **General Information**: Non-simulation related project information will be displayed in the PDF report

2. Workflows

2.1. Auto Design

Fill out the tabs in the following order, then run the program:

- **Parameters**
- **Auto Design**
- **General Information** (Optional)

2.2. Manual Design

Fill out the tabs in the following order, then run the program:

- **Parameters**
- **Temperature Forecast** (only if forecast data is used for ambient temperature)
- **Conceptual Design**
- **Detailed Design**
- **General Information** (Optional)

3. Parameters Tab

This tab must be filled by the user for all simulation modes. If temperature forecast data is used, Condition #1 and Condition #2 panels do not require user input.

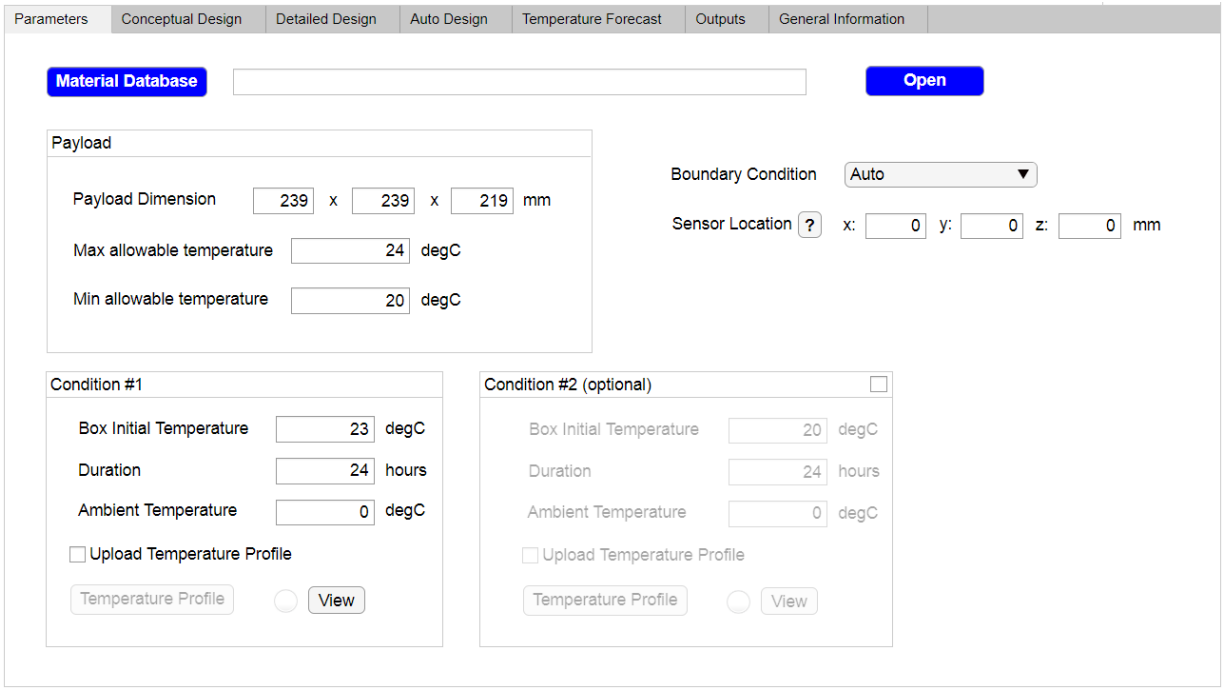


Figure 2 - Parameters Tab

3.1. Material Database

Name	Density	Cp	k	Cost	Transition Temperature	Latent Heat	Thickness	Type	Cost Unit
	kg/m^3	J/(kg*degC)	W/(m*K)		deg C	kilo*J/kg	in		
VIP1	276.8	80	0.00257	10	NA	NA	[1:5]	VIP	1/m^2
EPS1	24	1200	0.035	2	NA	NA	NA	EPS	1/m^3
Box1	145	1300	0.064	2	NA	NA	NA	Box	
18C	860	[2400,2500]	[0.21,0.21]	10	[15.2,18.3]	205	NA	PCM	1/m^2
24C	850	[2400,2500]	[0.22,0.22]	10	[20.2,23.7]	208	NA	PCM	1/m^2
HS22	1595.5	[2270,2530]	[1.13,0.56]	10	[22,23]	167.6	NA	PCM	1/m^2
Air	1.256	1007	0.02455	NA	NA	NA	NA	Other	
Water	984.45	4190	0.63	NA	NA	NA	NA	Other	
Default Gap	1.256	1007	0.02455	NA	NA	NA	NA	Gap/Bubble Wrap	

Figure 3 – Default material database

The material database is a CSV file that contains the material properties for all materials that can be used in the simulation. The format of the file is shown above. The first row is the column description, which should not be changed; the second row is the unit, which can be changed.

The ten columns in Figure 3 are;

- **Name**: material name
- **Density**: average density
- **Cp**: specific heat
- **k**: thermal conductivity
- **Cost**: cost of material, unit of this value is specified under the **Cost Unit** column
- **Transition Temperature**: transition temperature ranges from solid to liquid for PCMs
- **Latent Heat**: total latent heat released per unit mass as a result of phase change from solid to liquid for PCMs
- **Thickness**: the thickness of material if there are limited number of options
- **Type**: material type, value must be one of the following: *Box, EPS, VIP, PCM, Other*
- **Cost Unit**: unit of the cost, can be specified as one of the following:
    - **Cost per unit volume**: possible unit includes 1/m^3, 1/cm^3, 1/in^3, 1/ft^3, 1/L, 1/gal
    - **Cost per unit area**: possible unit includes 1/m^2, 1/cm^2, 1/in^2, 1/ft^2, 1/sqft
    - **Cost per unit mass**: possible unit includes 1/kg, 1/g, 1/oz, 1/lbm
    - **Cost per piece of material**: leave the field empty in this case. If a VIP is used on all six sides of the payload, the total cost is the unit cost multiplied by 6

The material unit should consistent with the input, for example, a density unit must be used for density input, and the unit can be a combination of the following units:

Length	m, cm, mm, um, nm, km, ft, in, yard, nmi, mile
Mass	slug, kg, g, oz, lbm
Time	s, ms, min, hr, day, week, month, year
Temperature	degC, degF
Area	acre, sqft
Volume	L, bbl, gal, cf, Mcf
Speed	knot, mph, kph
Force	lb, N, kN
Energy	J, kJ, cal, meV, eV, MeV, erg, btu, kcal
Power	W, MW, kW, hp
Prefix	nano, micro, milli, kilo, mega, giga, tetra

Figure 4 – Available units

Units can be combined using */^. For example, kilo*W/cm^2

If any input in the table is unnecessary or not applicable, NA should be specified, note that **Name, Density ,Cp ,k, Type** must be specified and cannot be NA.

If multiple numbers are needed for one input, the user can specify them using the format below: [number1,number2,number3…]

For example, if the material is PCM, then the transition temperature must be specified as [T1,T2], where T1 and T2 are temperatures at which the phase transform starts/finishes. T1 and T2 should not be the same.

If the material is PCM, **Cp**, and **k** must contain 2 numbers, specifying the material properties for the solid phase and liquid phase. Otherwise, **Cp**, and **k** must contain only 1 number.

Density must contain only 1 number; this is the average material density at all temperatures.

3.2. Payload

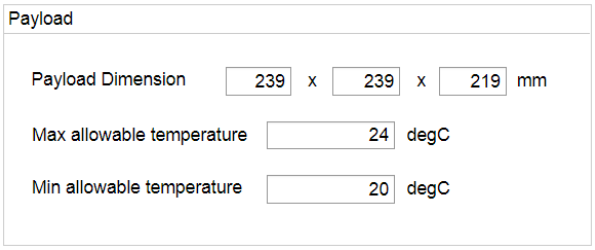


Figure 5 - Payload Panel

Payload dimension specified as L*W*H. Max/Min allowable temperature is the allowable temperature range at the center of the payload. If the temperature in the payload exceeds or drops below this range, the design will be classified as a failed design.

3.3. Ambient Temperature

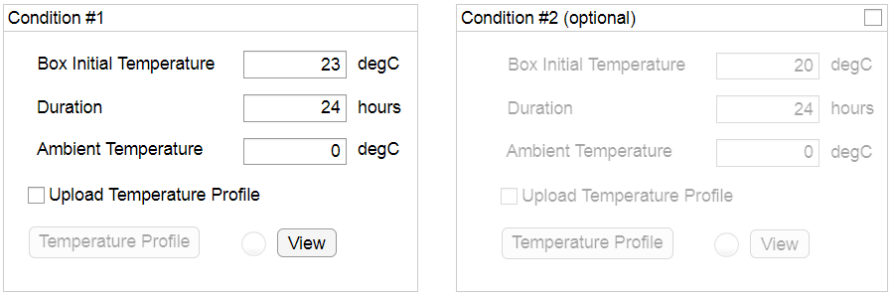


Figure 6 – Temperature Condition Panels

Specify one or two extreme ambient temperature conditions. Ambient temperature can be specified from a temperature profile by selecting the **Upload Temperature Profile** checkbox, or as a fixed temperature.

An example temperature profile CSV file is shown below:

	A	B
1	Time	Temperature
2	hr	degC
3	4	25
4	10	30
5	80	35
6	20	30

Figure 7 – Temperature Profile Example

In the temperature profile example above, the ambient temperature for the first 4 hrs will be 25 degC, and then the next 10 hrs will be 30 degC, and so on. The unit for the first column can be **s**, **min**, **hr**. The unit for the second column can be **degC** or **degF**.

3.4. Boundary Conditions

There are three boundary conditions available:

- **Auto**(recommended): Automatically select from **Fixed Temperature** or **Convection**
- **Fixed Temperature**: The temperature of the outer box surface is fixed at ambient temperature
- **Convection**: Convective heat transfer between the outside of the box and the ambient

3.5. Sensor Location

The program simulates and measures the payload temperature at the sensor location. The payload center is defined as the origin (x,y,z) = (0,0,0). To place the sensor elsewhere, use the following schematic as a reference:

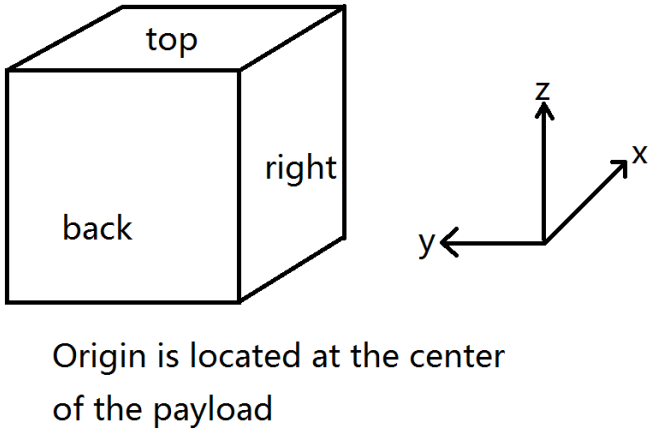


Figure 8 – Sensor Coordinate Specification

4. Conceptual Design Tab

Use this tab when running manual design simulation.

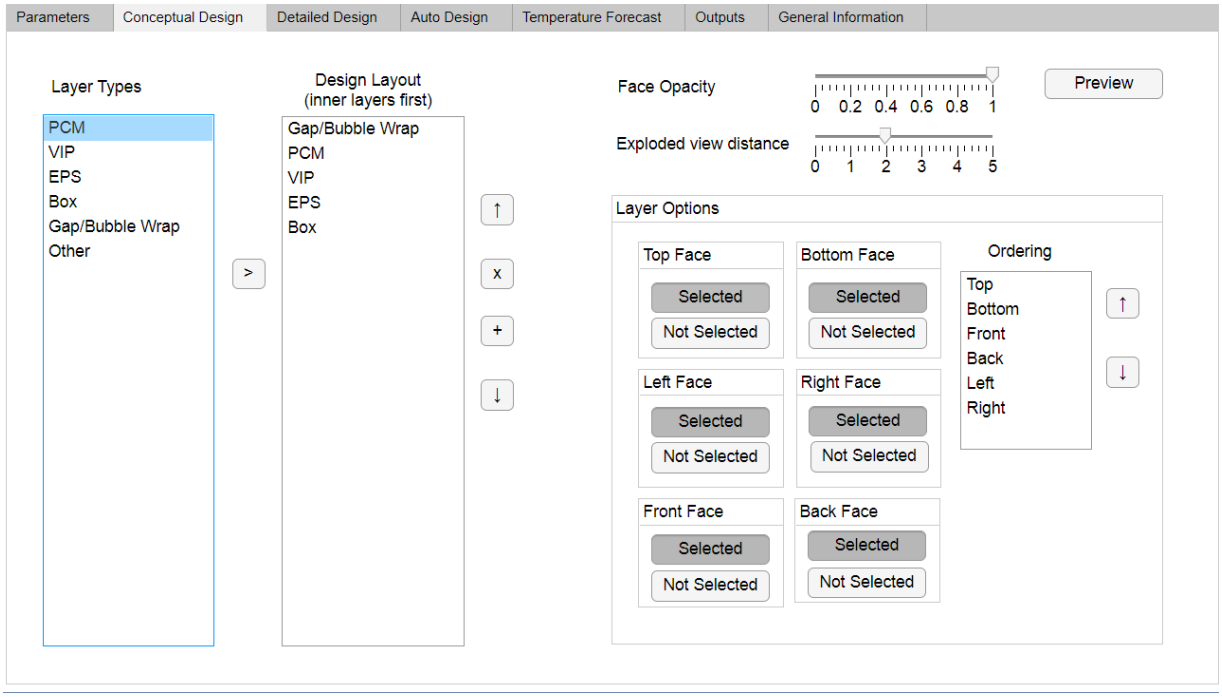


Figure 9 – Conceptual Design Tab

To create a manual design:

- Construct the box by selecting the insulation material closest to the payload first then the outer insulation materials, in the order of **PCM -> VIP -> EPS -> Box**. For example, to select PCM, click on **PCM** in the **Layer Types** list box, then click on **>** button to move it to **Design Layout** list box.
- Each "layer" represents one or more pieces of insulations with the same material type and thickness. If multiple PCM material types are used, create additional PCM layers.
- For each layer, by default, all 6 faces are selected. User can change the face selection if necessary

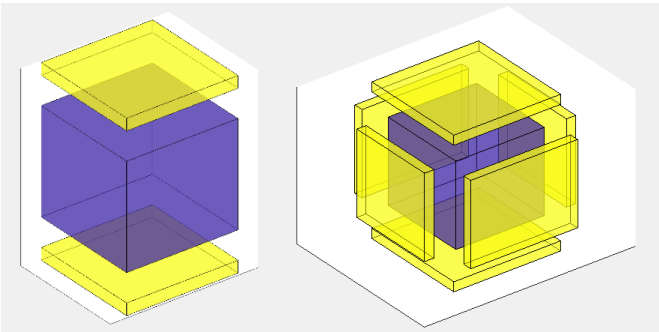


Figure 10 – Layer with 2 top/bottom selected(left) and Layer with all faces selected(right)

- For each layer, by default the ordering is Bottom>Top>Left>Right>Front>Back. In this configuration, space is filled by the bottom face first, then top face. This way, the insulation on top and bottom will be slightly larger than the faces on the other sides

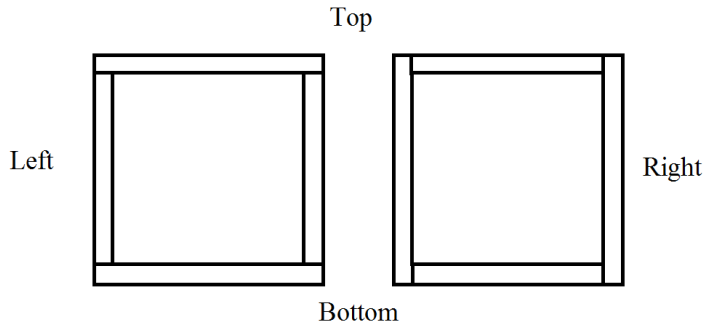


Figure 11 – Difference between Bottom>Top>Left>Right and Left>Right>Bottom>Top

- Make sure that the conceptual design is appropriately set up by clicking on the preview button.

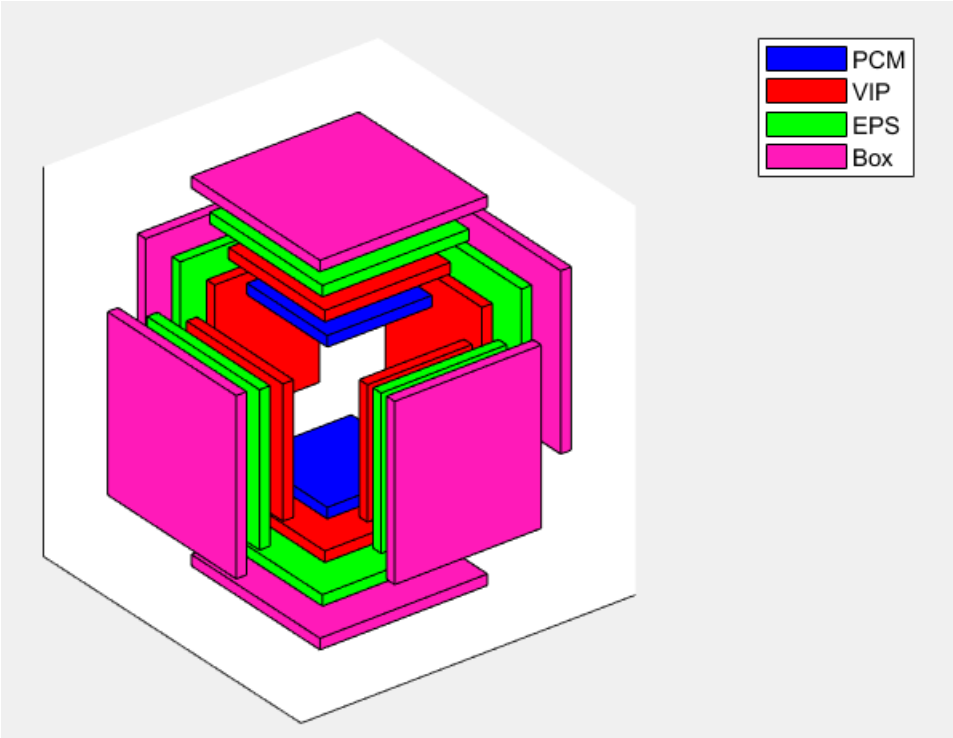


Figure 12 – Sample Conceptual Design Preview

5. Detailed Design

Use this tab when running a manual design simulation.

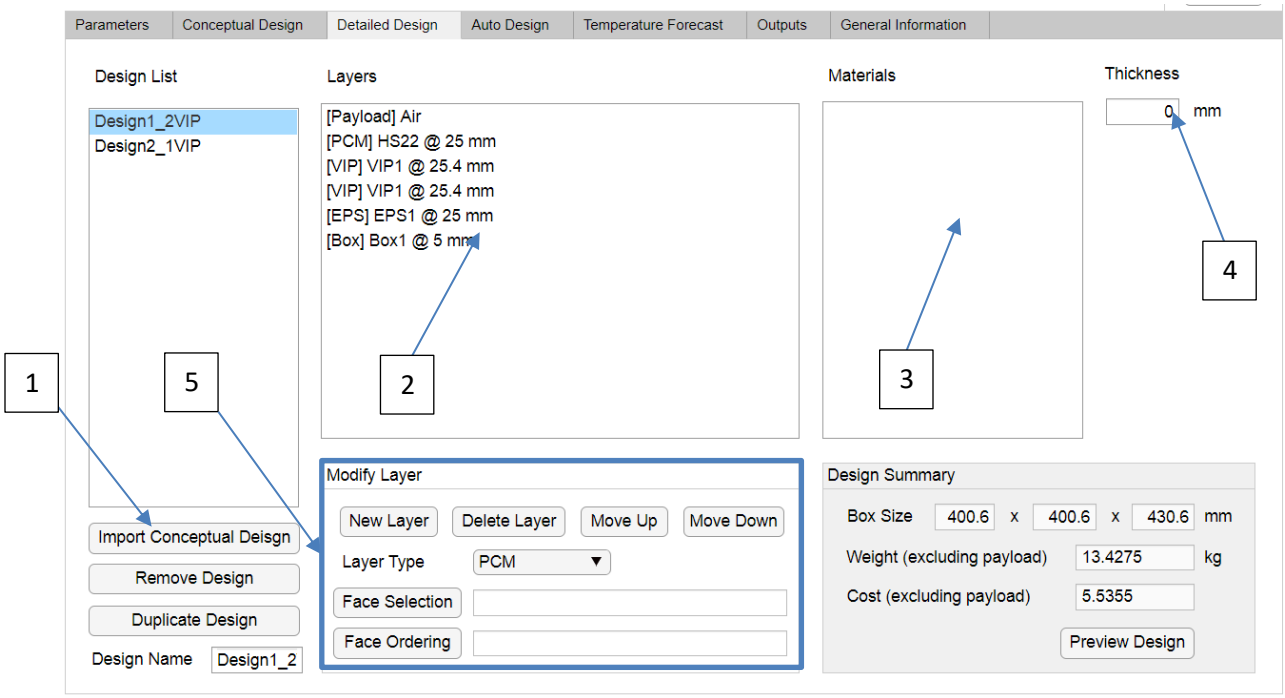


Figure 13 – Detailed Design Tab

1. Once a conceptual design is defined, click on the **Import Conceptual Design** button to import the conceptual design.
2. Select a layer from the **Layers list** box
3. Select the material for the layer highlighted
4. Specify the thickness of the layer (not required for payload)
5. The user can modify the design parameters previously defined in the conceptual design tab using the tools in this panel
6. Repeat steps 2, 3 and 4 until all layers are defined

6. Auto Design

Use this tab when running an auto design simulation.

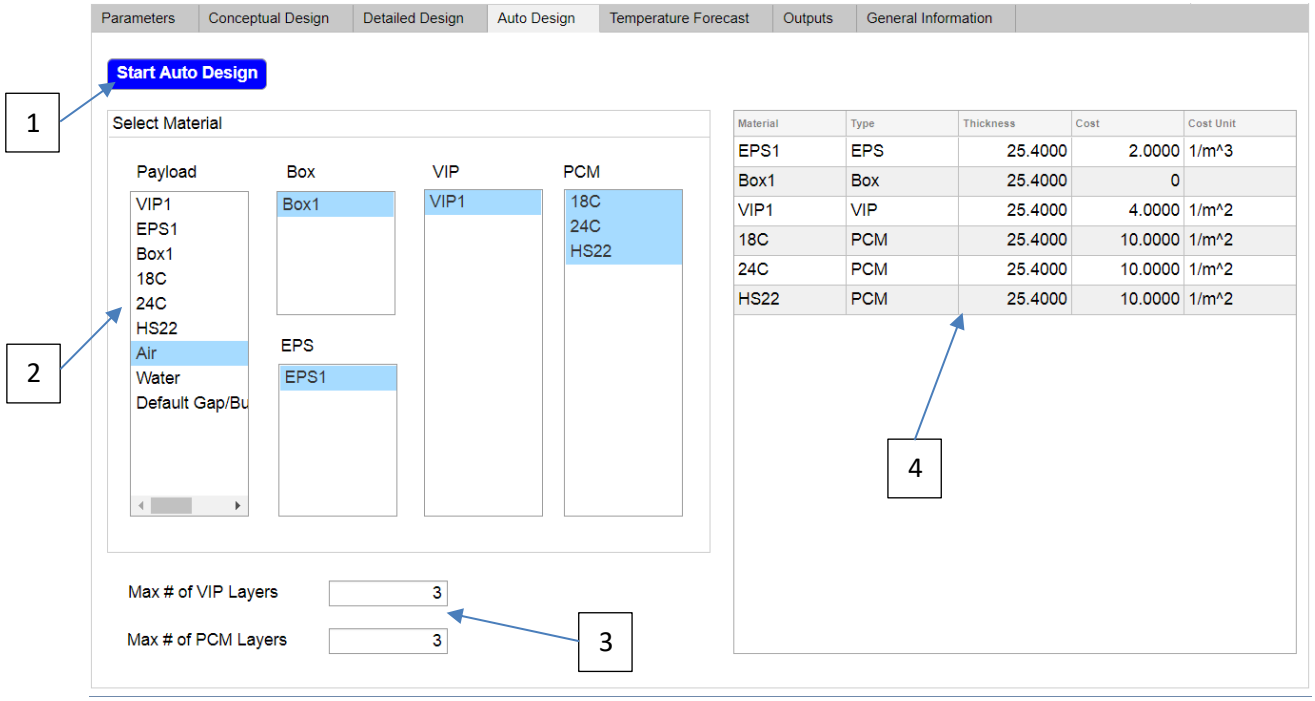


Figure 14 – Auto Design Tab

1. Click on Start Auto Design button
2. Select suitable materials for each material type.
3. Define the maximum number of layers of VIP and PCM

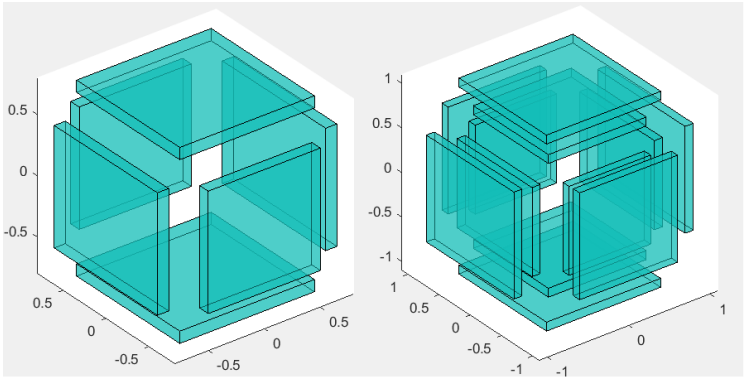


Figure 15 – 1 layer of materials vs. 2 layers of materials

4. Specify the thickness and cost of each material selected. The cost is the cost per piece of material used. For example, if there are two designs that meet the design requirement, a design with 4 pieces of VIP and 1 piece of PCM, and another design with 1 piece of VIP and 2 pieces of PCM. The cost will determine which design is the best.

7. Temperature Forecast

Use this tab when running a manual simulation with historical temperature.

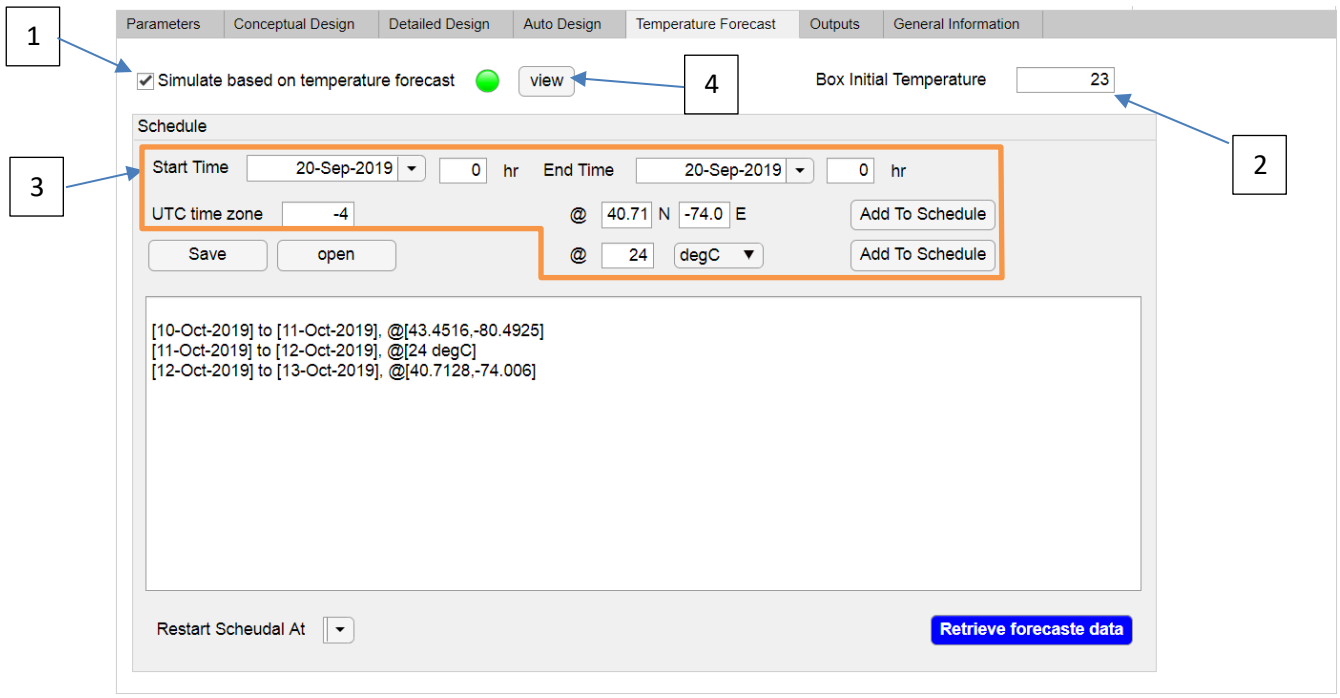


Figure 16 – Temperature Forecast Tab

1. Select **Simulate based on temperature forecast** checkbox
2. Provide initial temperature of the box
3. Break down the trip of the box into different segments of time intervals chronologically, specify either the location (in terms of latitude and longitude) or a fixed temperature for each time interval. Once an interval is defined, click on **Add to Schedule** button. A user can also modify or review the schedules in the textbox. Modify UTC time zone if necessary, **UTC time zone** is the hour differences between the current time zone, and the UTC time. For example, New York UTC time zone is -5 without daylight saving time.
4. Preview the temperature profile to make sure it is reasonable. The prediction is based on historical statistical data.

   Note: In order to obtain temperatures forecast, the computer must be connected to the internet. The start and end times cannot be more than 30 days from the current date. The program retrieves the temperature data from openweathermap.org, using the **Climate Forecast for 30 Days** API. Documentation available at: https://openweathermap.org/api/forecast30. Temperature forecast is based on historical data available from October 2012. The maximum/minimum temperatures are the average daily maximum/minimum temperatures from the available data, they are not tied with respect to the current weather data.

8. Output Tab

On completion of a simulation, use buttons in this tab to view results.

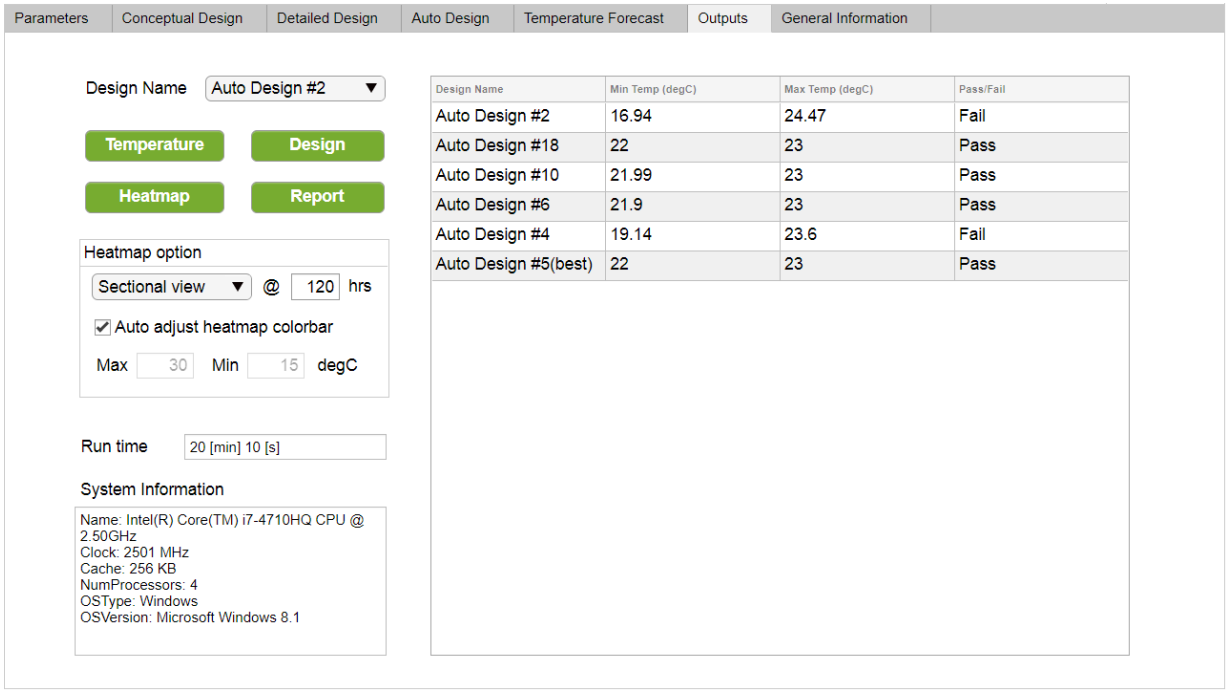


Figure 17 – Output Tab

To view a specific plot for any design, select **Design Name** drop-down and choose the design. For manual design simulations, the design name is defined by the user under the **Detailed Design** tab, in the **Design List,** list box. For auto design simulations, the design name is automatically generated by the program, in the format of **Auto design #X**, the higher the number X, the higher the cost (more insulation materials used).

The system information and the run time of the simulation are shown after a run completes. Simulation run time will vary on different computers depending on their specs.

A PDF report is generated containing the simulation plots/summaries for all designs. Click PDF Report button to view the report.

9. General Information Tab

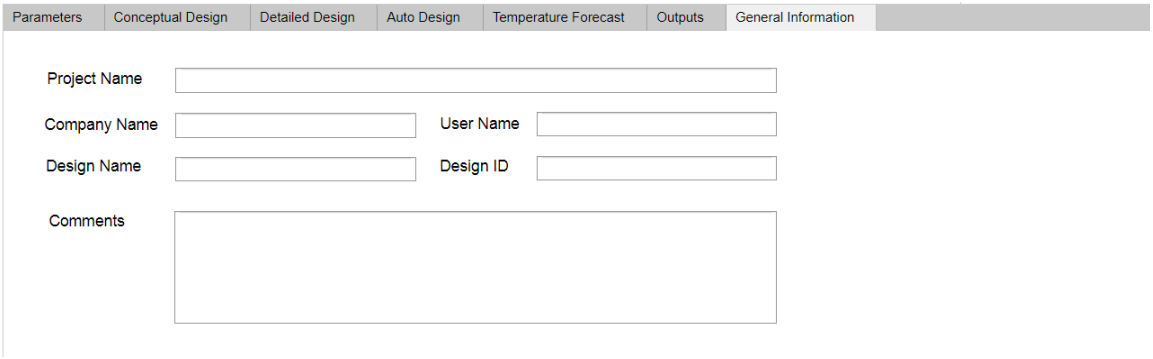


Figure 18 – General Information Tab

Inputs in this tab are optional; they do not affect the numerical computation. User inputs from this tab will be written to the PDF report.

10. Sample Plots

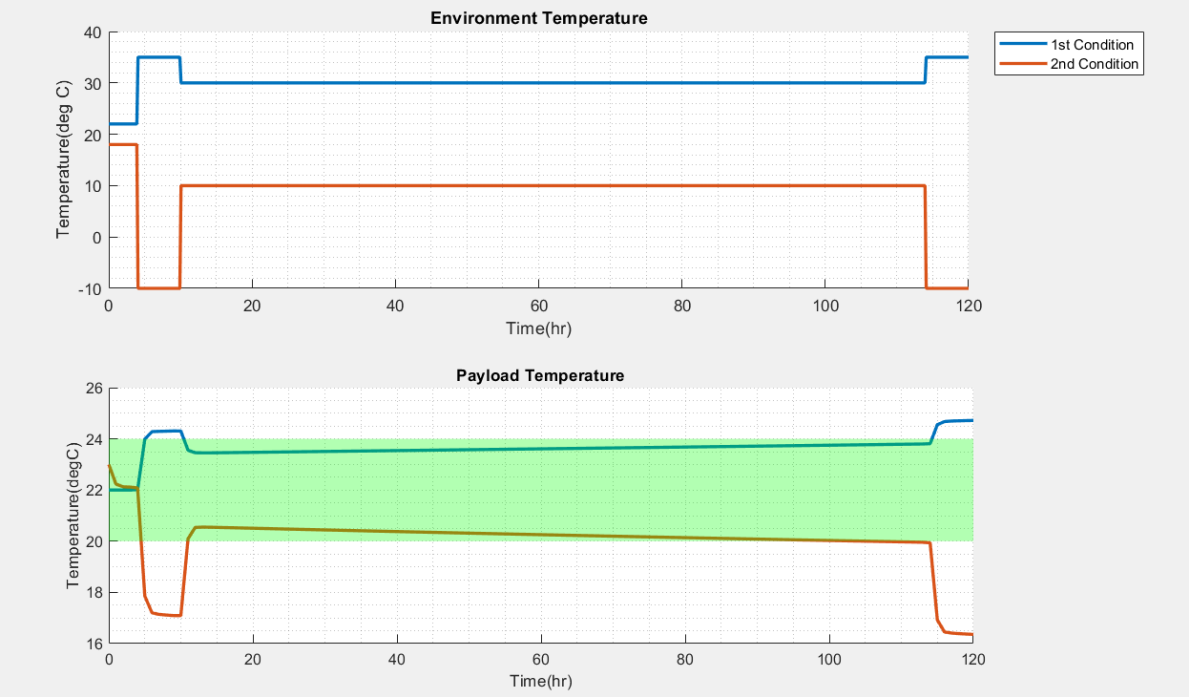


Figure 19 – Temperature Profile Plot

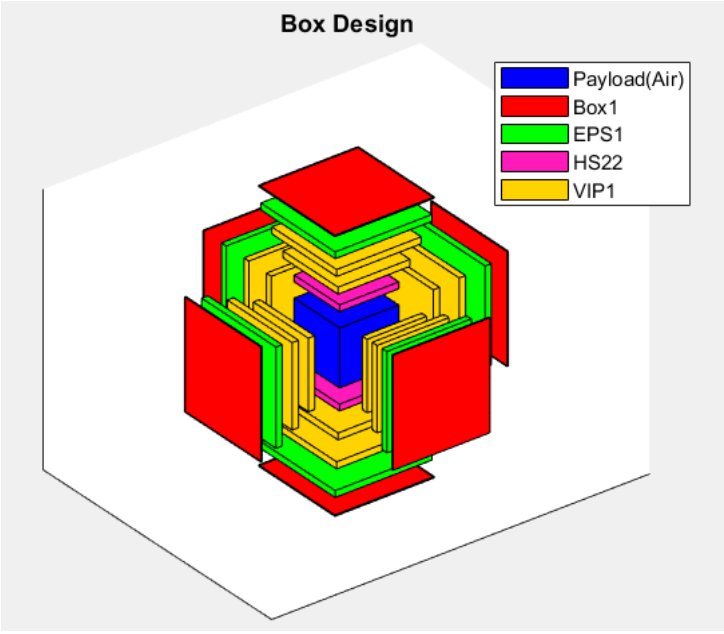


Figure 20 – Box Design Plot

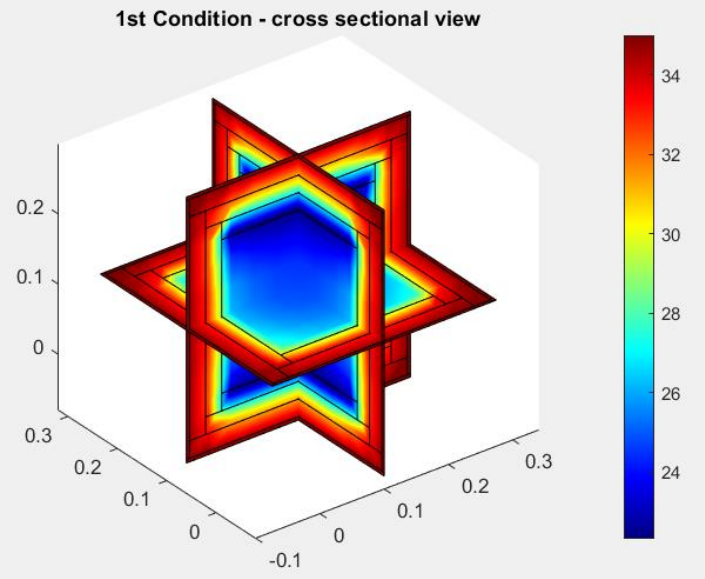


Figure 21 – Heat map (cross-sectional view)

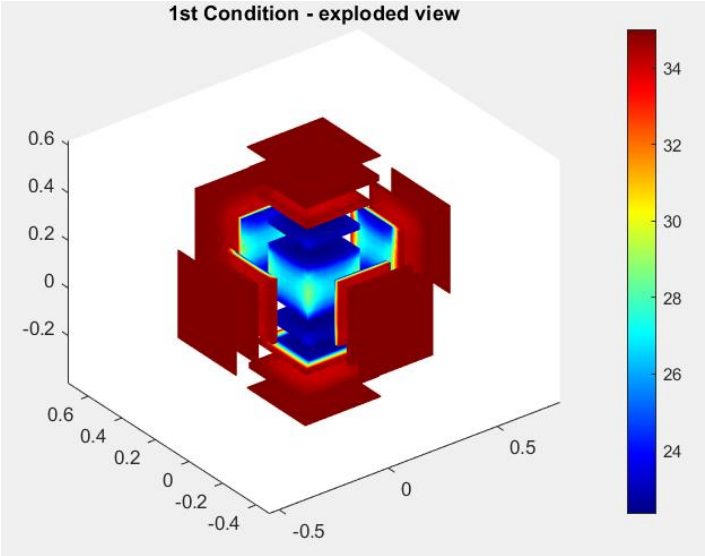


Figure 22 – Heat map (exploded view)

11. Working with figures

Plots produced by PSD is interactive, they can be zoomed in/out, labeled, and rotated. Take the following plot as an example:

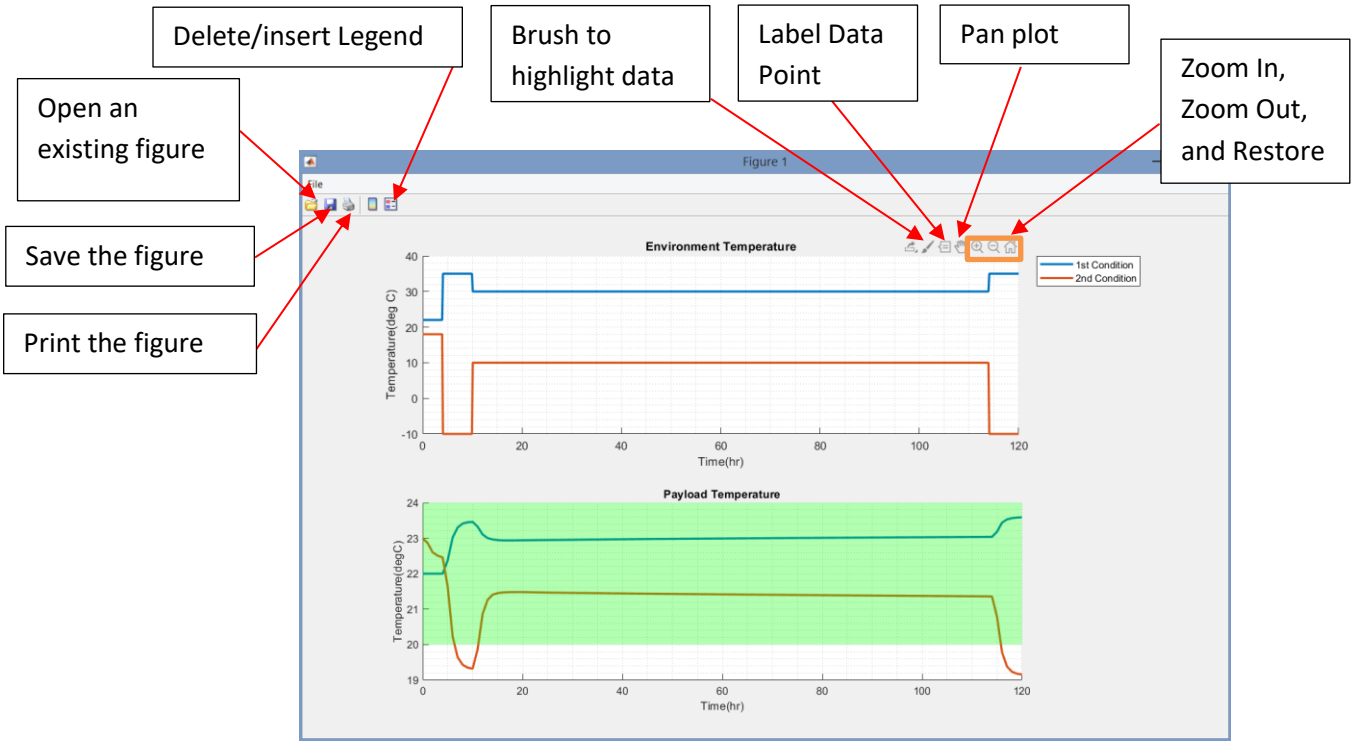


Figure 23 – Interactive figure produced by STIPumpCard

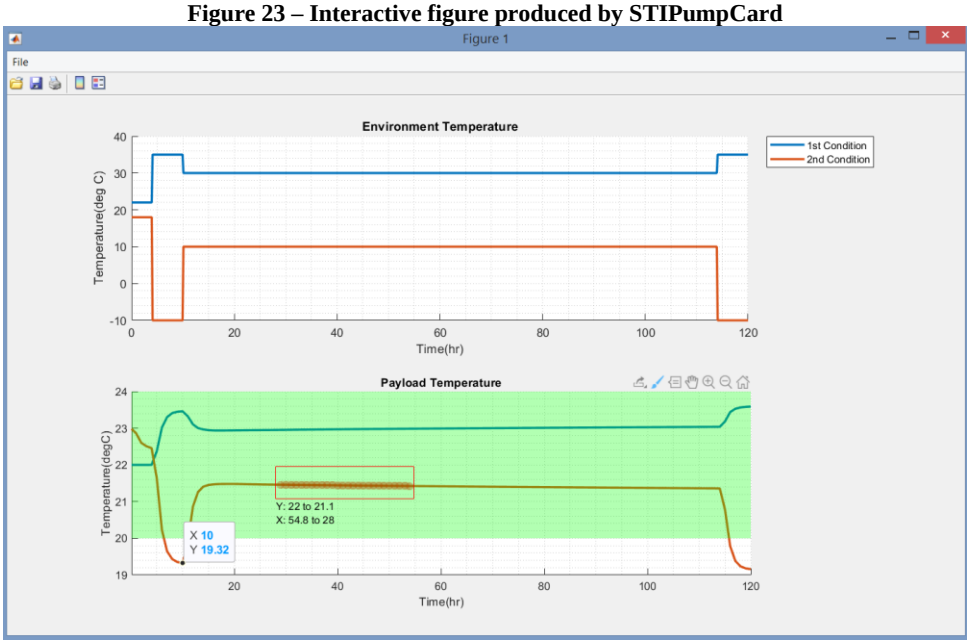
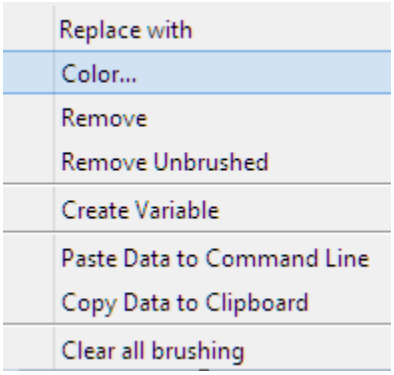
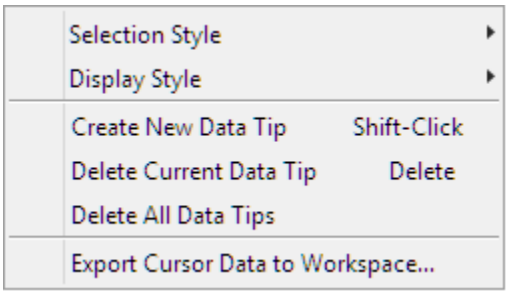


Figure 24 – Illustration of the brushing tool and the data labeling tool

As shown in the figure above, points can be highlighted using the brush tool  . Actions associated with a tool can be accessed by right-clicking after tool selection. Upon right-clicking after selecting the brush tool, a user can interactively mark, delete, modify, or save data points in plots, as shown by below



The data associated with the points can also be copied to the clipboard and pasted into another application, such as Excel or a text editor. The coordinates of any point on the plot can be displayed using the data labeling tool  . Right-clicking brings up a series of options, such as formatting of the data tip as well as the creation of multiple data tips, which can be used to mark salient areas of a plot.



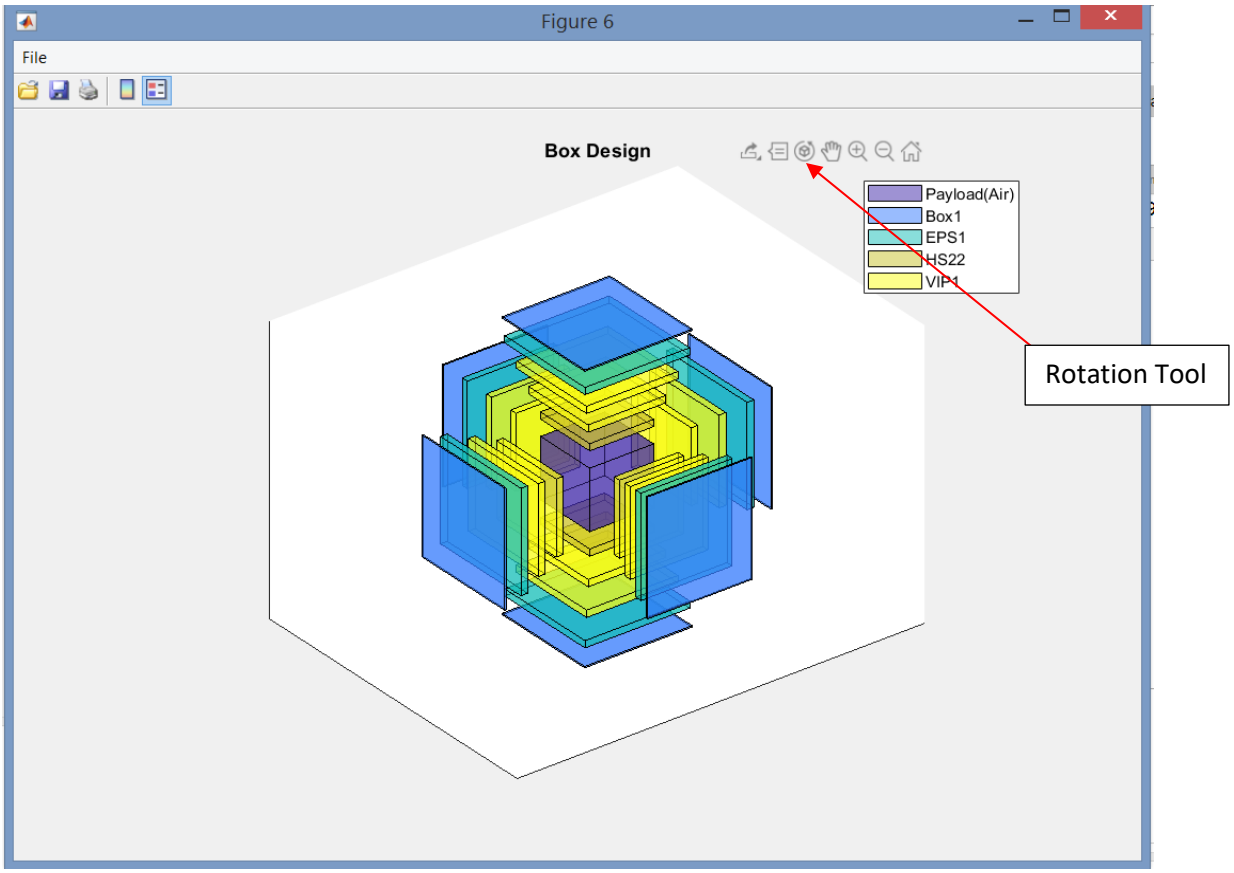


Figure 25 – Rotation capability for 3D plots

For 3D plots, the figure can be rotated interactively using the rotation tool  . If an orthogonal view is desired, user can right click anywhere on the figure and select *X-Y/X-Z/Y-Z* view as shown in the options below