DEPARTMENT OF
AEROSPACE ENGINEERING

TECHNION
Israel Institute
of Technology

(2018) Course on “Optimization Integrated Design” Final projects using modeFRONTIER

Dr. Savely Khosid

Course Details

**Course “Optimization Integrated Design” (87542),
Faculty of Aerospace Engineering, Technion, Israel
Spring semester 2018 (first time)**

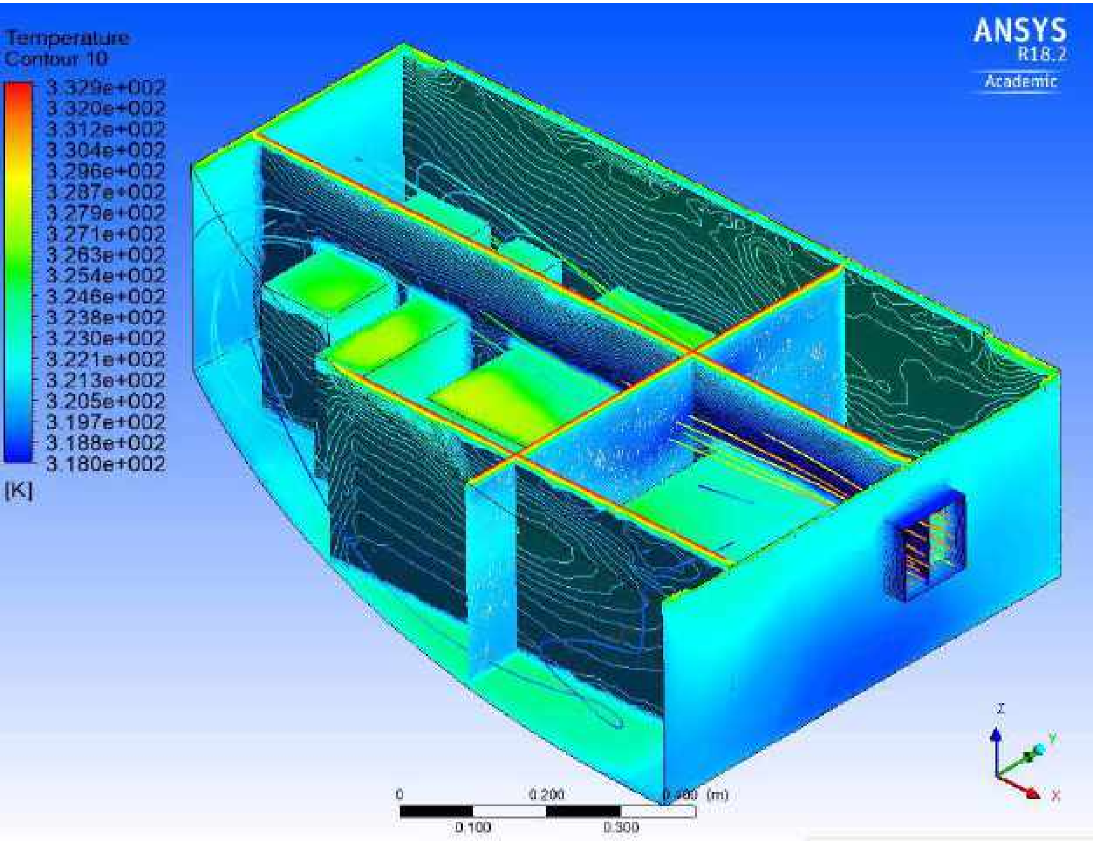
- ✓ **41 students**
- ✓ **25 final projects**

Performed mainly with:

- ✓ **ANSYS Workbench**
- ✓ **MATLAB**
- ✓ **modeFRONTIER**

**Course is initiated and given
by Dr. Savely Khosid (RAFAEL)**

Optimization of an Avionic Cell Cooling with a Fan

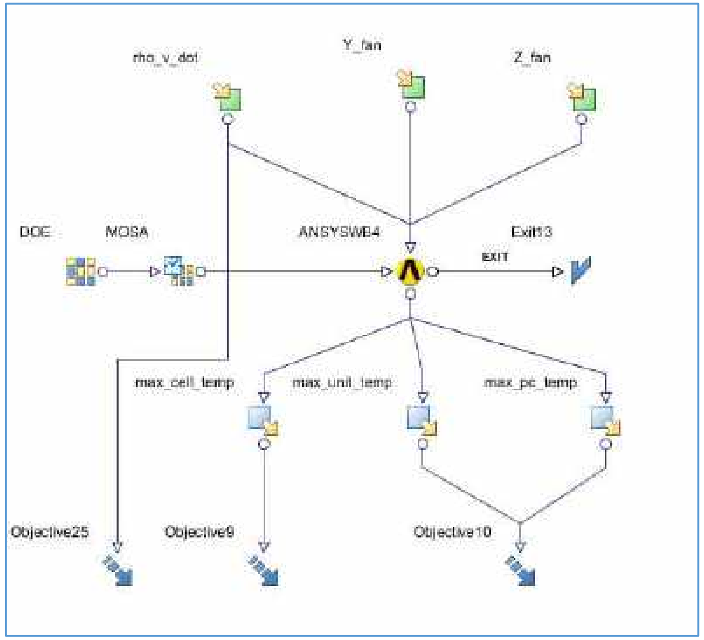


Problem

High air temperature in the avionic cell with electronic component

Purpose of optimization

To chose a best fan place and minimum flow rate for cooling



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Chemical Composition Optimization

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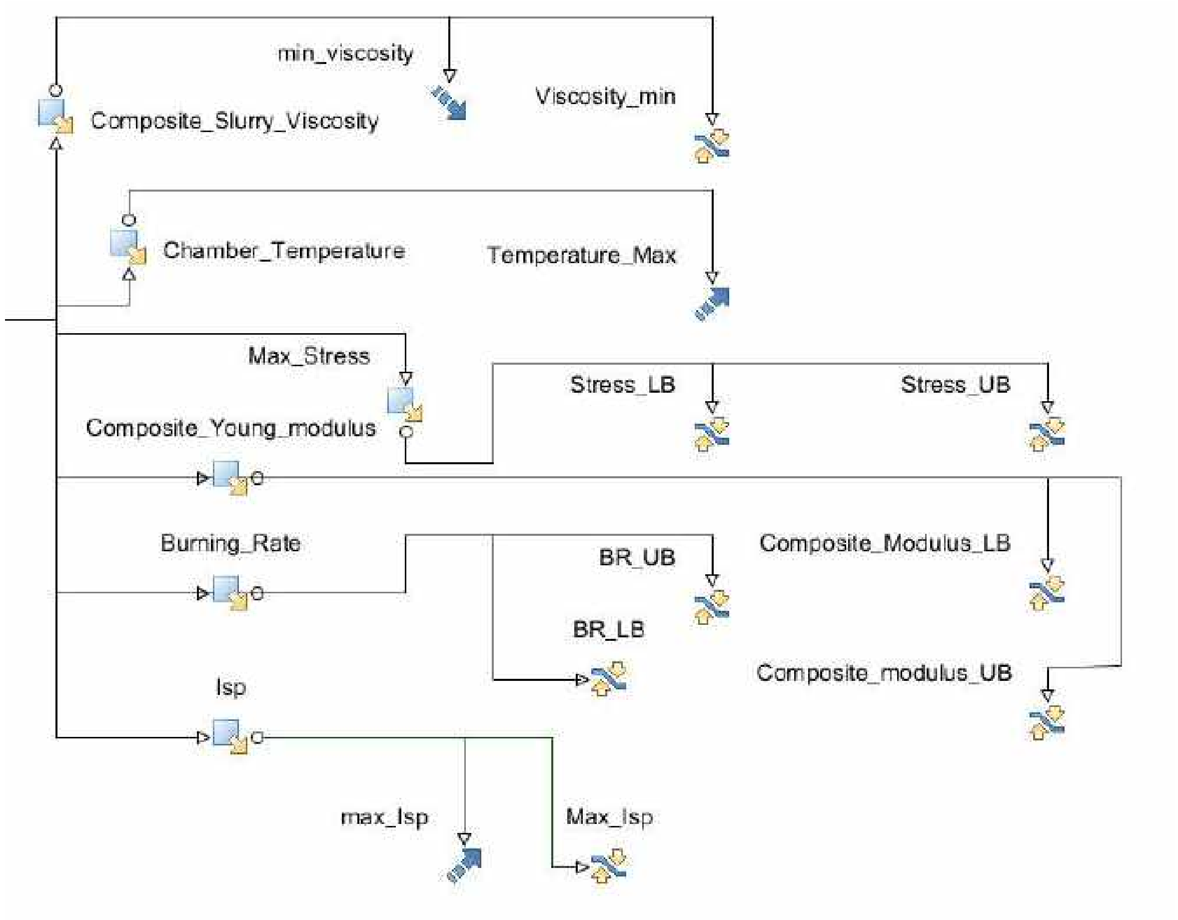
modeFRONTIER module (part)



Variables
- ✓Oxidizer percentage
- ✓Fraction composition
- ✓Size distribution

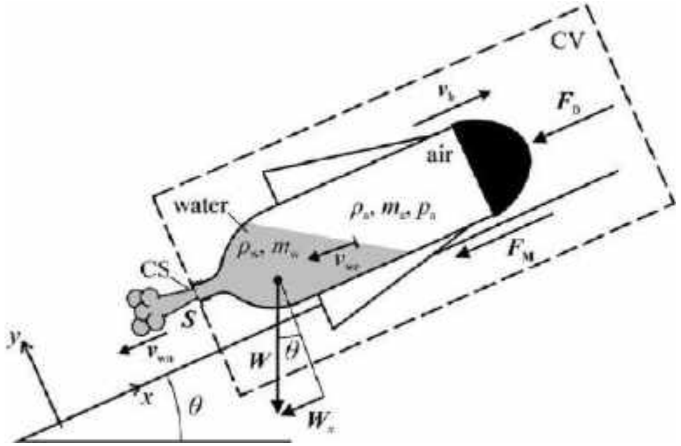
Objective functions
- ✓Maximum temperature
- ✓Minimum viscosity
- ✓Maximum energy release

Results
- ✓50°C temperature rise
- ✓2% improvement of energy content

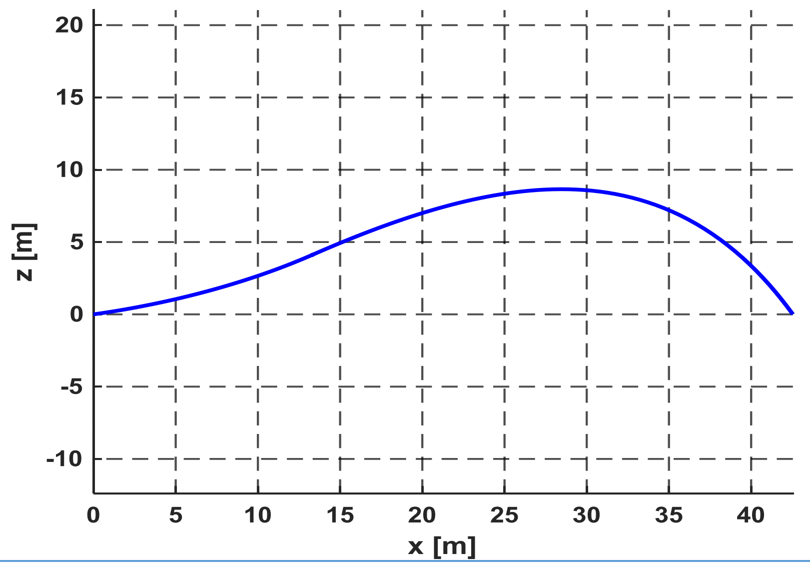
Water Rocket Optimization

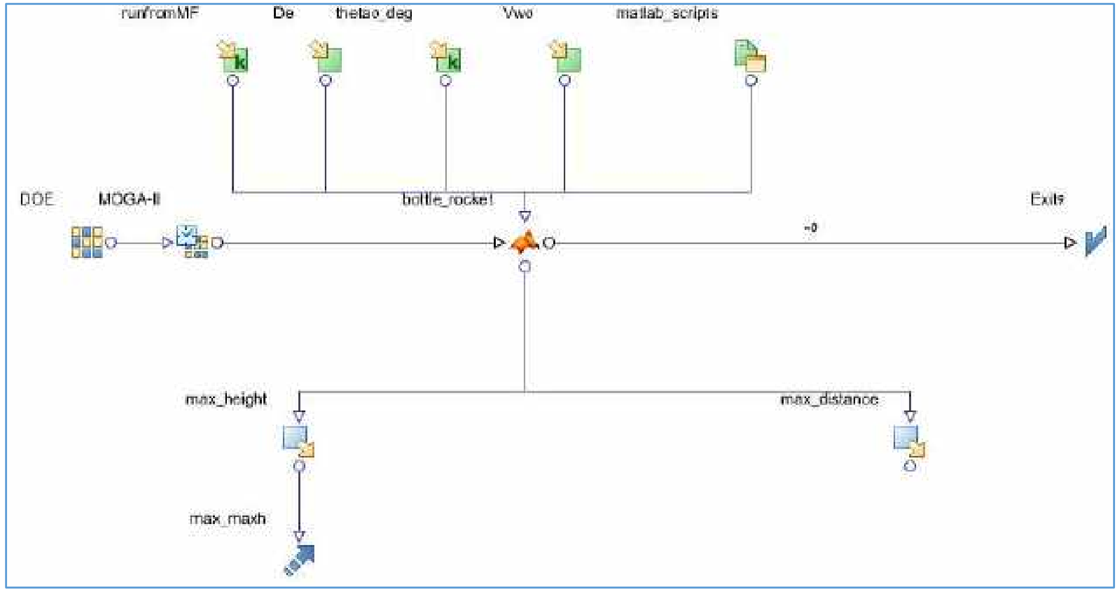
$$\ddot{x} = \frac{1}{m}\left(\rho_w A_{ex} u_{ex}^2 \cos\theta_0 - \frac{1}{2}\rho_{atm} A_{ref} C_D \dot{x}|\dot{x}|\right)$$
$$\ddot{z} = \frac{1}{m}\left(\rho_w A_{ex} u_{ex}^2 \sin\theta_0 - \frac{1}{2}\rho_{atm} A_{ref} C_D \dot{z}|\dot{z}| - g\right)$$
$$\dot{m} = -\rho_w A_{ex} u_{ex}$$
$$\dot{V}_a = A_{ex} u_{ex}$$

Model

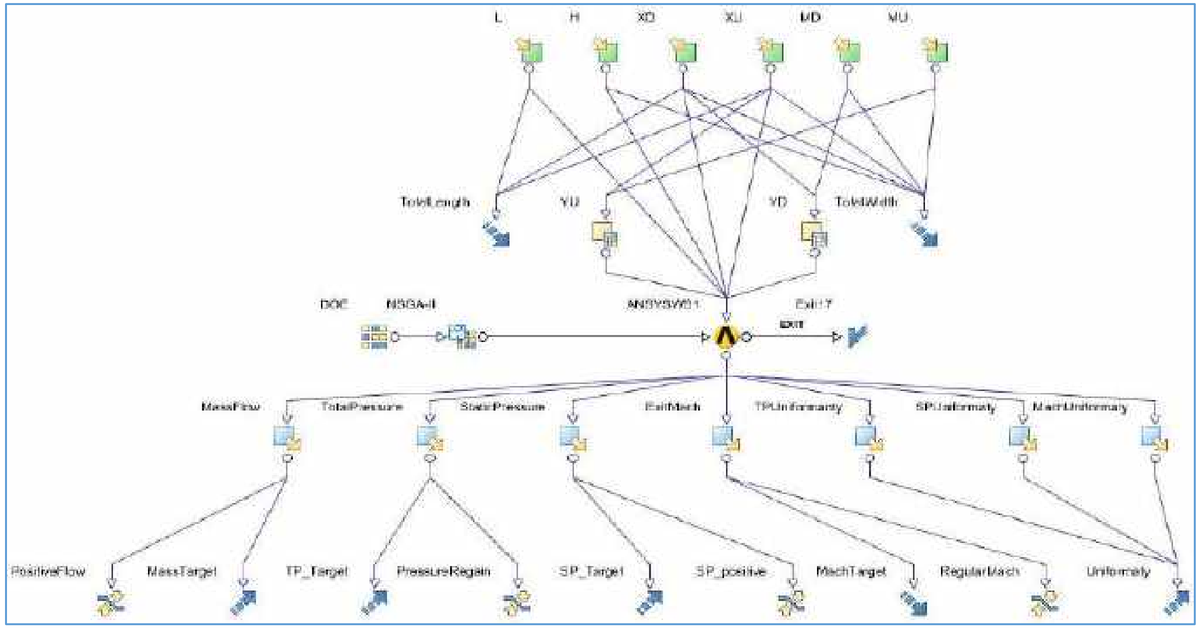


Rocket trajectory for maximum range

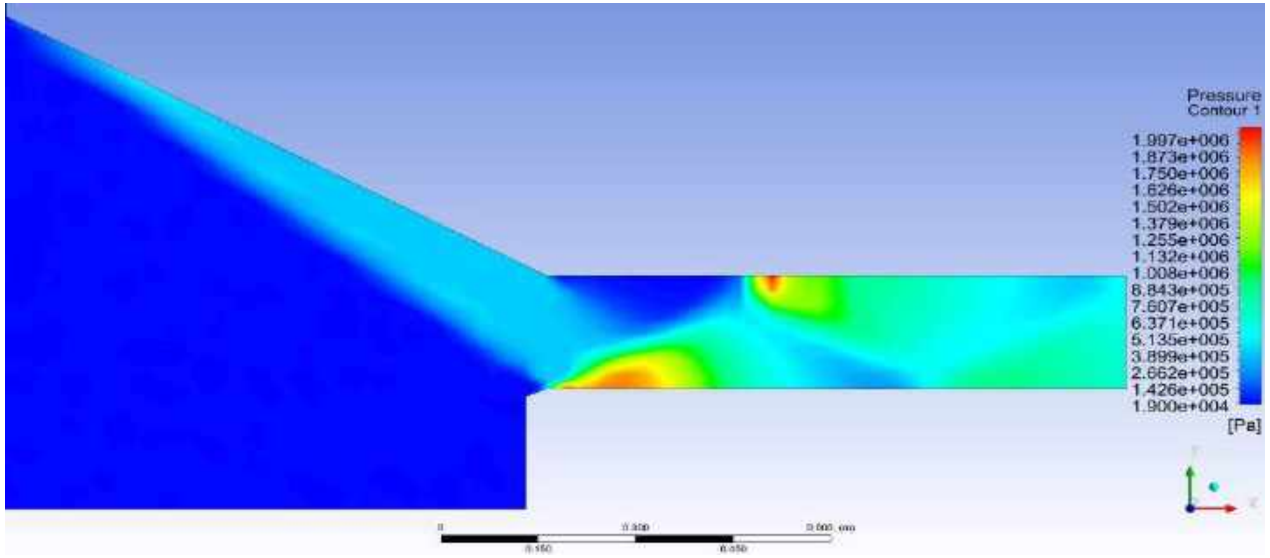




Scramjet Inlet Optimization



2117 designs

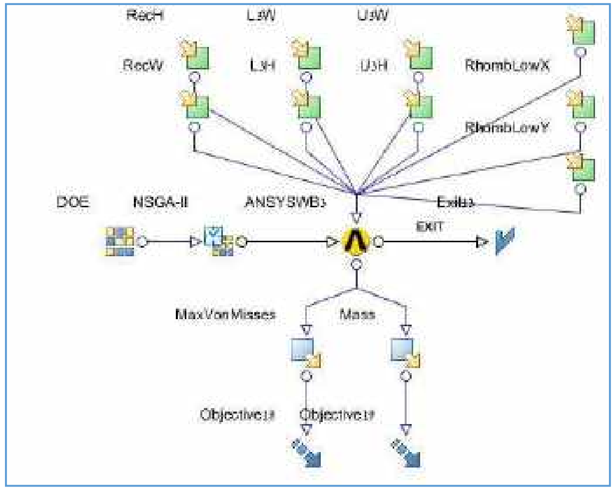


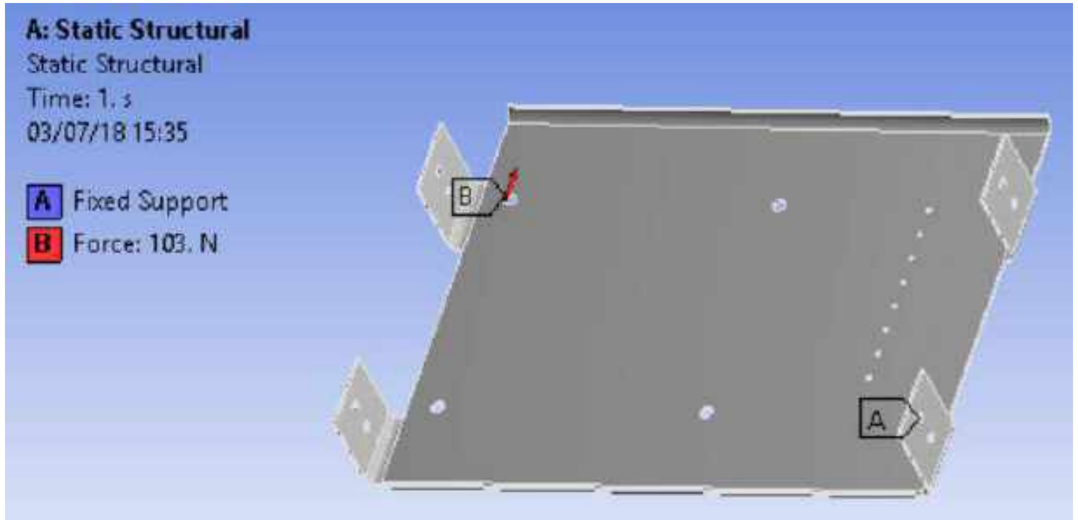
Sensitivity Table

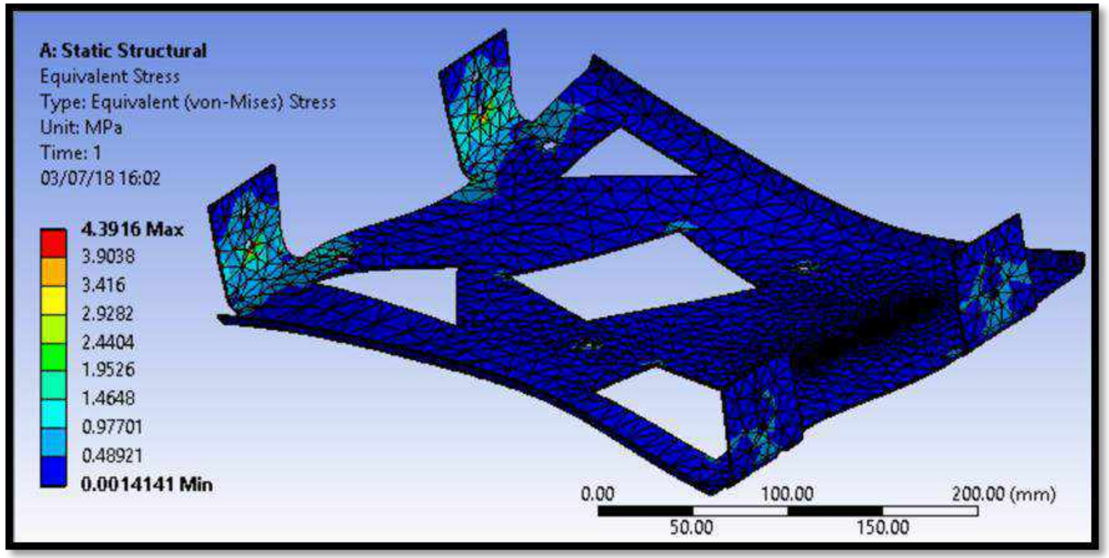
	Exit Mach	Target Mach	Flow rate	Static pressure	Total Length	Total pressure	Total width	Sum
H	**59%**	9%	**86%**	18%	1%	5%	**61%**	**239%**
L	0%	1%	0%	27%	**68%**	3%	0%	**100%**
MD	4%	36%	2%	2%	1%	3%	4%	**51%**
MU	29%	34%	0%	11%	0%	**58%**	2%	**134%**
XD	6%	13%	4%	16%	7%	27%	15%	**88%**
XU	2%	6%	8%	26%	23%	4%	17%	**87%**

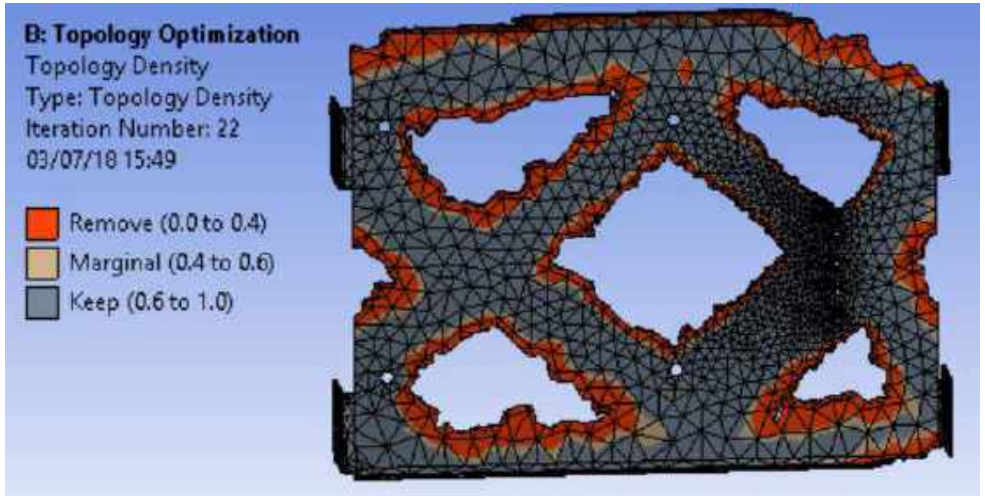
Topological Optimization of a Support

24% reduction of the support mass (due to 7% of stress increase only**)**









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Heat Break Optimization

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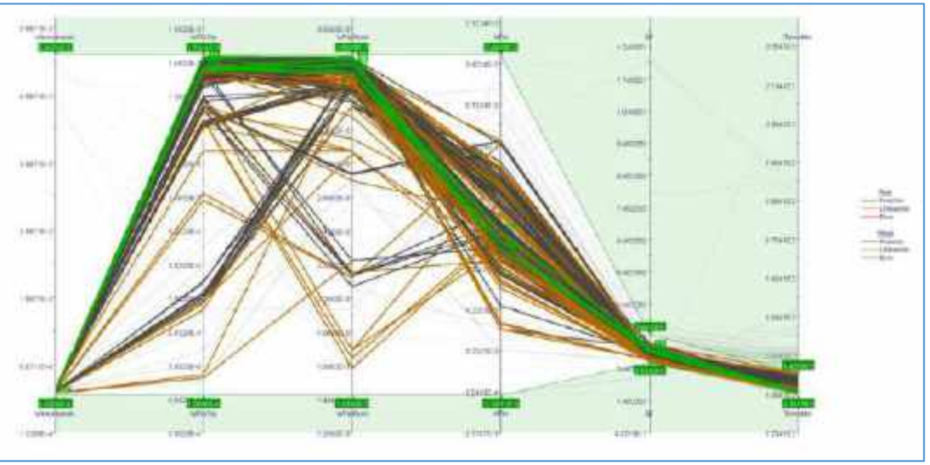
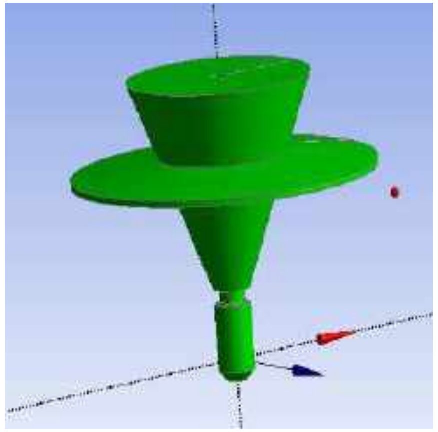
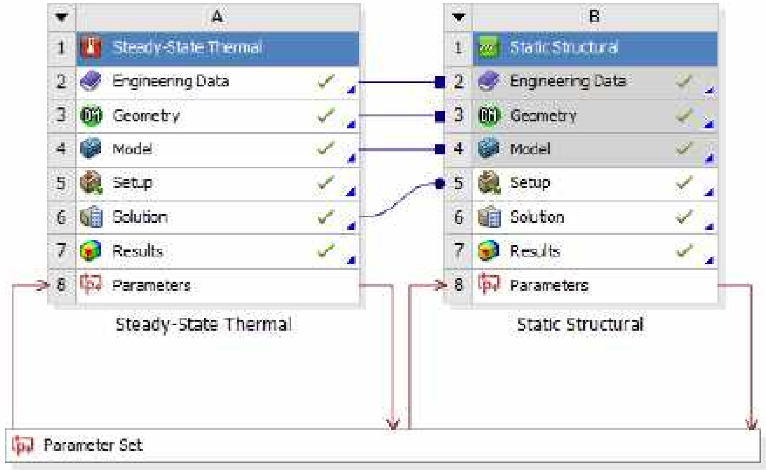
mF results

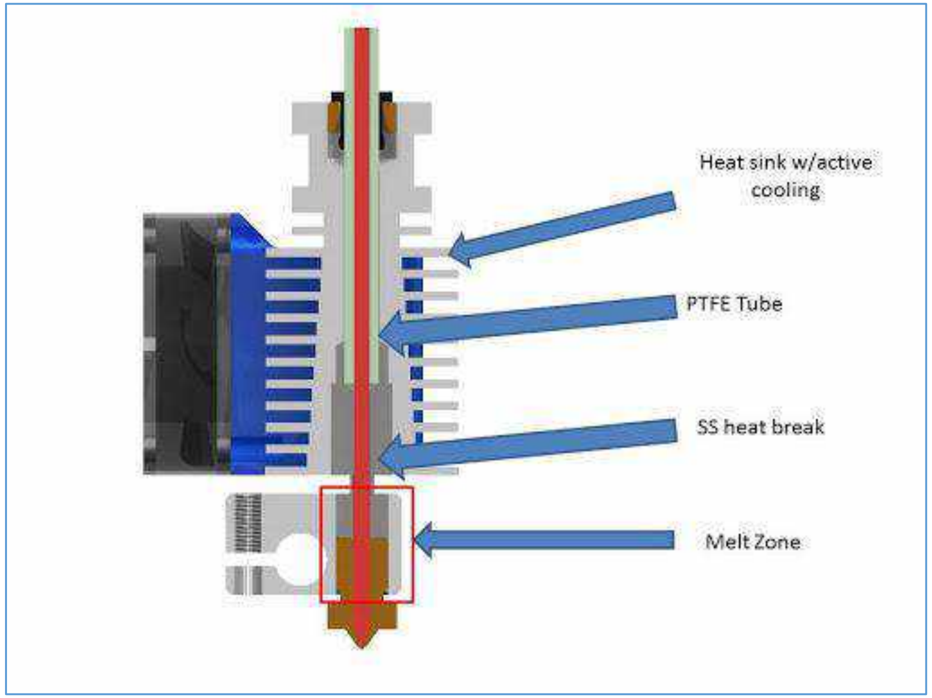


Stress/Thermal Model

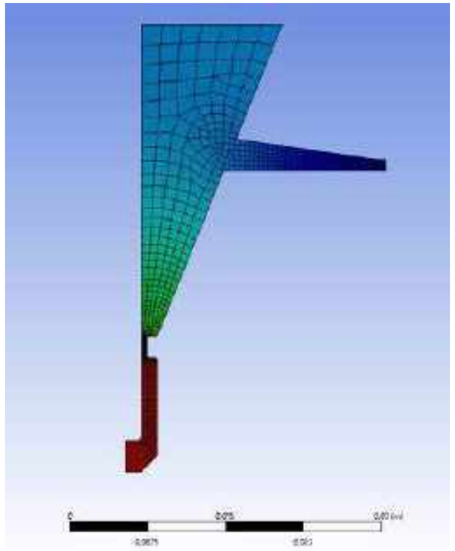




FDM Printer Head Design



Best design (#612)



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3D Wing Minimum Drag Optimization

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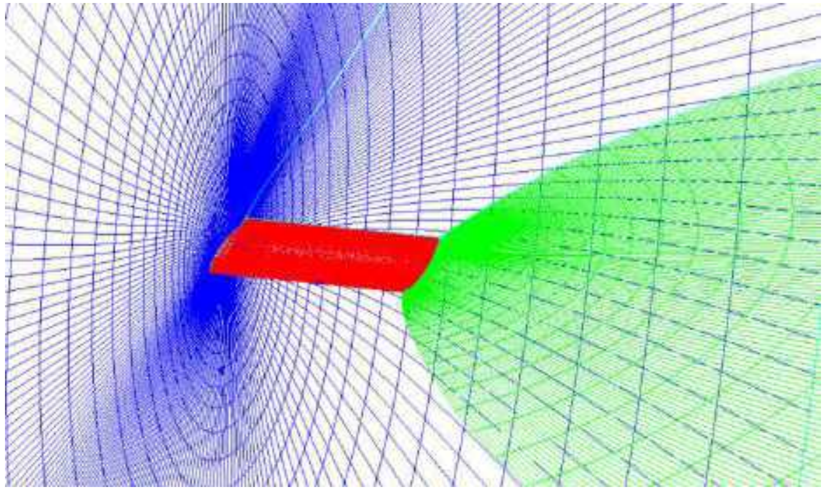
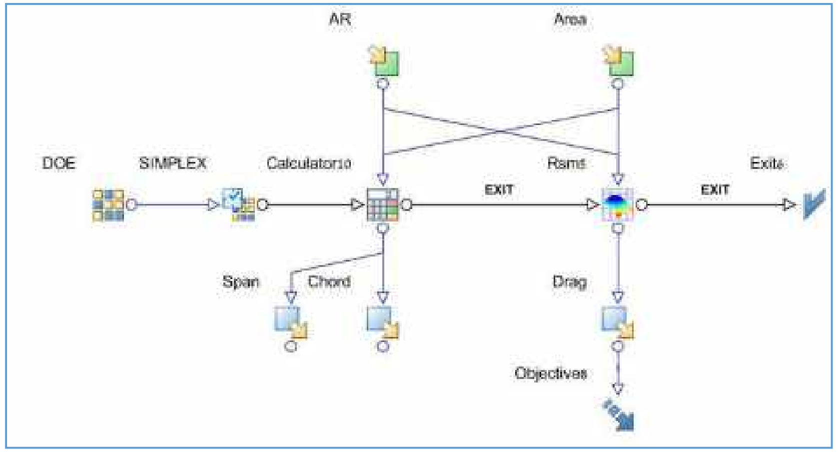
Mesh



**Benchmark Super Critical Wing (BSCW)
(from Aeroelastic Prediction Workshop)**

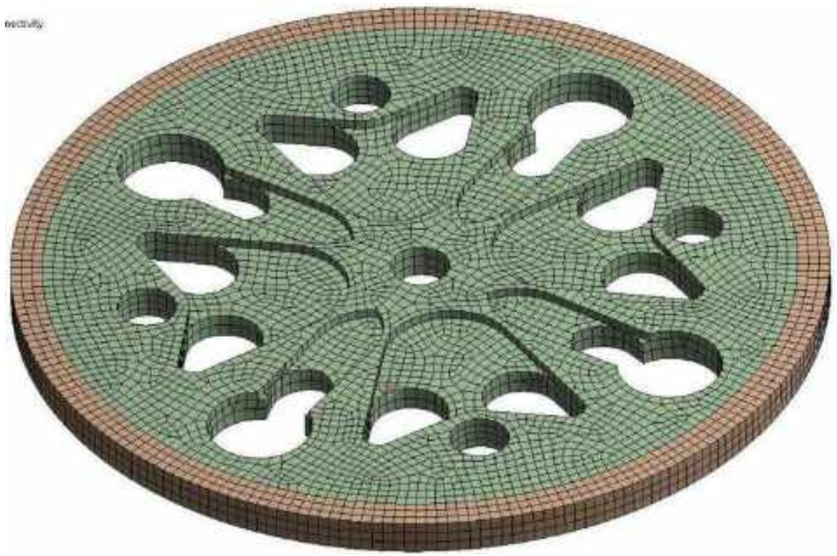
**CFD-based design optimization:
RSM formulation, Kriging & RBF**

**modeFRONTIER
model**



Disk Optimization (under acceleration)

Shape Optimization ← **Topology Optimization**



600 designs
27% Mass Reduction

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Shape & Topology Optimization of a Bracket

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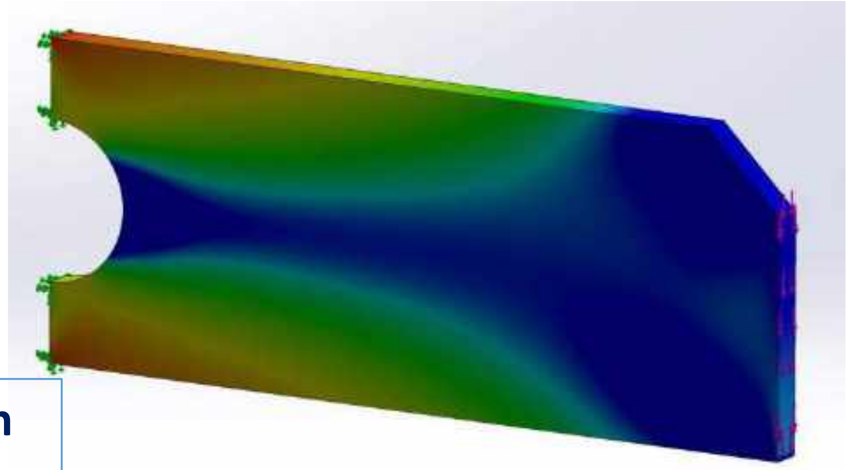
Topology optimization

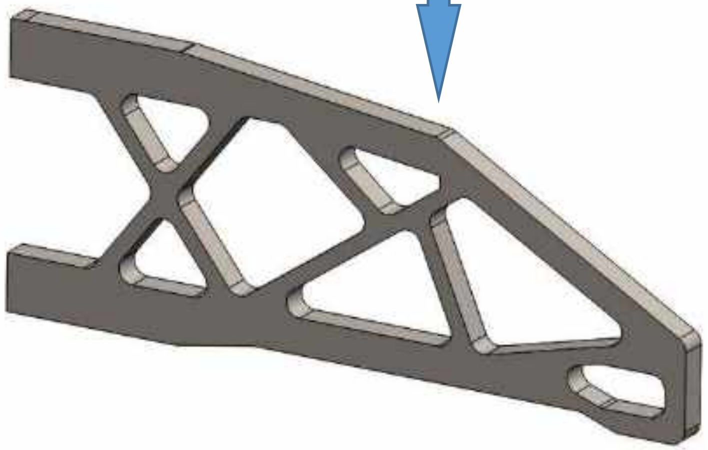
100%
מסה

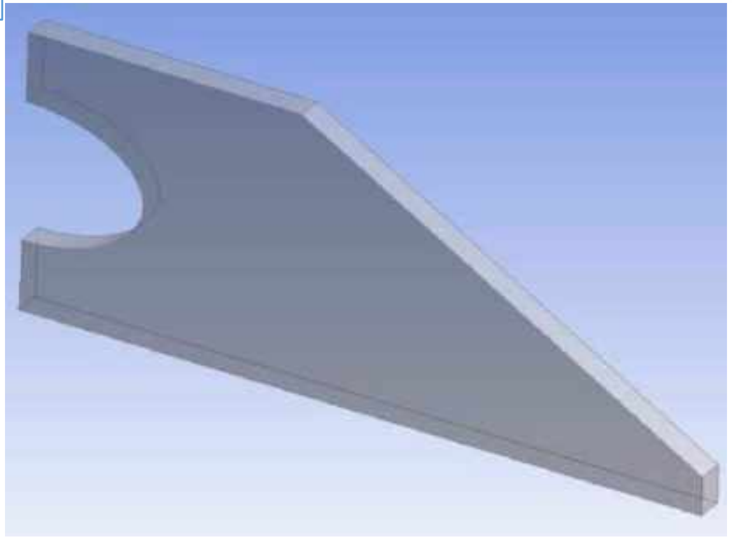


Shape optimization
(220 designs)

Shape optimization
(486 designs)

41%
Mass





71%
Mass

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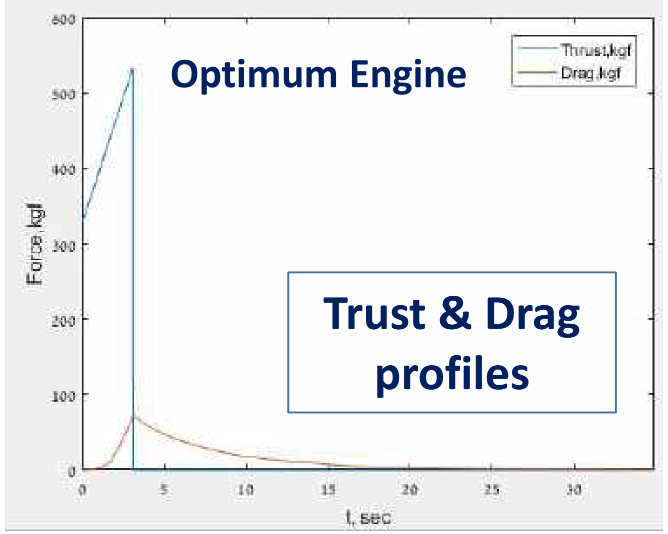
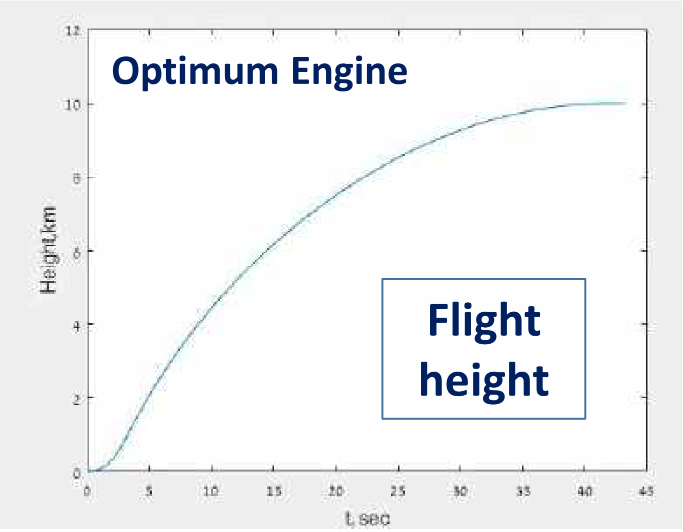
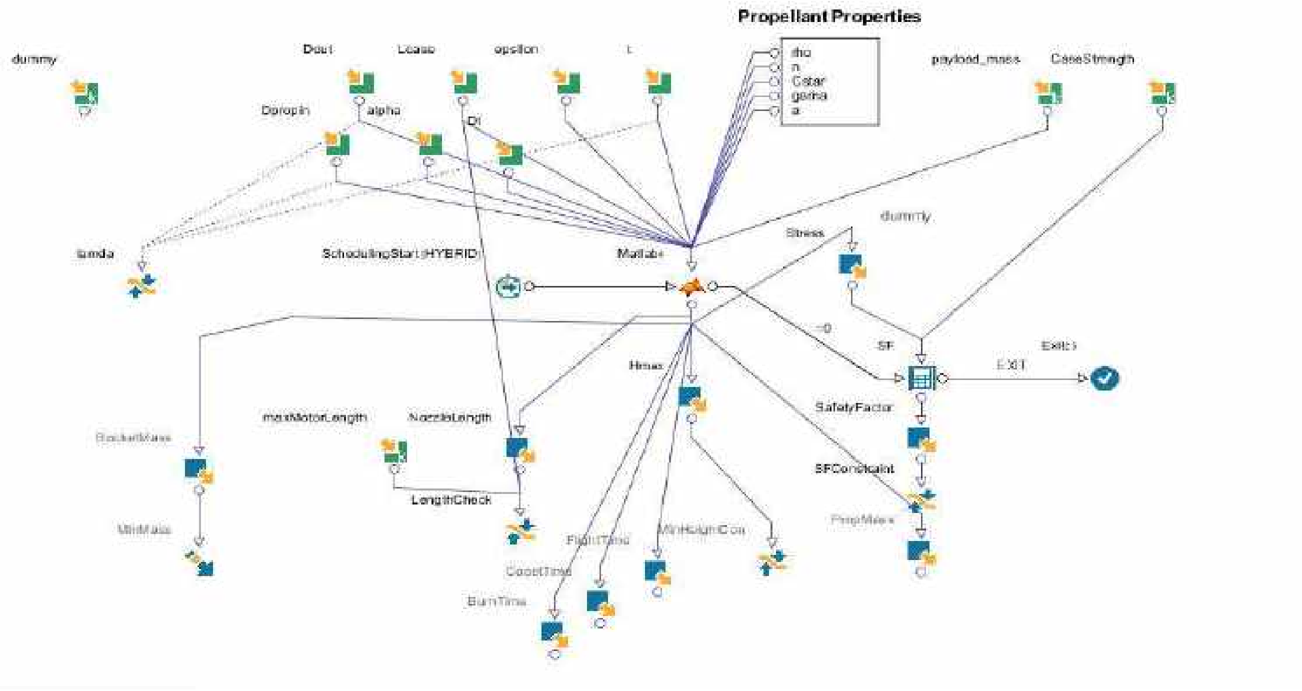
Rocket Engine for Maximum Height
(Goddard problem)





modeFRONTIER/MATLAB model



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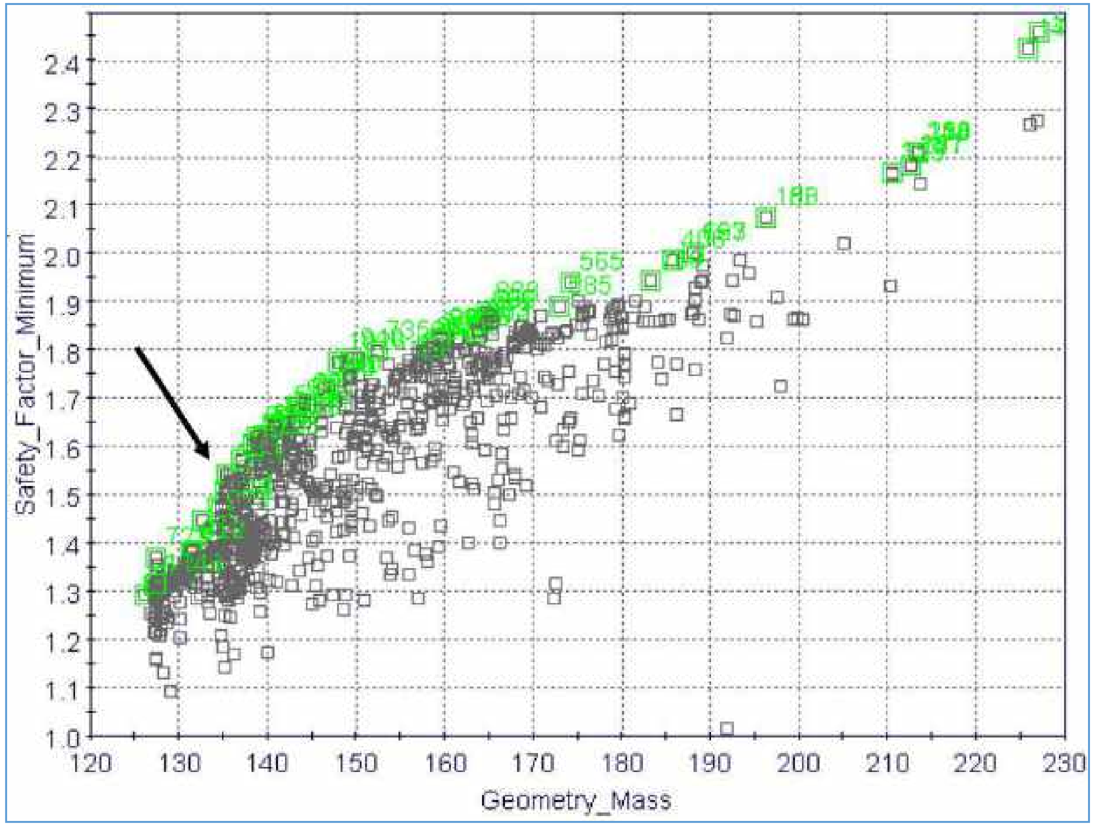
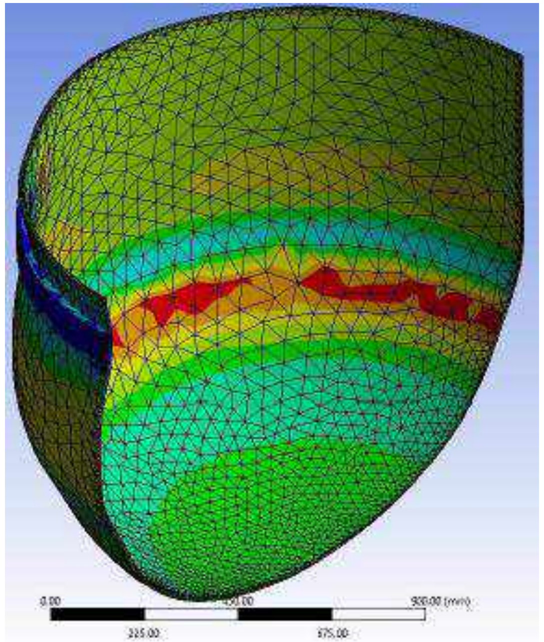
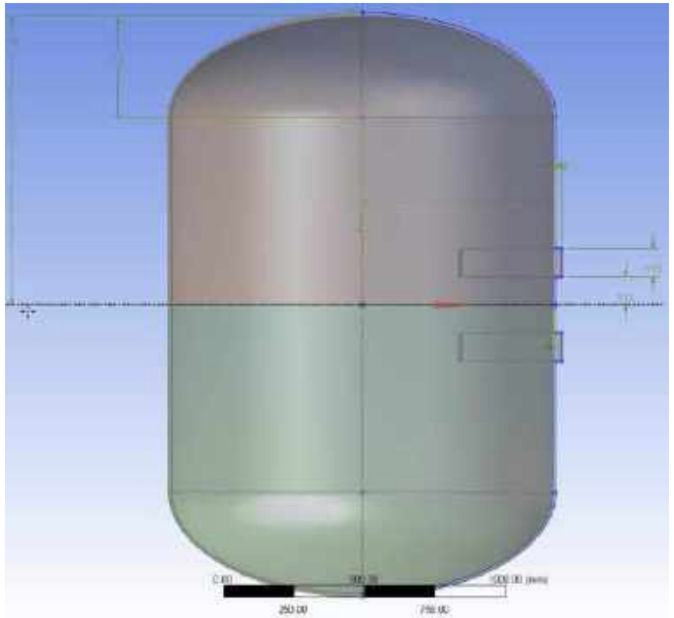
Pressure Vessel Optimization







Initial design	Optimum design	Parameter
675 [mm]	681.87 [mm]	R_shell
1020.5 [mm]	1026.5 [mm]	half_l
10 [mm]	6.5215 [mm]	t_Shell
12 [mm]	6 [mm]	t_head
358 [mm]	411.78 [mm]	h_head
212.86 [kg]	135.34 [kg]	Mass
1.973	1.543	Safety Factor

t_shell – עובי החלק הגלילי של המיכל
t_head – עובי החלק האליפטי של המיכל
R_shell – רדיוס המיכל בחלקו הגלילי
half_L – חצי אורך המיכל הפנימי
h_head – גובה החלק האליפטי של המיכל

Topology & Shape Optimization of a Bike Frame

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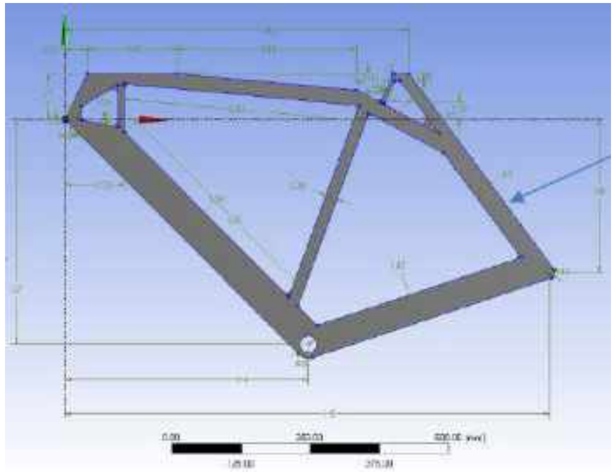
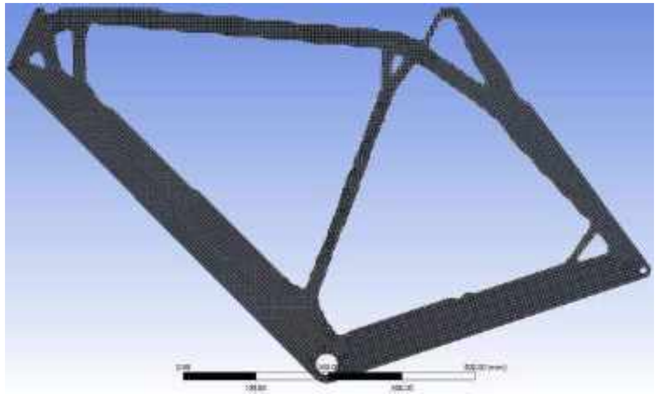
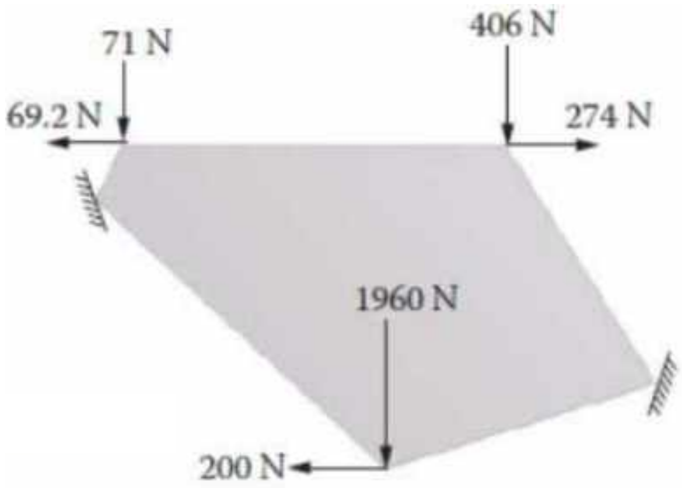
Requirements: Mass->min, SF>3

New model preparation



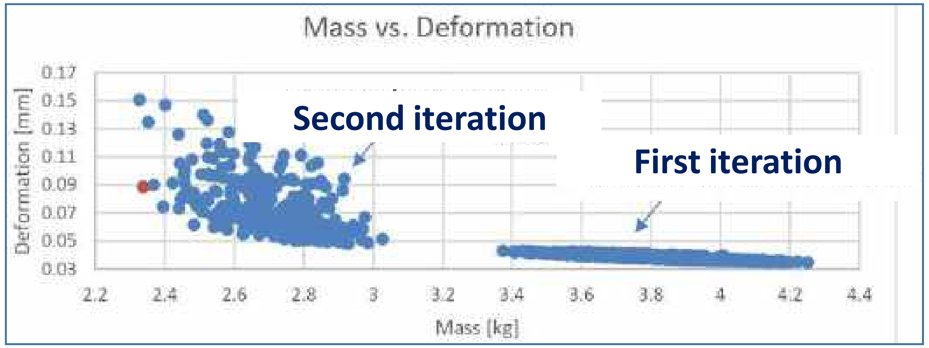


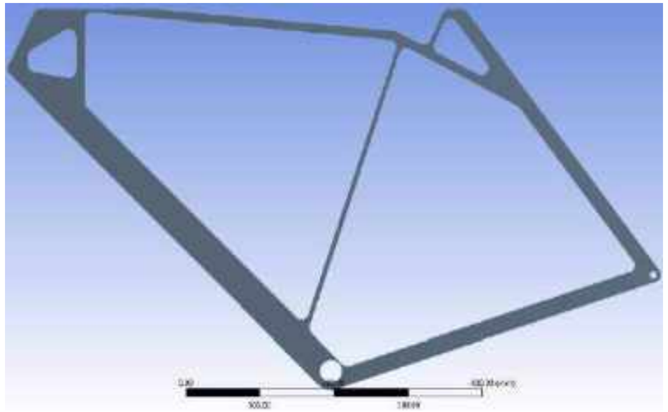
Topology optimization



The constraints and loads at the head, seat, and pedal positions.

Shape optimization



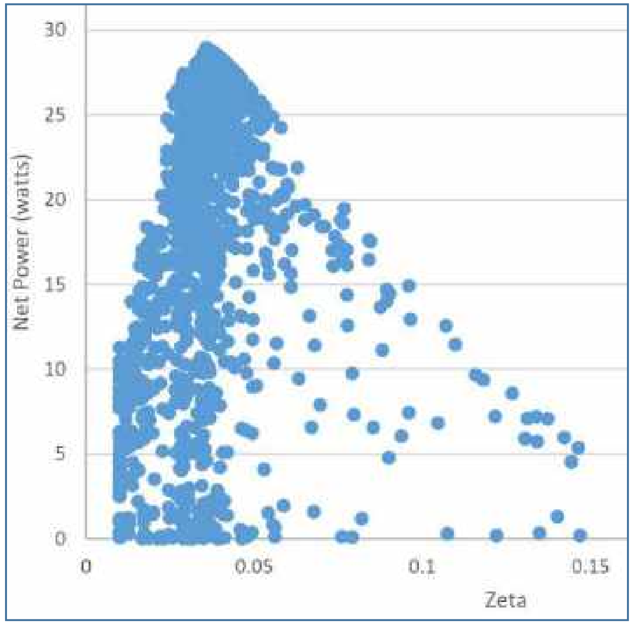


Optimum design:
79% mass reduction
SF=3.2

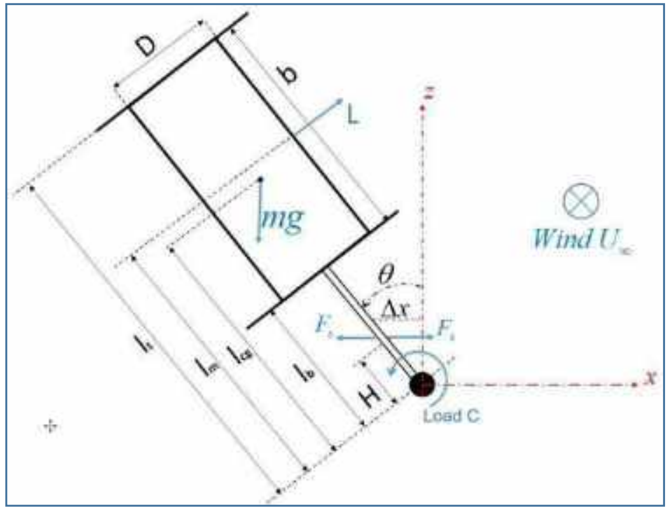
Wind Energy Converter Optimization

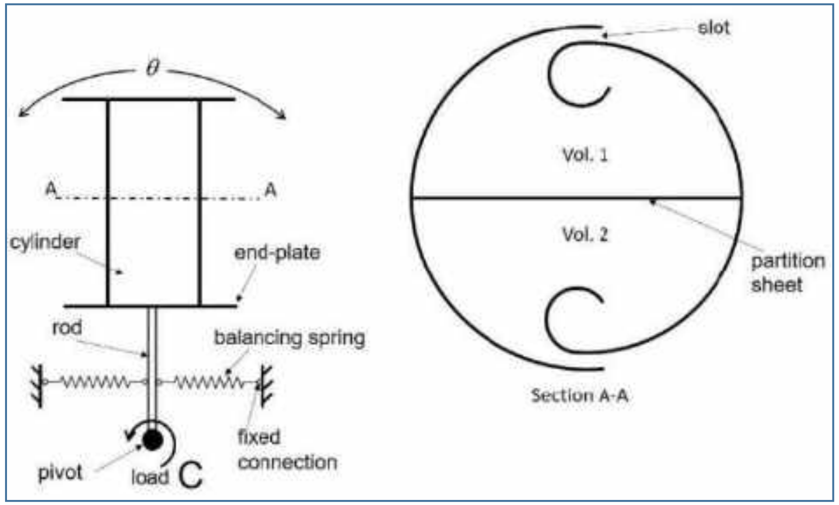
modeFRONTIER: MOGA-II, 10 random and 10 SOBOL parents, 5000 iterations

Oscillating wind energy converter uses the pulsed Coandă effect. It optimized to extract the maximum power from the wind.



Net power vs. damping





Maximum net power for the given wind speed is achieved for a specific value of the damping (representing load that extracts the power from the system's oscillations)

$$J_0\ddot{\theta} + C\dot{\theta} + K\theta - L_{CG} \cdot mg\sin(\theta) = M(t)$$

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Bypass Optimization for a Turbo-Fan

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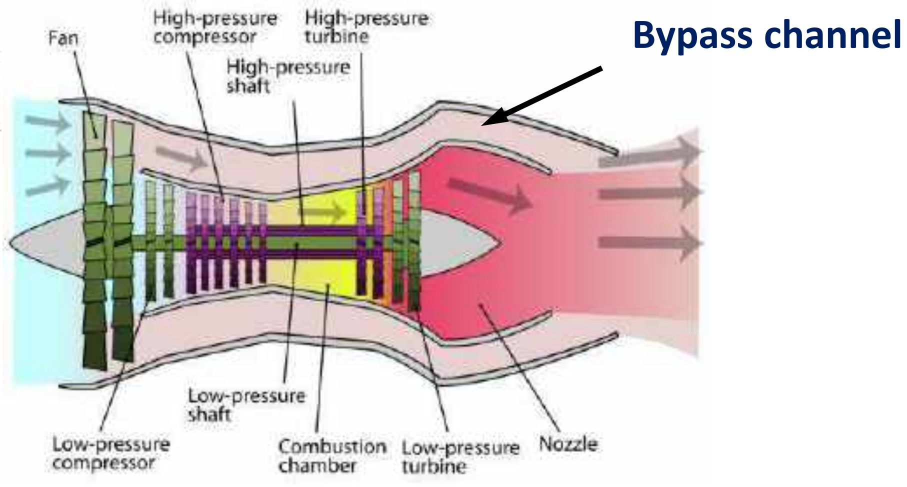
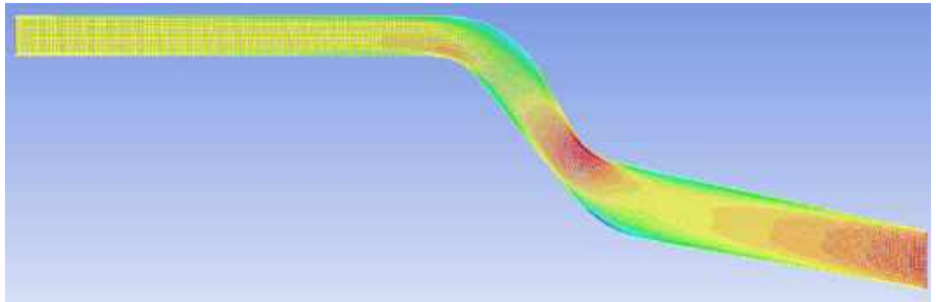
Results (2000 designs)
Thrust: +3.5%
Pressure Loss: -6.5%

Objectives	
Minimum Pressure Loss	$Min\left\{\int\left(P_{0\,in}-P_{0\,out}\right)dA\right\}$
Maximum Thrust	$Max\left\{Thrust=\int\rho\cdot V_{out}\left(V_{out}\cdot\bar{n}\right)dA\right\}$

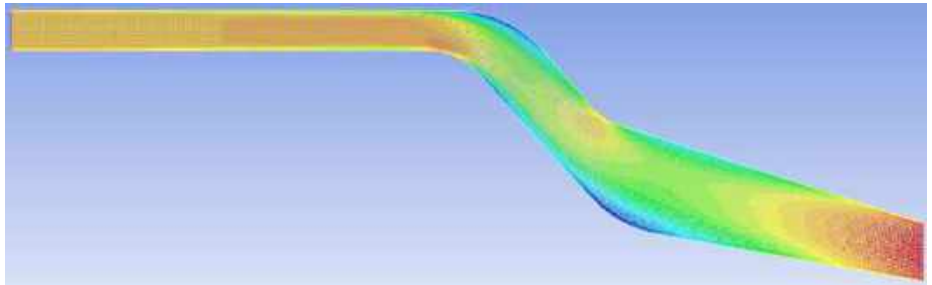
Turbo Fan schematic

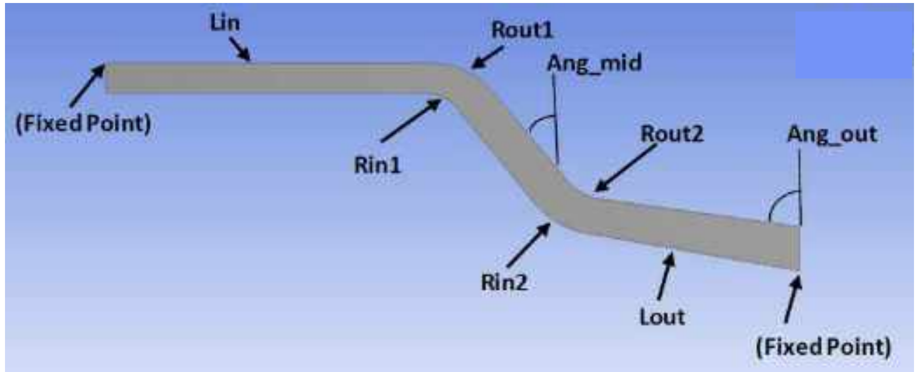


Velocity field
Base case



Velocity filed
Optimum case





Optimization of an Elliptical Helical Spring

Optimization

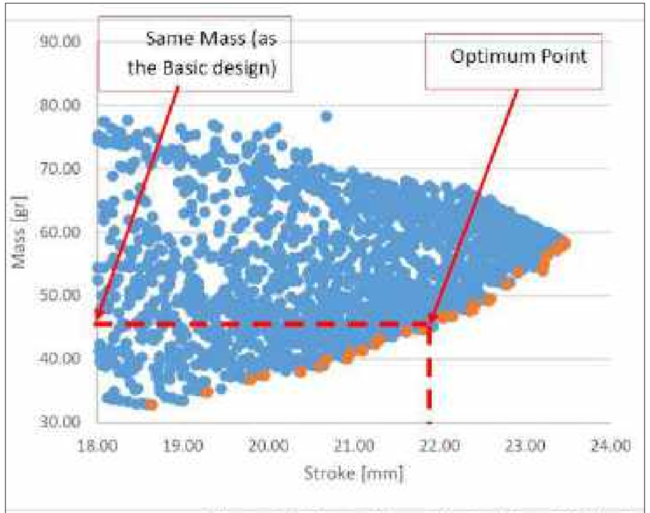
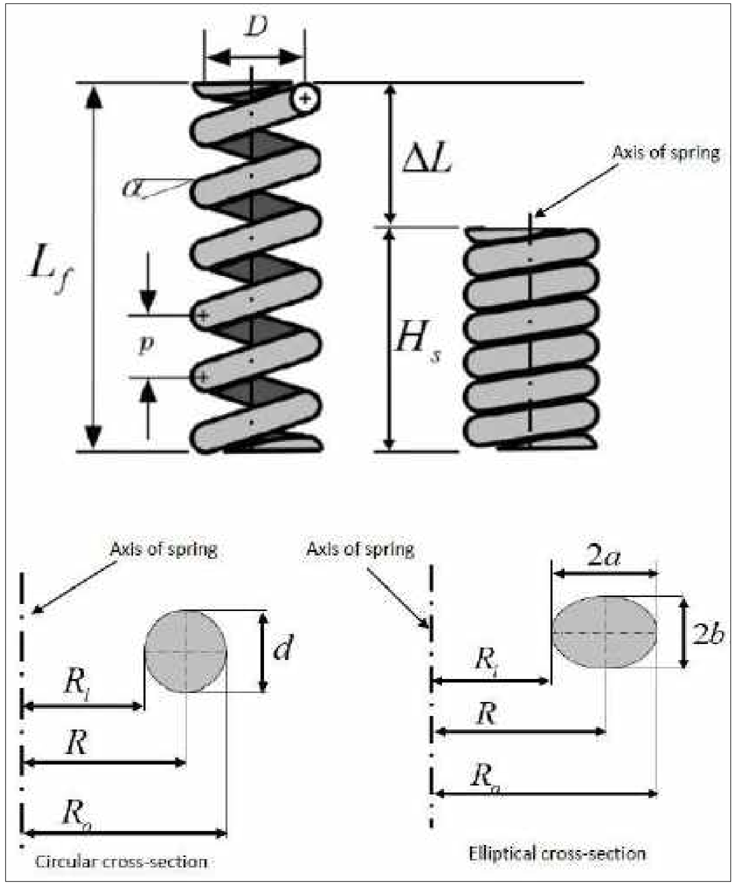


Figure 29: Pareto Curve- Spring Mass VS Stroke

Design Definitions

Design variables	Design conditions	Design objectives
$1 \le r \le 1.4$ $5.5 \le C \le 7$ $5^\circ \le \alpha \le 7^\circ$	Spring constant K and maximum stress τ_{eq}^{max} are kept constant (same as the basic design).	A: Minimize (M) B: Minimize (H_s)
$1 \le r \le 1.4$ $5.5 \le C \le 7$ $8.25[mm] \le R \le 17.5[mm]$ $5^\circ \le \alpha \le 7^\circ$	Spring constant K is kept constant (same as the basic design).	Minimize (M) and Minimize (S_F)
$1[mm] \le b \le 2.75[mm]$ $1 \le r \le 1.4$ $5^\circ \le \alpha \le 7^\circ$	Spring constant K and solid height H_s are kept constant (same as the basic design).	Minimize (τ_{eq}^{max})
$1 \le r \le 1.4$ $5.5 \le C \le 7$ $8.25[mm] \le R \le 17.5[mm]$	Spring constant K and free length L_f are kept constant (same as the basic design).	A: Maximize (ΔL) B: Minimize ($\Delta \tau$)



- ✓42% reduction of mass
- ✓24% reduction of solid height
- ✓30% reduction of stress gradient
- ✓7% increase of stroke

M. Gzal, M. Groper and O. Gendelman, "Analytical, experimental and finite element analysis of elliptical cross-section helical spring with small helix angle under static load", International Journal of Mechanical Sciences, 130, p. 476-486, 2017.

Optimization of a Support for Vibration Test

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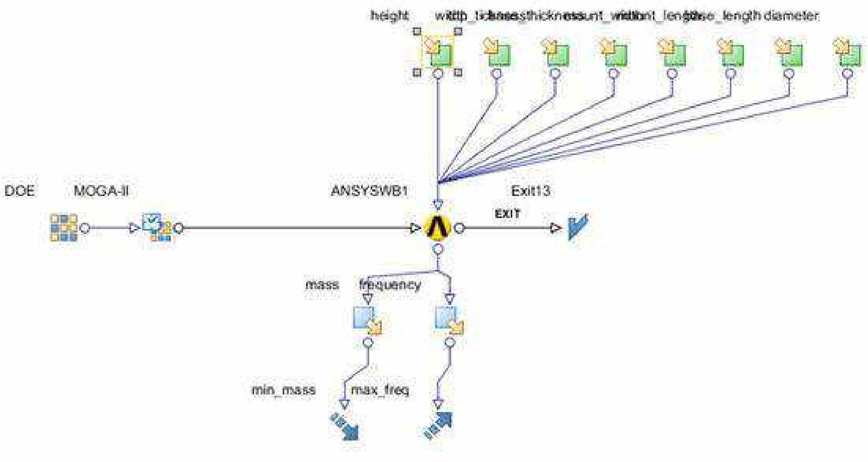
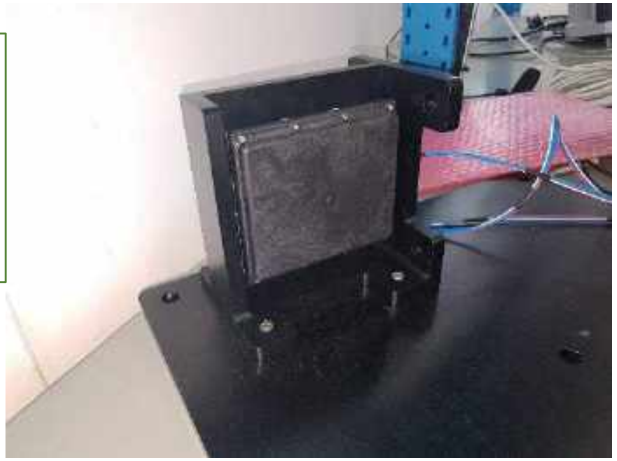
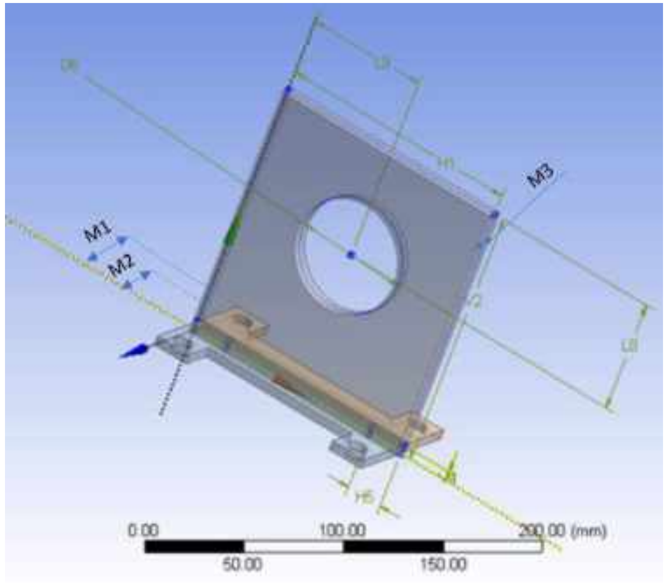


System requirements

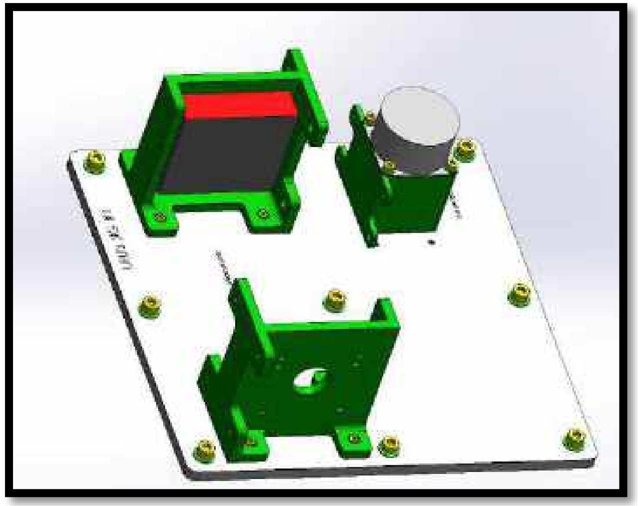
- **Natural frequency above 360Hz**
- **Minimum mass (there is 0.5kg mass in the center)**
- **Stress Safety Factor above 1.1 for all regimes**



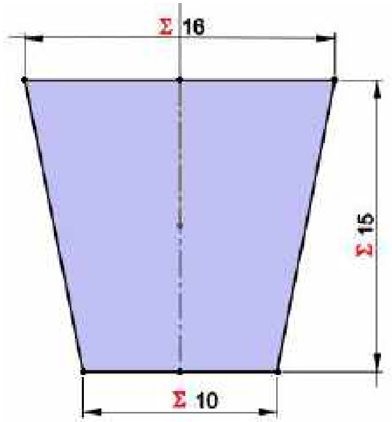


Design #	Freq [Hz]	Mass [kg]
0	258	1.4
466 (opt)	384	0.8
Improvement	48%	43%

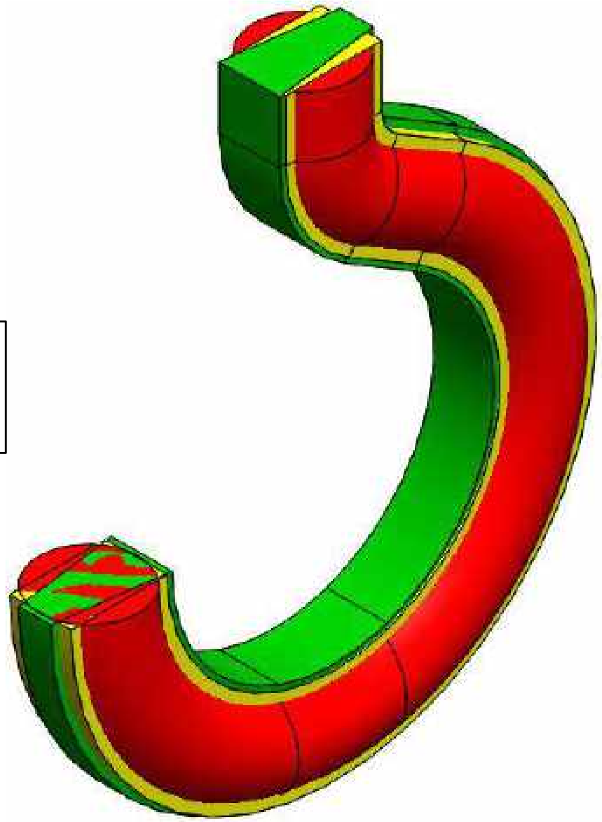
Schematic of the Support



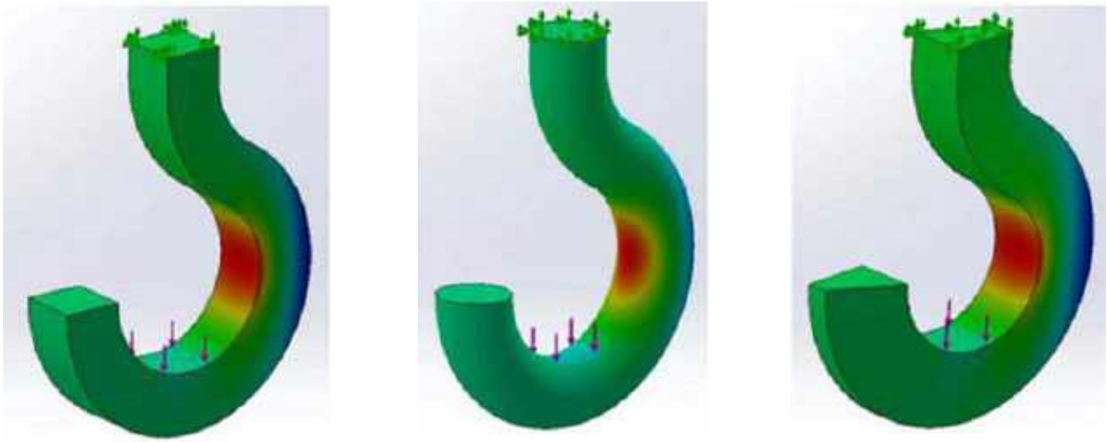
Optimization of a Crane Hook



Optimum configurations comparison



3 cross-sections – rectangular, round & trapezoidal



37% mass reduction
(relative to a round cross-section)

Real hook

Requirements:

- ✓ Carrying up to 3000 [N]
- ✓ Material: Al 6061-T6
- ✓ Safety Factor > 1.1
- ✓ Minimum hook mass

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U-bend Heated Channel Optimization

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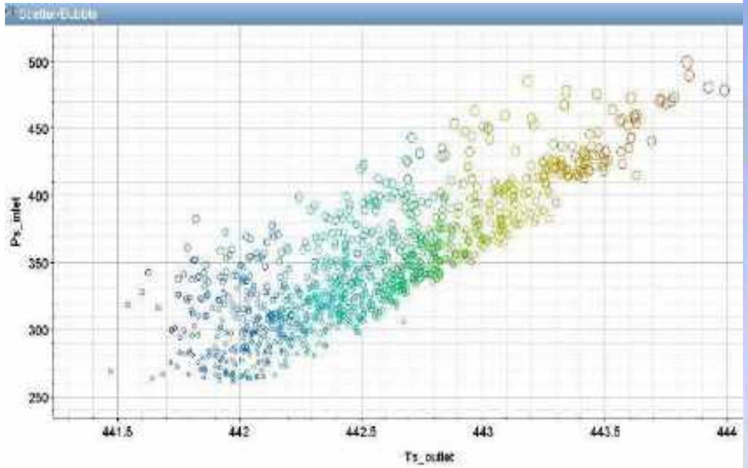
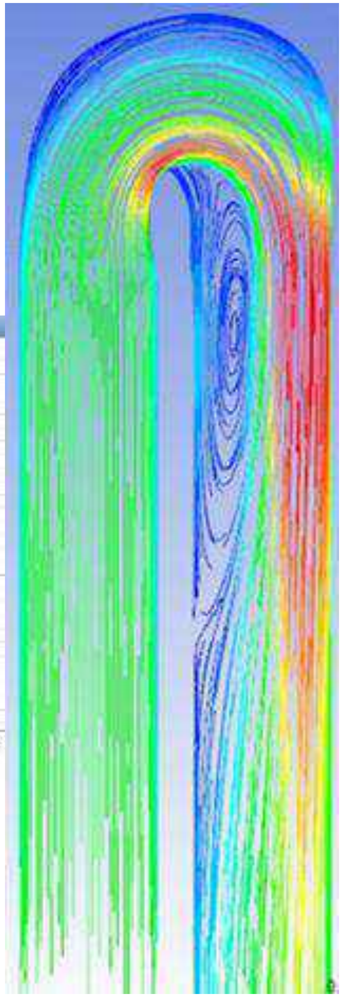
26% of pressure loss reduction

Pressure vs Temperature

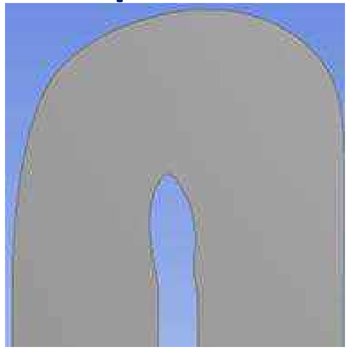


modeFrontier, MOGA-II
1200 designs

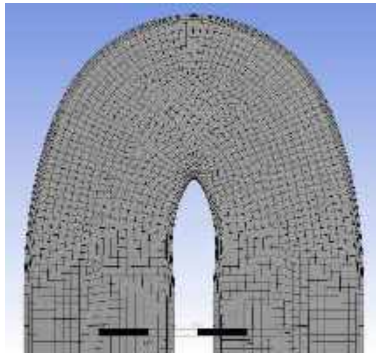
Velocity

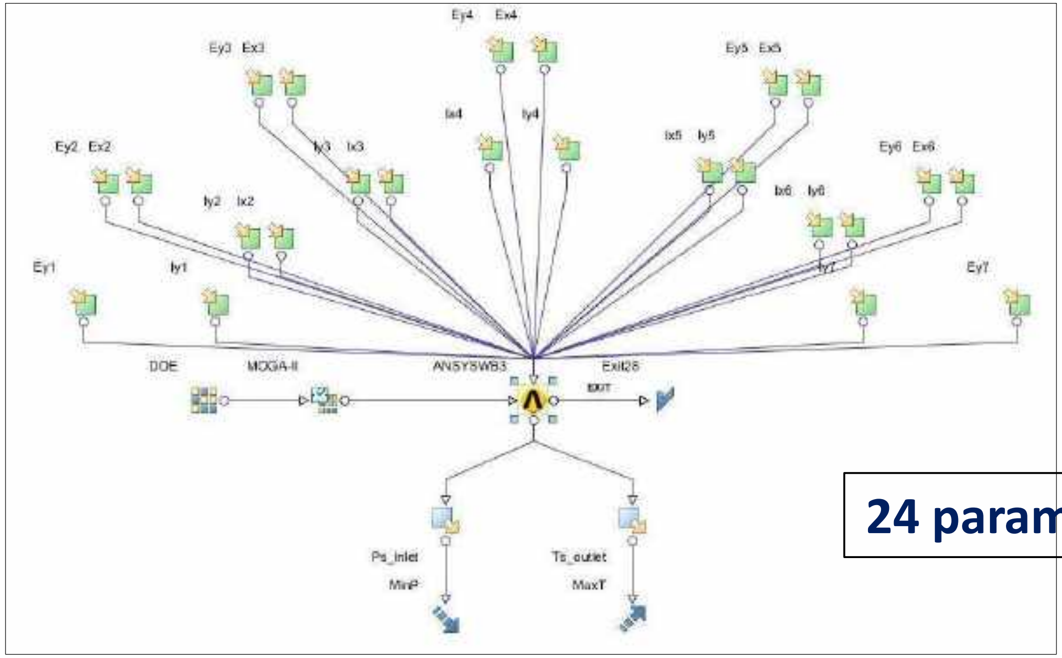


Optimum

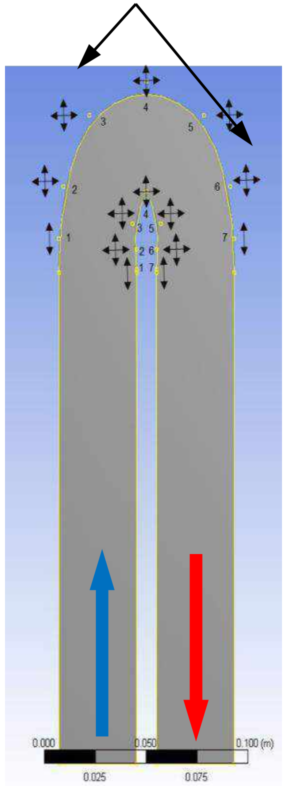


Base





Spline



24 parameters

Optimal Preliminary Design of a Rocket Motor

modeFRONTIER, NSGA-II, 1440 designs

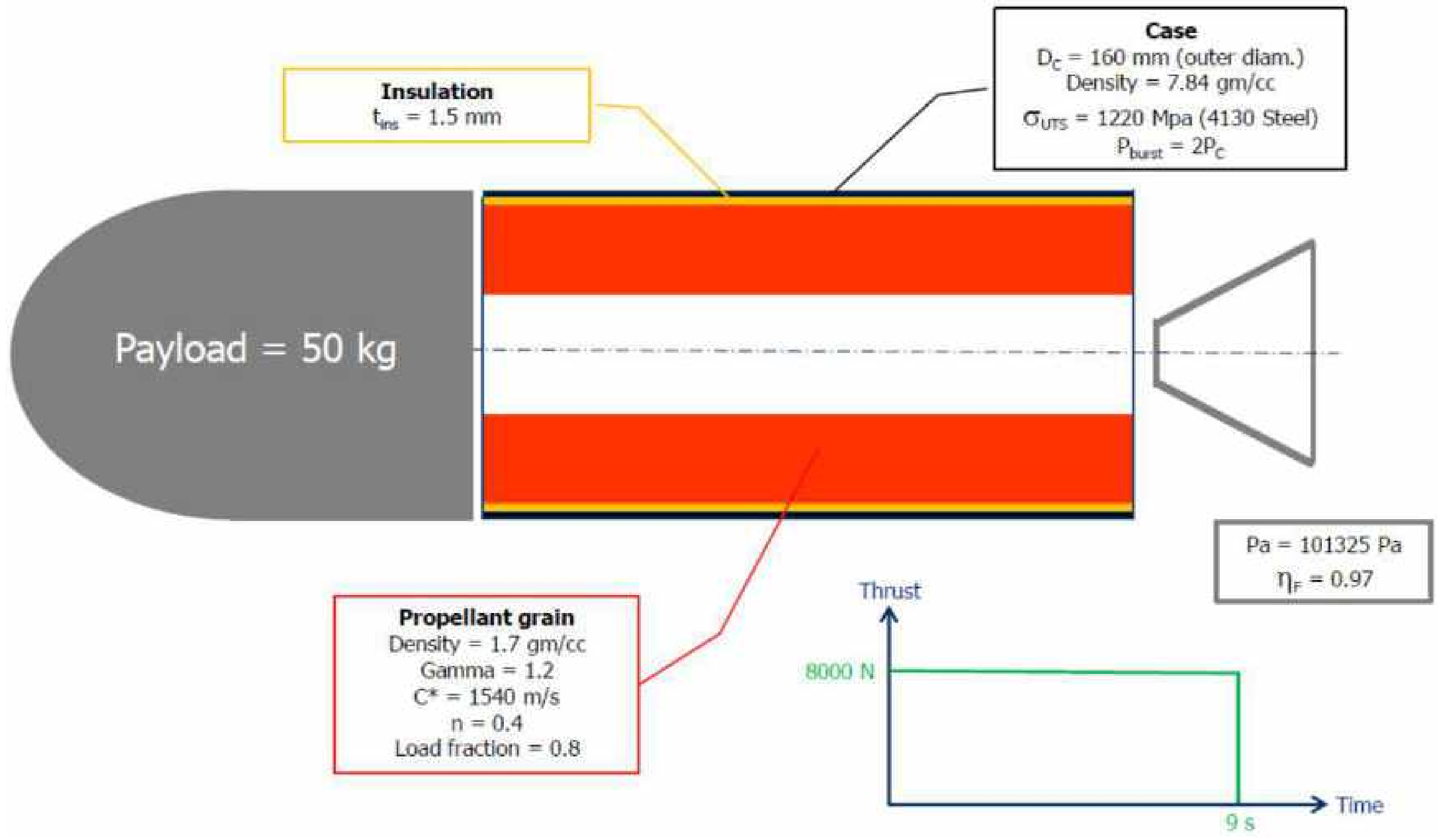
$$\Delta V = g \cdot I_{sp} \cdot \ln\left(\frac{m_{payload} + m_{propellant} + m_{case}}{m_{payload} + m_{case}}\right)$$

Objectives:
- ✓ Maximum velocity
- ✓ Minimum total mass

Optimum design

$$(\Delta V)_{\max} = 1040.2\ m/s$$
$$(m_{total})_{\min} = 85.1\ kg$$

$$P_c = 88.95\ bar$$
$$\lambda = 9$$
$$\alpha = 5°$$
$$d_e = 88.4\ mm$$
$$d_t = 26.9\ mm$$



Dynamic Model of FSAE Racecar

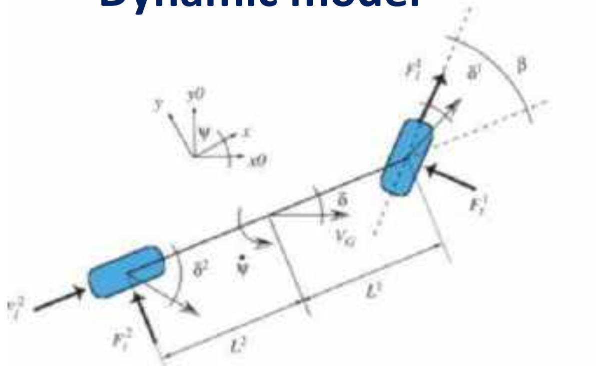
DEPARTMENT OF AEROSPACE ENGINEERING

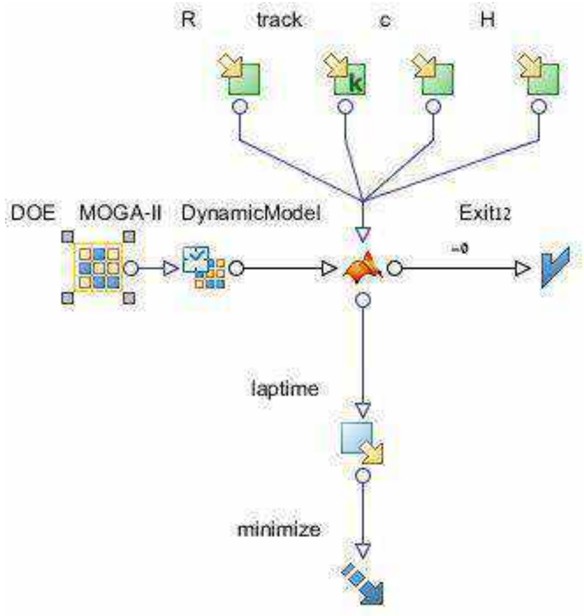
TECHNION Israel Institute of Technology

Formula Student is the largest world-wide student engineering competition. About 600 student teams from around the world annually design, build, test and eventually race a small-scale formula style racing car. We are team members of Formula Technion racing team.

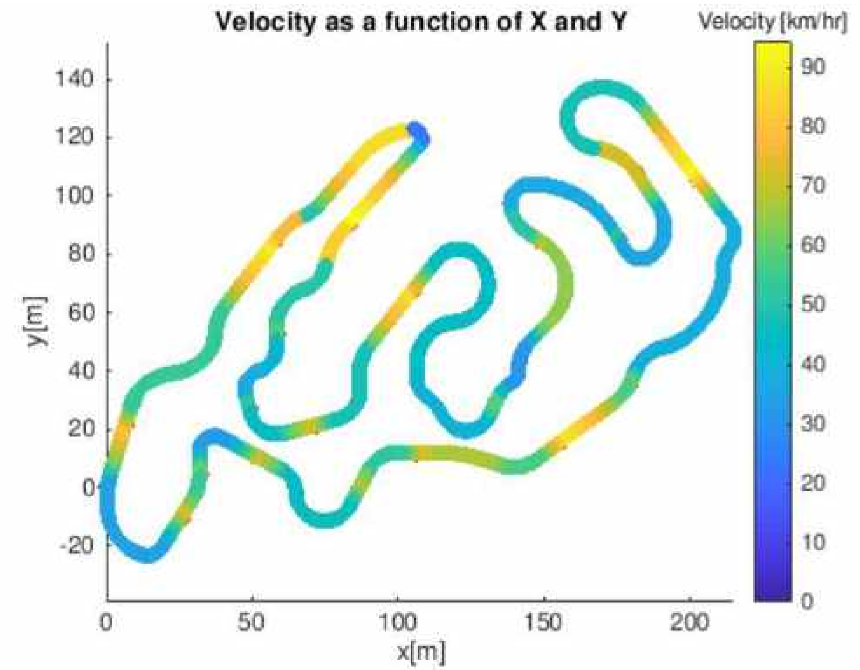
Formula Technion 2018 car on the formula student Germany competition track

Dynamic model





Optimum velocity map



In order to reduce our car's design duration and to achieve the shortest lap time, we would suggest that the project would take up the skill and software of modeFRONTIER for the years to come.