Report of Student Formula Project

Shigenori HASHIDA
Aerospace Engineering,
Tohoku University

Contents

Contents

Student Formula Japan

http://www.jsae.or.jp/formula/jp/

A student design competition

- Organizer: Society of Automotive Engineering
- Sponsor　: Toyota, Nissan, Honda …
- The number of teams: 78 (EV: 8)

http://www.sist.ac.jp/

We design, build and test a car on our own

Not only performance, but marketing, planning
design, production and cost aspects are judged

Outline of Events

http://blog.livedoor.jp/jsaeformula/

http://www.daido-news.jp/

Events (Points)

- Static : Cost (100)
  - Presentation (75)
  - Design (150)
- Dynamic: Acceleration (75)
  - Skidpad (50)
  - Autocross (150)
  - Endurance (300)
  - Fuel Economy (100)

Boeing Higher Education Program

Part	Unit Price(Yen)	Number	Price(Yen)
Impact Attenuator	20,000	1	20,000
Steel Plate	5,000	10	50,000
Steel Pipe	8,000	28	224,000
Insulating Material	1,000	14	14,000
Seat	16,000	1	16,000
Seat Belt	13,000	1	13,000
Coating Material	1,000	5	5,000
Steering Wheel	52,000	1	52,000
Universal Joint	3,000	2	6,000
Rack and Pinion	5,000	6	30,000
Brake Master Cylinder	8,000	1	8,000
Brake Pedal	58,000	1	58,000
Brake Caliper	2,000	4	8,000
Brake Rotor	6,000	4	24,000
Damper	30,000	4	120,000
Spring	4,000	4	16,000
Bolt	2,000	4	8,000
Bearing	1,000	36	36,000
Slick Tire	35,000	4	140,000
Wheel for Slick Tire	38,000	4	152,000
Rain Tire	35,000	4	140,000
Wheel for Rain Tire	38,000	4	152,000
Sprocket Adjuster	1,000	1	1,000
Sprocket	6,000	2	12,000
Chain	10,000	2	20,000
Limited-Slip Differential	8,000	1	8,000
Housing	500	1	500
Support Link	500	1	500
Shaft	18,000	2	36,000
Electric Motor	130,000	1	130,000
Total Price			1,500,000

We get support from Boeing to buy main components of EV

Contents

Objective

To win **the EV total performance award** at Student Formula Japan in 2013, we plan, design and build an EV car

http://www.jsae.or.jp/formula/jp/

Contents

Direction of Design

http://www.sist.ac.jp/club/f-sae/

Merits of EV

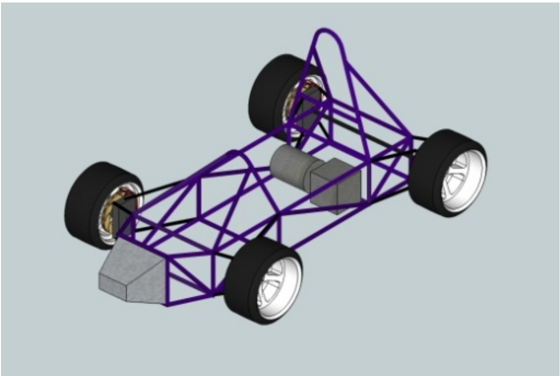
- The battery can be placed near the center
- ✓ **Good weight balance** and **mass concentration** will be achieved
- The electric motor does not need big space
- ✓ **The driving position** can be put **close to C.G.**

Rival Car: The frame designed for CV is used

x Cannot take full advantage of electrification

By designing a car tailored for the electric powertrain, excellent dynamic performance will be gained

Concept



Concept: **Human-Centric**

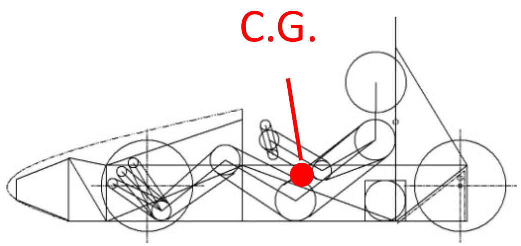
- Short wheelbase (1530 mm)
- Short overhang (600 mm)
- 50:50 front/rear weight balance
- Mass concentration
- The driving position close to C.G.

Quick and Neutral Handling

Good performance in the autocross and endurance event will be expected

Comparison with Rival Car

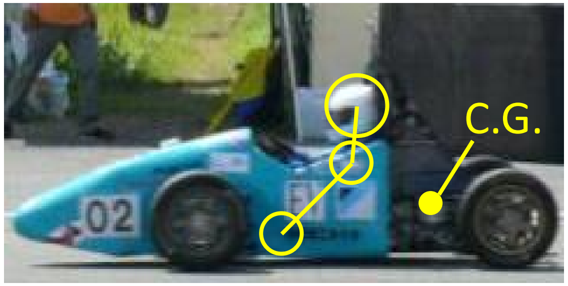
TF13



Specification (Not Firm)

Frame	Steel
Body-work	GFRP
Overall Length	2300 mm
Wheelbase	1530 mm
Track	Front: 1175 mm
	Rear : 1175 mm
Height	1050 mm
Ground Clearance	37.5 mm
Wheel	10 inch
Weight	270 kg
Weight Dist.	50 : 50
Rated Power	12 kW
Max. Power	30 kW
Battery	Li-ion, 5.9 kWh, 96 V
Suspension	Front: Pushrod
	Rear : Pushrod

The Rival Car (2011)



http://www.kumikomi.net/

Specification (2012)

Frame	Steel
Body-work	CFRP
Overall Length	2815 mm
Wheelbase	1600 mm
Track	Front: 1150 mm
	Rear : 1150 mm
Height	1074 mm
Ground Clearance	36 mm
Wheel	13 inch
Weight	270 kg
Weight Dist.	30 : 70
Rated Power	15 kW
Max. Power	37 kW
Battery	Li-ion, 380 V
Suspension	Front: Pushrod
	Rear : Pullrod

Photo of completed car

Contents

Results

Overall Standing (EV): 4th / 8 teams
(All): 69th / 78 teams

Event	Points	Time	Ranking (EV)	Ranking (All)
Cost	4.12		1st	61st
Presentation	52.50		1st	13th
Design	25.00		3rd	67th
Acceleration	0 (DNA)	0.00 (DNF)	–	–
Skid-Pad	0 (DNA)	0.00 (DNF)	–	–
Autocross	0 (DNA)	0.00 (DNF)	–	–
Endurance	0 (DNA)	0.00 (DNF)	–	–
Efficiency	0 (DNA)		–	–

Contents

Design Event

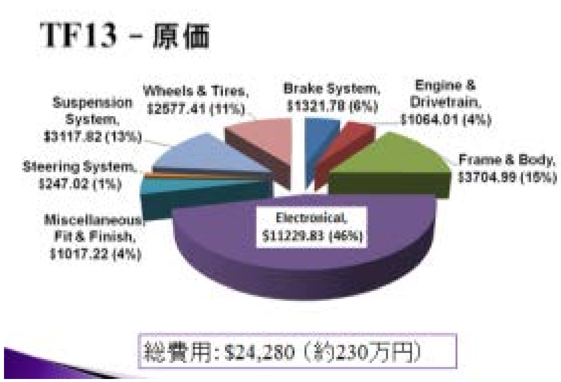
25 points / 150, 3rd / 8 (EV), 67th / 78 (All)

x Accuracy of design report

x Preparation for Q&A

Early confirmation of design is important

Cost Event

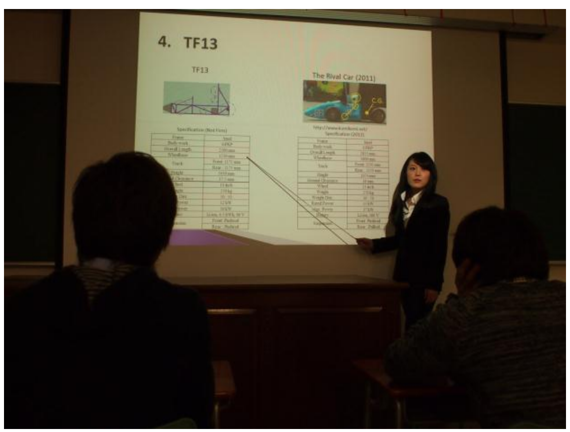


4.12 points / 100, 1st / 8 (EV), 61st / 78 (All)

- ✓ Real case scenario based on measurement
- x Accuracy of cost report
- x Addendum reflecting changes or corrections
- x Consensus for real case scenario
- x Drawing of manufacturing processes
- x Preparation for Q&A

Early confirmation of design is important

Presentation Event



52.5 points / 75, 1st / 8 (EV), 13rd / 78 (All)

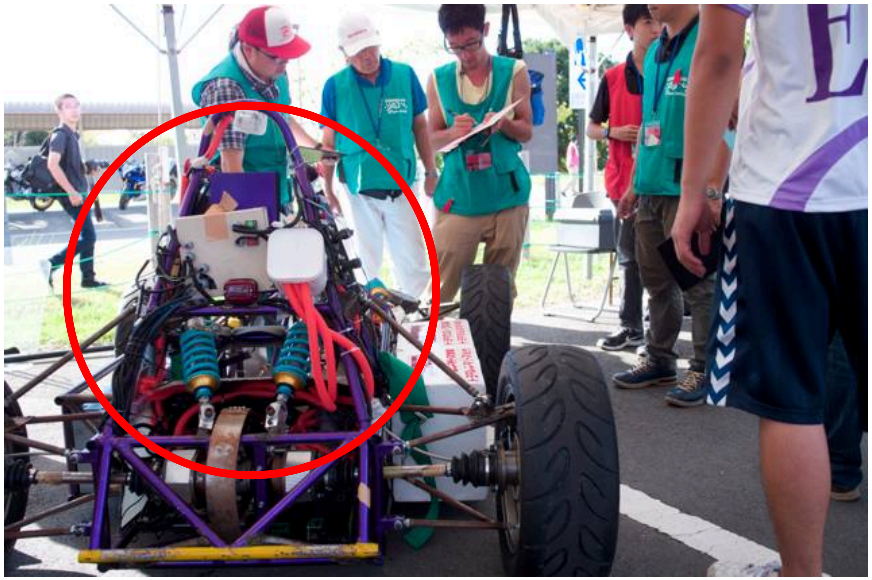
✓ Marketing making use of merits of EV

x Misunderstanding of rule

x Not enough rehearsal

Contents

Electrical



①Isolation in high voltage system
②Wiring
③Motherboard
④Illumination of brake lamp

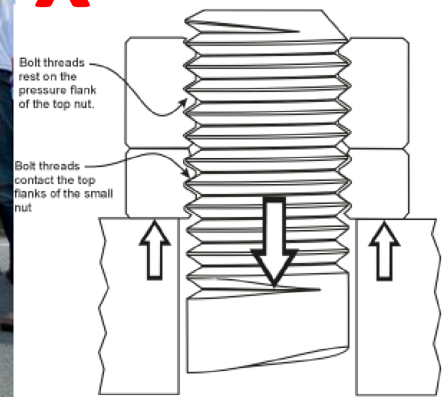
② and ③ are due to
lack of sufficient test

Improvement Approaches

- ✓ Tagging wire for easy identification of the cause of failure
- ✓ The motherboard in a dust-free / protection case
- ✓ Operation test in the early stage

Mechanical

X



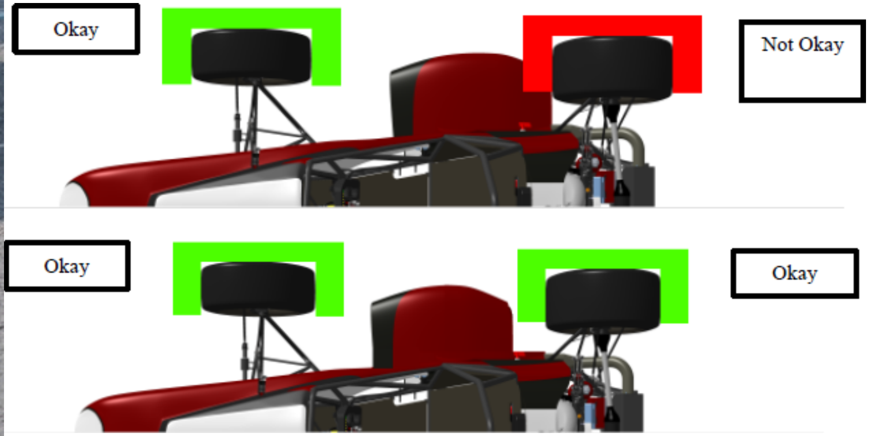
V

①Center nut for tire hub

Double nut is prohibited

Lock nut and split pin should be used

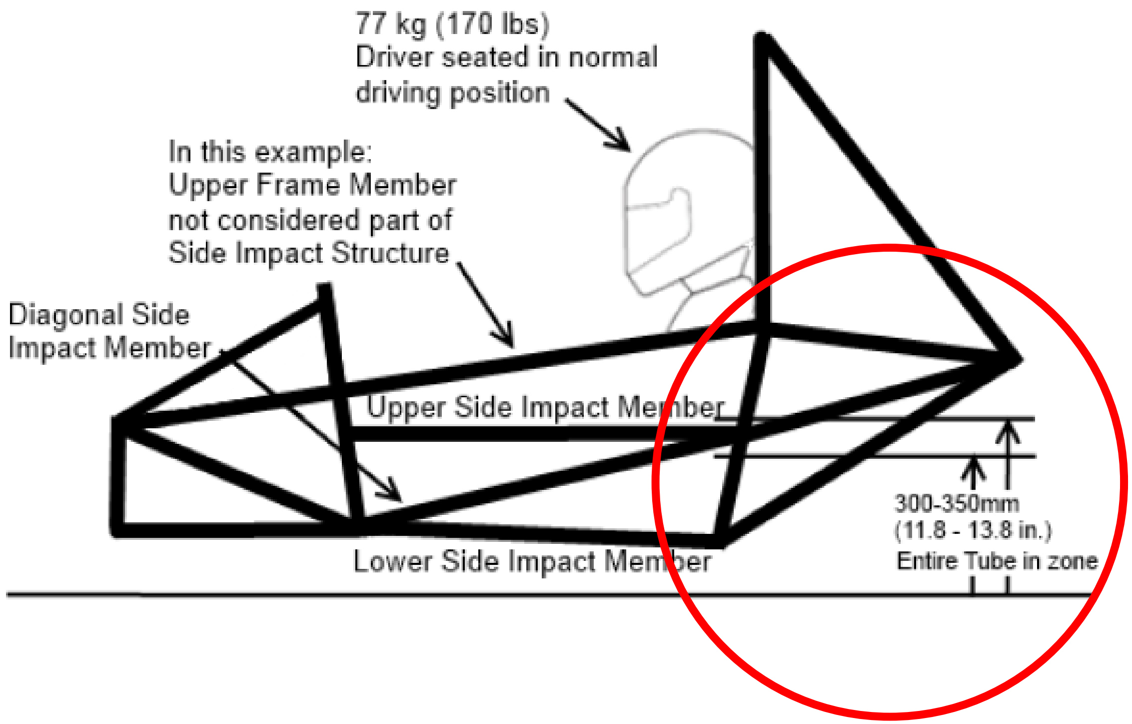
Mechanical



②Clearance around front tire

Tire and frame surrounding battery are close

Mechanical



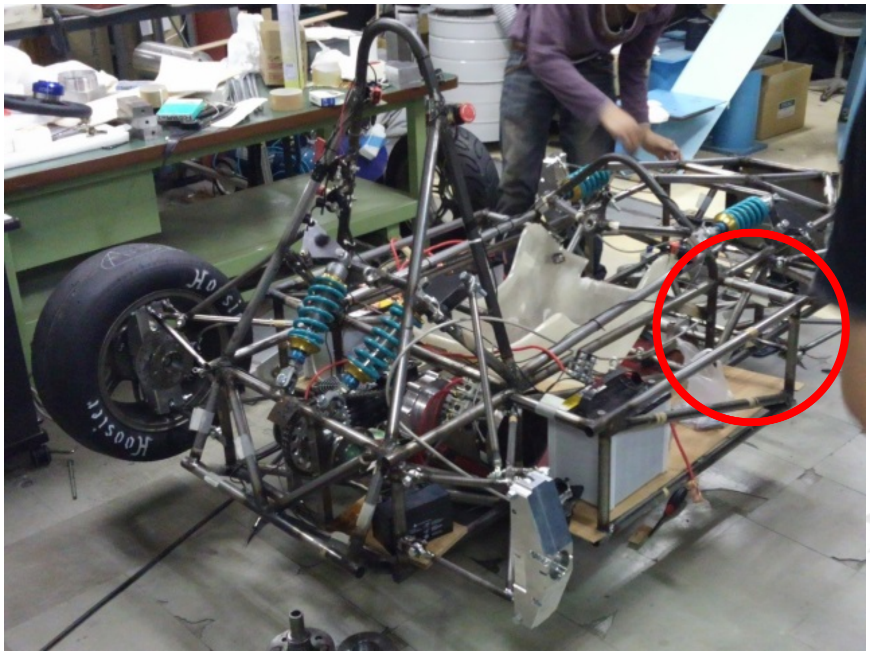
③Height of Side Impact Structure

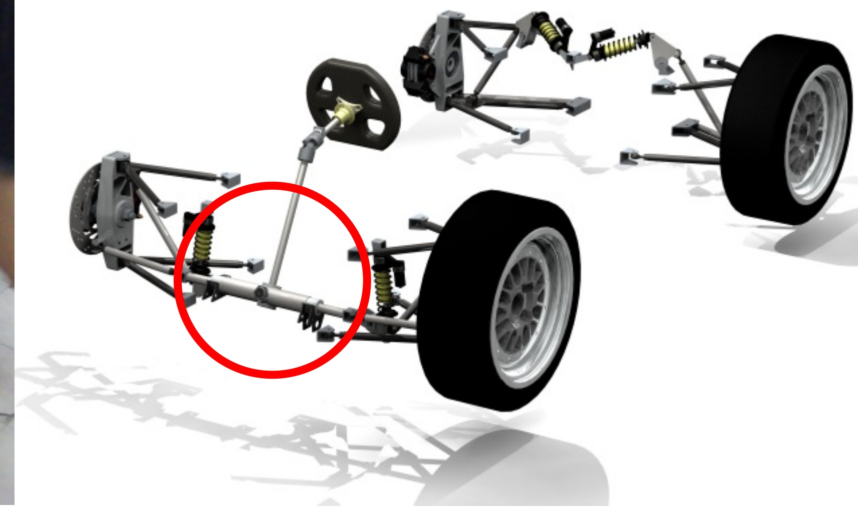
Result of ensuring suspension stroke

Mechanical

④"I" marks and torque control at bolt and nut

Mechanical

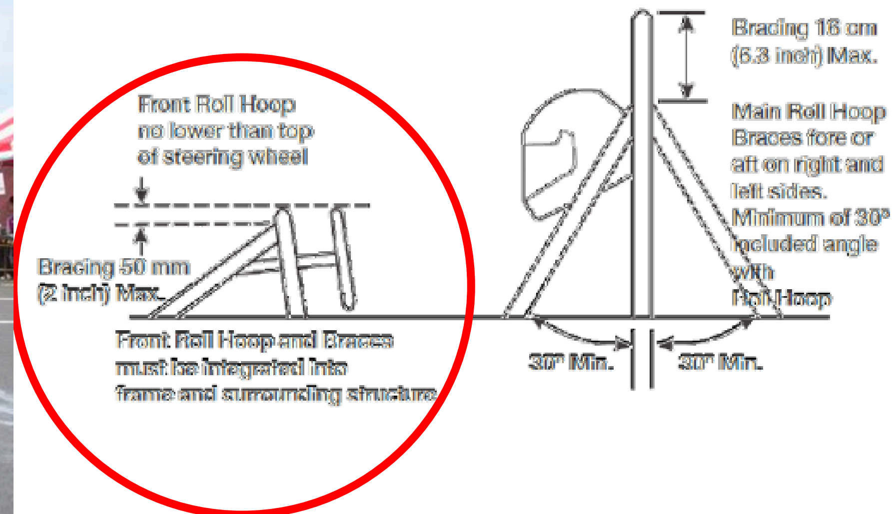




⑤Knuckle arm and frame are in contact

Stopper at rack and pinion is required

Mechanical



⑥Height of steering wheel

Failure in arrangement of steering shaft

Mechanical

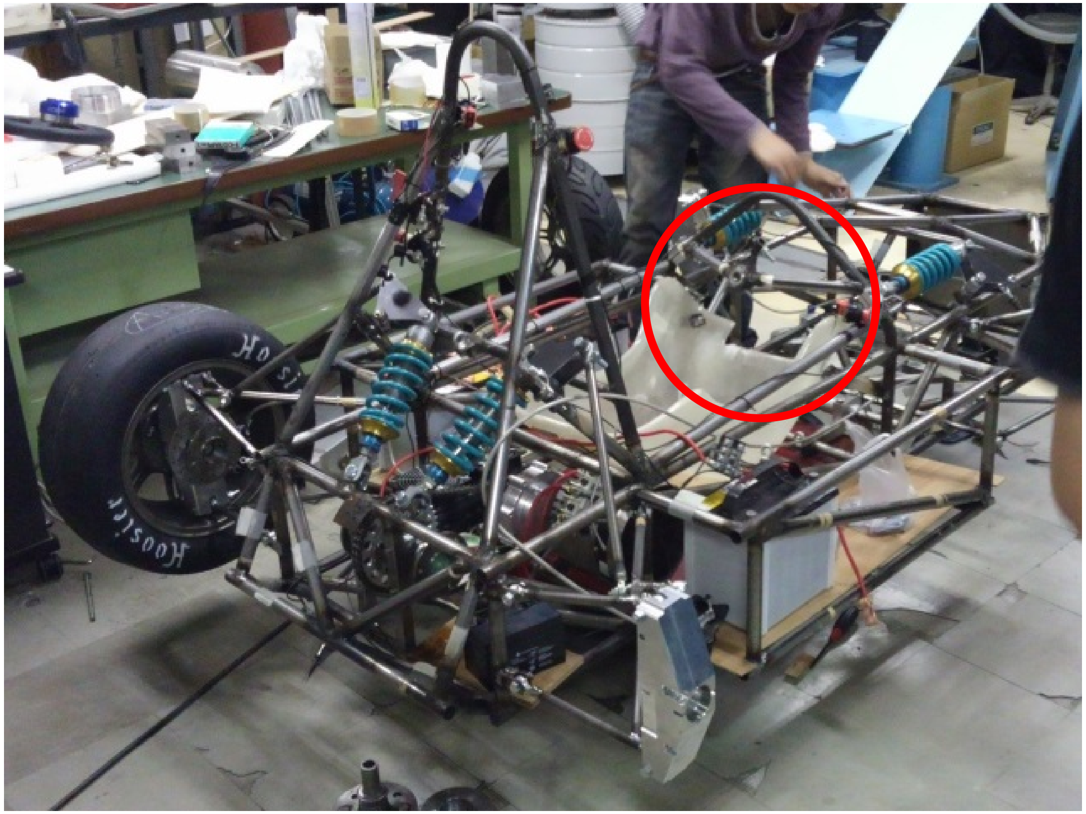
⑦Screws without securing strength are used in suspension and steering system

Strengthened screws should be used

Mechanical

⑧Interference of seat and belt

Mechanical



⑨Protection for steering shaft

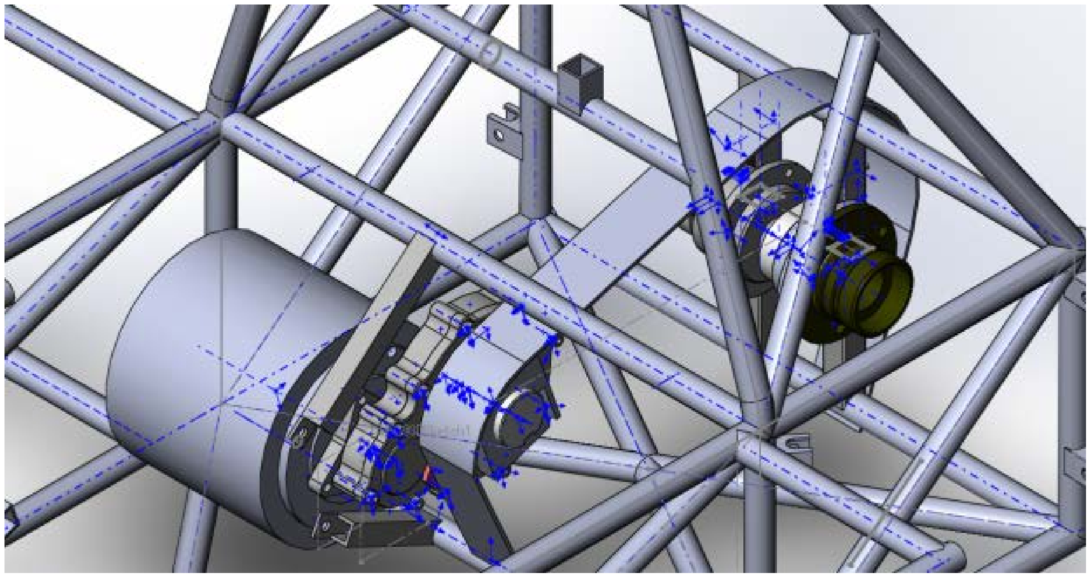
Mechanical

⑩Fixation of Roll Bar Pad

Mechanical

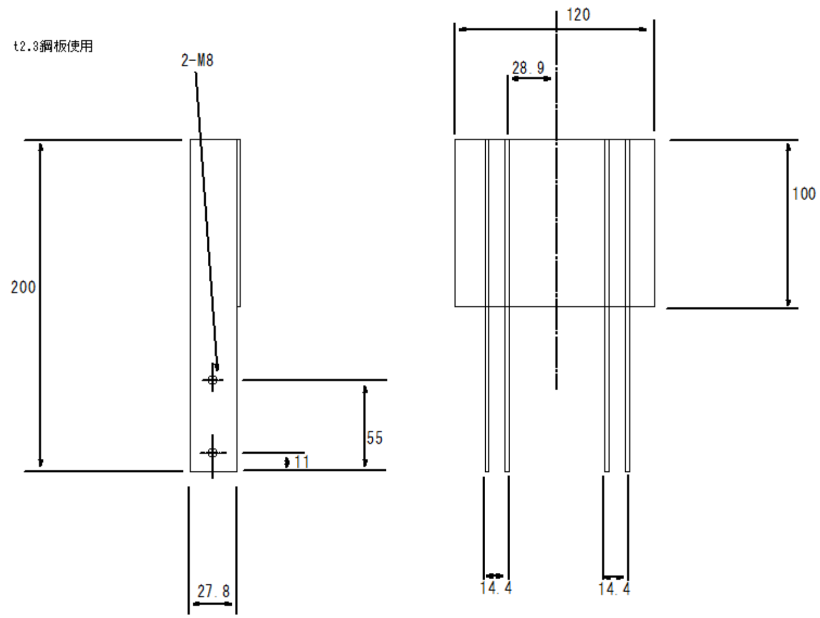
⑪Driver's foot space

Mechanical



⑫Gearbox and driven sprocket are misaligned

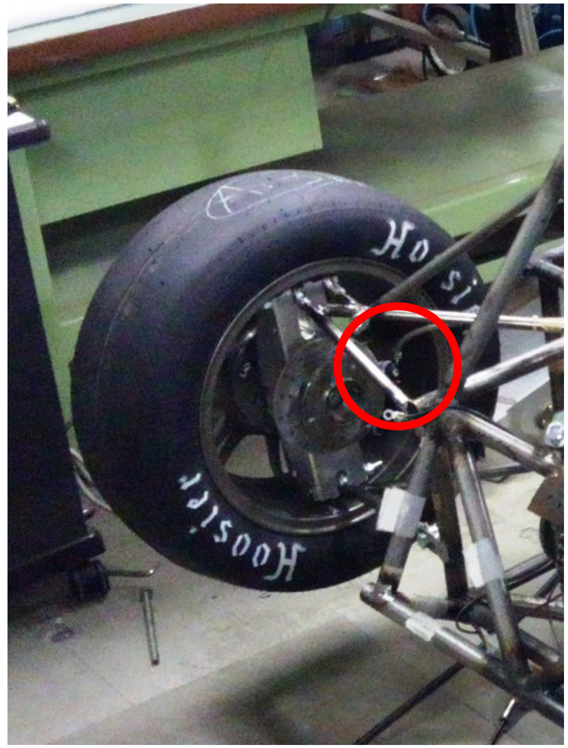
Mechanical



⑬Rigidity for brake pedal

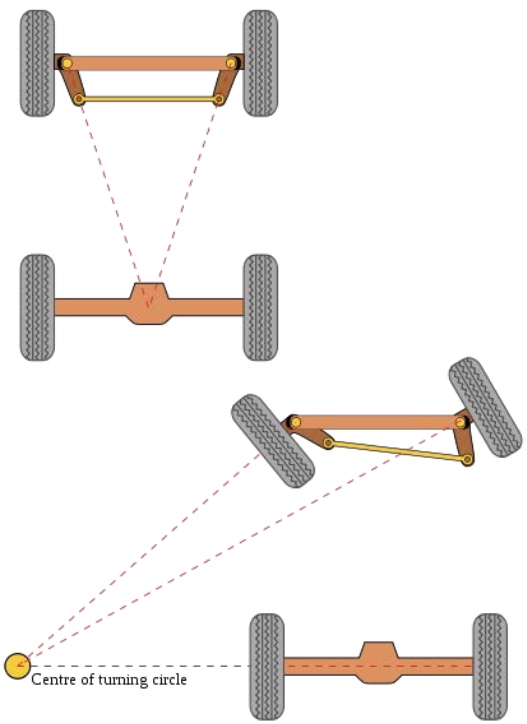
Direction of return spring

Mechanical



⑭Interference of brake caliper and wheel

Mechanical



⑮Steering gear ratio

Failure in arrangement of rack and pinion

Investigation of Cause

③Height of Side Impact Structure

…Suspension

⑤Knuckle arm and frame

…Frame

⑪Driver's foot space

…Steering

⑮Steering gear ratio

…Steering

Determination delay of specs of suspension and steering system caused these problems

Improvement Approaches

- ✓ Reuse main components for early production and improvement
- ✓ Arrangement of components prior to designing frame structure
- ✓ Design having additional margin for flexibility

Contents

Summary

- Our objective was to win **the EV total performance award** at Student Formula Japan in 2013
- We could not pass **the technical inspection** and fail to proceed to the dynamic events
- We challenge again next year and take the following improvement approaches to pass the technical inspection

Summary

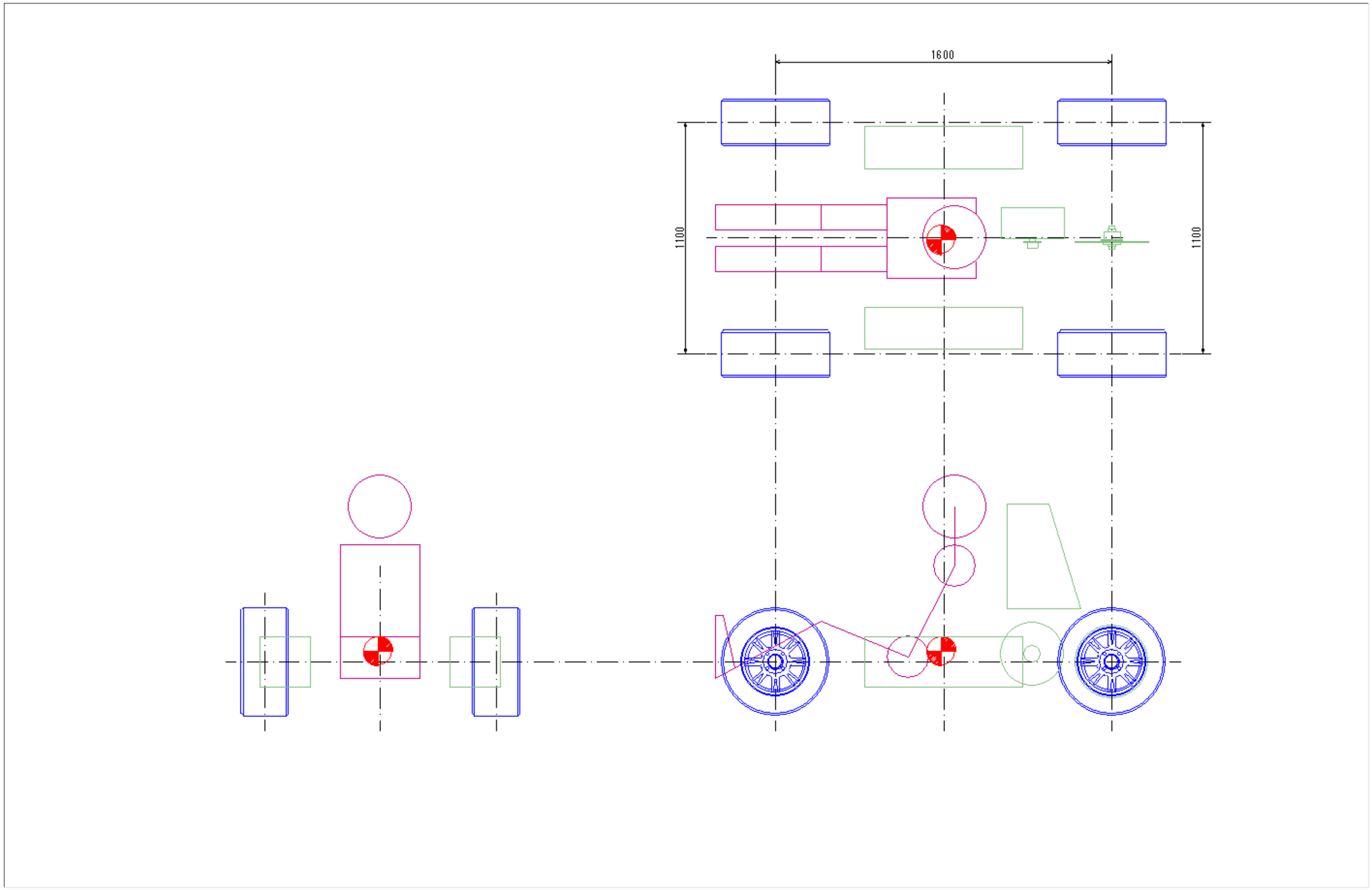
For Electrical Inspection

- ✓ Tagging wire for easy identification of the cause of failure
- ✓ The motherboard in a dust-free / protection case
- ✓ Operation test in the early stage

For Mechanical Inspection

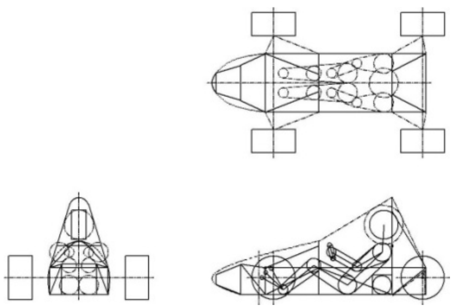
- ✓ Reuse main components for early production and improvement
- ✓ Arrangement of components prior to designing frame structure
- ✓ Design having additional margin for flexibility

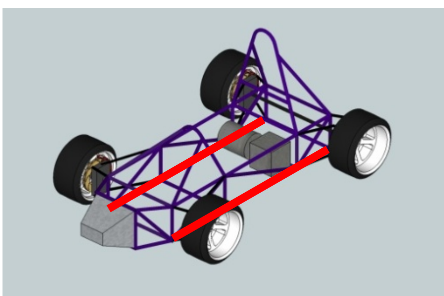
TF14

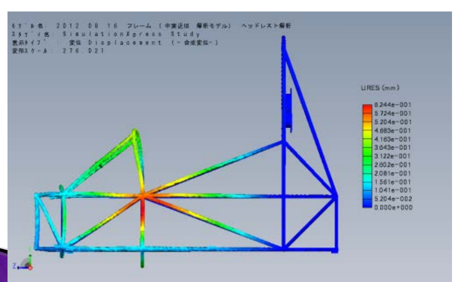


Thank you for your attention.

Frame







Human-Centric

- 50:50 front/rear weight balance
- Mass concentration
- Ergonomic driving position

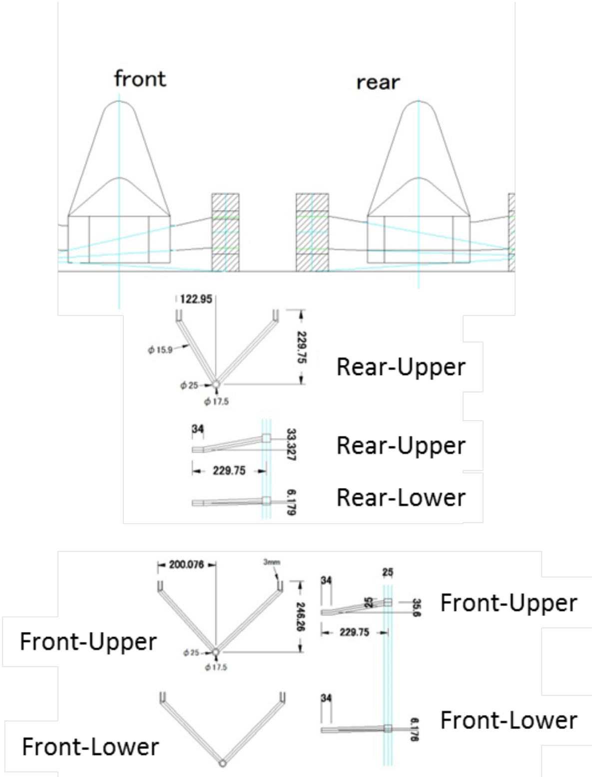
Easy to Manufacture

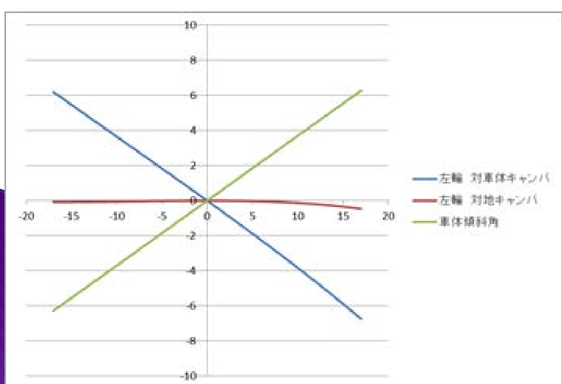
- Steel pipe space frame
- Reduction of the number of welded point

Extensibility

- Simple constitution

Suspension





Human-Centric

- Conventional geometry

Easy to Manufacture

- Simple constitution

Extensibility

- Wide Adjustable Range

Drivetrain

Human-Centric

- Abolishment of the gearbox

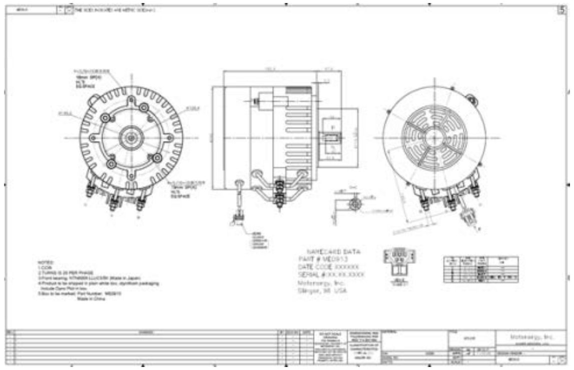
Easy to Manufacture

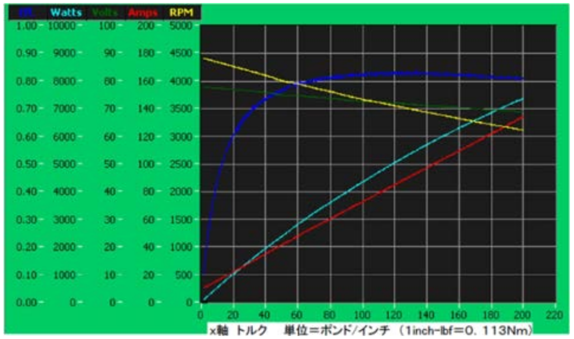
- Single-reduction system

Extensibility

- Chain drive

Motor

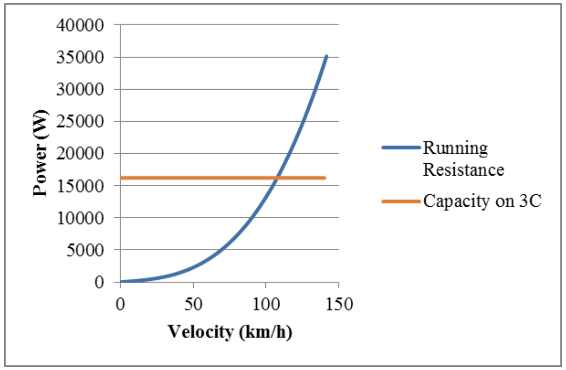




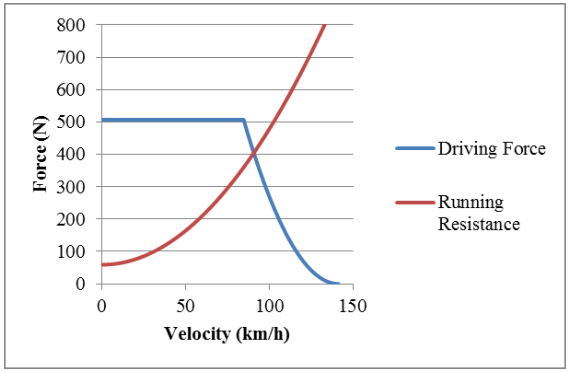
Human-Centric

- PMS Axial Gap Motor (30 kW / 5000 rpm)

Battery



Design based on performance curves



9. Outline of Events

Static Events	Cost	The validity/competitiveness of cost calculation are examined. (100P)
	Design	Appropriateness, the reformation, the processability, and the repair, etc. of the design are examined. (150P)
	Presentation	The presentation technology for the manufacturing sales is examined. (75P)
Dynamic Events	Acceleration	The acceleration performance from 0 to 75m . (75P)
	Skid-pad	The vehicle's cornering performance is evaluated in steady state turns over a figure-of-eight course.(50P)
	Autocross	Vehicles are driven over an approximately 800 m course comprised of a combination of straights, turns, and slaloms. (150P)
	Endurance	Vehicles are driven over an approximately 20 km course comprised of a combination of straights, turns, and slaloms.(300P)
	Fuel economy	Fuel economy is evaluated in terms of the amount of fuel consumed in the endurance .(100P)

10. Work Environment

- Funding

  $ 28,000 (from club budget, Univ. and Co.)

  ->We don't have enough money yet
- Design

  2D CAD: Jw_cad, 3D CAD: SolidWorks2010
- Manufacturing

  Tools, Welder (manual, semiautomatic), etc.

  * We don't have the surface plate

  ->**Made a small surface plate by steel scrap**

We need to use these **extremely limited** resources much effectively

11. Team Objective

The Ultimate Formula Student Car

- Overwhelming **Dynamic Performance**
- Universal **Stability and Controllability**
- Extremely High **Energy Efficiency**

Gasoline cars cannot achieve them at the same time

Electric Motor, **Battery** and **Electronic Control…,** only **EV**s can achieve them

Tohoku University will make

the ultimate formula student car

12. Team Plan

TF13 (2013) Objective : **Realize of entry and victory**
Approach: Basic of Car Design

TF14 (2014) Objective : **Challenge to TF13's limits**
Approach: Improvement Based on Data and Simulation
Traction Control

TF15 (2015) Objective : **Exceed the gasoline cars**
Approach: Twin Front Motor
Front-Rear Wheel Control

TF16 (2016) Objective : **The ultimate formula student car**
Approach: Twin Rear Motor
All Wheel Independent Control

3ヶ年ロードマップ

今後のレースで重要な性能：**エネルギー効率**
- 次世代のレースカーとしてEVが注目されている

レースカーとしての問題点：**バッテリー重量**
- 車両重量の削減のために電費向上が必要である

目的　：**電費性能向上によるバッテリー重量の削減**
目標　：**電費：0.1kWh/km**（2012年大会優勝校：0.13kWh/km）
　　　　バッテリー重量：50kg減
方策　：①**軽量化**，②**モータ制御**

2013年：ベンチマーク車両開発，各種データ取得，問題発見
2014年：解決方法模索，コンピュータ・シミュレーション，実験
2015年：走行試験，実戦投入

TF13

2013年：**ベンチマーク車両開発，各種データ取得，問題発見**
開発　：**工作性を最重視．挙動を把握しやすく，操作に鋭敏な設計**
①ボディ…溶接点数が少ない構造（ジグなし誤差最大5mm）
低慣性モーメント，良好な重量配分（50：50），
高剛性（1G旋回時トーイン0.001°未満）を狙った設計
入手しやすいGFRPを用いたカウル
②足回り…製作・調整しやすい単純な構造・ジオメトリ
③駆動系…ロバストで調整しやすいチェーンドライブ
軽量かつ運転しやすい変速なし自作ギアボックス
エネルギー密度の高いリチウムイオンバッテリ
研究　：サス・ブレーキ・ステア・モータ&バッテリセッティング，
電流・電圧値，加速度，アクセル・ブレーキ開度，舵角等の
走行データの取得，破損箇所の調査，滑り検出方法の模索

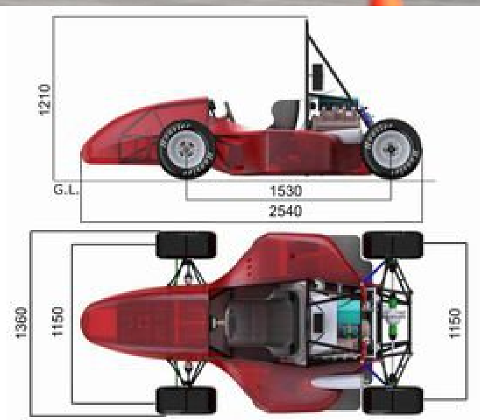
TF14

2014年：**解決方法模索，コンピュータ・シミュレーション，実験**
開発　：**マイナーチェンジ**（TF13をベースとした部分的改良）
①ボディ…ウェットカーボンカウルによる軽量化→-5kg
②足回り…部品形状最適化による軽量化
③駆動系…モータ・減速方式改善による軽量化（アルミ＆
カーボンハイブリッド減速機など）→-4kg
駆動力制御による消費電力の低減
研究　：ドライカーボンパネルの成形，金属との接着，
スチールパイプとのハイブリッドフレームの実験
フレーム・カウル形状変更による空気抵抗低減効果の検証（CFD）
走行データの取得，破損箇所の調査

TF15

2015年：**走行試験，実戦投入**
開発　：**フルモデルチェンジ**（TF13の問題を考慮した抜本的改革）
①ボディ…スチールパイプ＆ドライカーボンパネル
ハイブリッドフレームによる軽量化→-3kg
空気抵抗低減カウルによる消費電力低減
②足回り…10インチMgホイールによる軽量化→-5kg
③駆動系…自作コントローラによる軽量化
回生方式の再検討（キャパシタ，フライホイール等）
研究　：走行データの取得，破損箇所の調査，
エコ走行を補助するAndroidアプリの開発，
更なる電費向上方法の策定（4輪独立モータによる回生効率の向上，サス・ブレーキ・ステア制御による消費電力の低減等），
太陽光発電パドックによる創エネ等

13. Background



http://ynfp.jp/

The autocross and endurance course mainly consist of less than 10 m radius turns,
so the ability to turn in a small radius is needed

->Trend: **Short Wheelbase** (1525 mm ～)

Because of the engine behind the driver,
the driving position is apart from the C.G.
x Difficult to understand the vehicle behavior

To improve maneuverability, departure from the internal combustion engine and the alternative is needed

14. Objective

To **win the total performance award**, we design and build the formula student car **tailored for the electric powertrain** and realize “Jinba-Ittai”*

* Japanese word for unity of horse and rider