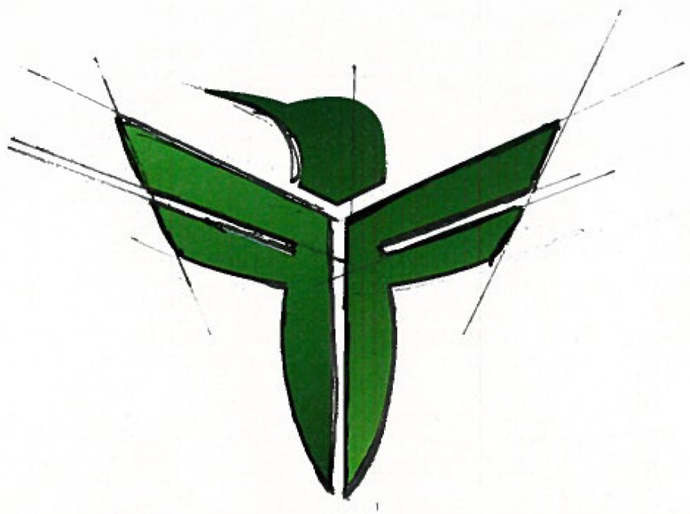


New car - New class - New world record

This is the 5th year of NTNU's participation in Shell Eco-marathon. A new and improved car will be made as this year's competition will be held in the city streets of Rotterdam, Netherlands.

The new car will participate in the plug-in class with the ambition of ranking first with a new world record.

01 TEAM MEMBERS

THE 2012 TEAM

This year's team is a versatile team consisting of 11 master students from various departments at NTNU. Through support from our departments, the previous team and capable suppliers, we are certain that we will achieve great results in the Shell Eco-Marathon 2012

HANS GUDVANGEN (24)

Home town:
Aure, Norway

Education:
Bachelor Mechanical Engineering
Master Mechanical Engineering

Responsibilities:
Rear suspension and rims

PETTER THORRUD LARSEN (23)

Home town:
Langesund, Norway

Education:
Bachelor Mechanical Engineering
Master Mechanical Engineering

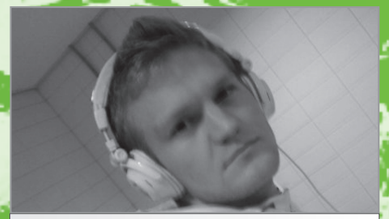
Responsibilities:
Chassis and aerodynamics

ITXASO YUGUERO GARMENDIA (23)

Home town:
Bilbao, Spain

Education:
Master Mechanical Engineering

Responsibilities:
Brake system and system engineering

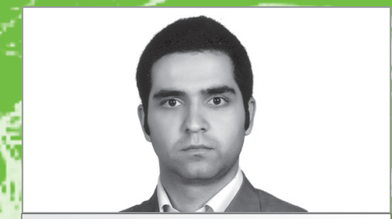


FREDRIK V. ENDRESEN (25)

Home town:
Oslo, Norway

Education:
Master Energy and Environmental Engineering

Responsibilities:
Motor



FARIBORZ ALI HEIDARLO (24)

Home town:
Tehran, Iran

Education:
Bachelor of Engineering
Industrial Engineering - Master of Science
Project Management

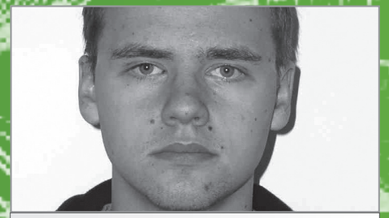
Responsibilities:
Project Manager

ØRJAN SJO (28)

Home town:
Stavanger, Norway

Education:
Master Mechanical Engineering

Responsibilities:
Monocoque



HÅKON JOHAN SEINESS (24)

Home town:
Tromsø

Education:
Master Engineering and ICT

Responsibilities:
Steering, brake system, front suspension

MATS HERDING SOLBERG (25)

Home town:
Oslo, Norway

Education:
Master Industrial Design

Responsibilities:
Chassis and interior

EIVIND SÆTER (25)

Home town:
Ålesund, Norway

Education:
Master Industrial Design

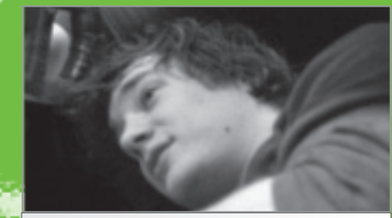
Responsibilities:
Chassis and interior

SILJE KRISTINE SKOGRAND (25)

Home town:
Trondheim, Norway

Education:
Master Media Communication and information technology

Responsibilities:
PR and media relations



AKSEL QVILLER (24)

Home town:
Oslo, Norway

Education:
Master Engineering and ICT

Responsibilities:
Suspension system and steering

02 PROJECT MANAGEMENT

Important Milestones

20.09.2011 Project Start

30.11.2011 Ordering carbon fiber and mold material

02.12.2011 Concept Day

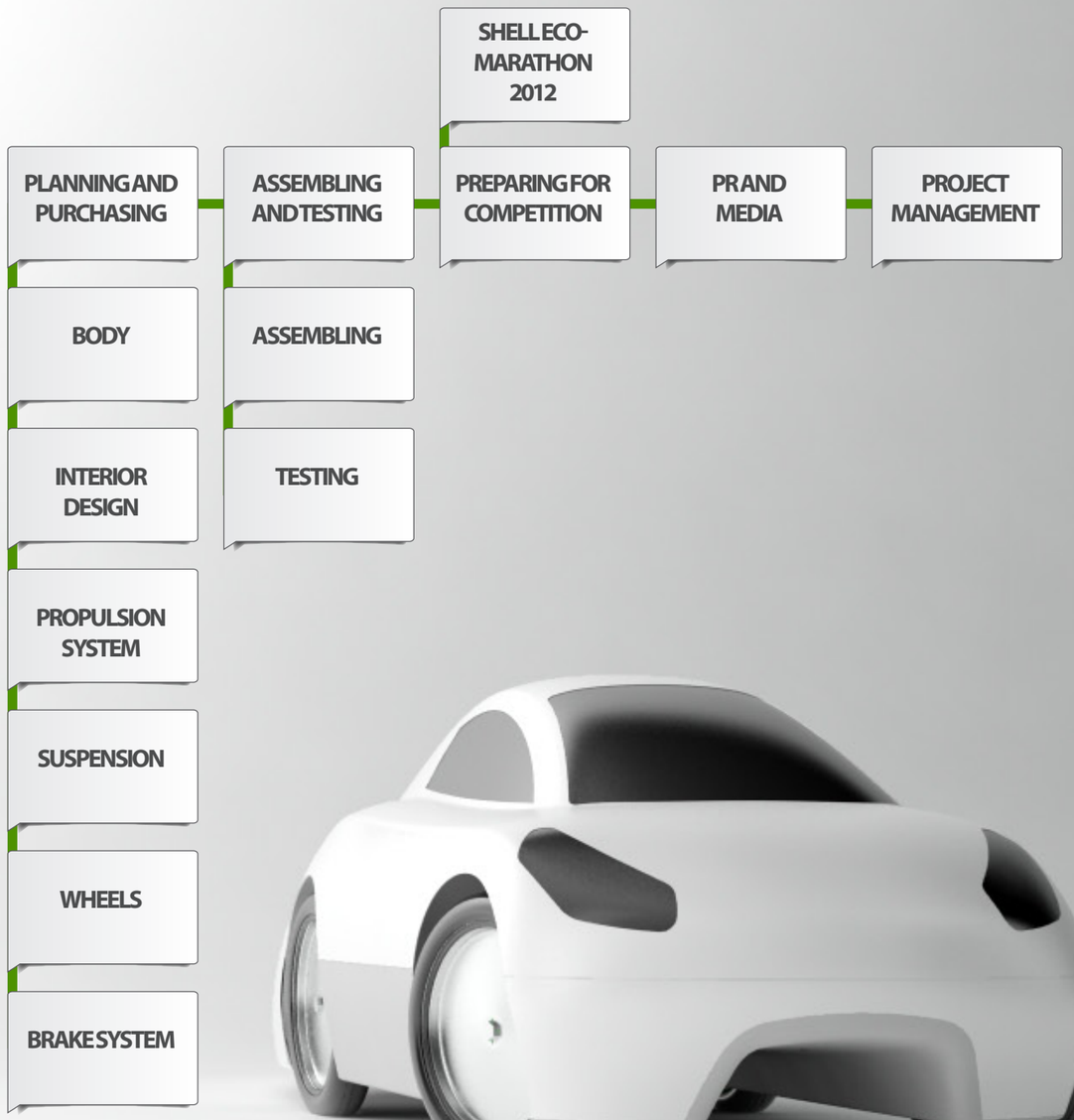
15.02.2012 Body is ready

12.03.2011 Assembling Starts

02.04.2011 Testing Starts

07.05.2011 Prepare Car for Competition

17.05.2011 Project Finish



03 COST ASSUMPTIONS

Mentioned costs in the table are the most likely expenses. As the Shell Eco-marathon 2012 project is categorized under the class of New Product Development (NPD) projects, risks and uncertainties are associated with any perspective of this undertaking. Mitigation methods for being ready in case of any exposures are applied to costs as margins on different parts and the total amount. The team of NTNU understands that having sponsors for different parts of the car is another method for decreasing costs and this is under way as the team members are in process of negotiation with different potential sponsors that have not been finalized yet.

Shipments cost is related to those travels which have to be done for receiving different parts of the car from different suppliers. Body production has the most influence on this amount, as it has been estimated based on having no sponsor for making the whole body in one corporation. So for finishing it, transportation between companies is unavoidable.

Miscellaneous costs are related to activities for preparing promo material and team building sessions.

Title	**Planned Cost** (NOK)
Engine	150 000
Exterior	350 000
Wheels	60 000
Suspension	129 000
Braking System	20 000
Battery	20 000
Cybernetics	60 000
Interior	15 000
Shipments	50 000
Trip	150 000
Misc.	40 000
Initial Budget	1 044 000
Margin	50 000
Proposed Budget	**1 094 000**

04 PR AND MEDIA

The media goal for the project is 150 articles and 15 events, this all achieved with a new car with goals of a new world record and 1st rank in the plug in class.

PHASE 1

Establish an overview, Get started! :
September-November

- Brainstorming
- Begin to establish a media package (including pictures, notes, logo)
- Sponsor Relations
- Get an overview of all relevant local newspapers
- Include Information Department of NTNU and work to get a closer cooperation with them
- Establish contact with photography - school
- Logo

Main focus: Making a profile

Media stunts in this period could be:
Official opening. Let the game begin - work shop – Official name: Eco-friendly workshop – invite all schools in Trondheim, let them see how we work – Official opening of the project with mayor Rita Ottervik, Principal of NTNU and representatives from the department. The team will drive the car through campus so everybody can cheer and wish us good luck. Show everybody how we are supposed to build the car. Main sponsor logo included. Project- opening dinner at night.

Nils Arne Eggen or another person lecture us: How to be a world champion. All local newspapers will be invited. (Adresseavisen – Ukeadressa)

PHASE 2

Implementation and Alignment
November - January

- Establish a social media platform (triangulation: FB, Blog, Twitter / + / - website) Ongoing updates and news. It will also include calendar, presentation of the project, presentation of team members, photos from the work and a separate page for press contacts and some pictures the press is free to use. Detailed information of sponsor as well. Including quotation from sponsor.
- Create a presentation of each team member. Begin to establish contacts / appointments to media, send out press releases to local newspapers in the first place and to student medias
- Events

Main focus: Advertising on web, get readers of blog and Facebook

Media stunts in this period could be:
Media training course: Burson - Marsteller AS
Movie trailer: stunts: Drive the car in Nordre, pretend we are in Rotterdam: publishing on blog, FB , You Tube.
Vitensenteret – Let people see and try the car at the science center on a Saturday. Much people there at the time.
One week with a banner over Perleporten with our name, name of the sponsors, links to Blog and Facebook and concept pictures.
Car - tour around the country visiting some Norwegian Universities; Contribute to make more students get interested in eco-friendly cars.

PHASE 3

Adaptation and improvement
January-March

- Test and adjust according to statistics
- Preparation regarding the unveiling of the car in April or May (media invitations, sponsor invitations, etc..)
- Creating a video that will be sent to the people in TopGear
- Establish contact with NRK and TV2, programs of in terested: Broom, Schrødingers Katt, God Morgen Norge. After (or before) our participate on television national newspapers could also be interested in our project: VG and Dagbladet

Main focus: Editing newspapers and TV- programs.

Media stunts in this period could be:
TV – programs: Dagsrevyen, Broom, Portfolio: Newtons Hage, Schrødingers Katt, Teknisk Ukeblad, Student – TV, Under Dusken , Gemini, Alfa, Illustert vitenskap; focusing, how to make an eco-friendly car.
Newspapers: A-magasinet, Magasinet
Conference: Eco - friendliness
Car auto show
Sports arrangement: Lerkendal Stadium – Football match. Our own stand before the match, allow people to try the car, inform people. Who are we?
Official opening of a new hotel in Trondheim: Petter Stordalen, focusing on eco-friendliness. Let him try the car.
TOP gear – sending a movie to the people in Top Gear.

PHASE 4

Full implementation
March-June

- Competitive phase: a new touch before the competition: could we fail? Or are we sure we will win?
- During the competition: keep the media informed, write articles, send pictures (ready for press)
- After the competition: how did it go?
- Loss = fire for a minimum
- Victory = ignite the flame for maximum benefit

Main focus: The competition

Media stunts could be:
The big stunt this period is the unveiling of the car: April – May on Aker Brygge. Célèbre guests such as the Prime Minister, Prince Haakon Magnus, energy and environment minister will be invited.
Sport arrangement: Bislett Games, Trondheim Marathon and Oslo Marathon.

PHASE 5

Evaluation and summary (June-August)

- What`s the real result: measuring the impact of work
- Inform sponsors of the outcome
- Transfer knowledge to the next year's team

05 SYSTEMS ENGINEERING

Concept

- Make an architectural design based on the user and systems requirements.
- Create a detailed TEMP (test and evaluation master plan)
- Work with the team members to implement testing in early stages of the project.

Improvements

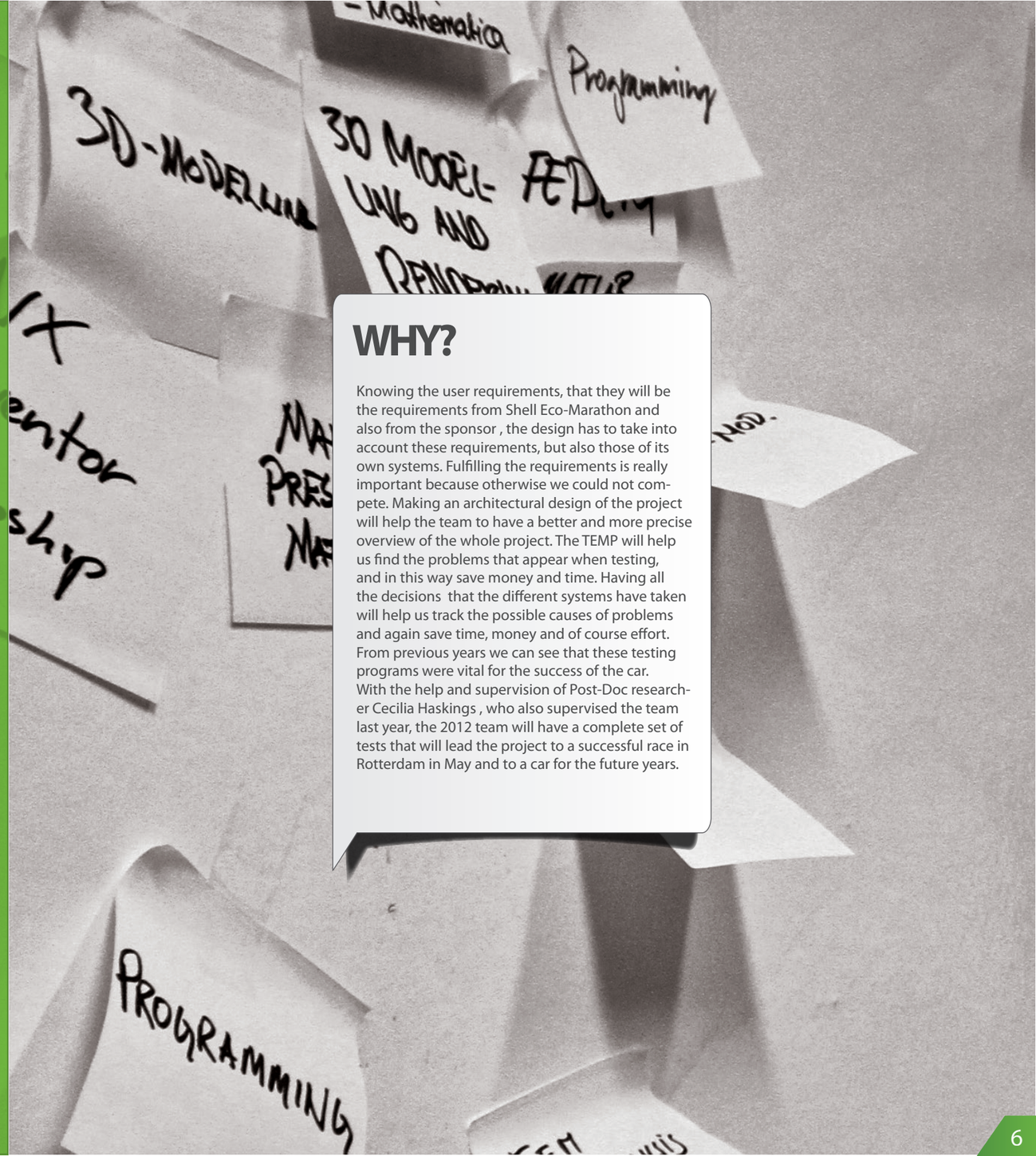
- Based on last team's architectural design, make our new design based on the new needs.
- Fulfil all the requirements.
- Make a good and efficient testing protocol for the new car.

Why

- Implementing testing early will save money and working time.
- The testing protocol and tracking of the decisions will make changes more efficient and economical.
- It will be a whole new car and the testing is going to be an extremely important issue this year.

How

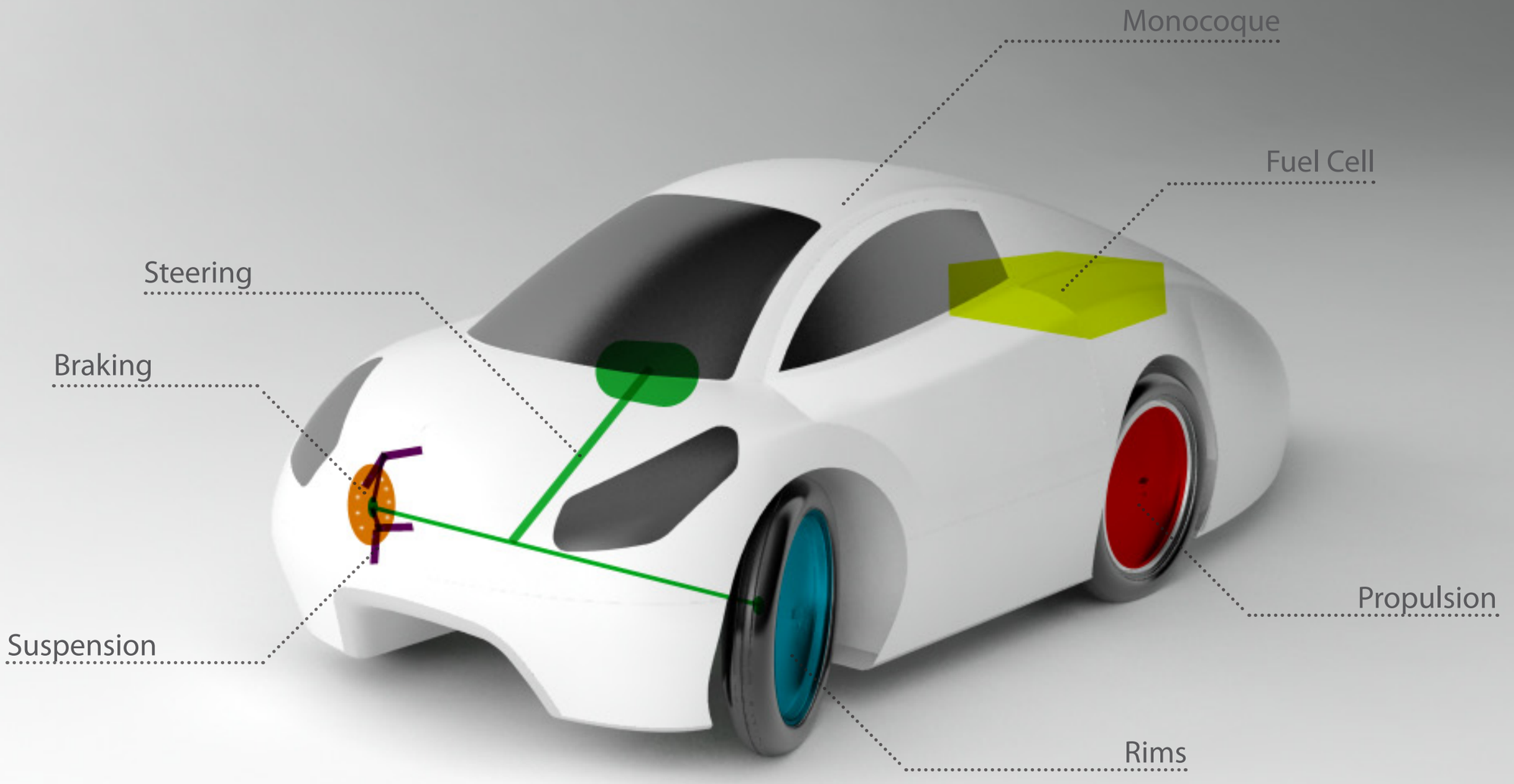
- With the acquired knowledge from the previous team.
- With the help of Post-Doc researcher Cecilia Haskins.



WHY?

Knowing the user requirements, that they will be the requirements from Shell Eco-Marathon and also from the sponsor , the design has to take into account these requirements, but also those of its own systems. Fulfilling the requirements is really important because otherwise we could not compete. Making an architectural design of the project will help the team to have a better and more precise overview of the whole project. The TEMP will help us find the problems that appear when testing, and in this way save money and time. Having all the decisions that the different systems have taken will help us track the possible causes of problems and again save time, money and of course effort. From previous years we can see that these testing programs were vital for the success of the car.
With the help and supervision of Post-Doc researcher Cecilia Haskings , who also supervised the team last year, the 2012 team will have a complete set of tests that will lead the project to a successful race in Rotterdam in May and to a car for the future years.

06 IMPROVEMENT POINTS ON THE OLD CAR



07 BODY DESIGN

Concept
- Design a new car

Improvements
- Appealing design
- Aerodynamics
- Surface finish
- Driver compartment
- Engine compartment

Why
- Reduce drag and weight to increase mileage
- More appealing
- Possible to optimise driver and engine compartment with new rules since the first design. The height of todays driver compartment is not in correspondence to the rules.

How
- Extensive use of CFD and CAD
- Close co-operation between specializations
- Use of knowledge from previous years

CONCEPT

Team of 2012 will design and produce a new car for the competition. This will include everything from designing, calculations, production and testing.

IMPROVEMENTS

The focus of this year will be to make a car that's both appealing to the audience and is better suited for the competition.

HOW?

With the use of CFD and CAD tools and close co-operation between specializations it is possible to design a new and better car body. The experience from previous years will contribute to making the improvements necessary to achieve a better result in the 2012 competition.

WHY?

Improved aerodynamics will reduce drag and increase mileage. A more appealing design will increase marketing and interest around the car. By developing a new car it is possible to optimise the driver and engine compartment, and incorporate the existing parts in a better way. A smoother surface will also contribute to make the car more attractive and reduce the aerodynamic drag.

08 MONOCOQUE BODY

Concept
- Produce a new monocoque that will be as light as possible.
- Will be made out of carbon fiber. Use sandwich structure containing environment friendly core material to increase stiffness in stress concentrated areas.
- Experiment on using super-light core material, aerogel, in the firewall.

Improvements
- Better suited for one-wheel drive and the use of shock absorbers.
- Use negative form for smoother surface finish.
- Accurate analysis to be able to reduce safety factor and weight.

Why
- Make it solid enough to handle the new race conditions.
- Not possible to make room for necessary suspension.
- The previous car was not designed for in-wheel drive.
- Possible to use lighter core material.

How
- By working with the Department of Product Development and Materials at NTNU.
- Study the work on several master thesis about this project.
- Get help from providers that give us the cheapest prize.
- By defining the stiffness matrix for different lay ups and materials, and to orient it in CAD for analysis.

Critical points of production
- Milling out mold.
- Curing the monocoque.

CONCEPT

Carbon fiber and core material will be used to make the monocoque. A sandwich structure will be used in the areas with the most stress to increase stiffness. Only a top and bottom part will be made and joined along a perfect horizontal line at the car's greatest cross-section. This will be done with glue by the help of a wide flange. We will try to use a newly developed core material made out of PET (Polyethylene terephthalate). This is a very environmentally friendly material. We will also investigate the possibilities to use aerogel (very light) as core material or laminate in the firewall.

WHY?

Due to major changes in race conditions we will make major changes to the suspension. The old wheel wells do not have enough space for our new, fully damped suspension system. The previous car was not designed for in-wheel drive. One of the reasons for this is that the track width of the rear wheels is wider than it has to be. Making it closer to each other will increase the efficiency of the motor.

CRITICAL POINTS

We have initiated contact with 6 firms with 5-axis CNC milling-machines. They all prioritize their important customers. This might reduce the chance of getting the milling sponsored. Worst case, this will also cause a delay of 1-2 months. Post-curing of prepreg might be a problem. Since our plan is to make two bigger parts, it might deform a bit without support from form. This is critical when it comes to joining the two parts. An estimate is made for the production, where we have specified all materials, work and equipment needed for the production.

IMPROVEMENTS

Amongst other goals, the monocoque will be designed to make room for our new suspension and motor, larger driver compartment and smaller engine bay. We will analyse the possibilities to reduce the rear track width, which will improve the motor's angle of attack. The smaller width in the body's rear improves aerodynamics. More environmentally friendly and/or lighter material will be used. But the wheel well will need stronger and heavier material to absorb the stresses, since the race now is in the streets. Balsa wood, polyurethane and carbon fiber will most likely be used for this. A negative mold will be used for nicer finish and better aerodynamic properties. Accurate analysis will also be done, to be able to avoid over-dimensioning and thus weight.

HOW?

The production method will be done in one of two ways. One could say that this will be decided by our goal to make the car as light as possible versus our economical limitations and the degree of help we get from our sponsors. We could use prepreg, where rather expensive mold material and prepreg is needed, or we could use vacuum infusion mold, which would increase the weight of the monocoque with 1-6 kg. depending on how much the prepreg bleed/ how good the layup is.

We will work closely with the Department of Product Development and materials at NTNU and study several master thesis about this project. We have several firms that are willing to help us with work, counselling and cheap prizes. These firms are mainly to be found in or near Fredrikstad. We will probably produce the whole monocoque here, in collaboration with HPC and Re-turn AS.

09 MOTOR AND PROPULSION

Concept

- We shall design an electric in-wheel motor
- This shall be placed inside a rear wheel
- This will give: High torque
  High efficiency
  Low weight

Improvements

- New car body – better suited for one-wheel drive
- New rotor - more efficient and lighter design
- 3D-analysis – more accurate

Why

- With center of gravity and drive wheel more in line with the direction of travel we get higher efficiency
- The previous car was not designed for in-wheel drive
- In-wheel drives have no transmission losses and high reliability

How

- By working with NTNU's Electrical Department
- By basing the work on several master thesis about this project
- Through our collaboration with SmartMotor

CONCEPT

We will make an in-wheel electric motor for three-phase alternating current. This gives us good control of the speed of the car when we use a good motor controller. This is more easily achieved with an AC motor than with a DC motor. We will make an axial flux permanent magnet motor. These have the advantages that they are very thin and the torque produced increases greatly with the diameter. They are therefore well suited for in-wheel applications.
We will make some significant changes from last year. The motor will use a magnet arrangement called Hallbach array which gives a higher flux density and eliminates the need for iron in the motor. This thereby reduces the weight considerably. The estimated weight of the motor is 6,24 kg.

IMPROVEMENTS

We will make a new body which is more suited for one wheel drive. In order to obtain the best overall performance of the car, the weight should be evenly distributed. The car body which has been used in the previous years was design for an in-board motor, not in-wheel motor. When the motor type was changed to an in-wheel motor the weight distribution became uneven. This we will now correct with two measures; first we will reduce the weight of the motor with 50 %. Second, we will make the distance between the rear wheel narrower than the front wheels.
Also, we are using the computing tool Maxwell to make a 3D-analysis of the motor before constructing it. This will give us a more accurate model of the motor and thereby prevent problems like the one encountered last year, when the motor had to be modified last minute due to an unexpectedly high back voltage. Avoiding such problems will ensure us a considerably higher efficiency than last year.

HOW?

We have a good cooperation with the scientific staff at NTNU's Electrical Department. Here, we are working closely with Ph.D. Candidate Zhang, who is working on very similar designs, and we are guided by Prof. Robert Nilssen.
The design of the motor for last year was the topic of the master thesis by André Dahl-Jacobsen in 2010. The optimization this type of motor for our project was the topic master thesis by Lubna Nasrin in 2011. We therefore have a good basis for our work already.
Finally we have a sponsor agreement with the company SmartMotor which produces this type of motors among others. They have been sponsoring this project with expertise and material in the past years, and have stated that they want to give us more man-hours than earlier years.

WHY?

Since the motor will be placed inside a rear wheel, the force will not be aimed directly towards the center of gravity. This will be compensated for by narrowing the distance between the rear wheels, thereby placing the drive wheel more centered.
Originally, the previous car did not have an in-wheel motor. The weight distribution was therefore different and the body was designed for that motor.
In-wheel motors have no transmission and only one moving part. This gives very limited possibilities for engine failure. We will thereby obtain higher reliability.

10 SUSPENSION AND STEERING

Concept
- Energy efficient
- Lightweight
- Smooth ride
- Compact
- Good handling abilities

Improvements
- Damped
- Carbon fiber
- Strong and rugged

How
- Interfaces
- Light and strong materials
- Simulations
- Testing and optimization
- Knowledge from previous years

Why
- Major changes in the race conditions
- Traverse uneven ground
- Never lose traction
- Less internal friction
- Increase overall system efficiency

CONCEPT

The aim for the new system is for it to be damped, lightweight and compact, with good handling abilities to provide a safe ride during the race. The light weight ensures overall low weight of the car, and the compact design allows for a small body. The damping minimizes stress on the body and enhances handling and safety, and the small size reduces aerodynamic drag, all of which contribute directly towards an energy efficient vehicle.

IMPROVEMENTS

The new suspension shall be stronger to ensure reliability and safety under anticipated and unexpected load cases on uneven surfaces. Replacement of the hubs and wheels will reduce wheel wobbling and steering instabilities. Introduction of damping allows for uneven road, less vibration and noise and easier transportation for showcasing. Reduction of friction in the new steering system will increase the driver's road feel and reduce driver fatigue.

HOW?

Emphasizing the interfaces between all the systems in the car ensures compatible components with as little manufacturing as possible and predictable behaviour. The use of lightweight materials, such as carbon fiber and light metals, together with advanced simulations and thorough testing, provides low weight, high strength and durability. All aspects of the suspension and steering geometry will be scrutinized and optimized for both a good end result and affordable manufacturing. We recognize the honour of being the team that sets out to make a new car for the first time since 2008, and we all want to make this project as huge a success as the previous one.

WHY?

Due major changes in the race conditions this year's car needs to be able to traverse uneven ground. This requires a fully damped suspension system to ensure the car will never lose traction during the race, both for fuel efficiency and the safety of the driver and other competitors. The old car body has weaknesses around the suspension connection points and doesn't allow for a fully damped design. Only a new body can, among other goals, give the opportunity to fit a fully damped suspension. In total, this will allow accumulated knowledge to be fully utilized to build an improved car.

11 BATTERIES VS FUEL CELL

Concept
- Use lithium battery as main power source
- Use existing control system from the old car
- Simplify drive line and minimize chance of problems/failure

Improvements
- Double efficiency over fuel cell
- Weight reduction in energy source by more than 80%
- Flexible mounting

Why
- Leasing deal with Ballard expires in 2013
- Batteries are more in tune with today's market than fuel cells (FC)
- Easier implementation

How
- Two companies are willing to sponsor us
- Using old control system minimizes implementation effort/time
- Plug and Play

WHY?

Fuel cells were very much in the wind a couple of years ago, but manufactures still haven't surpassed the major challenges in fuel production needed to launch it as a real alternative to fossil fuels. Battery power is the way to go for the time being, and a lot of the big car manufacturers have cars almost ready for the market. Batteries are also much more reliable and powerful than they used to be because of advancements in battery technology.

IMPROVEMENTS

The fuel cell we have from Ballard is very good, and has a efficiency of over 50% in race trim, but it weighs about 16kg in total and is generally over-dimensioned for Shell Eco-Marathon (SEM) use. The two Norwegian companies we have been in contact with are willing to provide us with battery packs providing much more stable currents than the fuel cell and weighing only 2 kilos! Batteries are different in the sense that they are only power storage units, and not power conversion like fuel cells and internal combustion engines are. Batteries only have to discharge their stored energy and do so very efficiently. There is some internal resistance, but they have an efficiency of about 98-99%, almost double that of our fuel cell. They can also be stored in a confined space, unlike the fuel cell that needs space around it for air to flow through it and react with the hydrogen.

CONCEPT

The number of components that needs to be designed, tested, manufactured and tested again when making a brand new car is quite monumental. So if there is a system, or part of a system, that can be simplified without any performance loss, that is very valuable for us. 2011 saw the first entry in the Plug-In Battery Electric class with results (km/kWh) almost double that of the fuel cell vehicles. Modern batteries offer very high performance and energy in a small and light package. Coupled with a battery management system (BMS) these battery packs are also very stable. From a user perspective they are very much plug and play, in contrast to fuel cells that need continual maintenance and complex optimization and startup procedures. The control system in the old car is still very much usable and doesn't differentiate between power sources as long as it provides a stable DC current. By using a battery pack as the main power source in place of the fuel cell we can drastically reduce overall system and implementation complexity.