



Discover Better Designs, *Faster*

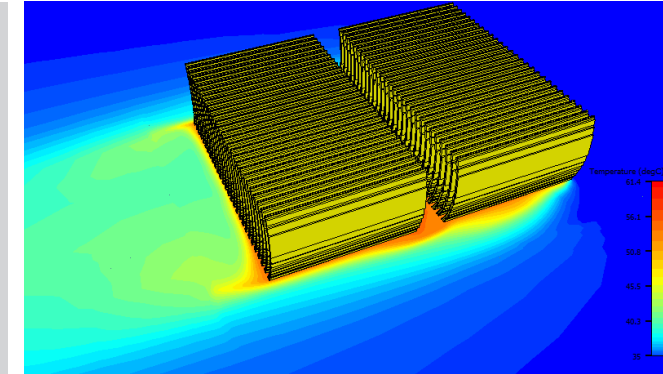
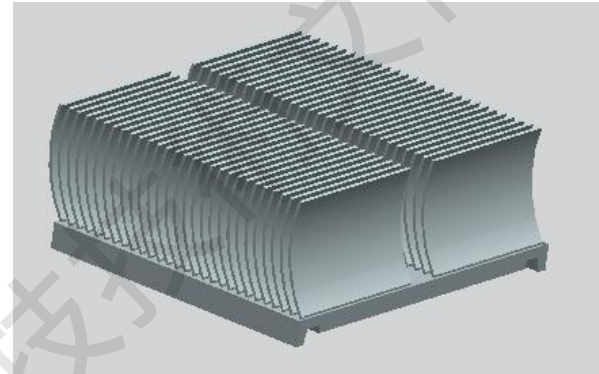
# Improving Cooling Efficiency of a Heatsink

## Tools

- FloTHERM v12.2
- NX v13.0

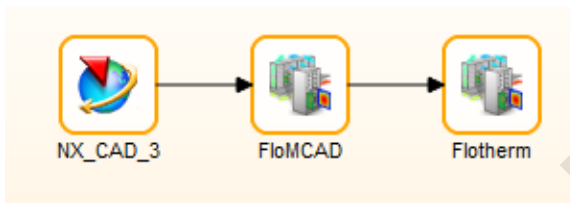
## Challenge

- Design a Heatsink that has high cooling efficiency (low chip temperature), while maintaining mass requirements

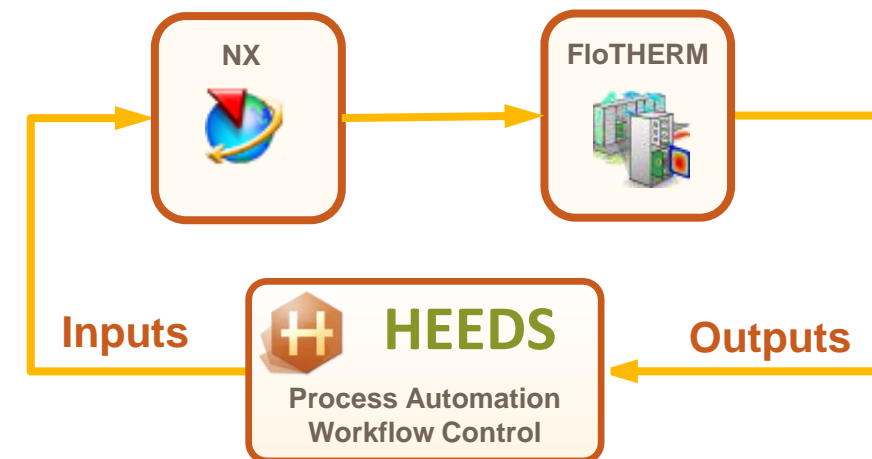


Heatsink model

## Process Flow



*\*Note: FloMCAD and FloTHERM are run with the General portal as opposed to the FloTHERM portal within HEEDS*



# Improving Cooling Efficiency of a Heatsink

## Problem Description

**Objective:** Pareto Trade-off:

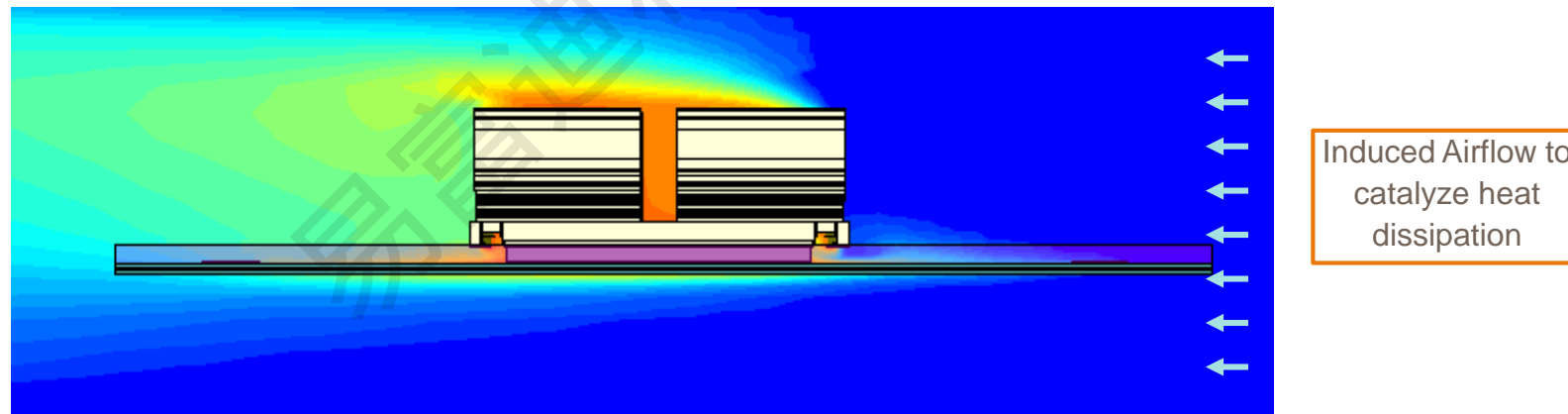
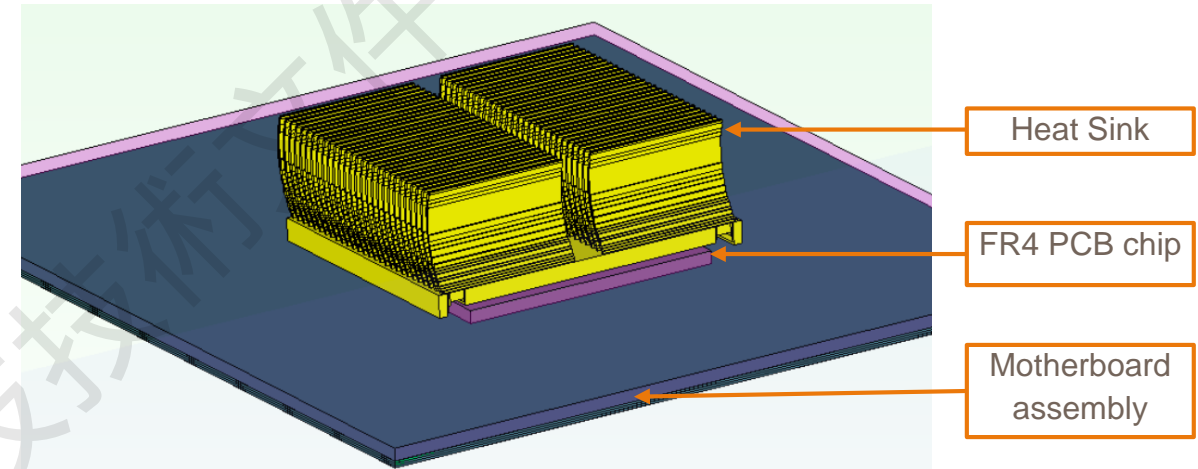
- Minimize chip\_temperature\_max
- Minimize Mass

**Constraints:**

- chip\_temperature\_max  $\leq 60^{\circ}\text{C}$

**Variables:**

- 10 geometric variables which control the Heatsink design



# Improving Cooling Efficiency of a Heatsink

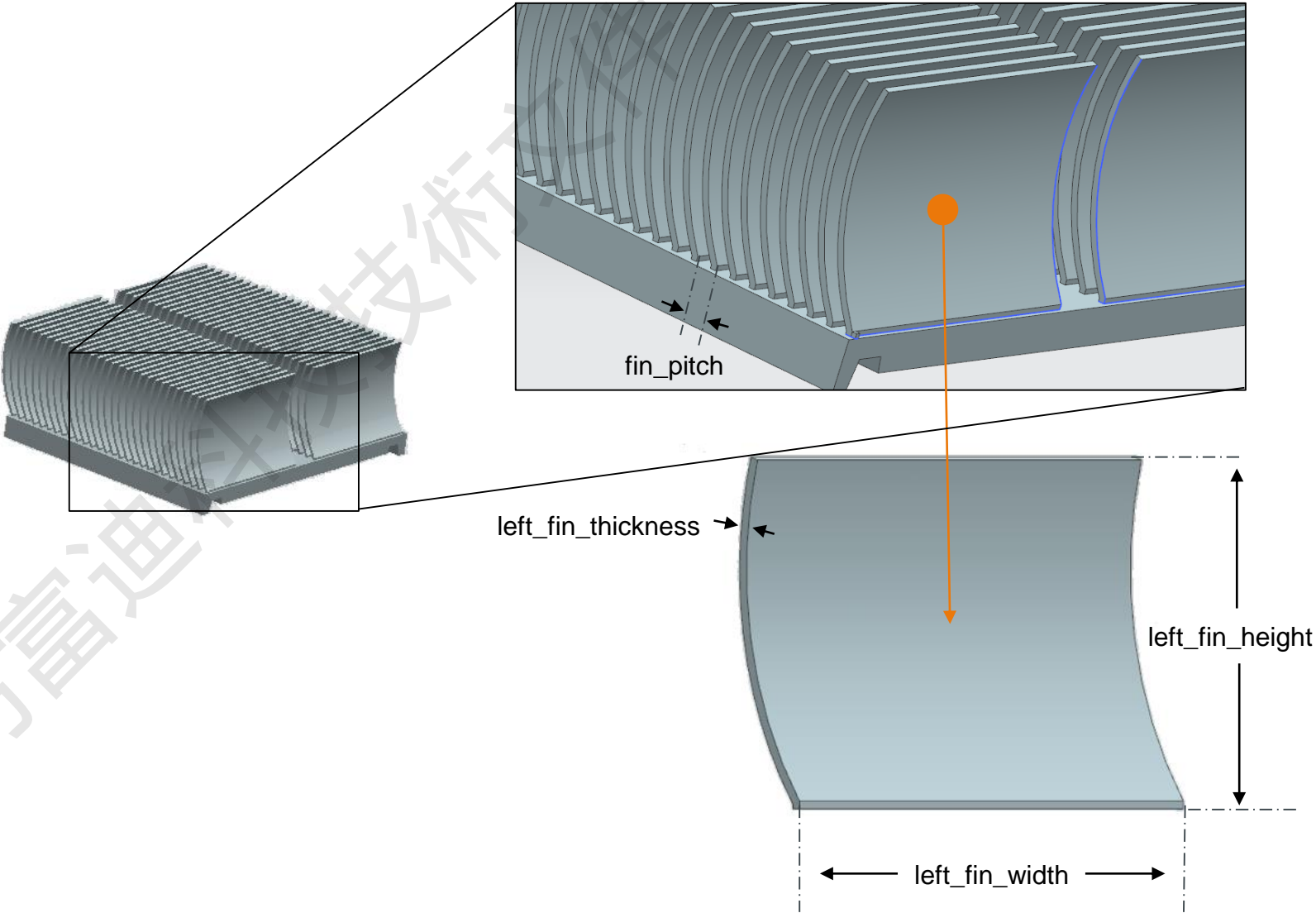
## Variable Description

### Continuous Variables

Variable Name	Baseline	Range
left_fin_width (mm)	34.91	10 ~ 39
left_fin_height (mm)	27.81	10 ~ 35
left_fin_thickness (mm)	0.61	0.3 ~ 0.8
left_fin_num	28	2 ~ 35
right_fin_width	34.41	10 ~ 38

### Dependent Variables

Variable Name	Relation
right_fin_num (mm)	= left_fin_num
right_fin_height (mm)	= left_fin_height
right_fin_thickness (mm)	= left_fin_thickness
right_fin_pitch	$= \frac{60}{\text{left\_fin\_num}-1}$
left_fin_pitch	= right_fin_pitch





## Model Preparation

- The user needs to expose the relevant Parameters as NX Expressions for usage as variables/responses by HEEDS

Expressions

Visibility

Displaying 35 of 35 expressions

Show All Expressions

Expression Groups Show Active Only

☒ Show Locked Formula Expressions

☐ Enable Advanced Filtering

Actions

New Expression

Create/Edit Interpart Expression

Create Multiple Interpart Expressions

Edit Multiple Interpart Expressions

Replace Expressions

Open Referenced Parts

Update for External Change

	Name	Formula	Value	Units	Dimensionality
19	p29	0	0		Angle
20	p34	0	0	mm	Length
21	p35	61.468	61.468	mm	Length
22	p36	0	0	mm	Length
23	p37	12.192	12.192	mm	Length
24	p38	0	0	mm	Length
25	p39	0.508	0.508	mm	Length
26	p40	5.84200056884	5.842000569	mm	Length
27	p41	5.33400056884	5.334000569	mm	Length
28	p52	(Measurement)	107743.9029	mm <sup>2</sup>	Area
29	p53	(Measurement)	52005.33964	mm <sup>3</sup>	Volume
30	p54	(Measurement)	0.4638876296	kg	Mass
31	p55	(Measurement)	4.549183623	N	Force
32	p56	(Measurement)	28.0000	mm	Length
33	right_fin_height	27.8113	27.8113	mm	Length
34	right_fin_num	28.0000	28		Constant
35	right_fin_pitch	2.22222	2.22222	mm	Length
36	right_fin_thickness	0.614656	0.614656	mm	Length
37	right_fin_width	34.4117	34.4117	mm	Length

Output Expressions

\* Note: Measure bodies are used to extract the Mass, Volume and Area of the Heatsink from within NX

Input Expressions

Expressions

Visibility

Displaying 35 of 35 expressions

Show All Expressions

Expression Groups Show Active Only

☒ Show Locked Formula Expressions

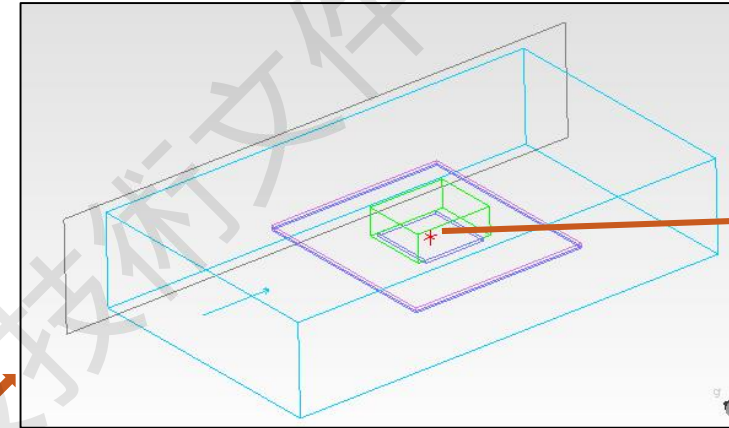
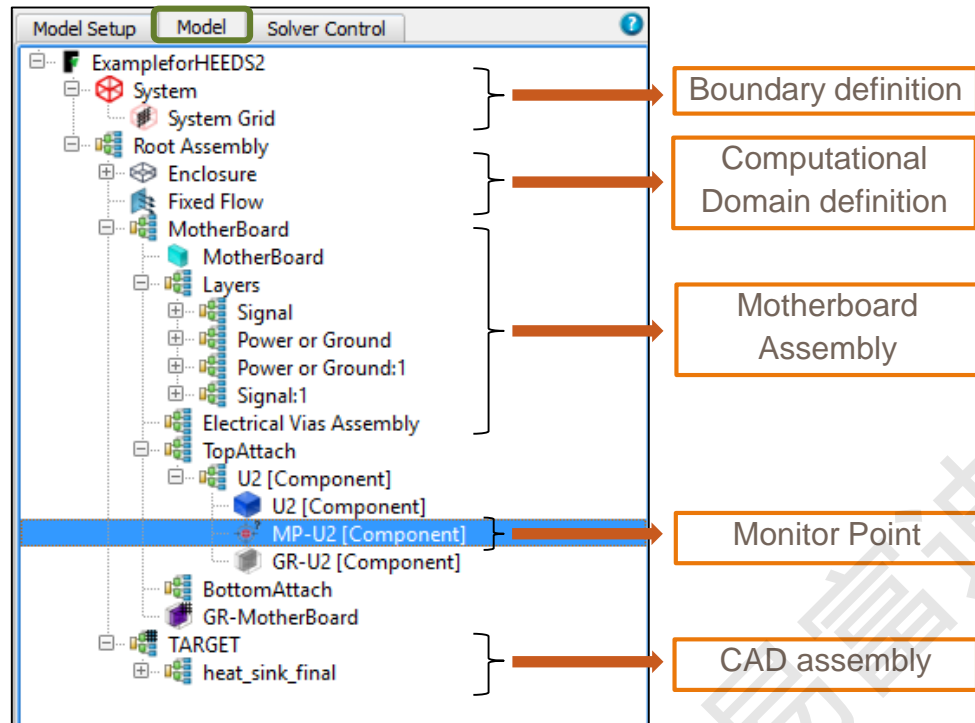
☐ Enable Advanced Filtering

	Name	Formula	Value	Units	Dimensionality
1	Default Group				
2				mm	Length
3	fin_pitch	2.22222	2.22222	mm	Length
4	left_fin_height	27.8113	27.8113	mm	Length
5	left_fin_num	28.0000	28		Constant
6	left_fin_thickness	0.614656	0.614656	mm	Length
7	left_fin_width	34.9143	34.9143	mm	Length

Input Expressions

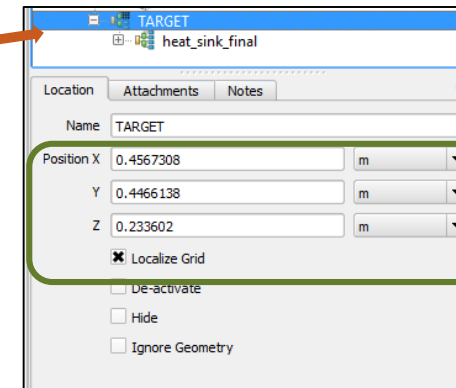


## Model Preparation: Model Settings



Monitor point placed at the junction

The user has to create a Monitor point at the junction between the chip and the Heat sink to monitor the final temperature at which the temperature stabilizes

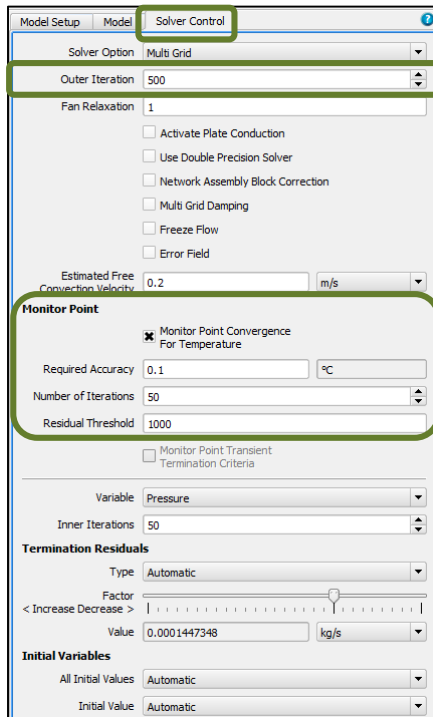


The user should create a **TARGET** assembly to which the CAD will be imported from the FloTHERM bridge. This will load the CAD and snap it to the local coordinate system which is defined in the **TARGET** assembly property card.

The simulation model should be fully defined such that when FloTHERM is executed in batch mode with the \*.pdml input file, the simulation will create \*.csv file(s) with the results

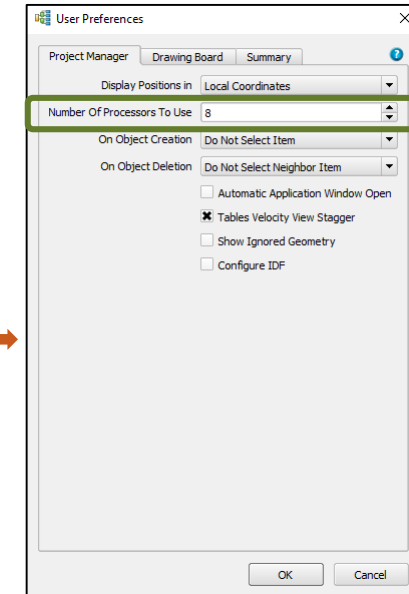
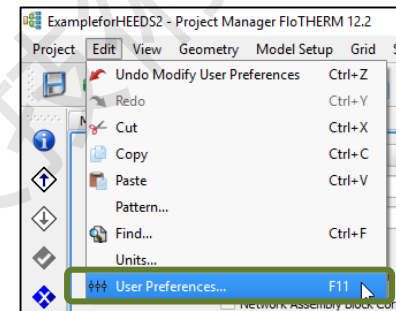


## Model Preparation: Solver Settings



Total number of Iterations is set to 500

Asymptotic convergence criteria is defined by selecting the **Monitor Point Convergence for Temperature** option. If the monitor point temperature stabilizes over 50 iterations within a tolerance of 0.1 degree, the solution is deemed as converged in this example





The number of processors to be used for each design evaluation can be set in user preferences

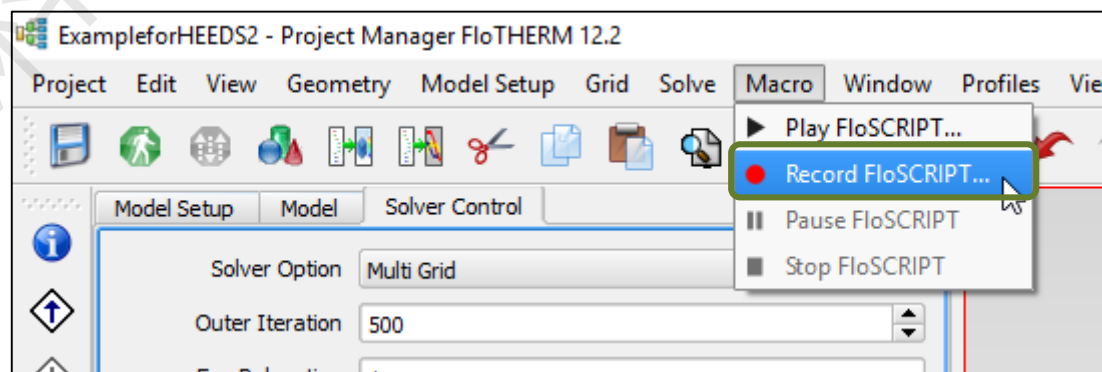


## Loading MCAD with FloSCRIPT

The \*.stp file generated by NX-CAD is read into FloTHERM by running a FloSCRIPT (\*.xml format macro file) in batch. The FloSCRIPT to replace CAD should contain the following steps:

- Change the solution directory to the current directory
- Load the updated model from the current directory (\*.pdm)
- Launch the FloMCAD Bridge  (steps on subsequent slide)
- Replace the Heatsink at the Target location
- Reinitialize and save the model
- Export a pack file with “No results”
- Close FloTHERM

*\*Note: the FloSCRIPT records the steps carried out on the “**Launch FloMCAD bridge**  ” section, with the steps shown on the next slide*



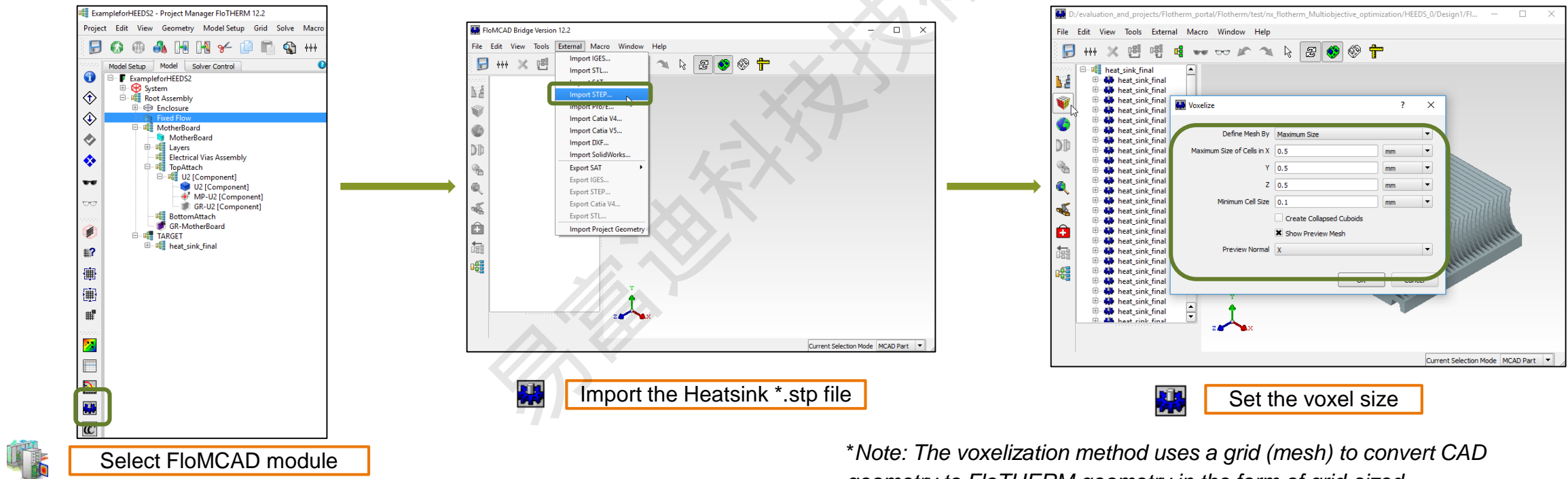
Recording a FloSCRIPT in FloTHERM





## Launch FloMCAD Bridge

- The “FloMCAD Bridge” interfaces FloTHERM with MCAD software packages. A neutral CAD file (\*.stp file in this example) is imported and converted to FloTHERM supported CAD format (\*.sat - simplifying where necessary), before transferring them to a FloTHERM project



# NX Portal



**SIEMENS**  
*Ingenuity for life*

- The NX portal modifies the Expression parameters and generates a \*.stp file of the updated Heatsink geometry

**Step export**

Execution Files **NX Portal** Dependencies Visualization Environment Comments

CAD export format: STEP 203  
☒ Save modified NX model for each design

Compute resource: Local  
Execution command: "%HEEDS\_NX\_PATH%/nxbn/run\_journal"  
Command options: "%RES\_DIR%/portals/HEEDS\_NX\_Interface.py" -args update\_%ANALYSIS%.in  
Num. designs to execute simultaneously: 1

Analysis Execution Options

Run in: Analysis folder  
Run condition: Always Run  
Finished condition: finish\_NX (10 s)  
Success condition: success\_NX  
Advanced: Modified...

Input File Name	Location	Connect from	Comment	Output File Name	Location	Comment
1 heat_sink_final.prt	<input checked="" type="checkbox"/> Project folder	Heatsink part file		1 heat_sink_final.stp	Project folder	STEP file generated from Updated CAD
				2 heat_sink_final.prt	Project folder	Updated Heatsink Part file for response extraction



# NX Portal - Output Tagging



- Mass of the Heatsink is extracted from the NX part file (output denoted by the blue arrow), from the Expression



Expressions

Visibility

Displaying 35 of 35 expressions

Show

All Expressions

Expression Groups

Show All

☒ Show Locked Formula Expressions

☐ Enable Advanced Filtering

Actions

New Expression

Create/Edit Interpart Expression

Create Multiple Interpart Expressions

Edit Multiple Interpart Expressions

Replace Expressions

Open Referenced Parts

Update for External Change

	Name	Formula	Value	Units
11	p10	2	2	
12	p11	10	10	mm
13	p12	10	10	mm
14	p13	0	0	°
15	p25	55.5498	55.5498	mm
16	p26	2	2	
17	p27	10	10	mm
18	p28	10	10	mm
19	p29	0	0	°
20	p34	0	0	mm
21	p35	61.468	61.468	mm
22	p36	0	0	mm
23	p37	12.192	12.192	mm
24	p38	0	0	mm
25	p39	0.508	0.508	mm
26	p40	5.84200056884	5.842000569	mm
27	p41	5.33400056884	5.334000569	mm
28	p52	1.0 (Measurement)	107743.9029	mm <sup>3</sup>
29	p53	1.0 (Measurement)	52005.33964	mm <sup>3</sup>
30	p54	1.0 (Measurement)	0.4638876296	kg
31	p55	1.0 (Measurement)	4.549183522	N
32	p56	1.0 (Measurement)	29.96715963	mm

NX expression table



Process Automation

Parameters

Tagging

Study

Run

File: heat\_sink\_final.pr

Variable:

Response: mass

Tag

Multi-Tag...

Update

Remove Tag

Print format: Default

Manage Print

Portal

Script

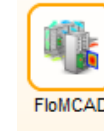
Tagging

File: D:/evaluation\_and\_projects/Flotherm\_portal/Flotherm/test/heat\_sink\_final.prt

Output Type	Name	Value
Expression	p34	0
	p35	61.468
	right_fin_num	28.0000
	fin_pitch	2.22222
	p41	5.33400056884
	p53	body_measurement45.volu...
	p54	body_measurement47.mass
	volume	volume
	area_of_model	area_of_model
	right_fin_pitch	2.22222
	left_fin_num	28.0000
	p25	55.5498
	p26	2
	p27	10
	p28	10
	p29	0
	left_fin_width	24.0142
	mass	mass
	p52	body_measurement43.surfa...
	right_fin_thickness	0.614656
	left_fin_width	34.4117
	p55	body_measurement49.weight

Parameter	Mode	Data
area_of_model	Portal	Expression.area_of_model
volume	Portal	Expression.volume
mass	Portal	Expression.mass

# FloMCAD - General Portal



**SIEMENS**  
*Ingenuity for life*

- FloMCAD uses the general portal to run the FloSCRIPT which converts the updated the \*.stp file from NX to FloTHERM CAD, replaces the Heatsink at the target assembly with the updated CAD, and reinitializes the model

The screenshot displays the FloMCAD General Portal interface with several key components and annotations:

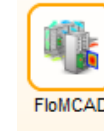
- Execution Command:** The command is set to `"C:\Program Files (x86)\MentorMA\flosuite_v122\flotherm\WinXP\bin\flotherm.bat"`. An annotation "Executing FloScript in Batch" points to this field.
- Command Options:** The options are set to `-b -f %INPUTFILE%`.
- Analysis Execution Options:**
  - Run in:** Analysis folder
  - Run condition:** Always Run
  - Finished condition:** file\_present (10 s)
  - Success condition:** error\_log
  - Advanced:** Modified...
- Manage Conditions:** A dialog box showing the properties of the `file_present` condition, where the file `ExampleforHEEDS.pack` is specified. An annotation "The pack file exported by running the FloSCRIPT is used as a completion check" points to this field.
- Properties of error\_log:** A dialog box showing the properties of the `error_log` condition, where the file `floerror.log` is specified. An annotation "The floerror.log file is used to confirm successful execution" points to this field.
- Advanced Options:** A dialog box showing various options for the analysis execution, including:
  - Max execution time:** 500 seconds
  - Job name prefix:**
  - Shared project path:**
  - Execution shell (Linux):** /bin/bash
  - Capture analysis output:** (checked)
  - Run portal on remote machine:** (unchecked)
  - Optional Analysis Commands:**
    - Before the analysis files are copied and modified:** PING localhost -n 5 >NUL
    - Before the analysis tool is run:** PING localhost -n 5 >NUL
- Input File Table:**

	Input File Name	Location	Connect from	Comment
1	Flomcad_load_model_new.xml	Project folder		FloSCRIPT to replace CAD
2	ExampleforHEEDS2.pdml	Project folder		Project PDML File
3	heat_sink_final.stp	Project folder	NX_CAD_3	Updated Step file
- Output File Table:**

	Output File Name	Location	Comment
1	ExampleforHEEDS2.pdml	Project folder	Updated Project file

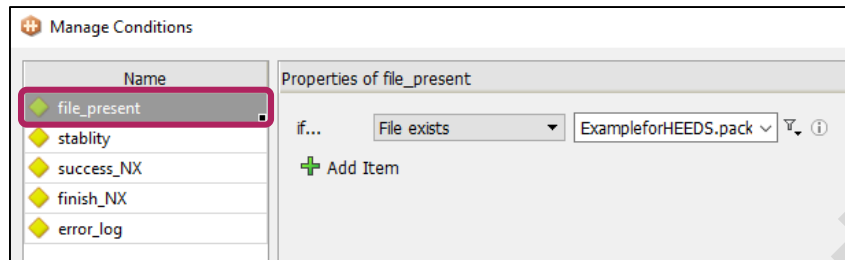
An annotation "A delay is enforced to make sure HEEDS accounts for the time taken for the files to be created by NX and the files are copied into the analysis folder (optional)" points to the "Optional Analysis Commands" section.

# FloMCAD - General Portal

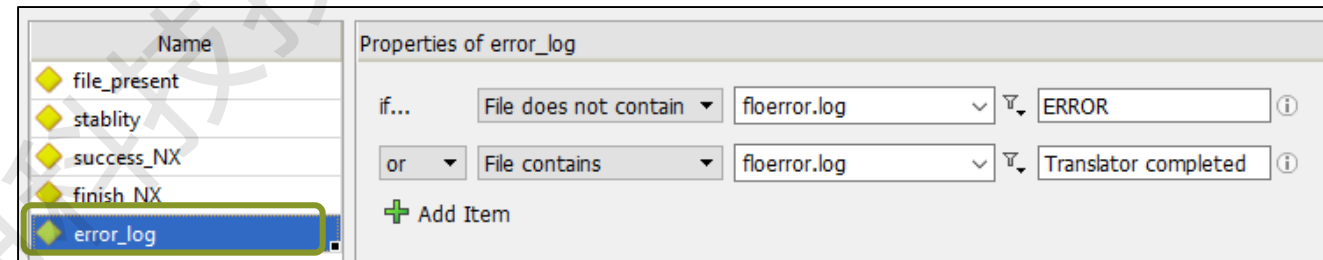


**SIEMENS**  
*Ingenuity for life*

- **Finished Conditions** can be used to detect analysis completion – here the presence of the file *ExampleforHEEDS.pack* is used to confirm when the FloMCAD analysis is complete
- **Success Conditions** can be used to validate successful execution – here the presence of the string “*Translator completed*” *or* the absence of the string “ERROR” in the *floerror.log* file is used to confirm successful execution

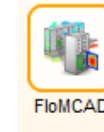


The presence of the pack file exported by running the FloSCRIPT is used as a completion check



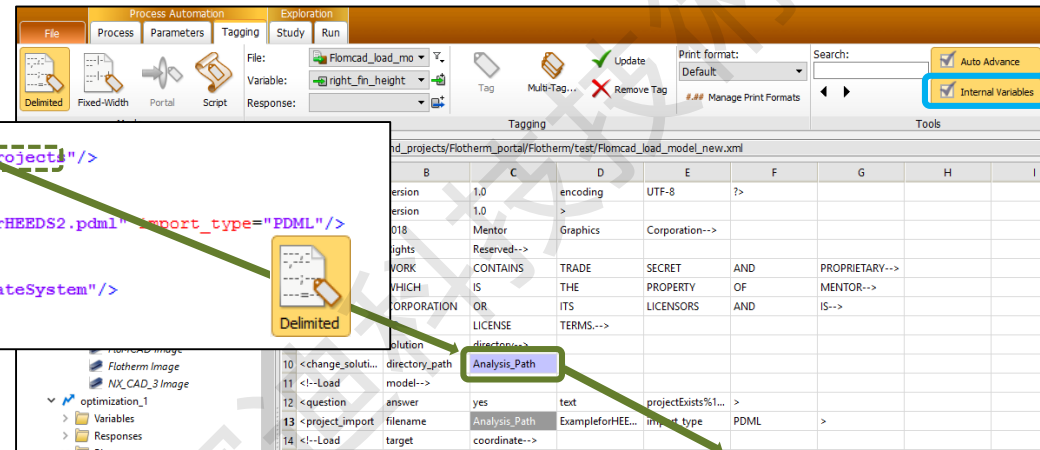
The strings present in the floerror.log are monitored to determine whether execution is a success or failure

# FloMCAD - Input Tagging



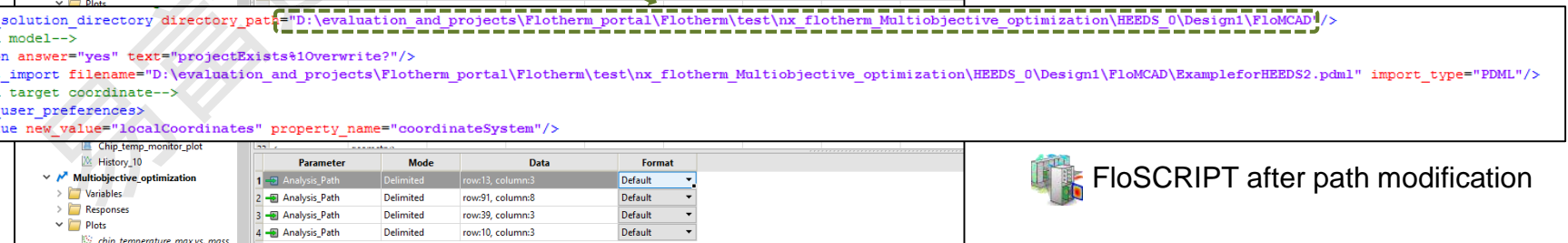
**SIEMENS**  
Ingenuity for life

- Delimited tagging is used to tag the analysis directory path to all the directory paths defined in the FloSCRIPT



The Internal variables have to be exposed to tag the analysis path

*\* Note: With FloTHERM v12.2, relative paths can be used instead of tagging the analysis directory path on the CAD file import, but the solution directory path must be a fixed path.*



FloSCRIPT after path modification



Portal Input tagging in  
HEEDS



# FloTHERM general portal



**SIEMENS**  
Ingenuity for life

- FloTHERM uses the general portal to execute FloTHERM in batch mode and generates the result table(s) in \*.csv format from which the outputs will be extracted

**Executing FloTHERM in Batch**

The floerror.log contains specific strings when the solution converges; used to confirm successful execution.

Analysis Execution Options

- Run in: Analysis folder
- Run condition: Always Run
- Finished condition: None
- Success condition: stability
- Advanced: Modified...

Advanced Options

- Max execution time: 3600 seconds
- Job name prefix:
- Shared project path:
- Execution shell (Linux): /bin/bash
- ☒ Capture analysis output
- ☐ Run portal on remote machine
- Optional Analysis Commands
  - Before the analysis files are copied and modified:
    - PING localhost -n 5 >NUL
    - ☐ Check return value: 0
  - Before the analysis tool is run:
    - PING localhost -n 5 >NUL
    - ☐ Check return value: 0

A delay is enforced to make sure HEEDS accounts for the time taken for the files to be created by FloSCRIPT (optional)

Properties of stability

- if... File contains floerror.log Monitor points are stable
- or File contains floerror.log Fully solution converged

Input File Name

Input File Name	Location	Connect from	Comment
1 ExampleforHEEDS2.p...	Project folder	FloMCAD	Updated Project File

Output File Name

Output File Name	Location	Comment
1 mon_Temperature.csv	D:/evaluation_and_proje...	*csv file containing Temperature at the Monitor Point
2 regvol_Temperature.csv	D:/evaluation_and_proje...	*csv file containing volume temperature data

\* Note: Appending -o to the execution command will output the results data as tables in CSV file format to the specified directory. In this case, the directory will be the FloTHERM analysis directory (<Project directory>\Study\_1\HEEDS\_0\Design%Design\_Num%\Flotherm)





# Output Tagging



**SIEMENS**  
Ingenuity for life

- The Monitor point Temperature data is extracted from the CSV results table using the Script Tagging technique

Monitor Point temperature data

Iteration	MP-U2 [Component] (degC)
1	218
2	217
3	216
4	215
5	214
6	213
7	212
8	211
9	210
10	209
11	208
12	207
13	206
14	205
15	204
16	203
17	202
18	201
19	200
20	199
21	198
22	197
23	196
24	195
25	194
26	193
27	192
28	191
29	190
30	189
31	188
32	187
33	186
34	185
35	184
36	183
37	182

Script output tagging in HEEDS to extract the temperature vector

2D function plot of the temperature vector in HEEDS post

Iteration	Number	MP-U2 [Component] (degC)
1	419	chip_temperature_max
2	418	46.4057

Delimited output tagging in HEEDS to extract the final temperature

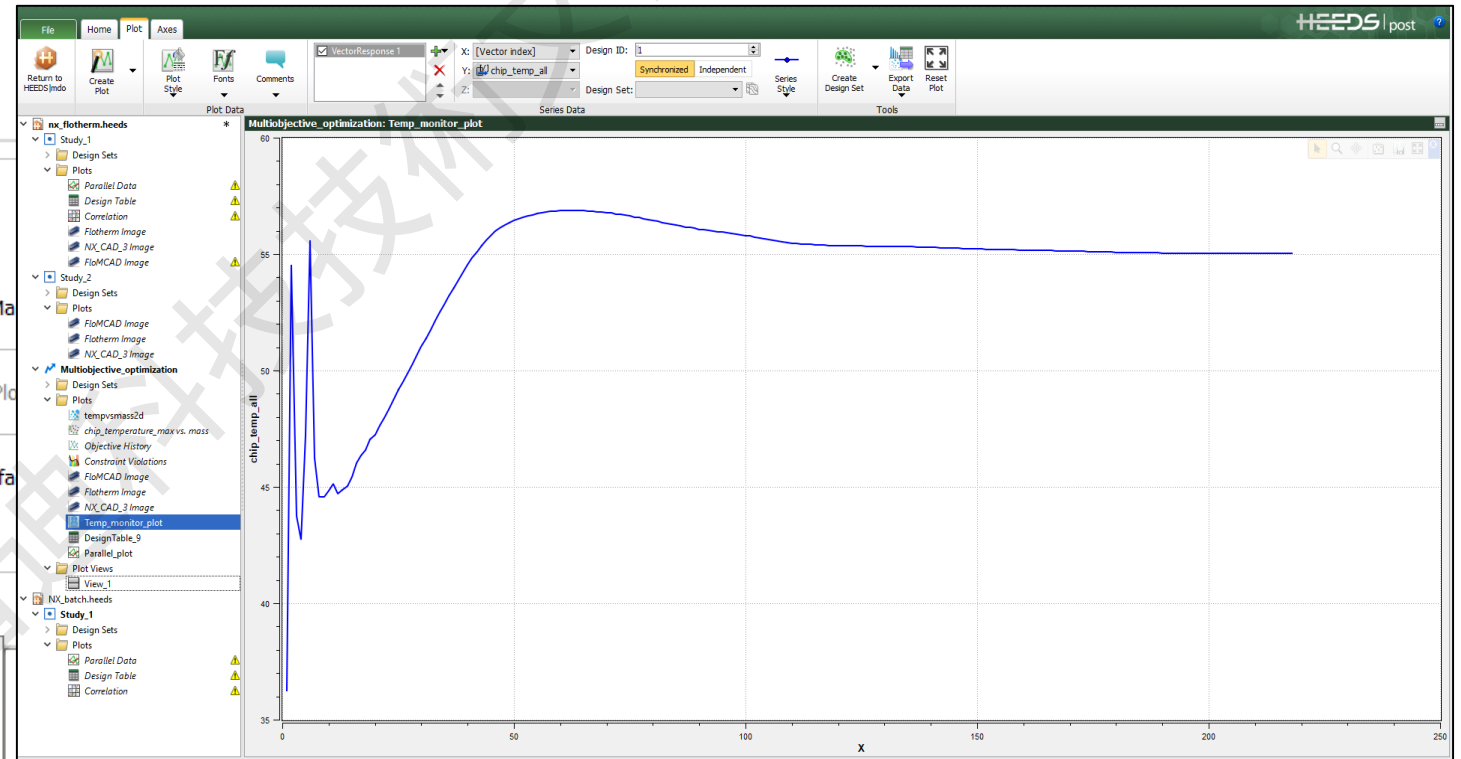
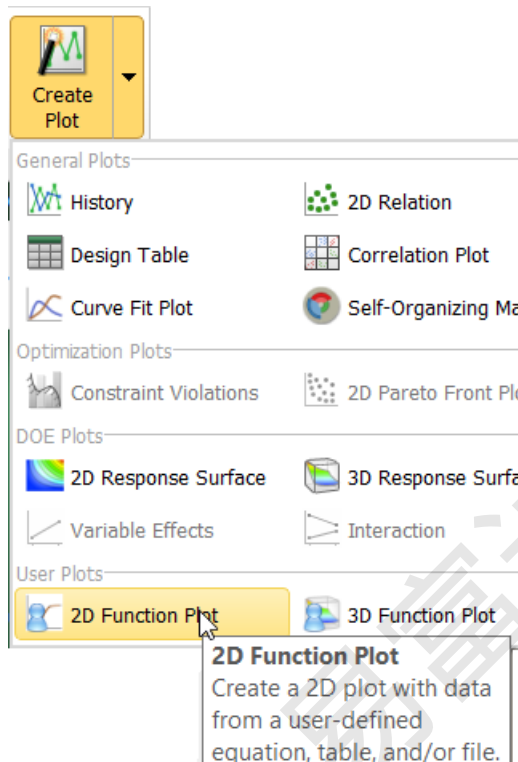
\* Note: The next slide details the steps on how the 2D function plot was setup in HEEDS POST

# Results



- The 2D function plot is used to plot in HEEDS POST the to monitor point Temperature Vector extracted from the csv file

	A	B	C	D
1	Iteration	MP-U2 [Component] (degC)		
2	218	55.0425		
3	217	55.0425		
4	216	55.0394		
5	215	55.0394		
6	214	55.0369		
7	213	55.0344		
8	212	55.0344		
9	211	55.0327		
10	210	55.0312		
11	209	55.0299		
12	208	55.0288		
13	207	55.0279		
14	206	55.0273		
15	205	55.0269		
16	204	55.0267		
17	203	55.0267		
18	202	55.027		
19	201	55.0275		
20	200	55.0283		
21	199	55.0293		
22	198	55.0306		
23	197	55.0322		
24	196	55.034		
25	195	55.036		
26	194	55.0382		
27	193	55.0404		
28	192	55.0429		
29	191	55.0454		
30	190	55.0482		
31	189	55.0509		
32	188	55.0539		
33	187	55.0567		
34	186	55.0599		
35	185	55.0631		
36	184	55.0665		
37	183	55.0699		
38	182	55.0737		



2D function plot



Monitor Point  
temperature data

# Results



- The Pareto plot reveals the tradeoff relationship between peak chip temperature and the mass of the heatsink. Combined in a plot view with other plots, the user can visualize trends for the low mass solutions (highlighted in green) comprehensively before making a design decision among the many high performing design alternatives available

