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HEEDS®

Discover Better Designs, *Faster*

Improving Cooling Efficiency of a Heatsink

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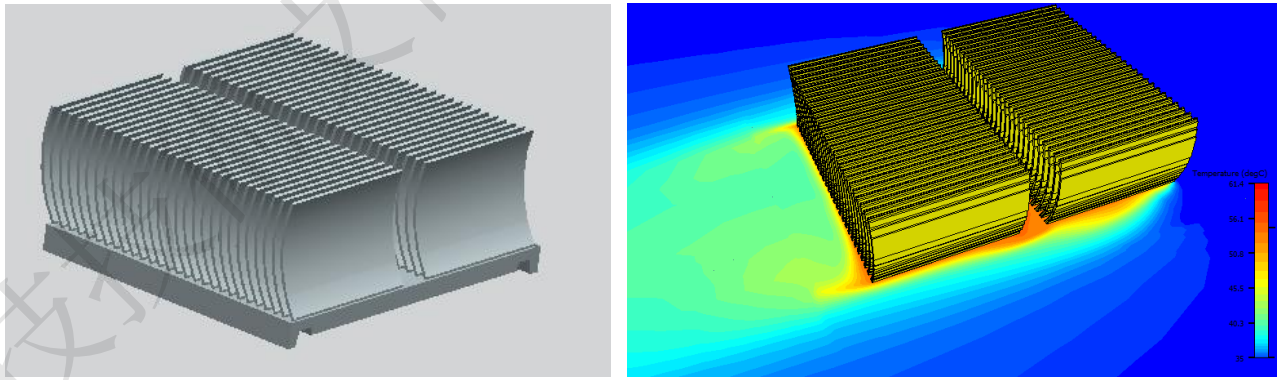
Tools

- FloTHERM v12.2
- NX v13.0

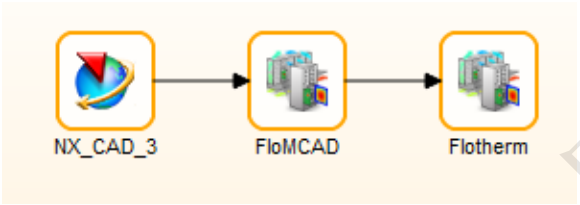
Challenge

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

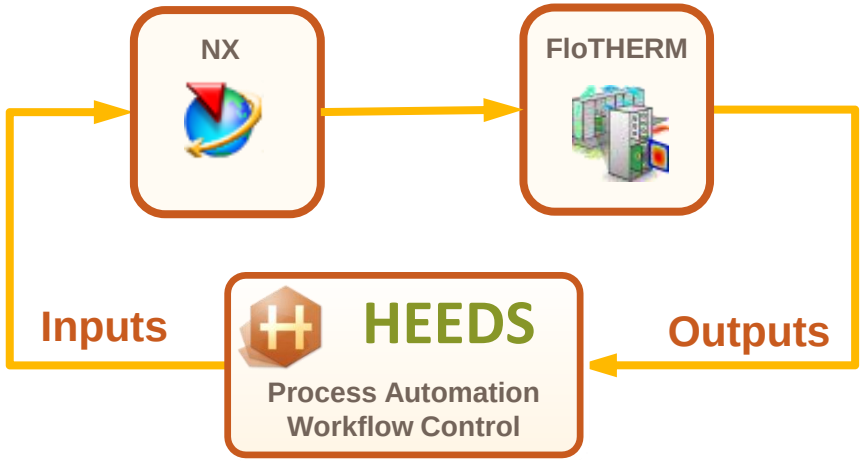


Heatsink model

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

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Problem Description

Objective: Pareto Trade-off:

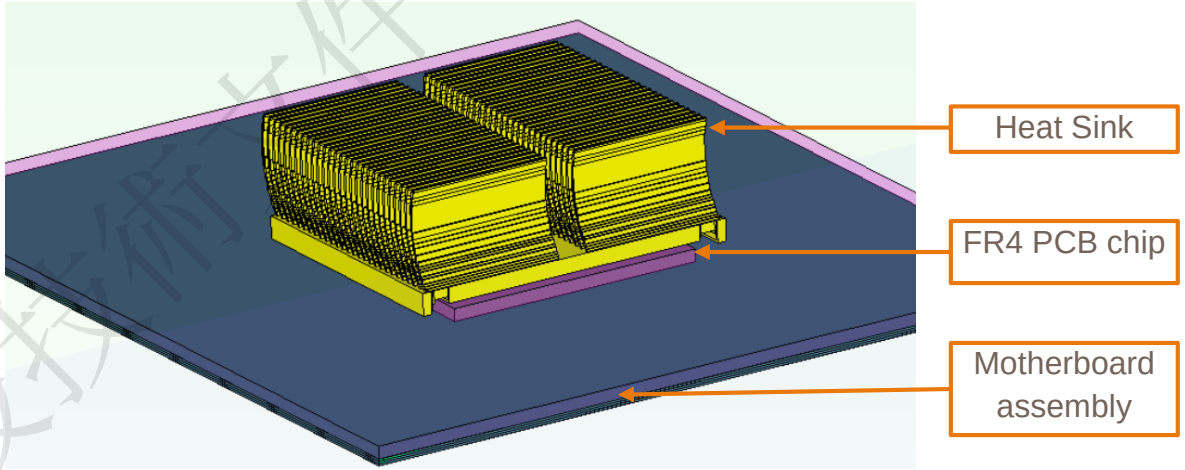
- *Minimize* chip_temperature_max
- *Minimize* Mass

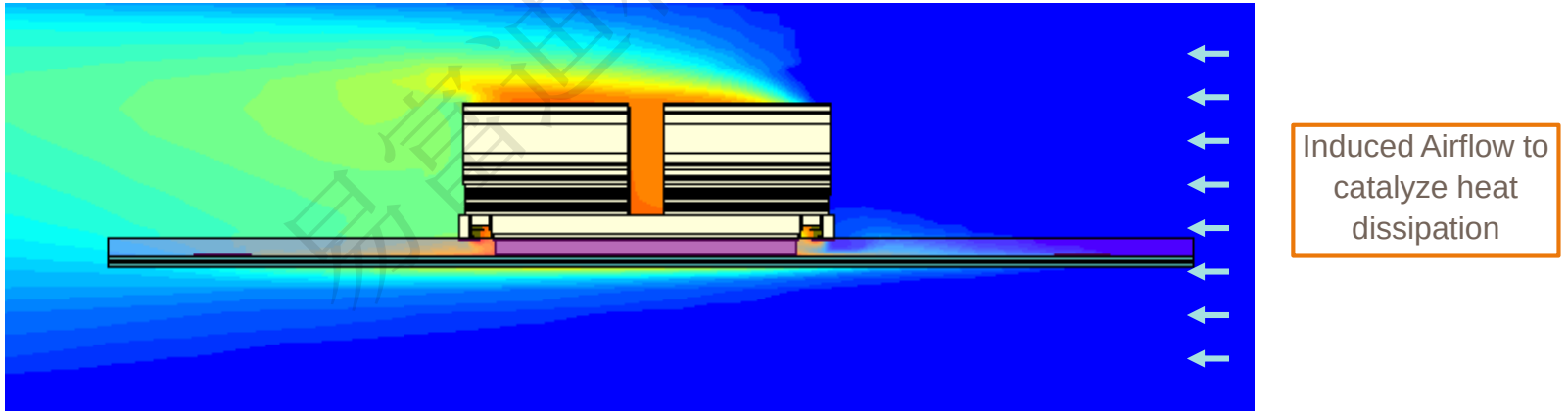
Constraints:

- chip_temperature_max ≤ 60°C

Variables:

- 10 geometric variables which control the Heatsink design





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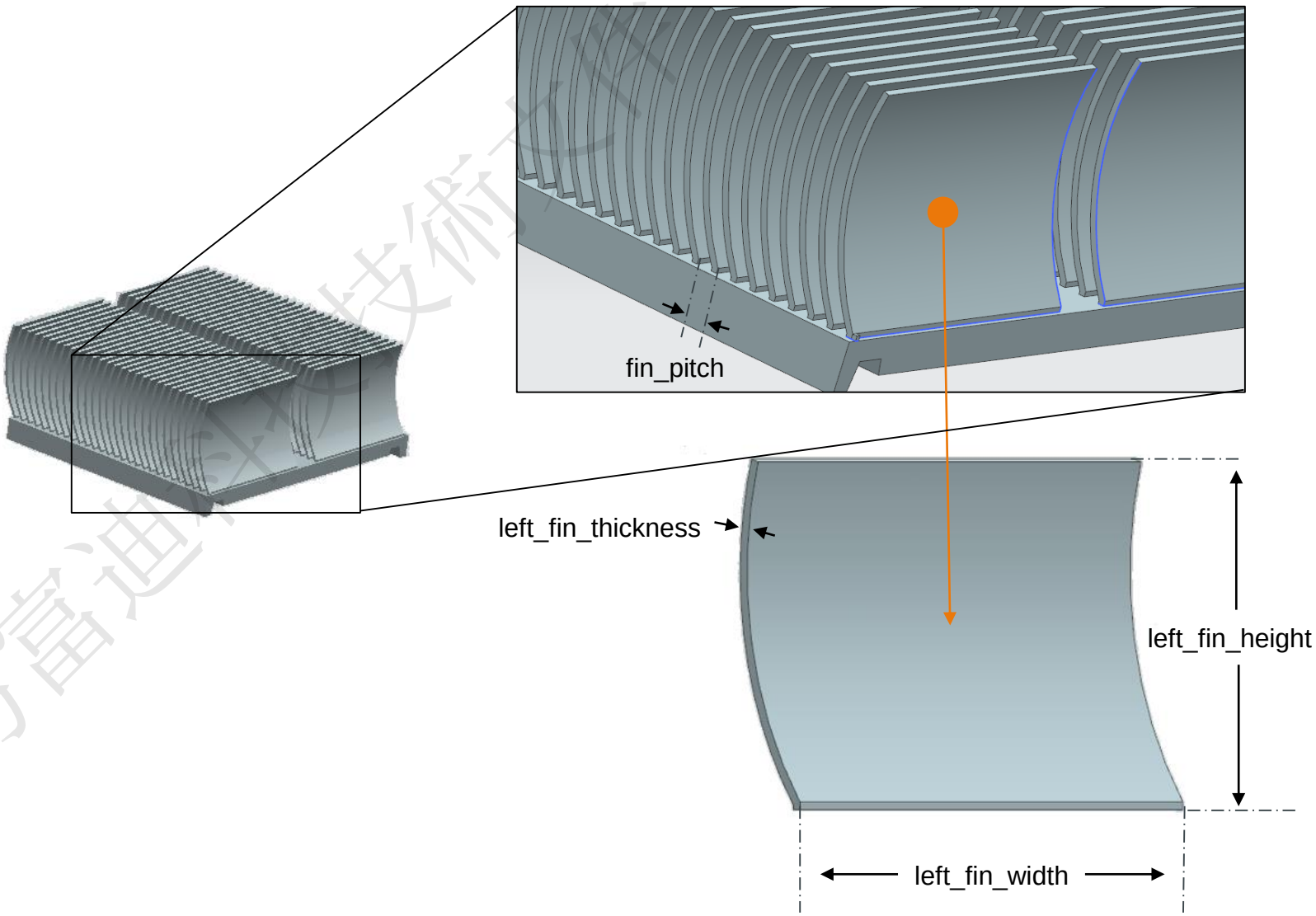
Variable Description

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

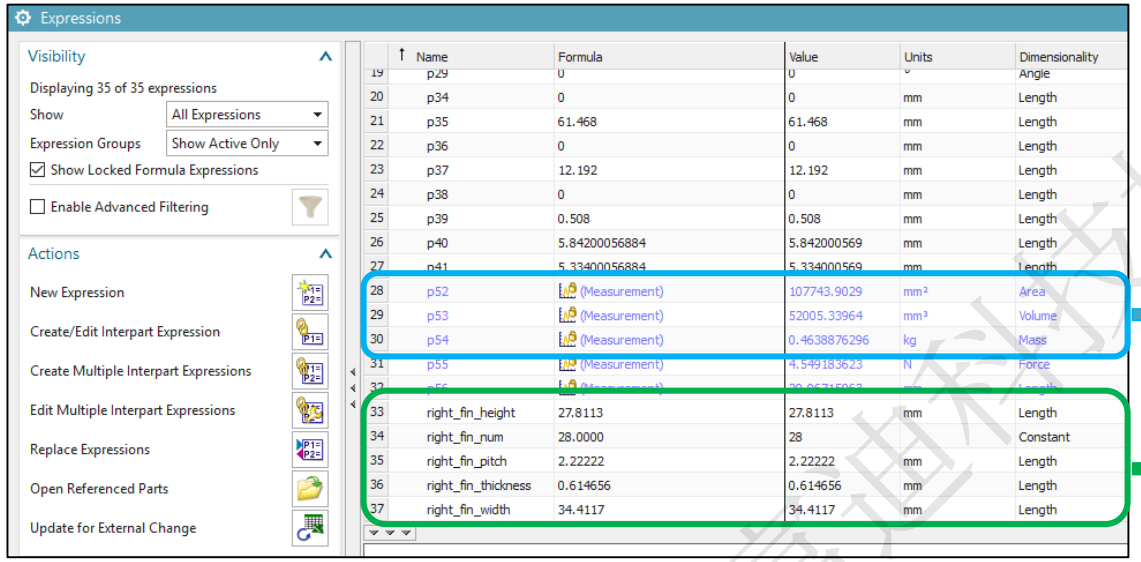
Dependent Variables

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	$= \frac{60}{left\_fin\_num - 1}$
left_fin_pitch	= right_fin_pitch

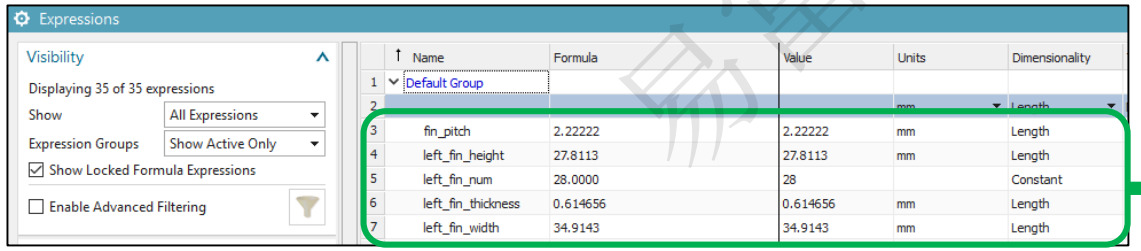


Model Preparation

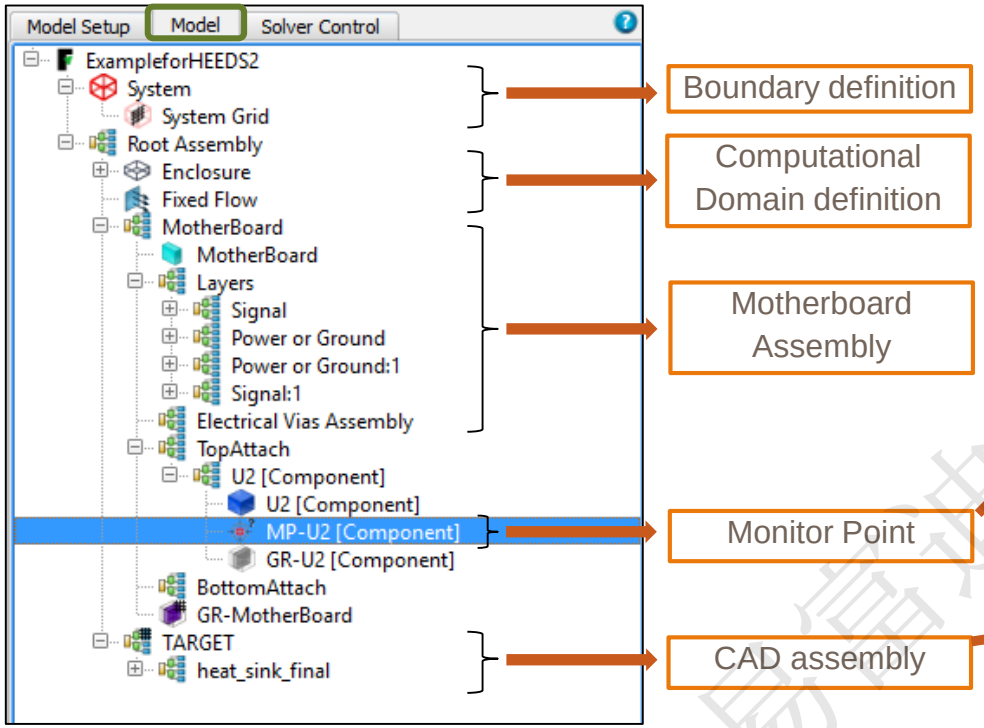
- The user needs to expose the relevant Parameters as NX Expressions for usage as variables/responses by HEEDS

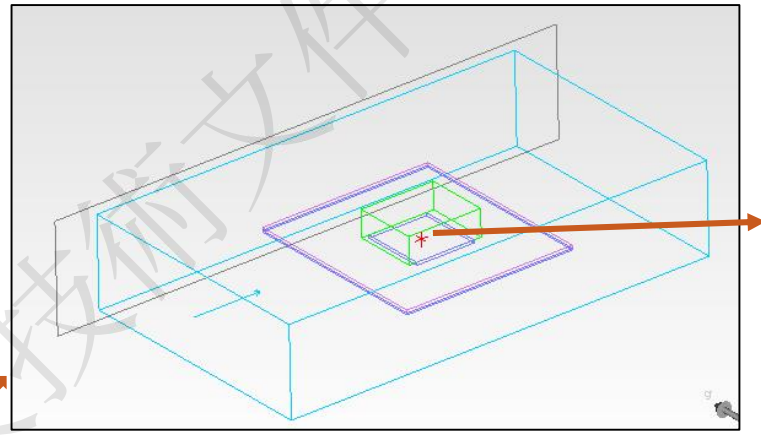


Note: Measure bodies are used to extract the Mass, Volume and Area of the Heatsink from within NX

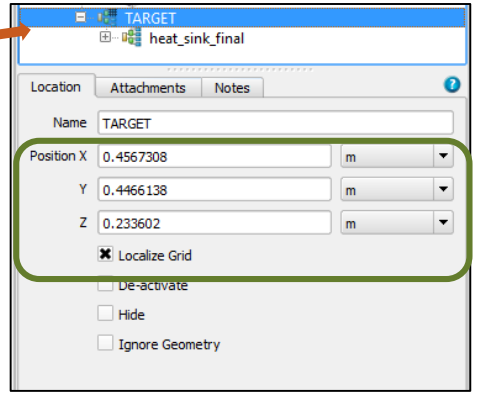


Model Preparation: Model Settings





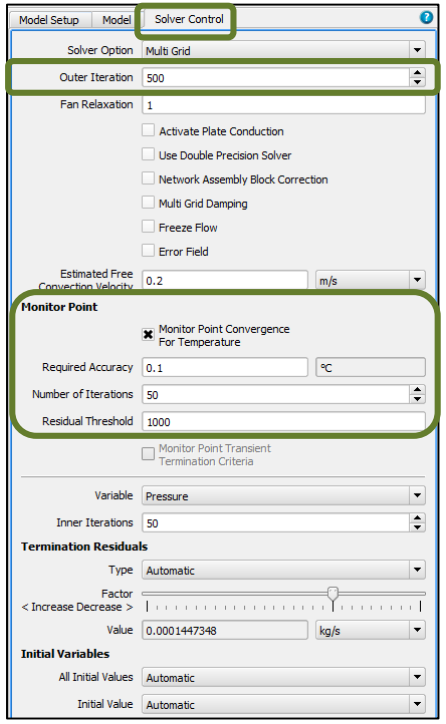
The user has to create a Monitor point at the junction between the chip and the Heat sink to monitor the final temperature at which the temperature stabilizes



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.

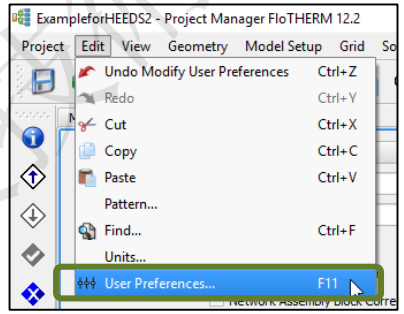
The simulation model should be fully defined such that when FloTHERM is executed in batch mode with the *.pdml input file, the simulation will create *csv file(s) with the results

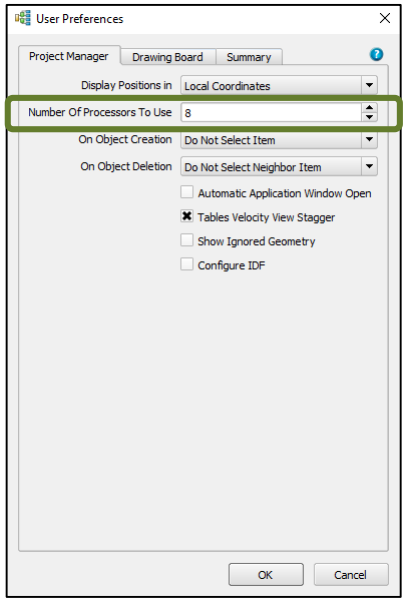
Model Preparation: Solver Settings



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





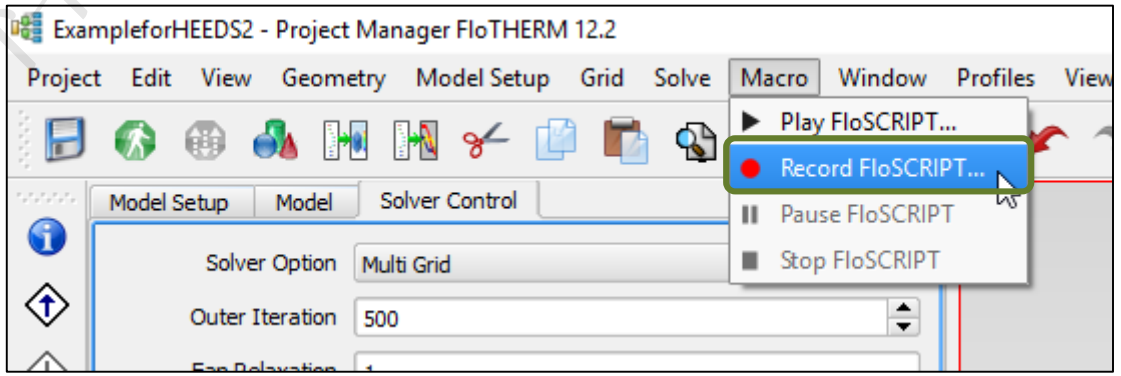
The number of processors to be used for each design evaluation can be set in user preferences

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 (*.pdml)
- 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

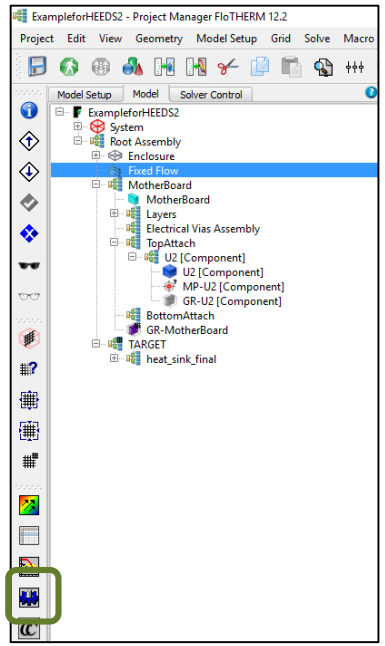
Note: the FloSCRIPT records the steps carried out on the “Launch FloMCAD bridge** ” section, with the steps shown on the next slide*



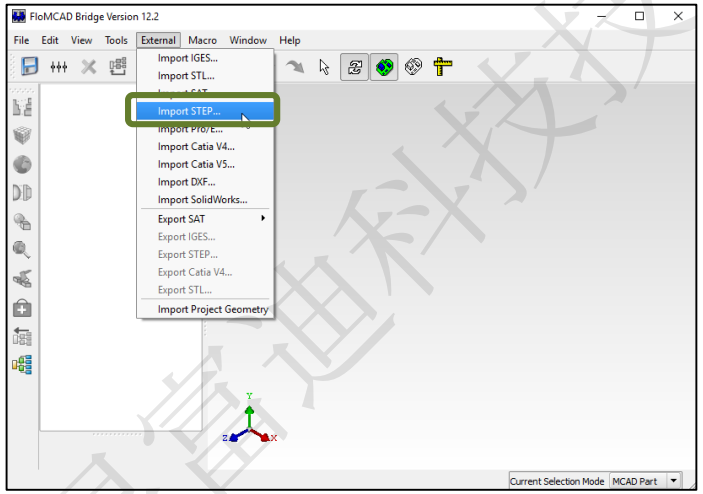
Recording a FloSCRIPT in FloTHERM

Launch FloMCAD Bridge

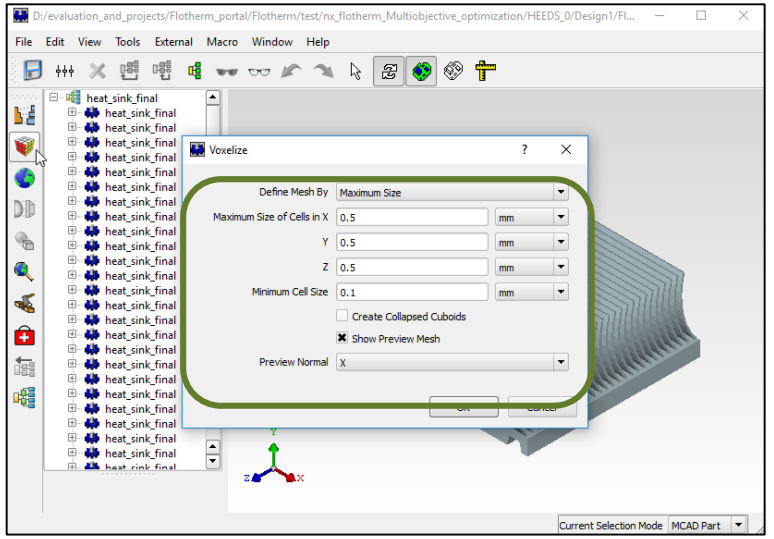
- The “FloMCAD Bridge” interfaces FloTHERM with MCAD software packages. A neutral CAD file (*.stp file in this example) is imported and converted to FloTHERM supported CAD format (*.sat - simplifying where necessary), before transferring them to a FloTHERM project



Select FloMCAD module



Import the Heatsink *.stp file

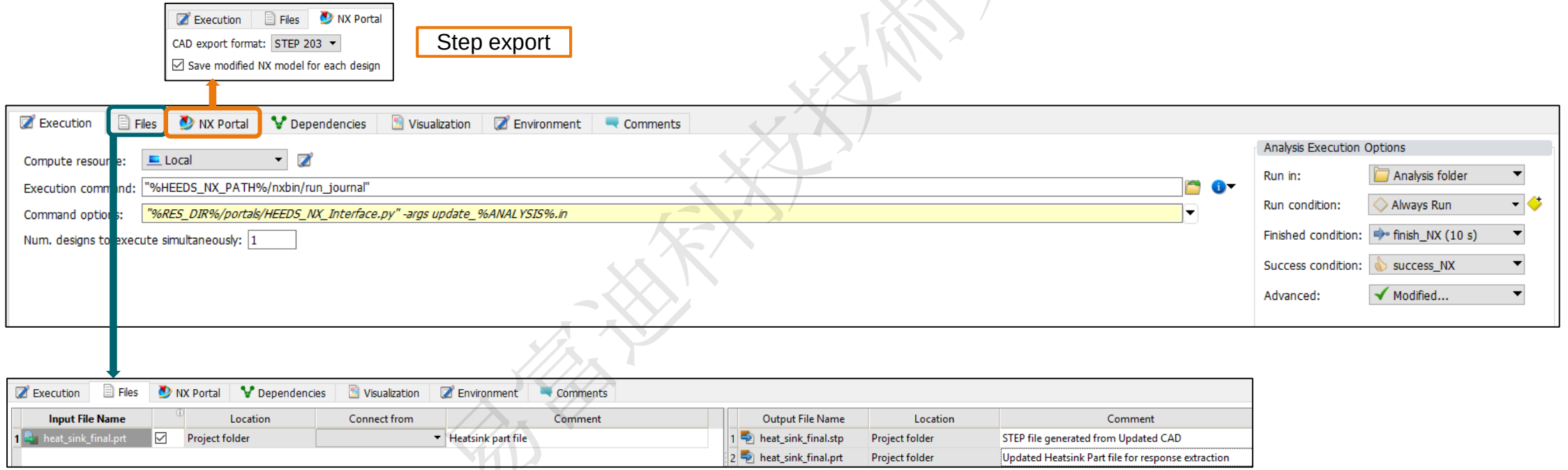


Set the voxel size

Note: The voxelization method uses a grid (mesh) to convert CAD geometry to FloTHERM geometry in the form of grid-sized cuboids, known as voxels

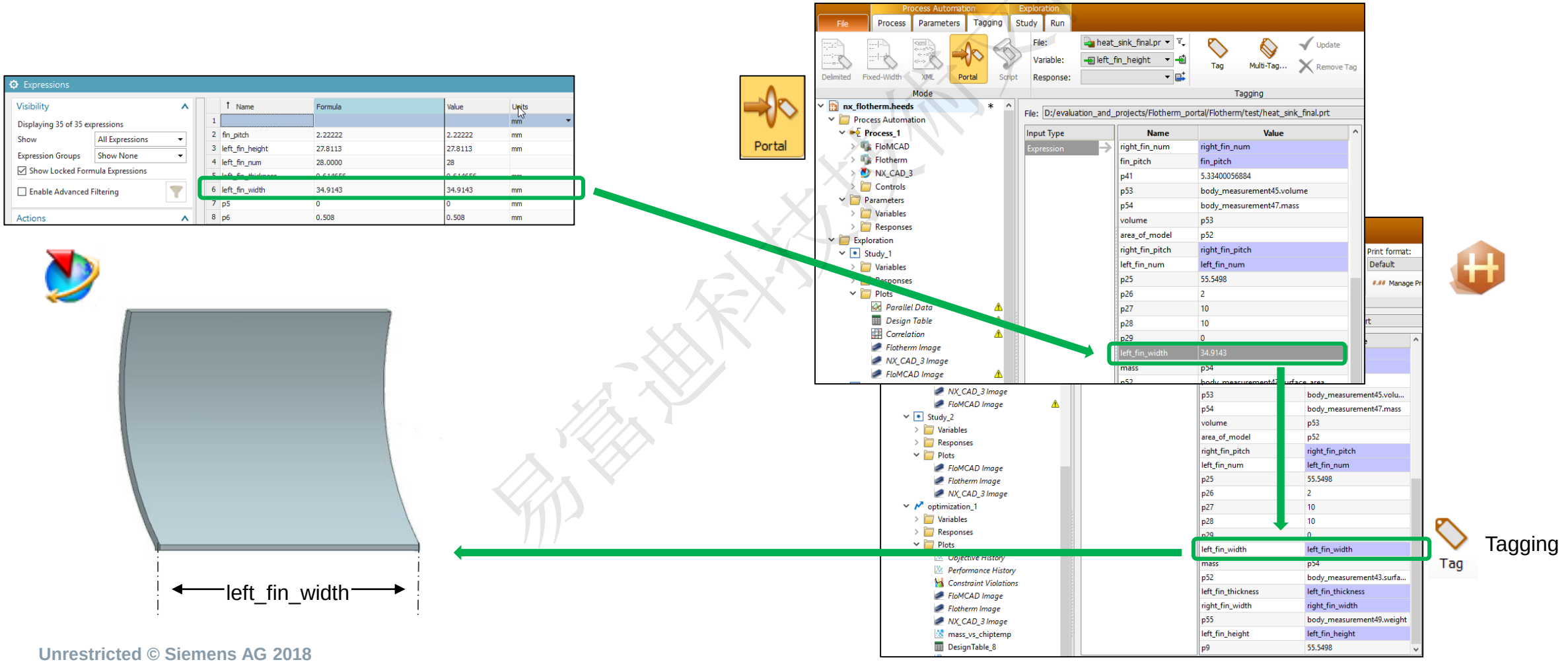
NX Portal

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



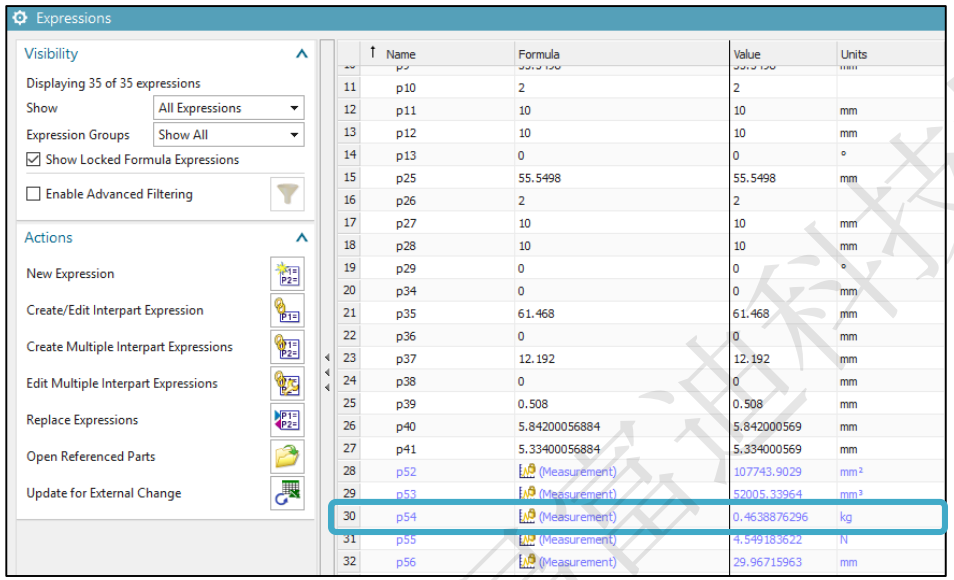
NX Portal – input tagging

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

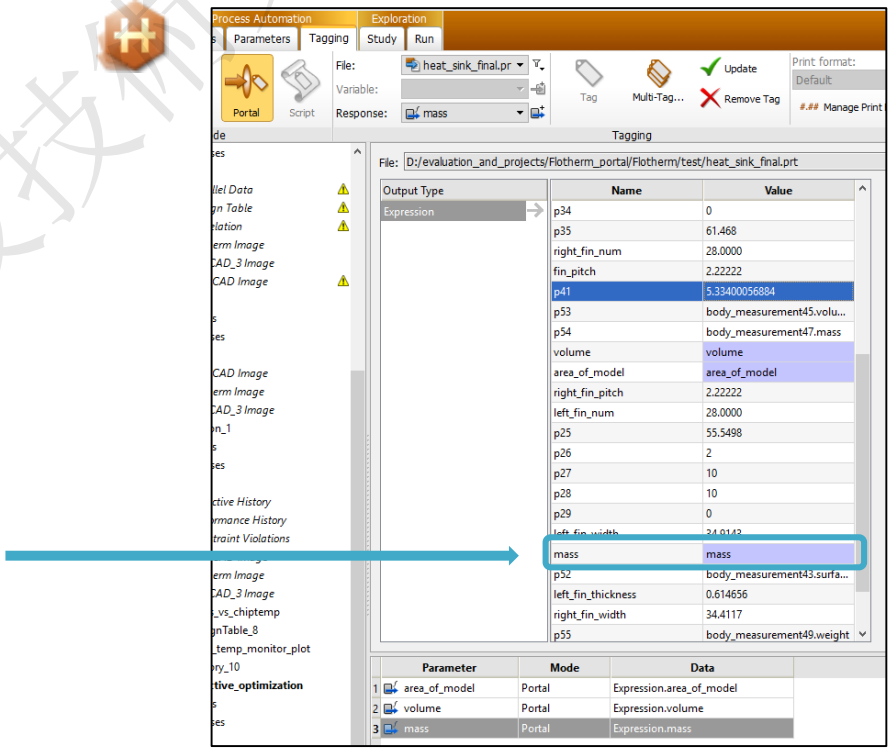


NX Portal - Output Tagging

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



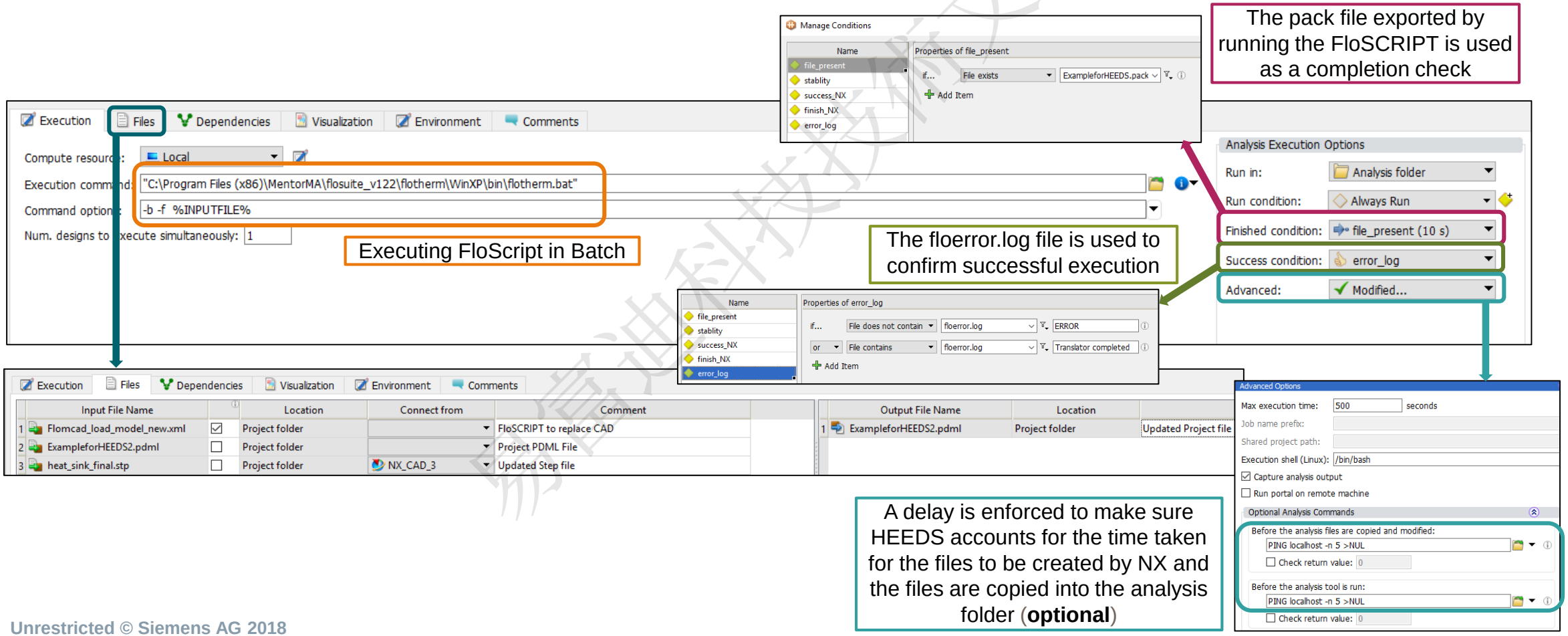
NX expression table



Tag

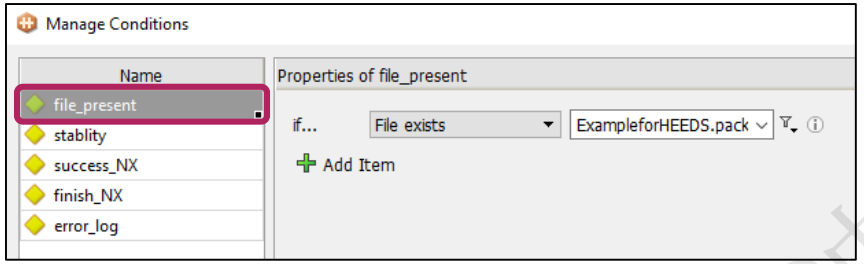
FloMCAD - General Portal

- 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

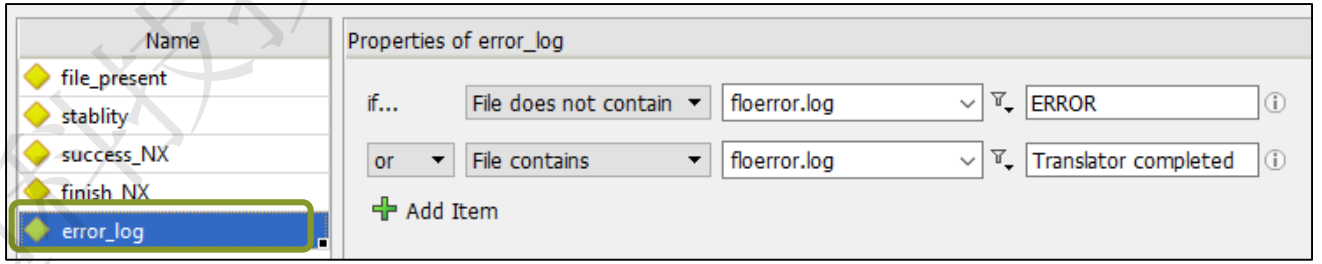


FloMCAD - General Portal

- 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



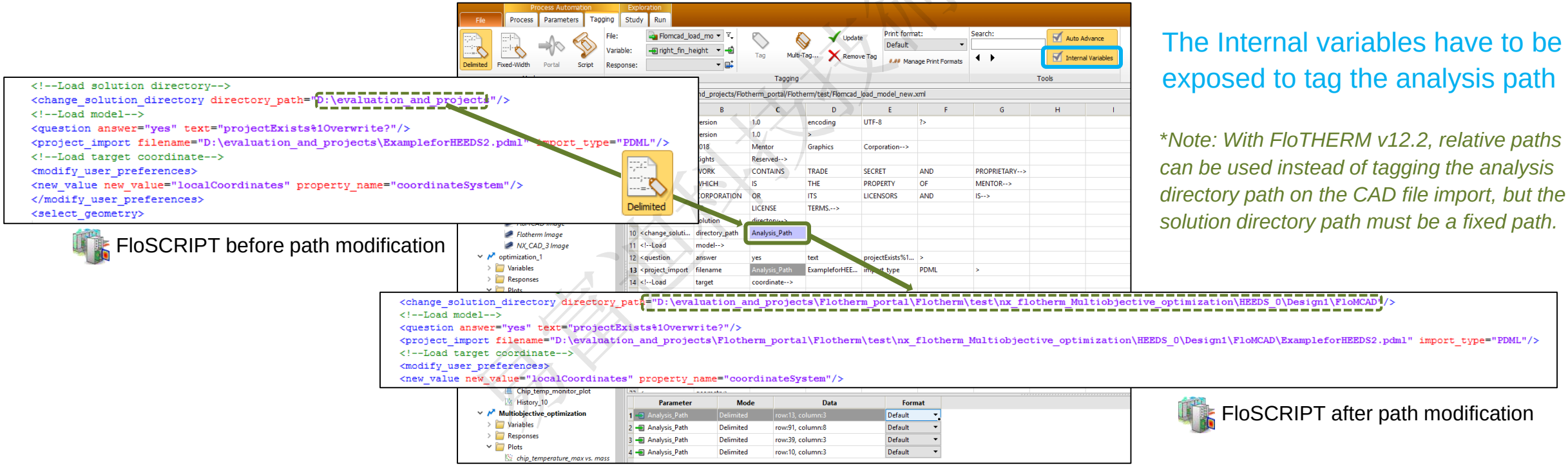
The presence of the pack file exported by running the FloSCRIPT is used as a completion check



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

FloMCAD - Input Tagging

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



FloSCRIPT before path modification

FloSCRIPT after path modification

Portal Input tagging in HEEDS

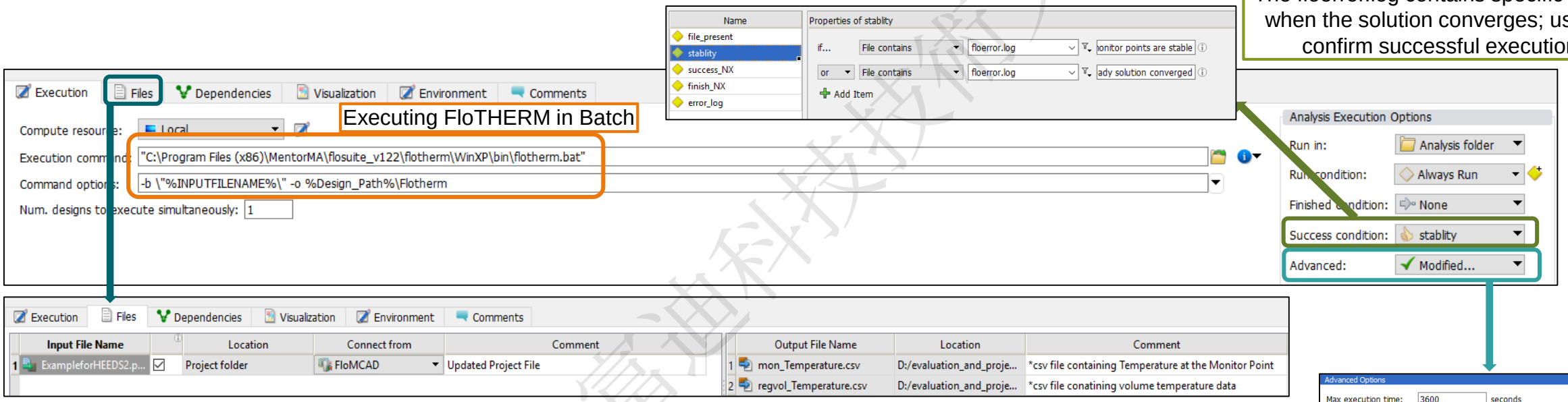
The Internal variables have to be exposed to tag the analysis path

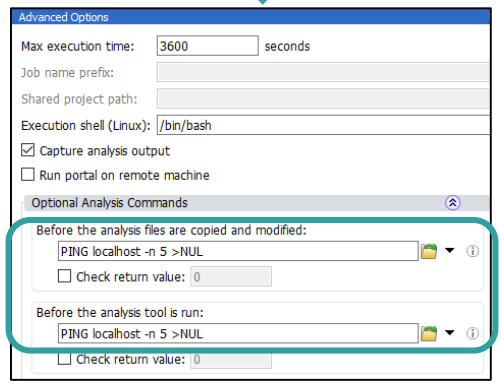
**Note: With FloTHERM v12.2, relative paths can be used instead of tagging the analysis directory path on the CAD file import, but the solution directory path must be a fixed path.*

FloTHERM general portal

- 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

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



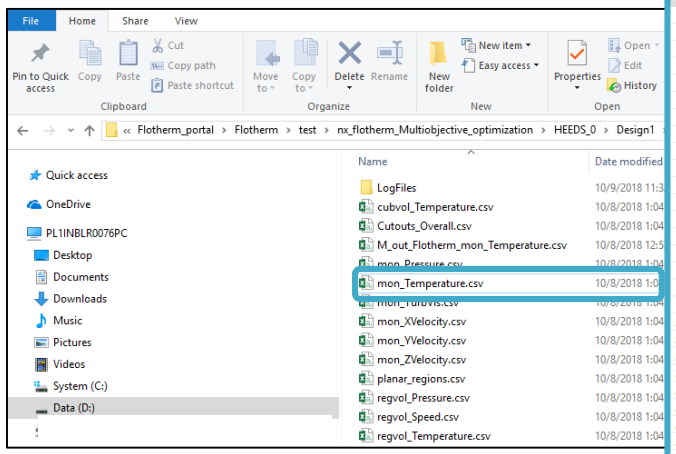


**Note: Appending –o to the execution command will output the results data as tables in CSV file format to the specified directory. In this case, the directory will be the FloTHERM analysis directory (<Project directory>\Study_1\HEEDS_0\Design%Design_Num%\Flotherm)*

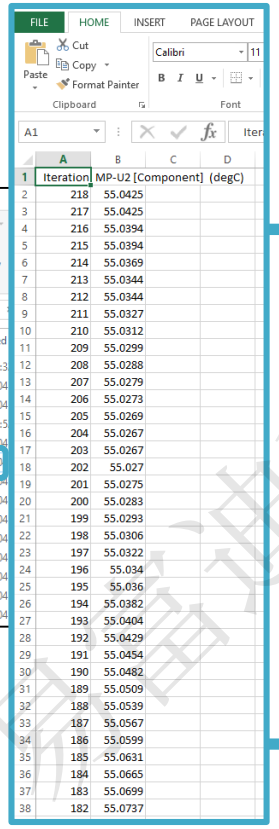
A delay is enforced to make sure HEEDS accounts for the time taken for the files to be created by FloSCRIPT (**optional**)

Output Tagging

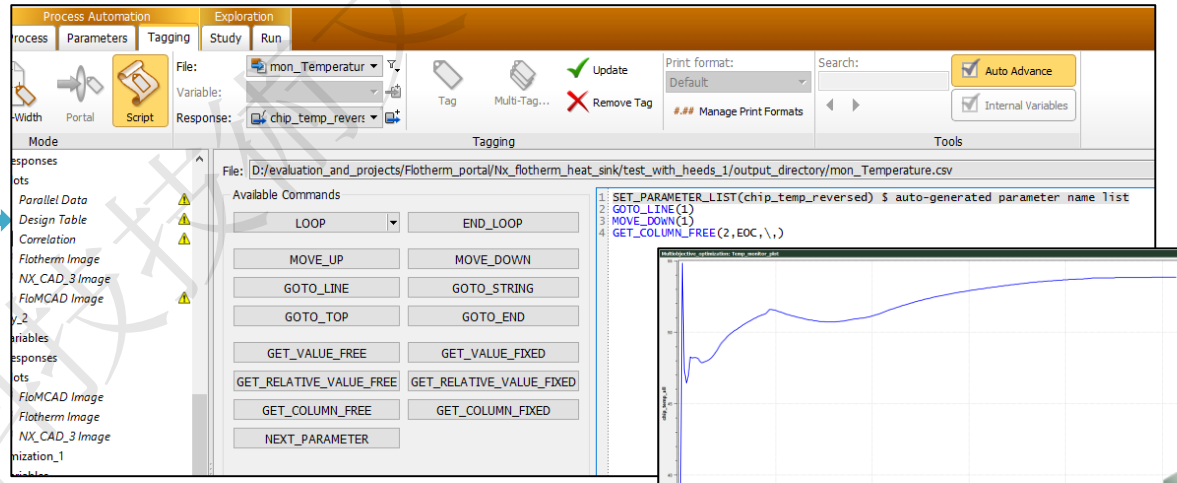
- The Monitor point Temperature data is extracted from the CSV results table using the Script Tagging technique



Monitor Point temperature data



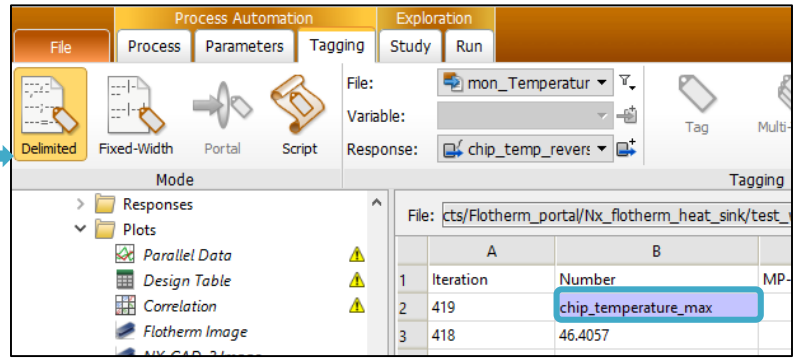
Script



Script output tagging in HEEDS to extract the temperature vector

2D function plot of the temperature vector in HEEDS post

Delimited

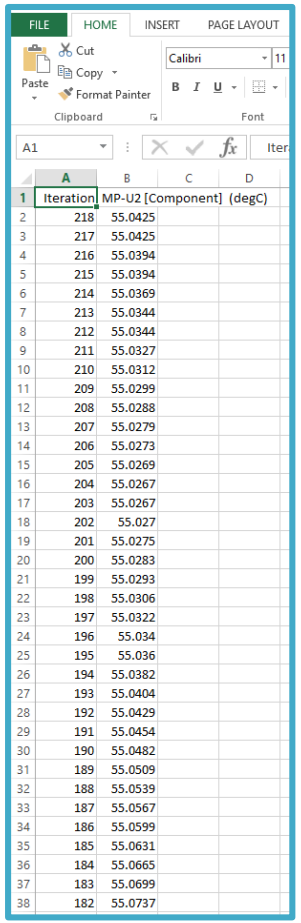


Delimited output tagging in HEEDS to extract the final temperature

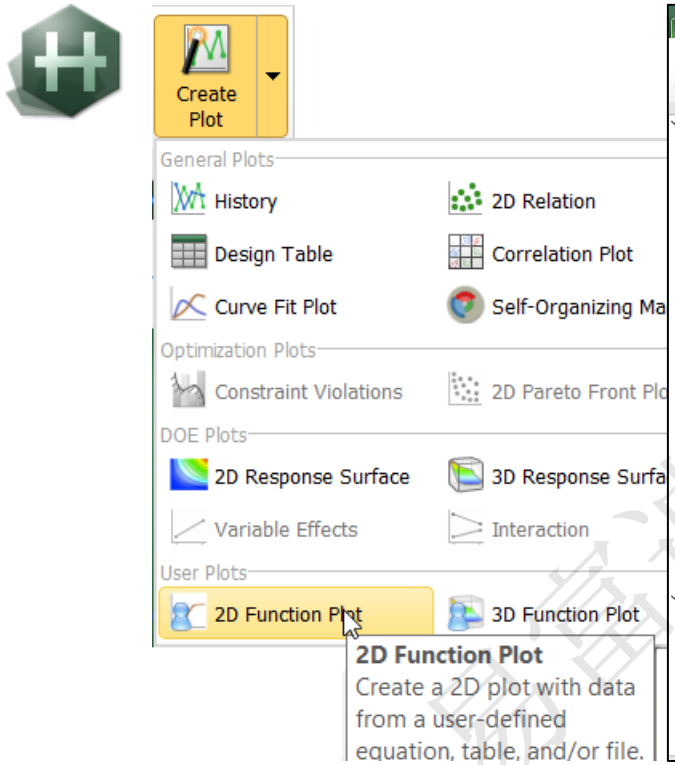
Note: The next slide details the steps on how the 2D function plot was setup in HEEDS POST

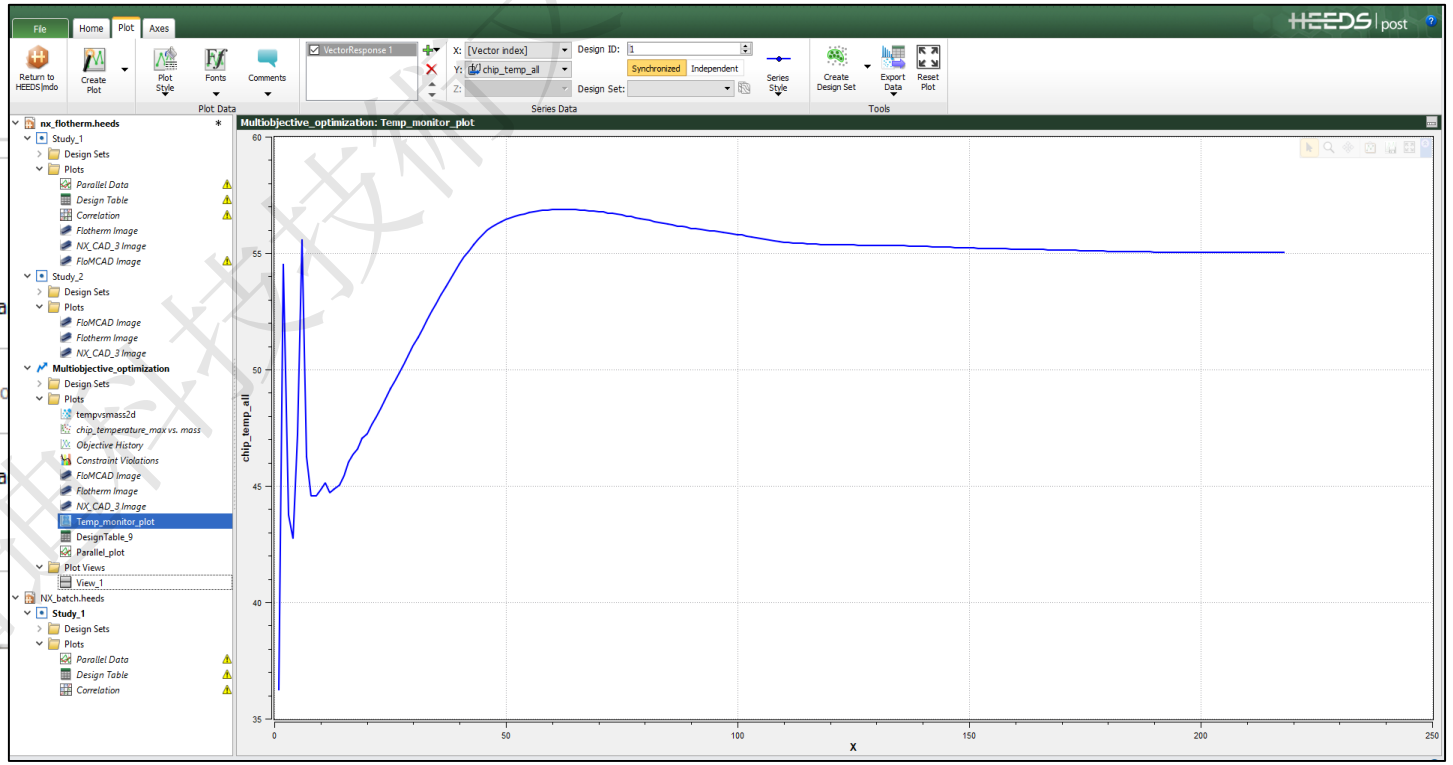
Results

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



Iteration	MP-U2 [Component] (degC)
218	55.0425
217	55.0425
216	55.0394
215	55.0394
214	55.0369
213	55.0344
212	55.0344
211	55.0327
210	55.0312
209	55.0299
208	55.0288
207	55.0279
206	55.0273
205	55.0269
204	55.0267
203	55.0267
202	55.027
201	55.0275
200	55.0283
199	55.0293
198	55.0306
197	55.0322
196	55.034
195	55.036
194	55.0382
193	55.0404
192	55.0429
191	55.0454
190	55.0482
189	55.0509
188	55.0539
187	55.0567
186	55.0599
185	55.0631
184	55.0665
183	55.0699
182	55.0737





2D function plot

Monitor Point temperature data

Results

Open HEEDS|post

- 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