MATLAB EXPO

2021

Meeting the Challenges of Design Optimization

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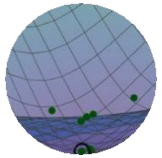
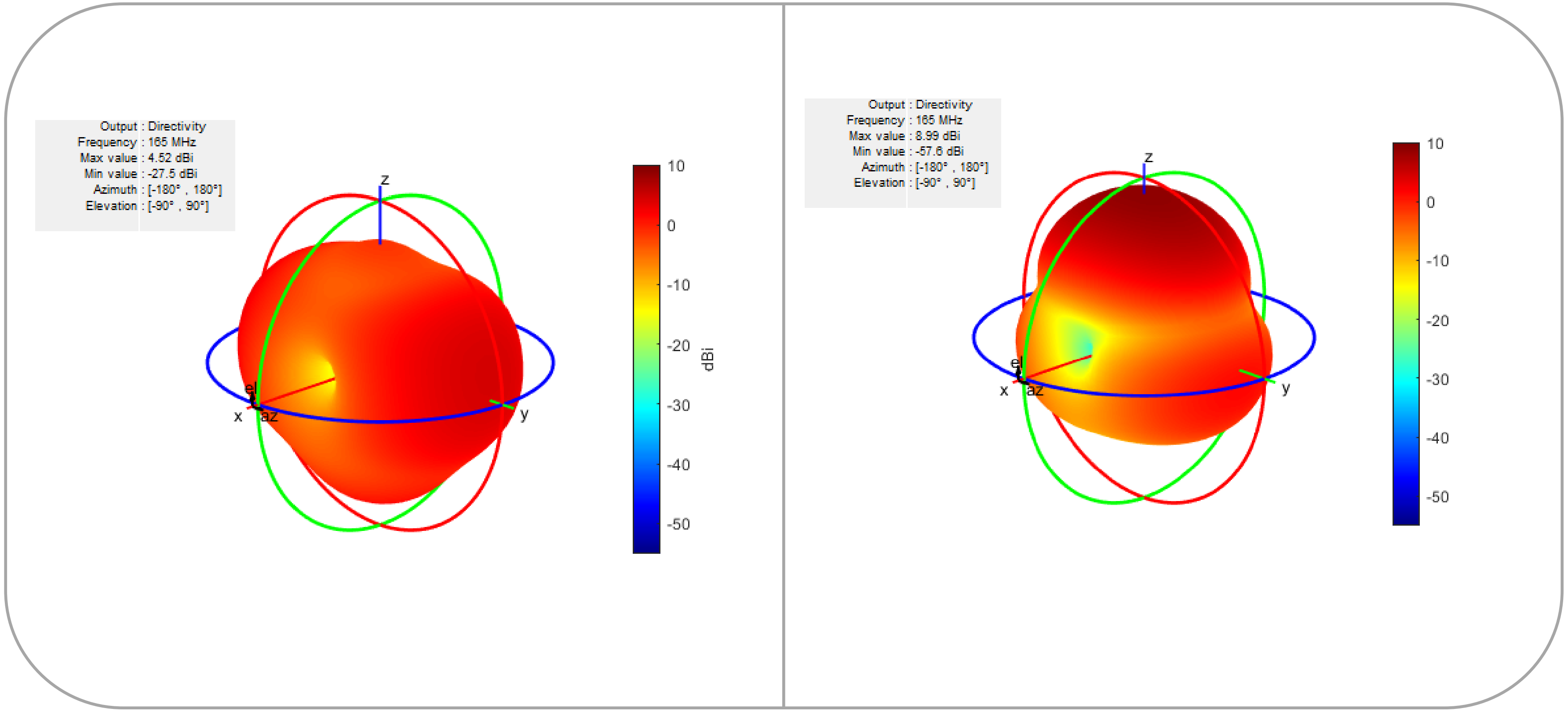
MathWorks®



Global Optimization Toolbox @globaloptimtbx · May 5

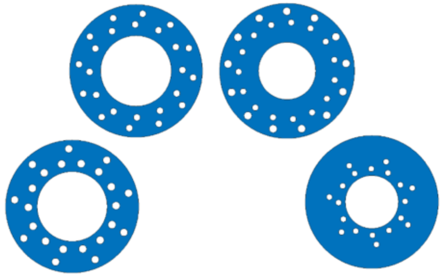
How it started. How it's going.

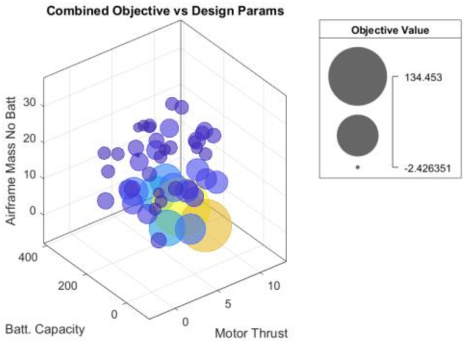


Optimization techniques improve and accelerate design

Find optimal designs while satisfying requirements

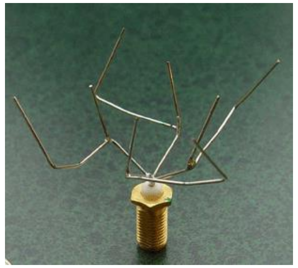
Reduce time of design iterations





Understand the design space and trade-offs

Find non-intuitive designs



Minimize cost of prototyping and production

Automate routine decision-making

Design Optimization Workflow

Design Optimization Challenges

Difficult to set up

- *Formulate optimization*
- *Connect multiple models*
- *Conflicting goals*
- *Choose solver/options*

Time consuming

- *Design iterations take too long*
- *Can't take advantage of existing results*

Difficult to analyze results

- *Understand solutions*
- *Understand trade-offs*
- *Collaborate with upstream/downstream teams*

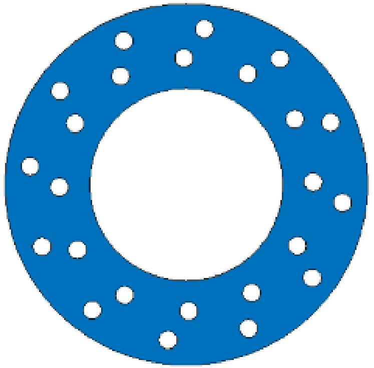
We'll see some ways to meet design optimization challenges through these case studies

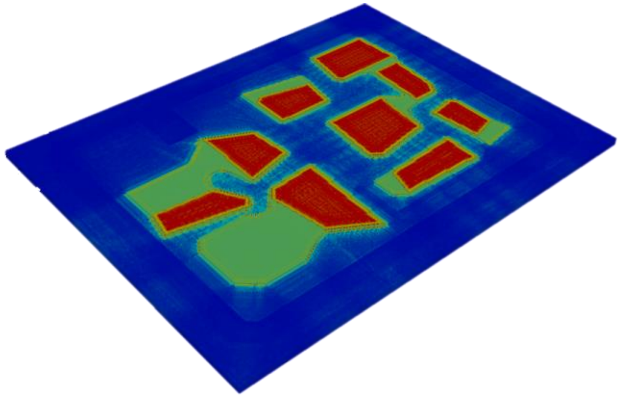
Disc Brake Design

5G RF Filter Design

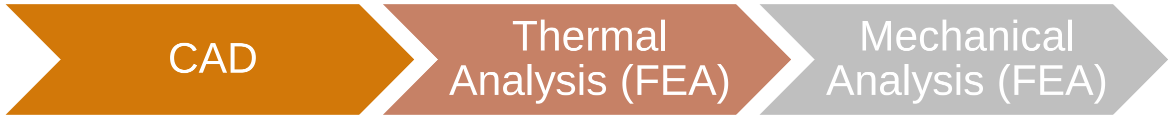
EV Gear Design

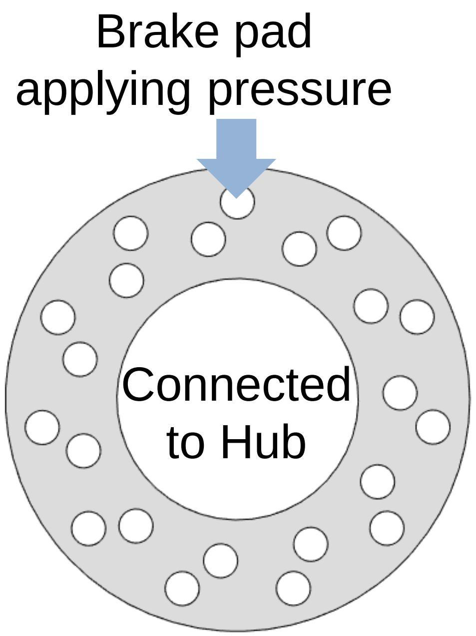
Quadcopter Design





CAD and FEA can model a disc brake under Thermomechanical Stress

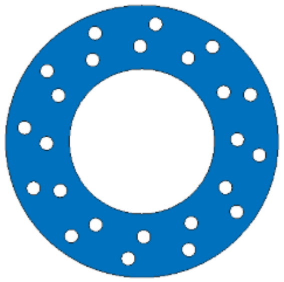


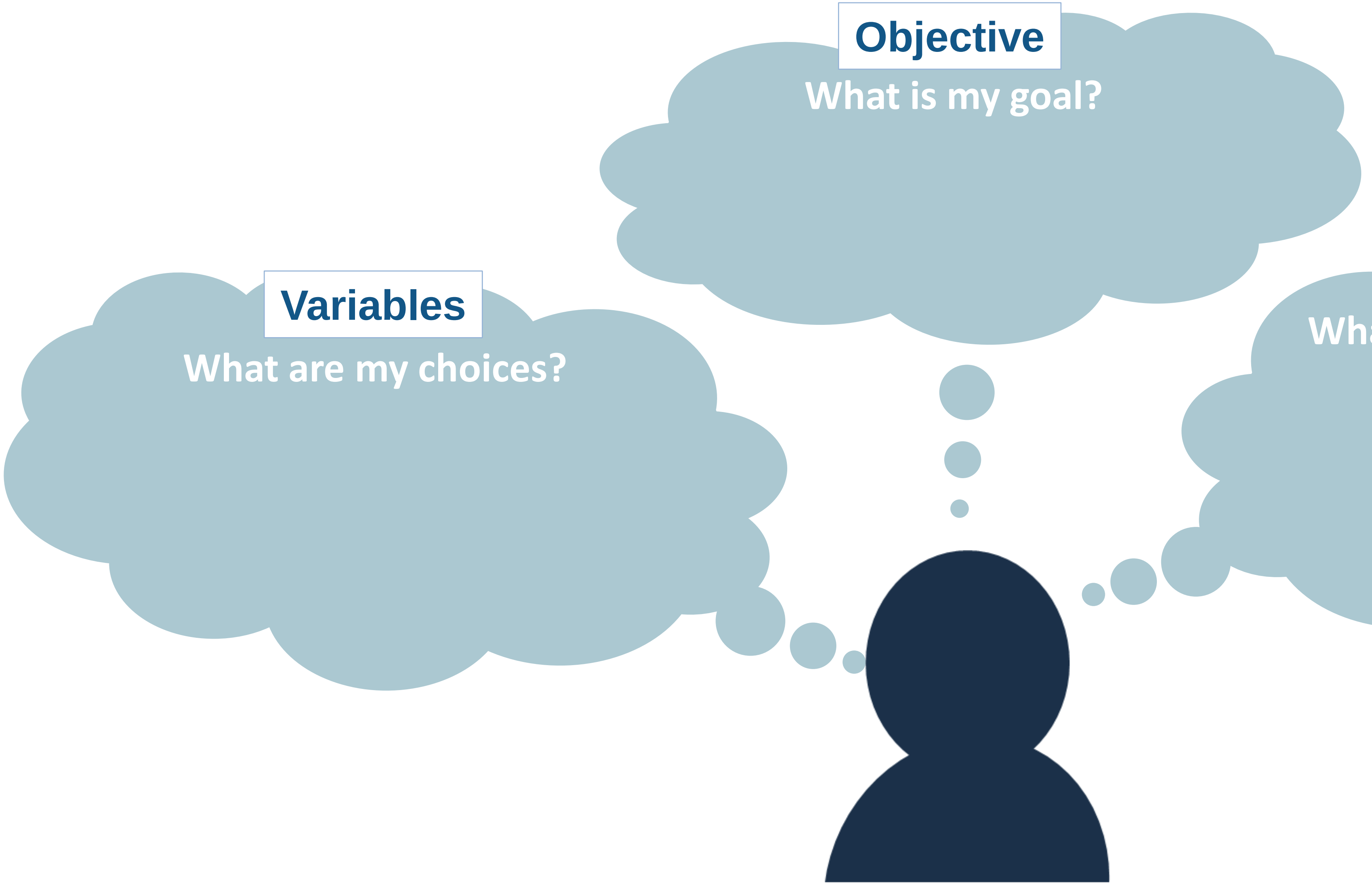


- **Goal:** A design with low manufacturing cost and that meets stress standards

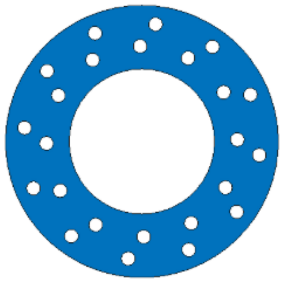
- **Challenges:**
  - How to set up the optimization
  - Disc brake is modeled with external CAD software and with FEA
  - Model evaluation takes several minutes

Formulating an Optimization Problem: Disc Brake





Formulating an Optimization Problem: Disc Brake



Objective

What is my goal?

Variables

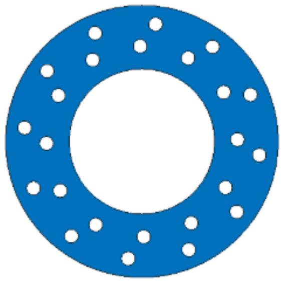
What are my choices?

disc diameter and thickness
number and diameter of holes
distance between holes

Constraints

What restricts my choices?

Formulating an Optimization Problem: Disc Brake



Objective

What is my goal?

minimize volume

Variables

What are my choices?

disc diameter and thickness
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distance between holes

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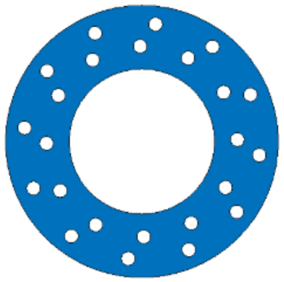
Formulating an Optimization Problem: Disc Brake



Objective

What is my goal?

minimize volume

Variables

What are my choices?

disc diameter and thickness
number and diameter of holes
distance between holes

Constraints

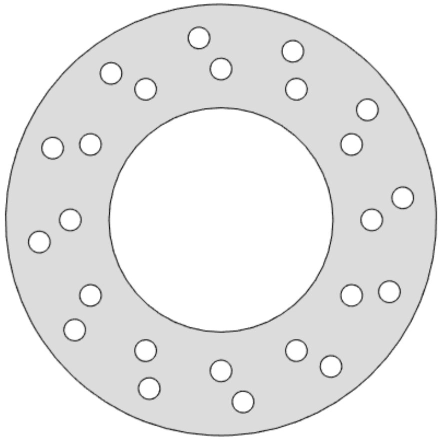
What restricts my choices?

stress limit
geometry parameter limits

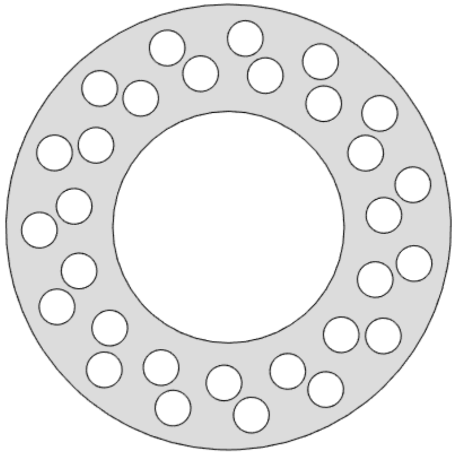
Surrogate Optimization finds an improved design

	Initial	Surrogate Optimization*
Volume (m^3)	4.75e-4	1.34e-4
Stress Ratio	0.19	0.49

*250 function evaluations



Initial

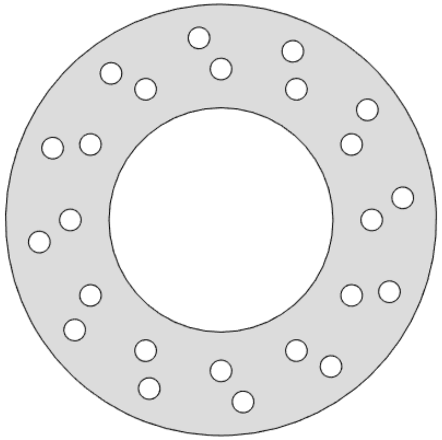


Surrogate Optimization

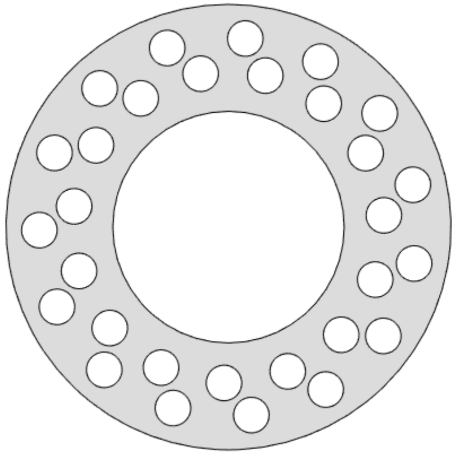
Surrogate Optimization finds a better design than the Genetic Algorithm when restricting the number of function evaluations

	Initial	Surrogate Optimization*	Genetic Algorithm*
Volume (m^3)	4.75e-4	1.34e-4	1.64e-4
Stress Ratio	0.19	0.49	0.92

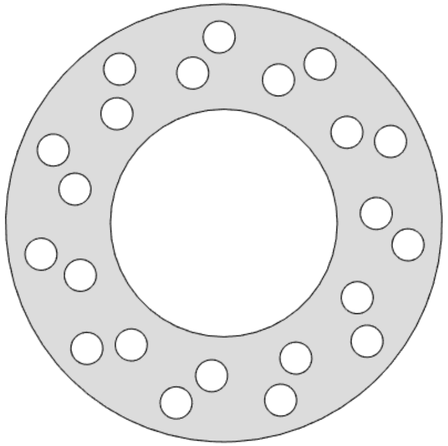
*250 function evaluations



Initial



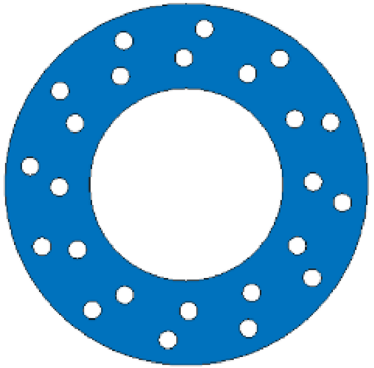
Surrogate Optimization

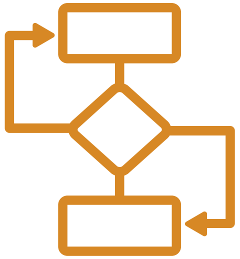


Genetic Algorithm

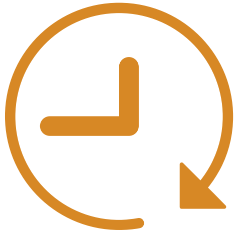
How we met the design optimization challenges

Disc Brake Design

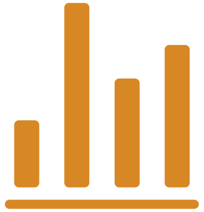




- *File-based I/O & “system” command to connect multiple models*
- *Optimize task for formulating problem and guidance on solver*



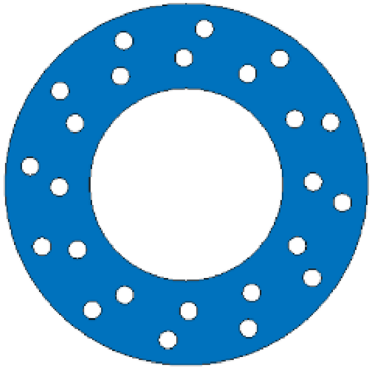
- *Surrogate optimization*
- *Use existing results to start optimization*
- *Checkpoint for restarting optimization*
- *Accelerate with parallel computing*



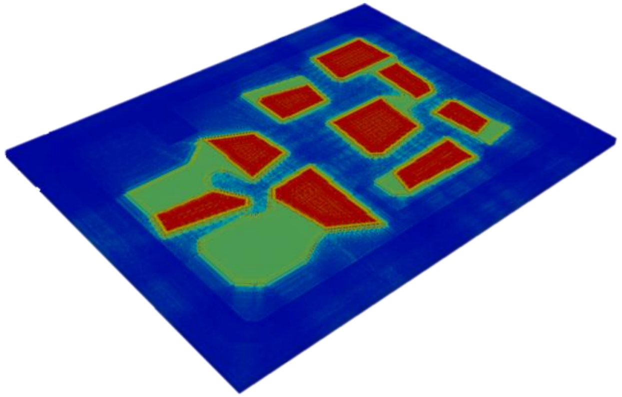
- *Progress plots*
- *Visualization of the temperature, stress, and design*

We'll see some ways to meet design optimization challenges through these case studies

Disc Brake Design



5G RF Filter Design



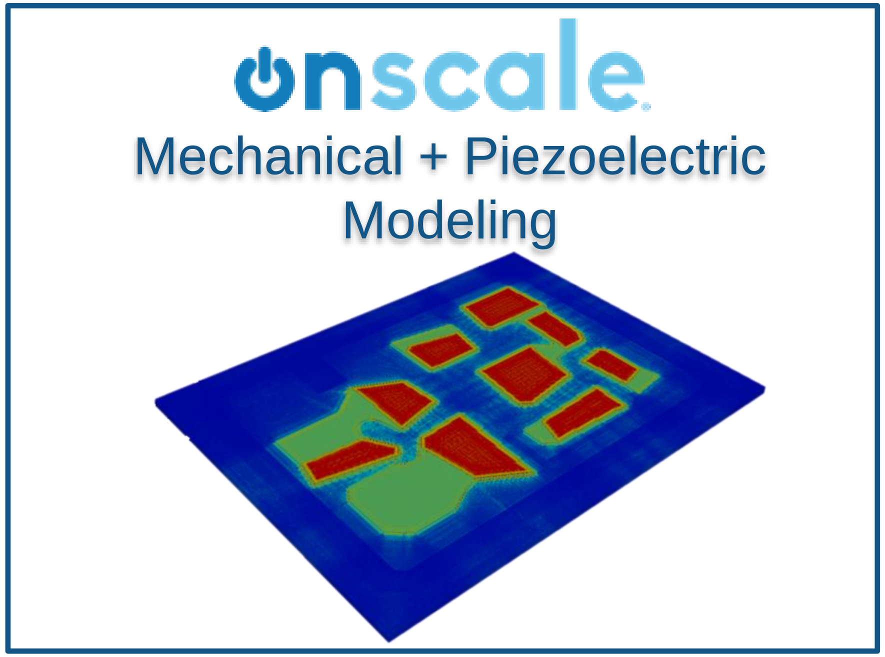
EV Gear Design

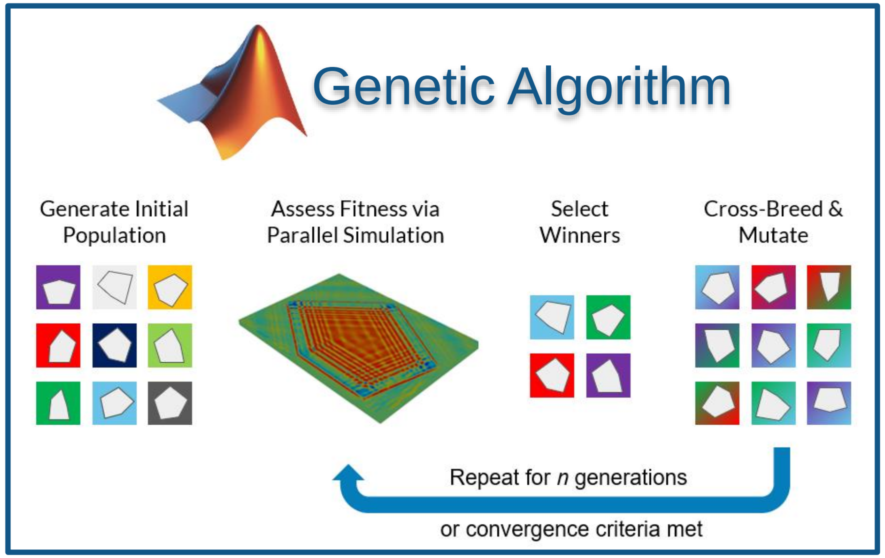
Quadcopter Design

5G RF MEMS Filter Design
Partner: OnScale

- **Goal:** Find optimal electrode alignment of FBAR resonator by minimizing spurious modes

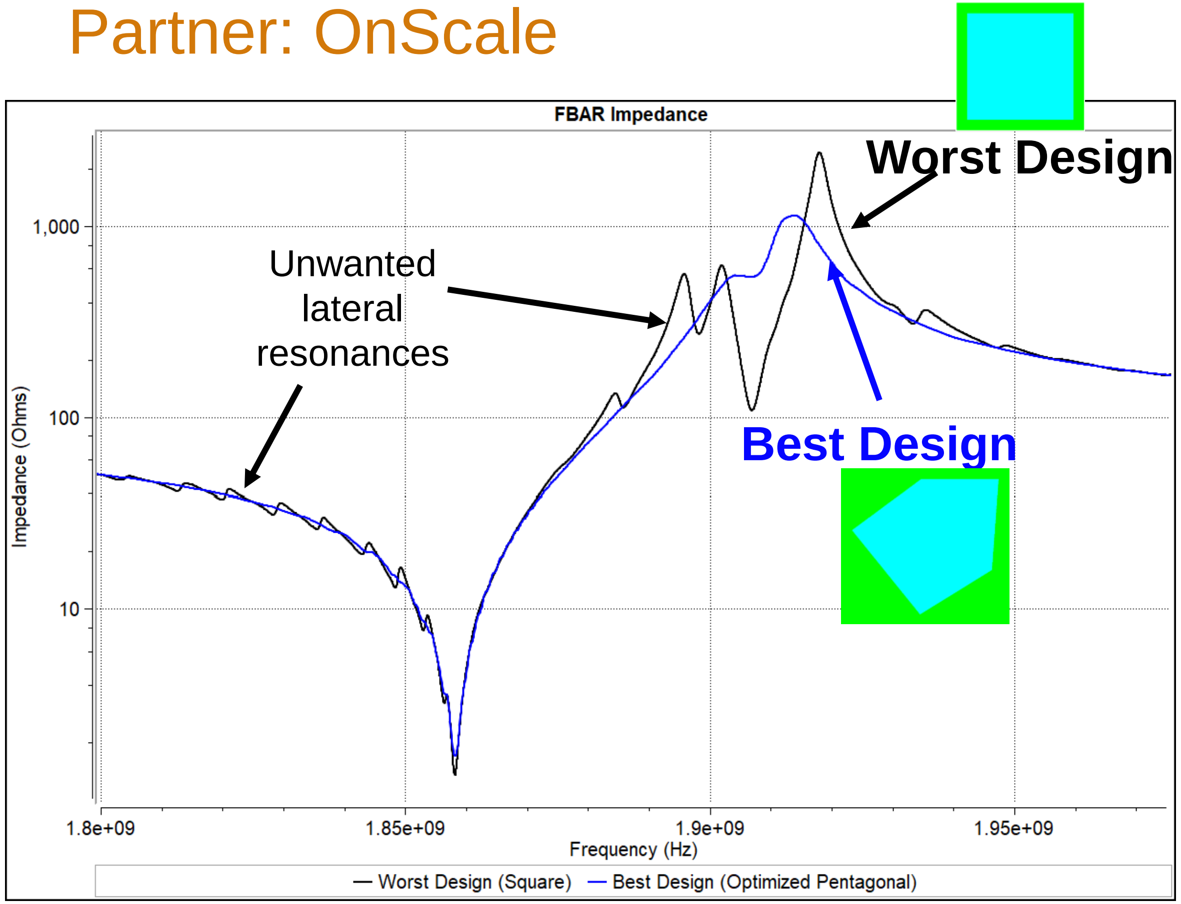
- **Challenges:** Full 3D simulation and exploring design space are time consuming
  - Population of 70, 52 Generations, 3,640 Simulations, >3,000 Core Hours





5G RF MEMS Filter Design

Partner: OnScale



>3000 core hours required <48 Hour on 64-Core Cloud HPC

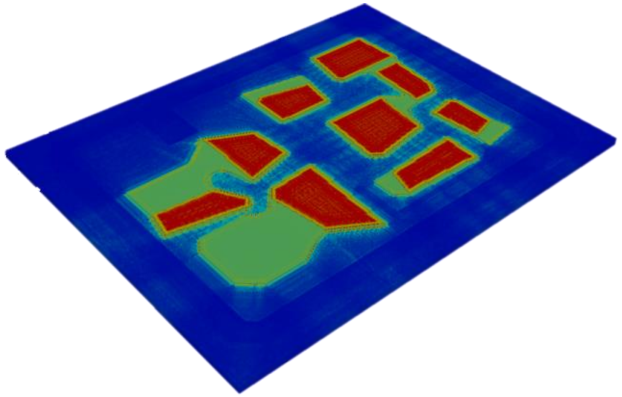
onscale + MATLAB TOOLBOX

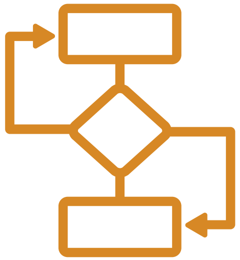
```
% Configure GA object
myGA = GAOnScale("RF_GA", "GA of Pentagonal FBAR");

% Create account object
myGA.Account = Account("MyAccount");

% Assign input files to genetic algorithm
myGA.setGAFiles(["fbar.flxinp","baw.prjmat"]);

% Set termination constraints
myGA.setGATerminate(5, 10, 28, Inf);

% Set input variables and limits
myGA.setGAVariables(["a", "b", "c", "d", "e", "f", "g"], ...
    [0.75 0.75 1.2135 0.75 1.2135 0.75 0.75], ...
    [1.25 1.25 2.0225 1.25 2.0225 1.25 1.25]);

% Set score function
myGA.setScoreFunction(@scoreFun);

% Run GA
myGA.startOrContinue();
```

Easy set up from MATLAB Toolbox by OnScale or OnScale API

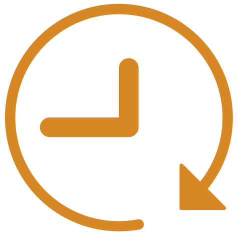
How we met the design optimization challenges

5G RF Filter Design





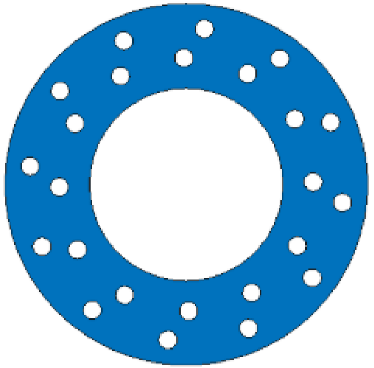
- *Genetic algorithm is easy to use*
- *MATLAB enables integration with external platforms*



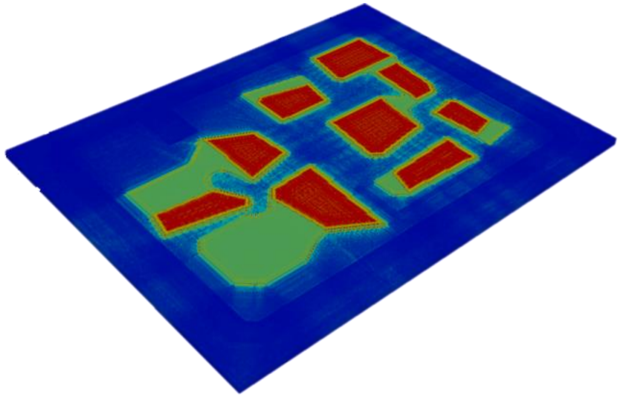
- *Cloud-based, high-performance computing through OnScale (MathWorks Partner)*

We'll see some ways to meet <u>design optimization challenges</u> through these case studies

Disc Brake Design



5G RF Filter Design

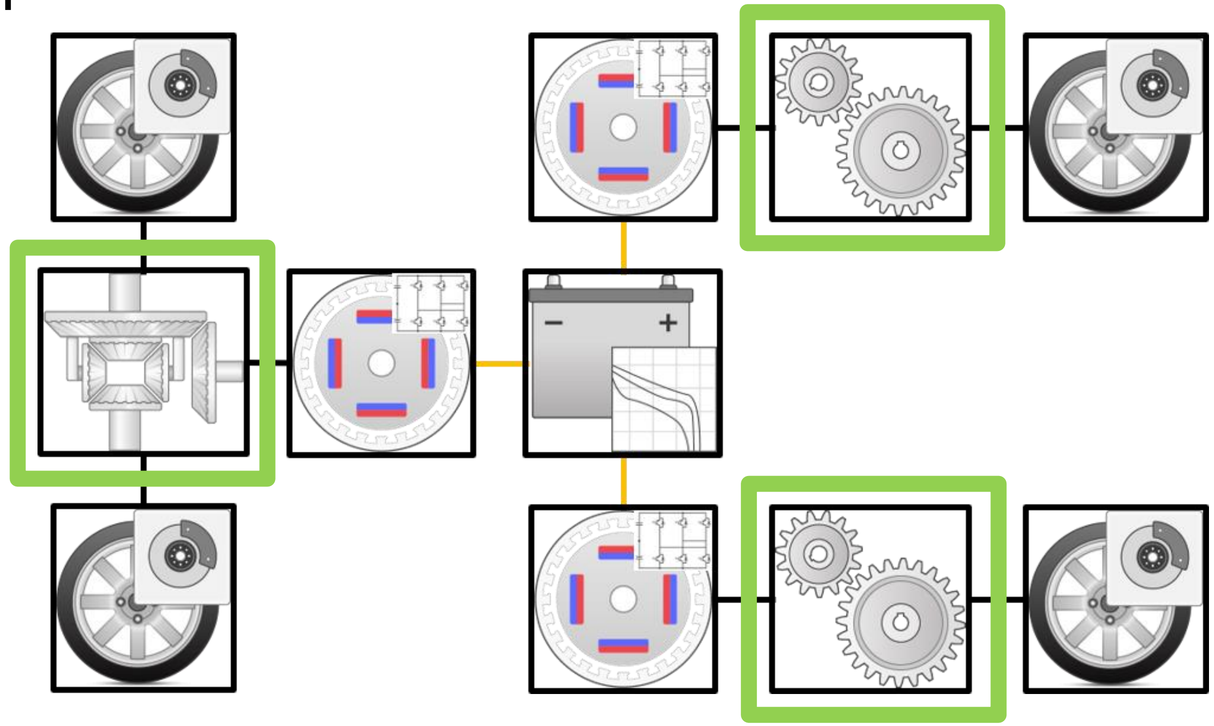


EV Gear Design

Quadcopter Design

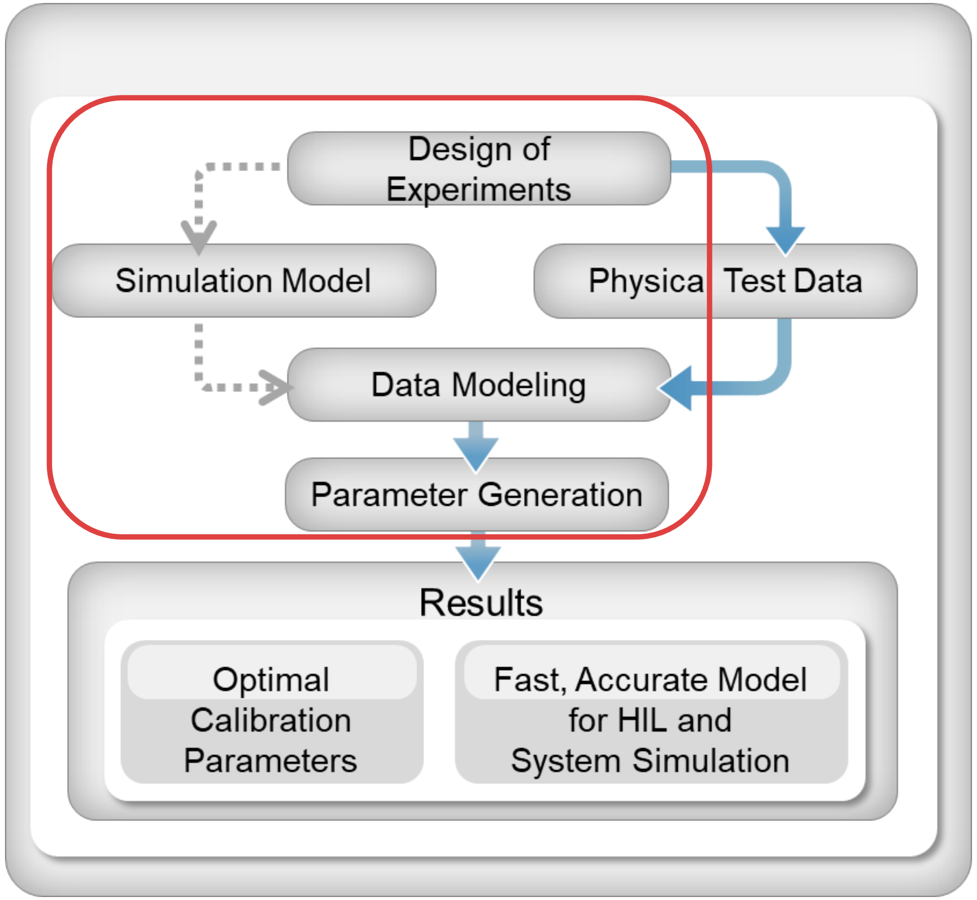
Electrified Powertrain Gear Ratio Case Study

- **Goal:** Determine gear ratios of a 3-motor EV to optimize competing objectives:
  - Fuel economy
  - Acceleration

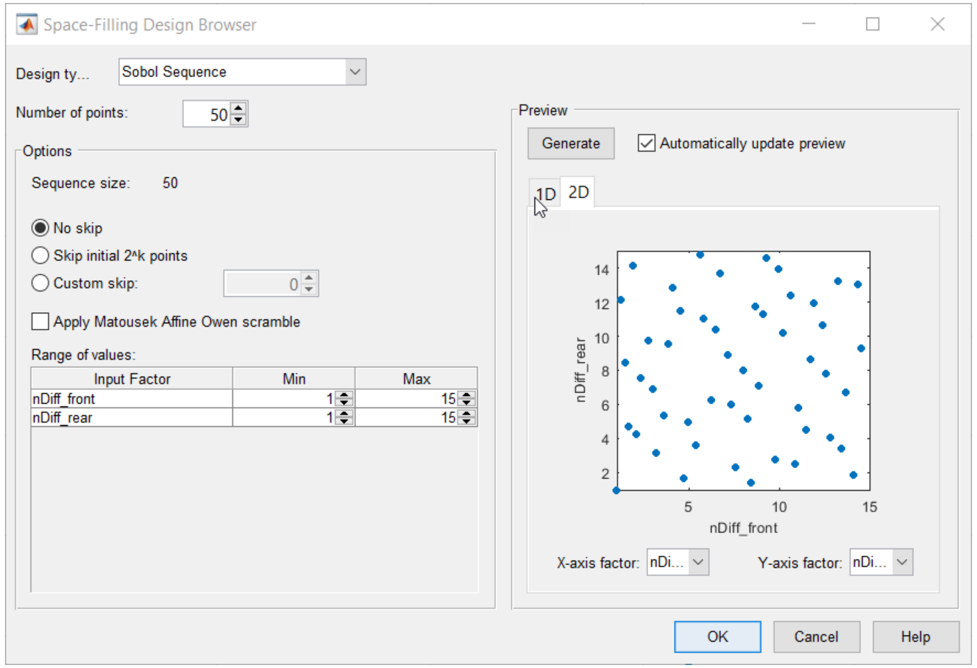


- **Challenges:**
  - Fuel economy and acceleration are competing objectives
  - The simulation takes 18 minutes to run

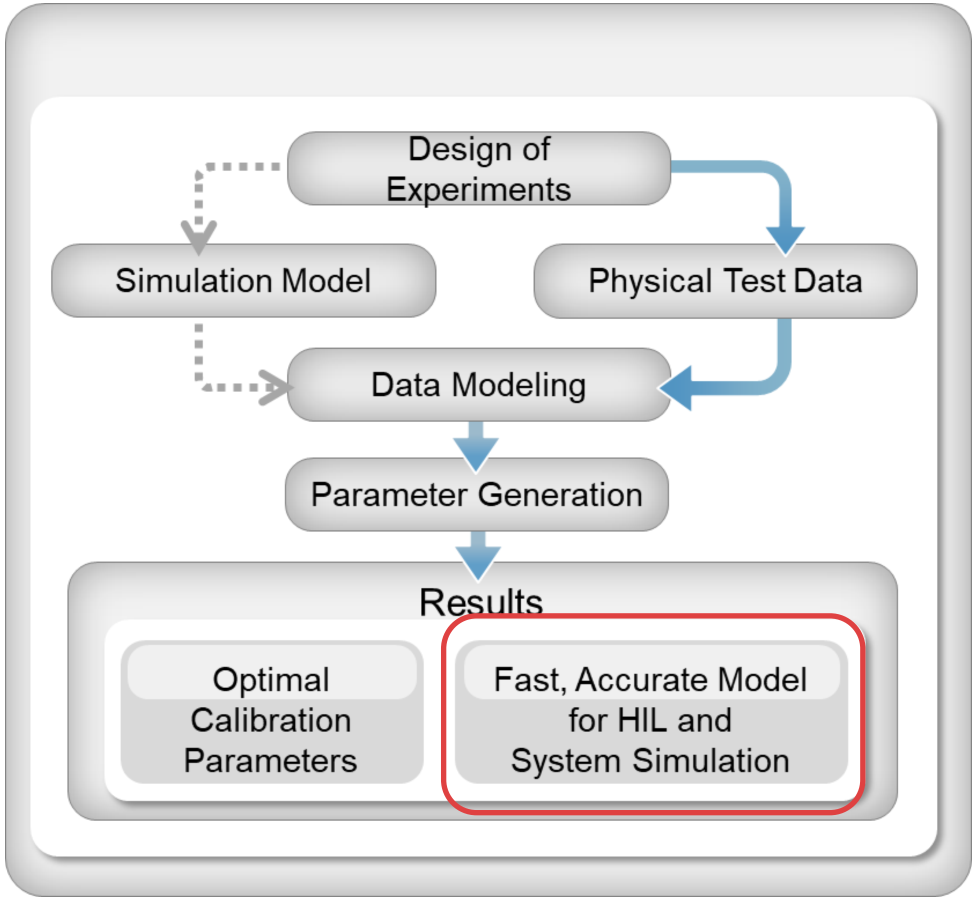
Build surrogate models with Model-Based Calibration Toolbox for fast model evaluations

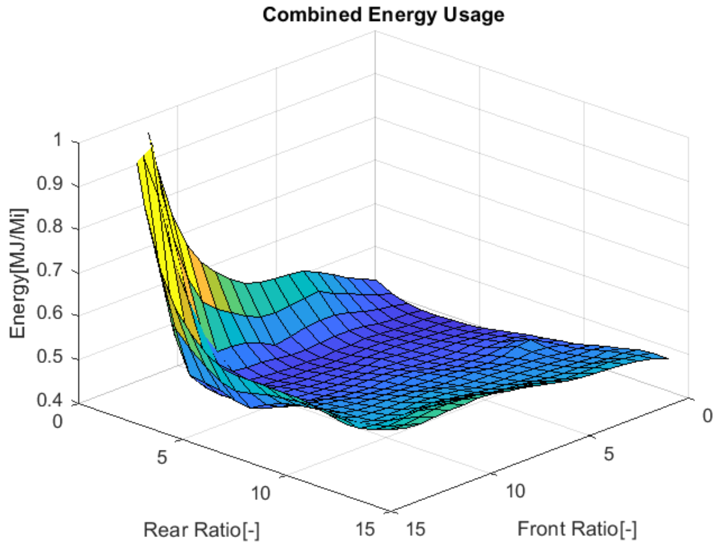


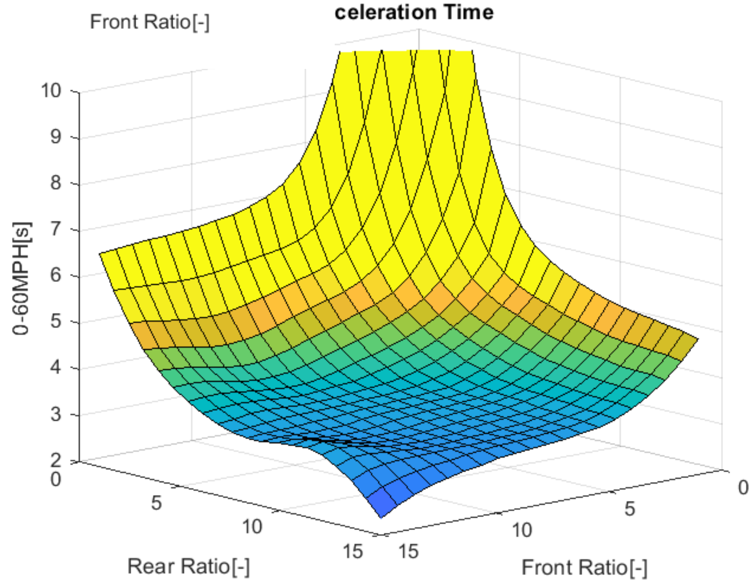
- Generate Design of Experiments
- Evaluate Powertrain Blockset model for fuel economy and acceleration
- Fit response model



Create look-up tables from the response models using Model-Based Calibration Toolbox







How we met the design optimization challenges

EV Gear Design

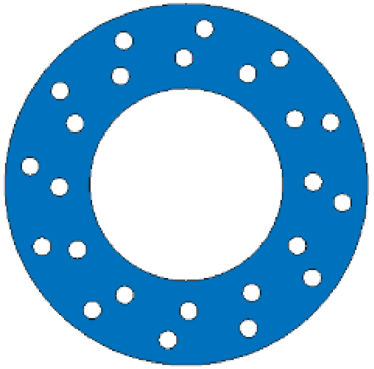
- *Multiobjective formulation for the competing objectives*

- *Parallel computing to build response surface model*
- *Look-up table for fast evaluations*
- *Paretosearch solver for effficient solution*

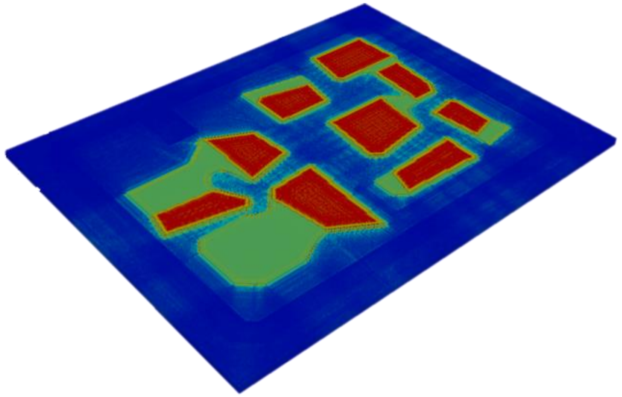
- *Pareto curves to explore tradeoffs*

We'll see some ways to meet design optimization challenges through these case studies

Disc Brake Design



5G RF Filter Design



EV Gear Design

Quadcopter Design

Use Design of Experiments and Optimization to understand trade-offs in the conceptual design stage

- **Goal:** Choose components to
  - Maximize endurance and power-to-weight ratio
  - Minimize cost

- **Challenges:**
  - Competing objectives
  - Work with architecture in System Composer
  - No model to use for analysis
  - Need to understand tradeoffs of objectives and requirements

Quadcopter Design

How we met the design optimization challenges

Quadcopter Design

- *Problem-based formulation*
- *Multi-Disciplinary Analysis and Optimization*
- *Design of Experiments*

- *Quick analysis before going to detailed models*

- *Create Plot task for visualizations*
- *Trade-off studies at system-level*
- *Integrate with System Composer*

Tools for Design Optimization

Generic design optimization

- MATLAB
- Statistics & Machine Learning Toolbox
- Optimization Toolbox
- Global Optimization Toolbox
- Parallel Computing Toolbox

Domain-specific design optimization

- Simulink Design Optimization
- Model-Based Calibration Toolbox
- Antenna Toolbox

Answers for the Challenges of Design Optimization

Difficult to set up

- *MATLAB workflow integration*
- *Optimize task*
- *Problem-based optimization*
- *Multiobjective solvers*

Time consuming

- *surrogateopt & paretosearch*
- *Starting with existing solutions*
- *Surrogate models*
- *Parallel computing*

Difficult to analyze results

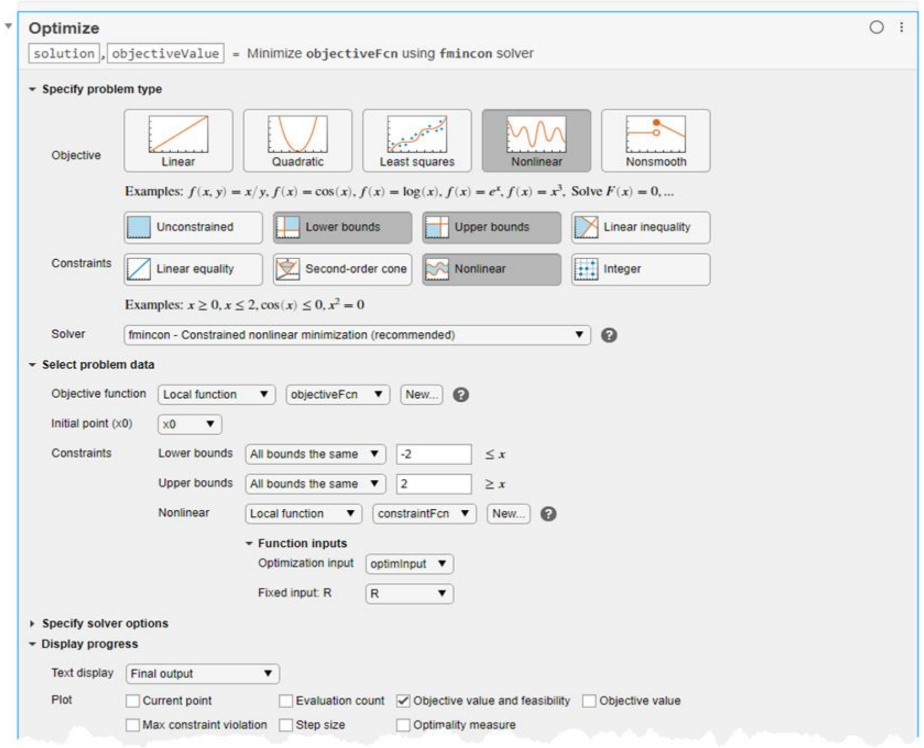
- *Create Plot task*
- *Many plot types*
- *Pareto plots*
- *Progress plots*

Do More

Try the Optimize task

tutorial

video



Try problem-based optimization

Workshop using MATLAB Online

Last hour of Expo Day 2

Learn More

Getting Started			
Optimization Toolbox	Overview	Video	Documentation
Global Optimization Toolbox	Overview	Video	Documentation
Cheat Sheets			
Training: Optimization Techniques in MATLAB			

How-To Videos	
Mathematical Modeling with Optimization	Master Class: Solving Optimization Problems with MATLAB
Optimize Live Task	Multiobjective Optimization
Surrogate Optimization	Design Optimization with MATLAB
Global Search	MultiStart Optimization

Basics
Nonlinear Programming
Linear Programming
Integer Programming
Quadratic Programming
Genetic Algorithm
Least Squares and Nonlinear Systems of Equations

Examples	
Flight Path Optimization	Traveling Salesman Problem
Production Planning	Portfolio Optimization
Minimizing Electrostatic Energy	Optimal Dispatch of Power Generators
Antenna Design	Circuit Component Selection

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Thank you

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