FORMULA TECHNION

Concept & System Engineering

Design Process & Deadlines

- **August 15th 2018** – Work on FT19 begins with team leader and system engineering.
- **October 21st 2018** – Manpower distributed; Vehicle concept freeze; System level design begins
- **November 7th 2018** – System requirements review; System concepts freeze
- **December 1st 2018** – Preliminary design review; Optimal alternative chosen
- **January 12th 2019** – Critical design review; One week to complete design freeze; Manufacturing begins
- **April 22nd 2019** – First vehicle drive; Preparation for static events begins; Manufacturing of aerodynamics
- **June 19th 2019** – Vehicle is in final state; Logistical preparation for the competition

Vehicle Evolution Since 2016

year	Weight [Kg]	Power [HP]	Downforce [N] at 80 [Km/h]	Drag [N] at 80 [Km/h]	Chassis roll stiffness [Nm/deg]	C.o.M height [mm]	Distance driven pre-competitions [Km]	Place
2016	253	77	n/a	n/a	600	320	600	East, 9/24 Cz, 8/25
2017	187	50	715	450	875	280	400	Aust, 8/31 Germany, 50/65
2018	139	58	1050	415	1250	250	280	Aust, 18/30 Germany, 35/60
2019	128	62	1100	415	2000	250	800	TBD

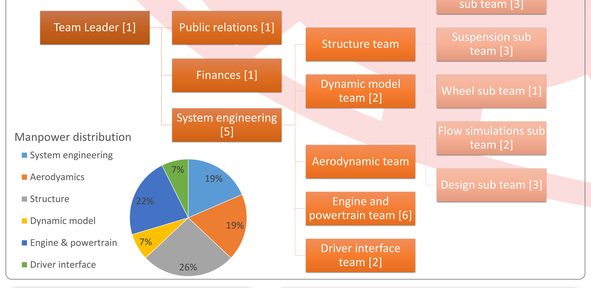
Establishing Vehicle and System Level Requirements

Vehicle-level 2019 Requirements:

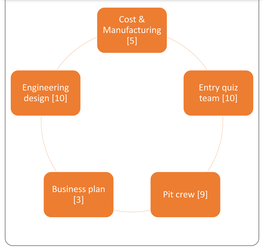
- Max Total weight of 130 Kg (W/out driver, ready-to-race)
- Minimum 60 Horsepower @ 8000 rpm
- Maximum C.o.G Height of 250mm
- Maximal gear-shift time: 40 milisecond
- Max wheelbase length of 1535 mm
- Front track: 1120 mm . Rear Track: 1150 mm

Weight Distribution

Team manpower structure



Designated teams



Engineering achievements

FT17 Austria, Germany
- Successful endurance track after a **COMPLETE** overhaul of FT16 vehicle and concept
- 3D titanium printed KTM muffler

FT18 Austria, Germany
- Top-mounted pedals
- First successful full vehicle CFD simulation
- DRS mechanism in rear wing
- Lightest winged vehicle in the competitions

FT19 Austria, Germany, Czech republic
- An active hydraulic anti-roll mechanism
- Transition form rod-end mounted A-arms to spherical bearings
- First transient weight distribution simulation of a defect track
- Radiators positioned inside the vehicle

Team Building

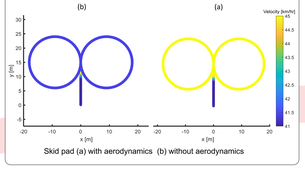
Challenges:
- Short team history (7 years)
- Non-existing Automotive industry in Israel
- Frequent manpower reshuffling (~1 year)
- Numerous issues from FT18

Measures:
- Close and constant relations with sponsors
- Designated training prior to design process
- Weekly team and sub team meetings
- Commercial organizational tools (GrabCAD, slack)
- Clear definition of responsibilities & interfaces
- Thorough documentation of issues and achievements

Performance

Aerodynamics Concept

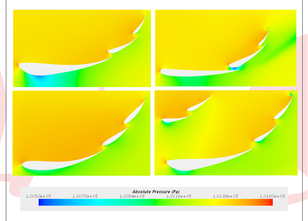
Utilization of overall concept change downforce/weight ratio
- **Aero pack weight reduction – from 14 kg to 11 kg**
- **Increasing downforce –1350N @ 80 kph (1000N@2018)**
  Reducing drag – 430N @ 80 kph (480N@2018)
  - Second year using CFD full car simulations for aerodynamic design
  - Aerodynamic interfaces maximizing overall downforce
- **Optimizing car performance** – automatic DRS.



Skid pad (a) with aerodynamics (b) without aerodynamics

CFD

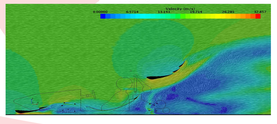
CFD simulation design procedure:
- Simulating changes in each wing per simulation
- Post-processing using velocity and pressure results
- Optimizing pressure distribution across the whole car.
- Increasing out-wash from front wing
- Directing air flow to the cooling system
- Proving divergence in analysis
- Increasing details and complexity in model



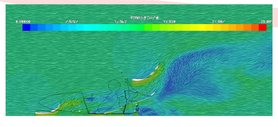
Simulations

CFD simulation results:

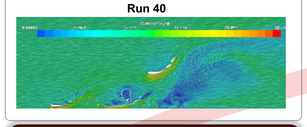
Run 6



Run 20



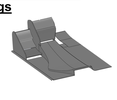
Run 40



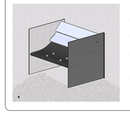
Final Design

Front wing

Undertray & Side wings



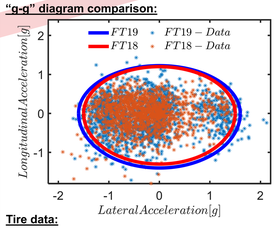
Rear wing



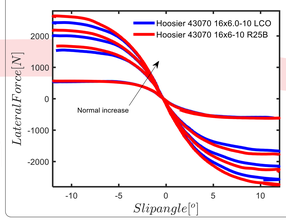
Aerodynamic Parameters @80Kph:
- $C_L A = 4.3$
- $C_D A = 1.65$
- $\frac{Downforce}{Weight} = 0.675$
- $\frac{Downforce}{Drag} = 3.13$

Vehicle Performance

"g-g" diagram comparison:



Tire data:



Spring & Damper

FSAE Ohlins TTX25 MKII:

$f_{front} = 4.6\ Hz$ $\quad f_{rear} = 4.9\ Hz$

$K_s = 4\pi^2 f_r^2 m_{sm} MR^2$ $\quad K_{s_{rear}} = 61.3\ kN/m$

$K_{s_{front}} = 43.8\ kN/m$ $\quad MR_{rear} = 0.82$

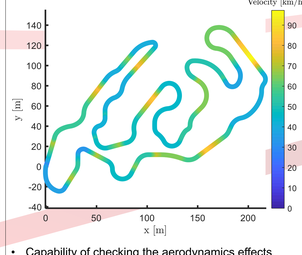
$MR_{front} = 0.91$ $\quad C_{rear} = 3500\ Nsec/m$

$C_{front} = 3000\ Nsec/m$

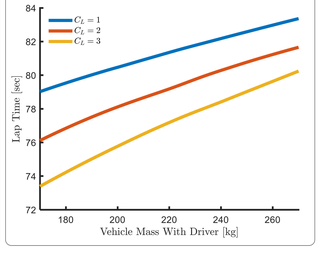
Two Degrees of Freedom System:

Dynamic Model

Main Improvements from last self developed model:
- Four wheels model
- Take into consideration the tire data
- Using dyno data
- Including the effect of the suspension system, spring and anti-roll system
- Option to consider adjustments as static camber and static toe

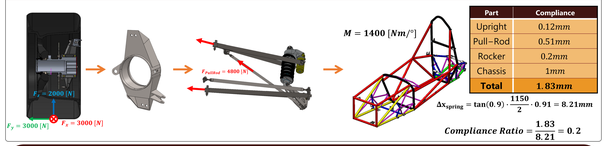


- Capability of checking the aerodynamics effects on lap times
- Including the effect of center of pressure of every aero component



Structure

Compliance Calculation



Part	Compliance
Upright	$0.12mm$
Pull–Rod	$0.51mm$
Rocker	$0.2mm$
Chassis	$1mm$
Total	$\mathbf{1.83mm}$

$$Compliance\ Ratio = \frac{1.83}{8.21} = 0.2$$

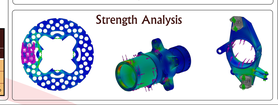
Wheel Assembly

General Changes
- Rear brake disc was removed from the axis center and replaced by a brake disc on each rear wheel.
- 18" Hoosier tires were replaced by 16" Hoosier tires.
- RPM sensor is adjusted radially instead of tangentially. Bearing spacer functions as encoder.

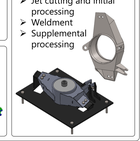
	FT 18 [gr]		FT 19 [gr]		Reduction Presents	
	Front	Rear	Front	Rear	Front	Rear
Assembly	7420	6400	6700	6750	↓10%	↑5%
Hub	360	444	240	430	↓33%	↓3%
Upright	330	372	290	260	↓12%	↓30%

Final Design

Strength Analysis

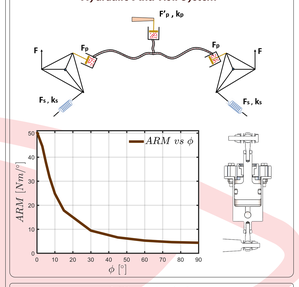


Manufacturing
- Titanium sheets (6Al-4v)
- Jet cutting and initial processing
- Weldment
- Supplemental processing



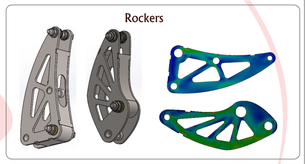
Suspension

Hydraulic Anti Roll System

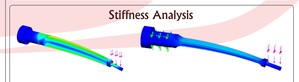


Suspension Assembly

Rockers



Stiffness Analysis

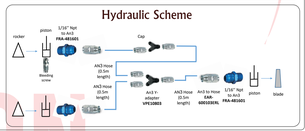


	Rigid mode	Soft mode
$K_\phi\ [N/m]$	200,380	17,950
$ARM\ [Nm/°]$	50.5	4.4

$$F'_D = 2tg(\theta)R\left(\frac{A_r}{A_p}\right)K_D$$

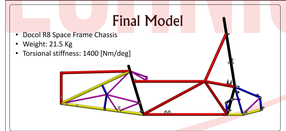
$$ARM = 4tg(\theta)R^2\left(\frac{A_r}{A_p}\right)^2 K_D$$

Hydraulic Scheme



Chassis

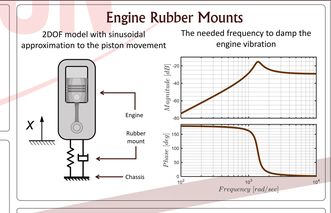
Final Model
- Dozol RB Space Frame Chassis
- Weight: 21.5 Kg
- Torsional stiffness: 1400 [Nm/deg]



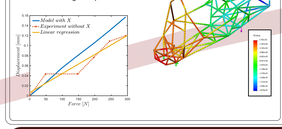
Engine Rubber Mounts

2DOF model with sinusoidal approximation to the piston movement

The needed frequency to damp the engine vibration



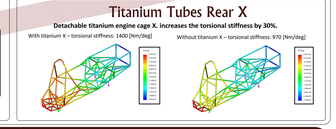
Integrated Carbon Fiber plates
- Function as aerodynamic floor of the car and as structural element.
- Increase the torsional stiffness by 25% and decrease 1.5 Kg of equivalent steel tubes.



Titanium Tubes Rear X

Detachable titanium engine cage X. increases the torsional stiffness by 30%.

With titanium X – torsional stiffness: 1400 [Nm/deg] | Without titanium X – torsional stiffness: 970 [Nm/deg]



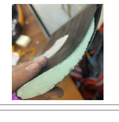
Aerodynamics

General
- Total weight: 11.5 kg
- Connections: rigid to the chassis
- Factor of safety: 1.5 for general design, 3 for composite materials connection.

Undertray and Side wings
- Carrier of the cooling duct
- Floor of the car

Rear Wing
- Head rest restraint supporter
- DRS housing
- Supported by carbon rods

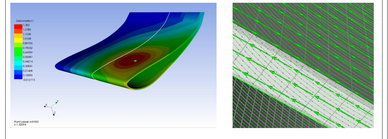
Front Wing
- Supported by titanium rods
- Mounted on mass optimized goose-necks
- Carbon-plastic printer hybrid elements.



Unique Manufacturing features
- Wet lay-up of Carbon T-300 CC 90 and epoxy 520
- Sandwich structure including Hexagon honeycomb, 3D printing, Polyurethane and Aluminum plates

Second year manufacturing composite materials in our workshop

Analysis validated displacement experiment with fiber orientation considerations.



FOR VIEW & TECHNOLOGY