Design Synthesis Exercise

Project Plan

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https://skylum.com/blog/drone-wedding-photography

TUDelft

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1 Introduction

In 2019 a drone race competition called the Artificial Robotic Racing circuit (AIRR) was held by the Drone Race League (DRL) [1]. Teams participating in the competition had to design artificial intelligence software for an autonomous drone race. To make the quality of the AI the deciding factor, identical hardware was used by all teams, which was provided by DRL. This meant that teams were not able to properly test their software beforehand, which resulted in a significant number of drone crashes during the race. Furthermore, the drones themselves were considered to be too expensive. It would be ideal for the teams to have the ability to manufacture their own drones and test their respective software. Therefore, to solve this problem, group 19 of the TU Delft DSE 2019-2020 aims to design a more affordable, open-source hardware drone for racing purposes.

The aim of this report is to provide an overview of the the proposed project plan of group 19. This group aims to design the aforementioned drone in ten weeks with eleven students. This will be done by first clearly defining the project, after which a team structure needs to be setup. Once this is done, a detailed planning can be made. In addition, the project's risks will be analysed and a sustainability approach will be formulated.

This report consists of a number of sections. First of all, the project overview is described in Chapter 2. Secondly, the team is setup and structured in Chapter 3, which includes the Organogram. Furthermore, an elaborate planning overview is given in Chapter 4, which includes the project Work Flow Diagram, Work Breakdown Diagram and the Gantt Chart. After this, an analysis of the project's risks and approach for project and product sustainability are given in Chapter 5. Finally, a conclusion on the projects planning is found in Chapter 6.

2
Project Description

This section presents the Mission and Project Statements in Section 2.1, followed by the Customer Requirements and System Overview in Sections 2.2 and 2.3, respectively.

2.1. Mission and Project Statements

Mission need statement:
Facilitate a worldwide collaboration on the development of artificial intelligence in agile autonomous drone flight, accomplishing faster decision making than human pilots.

Project objective statement:
Provide an open-source hardware racing drone design and demonstration software for the artificial intelligence robotic drone race competition by eleven students in ten weeks.

2.2. Customer Requirements

The customer has specified a set of requirements, which are expected to be met by the design. These requirements are necessary to formulate proper system requirements later in the design process. Customer requirements are labeled with 'AIGLE-CR'.

Performance

AIGLE-CR-01: The drone shall be able to reach a speed of 30 meters per second with tracks every 20 meters.

AIGLE-CR-02: The drone shall be able to linearly accelerate at an acceleration of at least 19.61 m/s^2 (2g).

AIGLE-CR-03: The drone shall be able to make 3 meter radius arcs at speeds of 10 meters per second.

AIGLE-CR-04: The drone shall be able to fly for at least 5 minutes.

AIGLE-CR-05: The computer vision on-board the drone shall be able to detect and track gates at 60 frames per second or higher.

Safety and reliability

AIGLE-CR-06: The drone shall have manual take-over capability.

AIGLE-CR-07: The on-board systems of the drone shall not damage upon impact with concrete when falling from a height of 3 meters.

AIGLE-CR-08: The drone structure shall not damage upon impact with concrete when falling from a height of 3 meters.

AIGLE-CR-09: Not more than the propellers shall break when the drone crashes into a gate.

Sustainability

AIGLE-CR-10: The drone shall only consist of recyclable materials.

AIGLE-CR-11: The drone components; motor, frame, electronics and camera shall be individually replaceable to establish modular repairs.

Engineering budgets

AIGLE-CR-12: The maximum dimension of the drone shall be smaller than 0.5 meter in all length, width and height dimensions.

AIGLE-CR-13: The total mass of the drone shall weigh 1000 grams or less.

AIGLE-CR-14: The drone shall contain at least one front-facing camera.

AIGLE-CR-15: A front facing camera on the drone shall have a frame rate of at least 60 Hertz.

Other

AIGLE-CR-16: The hardware costs of one drone shall not exceed 2500 euros.

AIGLE-CR-17: All parts of the drone shall be manufactured by 2D milling, 3D printing, small batch PCB (printed circuit board) assembly order, or by other standard drone assembly techniques.

AIGLE-CR-18: The drone shall use on-board computation only.

AIGLE-CR-19: The drone shall use the 'Betaflight' program as attitude controller.

AIGLE-CR-20: The drone shall have a telemetry option.

AIGLE-CR-21: Drone modules shall be able to be repaired/replaced in at most 2 minutes.

AIGLE-CR-22: Repairs/replacements of drone modules shall be possible without the need for electronic equipment.

2.3. System overview

The system that has to be designed is an AI racing drone. By drone design convention, the design process of the system is divided into the following subsystems: electronics, propulsion, control & stability, structures and aerodynamics. External factors influencing a drone system are the pilot and the operating atmosphere. Contradictory to a human piloted drone, for an AI drone the pilot is replaced by software. For this specific drone, the software to pilot the drone is implemented into the drone itself and thus, it should be able to operate without receiving instructions signalled from an external source. To achieve this, the system requires navigation based on machine vision to take over the pilot's function. However, manual piloting should also be possible. The system can be seen in Figure 2.1.

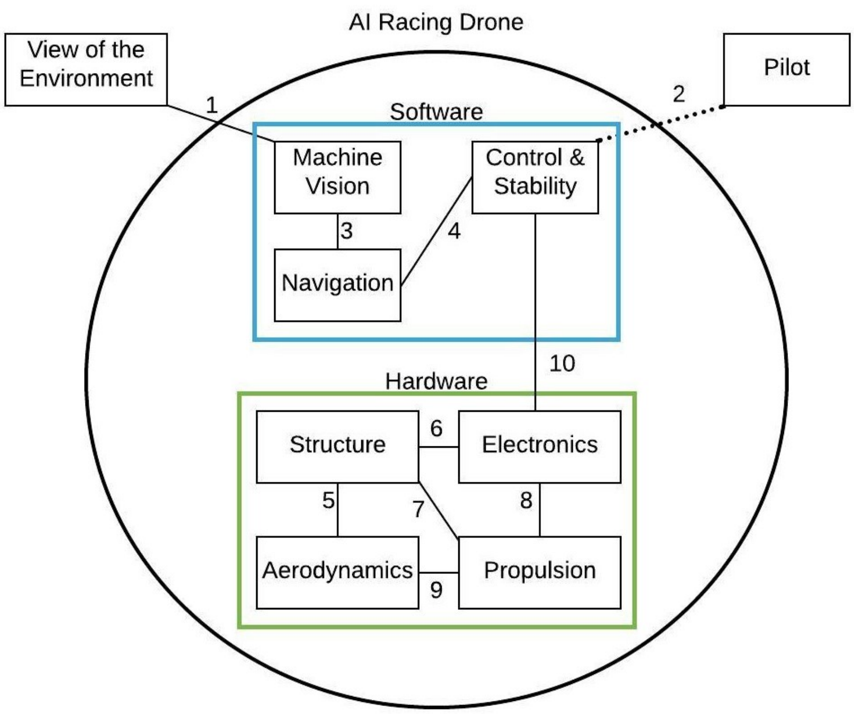

Figure 2.1: Global overview of the AI Racing Drone system

From Figure 2.1, the relations between subsystems are as follows:

1. The Machine vision is the eyes of the drone and gathers data from the environment.
2. Requirement AIGLE-CR-06 states that the drone must allow for manual control, the human/machine relation is thus present.
3. Navigation is performed based on the data collected by the machine vision.
4. Control and stability translates input from navigation or from a pilot into actuation orders for the drone.
5. Structure has to incorporate the aerodynamic design, but the aerodynamic design is also dependent on the structural requirements.
6. Space in the structure is needed to house the electronic components, and based on the safety requirements, the structure should be designed in a way to protect the electronics.
7. The propulsion system should be incorporated in the structure. The structure is also dependent on loads induced by the propulsion.
8. The electronics subsystem includes motors, which are responsible for generating the necessary propulsion.
9. Aerodynamics and propulsion are both designed based on the required performance of the drone.
10. Control and stability determines what actions the drone should take in order to achieve a desired result (e.g. orientation or velocity). These instructions are transferred to the electronics subsection, which results in electrical power supplied to the motor.

3
Team Structure and Organisation

This chapter presents how the team is organised regarding the task division and work procedures. Section 3.1 presents the structure of the team in an organogram and describes the responsibilities related to each role. Then, Section 3.2 presents a list of team procedures used to organise efficient work.

3.1. Organogram

The team consists of eleven members, where every person is assigned two roles. The first role relates to management and processing tasks, where each role has distinct responsibilities. Then, the second role relates to technical tasks. Based on a preliminary literature study, seven technical departments were established and the members are distributed among them. The structure of the team, as well as every position's brief description, is presented in Figure 3.1.

As indicated by the structure of Figure 3.1, project management is lead by the Team Leader, to whom all the other management positions report. Systems Engineers are the link between the management and the technical departments, and they directly manage the technical engineers' work. The responsibilities and inter-relations of all the management roles are described in detail below.

Team Leader

- Write out team agenda before each morning meeting.
- Manage resources i.e. assign tasks and monitor progress and time spent.
- Adjust planning and work division after delays or work disruptions, includes managing the Gantt chart.
- Chair meetings and steer discussions.
- Resolve technical and personal conflicts within the team.
- Organise the official reviews.
- Make sure everyone gets enough time to speak during team meetings.
- Have a quick conversation with each team member every week, to make sure everyone is feeling included and heard in the team.

Secretary

- Take minutes during the meetings.
- Update the project logbook.
- Make sure all relevant documents are close at hand, so things can be quickly looked up or referenced.

Internal Relations Manager

- Facilitate communication between the team, tutors, coaches and all other TU Delft staff members i.e. forward team questions, group availability and progress.
- Send out reminders about appointments and deadlines.
- Facilitate communication between different departments in the project.
- Hand in the reports.

External Relations Manager

- Contact external parties about product availability and specifications.
- Contact specialists outside of the TU Delft for technical advise and feedback.
- Establish product logo.

- Maintain social media platforms.

Business Manager

- Perform a market analysis on customer needs.
- Perform a cost analysis.
- Manage the financial budget.
- Establish promotion plan along with a go-to-market strategy.
- Establish integration plan on how to integrate the drone in the race.
- Be in contact with all technical compartments to ensure no cost overruns.

Sustainability Manage

- Stimulate the team in performing sustainability focused design trade-offs.
- Provide suggestions on improving the level of sustainability of the project and the design.
- Research commonly used methods in industry for improving sustainability of a product.
- Monitor environmental, social and economical sustainability of the product.

Risk Manager

- Perform a risk management analysis i.e. identify risks, probability and impact.
- Monitor risk status within the project.
- Develop and manage contingency strategies.

Quality Control Engineer 1 - Completionist

- Check the quality of technical writing requirements of the work done by team members.
- Check the spelling, grammar and sentence construction of the report.
- Ensure consistency in both lay-out and written parts.
- Ensure that all deliverables are elaborated on in the report.
- Identify possible improvements of the deliverables.
- Manage correctness of references.

Quality Control Engineer 2 - Monitor

- Check the correctness of equations used.
- Check for correctness of methods used.
- Check for the mentioning of underlying assumptions.
- Check for errors in computer scripts (Python, Matlab, etc.).
- Check the feasibility of the concepts selected.
- Ensure proper methodology for verification of the deliverables.

Systems Engineer 1 - Hardware

- Establish relations between the technical hardware departments.
- Coordinate with System Engineer II to ensure a good hardware/software integration.
- Facilitate a correct flow of data and information between the technical hardware departments.
- Ensure correct design integration after each iteration of technical hardware subsystems.

Systems Engineer 2 - Software

- Establish relations between technical software departments i.e. Navigation, Machine vision and Control & stability.
- Coordinate with System Engineer I to ensure a good hardware/software integration.
- Facilitate a correct flow of data and information between the technical software departments.
- Define a pipeline and overarching architecture for the software departments.
- Maintain the Git Repository used by the team.

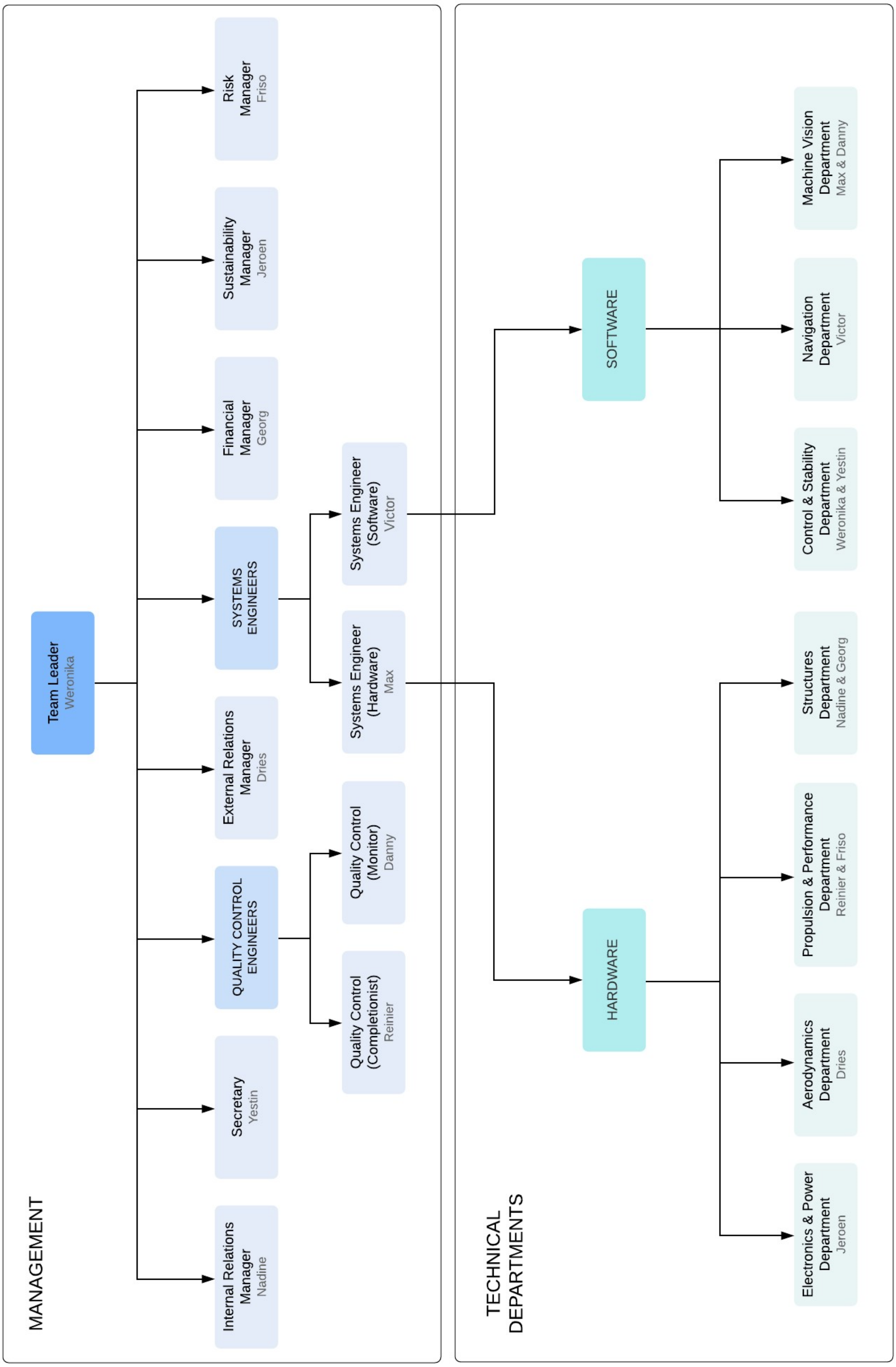

Figure 3.1: Organogram of the team.

3.2. Team Procedures

To allow for efficient work of the team, strict ground rules and procedures are established. They are meant to give a structure to each work day, allow for good resource management and facilitate a correct flow of data and information. The team has established the rules stated below however, as the project progresses, more rules and procedures are expected to be installed.

1. Every team member shall stick to the procedures. The team leader is responsible for monitoring if team members are working according to the procedures, and for enforcing the rules regarding late arrivals or other negligence of the team members.
2. Every work day starts at 8:45 with a morning briefing meeting, chaired by the team leader and minuted by the secretary. During the meeting, the plan for the day is finalised, based on members' updates and project developments. Questions for the principal tutor that arise during the meeting are noted down in a list that is later on presented to the tutor.
3. Every day, there is a quick meeting with the principal tutor at 13:00, in order to ask him for advice and feedback. The meeting is minuted by the secretary.
4. Apart from the morning briefing, the team gets together one or two more times each day, according to need as judged by Team Leader, to update each other on the developments.
5. Inter-team communication, as well as communication with the tutor and the coaches, is done via Discord.
6. The lunch break lasts 1 hour and starts at 13:30, unless other activities, such as T.A. sessions, are planned at that time. Work days end at 17:45.
7. The team establishes its own deadlines, which are planned prior to the official deadlines, in order to allow for sufficient quality control of the deliverables, as well as to account for any delays that may occur.
8. Late arrival to the morning briefing is tolerated within reasonable limits (< 5 min), unless previously communicated to the team. Members who are late more than 5 minutes (but still < 1h) shall compensate by working longer that day by the amount of time they missed. Members late by > 1 hour shall double the amount of time they missed. If a member is often late, the team shall take measures established upon such a situation. Measures can range from assigning extra work to the team member to even excluding the given member from the project.
9. Under extenuating circumstances and after discussing it with the team, members can miss a full work day but they shall compensate for it in the weekend.
10. The management roles assigned to the team members indicate who is responsible for making sure a given task or activity is done properly. However, most of those activities, such as writing a risk management plan or considering sustainability in the design, require input and work from many team members.
11. Contacting external parties, such as companies and professors from other universities, are done solely by the external relations manager or after consulting it with him.
12. The planning is updated on a daily basis, based on current project developments. The team leader may reassign people to different technical departments when necessary. In the occurrence of a big delay or an unexpected event that disrupts work, the relevant contingency plan is used to adjust planning accordingly.
13. All work is done using online tools such that the data cannot be lost. Overleaf is used for writing all reports, Trello is used for task distribution, Lucidchart is used for generating most diagrams, Agantty is used to generate and update the Gantt chart. A Github server is used share and save all the code.
14. Team members shall start documenting their work in the report when there has been significant progress to start writing. This will allow the quality control engineers to frequently check the methodology and logic behind the technical elements of the reports. Furthermore, the quality control engineers will also have sufficient time to ensure a correct layout and content of the report.
15. Any changes in the design shall be immediately communicated to the systems engineers, and they shall only be implemented upon the systems engineers' agreement.
16. Any difficulties in performing assigned tasks shall be communicated to the team sufficiently early such that either the team can give advice or the team leader can redistribute the resources.

4
Project Tasks and Planning

This chapter introduces the project planning approaches in three diagrams, the work flow diagram (WFD) (Section 4.1), the work breakdown structure (WBS) (Section 4.2) and the Gantt chart (Section 4.3). Together, they describe all the activities that need to be performed, as well as the deliverables that result from the activities.

4.1. Work Flow Diagram

This section explains how the work flow diagram was generated. The work flow diagram shows the time sequence of tasks step by step, accompanied with the person executing the task, the number of man hours needed to complete the tasks, also referred to as 'effort', and the throughput time indicating the deadline. Tasks can be executed in series, shown with a horizontal task alignment, or in parallel, corresponding to a vertical task alignment. The blue level indicates the first level of tasks to be executed, which are broken down into sub-tasks shown in green and yellow representing the second and the third level, respectively. The deliverables of the reports are shown in white hexagons. The workflow diagram can be found in figure 4.1.

Elaborating on the top level of tasks to be executed, the project plan is the first deliverable. This involves the planning of the project, the assignment of the management and technical team roles, and the allocation of tasks after their time sequence.

The second deliverable, the baseline report, involves the specification of the requirements and functions, after which all design options per subsystem are investigated. Then, non-feasible and weak subsystem concepts are eliminated, and possible full drone configurations consisting of different subsystem designs are established and grouped. Not all subsystem combinations are possible, taking into account the budgets and requirements. Therefore, some full drone configurations are eliminated, leading to a set of proposed concepts.
Then, in the midterm report, the project planning is reviewed and management roles are re-allocated. The proposed full drone concepts are investigated in more detail, where the interaction between different subsystems is considered. Then, selection criteria are defined along with their weights, and a trade off with different concepts is performed.

After making the design trade-off, one configuration is selected to be designed in detail in the final report. The detailed design is made for all subsystems, outputting performance characteristics of the drone. The procedures and models used are verified and validated. Then, the design is verified by checking its compliance with the requirements and the budgets, and validated to see whether it fulfills the mission objective.

Note that monitoring of the sustainability and risk assessment are both executed regularly, while working on the other deliverables.

Lastly, the design is presented to externals by means of a presentation at the symposium, a poster, and a publication.

4.2. Work Breakdown Structure

The work breakdown structure (WBS) depicts and breaks down the activities described in the Flow Diagram in more detail. Furthermore, it displays them in a hierarchical order, as can be seen in Figure 4.2 and Figure 4.3.

The WBS splits up the deliverable into more detailed actions, which are in turn split up into tasks. All tasks falling under a specific deliverable have to be finished to consider it as completed. The work flow diagram (WFD) is necessary to properly interpret the WBS. The numbering of actions and deliverables is kept consistent with the numbering in the WFD.

The design phase of the drone is split up into the Project Plan phase, the Baseline Report phase, the Midterm Report and Final Report phase. A Communicate/Present Design phase is also included to conclude the project. Each phase has a corresponding deliverable (level 0). These deliverables are often achieved after completing other tasks and obtaining other deliverables. These sub-level tasks and deliverables of each phase are presented one level lower (level -1). Even more detailed deliverables (sub-level with regard to level -1) are displayed another level lower (level -2), and also display the tasks required for the respective overarching deliverable.

4.3. Gantt Chart

A Gantt chart is a type of chart that is used to show the planning of tasks and the time allocated to them. This is done by using a graph with time along one axis, and the various divisions/tasks that need to be performed along the other. Each task is represented using a bar that starts and ends at the point in time where the task is planned to be started and finished. As such, a longer bar represents a task for which more required effort is expected.

The Gantt chart is generated following a methodology consisting of a few simple steps. Firstly, all tasks are identified, and their required effort is estimated. For this, information from the Work Flow Diagram is used. After this, tasks are planned into the Gantt chart in such a way that all tasks dependent on the result of other tasks are planned after the tasks they are dependent on. Furthermore, the planning takes into account that no group member should work more than 8 hours per day.
The Gantt chart is used as a reference for which tasks should be performed when by whom, and how much time should be spent on each task.

The Gantt chart, which can be found in Figure 4.4 and Figure 4.5, schedules the task specified in Figure 4.1. Each major task is included in it. The tasks are split between general tasks, which require collaboration of the entire team, and sub-system tasks, which are then specified for each respective engineering team. The Gantt chart board used here also contains a reference to the actual tasks durations (the visual representation only displaying tasks with a resolution of one day) along with who each are assigned to (again only visible in the software used). The Gantt chart being in its essence is a living document, the soft version of the document shall be maintained and updated as the project progresses. This should enable an effective tracking and planning of the project and its progress.

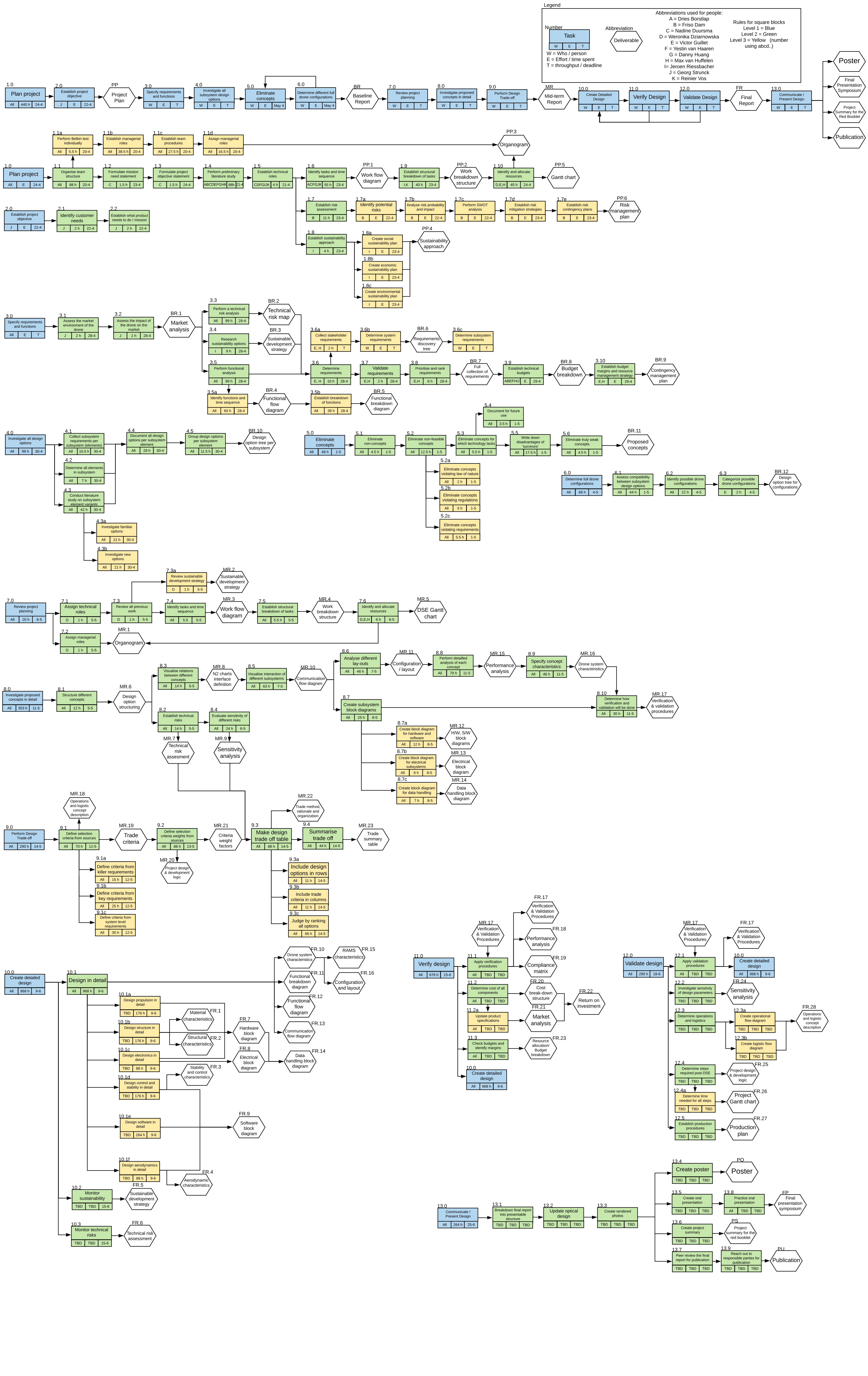

Figure 4.1: The work flow diagram

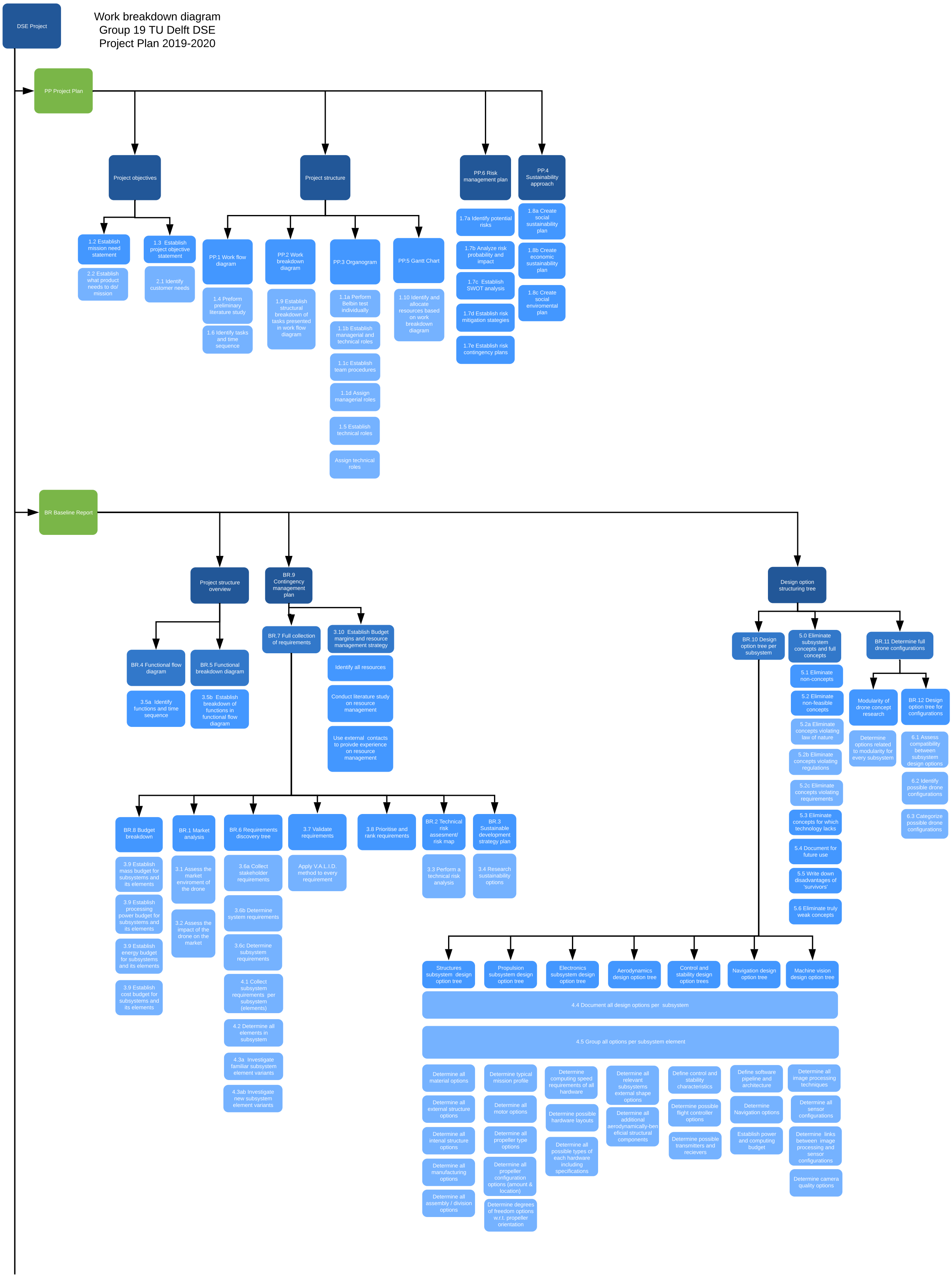

Figure 4.2: First part of the work breakdown diagram

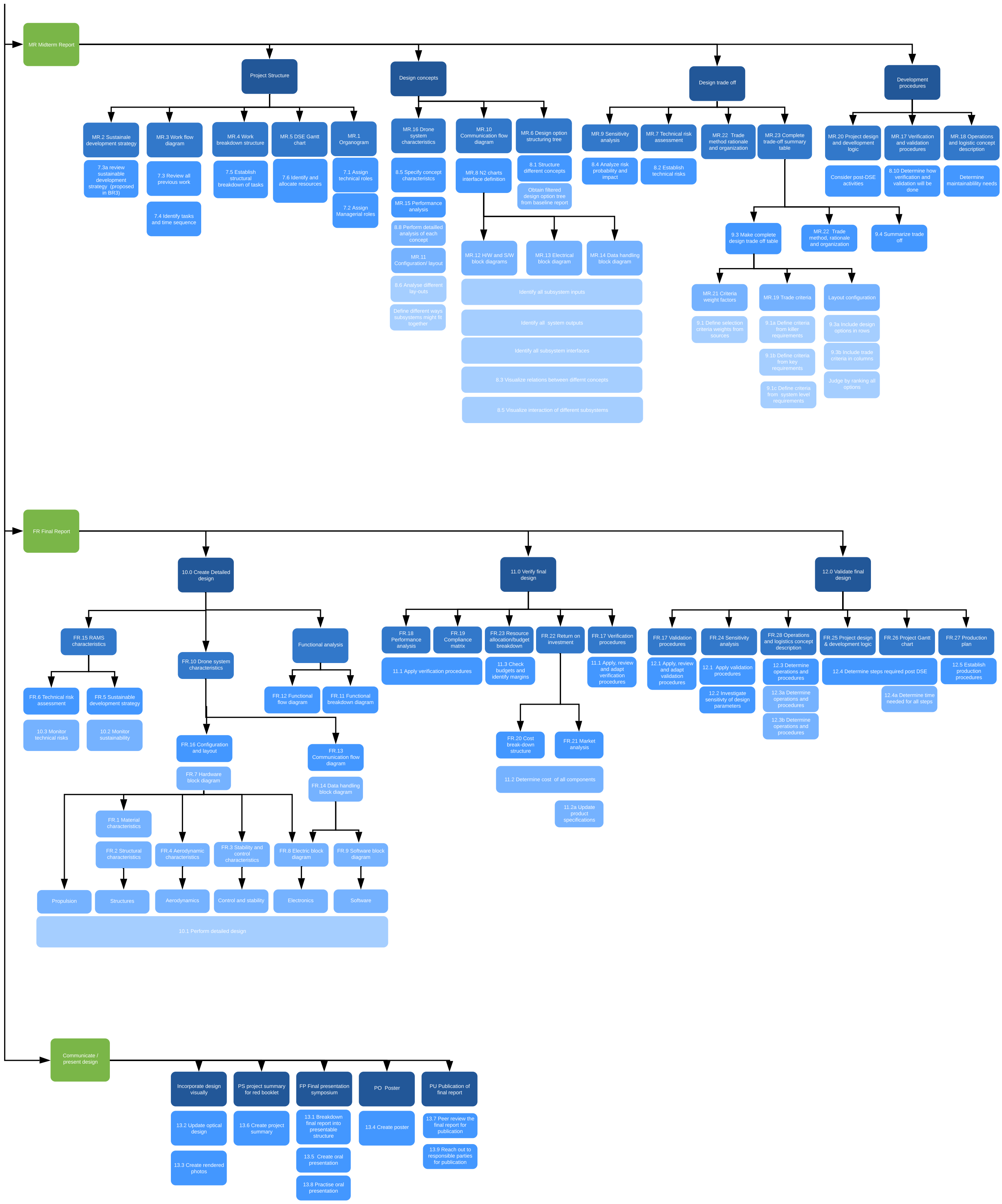

Figure 4.3: Second part of the work breakdown diagram

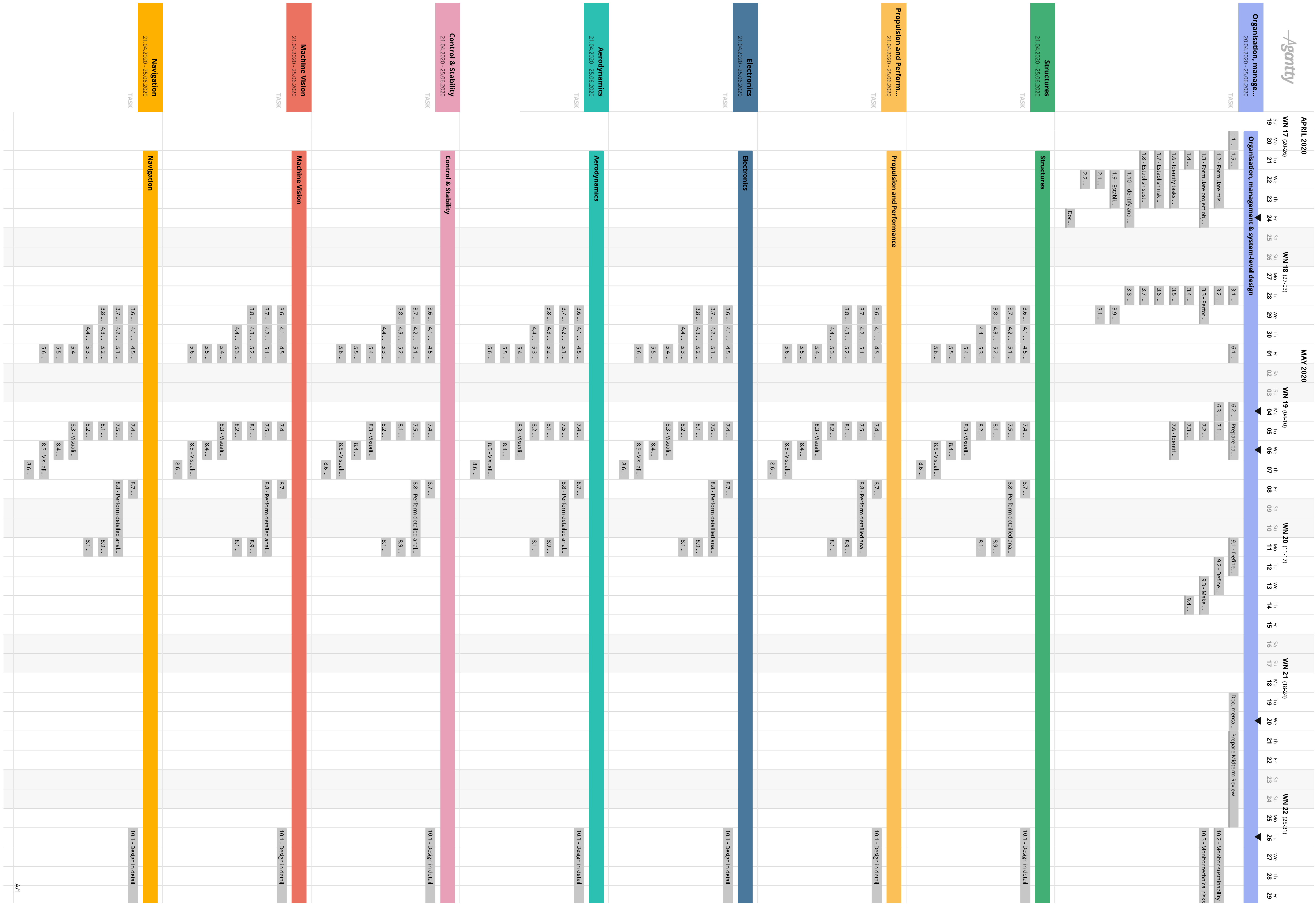

Figure 4.4: First part of the Gantt chart

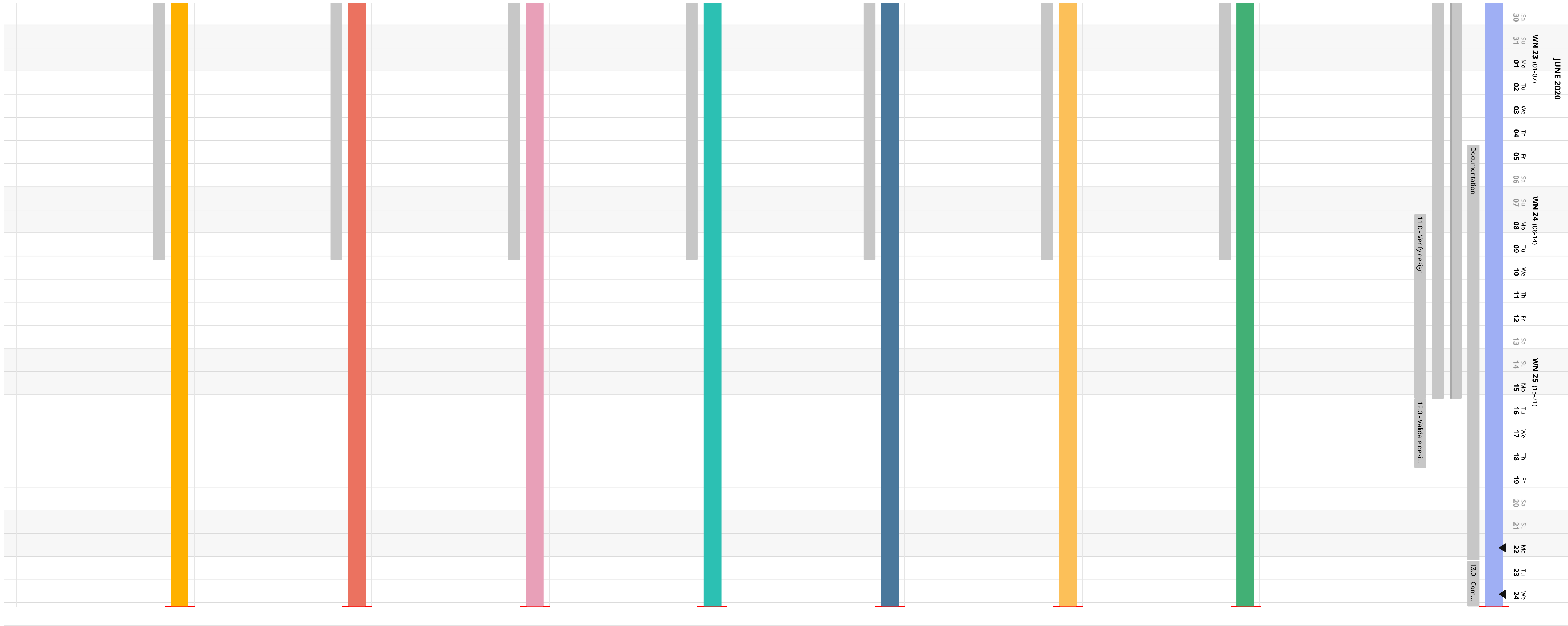

Figure 4.5: Second part of the Gantt chart

5

Project Risk and Sustainability

This chapter discusses the risks that might be encountered during the design phase in Section 5.1.2. In order to mitigate the possible risks, it is attempted to reduce either the risk or the probability of the event, which is explained in Section 5.1.3. Additionally an approach to sustainability is described in Section 5.2, which aims to help the team to balance social, environmental and economic aspects of working efficiently together.

5.1. Organisational Risk Analysis & Management Plan

Every project contains a certain risk, the only way to have no risk is when the resources are infinite. Unfortunately, this is never be the case during a project, therefore it is important to do a risk analysis. There are different types of risks that can be analyzed, however for this project plan the focus is on the organisational risk. The development of a risk management plan consists of two parts - the risk assessment and the risk management. The risk assessment consists of identifying the risks, analyzing the risks (the drivers, the probability, the impact and the loss) and prioritizing and mapping the risks. The risk management consists of resolving the risks by making an action plan to both reduce the likelihood of risks and actions to be taken when it fails [2].

5.1.1. SWOT Analysis

After forming an organisation and establishing the project objectives, it is useful to gain more knowledge about the group organisation and the project execution process. An often used approach in systems engineering is to perform a SWOT analysis, in which internal strengths and weaknesses, as well as external opportunities and threats are identified. Using this result, the organisation can play to their strengths and potential risks can be identified and mitigated.

Table 5.1: SWOT analysis for project organisation and execution

Strengths	**Weaknesses**
Availability of many professional resources	Lack of extensive experience in full system design
Having the basic knowledge needed in engineering	Lack of specialisation in any subject
Strong passion for aspects of the project	Inability to work together in the same place
Ideas and views on the design problem from many perspectives	Conflict in opinions
No employment costs	No project funding
Opportunities	**Threats**
Establishment of personal subjects of interest	Unpredictability of the situation caused by COVID-19
Gaining knowledge in many new fields	Unpredictability of the AE3212-I Flight Dynamics exam
Development of new technologies	Technology being used for malpractice
Better accessibility of drone technology	Entering of the market by competitors
Ability to use the technology for other applications	Drone regulations limiting the use of the technology

5.1.2. Risk Assessment

For the risk assessment, different cases that can occur during the DSE are analysed. Especially in a time of crisis like right now, there are different drivers and probabilities than normally would be the case and also the impact can be more or less severe.

1. **Team member(s) absent for a short period of time (< 3 days):** There can always happen something to a team member that will cause absence, for example sickness or an accident. For a short period of time the work can be taken care of by the rest of the team and it will have a negligible effect.
2. **Team member(s) absent for a long period of time (3 days or more):** When a team member is absent for a longer period of time the impact can be more significant, then a fundamental change might be needed.
3. **Minor computer problems:** Since the work is done mostly online with a computer, there is a good chance of facing some minor computer problems, like internet problems. Minor problems will not have a large impact.
4. **Major computer problems:** With major computer problems, like a computer crash resulting in the loss of documents and work, the impact can be critical.
5. **Loss of productivity:** Since the team is not physically together, there is less pressure to be productive and there can be a lot of distraction in the working environment, resulting in assignments not being finished on time. Also, personal circumstances and mental health have an influence in this case.
6. **Loss of morale:** It is less motivating working from home than in an actual working environment. When it gets to the point that some team member(s) is/are not motivated anymore for the project, the work flow will decrease drastically, which can be critical. Personal circumstances and mental health will also play a role.
7. **Team member(s) being late at meetings:** This is something that will always happen during a project, the impact in negligible at first, but if it happens too often it can seriously influence the team dynamic.
8. **Flight Dynamics Exam during DSE:** It was announced that the Flight Dynamics exam is postponed until the fourth quarter. Studying for the exam will influence the work that can be done for the DSE.
9. **Team member(s) not being able to get to the campus, when it is possible to continue DSE on campus:** The possibility to continue the DSE on campus is not that great at this point. However, if it happens and some of the team member(s) are not able to come to the campus, the working situation would not change for them, which is not a big problem, but they should not feel excluded.
10. **No communication about work not being finished on time:** Work not being finished on time will happen during every project, mostly due to underestimating the work load. However, not communicating this problem with the team can cause a real impact and high stress levels, which should be avoided.
11. **Tutor, coaches, TA's absent for a long period of time:** Although it is not very likely, it can happen. The impact will be critical, because they are a great source of information and feedback.
12. **High stress levels due to working from home:** One of the biggest problems in working from home is the vague boundary between working and time off since it is both done in the same environment. This can result in extremely long days, trouble getting sleep at night and that will cause high stress which is not beneficial in any way.
13. **Conflict between team members:** When working closely with other people on a project it is almost guaranteed there will be a conflict at some point. Conflict is not necessarily bad, it shows people care about the project and when it is a constructive conflict, it can even be beneficial. However, when a conflict is not constructive, it can have a critical impact on the team dynamic.

14. **Exclusion of a team member from the DSE:** This will be a little less relevant this year, since the rules for absence are not as strict as past years. However, there is still a small probability it can occur, leaving the group with one less member, which can be catastrophic.

All these cases can be placed in a Risk matrix, as can be seen in Table 5.2. In the bottom left corner the risk is the lowest and therefore acceptable, while in the top right the risk is the highest.

Table 5.2: Risk Matrix before risk mitigation

Impact	Very Unlikely	Unlikely	Likely	Very Likely
Catastrophic		4, 14	8	
Critical		2, 11	6	13
Marginal			5, 12	10
Negligible		9	1, 3	7
	Probability			

Very high risk, avoid if possible
High risk, action required
Medium risk, action preferred
Low risk, acceptable

5.1.3. Risk Management

The goal is to mitigate the risk into a lower level of risk by either reducing the probability or the impact it has. Since the risk matrix is not that detailed, there will not be large changes for every case. Some of the actions that have to be taken are already described in more detail in Section 3.2 or will be described in more detail in Section 5.2.1.

1. This risk is already in an acceptable region, therefore no actions will be taken at this point.
2. Following the guidelines set by the government will reduce the probability of a team member being absent for a longer period of time, because the coronavirus is the main driver. In case it happens the Team Manager should reallocate the resources to make up for the absent team member, to reduce impact.
3. This risk is already in an acceptable region, therefore no actions will be taken at this point.
4. Every document and piece of work should be stored online (e.g. Google Drive, Overleaf, etc.) so no work will be lost when major computer problems occur.
5. Team meetings have to be held frequently (at least twice a day), and every meeting clear working goals have to be set for the next meeting. That will reduce the probability and the impact since there is more social control and a frequent reset.
6. Besides only working on the project the team should also make time to do a fun activity together to keep up the morale. Also good communication is important so the morale loss can be anticipated on by measures agreed upon by the whole team.
7. Team members who are late have to make up for the time missed, so the impact can be minimised.
8. Since this case is very hard to predict how it will work out, almost no actions can be taken beforehand. Therefore the only thing that can be done is keep a close eye on the announcements about the Flight dynamics exam and mitigate the risk as soon as possible together with the team.
9. This risk is already in an acceptable region, therefore no actions will be taken at this point.
10. The initiative for communication in a case like this should come at first hand from the Systems Engineers, since they have a good overview of the work. They should at first mention it to the team member, but when the deadline is put at risk they should report back to the Team Leader so resources can be reallocated accordingly.
11. Every tutor, coach and TA working on this project should be kept involved and up-to-date to a certain level, so all can step in when needed.

12. Clearly defined start time, clearly defined end time and clearly defined breaks, which should be sticked to closely.

13. Good communication is key to avoid conflict or make the conflict constructive. Therefore, it should be considered to involve the Team Manager in an early stadium of the conflict, to make sure every party is heard and a solution is found.

14. The System Engineers and the Team Manager should have a good overview of the work so tasks can be redistributed if someone drops out to lower the impact.

Those actions lead to a shift in the Risk matrix as can be seen in Table 5.3. Since the matrix does not have much detail in the margins for every probability and impact not every case will shift a block, that does not mean that the risk is still as high as before the action taken. More risks are now acceptable. However, there are also a lot of risks that are not within a acceptable margin. The risk in the blue part of the matrix have to be watched carefully throughout the project and if needed more action has to be taken. For case nr. 8 there has to be taken action as soon as there is more information about the exam.

Table 5.3: Risk Matrix after the risk mitigation

Impact \ Probability	Very Unlikely	Unlikely	Likely	Very Likely
Catastrophic				
Critical		4, 14	8	
Marginal		2, 6, 11	12, 13	
Negligable		9	1, 3, 5	7, 10

Very high risk, avoid if possible
High risk, action required
Medium risk, action preferred
Low risk, acceptable

5.2. Organisational Approach to Sustainability

The project group will aim to achieve sustainability by balancing social, environmental and economic aspects of sustainability. Trade-offs need to be made between the three aspects to make sure sustainability is achieved in all of them. Each of these three pillars can be discussed in the frame of project group sustainability and product sustainability.

5.2.1. Project Group Sustainability

Social sustainability:

- Team members should feel integrated within the group and feel part of the team, allowing them to speak their mind. Weekly social events will be organized by the team in a casual manner to achieve this.

- If a team member feels unheard or remains on the sidelines for whatever reason other ways of integrating him/her should be found. If this problem is present, time should be allocated by the secretary to all group members to ensure their opinions are shared on important decisions. In order to find out whether all team members feel integrated short (semi-)weekly one-on-one interviews will be held by the project manager.

- Sufficient breaks should be included during project hours and should be at clearly indicated times to establish a sustainable routine and optimise the working efficiency.

- Project hours should remain within agreed limits in order to not cause people to become demotivated due to extended working hours. This schedule will be agreed upon by the entire group and monitored by the project manager.

- Group members should be allowed to conduct necessary social affairs, like going to a doctor appointment, during project hours. Time spent on such activities should be within reasonable limits and time the person should make up for the lost time after project hours.

- Other deviations from the schedule should be clearly communicated to the secretary for documentation. All group members have a responsibility with regard to communication towards this matter.

Environmental sustainability:

- Documents should only be printed when necessary. This should be easy since everything is online, and most team members do not have access to a printer.
- Environmental conscience should be fostered by group members. People should be encouraged to choose for environmental modes of transport when coming to project. people should be encouraged to recycle waste.

Economic sustainability:

- Internal human resource management: time will be managed using a Gantt chart, and reorganized when necessary to improve the efficiency of tasks.
- External human resources (tutors, supervisors) should be contacted frequently to avoid major do-overs. Regular scheduled meetings will be held where team members can ask questions.
- Resources provided by the TU Delft should be utilized throughout the project. This includes, for example, free access to professional software, WiFi, work spaces during project hours (whenever authorities allow it) and past research stored in the TU Delft library.

5.2.2. Product Sustainability

Social sustainability:

- Impact of the design on society should be analyzed. Will this design be socially accepted? A free drone design can lead to more people using drones, leading to problems with safety and privacy.
- Risk analysis of the final design will be conducted, with regards to safety. The design should limit injury in case of failure, misuse, or built incorrectly.

Environmental sustainability:

- Circular economy should be encouraged. Therefore, each component will be analyzed with regards to recyclability and re-usability and compared with greener alternatives if available.
- Manufacturing processes will be analyzed with regards to energy usage and waste material, and compared to greener alternatives if available.
- End-of-life techniques will be analyzed for each component. For example the ability of separating and techniques of safely disposing certain components (e.g. battery).
- Options of making the design as modular as possible will be analyzed to reduce waste when components break and to provide the opportunity for potential future updates/alterations.
- The possibility of bulk production of the drones sold to racing competitors and other individuals will analysed. This will reduce the environmental impact during production.

Economic sustainability:

- A financial manager has been appointed to make sure total costs of the design does not exceed 2500 euros for an individual to buy the required components and make it. This should ensure no unexpected negative cost deviations for the customers.
- The possibility of bulk production of the drones sold to racing competitors and other individuals will analysed. This could possibly reduce the economic cost and would in turn provide more people with the opportunity to use the product, increasing the number of potential customers for producers.

6
Conclusion

The following summary can be devised of what has been produced in this report. First of all, the project was investigated and an overview was created, from which an mission need statement and a project objective statement were created. After this, the important task of organising the team and clearly defining and dividing all team roles was done. Once these were established, a detailed project planning was made. This was done by first creating a work flow diagram and a work breakdown diagram, from which a Gantt chart followed. In parallel with this an investigation was done into project risk and a mitigation strategy was devised. Lastly, research was done into creating a sustainable project environment and a sustainability strategy was devised.

With all these tasks finished, a solid structure was made to continue the rest of the DSE. The Gantt chart will be used continuously to determine task for the day and keeping an eye on deadlines. The work flow diagram will be used to keep a clear view of how tasks are related, what things will be coming up and what people are working towards. The work breakdown structure will be used to clearly identify if all tasks have been finished and if nothing is forgotten. The risk management gives an overview of what roadblock may lay ahead, how severe their impact will be and what can be done to avoid them. The sustainability management ensures that an healthy work environment is ensured, with respect to team and society, environment and finance. Mention should be made that these document, however well researched, are not final. They are living and will be changing when new things come up or people finish ahead of schedule. Thus, they will at all times be monitored and update to ensure as smooth working as possible.

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