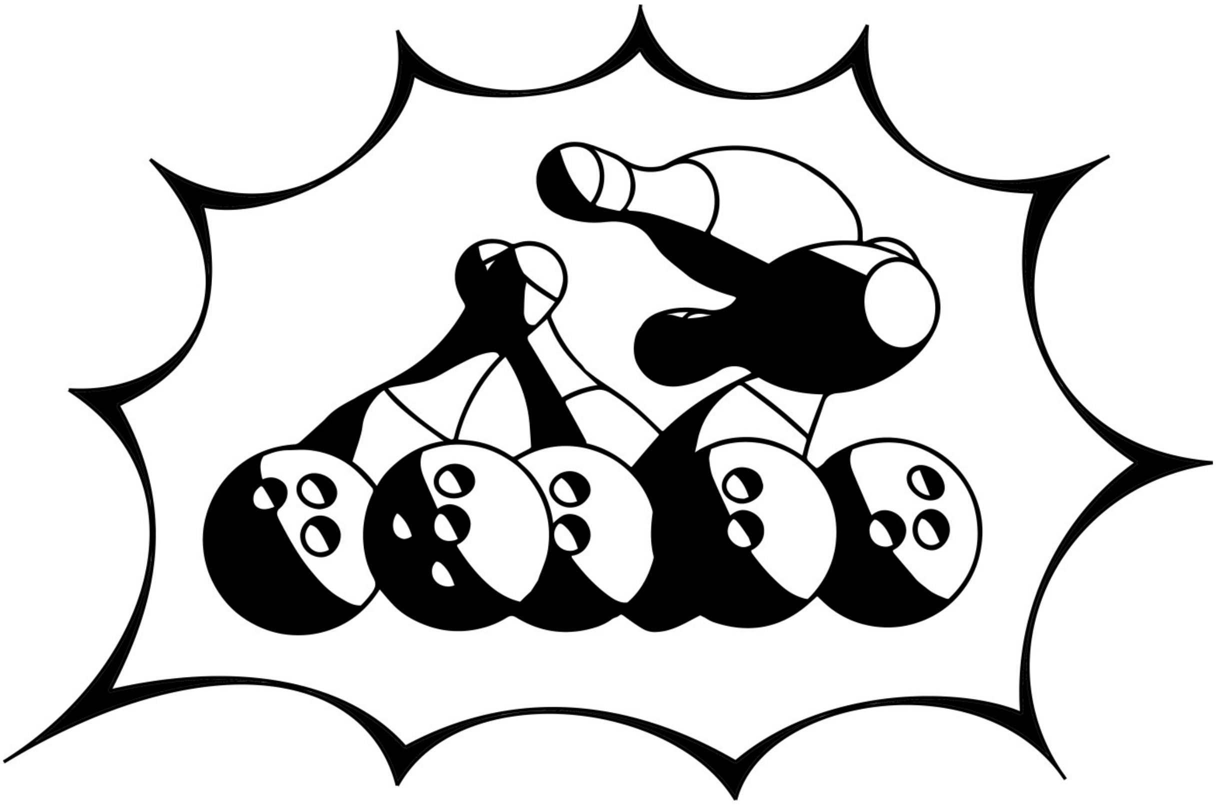
Engineering Design

Student manual



Course Year 2018/2019

Eindhoven University of Technology
Faculty of Mechanical Engineering

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Chapter 1

Introduction

1.1 Engineering Design

We live in a man-made world. Almost every object in our environment has been designed in one way or another. Most things that surround us are the result of a design process before manufacturing. Note that, there is always a two-way connection between design and manufacturing: the design influences the manufacturing process and, vice versa, the manufacturing process influences the design.

If one analyzes existing products, it becomes clear that almost every product is based on the contribution of many. Even in the simplest case, i.e. when you carve something in a branch of a tree, you would probably use a tool that has been designed and made by others. Complex devices such as aircraft, smart phones or MRI scanners are developed over many years with the contribution of thousands and thousands of people with a variety of skills and backgrounds.

All these products do not just happen to be there. They are the result of a structured activity: a design process. In a design process, many things are handled: the design goal is identified, possible problem solutions are generated, evaluated and selected, boundary conditions such as time, money and resources have to be dealt with.

The ability to design (to create something new, something that was not there before) is a core competence of any engineer. The Bachelor College has chosen to teach this common competence to all students of all majors in one course: "Engineering Design". In this course, the focus will be the creation of an artefact.
It is worth noting here, that the ability to design, to create something new, applies to the building of a measurement system, the creation of a computer game, the composition of a storage system, maybe even stretch as far as to the proof of a theory.
You will be a member of a small design team in which every participant comes from a different major. The background of every member is a complementary contribution to the project result and mutual trust is a prerequisite for success. Together, you will design a fairly complex artefact. You will learn to formulate design goals, to handle external and internal constraints and to manage time. You will experience the difficulties in prototype realization and the stress while presenting and demonstrating your design before a jury and your peers. This is not just an education setting, but a demonstration of how your design solution is perceived by a (factitious) client and would perform in the real world.

In this way, it can be seen as a realistic playground to learn about design. It has to be mentioned that a large number of teams will execute the same design task simultaneously. It is expected that many different design solutions will emerge. Reflection on your own results and comparing to the results of the other teams will certainly be a unique learning experience.

It could be tempting to see the realization of the artefact as the single goal of the activities in the project. Instead, the goal of the course "Engineering Design" is to learn how to structure a design process. During the project, you should always keep the underlying goal in mind.

The course "Engineering Design" is a challenge for both the participating students and the teaching staff. We wish all of you an inspiring design project and also lots of joy and fun in reaching your targets.

1.2 Lay-out of this document

The structure of this document is as follows: in Chapter 2 the subject of this design assignment is explained. Chapter 3 describes the design process which will be executed in this course. Chapter 4 contains the structure of the course, the expected deliverables and a provisional planning. The rules and regulations for the course and the events are given in chapter 5.
Section 3.9 and appendix A introduce tools to control your project.

1.3 Additional Course Documentation

The Files section of 4WBB0 on Canvas contains details about work and work flow in the project. There, you will find details on the Preliminary Design Fair and Closing Event and use of the provided 3D-printing support. The templates given on Canvas must be used to hand in your results. Furthermore, the grading of the groups and students will be scored by means of the predefined rubrics, which are all available on Canvas.

1.4 Integrity

In carrying out this course and delivering its products you must act according to the rules of the TU/e code of scientific conduct [1]. The Netherlands Code of Conduct for Academic Practice of the VSNU can be found on the same website. More information about scientific integrity is published on the websites of TU/e and VSNU.

[1] http://www.tue.nl/en/university/about-the-university/integrity/scientific-integrity/

Chapter 2

The Project Case

2.1 Project Goal

During this course, you and your group design and create an autonomous active sports-aid for people with a physical or mental disability.

Each group may choose a sport and the disability for which they want to develop the sports-aid. Furthermore, you may choose your type of user where you can choose age, but also for example level of activity (professional, amateur, beginner or maybe just for helping in physical activity).
Budget restrictions are explained in sections 4.1.6 and 4.1.7.

At the closing event, on Friday October 26, this sports-aid will be assessed by a jury and the other student groups in a demonstrator event for its unique features in originality, usefulness in the humanitarian context (user-friendly) and (constructive) elegance (following the rubric found on Canvas).

The sports-aid created by your team must be:

- user-friendly: you may choose your own user specification (age, level, etc.). The human-machine interface must be user-friendly and suited for the chosen user.
- addressing a disability : you may choose any disability for which an aid helps in performing the sport you have chosen.
- a sports-aid: the device must be intended to be used in some physical activity to train/excercise the body.
- active: the device needs to have some type of sensoring (pressure, proximity, smell, vision, etc.) to which it (autonomously) responds (lights up, moves, vibrates, etc.).
- autonomous: the device may be started from a laptop or phone, but once started only the user (so no additional operator) may interact with the device.
- elegant, such that the proposed user is willing to use it
- easily transportable: weigh less than 3kg and (when disassembled) it must fit in a box of $0.3 \times 0.3 \times 0.5\text{m}^3$
- built from parts that do not have a complete function. Using a DC-motor with integrated gearbox is acceptable, where a complete ready made motorized gripper is not.

2.2 Background

At least 10% of the population lives with the challenges of a disability [1]. In current times, the attention for people with disabilities has grown (for example in media attention[2]), but the risk of labelling stil exists, where disability sports is still not considered as legitimate sport. This stereotyping may lead to exclusion, creating barriers for participation.
The development of sports-aids is not only valuable for athletes trying to reach a top level, but also helps to increase the possibilities for any individual with a disability to participate in physical activity (for example school physical education) and sports-programs. Participation in sports is a tool for revalidation, but also (maybe even more) a social construct; a means for inclusion into society[3].

In a world where more and more small devices are developed, where smart technology becomes more-and-more common in everyday live, new possibilities arise to actively support individuals with a disability. Some trends in technology (cyborg technology, collaborative robotics, robotics supporting physical jobs, etc.) may lead to new exciting opportunities. A great challenge for these new tools is the optimisation of the human-machine interface. This field in engineering is (not only for disability sports) one or the major challenges of these days.

In the following, we will give a few examples of existing aids for individuals with disabilities. These examples may serve you as inspiration. You are encouraged to expand your search way beyond these examples. You and your group are challenged to be the best you can be. So, take risks and come up with innovative and creative designs with a clear user perspective.

In the assignment the term "sport" may be stretched towards enhancing the possibilities for physical activity. Two interesting examples:
The Hibbot: Giving Children with CP the Chance to Walk[4]
For the visually impaired:[5]
Should you decide to focus on youth and sports, you can find examples and explanations in:
"Disability and Youth Sport" , Edited by Hayley Fitzgerald, Series Editor: Richard Bailey, 2009, Routledge.

This tool for tremor reduction[6] is not used in sports/physical activity, but still shows an aid for the challenges for Parkinson's patients.
A student project for tremor reduction: TURB[7].

Sports and physical activity as a part of a recovery process: What is your story[8]

In some sports disciplines, athletes with a disability have become better, stronger, faster than their traditionally abled competitors: Disability sport is the future:[9]

Other examples:

- A suit which guides visually impaired skaters
- A device for playing darts with tremor

[1] "Disability Sport", K.P. DePauw and S.J. Gavron, 2005
[2] https://www.theguardian.com/sport/disability-sport
[3] https://www.un.org/development/desa/disabilities/issues/disability-and-sports.html
[4] https://www.youtube.com/watch?v=3o2quDqv3Rg
[5] https://www.cursor.tue.nl/en/news/2018/april/week-2/students-design-backpack-that-sees-for-the-blind/
[6] https://www.youtube.com/watch?v=HW9JPadlN2I
[7] https://www.youtube.com/watch?v=O4vJCB-12iM
[8] https://www.youtube.com/watch?v=bp_5-lIi8n4
[9] https://www.youtube.com/watch?v=8LQhhYgjlJ0

- A signaling device for playing football when completely deaf
- A self-inflating life vest for swimming with epilepsy
- A freeze-of-gait signal for walking with Parkinsons
- etc.

Chapter 3

The Design Process

There are many different design processes[1] aiming at defining different products, satisfying different customers, having different levels of complexity, etc. The design process, which you will follow in this course, consists of seven phases, which lead to a tested and evaluated design product.

This step-by-step description may lead to the misconception that the design process consists of a number of sequential steps, where the result of one step needs to be fixed before the next step starts; where you follow a prefixed sequence of steps. Evidently, this is NOT how it works. In any design process, you need to perform concurrent processes: at all times you need to look ahead to see what you need for future steps and need to look back to see if earlier decisions need to be re-evaluated. This must be an important topic at each of your group meetings.

As an example: should you propose to use electro-magnetic force in your design to grab something, you must wonder whether you know enough about that topic to design such a device and, if not, start studying its theory. As soon as you know enough about the electro-magnets, you have to make sure that it can deliver the necessary force (what is the weight of the lifted object?) and whether you can provide the necessary power (do you know enough about batteries?). This means that in the very early stages of the process, you need to acquire all the knowledge you need to finish the design in time: you need to start trying alternatives, test power supplies, check out the hardware, find out about the construction, etc.

Along this winding road of a design process, risk management is crucial: each step or choice has its consequence and each consequence leads to a different result. Taking an unsubstantiated decision may lead to a poor result, while taking no decision will give no result at all. You will have to take deliberate risks, but distribute/balance them for an optimal result. Note that: avoiding all risks is the biggest risk of all, while it will most likely lead to a conservative, non-innovative product. So, during the whole process, during each phase, you must keep track of your risk management to make sure that your final product indeed becomes innovative, fitting the humanitarian context and constructively elegant!

Technology Readiness Level is a method introduced by NASA and widely used for product development in the field of innovation. It is not only a tool to develop products but also an instrument for planning and tracking status.
Both managerial and technical aspects share the same view on the development process. Priorities, tasks and deadlines can be monitored regardless of the expertise of people involved.

A definition of Technical Readiness Levels is given in Appendix A. On Canvas (under Files/Templates),

[1] Examples can be found in "Tools and tactics of design" by P.G. Dominick et al., Wiley, 2001 or "Exploring Engineering" by P. Kosky, Elsevier, 2016

you will find a spreadsheet (ProjectPlanning.xlsx) where the seven design steps outlined in this chapter are combined with a Technical Readiness Level tool[2]. It highlights which development steps are to be followed in the project and gives you the freedom to develop the TRL of different functions in your design asynchronously.

[2]Note: we have translated and scaled the NASA TRL's to fit this project

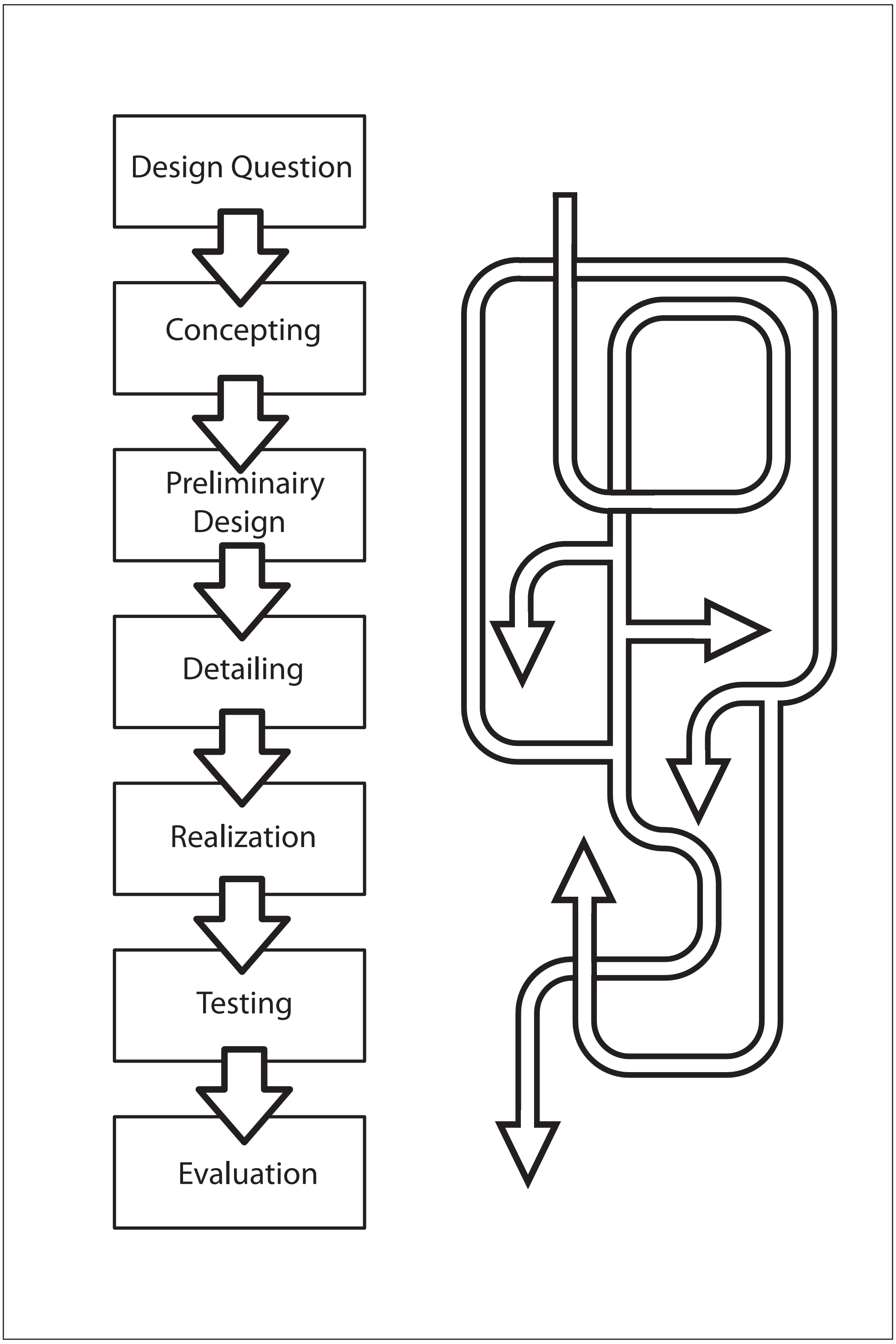


Figure 3.1: Block diagram of the formal design process and the long and winding road followed in reality.

3.1 Step 0: Group effectiveness

In almost every possible professional future, you will be confronted with work in groups where the collaboration of people with different backgrounds needs to lead to better results.

3.1.1 Knowledge and Skills

In any group project, your group consists of people with different interests, hobbies, skills, etc. One of the challenges of the work in such a group is to use all those different backgrounds to achieve the optimal result.
In the first meeting, you will have to clarify in which way you think you can contribute to the design project. Combining the profiles of all group members will form a crucial part of the first meeting. This means you can figure out together, where the strong points of the groups lie and how to use them, but also what the groups weaknesses are and figure out how to fix or avoid them. Make sure that these strengths and weaknesses cover all (technical and non-technical) topics and skills relevant to the project. During the midterm and final evaluation, you will explore whether the group proofs to be able to exploite its capacity to its full extend or how the group performance can be further improved.

3.1.2 Types of creators

There are many ways of categorizing the different types of creators. Here, we give three creator-descriptions. You are asked to select the description which fits you most.

The Inventor

The inventor is a person who has out of context ideas inspired by various fields. It is kind of a lifestyle of observing a lot on rational level, and finding weird connections between fields. It might not be even a working concept what they come up with, often these concepts are still unfinished. The main contribution of the inventor is to bring in the group really unique ideas/directions, opening up new windows.
The inventor needs from the group: openness, empathy and patience to accept these and somebody who can actually include elements or the whole concept in the context of the task.

The Artist

The Artist is a person who "steals" inspiration from basically any field. A poem, a picture, a study, technology etc. and somehow internally these sources connect and bring something new to life. Here, rational and emotional side of the brain are both active, style and mood are also present next to functions.
The artist can bring the group: stories behind creations which can be inspiring, expressing thoughts and ideas in a personal, even unique way.
The artist needs from the group: to be open to understand what they meant to express and what is behind their creation. Be constructive with them, cause criticism can hurt them.

The Hunter

The hunter is excellent in switching between contexts. He or she can look behind complex systems, objects etc. and see pure functions behind, plus play with these existing solutions, place them into different realities. A hunter surfs on the internet, refers to articles, studies, researches. He or she brings down to earth solutions and brings crazy options to the level of reality.
emphThe hunter needs from the group: some perspective broadening ideas, also having a practical

approach, which can be seen/done/tested easily.

3.1.3 Strengths and Weaknesses

The gathered results will be used to show the strengths and weaknesses of your group. It will show, where you as group can excel, but also where you have to be cautious and at which point in the process you lack knowledge, which you have to find in time. The mere fact that you follow a certain major is no guarantee that your knowledge and skills are sufficient for a meaningful contribution in your field.

The assembled strengths and weaknesses form the base for the major resources of your group. It is important to identify where your group can easily score better the others, on which topics do you need more information, in which phases of the project planning do you need to have taken care of the weaknesses (or can they be avoided).

3.2 Step 1: The Design Question

A design question[3] (like, in this case: “Build an ’active aid for sports for disabled people”) is inherently vague. Even more so, there is no single nor optimal answer to such a question. All answers and, therefore, all designs will be different and have different qualities.
The first step to a design assignment is to specify the actual design goal: which sport, which disability and what type of aid do you want to develop? You may want to look in your own experience, which sport do you practice and/or which disability would you like to support? Furthermore, you may want to choose a type of user: amateur or professional, child or adult. There are of course uncountable options! So, examine the examples and fields covered in Project Case (chapter 2) and check the internet, search for literature, look into your own experience and environment for inspiration.

3.2.1 Why?

The challenge is to not think in solutions: this phase of the process is only about defining the question, not about solving it. The arguments in these discussions concern the "Why?" only. For example:

- Why would you choose this sport or disability?
- Why would this help your user?
- Why would your user want your product?

This means that you can partly rely on your own knowledge and interests, but it is essential to also look at what you can find in literature[4]. So, make sure to use all information you can find on motivation, inspiration and whatever more for the development of these (or similar) types of aid.

As a group, you must decide which project-option (we define a project-option as a combination of sport and disability for which you can develop an active aid) you want to pursue; in which option you see the best possibility to develop a creative, innovative and user-friendly product according to the challenges given in section 2.1. Again, this decision should only be based on "Why?"-arguments.

[3] we loosely use "design question" as a reference to assignment, question, mission, request, etc

[4] For insight in academic literature, you may want to use "google scholar"[5] (or a similar tool). A search on "sport disability" gives 275.000 hits. So, there is a lot of information ready to be used!

3.3 Step 2: Concepting

The concepting phase is where you can create something special and unusual. This is the step when you as a team create innovation. The concepting phase is where you have to challenge yourself and force yourself to keep being open.

3.3.1 How?

The key questions in concepting concern "How?", for example:

- How are you going to solve the problem?
- How can we exploit the strengts in our group to their full extend?
- How can you come up with a innovative, user-friendly, esthetic, useful product?

This is all about creative engineering, let your fantasy run free! Inspiration comes from different sources, some people are more inventive, some can adapt already existing solutions, some go crazy, some stay closer to reality. To trigger ideas you can find ideas in fields of history, science fiction, nature, art, or even from cartoons and movies. Employing new fields leads to new ideas and/or new combinations. You will need all of these kind of sources to your work. In this phase (as in all phases) it is crucial to carefully listen to what all team-members contribute; to take advantage of the most creative, innovative, user-friendly, etc. suggestions and use them all to produce your teams best possible product.
To structure this phase, you first will define the functions necessary in your design, next gather all possible solutions for each function and from that to create a number of concept products in "Shitty Prototyping".

3.3.2 Functions

The first step in this concepting phase is to define the functions which your product needs to be able to fulfill, where functions are typically verbs, for example "catch something", "reduce tremor", "give signal".
The trick is to not be to specific; to simplify, merge and frame the actions necessary into general functions. A pittfall is that you already start to include solutions! For example: "giving a signal" might be necessary and correct, while "giving a light signal" is incorrect (since it already contains the chosen solution). So, functions can be: “aim at target”, “pick something up”, etc. Actually, "pick something up" may lead you to think that you have to lift an object, while, in fact, that may not be necessary.
Furthermore, the set of functions needs to be complete. Therefore, ask yourself the question, if the device could only do this, can it do everything which is necessary to support in doing the sports with the chosen disability.

It is crucial to have these generalized functions gathered before entering the creative phase. If you as a team do not create a good base for collecting ideas, it will be very hard to design something unique. A key goal of the course is to go through the design process to create something new, so do your best to build a solid ground for the concepting phase.

3.3.3 Solution Encyclopedia

Now, you start gathering solutions to each of the functions. Make sure that you process the new ideas and start doing! However weird, unfinished, unprofessional, simple/complex the idea is, make sure to sketch, write or build it, otherwise it will get lost.

Therefore, you gather a large set of function solutions (typically five for each function) in each "Solution Encyclopedia" (one "Solution Encyclopedia" per project-option).

3.3.4 Shitty-prototypes

The last step before the Preliminary design is to develop at least three fundamentally different concept products. For this purpose, you chose and combine different function-solutions from the "Solution-Encyclopedia".
These (at least three) concept products are to be build as "Shitty-Prototypes".

Prototyping Phases: Shitty Prototyping

- Is used mainly for internal communication in the design team.
- Just build something; visualizes ideas (structure , features); communication and design tool; common understanding of the device; can be parts, subsystems or the whole thing; talking vs. building!!
- Characteristics: made from scrap material, Lego©, clay, Knex©, paper, tape, etc; easy to make, effortless mockup, easy to change; explainable, visually easy, fast to process; understandable only for the team or people involved; fully intuitive

3.3.5 Selection

Based on these (at least three) "Shitty Prototypes", you and your group select the concept products, where you expect to find your groups' innovation strength, where you can create a very innovative, creative, esthetic, effective device.
This is the concept product which you will develop into a Preliminary Design.

3.4 Step 3: Preliminary Design

This Preliminary Design needs to be presented before your virtual client (let's suppose that the jury at the Preliminary Design Fair plays that role). Therefore, you need to create a presentable, esthetic, functional mockup, which shows the full potential of your product. In a real life situation, this is the point where a client chooses between different teams or between different design companies. If you present your product, you will definitely benefit from having a elegant/aestatic/user-friendly Preliminary Design. Giving it a name, logo, etc. clearly helps in product-identification.

3.4.1 Requirements, Preferences and Constraints (RPC's)

To convince your client you need to define specifications to which your product will adhere. For this purpose, you will define your requirements and preferences based on a study of the background of the chosen product: what type of solutions are already available, what do the rules in the chosen sport allow, what is needed to make the product attractive to use (aesthetically, weight, color, etc.)? Before you plunge into the design details, it is essential that these prerequisites are clarified.

First, let us distinguish the difference between requirements, preferences and constraints (though it may be obvious):

- **Requirements**: the design has to satisfy any requirement you formulate. The requirements form the "promise" that you make to your client. This means that a requirement needs to be specific or measurable! Therefore each requirement needs a quantification: a requirement can *not* be "the device has to be as light as possible": you can never know whether your solution is the fastest possible. Instead, you could use: "the device may not weigh more than 1kg". This is measurable and still has the option of being lighter.
- **Preferences**: these are likes and want-to-haves. Here, measurability is less important: you can, for example, want the device to be as "colorful" as possible (for visibility). Each preference is therefore linked to an optimization. Two designs that meet all preferences and constraints can be distinguished only on basis of preferences. You can state here that you have a preference "speed of reaction" which you want to optimize to "as fast as possible". This makes a design with a reaction time of 0.5s better than one with a reaction time of 4s.
- **Constraints** are design choices which are fixed from the start. Usually, these are formulated by the client. For example, in the case of this project: your solution must work autonomously.

Note, the quantifications of your requirements and optimization criteria for your preferences need a justification: for example why would you choose a maximum weight of 1kg?

The set of requirements, preferences and constraints needs to be sufficient and complete. This means that your product fulfills all requirements, is optimized to your preferences and takes all constraints into account. So, there are no loose ends (no requirements which are not met or preferences unanswered), nor are there hidden extra features (no hidden optimization criterion or requirement which was not set).

This also means that your list of requirements, preferences and constraints needs to cover both the technical and non-technical properties of your design. Note that, in this course, the assignment is defined in such a way that you may define your own set of requirements and preferences. In any practical situation, this step would be the result of elaborate consultation with your customer or user. In this course, we use "client" if we want to refer to your customer or the product's user. For checking the completeness of your product, you may want to check whether it describes all properties of the necessary techniques, the connection with the user and about the user-product interface.

We ask you to make reference to a "virtual" client and to relate the RPC's to their possible demands and wishes. Therefore, in the formulation of your list of requirements, preferences and constraints, you have to consider that your design has to be able to perform optimally in the real-world and that you need to be able to proof this in the presentation and demonstration before the jury.

Should, at some point in the following process) your product fail to satisfy all requirements, there are a couple of options:

- Reconsider the requirements: it might be that, at a closer look (in real practice in consultation with the client) the requirement set can be redefined so that the selected design does satisfy all of them.
- Reconsider the selection of the PD from the concept products; maybe you have erased a concept product which does satisfy all requirements.
- Reconsider the concept products: there might be different combination of function solutions which is (in hindsight) better than the ones you selected or (more likely) options you forgot in the first round.

Prototyping Phases: Preliminary Design

- Has a client relation, more understandable for people outside of the project
- Get more serious, make a real concept system; shows the proposed product to the client; others can interact with it; specialized on one function; better if it shows dynamics; more feasible than the shitty prototype, has to be a system and system properties are more considered
- In the course: has to be tangible, has to be specialized; made of scrap material; shows the full system but not all elements are detailed
- Presentable; understandable for others, aesthetics, coherence, elegancy, ratio, scale come to the picture; needs some effort to build.
- Prepares for the Fit Test and Detailing

In the upcoming phases of the design process, the preliminary design has to be extended/detailed. The thus developed prototype becomes more-and-more refined during the detailing and realization steps.

3.5 Step 4: Detailing

In the detailing (and subsequent realization) phase of the design process, risk management becomes decisive. Now, you have to weigh different choices for their consequence: do you take the risk of ordering cheap with the risk of late delivery, do you choose self-build or ordered components, when do you start assembly, have you done enough testing, etc.
Use the provided risk management information (see Appendix 3.9) to make a risk inventory on three dimensions. Keep in mind: this is all about risk balancing; taking no risks may mean that you end up with a mediocre, non-innovative, inhumane and therefore insufficient design product.
Risk management in these phases includes the testing of assumptions: as soon as you can you must always test parts/assemblies on their assumed functioning. Can the batteries turn the DC-motor (just connect them by wires)? Is the gripper balanced enough for picking up a ball?
Now that the preliminary design has been chosen, it is time to start detailing the system as a whole and all its components. The detailing step is a mix of practical implementation possibilities and theoretical optimization.
Optimization examples are:

- How many and what type of motors do you want to use? Are they controllable through the chosen hardware?
- If you want to use batteries: which type and how many? What does this mean in terms of operation time? On the other hand, the number of batteries will influence weight. Should you choose to use LiPo batteries make sure that you know about their safety issues![6]
- A long gripper may be easy to grasp a ball but can be too weak or too compliant to effectively hold it. Here, modeling (mathematical or physical) can be useful to find an optimal solution.

A risk of plunging into the detailing step is that you may loose track of the system as a whole; putting too much attention to one of the parts, while you should actually see it in the context of the full design. Therefore, it is important that you keep all aspects of the design in balance. So, keep updating the TRL-based project planning for all functions.

It is essential that, during the detailing stage, you bring the Preliminary Design to a Fit Test stage (Figure 3.2): all details in size, suspension, transmission, fit, etc. must be dimensioned and combined in this kit before you start the realization step.
The Fit Test answers the essential questions before you can go to the realization phase. Examples: does everything still fit in the size you have in mind, do all solutions match with the total budget, does the design not get too heavy, can your control-hardware still manage all components, etc. Use your Fit Test(s) to make sure that all components are compatible, so fit parts until the whole device is complete.
In the detailing step, you have to make sure that the components you want to use and the production techniques you need are available (check out the "Technical Guide" on Canvas/Files for the provided production facilities and deadlines), that the system you propose remains within the budget, etc.

The result of the detailing step is a list of necessary components (construction, motors, batteries, etc.) and the calculations to support them:

- Can the batteries deliver the necessary power (make sure to take the batteries internal voltage current dependency into account)? And for how long?
- Can the motors deliver the necessary power (for holding, throwing, forcing, support, etc)?
- Do all components match together and do you have solutions to connect all parts?

[6]Should you choose LiPo-batteries, you MUST contact the 4wbb0-organisation to receive a safety instruction

Make sure, that you make reference to the RPC's: they form the criteria that you have defined for your design. This might also be a reason to go back and refine or redefine the RPC's.
This is the chance to start taking your preferences as far as you can; the chance to optimize the system according to your own (or the client's) terms. Don't forget to also optimize the design with respect to the humanitarian context of the original assignment, so make sure that it is elegant and esthetic such that your prospective user will be willing to use it.

Prototyping Phases: Fit test / Breadboard

- Proof of concepts on subsystem level; actually build ideas for testing; dimensioning, sizing and leads to the Bill Of Materials (BOM)
- Once you have a feature you have to build it and test it; empirical proof that things work.
- Parts have physical representation, proper size and interaction; all joints are represented

The Fit Tests show size, orientation and connection of components of your product. It is a 3D verification of your design.
The Breadboards are used to test functionality. It proofs the connectivity of the electronics and the controls.

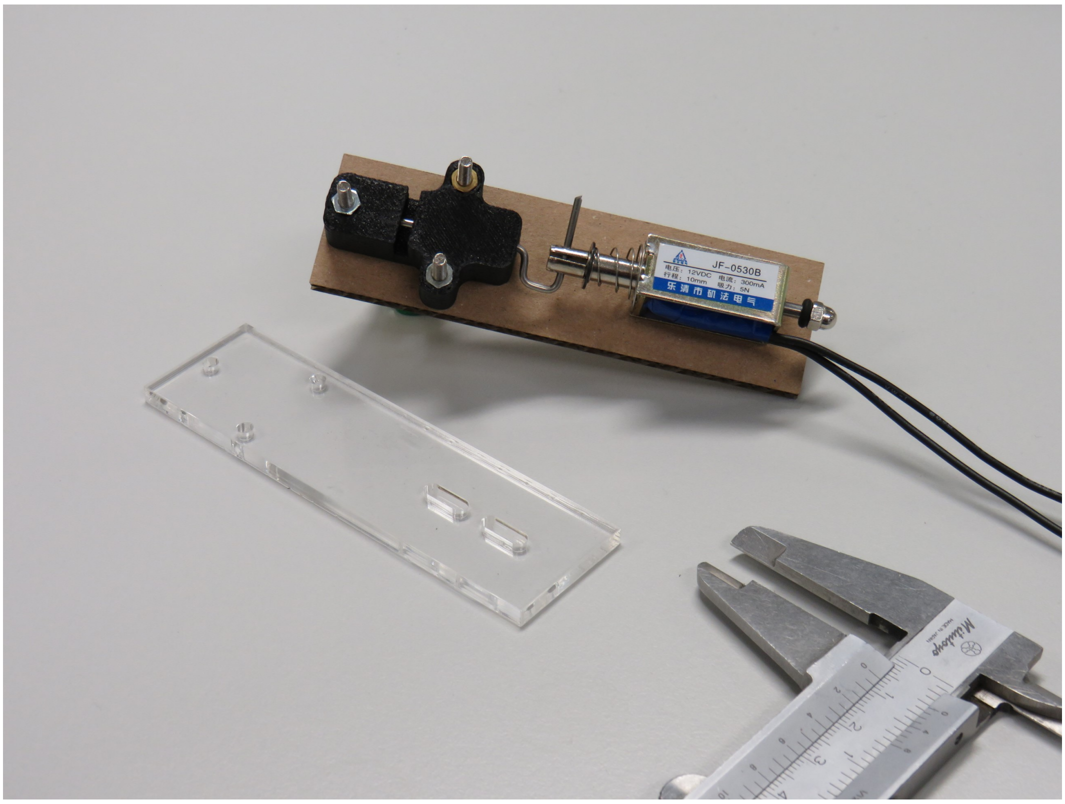


Figure 3.2: Example of a Fit Test, in this case a solenoid driving a slider mechanism. Some final parts, e.g. the solenoid and a 3D-printed guide are already present. The frame is made from corrugated cardboard to perform the fit test. Once OK, the final frame part could be made out of clear acrylic sheet material.

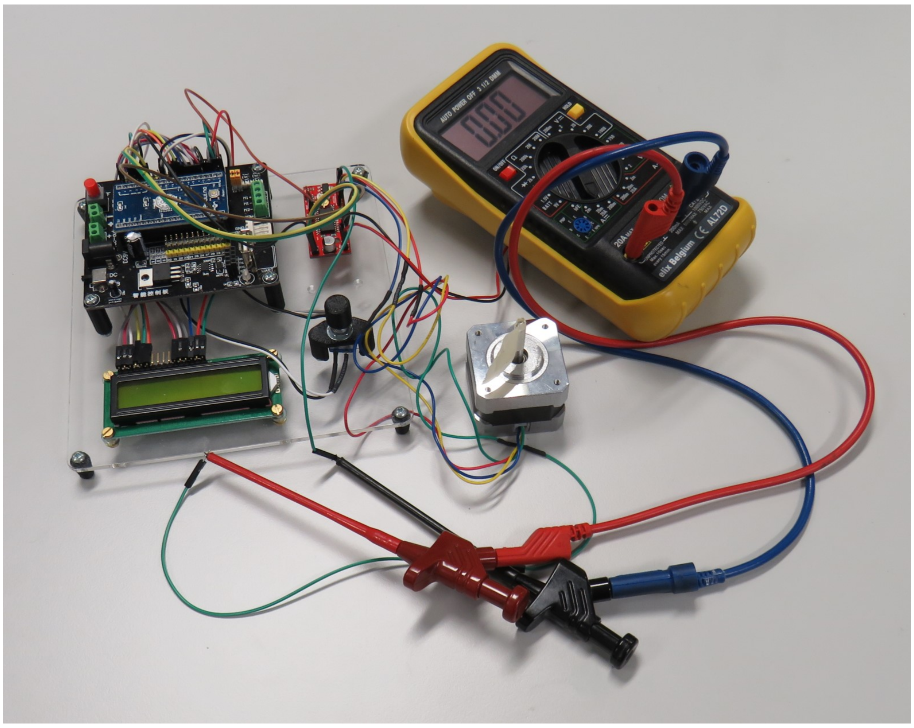


Figure 3.3: The breadboard contains electromechanical (a stepper motor) and control components (a stepper driver and a microcontroller). The functionality can partly be verified in an early stage of the design.

3.6 Step 5: Realization

All chosen components need to be made, ordered and assembled:

- From the Fit Test: specify all necessary parts, choose materials and the way to manufacture them
- Make the necessary (CAD-)drawings, for example for 3D-printing in the 4WBB0 workshop or at an external supplier.
- Draft a Bill Of Materials (BOM), which includes all parts to check whether the chosen realization matches the budget.

This step is extremely critical in the time scheduling. The realization of components always takes longer than you expect, the delivery time of ordered products is out of your control, there is always a chance of things not working as you hoped or not fitting the assembly as you expected. This means that you should include some buffer time, sometimes by taking realization decisions as you go along the previous design steps. For example, if you come across a component critical to your preferred design, but also hard to get, you might need to take the decision to order that product early in the detailing step.

Make sure that you start testing all parts that are ready. For example: as soon as you have your servos, start testing them together with the supplied hardware. As soon as your electronics start to come in, you can build them into a breadboard test system (see figure 3.3). On this system you can check your controls, find out about power supply, see if there is any noise on the signals, etc. Test all separate parts before assembly!

3.7 Step 6: Testing and Finalizing

As soon as the first parts have been realized and assembled, you should start testing them. Each test needs to be documented to make sure that all group members are aware of the test status.

After all separate parts have been tested and assembled, the prototype is ready to see how its performance compares to your RPC. To perform this test you have to make a test plan. This test plan and the test results are part of the final report. For example: the measured maximum lifted weight is 1.5 kg (how will you determine this?) and that exceeds your required weight of 1kg. The requirement is met.

Before the realized design is presented and demonstrated to the jury, the group needs to complete a set of tests which show that all requirements are satisfied and all preferences are fulfilled as expected. The group itself is responsible for these tests. During these tests, you can also do the final tweaking of your design, optimize the settings of your remote controls and adjust parts or connections.

Prototyping Phases: Minimum Viable Product

- In our project this prototype or beta version is the final product.
- Testable, assessable and has customer value.

3.8 Step 7: Evaluation

During the design process you have made choices, sometimes made on solid argumentation, sometimes on educated guesses and sometimes you just had to pick something to be able to move on. In the evaluation, you look back on all choices made during the process to see whether they have influenced the result. You can see, in hindsight, whether different choices in your design process and risk management could have lead to better results. It may help you to also evaluate your product from the virtual client perspective. For this client, you may want to do something like a Job safety analysis[7] in which you show the control of potential hazards of each step of the use of your product. The crucial question is: have you been able to creatie an innovative device; do you seriously feel that would you be able to convince for example a Sports Federation to invest money in the further development of your device into a sellable product.

[7] https://en.wikipedia.org/wiki/Job_safety_analysis

3.9 Risk analysis helps to be successful

Risks are conditions of the real world in which there is a possibility of an adverse deviation from a desired outcome that is expected or hoped for (Vaughan, 1994). In plain words: risk analysis is about finding out what might cause bad luck, mischief, set back, trouble.

As an example: several different things can go wrong at the closing event:

- Weak oral presentation
- Presentation not according to standards in the rubrics evaluation format
- Photos of the device do not give a clear image
- Building and testing the device runs out of planning because critical modules are purchased and delivered too late
- Buying costs run out of budget
- The device does not perform according to requirements, e.g. because:
  - The battery power is insufficient for the weight and functions of the device
  - Moving parts on the device do not work appropriately
  - The function of the device does not support the athlete.

The function of a good risk analysis is to identify potential failures while there is still time to take actions to avoid, recover or improve the unwanted outcome.

3.9.1 Dimensions of risk

Risk analysis describes potential failures/unwanted events in three dimensions (see example-table in the Report-template on Canvas):

- Probability: the likelihood of the occurrence of an unwanted event
- Impact: the loss or damage as a consequence of the occurrence of an unwanted event
- Control: the ability and resources of the team to avoid or mitigate the occurrence of an unwanted event

Risks can vary from fatal to low/safe:
A risk is fatal if an unwanted event is likely to occur, has potentially large negative consequences, and if the team has no solutions to solve the problem.
A risk can be considered low/safe when the event in unlikely and should it occur has littele effect or can easily be controlled.

The aim of sound risk analysis is not to be or become risk avoiding but to be aware of the risks in your project. Take risks consciously, build in fall back propositions (plan A, but also plan B), concentrate time and energy on the criticalities.

3.9.2 Steps in a risk analysis

1. Risk management planning: determine when and how you will carry out a risk analysis: in the Engineering Design course we ask you to start to do this at the end of concepting phase, just before building the Preliminary Design.

2. Risk identification: use a methodical approach and use it systematically (e.g. FMEA, FTA or RDM). See Figures 3.4 and 3.5, taken from TU/e course 1ZV30, Product Innovation Processes

3. Risk evaluation: summarize the identified risks.

4. Risk response planning: create solutions for risky issues (pro-active).

5. Risk monitoring and control: make sure that chosen solutions are being implemented and tests in time.

Take care:

Project failures are more often caused by organizational than by technical factors. Organizational factors relate to good team work, good internal and external communication, in time choosing and purchasing necessary modules, good planning, taking advantage of coaching opportunities, timely planning of the test runs so that repairs and changes can still be made, etc.

Technical issues have almost always high priority in project meetings, but organizational matters are not or indirect addressed!

Some background literature on risk management procedures:

Keizer, J.A., Halman, J.I.M. & Song, X.M. 2002, From Experience: applying the risk management methodology, Journal of Product Innovation Management, 19, 3, 213-231.
TA Carbone, DD Tippett, 2004. Project risk management using the project risk FMEA, *Engineering Management Journal*, 16, 4, 28-35. Bluvband, B, Polak, R. & Grabov, P., 2005. Bouncing failure analysis (BFA): the unified FTA-FMEA methodology, *Reliability and Maintainability Conference Proceedings*, p.463
Ruijters, E. & Stoelenga, M. 2015, Fault tree analysis: A survey of the state-of-the-art in modeling, analysis and tools, *Computer Science Review*, 15-16, February-May, 29-62.

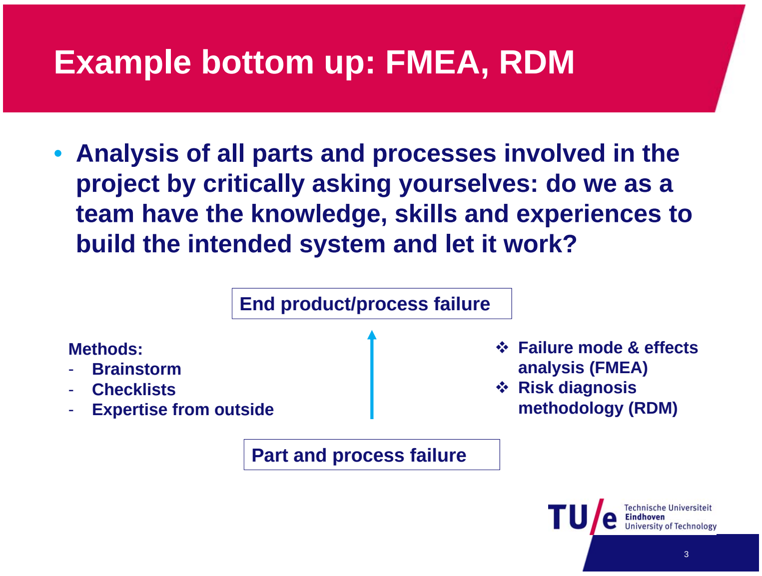


Figure 3.4: Bottom up procedure: Failure Mode and Effect Analysis (FMEA) and Risk Diagnosing Methodology (RDM). (1ZV30)

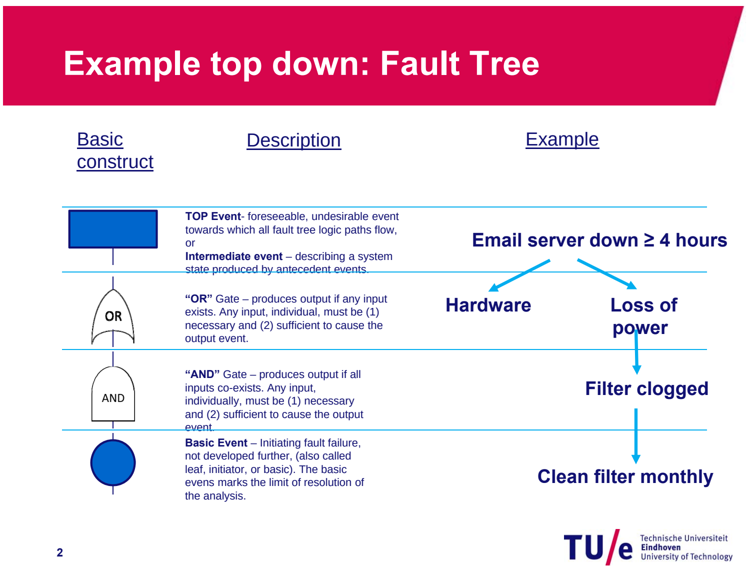


Figure 3.5: Top down procedure: Fault Tree Analysis (FTA). (1ZV30)

Chapter 4

Project Execution

4.1 Course Layout

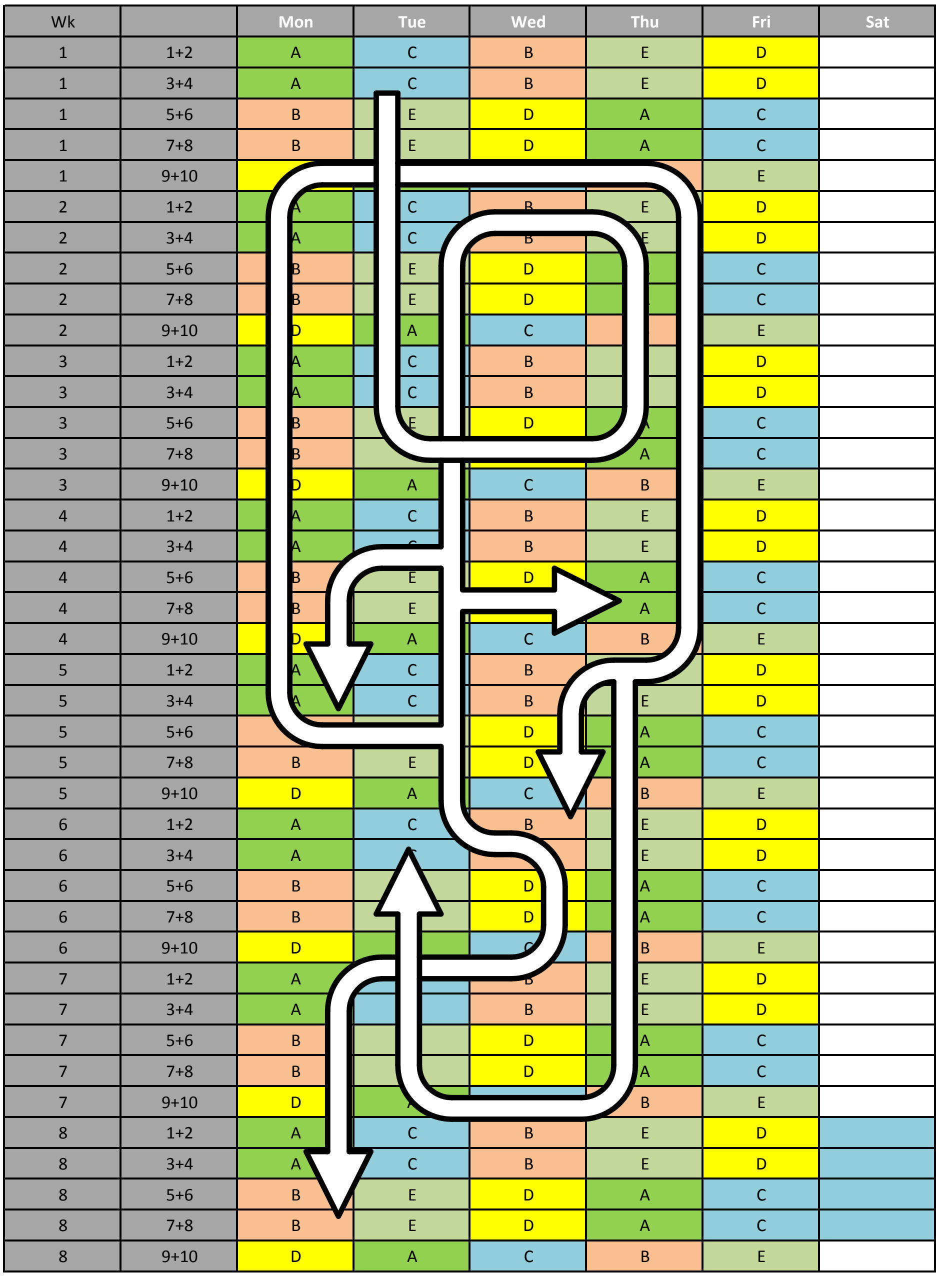
The language used in the course is English. This means that, even in the case that the common language in a design team is different from English, at least all communication external of the design group is English (reports, presentations, etc.).

All, approximately 1600, second year BSc students take part in this course. They will be divided into groups of about 6 students each. The group composition is determined by the course organisation and will be published on Canvas before the first group meeting. All groups get a tutor (each tutor gets 4 groups) and a lecturer (each lecturer gets 6 tutors). In all this means that there will be 288 student groups with 72 tutors and 12 lecturers taking part in the course.

The course has three plenary sessions:

- The introductory lecture
- The preliminary design fair (with compulsory attendance)
- The closing event (with compulsory attendance)

Where in a regular project the project result and project timing are negotiated with the client, in our case the project result and project timing are fixed. Most importantly the demand that the project must fit into 8 lecture weeks is a very tight constraint, for both students and the course organization.



Wk		Mon	Tue	Wed	Thu	Fri	Sat
1	1+2	A	C	B	E	D	
1	3+4	A	C	B	E	D	
1	5+6	B	E	D	A	C	
1	7+8	B	E	D	A	C	
1	9+10	[illegible]	[illegible]	[illegible]	[illegible]	E	
2	1+2	A	C	B	E	D	
2	3+4	A	C	B	E	D	
2	5+6	B	E	D	[illegible]	C	
2	7+8	B	E	D	[illegible]	C	
2	9+10	D	A	C	[illegible]	E	
3	1+2	A	C	B	[illegible]	D	
3	3+4	A	C	B	[illegible]	D	
3	5+6	B	E	D	A	C	
3	7+8	B	[illegible]	[illegible]	A	C	
3	9+10	D	A	C	B	E	
4	1+2	A	C	B	E	D	
4	3+4	A	C	B	E	D	
4	5+6	B	E	D	A	C	
4	7+8	B	E	[illegible]	A	C	
4	9+10	D	A	C	B	E	
5	1+2	A	C	B	[illegible]	D	
5	3+4	A	C	B	E	D	
5	5+6	[illegible]	[illegible]	D	A	C	
5	7+8	B	E	D	A	C	
5	9+10	D	A	C	B	E	
6	1+2	A	C	B	E	D	
6	3+4	A	[illegible]	[illegible]	E	D	
6	5+6	B	[illegible]	D	A	C	
6	7+8	B	[illegible]	D	A	C	
6	9+10	D	[illegible]	C	B	E	
7	1+2	A	[illegible]	[illegible]	E	D	
7	3+4	A	[illegible]	B	E	D	
7	5+6	B	[illegible]	D	A	C	
7	7+8	B	[illegible]	D	A	C	
7	9+10	D	[illegible]	[illegible]	B	E	
8	1+2	A	C	B	E	D	
8	3+4	A	C	B	E	D	
8	5+6	B	E	D	A	C	
8	7+8	B	E	D	A	C	
8	9+10	D	A	C	B	E	

Figure 4.1: The winding road of your design process has to be squeezed into one lecture quartile

4.1.1 Group Meetings

During the course you will have two group meetings a week (according to Table 4.1). These group meetings form the backbone of the course, therefore, attendance is *compulsory* as ruled in section 5. The first group meeting is scheduled for Friday September 7. Be sure not to miss it!

The global structure of each meeting is:

- Gathering results achieved by group members
- Planning for next step in the design process
- Formulation of Self-Study Assignments (SSA's)

At each of the meetings, one of the group members acts as chairman for the meeting (as a suggestion: you could just follow alphabetic order). This means that he/she prepares the meeting by reviewing the minutes of the last meeting, the uploaded SSA results of the group and the project planning. From this, the chairman prepares a meeting agenda which he/she shares with the group at the start of the meeting. Make sure that the agenda has a goal.

The chairman for the next upcoming meeting takes minutes, which are shared among the group and with the tutor within 4 hours after the meeting. These include the main results of the uploaded SSA's, the conclusions for the process steps and the formulated SSA's.

The only exception to the above structure, is the first meeting where the tutor acts as chairman. The SSA for this meeting is predefined (see section 4.2.2).

Tuesday	Sept 4	Introductory Lecture
Friday	Sept 7	Group meeting 1
Tuesday	Sept 11	Group meeting 2
Friday	Sept 14	Group meeting 3
Tuesday	Sept 19	Group meeting 4
Friday	Sept 21	Non-compulsory Group meeting
Tuesday	Sept 25	Preliminary Design Fair Group meeting 5 (without tutor)
Friday	Sept 28	Group meeting 6
Tuesday	Oct 2	Group meeting 7 (includes Midterm evaluation)
Friday	Oct 5	Group meeting 8
Tuesday	Oct 9	Group meeting 9
Friday	Oct 12	Group meeting 10
Tuesday	Oct 16	Group meeting 11
Tuesday	Oct 23	Group meeting 12 (includes Final evaluation)
Friday	Oct 26	Project Closing Event

Table 4.1: Meeting dates in the project. Time and location for each group specifically can be found under Files on Canvas.

4.1.2 Tutor

Your tutor is in no way responsible for the group result. The group members themselves need to keep track of the planning, make sure that the design product is in line with the assignment and context, deliverables are ready in time, etc. The tutor is an observer/facilitator during the group meetings. This means that he/she may ask questions about your choices or about the project structure, but will never suggest answers: the answers have to come from the group!

The tutor tracks the contributions of each of the group members based on the uploaded SSA's and observations during the meetings using the Rubrics for SSA's and group meetings. At the end of each meeting, the tutor will share his/her observations/evaluation with the group.

4.1.3 Self-Study Assignment (SSA)

All team members are assigned a task for self-study at every group meeting. Each self-study assignment result is reported using a template supplied on Canvas (Files/Templates). All SSA's must be handed in as described in chapter 5.
The SSA contributions of each student are assessed using the SSA rubric on Canvas. This means that each student must always upload his/her own SSA. When the SSA is the result of a cooperative action, you must indicate that in the uploaded text.
NOTE THAT: the total set of your SSA-entries forms the "portfolio" of your project contribution: it is the written proof of your work on the course. Therefore, you have to take the SSA's seriously: in the SSA's you show that you have substantially contributed to the project result.

4.1.4 The Group Report

The report MUST follow the template on Canvas under Files/Templates. Make sure to read this template carefully, as it contains a number of these deliverables and parts of the design process. It is essential that you align the writing of the relevant parts of the report with the progress of the project.
The report is assessed using a rubric (as given on Canvas under Files/Templates).
Details about handing in the report can be found in the "Closing event" document.

4.1.5 Locker

Every group has a locker at its disposal. The lockers are located in the basement of Gemini-North. You can store your device and materials in this locker. The coarse organization provides a cardboard box that fits exactly in your locker. You can use this for storage and transport of your materials.
You will receive the key of the locker from your tutor. On the day of the closing event, the key of the locker must be handed in to the organization.
If you loose your key, you must contact `4WBB0@tue.nl`. You can get a new key at a cost of €10.

4.1.6 Standard budget

Each group receives a standard budget of 40 euro to produce their product. This budget is provided to one of the group members using the reclaim form that you can find on Canvas (in the Files/Templates-folder). This form (printed, filled in and properly signed) must be delivered to the 4wbb0-organisation at the Preliminary Design Fair.
A complete Bill of Materials in the report must show how the budget was used. To prevent unfair competition, it is not allowed to use home-materials except for "zero-cost kitchen-drawer" materials (like paperclips, piece of tape, lick of paint, etc. This of course excludes batteries, electric equipment, motors, etc.).

NOTE: the complete product which is demonstrated at the closing event remains property of the TU/e.

4.1.7 Extra budget

Each group may apply for an extra budget of maximum 30 euro. This addition will only be allowed for extraordinary innovative, challenging, user-friendly, creative, esthetic, etc. designs. Applications for this extra budget need to be send to `4WBBO@tue.nl` before October 5, 17h00, with a motivation letter (why is your product extraordinary?) and the BoM (specifying how the total (standard+ extra budget) will be used).
If your application is approved, you will receive a separate reclaim form which needs to be filled in be the same group member who applied for the standard budget.

4.2 Time line until the Preliminary Design Fair

In any project planning is crucial. In this project, we have set two major deadlines: the preliminary design fair and the closing event.
The first three weeks of the project are planned beforehand, where each group meeting can be considered a milestone with fixed deliverables.
This section gives a step-by-step planning going through the first design phases. The results of these phases need to be recorded in the group report (following the template provided on Canvas). Therefore, make sure that, while going through the process, you keep recording the documentation necessary to fill the report.
To help you to keep your planning on track an example Excel sheet "ProjectPlanning.xlsx" is provided on the course Canvas-site. Using this spreadsheet you may help you to monitor technical progress, parts order status etc.

4.2.1 Intro Lecture, September 4

4.2.2 Tasks until the first group meeting - Deadline: September 6

To have a flying start, you must appear well prepared at first meeting. The overall project time is short!

- Read carefully the Student Manual (see Canvas under Files/Manuals).
- Use the first SSA-template (see Canvas/Files/Templates) to answer the expectation questions
- Determine what kind of a creator (see 3.1) you are or which kind of creator role you would like to try.
- Search and study literature on answers to the design question
- Assemble your ideas for project-options (see section 3.2)

4.2.3 First Group Meeting September 7

In this meeting four tasks have to be finished:

- Assemble knowledge frame work of the group based on the group members individual contributions
- Determine Strengths and Weaknesses of the group based on the individual evaluations
- Gather the ideas for project-options from all group members
- Decide which project-option is the most valuable (based on “Why?”-arguments) to pursue
- Assign studying tasks to fix the group knowledge gaps (the weaknesses).

Note that the description of the strengths and weaknesses of the group forms the base for the first chapter of the report.

4.2.4 Address group weaknesses.

For a good start in risk management, the identified weaknesses must be addressed. For each task that has to be executed the group knowledge and capability is sufficient. If you want to have parts made, drawing skills have to be sufficient. If you use electric motors you have to know how to drive them. Learn how to program a micro controller.
At this point, you need to define possible challenges for your group, define time frames and milestones for each item and make them visible in the planning sheet. You can freely add activities in

the planning worksheet.
This task can be redefined any time in the project as new challenges appear. Everything you do now, will save a lot of time and frustration at the end of the project.

??????????
One of the challenges in the project is the realisation of your product. Make sure that you prepare for any lack of tools and or production facilities.
??????????

4.2.5 Task until next meeting - Deadline: September 10

Assemble literature/background on the chosen project-option. Read about user-product interface, about possible forces/strength, about necessary product esthetics, about similar available products, etc.
Determine the list of functions necessary in your product-option.
Create a versatile "Solution-Encyclopedia": each team-member generates typically 5 solution ideas for each function. Forget all limits: here, you just gather solution ideas for the function.
The aim is to be creative and find all kinds of ideas: the more the better! Take the time to stretch the set of solutions as far as you can.

Example

Function = Hold an object
Solution ideas can be : grab, magnetic, vacuum, velcro, glue, elastic band, hook, etc.

It helps to attach an image for each solution (any kind: sketched, from literature or from the internet) to show examples and share inspiration to these solutions.

4.2.6 Meeting September 11

- Gather and agree on the functions for the "Solution-Encyclopedia"
- Compile the Solution-Encyclopedia with typically 10 to 15 solutions to each function and 5 images per function
- Based on the "Solution-Encyclopedia", define at least three concept-products will lead to the most promising, innovative, feasible, user-friendly result
- Make sure to have a good overview of all the documents available on Canvas

4.2.7 Tasks for next meeting - Deadline September 13

- Each group-member makes at least one shitty prototype (SP) for one of the concept products (make sure that as a team, you make at least one shitty prototype for each of the concept-product)
- Give each SP a name by which it can be clearly identified
- Define RPC's for concept-product for which you created the SP
- Validate the SP's and RPC's with people external to the project as well (other students, friends, professionals, internet, literature, etc.)
- Are you on your way to an innovative, creative, humanitarian and/or elegant design solution?

Note that this is still the concept phase, there is no ultimate solution needed yet, you are looking for unique, unexpected, creative, innovative ideas!!

4.2.8 Meeting September 14

In this meeting the group decides on the preliminary design and starts the detailing process.

- Finalize the group's SP's, make sure that this shows the innovative nature of your design
- Choose the concept product that the group wants to develop further as Preliminary Design (PD)
- Discuss and finalise the RPC's for the chosen PD
- Define the steps necessary for a successful presentation at the preliminary design fair
- Check the chosen PD on your RPC's
- Start the risk analysis: which parts of the PD will be most challenging in the detailing process
- Start the detailing process (see section 4.3.3)

4.2.9 Tasks for next meeting - Deadline: September 17

- Further develop your chosen Preliminary Design (PD)
- Read the Preliminary Design Fair document (on Canvas under Files/Manuals)
- Perform the calculations, search literature/internet to solve the highest risk issues
- Make an inventory of the possible components and production processes

4.2.10 Meeting September 18

- Study the Preliminary Design Fair document (on Canvas under Files/Events)
- Distribute tasks for the Preliminary Design Fair preparations
- Prepare the Bill of Materials (BoM) and Plan for Production (PfP)

You need to make sure that you will be able to fulfill your project goals in the upcoming weeks. This means planning and strategy are decisive for success. Therefore, risk management in this final project stage is crucial and should be discussed at each subsequent meeting! You must make a table (in the report) of your risk assessment before starting the detailing process.
All chosen components need to be 3D-printed in the workshop or ordered elsewhere. This step is extremely critical in the time scheduling: the realization of components always takes longer than you expect, the delivery time of ordered products is out of your control, there is always a chance of things not working as you hoped or not fitting the assembly as you expected.
This means that you should include some buffer time, sometimes by taking realization decisions as you go along the previous design steps. For example, if you come across a component critical to your preferred design, but also hard to get, you might need to take the decision to order that product early in the detailing step.

4.2.11 Meeting September 21 (not-compulsory due to MomenTUm); Virtual group meeting

If you want, you an use your usual meeting room at the usual time.

- Check the progress of the preparations for the Preliminary Design Fair

- Start planning towards the end phase of the project
- Start preparing the full risk analysis
- Initiate Final Design

4.2.12 Tasks before Preliminary Design Fair

Work on the PD and poster for the preliminary design fair (once again check the Preliminary Design Fair-document and the rubric on Canvas).
Start ordering components and start modelling parts.
Finalise your BoM and PfP.

4.2.13 September 25: Preliminary Design Fair

At the preliminary design your group presents its PD and a poster (one A1-, two A2- or four A3-format print) in an informal 4 minute oral presentation (in English). All is presented to a jury that uses the rubric (to be found on Canvas) for evaluation of the results.
The jury receives an A4-print of the poster (A2 or A3 posters must be gathered and printed on one A4) and a separate A4-print with a front and side view photograph of the Preliminary Design.
During the fair you must evaluate the PD's of the other groups. Therefore, you must assess the preliminary designs of four peer groups. For this assessment, you will use the exact same rubric as the one used by the jury based on originality, usefulness in the humanitarian context and (constructive) elegance.
Do not forget to deliver the 40-euro reclaim form.

The poster addresses:

- The project goal, the answer to: Why have you chosen this project aim?
- The chosen Preliminary Design and its specifications (in RPC's)
- The foreseen critical part(s) in the realization processes and the further planning
- Bill of Materials and Plan for Production
- The layout of the poster is totally free (one A1-, two A2- or four A3-format print)

The fair encourages you to take advantage of the common knowledge generated by all your peers. Further details (schedule, organisation, peer-assessment,etc.) on the Preliminary Design Fair can be found under Files/Events on Canvas.

4.2.14 Meeting September 25 (without tutor)

This meeting takes place at the usual scheduled meeting time and in the scheduled meeting place. Attendance will be randomly checked.
Make a detailed planning. Make sure that the production, ordering, assembly and testing of the design product will be finished in time for the Closing event.
Check out the hardware manual for production deadlines!

4.2.15 Meeting September 28

- Evaluation of the Preliminary Design Fair
- Assemble the risk analysis and check your planning to ensure all risks are dealt with in time
- As soon as they arrive: start testing of ordered products
- Check the parts modelled for 3D-printing

4.2.16 Meeting October 2

The SSA for this meeting includes answering the mid-term evaluation questions and the core-quadrants table (as given in the Midterm-SSA template).
Use the meeting to assemble these the mid-term evaluations and discuss whether the group is working to its best or whether its performance can still be improved.
Check whether the report is up to date (the chapters 2-6 can be finished by now).

4.3 Detailing, Realisation en Testing

4.3.1 Define Initial Planning

Unlike in the first phase of the project, where a strict planning was provided, the second phase has to be structured by the project team. You have to adapt the planning sheet to the planning you have defined for your particular needs. Critical activities become visible in this way. Also use the planning sheets to track your parts ordering process. Note that even a small unsolved issue may eventually become large and threatening!
In the remainder of this section you find the actions necessary to conclude the project. As said, we urge you to start these actions as soon as the PD-decision has been made!

4.3.2 Track and maintain your planning

Keeping track of the planning is an important and ongoing task. In the course of time tasks have to be refined, added or sometimes deleted. The project planning is the main tool to get an overview of the overall progress and individual contributions of the project members.
Remember that the closing event on October 26 is a non-negotiable deadline.

4.3.3 Detailed design

This process must start as early as possible. The first steps can be taken as soon as you have chosen the Preliminary Design!!

- Crucial in risk management: start checking your assumptions as soon as you can
- Start developing a Fit Test including all crucial mechanical parts needed
- If you are planning to use any kind of digital manufacturing technique, provide digital drafts of your design (not the whole assembly)
- Assemble the electronics and make a test-run. If your system lacks some electric or electromechanical parts to be ordered later you can replace those with LED's (and current limiting resistors of course). If you need to provide inputs for a control-loop, you can use buttons, IR-sensors (with IR remotes, etc.)

- Validation of parts (fit-tests, functional tests, assembly drafts).
- Discuss possible bugs of the embedded code and show the electronics assembled (without the parts to be ordered.)
- Create all the necessary CAD drawings for manufacturing.
- Specify parts and choose materials and techniques to manufacture them
- Finalise your Plan for Production. Make sure that you take notice of the limits in tech support; choose production methods which you can execute on your own and for which you have your own tools.
- Start developing a test plan.

4.3.4 Order parts

- Finalise the Bill of Materials (BoM) - including electronics and inventory for the parts needed to be ordered
- Look up online for parts together according to your BoM. You may want to use the CANVAS-Forum to share good retailer-contacts and best-practices on off-the-shelf purchase.
- Link price column prepare your grocery list to launch (leave some buffer in the budget)
- Discuss and decide on materials.
- Launch orders at the meeting
- Discuss manufacturing and merge delivery and due-dates. (*Use your planning sheet to visualize and track the ordering process.*)

4.3.5 3D-printing in the project workshop (see hardware manual in Files/Tech Manuals on Canvas)

4.3.6 Assembly

- Assemble parts and refine design if needed (learn to use measurement tools and iterate)
- Preliminary Test-assembly and electronics
- Sub-system tests with simplifications (test of crucial features with compromises at precision in order to avoid systematic flaws like drive-errors)
- Create a testing plan (team develops a check-list for testing for each part and sub-assembly separately)
- System testing and go-through checklist
- Note every point-of-change and redesign
- Plan redesign and refine (from the buffer left in your budget)

4.3.7 Prepare for last meeting on October 23

Answer the final evaluation questions and fill in the peer assessment table according to the Final-SSA template.
Read the Closing Event document (on Canvas under Files/Events).

4.3.8 Last Group Meeting October 23

Assemble the final evaluation.
Check closing event planning.
Finalise the report.

4.3.9 System tweak

- Perform tests on your design to proof that it fulfills your RPC's.
- Make sure that in the demonstration your device can act autonomously
- Refine parameters (motor-drive, servos, thresholds, etc.)

4.3.10 Closing event: October 26

At the Closing event, your group presents and demonstrate its product and a poster (one A1-, two A2- or four A3-format print) in an informal 8 minute oral presentation (in English) before their peers and a jury that uses the rubric (to be found on Canvas) for evaluation of the results. The jury receives an A4-print of the poster (A2 or A3 posters must be gathered and printed on one A4) and a separate A4-print with a front, top and side view photograph of the product.

Details on the Closing Event and the delivery of the report can be found in the "Closing event" document under Files/Events on Canvas.
Note that the group has to hand in the locker key during the Closing event.

Chapter 5

Rules and Regulations

Note: In any case where deadlines are not met through technical causes, the consequences remain.

5.1 Grades

During the course you will receive a group assessment grade and an individual assessment grade. For all assessments rubrics are available on Canvas.
The group assessment grade determines 70% of your final grade and consists of three evaluations:

- the Preliminary Design Fair (10%)
- the Closing Event (20%)
- the Report (40%)

The individual assessment grade determines 30% of your final grade. The individual assessment is done by the assessing teacher based on the SSA's (delivered on Canvas) and the tutor reports. This grade must be 6.0 or more to be sufficient. A student with an insufficient grade for the individual assessment has not contributed sufficiently to the group-product and, therefore, looses the right to the group assessment grade, which means that this student will receive a group assessment grade "0".

5.2 Self-Study Assignments (SSA)

Your SSA need to be uploaded on Monday and Thursday before 18h00 (for the Tuesday and Friday meetings, respectively). Failing to upload the SSA in time leads to an **insufficient** evaluation for that SSA.
You may upload only ONE file per assignment and MUST use the SSA template. Not following this instruction leads to an **insufficient** evaluation for that SSA.

All Self-Study Assignments must be uploaded in Canvas. In order to submit an assignment, you first have to log in.

1. After logging in, select the course **4WBBO Engineering Design** from your dashboard. You will now enter the home page of this course.
2. Click on **Assignments** in the menu on the left-hand-side of your screen to enter the page in which all SSAs are listed.

3. Click on the relevant assignment, e.g. SSA1, to enter the page of that specific assignment. This page contains all necessary information such as the deadline of the assignment.

4. Click on the blue button in the top right corner **Submit assignment** to open a new frame called **file upload** for your new submission.

5. Click on **Browse** to select your file. NOTE: you can only upload files in pdf-format. To save storage space: please use the "Minimum Size (publishing online)" option in Word.

6. Optionally, enter some text with your submission in the Comments text area.

7. Click on the blue button `Submit assignment` to complete your submission.

8. After successful submission, you will return to the previous page. In the top-right corner you will see the message **Submission turned in** with the date and time of submission.

5.3 Attendance to group meetings

1. The results of the group (the design product and report) depend on the contributions of all group members. This means that attendance of all group members to the group meetings is compulsory. Absence to a group meeting is registered by the tutor and passed down to the course coordinator.

2. Students with 3 or more “absent” registrations will be graded “4” or less for the individual grades with consequences as described in section 5.1.

3. Being late for a group meeting disturbs the meeting process. Therefore, late arrival is registered by the tutor and passed down to the assessing teacher. After arriving too late, the student is still allowed and assessed in the meeting.

5.4 Preliminary Design Fair

1. The poster needs to be on the numbered spot during the whole session (according to the schedule provided on Canvas under Files/Events).

2. Failure to present the poster and/or deliver the A4-prints (poster and pictures) will lead to a “0” grade for the preliminary design evaluation.

3. Failure to deliver filled-in peer-assessment rubrics will lead to a “0” grade for the preliminary design evaluation.

4. All group members are present when the jury assess the group poster. Students with unpermitted absence will be excluded from the group result of that day.

5. If there are compelling foreseeable reasons for absence, the students needs to notify the course coordinator (through email address 4wbb0@tue.nl) and the tutor at least two-days in advance.

6. The course coordinator rules on all decisions for allowed or unpermitted absence.

5.5 Closing event

1. All group members must attend the Closing Event (schedule can be found on Canvas). Students with unpermitted absence will be excluded from the group result of that day.

2. If there are compelling foreseeable reasons for absence, the students needs to notify the course coordinator (through email address 4wbb0@tue.nl) and the tutor at least two-days in advance.

3. The course coordinator rules on all decisions for allowed or unpermitted absence.

4. Failure of the group to turn up on time in for their session at the Closing event, leads to a “0” grade for the "Closing event".

5. Failure of the group to deliver the report (as explaned in the Closing-event document) leads to a “0” grade for the report.

6. Failure to deliver the locker key (as explaned in the Closing-event document) at leads to a “0" grade for the report.

Appendix A

Technology Readiness Levels

Technology readiness level	Description
TRL 1 - Basic principles observed and reported	This is the lowest "level" of technology maturation. At this level, scientific research begins to be translated into applied research and development.
TRL 2 - Technology concept and/or application formulated	Once basic physical principles are observed, then at the next level of maturation, practical applications of those characteristics can be 'invented' or identified. At this level, the application is still speculative: there is not experimental proof or detailed analysis to support the conjecture.
TRL 3 - Analytical and experimental critical function and/or characteristic proof of concept	At this step in the maturation process, active research and development (R&D) is initiated. This must include both analytical studies to set the technology into an appropriate context and laboratory-based studies to physically validate that the analytical predictions are correct. These studies and experiments should constitute "proof-of-concept" validation of the applications/concepts formulated at TRL 2.
TRL 4 - Component and/or breadboard validation in laboratory environment	Following successful "proof-of-concept" work, basic technological elements must be integrated to establish that the "pieces" will work together to achieve concept-enabling levels of performance for a component and/or breadboard. This validation must be devised to support the concept that was formulated earlier, and should also be consistent with the requirements of potential system applications. The validation is "low-fidelity" compared to the eventual system: it could be composed of ad hoc discrete components in a laboratory.
TRL 5 - Component and/or breadboard validation in relevant environment	At this level, the fidelity of the component and/or breadboard being tested has to increase significantly. The basic technological elements must be integrated with reasonably realistic supporting elements so that the total applications (component-level, sub-system level, or system-level) can be tested in a 'simulated' or somewhat realistic environment.
TRL 6 - System/subsystem model or prototype demonstration in a relevant environment (ground or space)	A major step in the level of fidelity of the technology demonstration follows the completion of TRL 5. At TRL 6, a representative model or prototype system or system- which would go well beyond ad hoc, 'patch-cord' or discrete component level breadboarding- would be tested in a relevant environment. At this level, if the only 'relevant environment' is the environment of space, then the model/prototype must be demonstrated in space.
TRL 7 - System prototype demonstration in a space environment	TRL 7 is a significant step beyond TRL 6, requiring an actual system prototype demonstration in a space environment. The prototype should be near or at the scale of the planned operational system and the demonstration must take place in space.
TRL 8 - Actual system completed and 'flight qualified' through test and demonstration (ground or space)	*In almost all cases, this level is the end of true 'system development' for most technology elements. This might include integration of new technology into an existing system.*
TRL 9 - Actual system 'flight proven' through successful mission operations	*In almost all cases, the end of last 'bug fixing' aspects of true 'system development'. This might include integration of new technology into an existing system. This TRL does not include planned product improvement of ongoing or reusable systems.*

Figure A.1: Definition of Technology Readiness Levels, compiled from NASA[3]and the USA Department of Defense[4].

[4]https://www.nasa.gov/pdf/458490main_TRL_Definitions.pdf
[4]http://www.acq.osd.mil/chieftechnologist/publications/docs/TRA2011.pdf