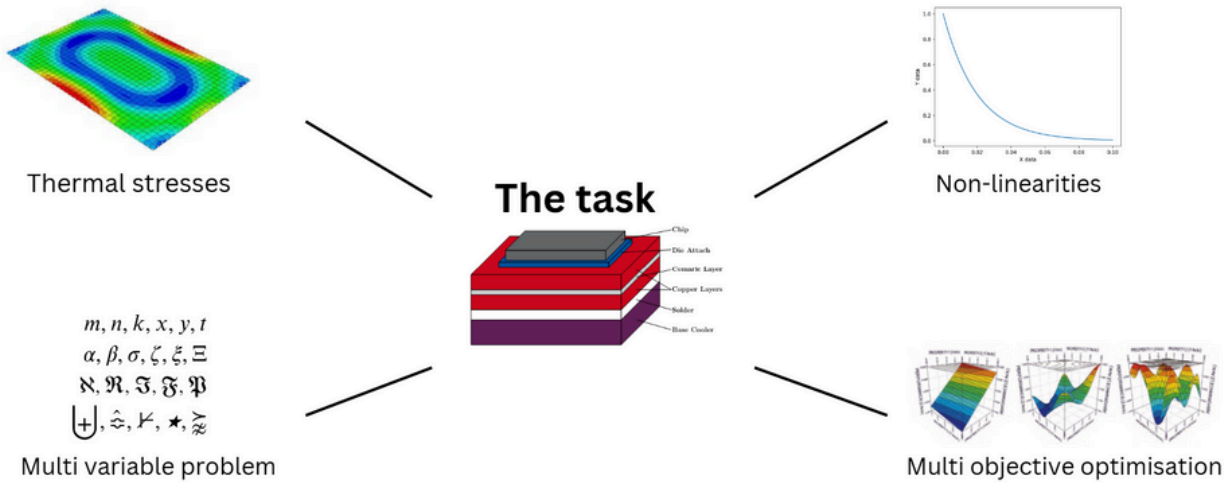
PROJECT OVERVIEW

AUTOMATED FEM AND ML DRIVEN OPTIMIZATION FOR POWER MODULE DESIGN

PROJECT OBJECTIVE:

Optimize a high-heat power module to improve thermal dissipation, ensure structural integrity, and reduce production costs, maintaining component temperatures below 125°C.

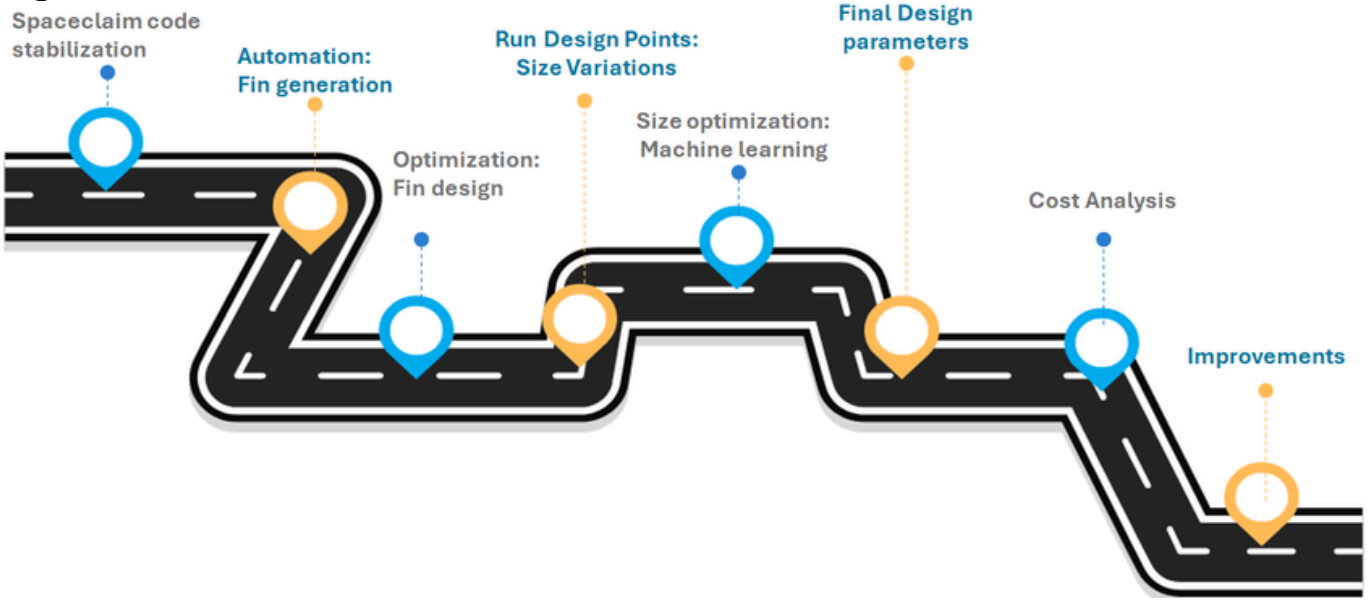


TRADITIONAL FEM APPROACH:

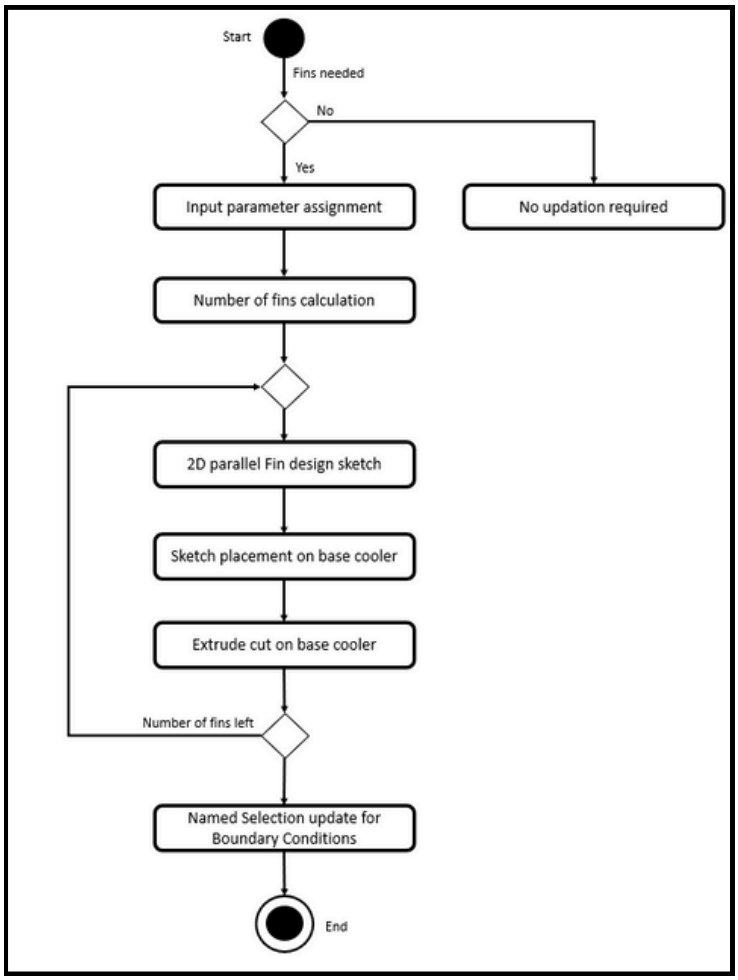
A manual FEM analysis was initially conducted to assess thermal and structural performance, but manual iterations proved insufficient for achieving optimal design within the timeframe.

CHALLENGE AND NEED FOR FEM AUTOMATION:

To efficiently explore multiple design points, automation was essential. Using PyAnsys and APDL scripting, we built an automated FEM workflow to rapidly test configurations, focusing on optimizing heat dissipation and stress reduction. Additionally fins were included for cooling



SPACECLAIM SCRIPT - WORKFLOW (PYANSYS):



INCORPORATING MACHINE LEARNING FOR ENHANCED DESIGN SELECTION:

With automated FEM providing ample data, machine learning models were introduced to further streamline the optimization process. The Preprocessed data was fed into a Random Forest regression model, which accurately predicted optimal configurations with an R^2 score of 0.96. This ML integration accelerated our ability to pinpoint effective designs without exhaustive simulations on each new configuration.

Spaceclaim Automation

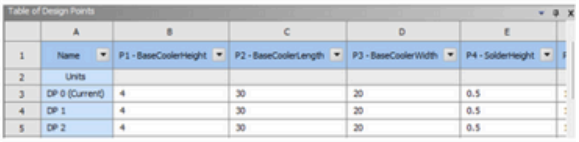
Parameter Definition → Design Point Creation → Simulation → Data to CSV

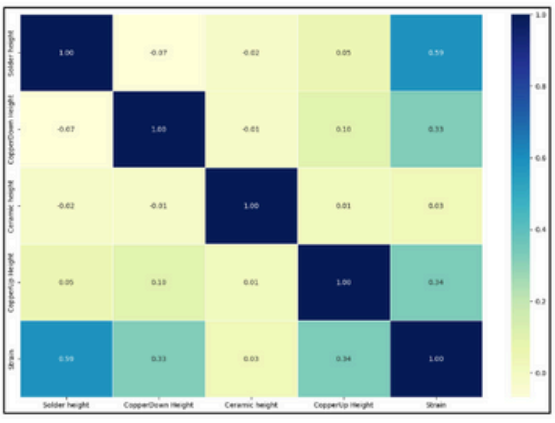
Machine Learning - Regression

Data Normalization → Model Training → Cross Validation → Final parameter Extraction

Performance Metric - Random Forest Regressor

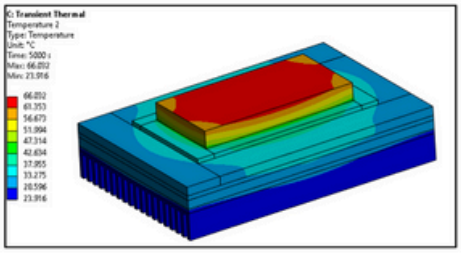
R2 Score- 0.94
Mean Absolute error - 0.01
Mean Squared Error - negligible
Cross Validation R2 Score - 0.96 (5 Fold)

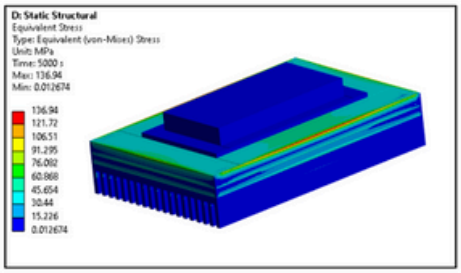




RESULTS:

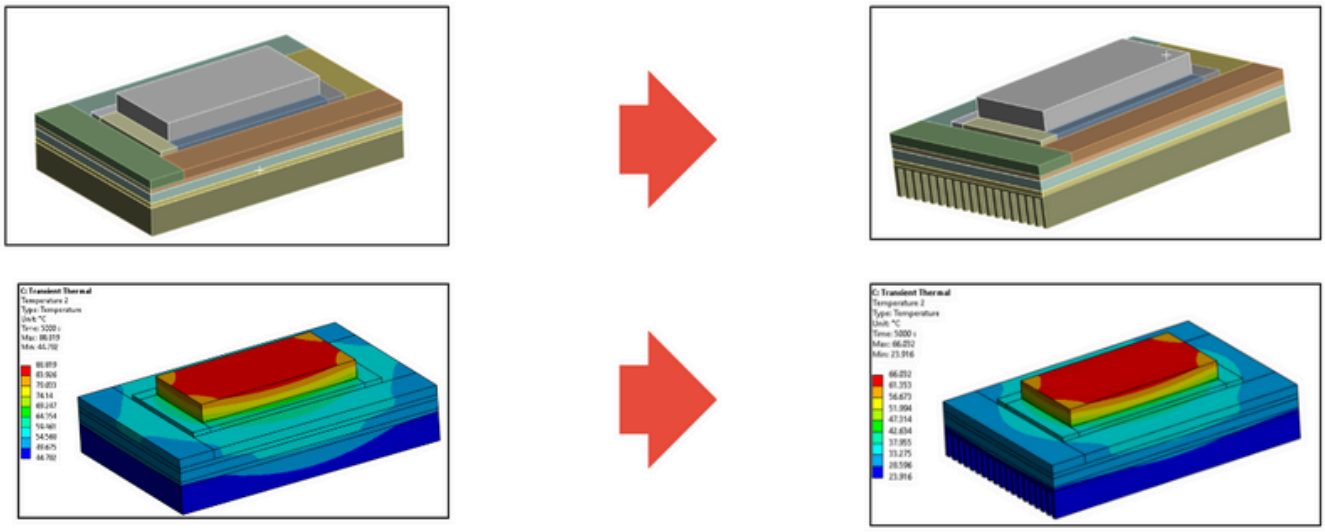
- Thermal Performance: 25.65% reduction in maximum temperature.
- Material and Cost Efficiency: Achieved a 64% reduction in module mass and an 82.2% reduction in material costs.
- Structural Integrity: Decreased Von-Mises stress by 64%, ensuring robust and reliable module performance.





	Original	Final Design	% Reduction
Von-Mises Stress	422 Mpa	136 Mpa	64
Temprature	88 degrees	66 Degrees	25
Equivalent Strain	4.1 e-3	1.5e-6	>>100

Fatigue Life >> e06 - Considered Infinite life



25.65 % Reduction in maximum temperature

OUTLOOK:

- Future work will refine design criteria with added boundary conditions and explore die-hole designs for better heat dissipation.
- Expanding automation for more design points will boost ML accuracy, enhancing efficiency and adaptability for various module specifications.