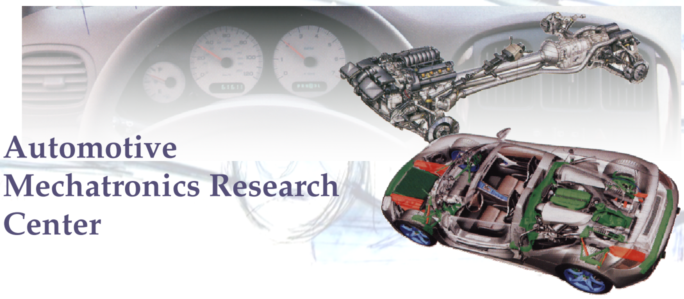
Designing All-Terrain Vehicle Frames Using Topological Optimization



Automotive Mechatronics Research Center

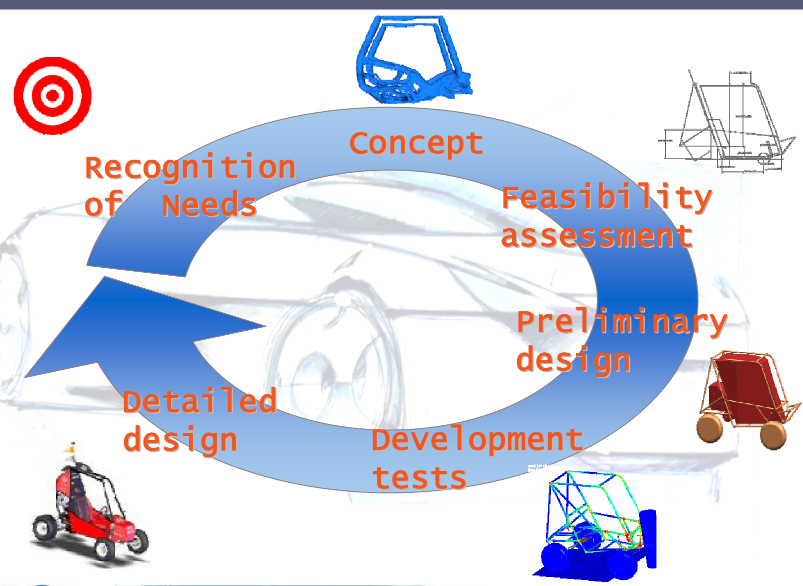
Problem description

- Energy absorption
- Lightness
- Support and packaging

Objectives

- Design a frame topology that packages the components of a vehicle and protect the pilot integrity. This structural steel frame (~36 Kgs.) must compete against thin walled frames made of alloyed steel (~28 Kgs.)
- Determine a topology that fulfills the operating conditions of the vehicle using topological optimization tools, satisfying Minibaja regulations.
- Determine a frontal nose topology that reduces the impact effects over the pilot.

Methodology



Recognition of needs

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Duties

- Safety
- Support

Main Characteristics

- Stiffness
- Energy absorption
- Regulation fulfilling

Operating conditions

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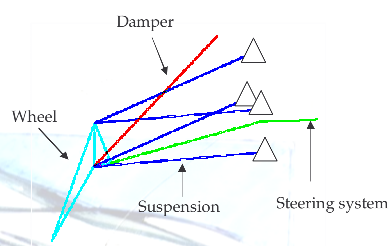
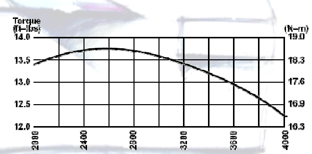
Loads

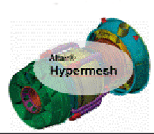
- Suspension

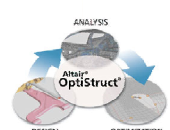


- Engine

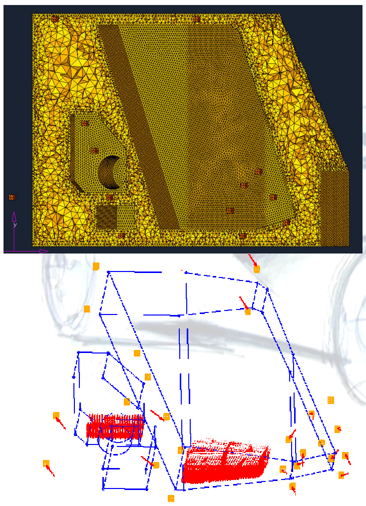


- Mass elements





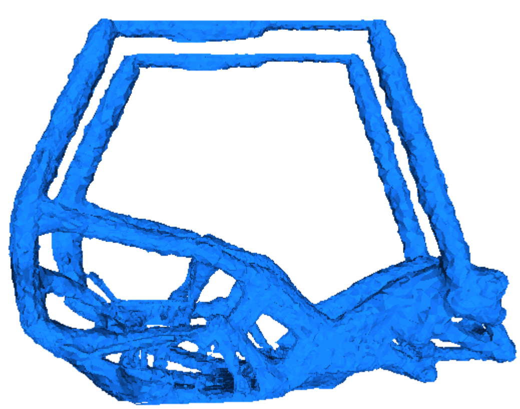
Conceptualization



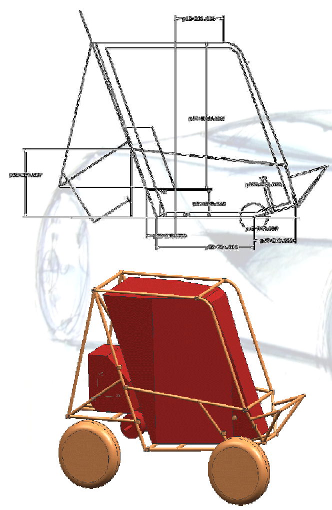
- Objective
- Removable material
- Void spaces
- Fixed points
- Operating conditions

Concept

The optimization process took 25 hrs. to determine the optimum topology for the specified load case. More than a million tetrahedral elements were used.



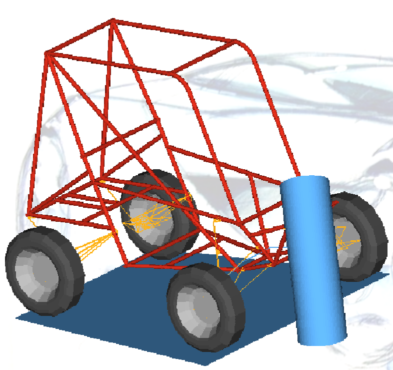
Project feasibility and preliminary design



- Packaging
- Ergonomic issues
- Manufacturing
- Competition regulations

Preliminary design

Frontal impact test

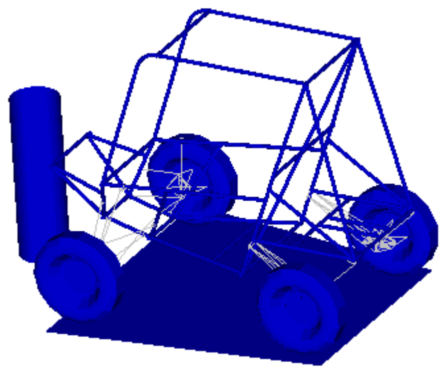


Against a tree at 25 km/hr with LS DYNA

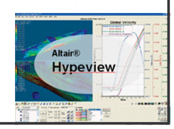
Assumptions

- **Homogeneous material that includes Strain Rate effects**
- **Perfect joints (no welding)**
- **Simplified components**
- **Undeformable tree.**

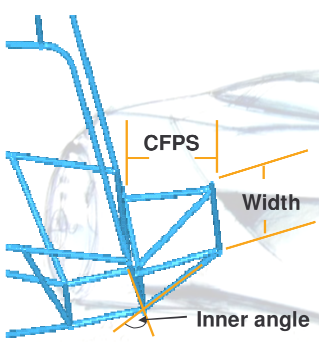
LS DYNA Model



- Shell and beam elements
- Suspension and steering system
- Contact pairs
- Termination time 0.12 s.



Influence and evaluation variables

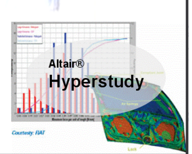


Input variables for frontal impact

- Nose width
- Roll cage and nose angle

Output variables

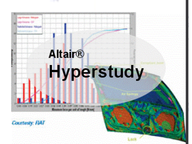
- Maximum acceleration
- Mean acceleration
- Closeness of frame to Pilot space (CPFS)



Design of Experiments Matrix

Exp	Factors 1	Factors 2
1	1	1
2	1	2
3	2	1
4	2	2

Level / Factor	Angle (deg)	Width (mm)
1	46.6	486
2	58.6	586



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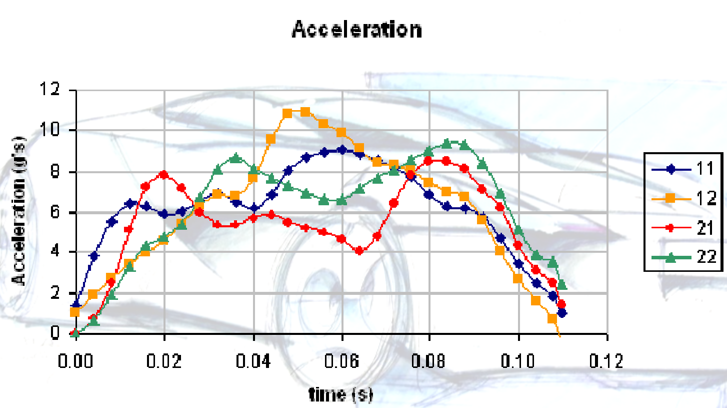
Acceleration plots



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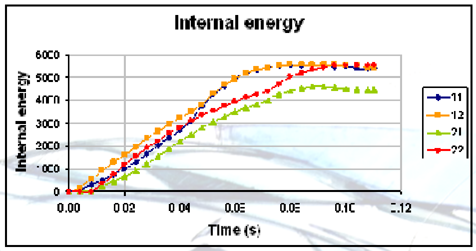
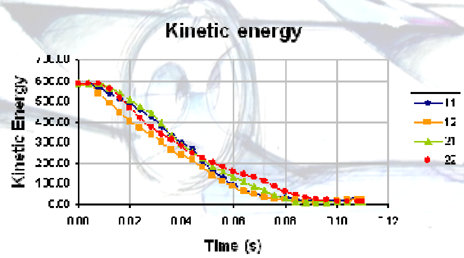
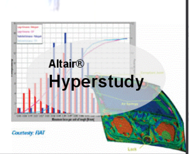
Energy





Results

Exp	FACTOR A (Angle, deg)	FACTOR B (Width, mm)	MAX ACCEL (g´s)	MEAN ACCEL (g´s)	DIST (mm)
1	46.61	486	9.01	6.28	119
2	46.61	586	10.25	6.13	115.6
3	58.6	486	8.01	5.67	123
4	58.6	586	9.31	6.29	124



Maximum Acceleration (g's)

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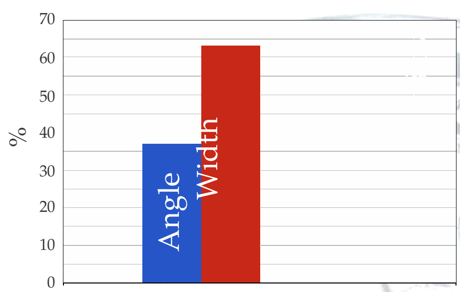
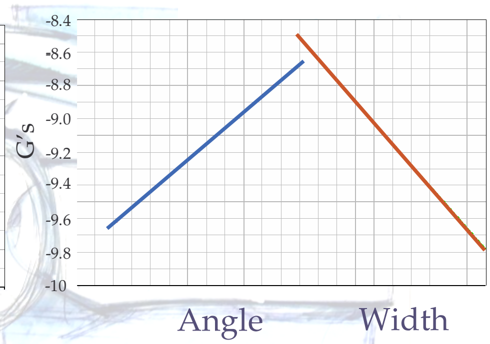
Contribution Source



Main effects



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Mean Acceleration (g's)

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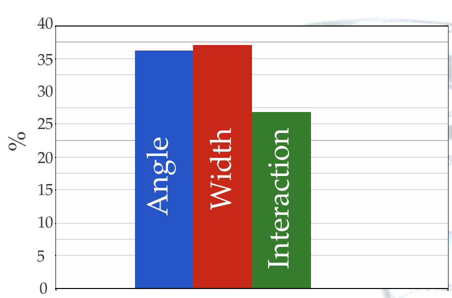
Contribution Source



Main effects

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Closeness of frame to Pilot space

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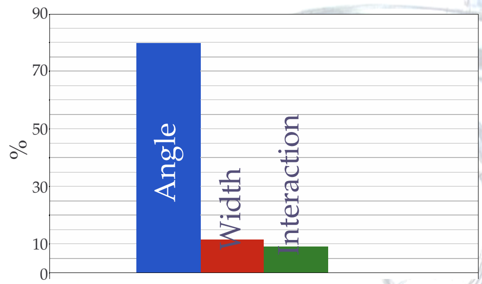
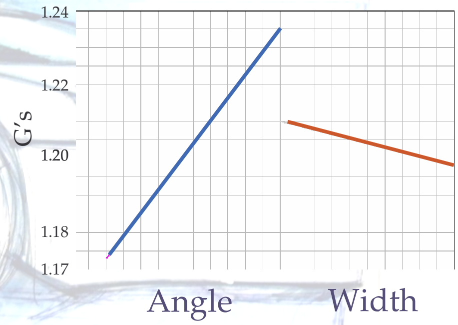
Contribution Source



Main effects



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Optimum Levels

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Output	Factors	Optimum level
Max Acceleration	Angle	2
	Width	1
Mean Acceleration	Angle	2
	Width	1
Distance	Angle	2
	Width	1

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Conclusions

- The energy plots show agreement.
- Peaks are shown in the acceleration plots due to the impact of the two frontal beams (nose and base)
- The results from DoE show the optimum levels of each factor for every selected output. Level 2 for factor A (Angle) and level 1 for factor B (Width) are selected.
  - Angle= 58.6 deg.
  - Width = 486 mm.

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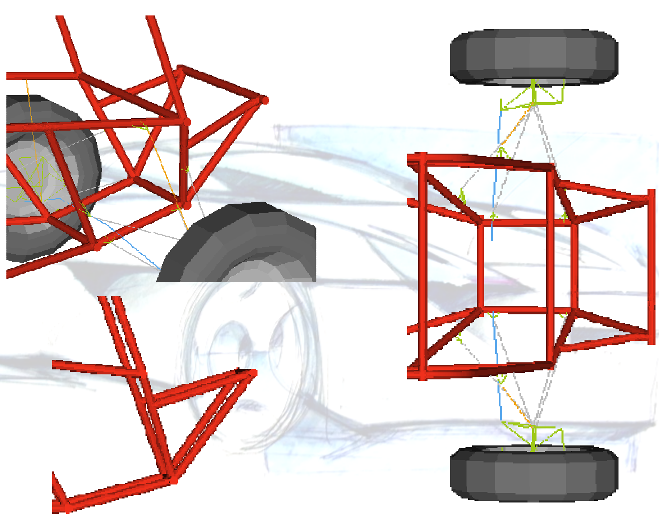
Final nose topology



Preliminary design

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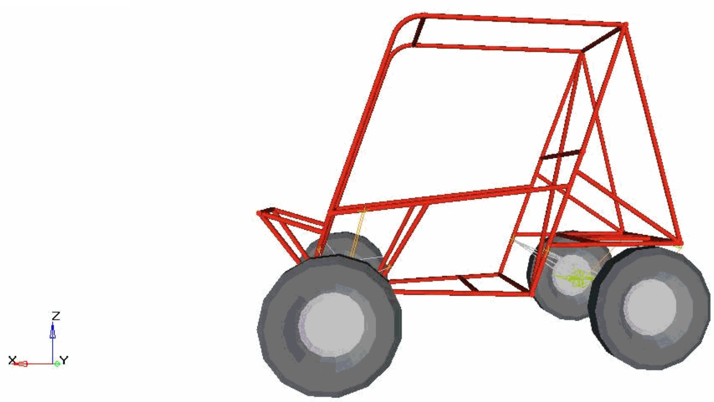

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Objectives checklist

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- ✓ The frame topology packages and supports all the components and protects the pilot integrity with a total weight of 32 Kgs.

9% of weight reductio n

- ✓ The frame topology fulfills the Minibaja West regulations and the operating conditions.

- ✓ The chosen frontal nose topology reduces the impact effects over the pilot

22% of acceleration reduction

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Future Work

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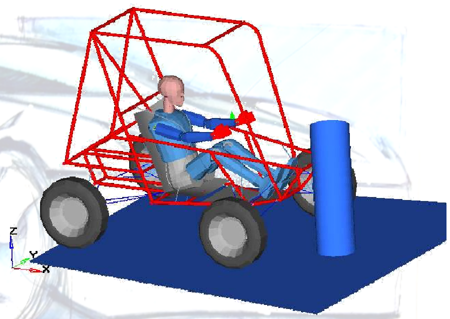
- Use more components and greater detail.
- Use computational dummies to estimate more closely the acceleration and impact effect over the pilot.
- Simulate different impact conditions.



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Acknowledgments

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Altair Engineering

LSTC Livermore Software Technology Corp.

PACE

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