Sensur av hovedoppgaver
Høgskolen i Buskerud
Avdeling for Teknologi

Prosjektnummer: 2011-12
For studieåret: 2010/2011
Emnekode: SFHO-3200

Prosjektnavn
Utviklingsstudie av opptrekkbar understellsmekanisme
Retractable Gear Development Study

Utført i samarbeid med: Equator Aircraft Norway SA

Ekstern veileder: Tomas Brødreskift

Sammendrag: Vår bacheloroppgave gikk ut på å utvikle og konstruere et opptrekkbart understellsmekanisme for Equator Aircraft Norge SA. Det ble utviklet en prototypemodell av unstellsmekanismen, samt forslag til aktuering.

Stikkord:
- Luftfart
- Elektrisk/mekanisk design
- Opptrekkbar understellsmekaniske

Tilgjengelig: DELVIS

Prosjekt deltagere og karakter:

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Dato: 30. Mai 2011

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30. May 2011

BUSKERUD University College

Department of Engineering
Institute of Technology

POST - GRADUATE THESIS	
Utviklings Studie av Opptrekkbar Understellsmekanisme Retractable Gear Development Study	
Subject(no./name): SFHO3200 - Hovedoppgave med prosjektstyring	
Group Members: Group 2011-12 Rebaz Aziz, Sakariya H. Dahir, Sindre D. Flaten, Sigbjørn Gunnrød, Jeremy Marchand, Stein Erik Thoen	
Sensors: Olaf Hallan Graven Øyvind Eek Jensen Knut Brødreskift	**Supervisors:** Øyvind Eek Jensen Tomas Brødreskift Knut Brødreskift
Date: 30. May 2011	

Rebaz Aziz	Sakariya H. Dahir	Sindre D. Flaten
Sigbjørn Gunnerød	Jeremy Marchand	Stein Erik Thoen

Preface

This report describes the work done and the results achieved during the project by the group aRGie at Buskerud University College, division Kongsberg, through the spring of 2011.

The bachelor studies for the engineering degree at Buskerud University College, is ended through a thesis. The thesis counts 20 credits, and is solved in groups across different lines of engineering.
The group aRGie is composed of 6 students.

3rd year Mechatronics:

Sindre D. Flaten
Sigbjørn Gunnerød
Stein Erik Thoen

3rd year Product Development:

Rebaz Aziz
Sakariya H. Dahir
Jeremy Marchand

Our contractor for the assignment is Equator Aircraft Norway SA (EAN), with Tomas Brødreskift as external guidance councilor and Knut Brødreskift as external sensor.
From Buskerud University College we had Øyvind Eek Jensen as internal guidance councilor and Olaf Hallan Graven as internal sensor.

Thanks too

Equator Aircraft Norway, Knut and Thomas Brødreskift for all their knowledge and information about aircraft and mechanical design. And for following up throughout the project.

From EAN, thanks too:

Øyvind Berven, Aviation experience
Rajeev Lehar, FEM analysis.
Martin Krafft, Design
Jon Roger Fossen, Visiting and take a look at his aircraft.
Frode Eldevik, 3D Printing

From Buskerud University College, thanks too:

Olaf Hallan Graven, internal sensor
Øyvind Eek Jensen, internal guidance councilor
Richard Thue, Helping us with SolidWorks and other computer related problems.
Åge Skaug, Borrowing tools.
Arne Bjørnar Næss, Lab testing and components.
Kjell Enger, Calculations on mechanical design.
Dag Samuelsen Calculations on electrical design.
Barbro Gulbrandsen, Office supplyments and general help.
Øivind Johannesen, Not complaining when we had loud discussions in the room next door.

Family and friends for patience during the project.

Summary

The thesis was given to us from Equator Aircraft Norway SA (EAN). The company is in the early stages of establishing themselves as a competitor in the aviation industry, with their new groundbreaking design to an amphibious aircraft.

Our assignment was to develop a retractable gear system for their new amphibious aircraft EqP2 Excursion. In our task we should come up with a new design specially fitted for their aircraft. Included in the task was setting up an overview of requirements to the aviation industry, analysis of materials that can be used and calculations on the system.

Our motivation was firstly driven by the challenge of making a construction for an interesting and cool aircraft concept with a new vision of flying. We must also admit that we saw the possibility to get a free flight with the aircraft.

In the requirement specification, we created use cases describing real life scenarios of the applications the RG system is supposed to perform. In this way, we were able to identify the customer needs, the functions the system must have, and the environment in which the system must be able to operate. We stretched the requirements outside of what we would be able to accomplish during the project, because our employers wished to have a full-defined requirement list to be used after our project.

During the brainstorming phase, we came up with several concepts in cooperation with EAN. After choosing one final concept for the front and rear RG, we started the construction of a prototype in plaster which EAN printed out from our design in Solidworks. We encountered difficulties to actuate this prototype and had to make a second prototype, which has the possibility to be actuated by an electrical motor.

When the design and development phase of the project was completed, we committed ourselves to the more technical part of the assignment. Calculations both electrical and mechanical test and reports and analysis in software was performed.

In the final stages of the project the time spent was on finalizing documents, and preparations for the final presentation.

This version of the report is open to public and does not contain any technical information about the design and actuation method. The reason for this is that our employer wants to keep the design confidential.

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aRGie
Retractable Gear Development Study

Pre Study Report

Buskerud University College, Department of Engineering Institute of Technology

Equator Aircraft Norway SA

Document responsible: Sindre D. Flaten
Version 3.0
Date: 26. May 2011

Internal guidance councilor: Øyvind Eek-Jensen

Rebaz Aziz	Jeremy Marchand	Stein Erik Thoen
Sindre D. Flaten	Sigbjørn Gunnerød	Sakariya H. Dahir

Abstract

This pre study report is meant to be a more detailed version of the previous vision document. The assignment, its challenges and consequences are discussed in this document. There is also an evaluation and analysis of several project models.

Our project group consists of three mechanical engineer- and three electrical engineer students. Our assignment is to develop and design a retractable undercarriage for a new type of amphibious aircraft. The employer, Equator Aircraft Norway (EAN) is in their final stage of developing their first aircraft, the Equator P2 Excursion. This document describes in detail what the assignment is and how we will proceed to start the project.

Requirement specification, test specification and project plan are also a part of the pre study. These will be handed-in as separate documents.

Sammendrag

Denne forstudierapporten er en mer detaljert utgave av visjonsdokumentet. Oppgaven og dens utfordringer og konsekvenser er drøftet. Det foreligger også en vurdering og analyse av flere prosjektmodeller.

Vår prosjektgruppe består av tre maskiningeniør- og tre elektroingeniør studenter. Vårt oppdrag er å utvikle og designe et opptrekkbart understell for en ny type amfibiefly. Arbeidsgiveren, Equator Aircraft Norge (EAN) er nå i den siste fasen i utviklingen av deres første fly, Equator P2 Excursion. Dette dokumentet beskriver oppgaven i detalj, samt hvordan vi skal gå frem for å starte på den.

Kravspesifikasjon, testspesifikasjon og prosjektplan er også en del av forstudien. Disse vil bli innlevert som separate dokumenter.

Document history

Version	Date	Responsible	Changing
0.1	13.12.2010	Sindre D. Flaten, Stein Erik Thoen	
0.2	14.12.2010	Sindre D. Flaten, Stein Erik Thoen	Quality check, spelling.
0.3	14.12.2010	Rebaz Aziz, Sindre D. Flaten	Conclusion.
0.4	15.12.2010	Stein Erik Thoen	Abstract, education, layout, spelling.
1.0	15.12.2010	Sigbjørn Gunnerød	Front page, layout.
1.1	16.12.2010	Stein Erik Thoen	Changed all airplane words to aircraft. Added CS-23 in description.
1.2	03.01.11	Sindre D. Flaten	• Changed abstract, and spelling in abstract • Last sentence in responsibility range added • First sentence in EQP2 model
2.0	04.01.11	Rebaz Aziz	
2.1	01.02.11	Rebaz Aziz	Changed the conclusion
2.2	26.05.11	Stein Erik Thoen	Change logo
3.0	26.05.11	Sindre D. Flaten	

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Definitions

Abbreviation	Extension	Description
EAN	Equator Aircraft Norway SA	Employer
EQP2	Equator P2 Excursion	The aircraft now under development by EAN
LSA	Light-Sport Aircraft	A classification of aircraft, specific to the USA. With max weight of 650 kg and max speed of 220km/h.
BUC	Buskerud University College	Høgskolen i Buskerud
CS-23	Certification Specifications 23	Certification Specifications for Normal, Utility, Aerobatic, and Commuter Category Aeroplanes.

1. Introduction

1.1 Company information

Equator Aircraft Norway SA (EAN) is a Norwegian company based in Oslo founded by Tomas Brødreskift and Øyvind Berven in 2009. EAN is the Norwegian branch of Equator Aircraft Company Germany, which was founded in Ulm Germany by Guenter Poeschel in 1974. The Norwegian branch of Equator Aircraft was founded after Tomas Brødreskift had developed the EQP2 Excursion (EQP2) concept. EQP2 is based on the Equator aircraft developed by Guenter Poeschel. EAN is currently working on the prototype for EQP2 and the project is now entering a detailed engineering phase.

1.2 Receiving the assignment

When we were in the process of getting an assignment for our main project, we contacted Hamworthy Gas systems AS in Asker. There we came in contact with Knut Brødreskift who, in his spare time, is involved in the EQP2 project. He sent us an email explaining that Hamworthy did not have any project for us, but instead he gave us two potential assignments regarding the EQP2 project. The first one was to build the retractable landing gear for the EQP2 Excursion aircraft, and the second one was to design and build a "fly by wire" control system for the aircraft. After we had looked at both of the assignments and discussed them in our project group, we decided that the first assignment (to design and build the retractable gear) was the one that suited our project group the best. Since the assignment includes both a mechanical and an electrical part.

2. Project goals

2.1 Introduction of the aircraft

The EQP2 excursion aircraft is a two-seater aircraft to be powered by a hybrid engine. This hybrid solution, of the propulsion system, will use a combustion engine with a generator that produces electric power for operation of the propeller. The goal of EAN is to develop a new type of amphibian aircraft in Norway. This means that the aircraft will have the ability to land on both water and land, and therefore it must have a retractable landing gear. The gear must also be able to withstand rough conditions in seawater and on shore.

Figure 1: Concept drawing with retractable gear

There have already been made some concept drawings, which need detailing and dimensioning. EAN wants us to develop this retractable undercarriage and its control system. More specifically, our task will be:

- Make a study on today's design rules for retractable gear and undercarriage for smaller aircrafts.
- Set up the design requirements for the relevant landing gear.
- Construct a SolidWorks model of the main wheel and nose wheel mechanism.
- Verify mechanical function of the drive system and control system, including emergency operation.
- Based on stated strains, choice of materials and dimensioning, analyze the stress levels to meet the strength requirements with minimum weight.
- Construct a prototype (1/4 scale).
- Practical verification test that involves drop test with measurements if time allows.

Figure 2: Concept drawing

2.2 Final product

EAN wants to complete as much as possible on the undercarriage of the EQP2 during this project. Designing the function of the retractable landing gear will be the main goal, and in order to do that there are many guidelines and requirements we have to follow. Another part of this project will be to determine the right materials and components needed in accordance to the aircraft's undercarriage and control unit. We must implement certain strength measurements and calculations to maintain the requirements for the LSA class. These requirements will be listed in the requirement specification document.
We will also construct a scaled-down prototype to see that the function of the retractable gear works in practice.

2.3 Finding solutions

We will consider some project models and find the most suitable for us to follow in this project. The project plan describes what we should do to what time, in order to reach our goal, will be used as an overview through the project. We will use the requirement specification to set up the test specification. These documents will show concretely what is required and how to set up solutions to these requirements. We will have to make a study individually and discuss the solutions we come up with together with our supervisors, to ensure that they're good enough.

2.4 Covering expenses

We are going to write down all the expenses we have in relation to the project. EAN have told us they will cover everything regarding literature, materials for the prototype and other expenses that are necessary to reach the project goals. This is also a requirement from BUC.

3. Project organization

3.1 Internal project group

Name	Education	Role	Contact
Rebaz Aziz	Product development	Project manager	az.rebaz@gmail.com
Sindre D. Flaten	Mechatronics	Document responsible	sindredf@gmail.com
Jeremy Marchand	Product development	Responsible of requirements	jeremymarchand87@gmail.com
Sakariya H. Dahir	Product development	Economy and timesheet responsible	sakariyadahir@gmail.com
Stein Erik Thoen	Mechatronics	Co responsible of project planning and meeting activity.	steine.thoen@gmail.com
Sigbjørn Gunnerød	Mechatronics	Responsible of testing	sgunneroed@gmail.com

Table 1: Internal group

3.2 Reference group

Name	Role	Contact
Tomas Brødreskift	External guidance councilor	tb@equatoraircraft.com
Knut Brødreskift	External councilor/ sensor	kb@equatoraircraft.com
Øyvind Eek-Jensen	Internal guidance councilor	oyvind.eek-jensen@hibu.no
Olaf. Hallan. Graven	Internal sensor	olaf.hallan.graven@hibu.no

Table 2: External group

3.3 Responsibility range

There are different types of roles in larger projects. We will in this section describe some of the roles that are assigned internally in the project group. A more detailed description of all the project responsibilities will be listed in the project plan.

3.3.1 Project manager and project planning

The project manager will have the main responsibility for the project plan. He/she will also have to insure the project progress, so that the project group reaches its goals. He/she will be the link between the internal and external supervisors and sensors.
The purpose of the project planning is to give a general explaining of the project and to determine the difference tasks. It is also important to determine when these task need to be done. This will give us a good overview of the project. Project planning is a large responsibility; therefore we have divided it between two persons in our group.

3.3.2 Document responsible

The document responsible control the life cycle of the documents produced throughout the project, he/she will also control how the group, create, reviewed and publish all documents.

3.3.3 Economy responsible

The person responsible for economics is responsible for setting up the budget and handling all purchases made in the group. This will include ordering tools, component and materials we need, and handling travel expenses**.**

3.3.4 Requirement responsible

Requirement responsible is responsible for the requirements specification set by the group and the employer. He/she also has to ensure that all requirements are followed up.

3.3.5 Test responsible

The test responsible person will have the responsibility for all testing during the project. He/she will also have responsible of the test specification and test reports.

3.4 Education

Our group consists of three electrical engineer- and three mechanical engineer students. We believe this assignment suits our group composition well. The project requires design and construction- and electrical control system knowledge. The group's field within studies is mechatronics and product development.

3.4.1 Mechatronics

Include knowledge of the design of electronic circuits, computer-aided design (CAD) and strength calculation. Other key topics are communications, signal processing, hydraulics and robotics.

3.4.2 Product development

Include knowledge about mechanical engineering with specialization in 3D modeling (CAD), mechanics, statics, materials engineering, thermodynamics and quality assurance of the development process.

4. Project models

4.1 Analyzing the project models

A solid structure is the basis of an efficient work. A project model gives control, overview and efficiency by creating a common work method for everyone in the project. It is used as a support or a frame in order to lead a project. There are several different models to be used depending on the nature of the project. We will in this section explain some different project models.

4.1.1 The waterfall model

This is the most common and structured model. It requires each phase to be completed before moving on to the next one. Any change in requirements or mistakes, demand a lot of work and money to correct. Therefore, using this model demands the requirements to be fully defined before the project starts. The project ends only when the requirements are satisfied through a verification test.

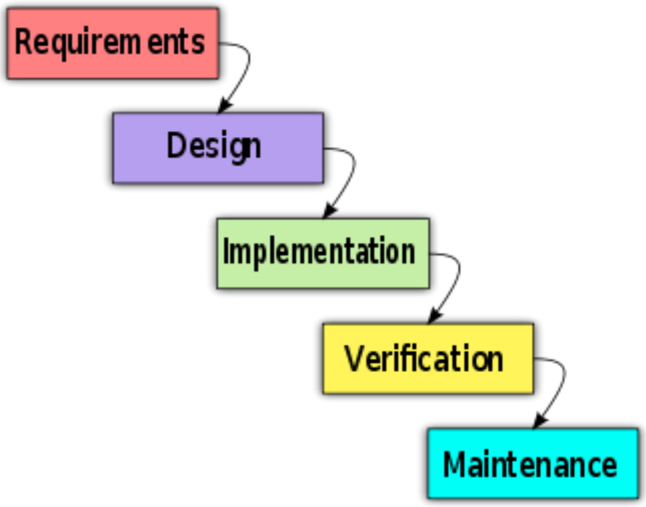

Figure 3: Waterfall model

Strengths:

- Minimizes planning overhead since it can be done up front.
- Is structured and easy to understand for less experienced staff, in order to reduce wasted efforts.
- Fits well for longer projects like ours.

Weaknesses:

- Inflexibility. Minimizes the amount of changes in requirements during the process.
- Backing up to correct mistakes is difficult.
- All requirements must be known up front. This is often not possible.

4.1.2 The iterative/incremental development model

This model is an answer to the weaknesses of the waterfall model. The main idea is to develop a system through repeated cycles (iterative) and in smaller portions at a time (incremental), making it more flexible and easier to back up. It consists of an initialization step, an iteration step and a project control list. The initialization step's goal is to develop an initial product, a basic version of the system, which is simple to implement on. The project control list contains functions and implementations to be added to the system in the iteration step. This iteration step is repeated several times in order to improve the system continuously, ending up with several operational products, until the requirements are satisfied.

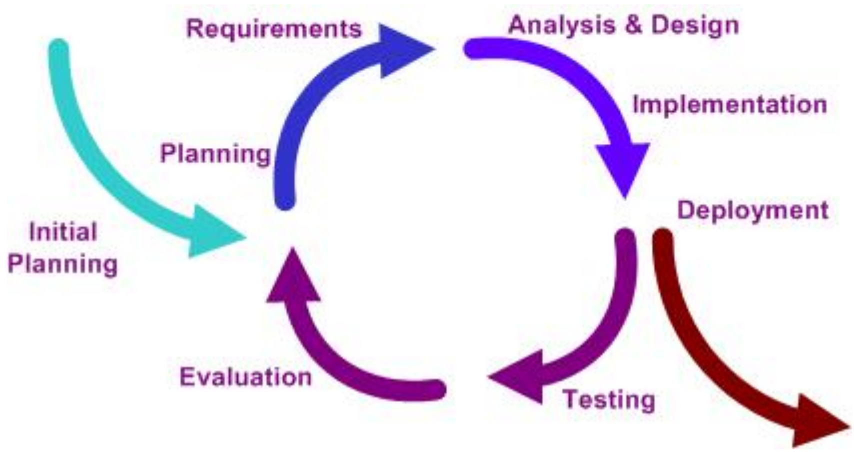

Figure 4: Iterative/ incremental model

Strengths:

- Can be used when the requirements are evolving during the project.
- Several operational products released to which the customer can respond.
- Low cost and fast release of the initial product.

Weaknesses:

- Adapts itself better for experienced staff, as it requires good planning and design abilities.
- High total cost of the complete system.

4.1.3 Spiral model

As it operates in iterations each ending with a prototype, this model is much similar to the iterative/incremental model in its structure. On the other hand, each iteration contains the same phases as the waterfall model, focusing on risk analysis. It is common to develop the most risky functions first.

1. The first quadrant consists of determining objectives, alternatives and constraints, defining requirements in detail.
2. The second quadrant's task is the most important. It involves an evaluation of the alternatives and a risk analysis.
3. A rough prototype is built from the previous design, usually in small scale.
4. The prototype is tested in the last quadrant. Conclusions are drawn from the first prototype and the planning of the next iteration begins.

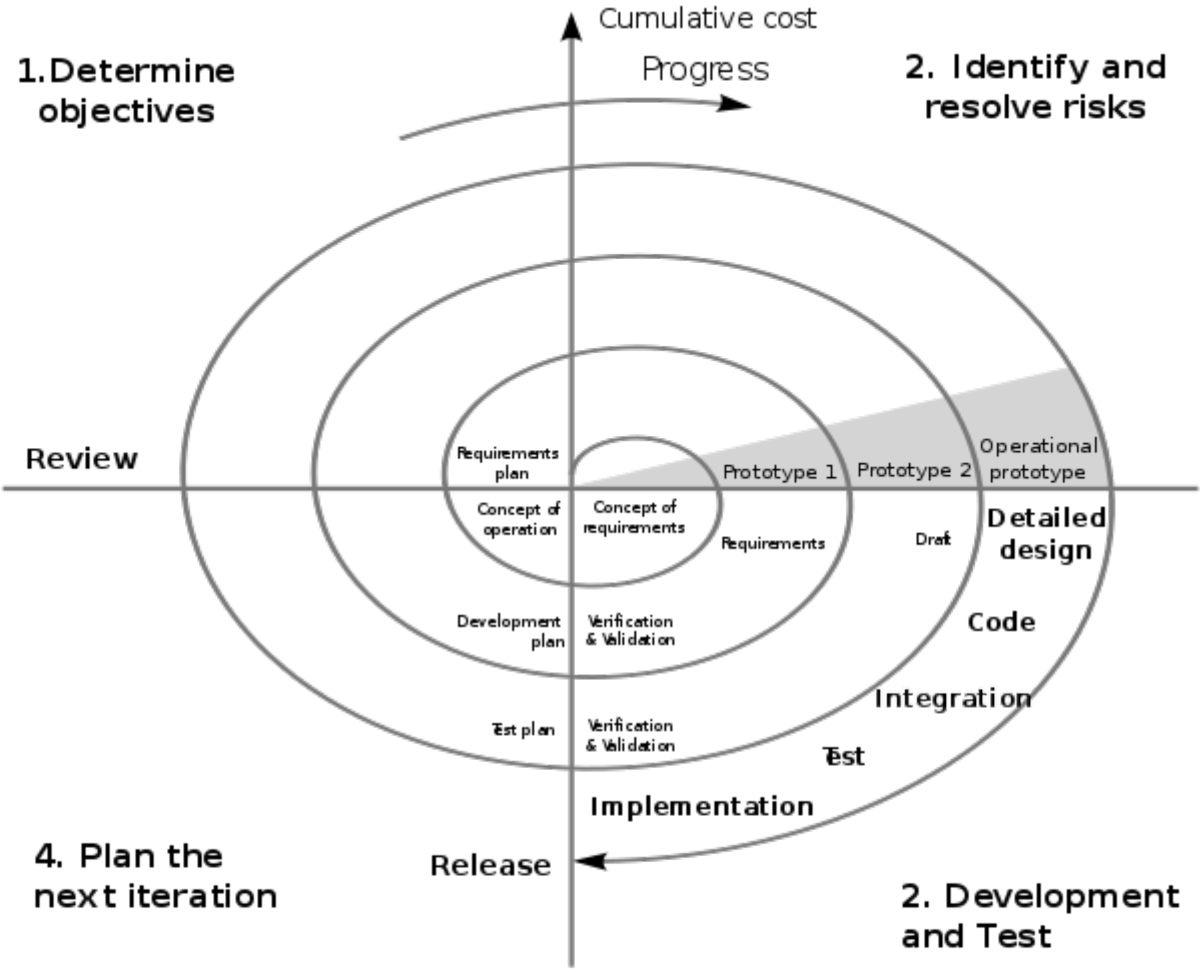

Figure 5: Spiral model

Strengths:

- Gives early and frequent feedback from the customer
- Deals with the most risky functions early in the process, which means that the risks decrease as the costs increase.
- Flexible. Allows a margin of error, as the design is not meant to be perfect.

Weaknesses:

- Complex model for inexperienced staff.
- Inappropriate for low-risk projects, as the time spent on risk analysis is large.
- High costs to final prototype.

4.1.4 V-model

This is another variant of the waterfall model, with only difference that it focuses on verification and validation by running tests in parallel with the different development phases of the product. This model is useful when reliability is first priority.

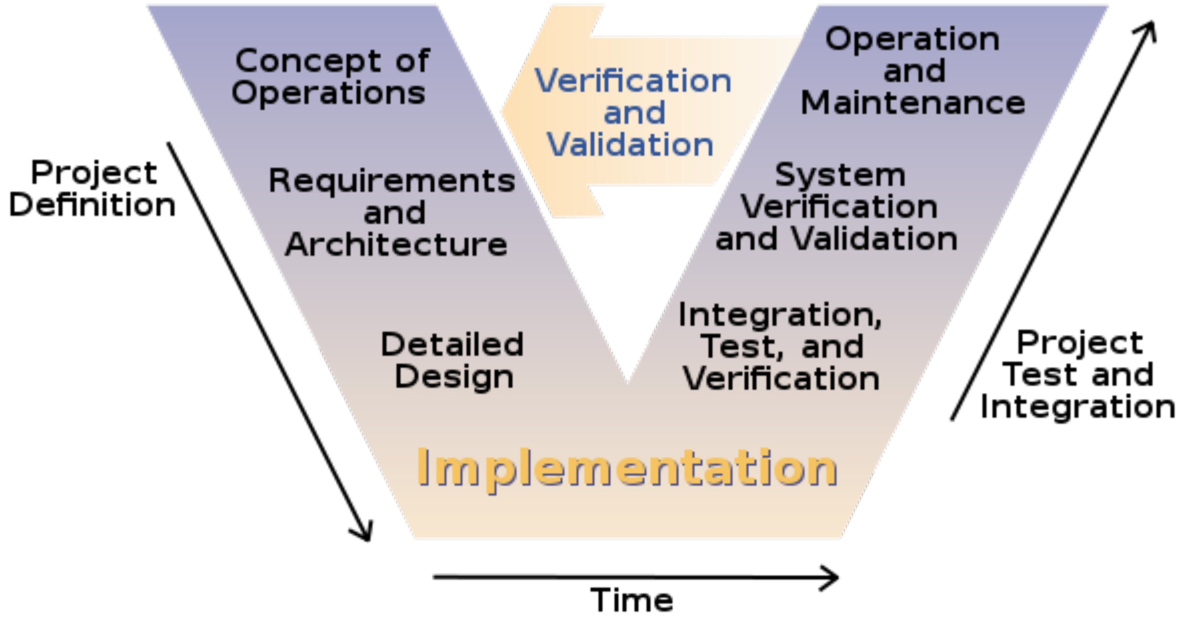

Figure 6: V-model

Strengths:

- Easy to use for inexperienced staff.
- Gives high reliability.
- Every deliverables are testable.

Weaknesses:

- No focus on risk analysis
- Inflexible. Allows very little change or addition to the requirements during the process.

4.1.5 Unified process

Unified process is an iterative process that can be divided into 4 phases:

1. Inception phase (Requirements)
    - Find and choose a project
    - Preparing the environment for the project
    - Determining the limits of the project
    - Make a requirement and test specification
    - Identify potential risks
    - Discuss possible solutions
    - Creating a pre-study

2. Elaboration phase (Design)
    - Make research
    - Define a final architecture as soon as possible

- Define the vision for the project
- Make a detailed plan for the construction phase

3. Construction phase (Implementation)
   - Construct the system
   - Work effectively
   - Make sure to get a quality product as soon as possible

4. Transition phase (Testing)
   - Analyze the finished product
   - Make sure the final system is good enough and responds to the requirements by testing it
   - Creating a user guide

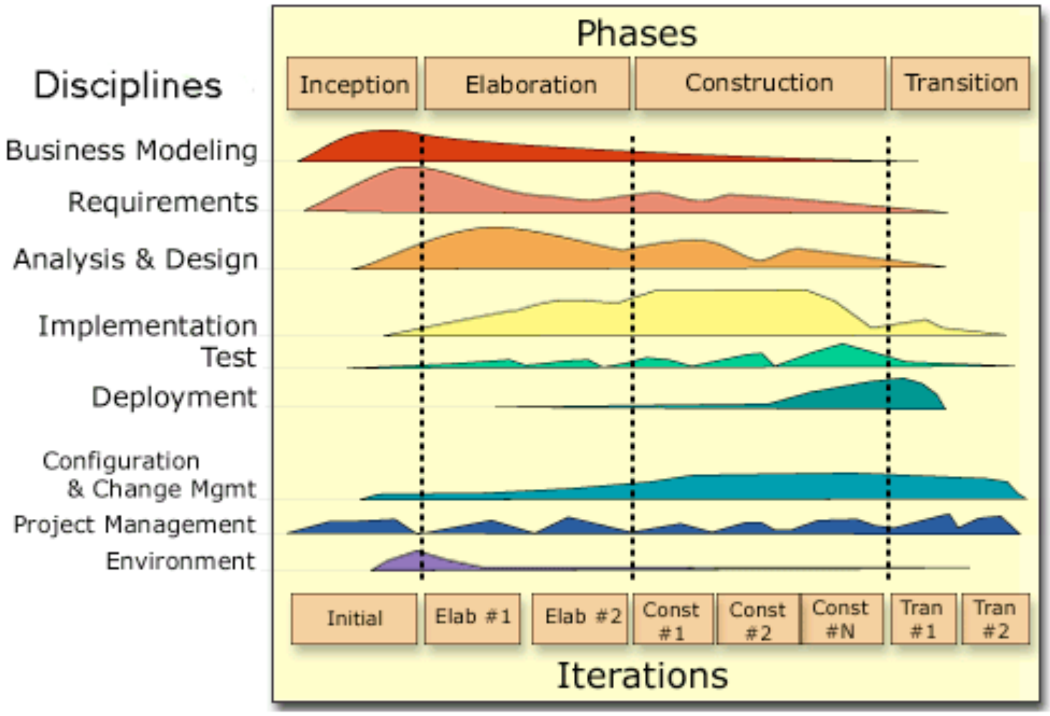

Figure 7: Unified process

Strengths:

- Good structure, since we work in various phases

Weaknesses:

- No focus on risk analysis
- Little implementation and testing in the initial phase

4.1.6 EQP2 model

The EQP2 project model is to be understood as an internal project model in the company. It is not a standard model as the previously mentioned. The model is based on an iterative working methodology where the initial steps in design and technical functionalities are all produced in software programs. This is in order to allow changes to be made with little effort and money spent.
The final steps in the model are detailing and production of the product. The majority of the money spent in the project happens in the final steps.
Before moving on from step to step all documentations produced must be approved.

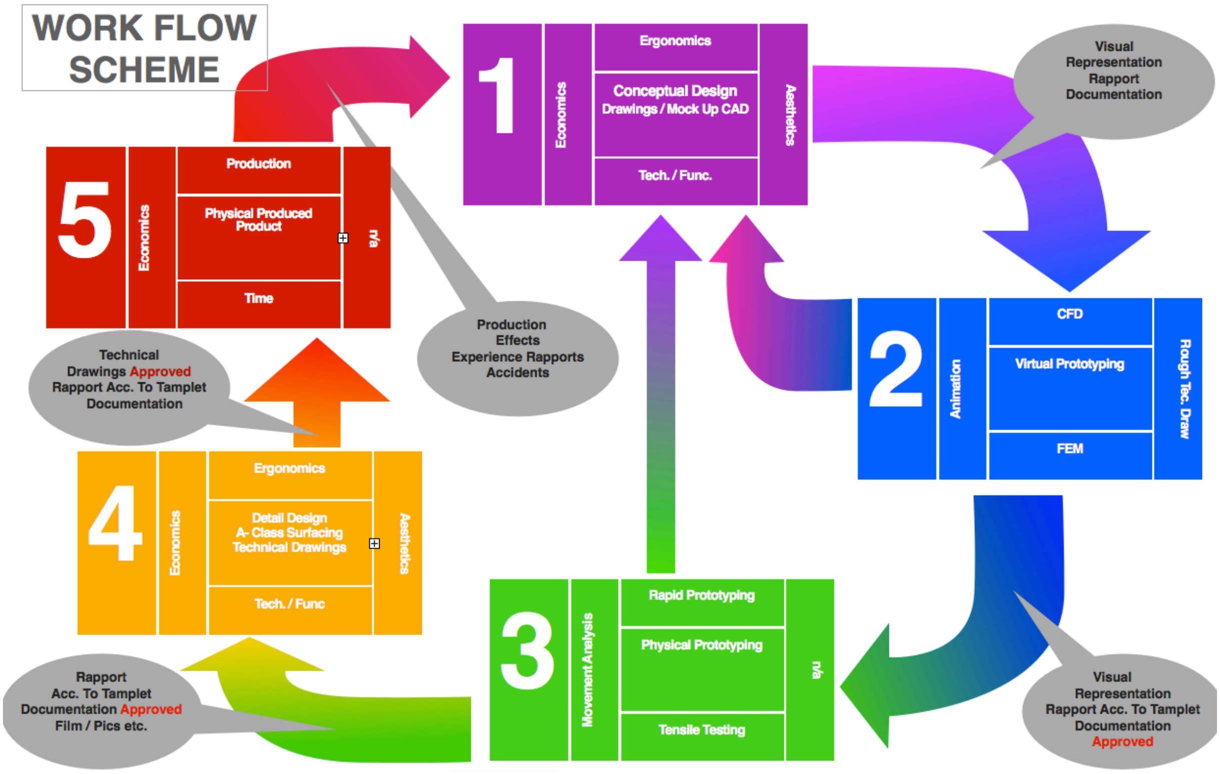

Figure 8: EQP2 model

5. Project plan

5.1 Projects in general

During a project there will be a number of activities or tasks that have to be solved as the project takes place. In order to keep an overview of the numerous activities in the project, we have to organize the project. This is so that every person involved in the project knows their duties and tasks, as the project takes form. There are several methods of planning a project successfully, and we will try to explain some of the key points in the project planning phase in this section.

Because a project is a onetime assignment, the planning phase of the project is unique every time. There is not a path that is right or wrong in the project planning phase. The planning of projects is a skill that become easier the more you do it. A good advice is to look at similar projects to gain knowledge about the project planning.

The most common methods for progress planning are Gantt-chart and milestone planning, or a combination of those.

5.1.1 Gantt-chart

A Gantt-chart is a free form planning method. There are initially no restrictions or demands on how to align the numerous activities in relation to each other. The Gantt-chart gives us an immediate visual impression of the plan's content and the extent and location in relation to each other. This is why this form of planning is widely used as a tool in presentations and discussions, rather than a planning technique.

5.1.2 Milestone planning

Milestone plans focus mainly on the end-dates by which something needs to be complete or by which certain objectives need to be achieved. That is why in the formulation of the milestones, there should be emphasis on describing the criteria's that should be fulfilled, to conclude that the milestone has been reached.

In the milestone planning it is important to specify the goals, in accordance to the demands and the goals of the project.

The milestone plan is usually presented as one or several parallel sequences of events, which is based on the project goals. This form of planning has largely the same flexibility as the Gantt-chart, and gives us large amount of freedom to choose the path of actions to reach the end goals.

5.1.3 Network planning

In large projects with numerous activities and dependency between the activities, the network planning method may be current for the progress planning. The network planning method is basically a combination of Gantt-chart and milestone planning. It gives the project manager better control of tasks and milestones during the project, because there is possibility of having numerous subprojects in larger ones. Were each subproject may have its own charts for progress.

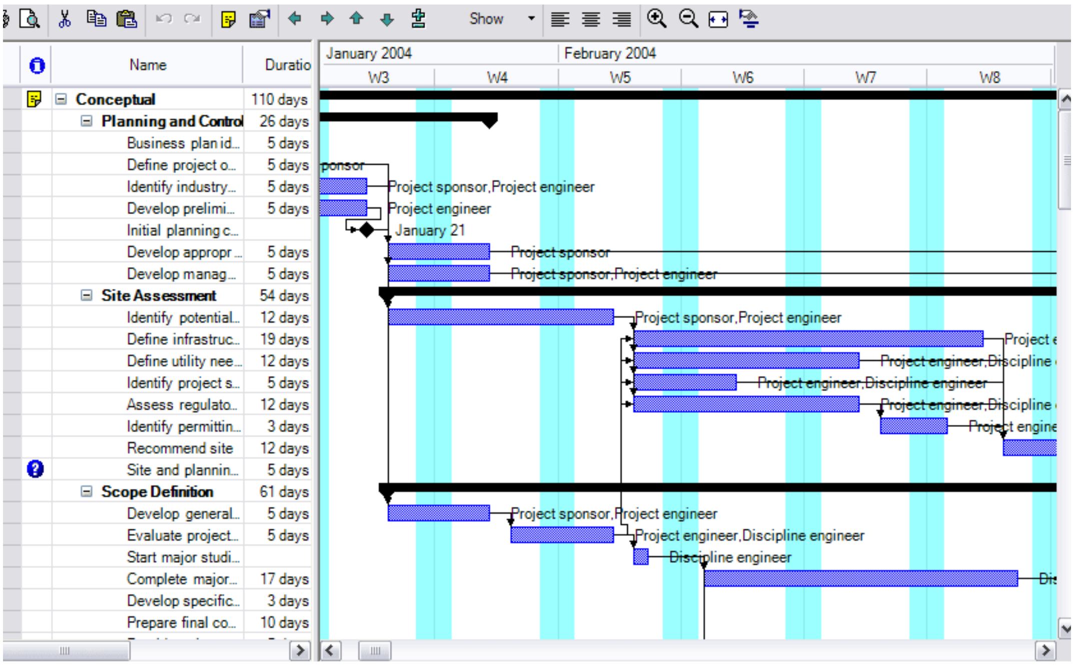

Figure 9: Gantt-chart

5.1.4 Resource planning

The resource planning is an important and critical part of the project planning. During the project we have equipment and people, which is required at certain moments during the project life cycle. To be sure we have the equipment we need, we must plan ahead and make reservations of equipment.

When it comes to people we must also plan ahead. A person may have many assignments he is working on simultaneously. When we estimate the duration of an activity we must plan how many hours that person have available on that certain activity. This is so that the person is not overworked and that he knows what activities he is to work on day to day- or week basis.

5.2 Economy/Budget

I every project we have an amount of money available, there is a specified amount that is available at certain moments. To ensure that the money will last until the end of the project, we have to set up a budget that lists up when, and what amount of money is needed at that specified time.

When we start making the budget for the project we also must look back at the resources, to make sure that the money spent is in accordance with the resources used.

The majority of the money spent will be on human resources.

6. Interest analysis

6.1 Stakeholders

In this interest analysis we are using the term stakeholders. Stakeholders are organizations, people or authorities who somehow are related to the project. We divide stakeholders in two groups, active- and passive stakeholders.
Active stakeholders are the group that is seeking to participate in the product trough its life time, such as managers, employees and customers.
Passive stakeholders are the group, who normally would not seek to participate but pay a role if the product is to exist, such as shareholders and authorities.

We will describe the stakeholders for the whole EQP2 aircraft system although our assignment is just a part of it.

6.1.1 Active stakeholders

- Managers of Equator Aircraft Norway SA.
- Future employees of EAN.
  - The engineers and maintenance workers on the EQP2.
- Customers/users
  - The customers buying the finished aircraft

6.1.2 Passive stakeholders

- The national aviation authorities.
  - Their role is to approve aircrafts and its equipment, controlling air traffic, direct laws concerning maintenance and licensing of pilots and aviation engineers.
- EASA (European Aviation Safety Agency)
  - The Certification Specifications for Normal, Utility, Aerobatic, and Commuter Category Aero planes. CS-23.
- Manufactures of material used in EQP2.
  - To keep the cost of the aircraft down, EAN want to use as little as possible specialized- but mostly off the shelf materials.
- Developers of the systems used in EQP2.
  - Developers requested from EAN to produce systems for EQP2.

6.2 Project size

At our first meeting with EAN there were some discussions on whether we should take both front and rear landing gear. We have now decided on taking on both of the gears in the project. Since our group consists of 6 people, which is plenty in this type of project, we believe that we have the time to take on both gears. This however, can be made changes to when we get the project plan finish before New Year.

6.3 Existing projects

When the LSA class where introduced in USA, one of the requirement was that the planes must have a fixed landing gear. For sea- and amphibian aircrafts however a retractable gear is allowed.
The retractable landing gear means less drag under water when taking off. This again means that the aircraft can take off on shorter distances, and have a more stabile landing.

There are companies who have similar aircrafts already tested and ready for production. The most relevant to EAN is Lisa Airplanes and Icon Aircraft.

Lisa Airplanes is a French company developing two types of amphibian aircrafts, Akoya and Hy-Bird. Akoya is today under production and is expected to be ready in spring 2011. Hy-Bird is essentially the same plane as Akoya, using only renewable energies. The plane will have solar panels on both wings and fuel cell powered engine. This plane is still in the developing stage.

Icon Aircraft is a California located company started up after the LSA class got introduced. Their plane, the Icon A5 has been made after the LSA requirements and is a lot smaller than the EAN EQP2, also shorter flying distance. The first Icon A5 aircrafts are expected delivery in fall 2011.

7. External conditions

7.1 Analyzing problems and limitations

Up to this date, only volunteers are working on the project. We must assume that there will be some problems during the project, therefore it is important to anticipate this and plan well, so we have time to finish before the deadlines. To keep an overview of this we are going to make a risk analysis. It will also be important to delegate work so everyone in the group has roughly the same amount of work to do. This is something the group manager should have an overview of at all time. The company has contacts that can help us implement the prototype we develop.

7.2 Quality control

An important question is to determine the quality of the product we come up with. Firstly, we must perform stress analysis and strength calculations for each mechanical part. This will be done in FEM (Finite Element Method). We will also run some tests of the products to check that everything is in accordance to the requirements.

8. Risk analysis

8.1 Critical success factors

There are two big factors that determine if the project is a success. These factors are; Have the project group been able to build a prototype of the retractable gear? And have the group managed to hand in all the written documentation before the different deadlines? These factors are again determined by several minor factors that we now will take a look at.

It is important that the different group activities have been appointed to persons inside the group that are able to handle them. If for instance the person that is responsible for the electronics in a project doesn't have any experience within electronics, it can cause big problems for the project. This can cause circuits to be made wrong etc. To prevent these things, the project group has to sit down and discuss the different responsibilities in the project before they appoint assignments to persons. The group can then see which people that have competence to be, for instance, head of electronics.

Time is also a big factor, when we are talking about a project like the one we are doing. In the project it is important that we have enough time to finish each assignment. It is therefore crucial that a good project plan with a Gantt-chart is made, before we start working on the important tasks in the project. With a good project plan it will be easier for the members in the group to plan which activities that they have to prioritize and when they have to start working on them. There are several deadlines were we have to hand inn documentation, and it is especially important that we hold these deadlines.

The solutions we choose under the construction process are also an important factor. If we choose a particular way of constructing the retractable gear we have to be sure that the solution is possible to build. If not, there can be a big chance that we will lose a lot of time, because we have to start the construction process all over again. So a good preliminary work is a keyword here. The retractable gear also has to be made based on some rules and regulations determined by the CS-23. CS-23 is a document that explains the rules and regulation in which you have to maintain when building an aircraft. If we don't follow the set of rules and regulation set by the CS-23 document, we cannot implement our retractable gear into the EQP2 aircraft.

9. Consequences

9.1 Different outcomes

Since this rapport is a document on whether we should go on with the project it must include a part where we consider the consequences on different outcomes. This includes accepting, declining, if the assignment is too big and if it is too small.

9.1.1 We take the project

As we entered the first semester of the last year in our bachelor's degree, we were all prepared to take on a much larger assignment then we have done the last few years. We believe and hope that this project will give us more and better knowledge on how to run and work in a project of some size. We are all prepared to work a lot on this project.

9.1.2 We do not take the project

Because EAN in this stage is a company drifted mostly on good will and different collaborations, there is not much money and investors involved. EAN has had collaborations with other universities before, and have expressed that this is a good way of having a lot done in an affordable way. Plus we as students learn a lot in the process. The outcome of we not taking this project would mean that EAN had to wait and to take on the part later on.

9.1.3 The project is too big

When we write the requirement specification for the retractable gear we must divide the requirements in to different grades of importance. This gives us which requirements we must include, which we should include, and some we can include if we get time. When we start the main part of the project after the first presentation and hand-in, in January 2011, we have to consistent start working on the most important requirements first. We need to work our way through the requirement specification and end with the least important. This means that if we, at the end of the project, see that there are some requirements that we don't have time to do, these are the least important. The test specification and tests has to be done in the same way.

9.1.4 The project is too small

To start with, our project group does not think the assignment is too small. If we during the project see that we are ahead of schedule this is a positive thing, then we can work more detailed on the task we have left.

10. Conclusion

As we the project group and EAN wish a close cooperation with each other to have an influence on the product made. We must choose a project model that gives us the opportunity to do that.

The unified process project model is the project model we will be using throughout our project. We believe that this project model is suitable for our project, giving us all documentation that has to be in place, before starting making design and models.

In order to keep the money spent in the project as low as possible, the majority of the design and development of our product will be done with use of software. Giving us the possibility to design and make changes to the design far out in the project. This is in compliance with the unified process, described as iterations of design.
It is through these iterations we will be developing our product (in software).

As we get to the finishing phase of the project, there will be made a prototype of the product, where the product is tested and the functioning of the product is verified.

Regarding the project plan, the best solution for our project group is to use the network planning method in a smaller scale. The reason why, is that our project consists of two sub-projects that merge before the assembly of the prototype. This is respectively the front- and back retractable gear.

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Project Plan

aRGie
Retractable Gear Development Study

Buskerud University College, Department of Engineering Institute of Technology

Equator Aircraft Norway SA

Document responsible: Rebaz Aziz
Version 3.0
Date: 27.05.2011

Internal guidance councilor: Øyvind Eek-Jensen

Rebaz Aziz	Jeremy Marchand	Stein Erik Thoen
Sindre D. Flaten	Sigbjørn Gunnerød	Sakariya H. Dahir

Abstract

This document describes the different project phases and what they include. It consists of a simple Gantt-chart over what the different tasks are. There will be done changes on this document during the project, and all work hours are only an estimate.
The activities up to date are listed and explained, there may be added and changed activities.

This document is a part of the pre study along with requirement and test specification.

Sammendrag

Dette dokumentet beskriver de forskjellige fasene i prosjektet og hva de inneholder. Dokumentet inkluderer et enkelt Gantt diagram over de forskjellige oppgavene som skal gjøres underveis. Det vil bli gjort endringer på denne planen utover prosjektet, og timelister er kun et estimat.
Aktivitetene vi har til nå er listet og forklart, det kan bli tilført og endret aktiviteter under prosjektet.

Dette dokumentet er en del av forstudien sammen med krav og testspesifikasjonen.

Document history

Version	Date	Responsible	Changing
0.1	20.12.2010	Stein Erik Thoen	
0.2	21.12.2010	Stein Erik Thoen, Rebaz Aziz	• Determine activity hours. Define phase activities. • Introduction, abstract.
0.3	21.12.2010	Rebaz Aziz	• Spell checking • 14. Conclusion added
0.4	21.12.2010	Stein Erik Thoen	• Abstract • Introduction • Conclusion • Layout
0.5	21.10.2010	Rebaz Aziz	• 3. effects/goals added
0.6	04.01.2011	Jeremy Marchand	• Spell checking • Text size and number on tables • Table content order • Changed titles font • Added word in 3.1 • Changed sentence in Sammendrag • Role names in project organization • Sentence in 3.1, 3.2, 4.1, 4.2, 5.1, 6, 8 • Removed conclusion • Added internal guidance councilor on front page • Added budget • Milestones edited • References added
1.0	04.01.2011	Rebaz Aziz	
1.1	02.02.2011	Stein Erik Thoen, Sindre D. Flaten	• New activities • Changed activity ID • Milestones edited • Phases added
1.2	20.04.2011	Sindre D. Flaten	• Added new numbers on headlines from 8 – 11 • Added iteration report under 4. Phases and tasks • Added Gantt-chart • Added 4.3 iterations

2.0	20.04.2011	Rebaz Aziz	
2.1	26.05.2011	Rebaz Aziz	• Final check on the document • Fixed up appendix names
3.0	27.05.2011	Rebaz Aziz	

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Definitions

Abbreviation	Extension	Description
EAN	Equator Aircraft Norway SA	Employer
EQP2	Equator P2 Excursion	The aircraft now under development by EAN
LSA	Light-Sport Aircraft	A classification of aircraft, specific to the USA. With max weight of 650 kg and max speed of 220km/h.
BUC	Buskerud University College	
CS-23	Certification Specifications 23	Certification Specifications for Normal, Utility, Aerobatic, and Commuter Category Aero planes.
FEM	Finite Element Method	Analyzing tool in 3D modeling software.

1. Introduction

This project plan will give an insight into what we will be doing in the different phases during the project.
A large part of the thesis, from a BUC view, is to get to know the project phases. In this document we have reviewed the tasks and resources we have set early in the project.

Our assignment is to design and develop the retractable gear for the EQP2 aircraft.

2. The project group

2.1 Project organization

Name	Age	Education	Email	Telephone
Rebaz Aziz	24	Product development	az.rebaz@gmail.com	45257723
Jeremy Marchand	23	Product development	jeremymarchand87@gmail.com	92894166
Sakariya Dahir	36	Product development	sakariyadahir@gmail.com	41608563
Stein Erik Thoen	23	Mechatronics	steine.thoen@gmail.com	98602390
Sigbjørn Gunnerød	21	Mechatronics	sgunneroed@gmail.com	40883401
Sindre D. Flaten	21	Mechatronics	sindredf@gmail.com	48190140

Table 1: Project group

We have made a collective email address which can be used for contacting the whole group: eqp2.hibu.project@gmail.com

We also have made a homepage for the project under the EAN domain. This is meant so that outsiders can follow the progress of the project.
http://www.equatoraircraft.com/hibu_rgproject

Name	Role	Contact
Tomas Brødreskift	External supervisor	tb@equatoraircraft.com
Knut Brødreskift	External sensor	kb@equatoraircraft.com
Øyvind Eek-Jensen	Internal supervisor	oyvind.eek-jensen@hibu.no
Olaf. Hallan. Graven	Internal sensor	olaf.hallan.graven@hibu.no

Table 2: Sensors/supervisors

3. Targets

Our target of the project is to have a scaled down prototype of the undercarriage finished to the final presentation. This will show the mechanical function of the different use cases; take-off, landing and emergency operation. EAN wants us also to have the material specification as clear as possible, so that they can start the full scale prototype by the end of 2011. This includes calculation of strength and FEM analysis.

3.1 Effect goals

The effects of developing the undercarriage for the EQP2 Excursion aircraft is among others increased market competition among already existing aircraft models, within the same industry but also within sea and land aircrafts.
The market of potential customers and users will get an increase, given that more people want a multi functional aircraft that can land on different surfaces.
The undercarriage will make maintenance of the aircraft and the undercarriage itself easier, given the fact that transporting the aircraft is made easier with the undercarriage, where it previously was necessary to transport with a boat trailer.
By executing this assignment from EAN, the completion date of the EQP2 Excursion will be shortened. And a confirmation on already existing drawings and designs made on the undercarriage will be confirmed.
The cooperation with students will make the innovative aspects on the assignment larger, as there are more people gathered and working on the same problem.
Cooperation with colleges/universities will make EAN more desirable on the market, regarding future projects in EAN's life time.

3.2 Result goals

At the end of this project, a working scaled prototype of the undercarriage system will be in place, where all of the mechanical and electrical functions of the system are well functioning.
An analysis of CS-23 requirements will be performed, giving foundation for further requirements delivered in this project.
An analysis of stresses on the system will be performed after the design of the mechanical parts in SolidWorks. This analysis will be performed in FEM, resulting in changes done on the system, to optimize it.
An analysis and development of emergency solutions for landings will be produced, either as solutions where the RG is used, or as alternative solutions for safe emergency landings.
Material analysis is to be performed during the project, giving EAN alternatives on types of materials to be used in different parts of the RG.

4 Phases and tasks

4.1 What are the different phases in the project

- First phase: From project start to January 4th 2011 (two days before first presentation). In this phase our objective is to have finished the pre study report, requirement- and test specification and project plan. We also have to put together a presentation of these documents for the presentation on January 7th. The presentation should answer the questions: What is the assignment, and when should the different tasks be done.

- Second phase: From first presentation to second presentation. Between March 14th and April 1st 2011 (Dates will be included when they are set). The second presentation will include a new project plan, which will be more detailed, and describe how we will go through with the last part of the project.

- Third phase: From third presentation to final presentation 3rd to 8th of June (Dates will be included when they are set). The final presentation will consist of two separate parts, with 20 minutes in each presentation. We should present the finished product in two ways. One sales presentation to try and sell the product, not going too far into the technical part. After that there is a technical presentation, this will describe the system and product in a technical way to our sensor and supervisors.

All documentations should be delivered on a CD two days before every presentation; this should also include documents history.

4.2 Tasks

In the first phase of the project we should focus on getting the documents detailed. This is to be well prepared when we start the technical part of the assignment after the first presentation. We need to get the requirements as detailed as possible, which means it is easier to follow the project plan we set up. Milestone of this task is the preliminary work, with the documents included.

The second phase will be the most technical phase. Our first assignment in this phase will be to sit down and analyze the undercarriage design of today's aircrafts. We will develop and design the retractable gear, and also estimate the force of the design.

The last phase will be to construct the prototype. This will be done in close collaboration with EAN and their contacts. A large part will also be to evaluate the project and set up a final presentation.

Documentation of our work will be an important part in all phases.

4.3 Iterations

As explained above we have different phases in the lifetime of the project. But a phase is just a method of dividing the lifetime of the project into sections that can help the members of the project and give them an overview. To allow the members of the project group to know what they are doing in each phase, we divide each phase into what is known as iterations. Iteration is a plan that explains the members of the project what is to be done, and at what time. It is a method of giving the project manager an overview of what is done, and what need to be done, so that the project manager can update the project plan accordingly.

In the first phase, we decided to have one iteration (appendix 3). This is because the workload was focused on producing the documents, and it was not necessary to divide the phase into different iterations. To see how the iteration went look at the iteration report (appendix 4). The second phase is divided into 3 iterations, where the iterations are in accordance with the project model we have chosen.

First iteration in phase 2 is the elaboration iteration (appendix 5) where the focus is on starting the project, looking at how the task can be solved etc. The report on the elaboration iteration explains what was done and what needs to be done (appendix 6).

The Second iteration is the design and development iteration (appendix 7). The focus here is to come up with designs, and to analyze what works and what don't. The report (appendix 8) tells us how it went.

The final iteration in phase 2 is the construction iteration (appendix 9), where the main focus is on constructing and developing the ideas we have made up in the previous iterations. The results from this iteration can be seen in the report in (appendix 10). The final phase of the project, phase 3, is divided into 2 iterations. The first one is the finalize design iteration (appendix 11), and the second one is the final work iteration (appendix 13).
The report on how the two final iterations went can be seen in (appendixes 12 and 14).

5 Conditions and limits

To construct a prototype we are going to use a technique called rapid prototyping. This means to print out a part in a 3D printer, often done in plastic. EAN will provide us with these models, but we have to take in consideration that this may take several weeks to be delivered.

5.1 Available time

BUC estimates approximately 500 work hours per student on the bachelor's thesis. This means that our group of 6 persons should use about 3000 hour combined on the project. It is important to use this number when we set up the project planning.
In the fall 2010 we have estimated that we work approximately 50 hours each. This is the phase when we decide for a project, up to first presentation, when the pre study report, requirement specification, test specification and project plan are finished.

It has been set up 14 hours per week from January 2011 to the exam period before Easter, this is the second phase. After Easter we have 5 days per week (37.5 hours per week) to work on the project until project end in late May.

6 Resources

Since none of our group members have experience with airplanes and undercarriages, a large part of our project will be to analyze today's concepts. EAN has set this task so that we can use the knowledge we get to come up with the best solution for the project. EAN has a large contact network in the airplane business and we will use that during the project. The project plan will describe which resources we need to use at what time.

Since we also will construct a working scaled down prototype, EAN will set us in contact with someone who can help us with that. This will be done with the technique rapid prototyping, and must be considered when making the project plan. EAN has said that the prototype part takes approximately three weeks to be made and shipped to us. The large delivery time is because this is done in the spare time of EANs contacts.

7 Milestones

Name	Date
Initial design approved	15. February 2011
Ordering of electrical parts	28. March 2011
All files ready for delivery	17. May 2011

Table 3: Milestones

8. Activities

We have divided the activities into five different parts, organization, analysis, mechanical, electronics and verification.

8.1 Organization

Name	ID
Project organization	O01
Requirements	O02
Test	O03
Brainstorming	O04
Presentations	O05
Website	O06
Hour list	O07
Risk analysis	O08
Economy	O09
External meetings	O10
Internal meetings	O11
Tracking	O12
Assembly guidance	O13

8.2 Analysis

Name	ID
Analysis of construction rules	A01
Research	A02
Material analysis	A03
Component research	A04
Emergency analysis	A05
Software education	A06

8.3 Mechanical

Name	ID
Front gear mechanical design	M01
Rear gear mechanical design	M02
Front gear mechanical assembly	M03
Rear gear mechanical assembly	M04
Emergency design	M05
Emergency implementation	M06

8.4 Electronics

Name	ID
Decide on electrical circuit	E01
Electronic calculations	E02
Electronic construction	E03
Circuit simulation	E04
Ordering of electrical parts	E05
Front electrical implementation	E06
Rear electrical implementation	E07

8.5 Verification

Name	ID
Mechanical components testing	V01
Mechanical system testing	V02
Front calculation of strength	V03
Rear calculation of strength	V04
Electronics component testing	V05
Electronics system testing	V06
Final acceptance test (prototype)	V07

Organization

Activity name: Project organization	**Activity code:** O01	**Responsible:** Rebaz Aziz
Description: Organize the project and group to be as effective as possible.		
Purpose: To validate progress and development of project/RG. Involve everyone in the project, and make sure they get the same amount of work.		
Procedure: Set people to do task closets to their knowledge field. Motivate group members.		
Result: Different documents involving who does what, and how.		
Date set: 15.12.2010	**Resources:** EAN	

Table 4: Project organization

Activity name: Requirements	**Activity ID:** O02	**Responsible:** Jeremy Machand
Description: Making requirements for the project.		
Purpose: Define functions and limitations for the system.		
Procedure: Create use cases to find different requirements. Afterwards make a requirement specification which lists requirements to the different use cases.		
Result: Better defined assignment.		
Date set: 10.01.2011	**Resources:** EAN, CS-23	

Table 5: Requirements

Activity name: Test	**Activity ID:** O03	**Responsible:** Sigbjørn Gunnerød
Description: Making tests for all the requirements.		
Purpose: Check that the system meets all the requirements.		
Procedure: Find out which components to test and how.		
Result: Have tests ready to be used later in the project.		
Date set: 10.01.2011	**Resources:** EAN	

Table 6: Test

Activity name: Brainstorming	**Activity ID:** O04	**Responsible:** Rebaz Aziz
Description: Have a brainstorming session with all the members in the group.		
Purpose: To come up with new ideas for the design of the retractable gear.		
Procedure: Sit down in a group and suggest many different ideas that we individually have come up with, and then discuss them in the group.		
Result: Have a deeper insight in different designs and technologies to be used in a final solution.		
Date set: 10.01.2011	**Resources:**	

Table 7: Brainstorming

Activity name: Presentations	**Activity ID:** O05	**Responsible:** Stein Erik Thoen
Description: There are 3 mandatory presentations, one by the end of each phase.		
Purpose: Mandatory presentations set by BUC. The sensors should evaluate the group on our project and presentations.		
Procedure: Create presentations in PowerPoint.		
Result: Display our progress and results during the project.		
Date set: 15.12.2010	**Resources:** Location, equipment.	

Table 8: Presentations

Activity name: Website	**Activity ID:** O06	**Responsible:** Sindre D. Flaten
Description: Construct a website and update frequently		
Purpose: Distribute the work on the project to outsiders.		
Procedure: EAN will give the group access to an area on the EAN domain. We will write html code and post news frequently. The site will also have contact information to the group.		
Result: People interested in the project can find out more, as the project goes on.		
Date set: 15.12.2010	**Resources:** When required; a website experienced.	

Table 9: Website

Activity name: Hour list	**Activity ID:** O07	**Responsible:** Sakariya H. Dahir
Description: Keep track of every hour we work on the project.		
Purpose: To know what type of effort we have put in to the project. To the employer it is important to know how much potential money has been put in to the project. Detailed view to see how many hours have been put in to each task.		
Procedure: Each member of the group has to keep track on how many hour they work on the project. Every week from phase two, there should be delivered a follow-up document which states how many hours on which tasks.		
Result: Get to know how many hours have been put in to the project. Compare it with the result of the project to see efficiency.		
Date set: 15.12.2010	**Resources:** Equipment.	

Table 10: Hour list

Activity name: Risk analysis	**Activity ID:** O08	**Responsible:** Stein Erik Thoen
Description: Create a risk document.		
Purpose: To get an overview of the different risks we may run into during the project.		
Procedure: Consider every risk possible during the project, and estimate the possibility of these. Evaluate what we should do if something does not go as planned.		
Result: A risk document that states all risk and possibilities of some of them occur.		
Date set: 15.12.2010	**Resources:** EAN, internal/external supervisor.	

Table 11: Risk analysis

Activity name: Economy	**Activity ID:** O09	**Responsible:** Sakariya H. Dahir
Description: Keep track of the economy of the project.		
Purpose: Get to know if we are following the budget set before start.		
Procedure: Create budget and handle/explain all expenses connected to the project.		
Result: Have an overview of the economy. If something is not as planned it is explained why.		
Date set: 11.01.2011	**Resources:**	

Table 12: Economy

Activity name: External meetings	**Activity ID:** O10	**Responsible:** Rebaz Aziz
Description: Monthly formal meetings together with external supervisor and sensor.		
Purpose: To ensure that both employer and the project group agree on what is being done on the project. Discuss new ideas for the employer.		
Procedure: All meeting activities should be prepared with a notice of meeting at least 48 hours before the meeting takes place. This includes an agenda over the meeting to be held. At least 24 hour after the meeting there should be a draw up of the minutes delivered to all involved in the meeting, and eventually supervisors not present. Meeting should at all time have one meeting recorder.		
Result: External sensor and supervisor know how the project is moving on. The project group needs the meetings to answer technical and functional questions about the project.		
Date set: 11.01.2011	**Resources:**	

Table 13: External meetings

<table>
<tr><td>Activity name: Internal meetings</td><td>Activity ID: O11</td><td colspan="2">Responsible: Stein Erik Thoen</td></tr>
<tr><td colspan="4">Description:
Weekly meetings with internal supervisor.</td></tr>
<tr><td colspan="4">Purpose:
To ensure that the project group and internal supervisor agree on what is being</td></tr>
<tr><td colspan="4">Procedure:
All meeting activities should be prepared with a notice of meeting at least 48 hours before the meeting takes place. This includes an agenda over the meeting to be held. At least 24 hour after the meeting there should be a draw up of the minutes delivered to all involved in the meeting, and eventually supervisors not present. Meeting should at all time have one meeting recorder.</td></tr>
<tr><td colspan="4">Result:
Internal supervisor have good knowledge on how the project is moving on. The project group needs the meetings to answer questions during the project.</td></tr>
<tr><td colspan="2">Date set: 11.01.2011</td><td colspan="2">Resources:</td></tr>
</table>

Table 14: Internal meetings

<table>
<tr><td>Activity name: Tracking</td><td>Activity ID: O12</td><td colspan="2">Responsible: Sigbjørn Gunnerød</td></tr>
<tr><td colspan="4">Description:
Track the progress of the project.</td></tr>
<tr><td colspan="4">Purpose:
To know whether the group is behind or in front of schedule in accordance with the project plan.</td></tr>
<tr><td colspan="4">Procedure:
Every week create a follow up document on what has been done the following week and what is to be done the next week, including hour lists. Describe if something does not go as planned.</td></tr>
<tr><td colspan="4">Result:
An overview of what we have done and how many hours spent on the activities.</td></tr>
<tr><td colspan="2">Date set: 11.01.2011</td><td colspan="2">Resources:</td></tr>
</table>

Table 15: Tracking

Activity name: Assembly guidance	**Activity ID:** O13	**Responsible:** Sindre D. Flaten
Description: Assembly guidance over the system.		
Purpose: Make it easier for service engineers to maintain and assemble/disassemble the system.		
Procedure: Create assembly guidance for production and service.		
Result: An installation and maintenance guide will be present.		
Date set: 15.12.2010	**Resources:** None	

Table 16: Assembly guidance

Analysis

Activity name: Analysis of construction rules	**Activity ID:** A01	**Responsible:** Sindre D. Flaten
Description: Analyze the construction rules to consider when designing the system.		
Purpose: Know the rules for strength and stress on the undercarriage.		
Procedure: Analyze the document CS-23.		
Result: Secure that we follow the requirements and rules for designing the undercarriage.		
Date set: 10.01.2011	**Resources:** CS-23	

Table 17: Analysis of construction rules

Activity name: Research	**Activity ID:** A02	**Responsible:** Sigbjørn Gunnerød
Description: Insight in already existing designs.		
Purpose: To learn more about the undercarriages on aircrafts in use today.		
Procedure: Use mostly internet to look for details on how the undercarriage works on aircrafts.		
Result: A document that states what the most common solutions today.		
Date set: 15.12.2010	**Resources:** Equipments, internet.	

Table 18: Research

Activity name: Material analysis	**Activity ID:** A03	**Responsible:** Jeremy Marchand
Description: Do a material analysis.		
Purpose: Find what materials that can be used for a full-scale model.		
Procedure: Find the strengths and weaknesses of different materials in matter of cost, strength, weight, corrosion resistance and availability.		
Result: Know what materials that can be used in the full-scale model		
Date set: 10.01.2011	**Resources:** Internet, books	

Table 19: Material analysis

Activity name: Component research	**Activity ID:** A04	**Responsible:** Sigbjørn Gunnerød
Description: Research on electrical components we can use in the circuit.		
Purpose: To find the right components that we can use in the electrical control system for the RG.		
Procedure: After we have decided on the basic circuit we can use for the control system we have to research different components that we can use for this circuit. We will use the information we have learned at school, look in data-sheets and on the internet.		
Result: Have components that can be used to simulate the circuit in for instance OrCad.		
Date set: 25.01.2011	**Resources:** Internet, books	

Table 20: Component research

Activity name: Emergency analysis	**Activity code:** A05	**Responsible:** Sindre D. Flaten
Description: Analyze the different ways we can integrate an emergency operation to the system.		
Purpose: A requirement set by CS-23 that the undercarriage must have an emergency operation. This is an important part if the main system fails.		
Procedure: Find out more on emergency solutions on other aircrafts.		
Result: Get to know more about what our options are for designing the emergency operation.		
Date set: 11.01.2011	**Resources:**	

Table 21: Emergency analysis

Activity name: Software education	**Activity ID:** A06	**Responsible:** Sindre D. Flaten
Description: Educate group members in the software we are going to use in the project.		
Purpose: Get to know the computer software to be used later in the project.		
Procedure: Walk trough tutorials in the different programs.		
Result: Better foundation before starting to use the software in the project.		
Date set: 10.01.2011	**Resources:** Computer software	

Table 22: Software education

Mechanical

Activity name: Front gear mechanical design	**Activity ID:** M01	**Responsible:** Jeremy Marchand
Description: Mechanical design of the front gear undercarriage.		
Purpose: Make a working mechanical design of the front gear undercarriage.		
Procedure: Design and develop the front retractable gear, using computer-modeling software (SolidWorks). This is done in 5 iterations.		
Result: Have a working mechanical software model of the front retractable gear, which we can implement into the ¼ prototype.		
Date set: 10.01.2011	**Resources:** Equipment (software), EAN	

Table 23: Front gear mechanical design

Activity name: Rear gear mechanical design	**Activity ID:** M02	**Responsible:** Rebaz Aziz
Description: Mechanical design of the rear gear undercarriage.		
Purpose: Make a working mechanical design of the rear gear undercarriage.		
Procedure: Design and develop the rear retractable gear, using computer-modeling software (SolidWorks). This is done in 5 iterations.		
Result: Have a working mechanical software model of the rear retractable gear, which we can implement into the ¼ prototype.		
Date set: 10.01.2011	**Resources:** Equipment (software), EAN	

Table 24: Rear gear mechanical design

Activity name: Front gear mechanical assembly	**Activity ID:** M03	**Responsible:** Jeremy Marchand
Description: Assemble the mechanical part for the front gear.		
Purpose: Make a physical working model of the front retractable gear.		
Procedure: Assemble all the mechanical parts that we have developed for the front retractable gear.		
Result: Have a physical working model of the front retractable gear that is implemented into the ¼ prototype.		
Date set: 10.01.2011	**Resources:** Equipment (3D print, parts ordered), EAN	

Table 25: Front gear mechanical assembly

Activity name: Rear gear mechanical assembly	**Activity ID:** M04	**Responsible:** Rebaz Aziz
Description: Assemble the mechanical part for the rear gear.		
Purpose: Make a physical working model of the rear retractable gear.		
Procedure: Assemble all the mechanical parts that we have developed for the rear retractable gear.		
Result: Have a physical working model of the rear retractable gear that is implemented into the ¼ prototype.		
Date set: 10.01.2011	**Resources:** Equipment (3D print, parts ordered), EAN	

Table 26: Rear gear mechanical assembly

Activity name: Emergency design	**Activity ID:** M05	**Responsible:** Sindre D. Flaten
Description: Design the emergency operation for the system.		
Purpose: A requirement set by CS-23 that the undercarriage must have an emergency operation. This is an important part if the main system fails.		
Procedure: Consider the analysis and find the best design for emergency operation on the system we have developed.		
Result: Have a finished design of the emergency operation to implement.		
Date set: 11.01.2011	**Resources:**	

Table 27: Emergency design

Activity name: Emergency implementation	**Activity ID:** M06	**Responsible:** Sindre D. Flaten
Description: Implement the finished emergency operation into the system.		
Purpose: A requirement set by CS-23 that the undercarriage must have an emergency operation. This is an important part if the main system fails.		
Procedure: Have finished design of the emergency operation and implemented this into drawings and models of the existing system.		
Result: A functional and working emergency operation for the retractable gear if the main system fails.		
Date set: 11.01.2011	**Resources:** EAN	

Table 28: Emergency implementation

Electronics

Activity name: Decide on electrical circuit	**Activity ID:** E01	**Responsible:** Stein Erik Thoen
Description: Decide on which electrical circuit type we are going to use.		
Purpose: To find out which electrical circuit we will be using for the control system to the RG, and also to decide if we are going to use an analog and digital circuit or just an analog one.		
Procedure: Discuss in the group which circuit that fits the RG best (have pros and cons), and decide on one circuit concept.		
Result: Have a concept for the electrical circuit that we can further use to develop the electrical control system circuit.		
Date set: 25.01.2011	**Resources:** Project group, EAN	

Table 29: Decide on electrical circuit

Activity name: Electronic calculations	**Activity ID:** E02	**Responsible:** Stein Erik Thoen
Description: Calculate the electric components and systems		
Purpose: Find appropriate electric components to use in the control system.		
Procedure: Using simulating software to sketch basic electric component layouts.		
Result: Know what electric component to use in the control system.		
Date set: 10.01.2011	**Resources:** Equipment (software)	

Table 30: Electronic calculations

Activity name: Electronic construction	**Activity ID:** E03	**Responsible:** Sindre D. Flaten
Description: Electrical construction and design of the control system for the retractable gear		
Purpose: Make a working electrical design of the control system for the retractable gear.		
Procedure: Determine components, put together in computer software and simulate. Design and develop the control system using computer software. This is done in 4 iterations.		
Result: Have a working electrical control system for the retractable gear, which we can implement into the ¼ prototype.		
Date set: 10.01.2011	**Resources:** Equipment (software), EAN	

Table 31: Electronic construction

Activity name: Circuit simulation	**Activity ID:** E04	**Responsible:** Stein Erik Thoen
Description: Simulation of the electrical circuit to the RG.		
Purpose: To verify the function of electrical circuit for the RG, before building it for the ¼ prototype. This will also give us a conformation on that the circuit we are developing throughout the projects developing-phase, is working.		
Procedure: After we have made a suggestion for a possible electrical circuit, we will design this circuit in OrCad and simulate it there, in real time. This is done in 4 iterations.		
Result: Have a working electrical circuit that easily can be constructed with real electrical components.		
Date set: 25.01.2011	**Resources:** Software (OrCad)	

Table 32: Circuit simulation

Activity name: Ordering of electrical parts	**Activity ID:** E05	**Responsible:** Sigbjørn Gunnerød
Description: Order the components for the electrical circuit.		
Purpose: To have electrical components that we can use to construct the electrical circuit for the ¼ prototype.		
Procedure: Use the internet/phone to order the electrical components/parts. (We have not yet decided on were we will be order these parts from)		
Result: Have all the components/parts that we are going to use to construct the electrical circuit for the ¼ prototype of the RG.		
Date set: 25.01.2011	**Resources:** Internet, phone	

Table 33: Ordering of electrical parts

Activity name: Front electrical implementation	**Activity ID:** E06	**Responsible:** Stein Erik Thoen
Description: Implement the electrical control system for the front gear.		
Purpose: Make a physical working model of the front retractable gear.		
Procedure: Implement all the electrical parts for the electrical control system that we have developed for the front retractable gear.		
Result: Have a physical working model of electrical control system for the front retractable gear that is implemented into the ¼ prototype.		
Date set: 10.01.2011	**Resources:** Equipment (parts ordered), EAN	

Table 34: Front electrical implementation

Activity name: Rear electrical implementation	**Activity ID:** E07	**Responsible:** Sigbjørn Gunnerød
Description: Implement the electrical control system for the rear gear.		
Purpose: Make a physical working model of the rear retractable gear.		
Procedure: Implement all the electrical parts for the electrical control system that we have developed for the rear retractable gear.		
Result: Have a physical working model of electrical control system for the rear retractable gear that is implemented into the ¼ prototype.		
Date set: 10.01.2011	**Resources:** Equipment (parts ordered), EAN	

Table 35: Rear electrical implementation

Verification

Activity name: Mechanical component testing	**Activity ID:** V01	**Responsible:** Rebaz Aziz
Description: Testing of mechanical components.		
Purpose: Insure that the mechanical components work as planned during the project.		
Procedure: Use FEM analysis in SolidWorks to test/analyze strength and stress on mechanical components.		
Result: Secure that mechanical components keep the requirements set.		
Date set: 10.01.2011	**Resources:** Equipment (software), EAN	

Table 36: Mechanical component testing

Activity name: Mechanical system testing	**Activity ID:** V02	**Responsible:** Rebaz Aziz
Description: Testing of mechanical systems/interfaces.		
Purpose: Insure that the mechanical systems work together as planned during the project.		
Procedure: Test both using computer software and physically on model.		
Result: Secure that the mechanical components work in a system.		
Date set: 10.01.2011	**Resources:** Equipment (software), EAN	

Table 37: Mechanical system testing

Activity name: Front calculation of strength	**Activity ID:** V03	**Responsible:** Sakariya Dahir
Description: Software calculation of strength of the front gear.		
Purpose: See that the system can tolerate the forces given under operation. These rules can be found in CS-23.		
Procedure: FEM analysis of front gear. This must be done after the design period is closed and finished.		
Result: Proof that the undercarriage works under take off, in air and in landing.		
Date set: 11.01.2011	**Resources:** Equipment (software)	

Table 38: Front calculation of strength

Activity name: Rear calculation of strength	**Activity ID:** V04	**Responsible:** Sakariya Dahir
Description: Software calculation of strength of the rear gear.		
Purpose: See that the system can tolerate the forces given under operation. These rules can be found in CS-23.		
Procedure: FEM analysis of rear gear. This must be done after the design period is closed and finished.		
Result: Proof that the undercarriage works under take off, in air and in landing.		
Date set: 11.01.2011	**Resources:** Equipment (software)	

Table 39: Rear calculation of strength

Activity name: Electronics component testing	**Activity ID:** V05	**Responsible:** Stein Erik Thoen
Description: Testing of electronic components.		
Purpose: Insure that the electrical components work as planned during the project.		
Procedure: Testing electrical components with use of measuring instruments.		
Result: Secure that all components use as they should.		
Date set: 10.01.2011	**Resources:** Equipment (software), EAN	

Table 40: Electronics component testing

Activity name: Electronics system testing	**Activity ID:** V06	**Responsible:** Sigbjørn Gunnerød
Description: Testing of electric systems/interfaces.		
Purpose: Insure that the electrical systems work as planned during the project.		
Procedure: Testing electrical systems in simulation software and with use of measuring instruments.		
Result: Secure that all systems work as they should.		
Date set: 10.01.2011	**Resources:** Equipment (software), EAN	

Table 41: Electronics system testing

Activity name: Final acceptance test (prototype)	**Activity ID:** V07	**Responsible:** Sigbjørn Gunnerød
Description: Test the whole system on the scaled prototype model.		
Purpose: Insure that the system work as planned on the physical model.		
Procedure: Since the model is not in correct materials the test will be mainly on functionality of the mechanical and electrical system.		
Result: Show that the functionality of the system works with the whole system implemented.		
Date set: 10.01.2011	**Resources:** Location	

Table 42: Final acceptance test (prototype)

9. Budget

It is specified in the contract between BUC and EAN that EAN will cover all expenses regarding the project. After receiving an early estimate from Tomas Brødreskift (TB) regarding prices this document has been set up.

All receipts and ordering bills must be retained.

For further detailed information, look at the "Economy document" which will be added later on in the project.

9.1 Organization budget

Activity name	Cost in NOK
Documentation	1500,-
Presentations	600 ,-
Transportation	1750,-
Grand Total	**3850,-**

Table 43: Organization budget

9.1.1 Documentation

There will be expenses for materials in all documentation written in this project. Such as binders, separators, the CS-23 document etc. EAN have told us that they can print out the CS-23 document since this is a big file and it takes some time to print out.

9.1.2 Presentations

There will be three presentations during the life time of this project. At each presentation there will be serving of beverages and small snacks, to the audience, guidance councilors and sensors.

9.1.3 Transportation

There has been made an agreement between the group and EAN that a public transportation allowance will be a bit too much for EAN. The students will therefore make an estimate on the gas used, and EAN will pay it back.

9.2 Material budget

The material budget covers all expenses regarding production of special parts, prototyping and modeling parts such as motors and actuators. This is an estimate based on information given to us from TB. The material budget will be spread over the tasks that have costs linked to it.

Material Budget	Cost in NOK
Construction	10000,-
Testing	2000,-
Grand total	**12000,-**

Table 44: Material budget

9.2.1 Construction

After it has been done research on components and special parts we need for the system, these will be ordered from suppliers/business found on the web given to us by EAN.
The construction part of this project consists of building a working prototype, therefore there will not be expenses regarding real parts in the aviation business. There will instead be expenses regarding the rapid prototyping, and this is where the majority of our costs will be.

9.2.2 Testing

In the testing part of the project we will test parts that have already been purchased. If any faults are found, new parts need to be ordered. The testing activity will run continuously with the construction and design activities.

10. Phases

10.1 Phase 1

Activity	Description	Dependence	Participants	Total time
O01	Decide on project. Organize the group. Project plan document. Vision document. Pre study and pre study report.	Decided on project, and organize group before project plan.	All group members	142
O10	Meeting with employer, discuss the assignment, requirements.		All group members	54
O07	Keep track on work hour; deliver to hour list responsible every week.		All group members	21
O11	Meeting with internal supervisor, discuss the assignment and documents to be delivered.		All group members	18
O02	List requirements, write requirement specification.		Sindre D. Flaten, Sigbjørn Gunnerød, Jeremy Marchand.	45
O03	List tests, write test specification.	O02	Sindre D. Flaten, Sigbjørn Gunnerød, Jeremy Marchand.	45
O05	First presentation 7th January. Preparation of 20 minutes presentation.		All group members	40
Total				365

Table 45: Phase 1

10.2 Phase 2

Activity	Description	Dependence	Participants	Total time (hrs)
A01	Analyze construction rules, use CS-23		Sindre. D Flaten, Rebaz Aziz	56
A02	Analyze today's constructions. Create a document with the most common solutions.		Sigbjørn Gunnerød, Sakariya Dahir	56
A03	Find out what materials can be used in full scale. Suggest materials to EAN.		Jeremy Marchand	24
O01	Further organization of the project, update project plan.		Sindre D. Flaten, Stein Erik Thoen, Rebaz Aziz	42
O02	Create more requirements and update the requirements specification.	A01 (Analyzing construction rules)	Jeremy Marchand, Rebaz Aziz	42
O03	Create test for new requirements, update test specification	O02 (Requirements)	Sigbjørn Gunnerød, Jeremy Marchand	42
O04	Come up with ideas for design of the product.		All group members	84
O05	2nd presentation. Create presentation and organize.		All group members	42
O06	Weekly update of the website with news and information on the progress of the project.		Sindre D. Flaten	4
O07	Weekly keep track of hours worked on the project. Update time sheets.		All group members	30

O08	Perform a risk analysis, create a risk document.		Jeremy Marchand, Stein Erik Thoen	56
O09	Keep track of the economics of the project.		Sakariya Dahir	21
O10	Monthly meeting with employer, supervisor/sensor.		All group members	36
O11	Weekly meeting with internal supervisor.		All group members	66
O12	Weekly track the progress of the project. What have been done, and what should be done.		All group members	33
A06	Learn software to be used in the project. Software: Orcad		Sindre D. Flaten, Stein Erik Thoen, Sigbjørn Gunnerød	42
M01 – 1	First iteration, initial mechanical design for front gear.	O04	All group members	63
M02 – 1	First iteration, initial mechanical design for rear gear.	O04	All group members	63
E01	Decide on which electrical circuit type to use.		Sindre D. Flaten, Stein Erik Thoen, Sigbjørn Gunnerød	42
E02	Calculate the electrical components to find appropriate component to use.		Sindre D. Flaten, Stein Erik Thoen, Sigbjørn Gunnerød	24
E03 – 1	First iteration, initial electronic construction.		Sindre D. Flaten, Stein Erik Thoen, Sigbjørn Gunnerød	30
E04 – 1	First iteration, simulate initial electronic circuit.	E03 – 1	Sindre D. Flaten, Stein Erik Thoen, Sigbjørn Gunnerød	6
M01 – 2	Second iteration, mechanical design for front gear.	M01 – 1	Jeremy Marchand, Rebaz Aziz, Sakariya Dahir	42
M02 – 2	Second iteration, mechanical design for rear gear.	M02 – 1	Jeremy Marchand, Rebaz Aziz, Sakariya Dahir	42
E03 – 2	Second iteration, electronic construction.	E03 – 1	Sindre D. Flaten, Stein Erik Thoen, Sigbjørn Gunnerød	36

E04 – 2	Second iteration. Simulate the electronic circuit.	E04 – 1, E03 – 2	Sindre D. Flaten, Stein Erik Thoen, Sigbjørn Gunnerød	6
M01 – 3	Third iteration, mechanical design for front gear.	M01 – 2	Jeremy Marchand, Rebaz Aziz, Sakariya Dahir	21
M02 – 3	Third iteration, mechanical design for rear gear.	M02 – 2	Jeremy Marchand, Rebaz Aziz, Sakariya Dahir	21
E03 – 3	Third iteration, electronic construction.	E03 – 2	Sindre D. Flaten, Stein Erik Thoen, Sigbjørn Gunnerød	36
E04 – 3	Third iteration. Simulate the electronic circuit.	E04 – 2, E03 – 3	Sindre D. Flaten, Stein Erik Thoen, Sigbjørn Gunnerød	6
M01 – 4	Fourth iteration, mechanical design for front gear.	M01 – 3	Jeremy Marchand, Rebaz Aziz, Sakariya Dahir	15
M02 – 4	Fourth iteration, mechanical design for rear gear.	M02 – 3	Jeremy Marchand, Rebaz Aziz, Sakariya Dahir	15
E03 – 4	Fourth iteration, electronic construction.	E03 – 3	Sindre D. Flaten, Stein Erik Thoen, Sigbjørn Gunnerød	36
E04 – 4	Fourth iteration. Simulate the electronic circuit.	E04 – 3, E04 – 4	Sindre D. Flaten, Stein Erik Thoen, Sigbjørn Gunnerød	6
M01 – 5	Fifth iteration, mechanical design for front gear.	M01 – 4	Jeremy Marchand, Rebaz Aziz, Sakariya Dahir	21
M02 – 5	Fifth iteration, mechanical design for rear gear.	M02 – 4	Jeremy Marchand, Rebaz Aziz, Sakariya Dahir	21
V01	Testing of mechanical components.	M01, M02	Jeremy Marchand, Rebaz Aziz, Sakariya Dahir	21
V03	Calculation of strength on front gear.	M01	Jeremy Marchand, Rebaz Aziz, Sakariya Dahir	9
V04	Calculation of strength on rear gear.	M02	Jeremy Marchand, Rebaz Aziz, Sakariya Dahir	9
V05	Testing of electronic components.	E03, E04	Sindre D. Flaten, Stein Erik Thoen, Sigbjørn Gunnerød	24
A04	Research on electronic components we can use.		Sigbjørn Gunnerød	6

A05	Emergency system analysis.	A02	Sindre D. Flaten, Sigbjørn Gunnerød	15
M05	Design of emergency operation.	A05	Sindre D. Flaten, Stein Erik Thoen	30
O13	Create an installation and maintenance guide for the system	Mechanical and electrical systems are finished	Sindre D. Flaten	15
Total				1357

Table 46: Phase 2

10.3 Phase 3

Activity	Description	Dependence	Participants	Total time (hrs)
E05	Order all components to be used in the prototype.	E03, E04, A04	Sindre D. Flaten, Stein Erik Thoen, Sigbjørn Gunnerød	6
O09	Keep track of the economics of the project.		Sakariya Dahir	14
O10	Monthly meeting with employer, supervisor/sensor.		All group members	54
O11	Weekly meeting with internal supervisor.		All group members	36
O12	Weekly track the progress of the project. What have been done, and what should be done.		All group members	18
O13	Create an installation and maintenance guide while assembling the prototype.			60
V02	Testing the mechanical system/interfaces.		Jeremy Marchand, Rebaz Aziz	32
V05	Testing the components ordered.		Sindre D. Flaten, Stein Erik Thoen	16
V06	Testing the ordered components in the system prototype.		Sindre D. Flaten, Sigbjørn Gunnerød	32
V01	Testing of mechanical components.	M01, M02	Sakariya Dahir, Rebaz Aziz	16
M06	Implement the designed emergency operation.	A05, M05	Sindre D. Flaten, Sakariya Dahir	28
V07	Test the whole system on the scaled down prototype. Last verification before finished prototype.	Whole system finished.	Sigbjørn Gunnerød, Jeremy Marchand, Stein Erik Thoen	63
O05	Final presentation. Create presentation and organize.		All group members	84

O06	Weekly update of the website with news and information on the progress of the project.		Sindre D. Flaten	3
O07	Weekly keep track of hours worked on the project. Update time sheets.		All group members	18
M03	Assemble the front gear on the physical model. Mechanical part.	M01	Jeremy Marchand, Rebaz Aziz, Sakariya Dahir	63
M04	Assemble the rear gear on the physical model. Mechanical part.	M02	Jeremy Marchand, Rebaz Aziz, Sakariya Dahir	63
E06	Implement the electrical system info the front gear.	E05, E03	Sindre D. Flaten, Stein Erik Thoen, Sigbjørn Gunnerød	84
E07	Implement the electrical system info the rear gear.	E05, E03	Sindre D. Flaten, Stein Erik Thoen, Sigbjørn Gunnerød	84
O01	Further organization of the project. Ex-post evaluation.		All group members	102
A03	Suggest materials and manufacturers that EAN can use in full scale model.		Jeremy Marchand, Rebaz Aziz, Sakariya Dahir	56
Total				932

Table 47: Phase 3

11. Gantt-Chart

The Gantt-chart has been made using Microsoft Project.

This file is appendix 1. The new Gantt-Chart for phase 3 that starts after the second presentation is appendix 2. The reason for updating the Gantt-Chart is because we now know more certain what needs to be done to finish the project.

References

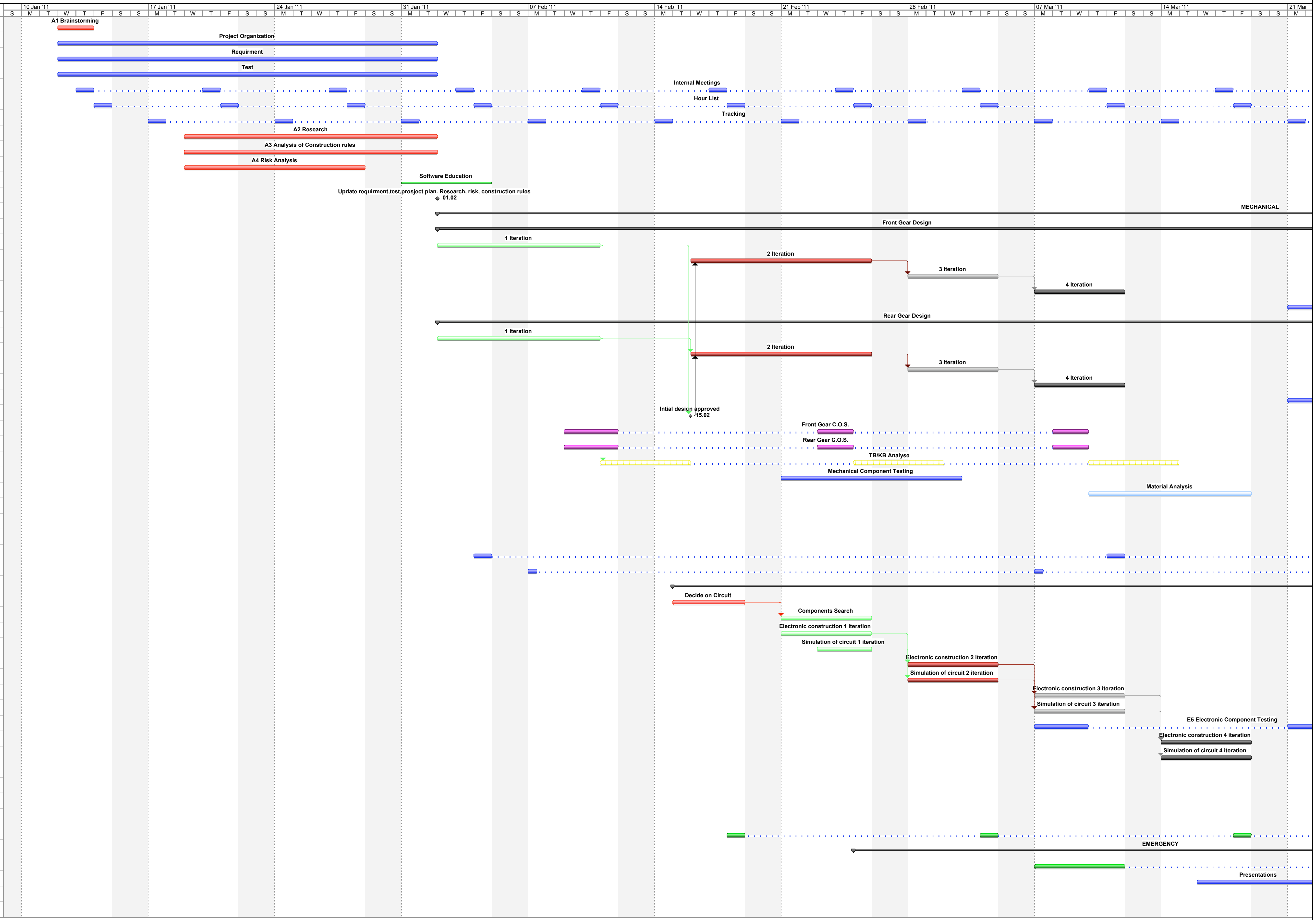
Literature

Harald Westhagen. Prosjektledelse, utvikling og endringskompetanse. ISBN 978-82-05-30539-7.

Prosjekthåndbok, Høgskolen I Buskerud, Torbjørn Strøm & Olaf Hallan Graven, Avdeling for teknologi, 2010

APPENDIX 1: PROJECT PLAN

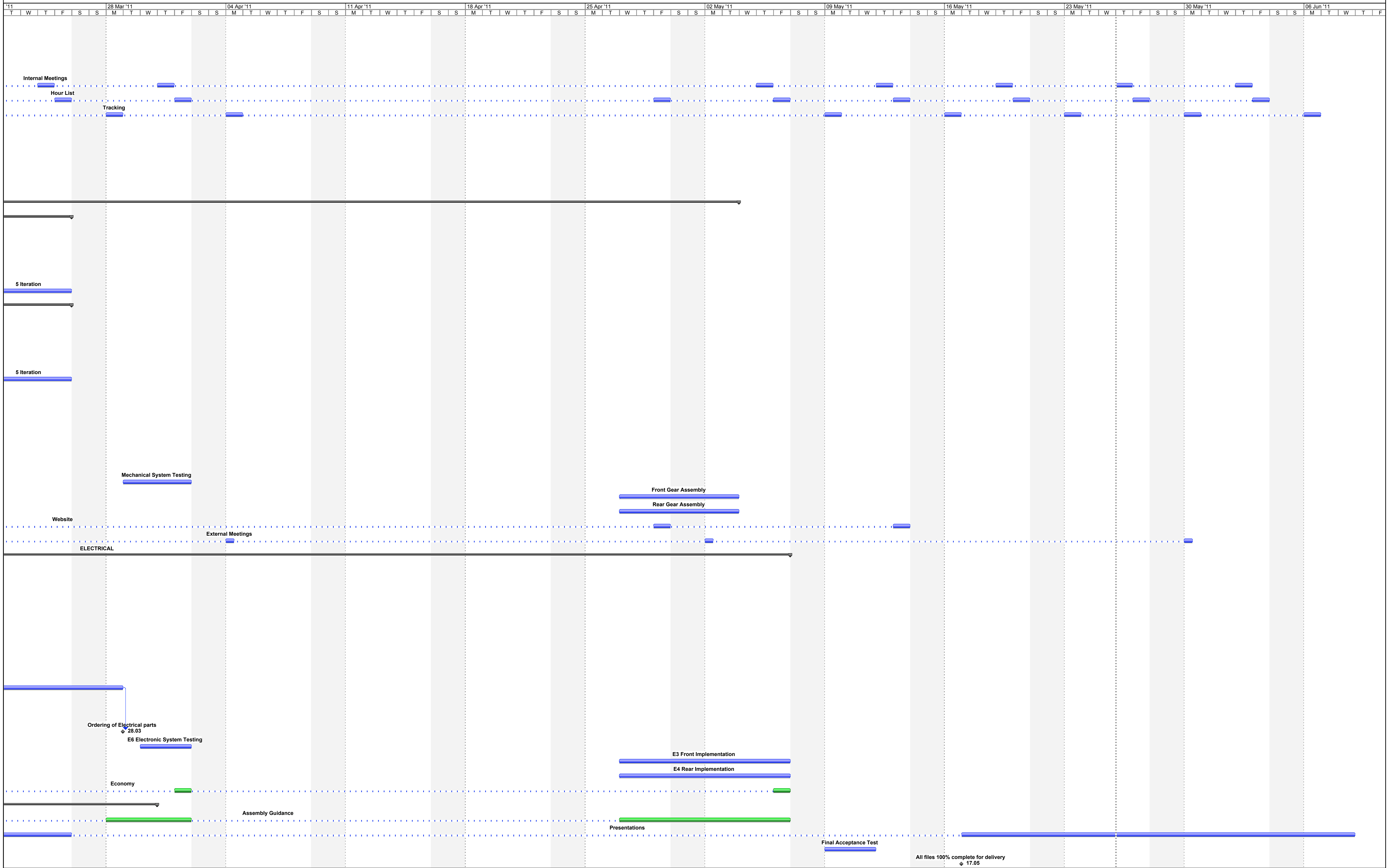
ID	Task Name
1	A1 Brainstorming
57	Project Organization
60	Requirment
61	Test
56	Internal Meetings
59	Hour List
58	Tracking
2	A2 Research
3	A3 Analysis of Construction rules
4	A4 Risk Analysis
6	Software Education
5	Update requirment,test,prosject plan. Research, risk, construction rules
23	**MECHANICAL**
24	**Front Gear Design**
25	1 Iteration
26	2 Iteration
27	3 Iteration
28	4 Iteration
29	5 Iteration
30	**Rear Gear Design**
31	1 Iteration
32	2 Iteration
33	3 Iteration
34	4 Iteration
35	5 Iteration
36	Intial design approved
40	Front Gear C.O.S.
41	Rear Gear C.O.S.
37	TB/KB Analyse
43	Mechanical Component Testing
42	Material Analysis
44	Mechanical System Testing
38	Front Gear Assembly
39	Rear Gear Assembly
54	Website
55	External Meetings
7	**ELECTRICAL**
8	Decide on Circuit
9	Components Search
10	Electronic construction 1 iteration
11	Simulation of circuit 1 iteration
12	Electronic construction 2 iteration
13	Simulation of circuit 2 iteration
14	Electronic construction 3 iteration
15	Simulation of circuit 3 iteration
19	E5 Electronic Component Testing
16	Electronic construction 4 iteration
17	Simulation of circuit 4 iteration
18	Ordering of Electrical parts
22	E6 Electronic System Testing
20	E3 Front Implementation
21	E4 Rear Implementation
53	Economy
46	**EMERGENCY**
45	Assembly Guidance
52	Presentations
50	Final Acceptance Test
51	All files 100% complete for delivery



Project: Revidert plan
Date: Thu 26.05.11

Task	Milestone	Rolled Up Task	Rolled Up Progress	External Tasks	Group By Summary
Progress	Summary	Rolled Up Milestone	Split	Project Summary	Deadline

APPENDIX 1: PROJECT PLAN

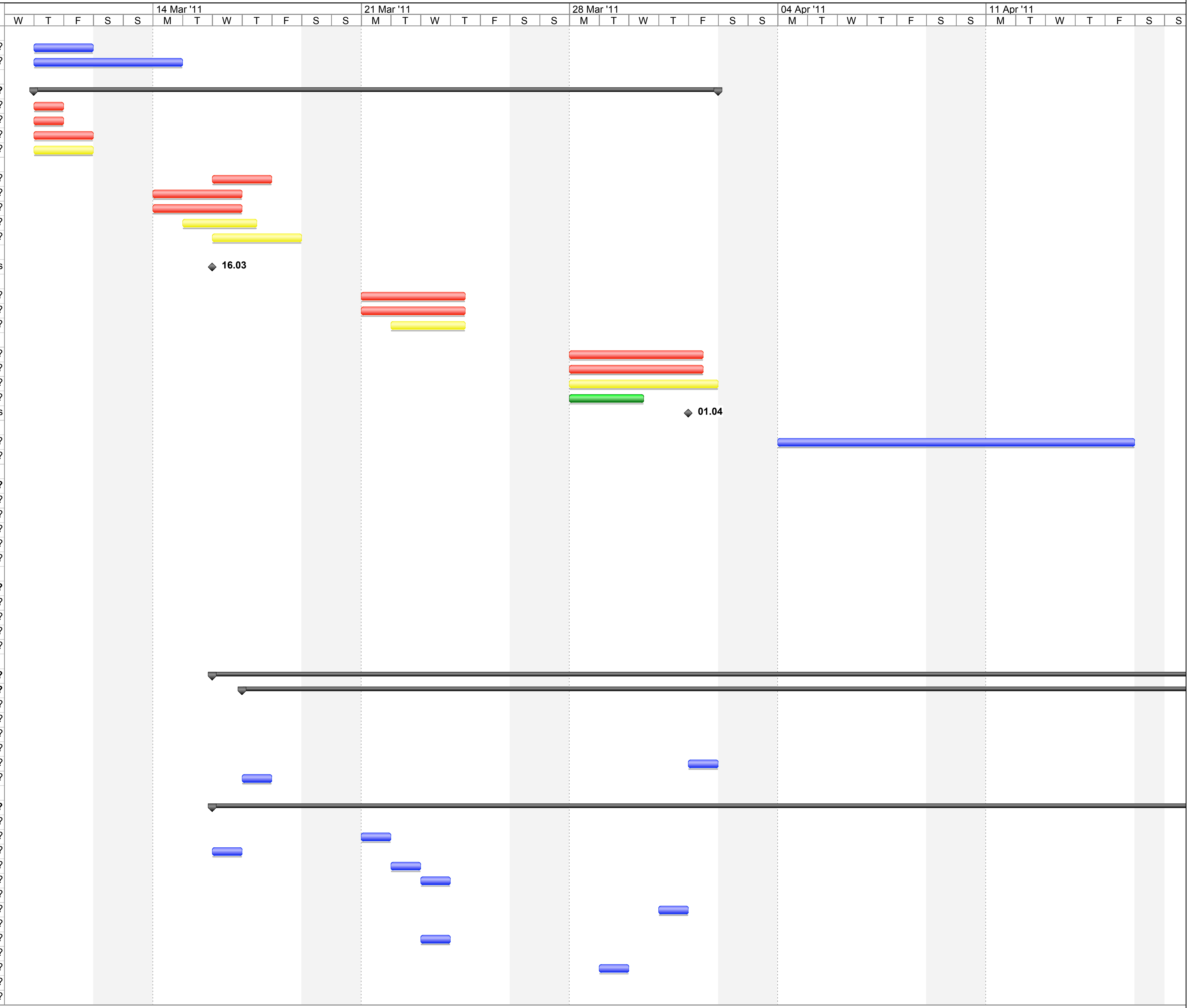


Project: Revidert plan
Date: Thu 26.05.11

Task	Milestone	Rolled Up Task	Rolled Up Progress	External Tasks	Group By Summary
Progress	Summary	Rolled Up Milestone	Split	Project Summary	Deadline

APPENIX 2: PROJECT PLAN REVISED

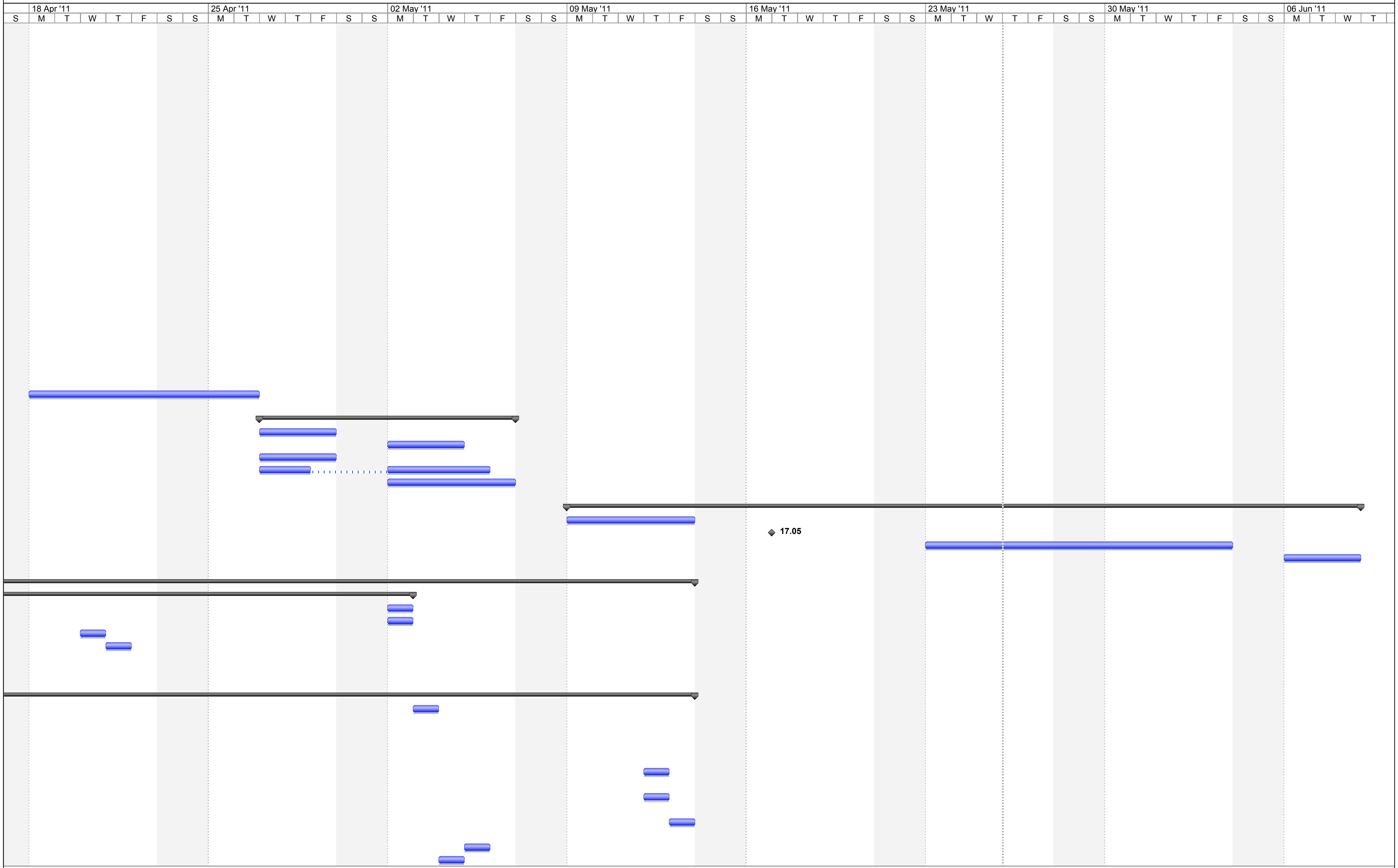
ID	Task Name	Duration
1		
2	Update projectplan	2 days?
3	Make test plan	3 days?
4		
5	**Construction Iteration**	**17 days?**
6	Calculate forces acting on system during landing	1 day?
7	calculate center of gravity (C.G.)	1 day?
8	Make schech with attacment points and length on arms	2 days?
9	Look up sensors and actuators	2 days?
10		
11	Calculate forces on each member/arm	2 days?
12	Design front RG	3 days?
13	Design rear RG	3 days?
14	Find components for prototype	2,5 days?
15	Circiut layout	3 days?
16		
17	MÅ BESTEMME DATO FOR 2 PRESENTASJON	0 days
18		
19	Design front RG	3,5 days?
20	Design rear RG	3,5 days?
21	Circiut layout	2,5 days?
22		
23	Designe front RG	4,5 days?
24	Designe rear RG	4,5 days?
25	Develop el. System	5 days?
26	choose parts for prototype	2,5 days?
27	Order parts for Prototype	0 days
28		
29	Eksamen	10 days?
30	Påske	7 days?
31		
32	**Transition 1**	**8 days?**
33	Detailing of RG design	3 days?
34	Assembly of mockup prototype	3 days?
35	Assemble the electrical circuit	3 days?
36	Assembly guidance	6 days?
37	Material analysis	5 days?
38		
39	**Transition 2**	**23 days?**
40	Finalize documents	5 days?
41	final hand in date	0 days?
42	Presentation Prep.	10 days?
43	Final presentation	3 days?
44		
45	**Test**	**43 days?**
46	**COMPONENTS TEST**	**33 days?**
47	TC02	1 day?
48	TC03	1 day?
49	TC04	1 day?
50	TC05	1 day?
51	TC06	1 day?
52	TC07	1 day?
53		
54	**SYSTEMS TEST**	**43 days?**
55	TS01	1 day?
56	TS02	1 day?
57	TS03	1 day?
58	TS05 (RG front)	1 day?
59	TS07	1 day?
60	TS08	1 day?
61	TS10	1 day?
62	TS14	1 day?
63	TS17	1 day?
64	TS19	1 day?
65	TS21	1 day?
66	TS23	1 day?
67	TS24	1 day?



Project: Prosjektplan revidert 10.03. v
Date: Thu 26.05.11

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

APPENIX 2: PROJECT PLAN REVISED



Project: Prosjektplan revidert 10.03. v
Date: Thu 26.05.11

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

APPENDIX 3:
INITIAL ITERATION PLAN

Name of iteration	Date from:	Date to:
Initial	13.09.2010	07.01.2011

Description of iteration	This iteration is the initial establishment iteration of the project. During this iteration all of the collaboration channels with the employer will be established. The group will establish a foundation of the assignment, and an overview of the product to be developed during the project.
Purpose of the iteration	The purpose of this iteration is to give all participants of the project a common understanding of the assignment. At the end of this iteration the group is to make a presentation that gives all other interested in the project an introduction to what the group is to develop.
Activities during iteration	The activities listed in this iteration will be: - Establishment of collaboration channels - Understanding of the assignment - Various documents: Vision document Requirement specification Project plan Test specification - Presentation 1

APPENDIX 4:
INITIAL ITERATION REPORT

Name of iteration	Date from:	Date to:
Initial	13.09.2010	07.01.2011

How it was conducted	The iteration was conducted according to the iteration plan.
What was carried out	All cooperative channels are established. The documents listed in the iteration plan are I place.
What must be carried out	After feedback from EAN and internal guidance councilor, some of the documents that were in place for the first presentation still remains some work. One of these documents is the requirement specification. Were EAN wanted us to add some use cases, in order for us to get an overview of the functional requirements.
Conclusions made during the iteration	The project group and EAN have agreed on not using openAE, which is one of the collaboration channels.

APPENDIX 5:
ELABORATION ITERATION PLAN

Name of iteration	Date from:	Date to:
Elaboration	08.01.2011	17.02.2011

Description of iteration	This iteration will begin with a brainstorming activity, to sort of establish the starting point of the solution solving part of the project. Afterwards the group members will be given assignments to work on, and produce/update documents involved their assignment.
Purpose of the iteration	The purpose of this iteration is to give the participants (group members) a deeper understanding on the requirements and problems involving development of our product. This iteration is also meant to be the kick off on the problem solving part of the project.
Activities during iteration	Activities during this iteration are: - CS-23 analysis - Risk analysis - Brainstorming - Analysis of current designs and products/solutions - Take a look at possible solutions on our assignment The CS-23 analysis will result in an update of the requirement document.

APPENDIX 6:
ELABORATION ITERATION REPORT

Name of iteration	Date from:	Date to:
Elaboration	08.01.2011	17.02.2011

How it was conducted	The iteration was conducted according to the iteration plan.
What was carried out	The brainstorming activity was used to get an overview of the ideas and possible solutions that each member had pictured for themselves. Furthermore an analysis on solutions used on airplanes was run through. And we started looking at how some of these solutions could be implemented to our problem. The documents that was planned to be either updated or started on during the iteration, was started.
What must be carried out	The use cases in the requirement specification are still not complete.
Conclusions made during the iteration	In agreement with EAN we have chosen to allow the work on the use cases to be performed into the next phase, this is because EAN want us to use the use case method for what it's worth. And they believe it will give them an advantage in further development of the retractable gear and perhaps other parts of the eqp2 excursion.

APPENDIX 7:
DESIGN ANALYSIS AND CONSTRUCTION ITERATION PLAN

Name of iteration	Date from:	Date to:
Design analysis and Construction	18.02.2011	01.04.2011

Description of iteration	The group will work with choosing design, and construct/develop the product. At the end of this iteration the final design will be shipped to EAN, where they will through cooperatives will produce our product in plastic (rapid prototype), so that we can in the final phase can assemble the physical product.
Purpose of the iteration	The purpose of this iteration is to come up with design solutions, and to choose one design to develop, in consensus with EAN. When design has been chosen the group will work with the development of the product, until the ordering date.
Activities during iteration	Activities during this iteration are: - Make initial design proposals - Choosing of design - Design/Develop (Electrical/Mechanical) - Test - Ordering of parts

APPENDIX 8:
DESIGN ANALYSIS AND CONSTRUCTION ITERATION REPORT

Name of iteration	Date from:	Date to:
Design analysis and Construction	18.02.2011	01.04.2011

How it was conducted	The design part of this iteration took longer time than estimated. We had a design day with EAN were the group came together with TB and some of their cooperatives to make a couple of designs to work on. The group afterwards made some simple designs of the ideas and looked at what worked and what didn't.
What was carried out	There was made analysis on which solution that suits our project best. The final solution was chosen, and we went on with developing it.
What must be carried out	Calculations on each member of the RG (front and back) remains. There are test that remains also, that hasn't been conducted because the development part of the project still remain some work.
Conclusions made during the iteration	

APPENDIX 9:
CONSTRUCTION ITERATION PLAN

Name of iteration	Date from:	Date to:
Construction	15.03.2011	26.04.2011

The Project plan has been updated, and we can now from the progress see that we are falling behind with certain assignments. That is why phase 2 now has been divided into a third iteration named construction. This is a result of the previous iteration (choosing design) took longer time than estimated. As the group now in consensus with EAN has chosen a final design, we can put focus on developing/producing the product.

Description of iteration	The group will now separate into mechanical and electrical groups and put focus on developing the product. We will calculate the forces acting on the system, and start designing and choose the layout on the electrical system. The product will be tested continuously, and the test that we won't be able to perform before shipping, will be taken afterwards. These will not have any influence on the concept of the product.
Purpose of the iteration	The purpose of this iteration is to design and develop our product as far as practicable, before the shipping date.
Activities during iteration	Activities during this iteration are: - Calculations - Development - Design - Implementation - Test - Ordering of parts

APPENDIX 10:
CONSTRUCTION ITERATION REPORT

Name of iteration	Date from:	Date to:
Construction	15.03.2011	26.04.2011

How it was conducted	The phase was conducted according to the new updated project plan. The project group separated and started to concentrate on the tasks they were given.
What was carried out	The design and development of the system was started. The mechanical students started designing in solid works, and used their time on this. The mechatronic students started developing the electrical circuits, and looked at how the system may be actuated. Calculations on mechanical and electrical parts of the project were performed.
What must be carried out	There is still remaining calculations on single parts of the mechanical solution. Some test are still not been conducted, because of the progress of the project.
Conclusions made during the iteration	

APPENDIX 11:
FINALIZE DESIGN ITERATION PLAN

Name of iteration	Date from:	Date to:
Finalize design	27.04.2011	06.05.2011

Description of iteration	This iteration is the start of the ending of the project. During this iteration all test and design will be ended. The physical product will be assembled and the tests that require a physical product will be performed.
Purpose of the iteration	The purpose of this iteration is to get the product assembled electrically and mechanically, and finalize the product as far as practicable.
Activities during iteration	Activities during this iteration are: - Detailing of RG in Software - Assemble of mockup prototype - Assemble of electrical circuit - Material analysis - Assembly guidance - Test

APPENDIX 12:
FINALIZE DESIGN ITERATION REPORT

Name of iteration	Date from:	Date to:
Finalize design	27.04.2011	20.05.2011

How it was conducted	This iteration was conducted by allowing everyone in the group to concentrate on their tasks, to manage to meet the deadline set.
What was carried out	The tasks that was carried out through this iterations was: • Finalize design (front/back) • Test • Assembly of electrical circuit • Prototype was assembled • Material analysis
What must be carried out	There is still some test that has to be performed.
Conclusions made during the iteration	We had originally some plans to perform a FMECA analysis on our design. But as the work on the project was performed after the second presentation, we realized that we didn't have sufficient time to perform an analysis of this manner. The activities took longer time than estimated, therefore the initial plan of being done by the may 6, was pushed back by one week. Therefore the last iteration will be started after may 17.

APPENDIX 13:
FINAL WORK ITERATION PLAN

Name of iteration	Date from:	Date to:
Final work	09.05.2011	09.06.2011

Description of iteration	This is the final work on the project, all design and development work must before this iteration be ended. And all documents are to be handed inn by the hand inn date set by the group. At the end of this iteration, the final presentation will be held.
Purpose of the iteration	The purpose of this iteration is to end the project. All documents that are to be handed inn must be finalized, and checked. After hand in date, the time will be used on preparation for the final presentation.
Activities during iteration	Activities during this iteration are: - Finalize documents - Hand in date (milestone) - Preparation of final presentation - 3 presentation

APPENDIX 14:
FINAL WORK ITERATION REPORT

Name of iteration	Date from:	Date to:
Final work	20.05.2011	07.06.2011

How it was conducted	This iteration was performed through every participant in the group getting a document to focus on. In that way we could work effectively and be sure that all documents are complete until hand in date.
What was carried out	All documents were read through and completed before shipped off to printing.
What must be carried out	Poster and presentation is left to be done after hand in date of all documents.
Conclusions made during the iteration	In agreement with our employee we agreed to not publish any document in an open accesses area. This is because our employee doesn’t want to risk the design being stolen from other companies, before they can take out a patent on the design and solution.

EQUATOR AIRCRAFT

BUSKEREUD University College

Risk Document

aRGie
Retractable Gear Development Study

Buskerud University College, Department of Engineering Institute of Technology

Equator Aircraft Norway SA

Document responsible: Stein Erik Thoen
Version 1.0
Date: 20.04.11

Internal guidance councilor: Øyvind Eek-Jensen

Rebaz Aziz	Jeremy Marchand	Stein Erik Thoen
Sindre D. Flaten	Sigbjørn Gunnerød	Sakariya H. Dahir

Abstract

In this document we have gathered all the risk factors which may occur in the project. We have calculated which factors will harm the ongoing project, and which who can easily be solved. The factors with the highest probability will have to be those easiest to get through. The one with lowest probability can delay or change the project, but we have explained how we will handle it in this document.
The probability and severity numbers are only an estimate and can be revised during the project.

Sammendrag

I dette dokumentet har vi samlet alle risikofaktorene som kan oppstå i prosjektet. Vi har kalkulert hvilke faktorer som vil skade prosjektets gang, og hvilke som enkelt kan løses. De faktorer som har størst sannsynlighet vil måtte være de som vi kan klare oss gjennom. De med liten sannsynlighet vil kunne forsinke eller endre prosjektet, men vi har forklart hvordan vi skal takle det i dette dokumentet.
Sannsynlighet og konsekvens tallene er kun estimater og kan bli revidert under prosjektets gang.

Document history

Version	Date	Responsible	Changing
0.1	19.01.2011	Stein Erik Thoen	
0.2	20.01.2011	Jeremy Marchand, Stein Erik Thoen	• Risk factors R08 – R13 • Risk calculation • Risk factor diagram
0.3	20.01.2011	Stein Erik Thoen	• Changed abstract • Spelling
1.0	20.04.2011	Stein Erik Thoen	

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List of Tables

1. Introduction

This risk analysis document will include all risk factors and the probability and severity if the risk occurs. It also includes what can be done to prevent the risk factors and what solutions we have.
We made a risk analysis to know what factors are most likely to occur, and which are least possible.

2. List of risks

2.1 Risk analysis

To analyze and calculate the different risks we have discussed, in the group what kind of risk factors we have during the project. We have set the probability of the factor between 0 and 100 % (0.0 – 1.0). The severity have been set between 0 (not hard to get through) and 100 (cannot get the assignment finish). These numbers have been multiplied to get a calculated risk. The factors with the highest calculated risk have high probability and high severity; these factors are the worst if should occur.

2.2 Risk factors

We have listed all risk factors in tables which state a description of the factor, the cause for the factor, what we can do to prevent it from happen and a solution if it does happen. The factors has also been given a identification number to be used if made reference to in other documents.

ID	Name
R01	Illness
R02	Conflict between group members
R03	Attendance
R04	Misunderstanding of the assignment
R05	Defect components
R06	New requirements
R07	Loss of data
R08	Project is to large
R09	Delivery times
R10	Requirements not met
R11	Software fail
R12	Behind schedule

Table 1: Risk factors

Risk name: Illness		**ID:** R01
Description: One or more person(s) of the project group are ill over a long period of time. Internal/external supervisors are ill and cannot supervise the group. The severity depends on if there are many people sick.		
Probability: 0,7	**Severity:** 20	**Calculated risk:** 14
Cause: Get sick from food, environment, etc.		
Prevention: Keep in good health.		
Solution: Distribute tasks on the remaining group members and make sure the person(s) sick know what is being done.		

Table 2: Illness

Risk name: Conflict between group members		**ID:** R02
Description: Disagreement between group members that lead to a conflict.		
Probability: 0.2	**Severity:** 30	**Calculated risk:** 6
Cause: Different ideas/views on problems and solutions.		
Prevention: Make sure the group agrees on decisions made.		
Solution: Talk together and explain why there are disagreements and how to solve them. Prioritize on this if there are any conflicts.		

Table 3: Conflict between group members

Risk name: Attendance		**ID:** R03
Description: One or more of the group members does not attend in the project group.		
Probability: 0.1	**Severity:** 40	**Calculated risk:** 4
Cause: A person may not feel included in the group, or be late for work every day.		
Prevention: Keep a good working environment in the group. Penalize for showing up late.		
Solution: Talk together and get an explanation on why the person(s) not want to include. Talk with internal supervisor.		

Table 4: Attendance

Risk name: Misunderstanding of the assignment.		**ID:** R04
Description: The group misunderstand the assignment and ends up with something else than the employer wanted.		
Probability: 0.1	**Severity:** 80	**Calculated risk:** 8
Cause: The group does not get the necessary information on the assignment. The group does not ask questions to get clarity on what we should do.		
Prevention: Keep god contact with employer and keep them updated on what is being done in the project.		
Solution: Sit down and talk with the employer, it is necessary to get to an agreement.		

Table 5: Misunderstanding the assignment

Risk name: Defect components		**ID:** R05
Description: Components not working properly.		
Probability: 0.4	**Severity:** 40	**Calculated risk:** 16
Cause: Components can be damaged on transport or under assembly.		
Prevention: Make sure to handle delicate components with care. Order spare components of the one most likely to become defect.		
Solution: If we have spare parts there should be no problem, if not we need to order new components and maybe extent the work period.		

Table 6: Defect components

Risk name: New requirements		**ID:** R06
Description: The assignment is given new requirements late in the project.		
Probability: 0.6	**Severity:** 20	**Calculated risk:** 12
Cause: We have not included all the requirements. This can be because we have not done sufficient research.		
Prevention: Set detailed requirements before the design phase start. Make sure our employer knows all our requirements.		
Solution: Talk with employer and get to know how important the requirements are, implement if possible. If not possible, explain in documents why it is not implemented.		

Table 7: New requirements

Risk name: Loss of data		**ID:** R07
Description: Computer crash which results in loss of project files.		
Probability: 0.1	**Severity:** 80	**Calculated risk:** 8
Cause: Data can be lost if computer is damaged or crashes, and the data is only locally on the computer's hard drive.		
Prevention: All documentation is backed up on internet, on a private web space only for group members.		
Solution: If data is lost and cannot be retrieved, it is important to let supervisors and sensors know about this and minimize the damage as soon as possible.		

Table 8: Loss of data

Risk name: Project is too large		**ID:** R08
Description: The project shows itself too be too large and not completed by the final deadline.		
Probability: 0,3	**Severity:** 60	**Calculated risk:** 18
Cause: Technical solutions involving creation of new technologies. Too much iteration as a result of too many requirements.		
Prevention: Set up requirements and goals that are realistic to fulfill, not too optimistic. Respect the milestones we have set in the project plan.		
Solution: Find a compromise with the employers, lowering the amount of tasks and requirements in the project.		

Table 9: Project is too large

Risk name: Delivery times		**ID:** R09
Description: Excessive or delayed delivery time of components, which can result in incompletion of the project by the final deadline.		
Probability: 0.3	**Severity:** 30	**Calculated risk:** 9
Cause: Ordering parts from distant countries. Ordering parts that are not in stock or not yet developed. The company which we order from goes bankrupt. Post strike, air traffic blocked (volcano in Island, terror action…)		
Prevention: Order parts in advance considering a margin of error. Order parts from Norway or Europe. Order storage parts. Perform a test delivery and measure delivery time.		
Solution: Work harder once the parts are delivered, also in the weekends. If the final deadline still is not reachable, extend the final deadline for the project.		

Table 10: Delivery times

Risk name: Requirements not met		**ID:** R10
Description: One or more requirements are not met.		
Probability: 0.2	**Severity:** 30	**Calculated risk:** 6
Cause: Requirement cannot be fulfilled with today's technology.		
Prevention: Set up requirements and goals that are realistic to fulfill, not too optimistic.		
Solution: Agree with the employer to change the requirement(s).		

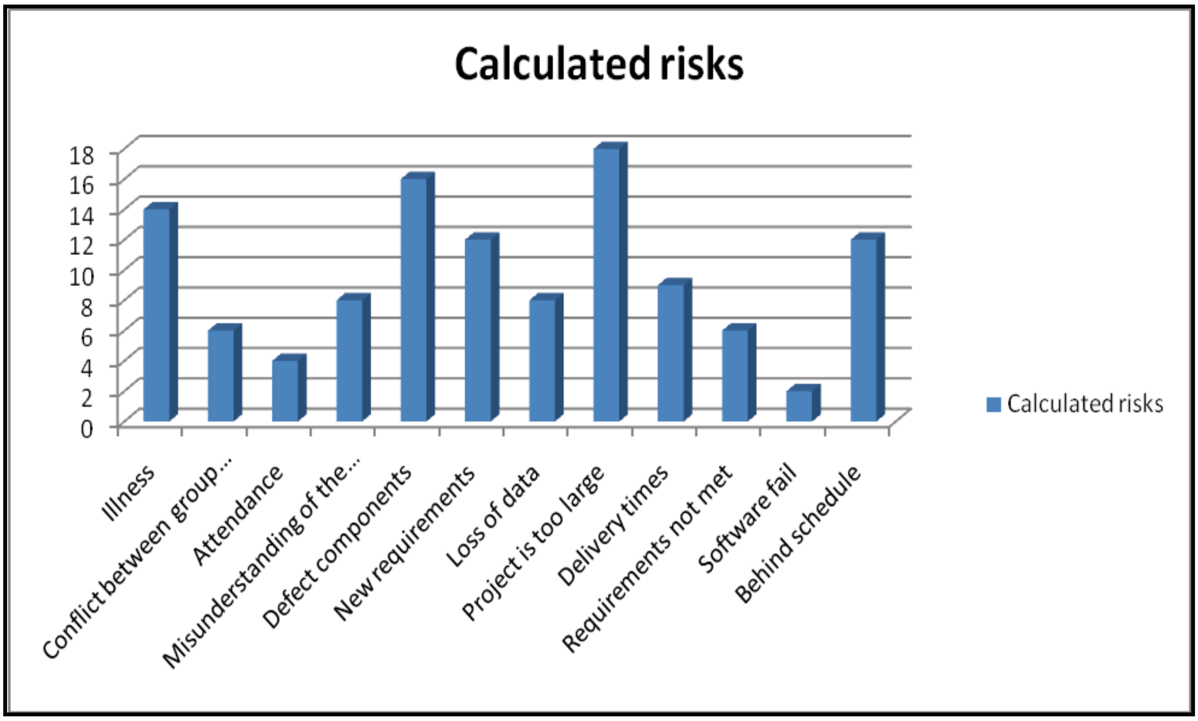
Table 11: Requirements not met

Risk name: Software fail		**ID:** R11
Description: Software is not functioning properly.		
Probability: 0.2	**Severity:** 10	**Calculated risk:** 2
Cause: Installations fail, bad processor, graphic card…		
Prevention: Use the school's PC, follow the installation instructions.		
Solution: Reinstall the software or use another PC.		

Table 12: Software fail

Risk name: Behind schedule		**ID:** R12
Description: Difficulties to follow the project plan, being several weeks behind schedule.		
Probability: 0.6	**Severity:** 20	**Calculated risk:** 12
Cause: Lack of follow-up between work done and expected work.		
Prevention: Weekly follow-ups.		
Solution: Catch up by working harder and in weekends.		

Table 13: Behind schedule



This diagram shows that the factor "project is too large" has the highest risk; this means that if this happens, the project group has a problem to take care of.
The factor with the lowest calculated risk is "software fail"; it has low severity because if it happens, is can easily be solved.

3. Conclusion

After this analyze of risks we know many of the possibilities we have if something unexpected happens. We have calculated a risk for the different factors and know how important they are. The different factors have been given an identification number which can be used for reference in other documents.
We found out after a risk analyze that the worst risk factor is that the project is too big and we can't get finished.

Requirement Specification

Retractable Gear Development Study

Buskerud University College, Department of Engineering Institute of Technology

Equator Aircraft Norway SA

Document responsible: Jeremy Marchand
Version 4.0
Date: 27. May 2011

Internal guidance councilor: Øyvind Eek-Jensen

Rebaz Aziz	Jeremy Marchand	Stein Erik Thoen
Sindre D. Flaten	Sigbjørn Gunnerød	Sakariya H. Dahir

Abstract

This document lists the different functionalities our system is required to do. We also express how the functional requirements will work in different concrete situations by making some use case scenarios.
Most of the requirements are set by Equator Aircraft Norway (EAN), while some are predetermined by the standards for small aircraft (CS-23). It has to be taken in consideration that the requirements might change during the project.

Sammendrag

I dette dokumentet har vi laget en liste over de forskjellige funksjonene vårt system skal gjøre. Vi forklarer også hvordan de funksjonelle kravene skal fungere i forskjellige konkrete situasjoner ved å lage flere bruker scenarioer.
De fleste kravene er satt av Equator Aircraft Norge (EAN), mens andre er forhåndsbestemte av standardene for småfly (CS-23). Det må tas i betraktning at kravene mest sannsynlig vil forandres i løpet av prosjektet.

Document history

Version	Date	Responsible	Changing
0.1	17.12.10	Sindre D. Flaten, Sigbjørn Gunnerød, Jeremy Marchand	First version
0.2	20.12.10	Sigbjørn Gunnerød	• Requirement list added • Changed the order of Use case and Requirements • Formatting headings
0.3	20.12.10	Jeremy Marchand	Added the abstract
1.0	20.12.10	Sigbjørn Gunnerød	
1.1	03.01.11	Sindre D. Flaten	• Changed “retractable gear” to the abbreviation RG in requirements C01A and C02A • Spelling in abstract • Spelling in 1.1 Classification of requirements • Spelling in 2.1.2 U02 Take off/landing - water • Related requirements F04A removed from use case U02 • Changed the word “handle” to “steer” in F010C • Changed first sentence in 2.1.3 U03 – Emergency-landing operation • Added literature reference • Changed sentences in U01 and U02
1.2	04.01.11	Sigbjørn Gunnerød	• Changed requirement C05A • Corrected the date and use case ID in the document history v.1.1
2.0	04.01.11	Sigbjørn Gunnerød	
2.1	07.01.11	Jeremy Marchand	• Inserted new requirements and use cases • Changed constrain requirements to CS23

			requirements • Deleted N01A, F04A, C07A, C08A, F01A • Changed C09B, C10B, F02A • Changed N14B to N14C, N20B to N20C, F02A to C02A • Changed logo
2.2	22.02.11	Jeremy Marchand	• Detailing of the use cases and relations to requirements
2.3	01.03.11	Jeremy Marchand	• Changed C35A to C36A, C14B to C38B, F08B to F08A • Changed definition of F16A and F08A • N14B and N15B deleted and replaced by N34A
2.4	09.03.11	Sindre D. Flaten	• Changed C02A to C38A
3.0	20.04.11	Sindre D. Flaten	
3.1	26.05.11	Sindre D. Flaten	• Changed spaces between requirements • Changed first sentence in abstract
4.0	27.05.11	Jeremy Marchand	

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List of requirements

List of figures

Definitions

Abbreviation	Extension	Description
EAN	Equator Aircraft Norway SA	Employer
EQP2	Equator P2 Excursion	The aircraft now under development by EAN
RG	Retractable Gear	
Vs_1	Stall speed	Is the stalling speed or the minimum steady flight speed obtained in a specific configuration (usually a “clean” configuration without flaps, landing gear and other sources of drag)
V_{LO}		
V		

1. Introduction

1.1 Classification of requirements

The requirement specification is a list of requirements that defines the characteristics of a system and its functions. It doesn't describe *how* we intend to implement the functions the system should be able to do. It describes *what* functions the system should be able to do.

The requirements are divided into:

1. CS-23 requirements
   - They describe the specifications the system must fulfill in order to be certified by CS-23. Analyzing CS-23 gave us many specified requirements. Therefore, we have chosen to replace the constraint requirements by the CS-23 requirements, giving us more insight and removing the nuance between the constraint and the non-functional requirements.

2. Functional requirements
   - They describe *what* the system must do.

3. Non-functional requirements.
   - They describe *how well* the system must perform its functions in matter of reliability, robustness, usability, maintainability, ergonomics etc.

Further, we have categorized these requirements into A-, B- and C-priority:

- A-priority defines the requirements that *must* be integrated into the system and are therefore the most important requirements.

- B-priority defines the requirements that *should* be integrated into the system. These requirements are not as important as A-priority.

- C-priority defines the requirements that *could* be integrated into the system. These requirements are not important and should not be given priority before all A- and B-requirements are met.

This document will be updated continuously throughout the project, since requirements can appear or have to be changed.

2. Use cases

2.1 Use case scenarios for functional requirements

We have constructed a few use case scenarios to describe how the functional requirements will work from a customer point of view. With this, we can link the functional requirements with a scenario, which is more visually descriptive.

2.2 U1: TAKE-OFF

External visual inspection

Before the pilot enters the cockpit, he inspects the retractable gear with a flashlight, checking that the mechanism is not obstructed, looking for visible cracks, damage on critical parts, loose screws, rust, ice, impurities etc. This involves that the system is easily available to maintenance and inspection.

Cockpit entrance

When the pilot has insured the RG is operational, he opens the cockpit door and takes place in the driver's seat. The entrance is situated at a proper height, so the pilot easily can get in. The aircraft remains stable as the pilot gets in. Damping is not too soft.

Engine start

The pilot starts the aircraft's engine using the control power device. Since the engine is far away from the cockpit, noise is not disturbing the pilot. He doesn't even need a headset!

Internal check before taxi

The pilot checks that there are no warning lights flashing from the alarm system, and that the indicators for the RG are correct (shows that the RG is extracted). For security reasons, the RG has a function that makes it impossible to retract when the aircraft is in contact with ground. In addition, the aircraft is equipped with sensors that indicate the weight distribution and the total weight of the aircraft.

Taxi to runway

The pilot releases the park brakes and taxis to the runway. In order to check that the brakes are functioning, he will activate the brakes one time as soon as the aircraft is in movement. The RG withstands the constant vibrations, which might occur during taxiing on rough surfaces. The dampers are not too stiff, so the pilot doesn't feel too much vibration. The aircraft turns/rotates by turning the main control stick which controls the nose gear. The pilot lines up the aircraft with the runway.

Stop

The pilot uses the power lever, to control the wheel brakes. The wheels are immobilized even when the engine power is on.

Acceleration

The pilot releases the brakes and increase power with the power lever, still using the pad, slowly advances the control pad all the way to full power. The aircraft stays steady and the nose doesn't lift up as the engine boosts.

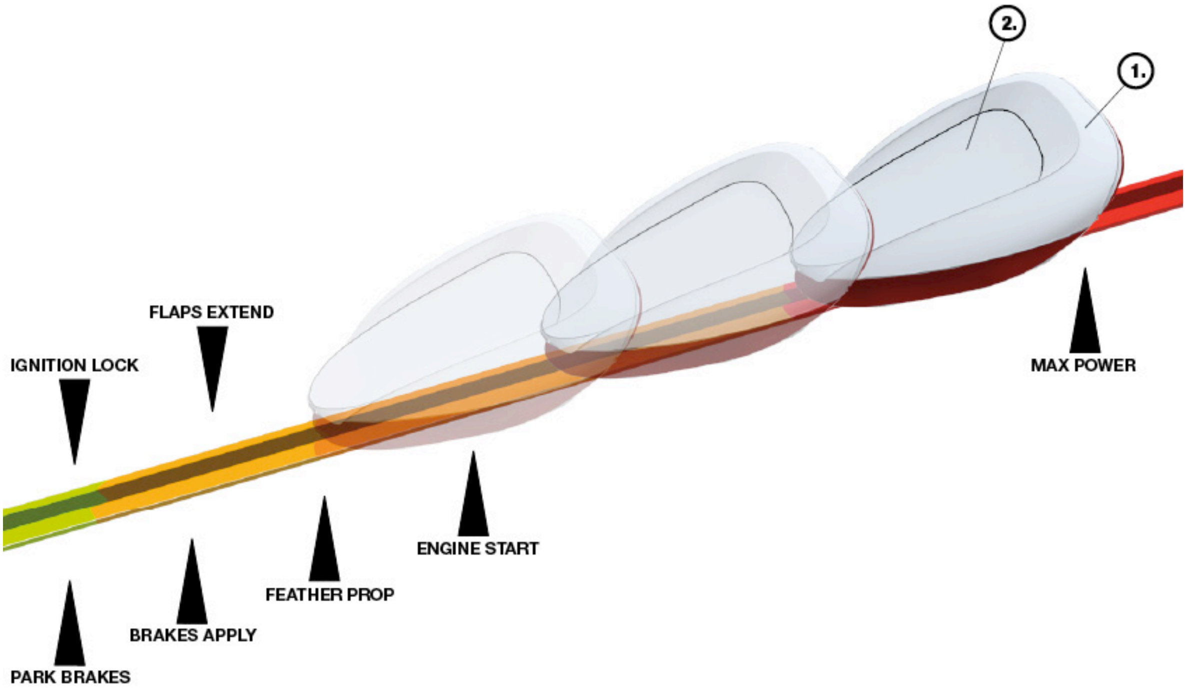

Figure 1:Second main control system concept

Check before takeoff

The pilot performs a visual check for warning lights as soon as the aircraft starts moving. The display shows that oil pressure and temperature are valid.

Start rolling

The aircraft holds course straight ahead, aligned with the centerline of the runway. In case of crosswind, the pilot adjusts the line of the aircraft by rotating the main control stick. As the velocity of the aircraft gradually increases, steering the aircraft gradually turns from front wheel steering to ruder steering. Reaching a certain speed, the front wheel locks itself in strait forward direction so it remains stable and withstand the vibrations that might occur. The wheels are balanced so they don't create additional vibrations to the aircraft. The wheel covers are inclined so they produce little air resistance and turbulences, in accordance with the aircrafts aerodynamic. The vibrations and noises in the cockpit are small.

Lift off

The pilot checks the speedometer and slowly pulls back the main control stick when take-off speed is reached. The nose slowly lifts up to a maximum angle of 15 degrees, so the tail of the aircraft doesn't touch the ground as this happens. In case of crosswind, the pilot must ensure that the angle between the aircrafts heading and the aircrafts course is correct, in order to avoid drifting after liftoff.

Climbing

Once off the ground, the pilot lowers the nose using the main control stick in order to find an adequate rate of climb speed.

Retracting the landing gear

Soon after take-off, the pilot checks the indicators for the RG which shows that it is deployed. He pulls the RG lever to retract it. The retracting time takes a maximum of 2 minutes. The indicator shows first that the RG is being retracted as long as it is moving. It shows that it is fully retracted and locked when the wheel covers are shutting the wheel wells. In addition to that, a window under the cockpit gives the pilot the possibility to visually check the position of the RG.

Cruising

When the RG is fully retracted, the wheel covers are a part of the aerodynamic fuselage. They don’t disturb the aerodynamics of the aircraft during flight. The RG lock function withstands G-forces that might occur during flight, so it doesn’t fall out.

2.3 U2: WATER TAKEOFF

Inspection before taxiing

The pilot checks that there are no warning lights flashing from the alarm system, and that the indicators for the RG on the main control stick are correct (shows that the RG is retracted).

Taxi in water

The wings are so called "float-wings". They lie just above the water level and stabilize the aircraft laterally much better than the usual pontoons, especially in case of cross wind or high waves. They also incorporate the rear RG. The aircraft floats so the level of water stays under the openings for the rear RG. The V-shape of the hull, inspired by the boat industry, makes maneuvers in water easier. It is designed to withstand high dynamic longtime stresses and it is not subjected to either fatigue or corrosion. This reduces considerably the maintenance costs for the pilot. One less thing to think about!

From the cockpit, the pilot has good view out on the water. Before the takeoff, he taxis along the intended takeoff path to check that it is not obstructed by hazardous floating or submerged objects and that it will remain clear throughout the takeoff. The pilot uses the main stick to control the flaps and choose his direction on the water.

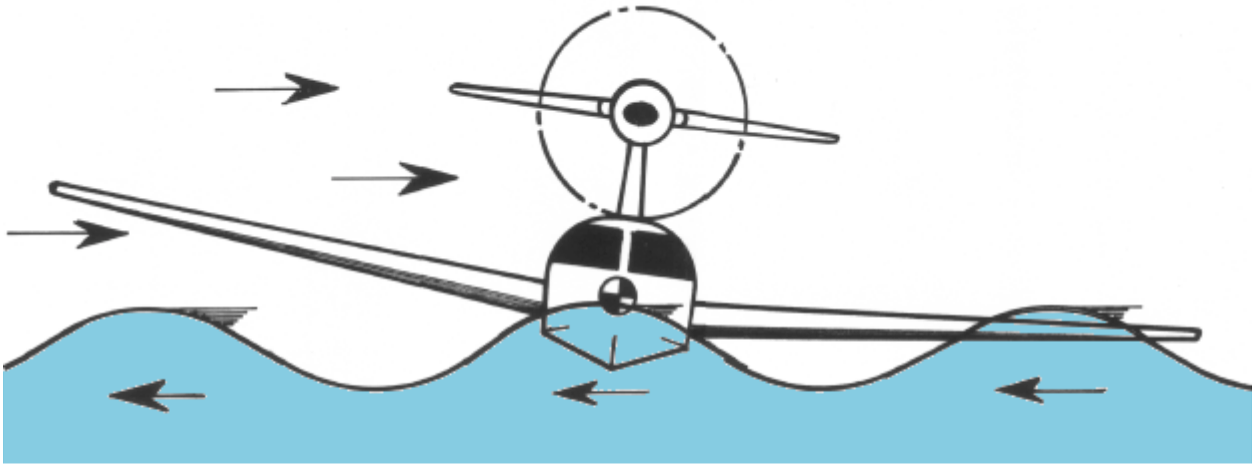

Figure 2:Taxiing with high waves and cross wind

Rolling water

Water takeoffs require more propeller thrust than usual takeoffs since water drag produces more resistance than air drag. Water is sprayed to the rear and on the anti-corrosive coated propels. This doesn't affect the propeller thrust significantly.
In case of heavy loading of the aircraft, low air density and/or glassy water conditions, the water drag might exceed the maximum propeller thrust and the aircraft won't plan or lift.

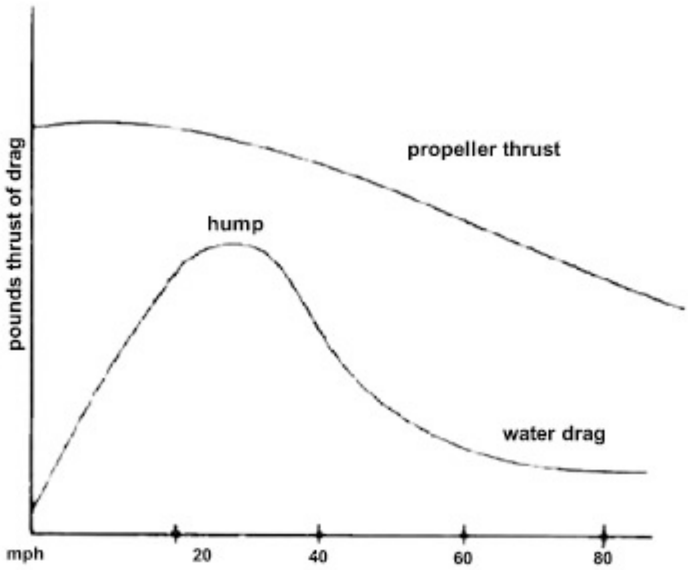

Figure 3: Propeller thrust vs. water drag

Check before takeoff

The pilot performs a visual check for warning lights as soon as the aircraft starts moving. The display shows that oil pressure and temperature are valid. He also checks that the takeoff path stays clear.

Full throttle on water

Reaching a certain speed, the aircraft starts planning on the water. It bounces from a wave crest to the next. The pilot performs corrections by pulling or pushing the main stick, allowing the aircraft to "skim" across each wave as speed increases. The pitch moment during take of roll pushes the nose down in the water. The undercarriage is designed so it can withstand the pressure of the bounces on the waves. The vibrations and noises in the cockpit are small. The drainage of the water trapped into the wheel wells starts as the aircraft is planning. All water is drained out in a maximum of 20 seconds.

Lift off

Under perfect conditions, the aircraft needs less than 100 meters to lift off. This increases the pilot's possibilities of takeoff spots. The aircraft lifts off when the pilot pulls the main control stick backwards. Drainage of the wheel wells should be complete or nearly complete as the aircraft lifts off.

Climbing

Once off the ground, the pilot lowers the nose using the main control stick in order to find an adequate rate of climb speed.

Cruising

When adequate altitude is reached, the pilot can then set the aircraft on autopilot. It will follow the course uploaded to the second control pad by the pilot yesterday evening. Enjoy the flight!

2.4 U3: LANDING

Landing preparation

The pilot approaches the landing area and gets ready for landing. In case the RG isn't deployed at a certain height over the ground, a voice alarm reminds the pilot to do so.

Deploy RG

The pilot deploys the landing gear by pulling a lever, this gives sound and lights explaining that the gear is being deployed. There is also a little window in the cockpit so that the pilot can directly visually check the position of the RG. The deploying time takes a maximum of 2 min. The speed of the aircraft has to be below that V_{LO} (max speed operating retractable gear) and V_{LE} (max landing gear extended speed). When fully deployed and locked in position there is lights explaining this.

Descent

The aircraft lines up with the airfield or required landing field and starts descent. The speed is below V_{LE} and V_{LO}. The front wheel is locked in a linear position with the aircraft's heading so it remains stable under the landing operation.

Landing

The aircraft touches down with the rear wheels first and the energy from the touchdown shock is absorbed.

Decelerate

Right after touchdown the pilot turns on the brakes and extracts the flaps to decelerate. The weight of the aircraft is transferred to the nose of the aircraft in this decelerating phase. The front RG is designed to withstand this.

Taxi to hangar

After slowing down the speed of the aircraft, the pilot taxis to the hangar or parking area. The pilot adjusts the power of the engine to get a desired speed and steers the aircraft to the parking area using the front wheel steering. The pilot slows down the speed before attempting a turn, so that the aircraft remains stable.

Last check before turning the aircraft off

Before switching the aircraft off, the pilot does a last check, ensuring that all instruments and lights work as they should.

External visual inspection

When out of the aircraft, the pilot inspects the whole aircraft for irregularities, especially the retractable gear. The pilot uses a flashlight to see up in the wheel wells.

2.5 U4: WATER LANDING

Descent

The pilot lines up the aircraft with the intended landing path and uses the main control stick to start the descent with a proper angle. He also checks the wind position indicated on the pad and that the RG is retracted. To be sure, he also visually checks that the wheels are not out. The speed is below V_{LE} and V_{LO}.

Landing

The aircraft touches down with a proper angle that allows planning on the water. The V-hull and RG withstand the stresses and chocks that occur during landing, and it is not affected by corrosion or fatigue.

Deceleration

The pilot uses the flaps to reduce the velocity of the aircraft. He should not reduce the throttle before he has ensured that the aircraft is floating on the water.

2.6 U5: TAXI INTO/OUT OF WATER

Taxi on different surfaces

The wheels' size makes taxiing on rough surfaces possible (dirty soil, sand…). The pilot doesn't feel too much bumping as the shocks are absorbed. He can taxi safely, knowing that the wheels are tubeless and difficult to puncture. The wheel cover must be able to hit stones without damage.

Taxi into/out of water

The pilot heads to a beach where the aircraft enters into/gets out of the water. The RG mechanism and the wheels are anti-corrosion coated.

Retract/extract RG in water

The pilot can retract/extract the RG by pulling the RG lever. The RG retracts until the wheel covers are a part of the aerodynamic/hydrodynamic fuselage and the whole mechanism locks itself. Minimum amount of water is trapped into the wheel wells. The RG can withstand the forces inflicted on the system when extracting in water. The simplicity of the gear allows seaweed and other components in the water to slide through. The RG doesn't suffer from humidity damages when staying extended periods in water, either it is retracted or extracted.

2.7 U6: WORST CASE SCENARIOS

RG will not retract in air

During climb, the pilot pulls the lever to retract the landing gear. The speed is below max operating speed for retractable gear V_{LO}. The indicator that shows that the landing gear does not retract as it should. Because flying with the landing gear deployed is not desirable, the pilot needs to perform a precautionary emergency landing. The aircraft cannot be flown in speeds exceeding V_{LE} (landing gear extended speed) with the landing gear deployed. Alternatively, the pilot uses the emergency operation for the gear to retract it. This is not desirable as there may be something critically wrong.

RG will not deploy in air

During descent the pilot pulls the lever to deploy the landing gear. The speed is below max operating speed for retractable gear V_{LO}. The indicator shows that the landing gear does not deploy as it should. The pilot then uses the emergency operation for deploying the landing gear. Now indicators show that the landing gear is deployed and locked.

Cross wind landing

Approaching the runway during descent there is a crosswind that pulls the aircraft to one side. The flaps and rudder are set in position to compensate, but the aircraft lands angled to the runway. The landing gear wheels slide a bit sideways before correcting and driving normally. There is no damage to the gear or wheels other than extra wear to the tires.

Landing with wrong centre of gravity

Approaching the runway during descent, the aircraft suddenly gets pulled over to one side due to downwash. The aircraft touches down on one wheel before the other. The energy to the gear that is landed on is absorbed in the damper function, which is designed to support the complete weight of the aircraft alone.

RG deploys during flight

The landing gear deploys unexpectedly during flight, which interferes with the aerodynamic of the aircraft. The pilot has two possible solutions. If possible, he performs a precautionary emergency landing, or uses the emergency operation to retract the landing gear. To perform an emergency landing, it requires the gear to be locked in deployed position. Should the emergency operation fail, the RG is designed to withstand the additional stresses inflicted when it is deployed at max cruising speed.

Nuts and bolt are loose

During inspection the pilot sees that some of the bolts and nuts have become loose. The pilot has to tighten the bolts before using the aircraft, preferably get a check of the aircraft before using it.

Electrical system gets wet

Water enters the electrical system, while the aircraft is landing, during takeoff or taxi in water. This results in a malfunction of the electrical system.

Loose grip

After landing, the pilot brakes to reduce speed, the landing is slippery and the aircraft looses grip and starts to slide.

RG hatch does not open in water

The hatches to the wheel wells do not open, there may be dirt or seaweed that is trapped or blocking the hatch. The pilot has to check what the cause is before using the aircraft.

RG hatch does not close in water

When taxiing into water, the landing gear should be retracted before takeoff. When retracting the gear, the hatches for the wheel well do not close. The pilot cannot take off before the hatches are closed because of the drag created inside the wheel wells.

RG hatch does not open in air

When trying to deploy the landing gear before landing, the hatches for the wheel wells do not open. There may be ice or dirt preventing it from opening. The pilot uses the RG emergency operation which is strong enough to crack ice layers in the wheel wells.

RG hatch does not close in air

After takeoff and retracting the landing gear, the hatches covering the wheel wells do not close. There may be ice or dirt preventing it to close.

Too much weight on the system

When loading the aircraft with luggage and fuel the maximum gross weight is exceeded. This is monitored by sensors on the landing gear, and gives a warning in the form of light and/or sound to the pilot before starting the aircraft. The pilot then has to take out something before takeoff.

Damage to critical parts

While inspecting the undercarriage before flying, the pilot finds irregularities on the landing gear. Those might be cracks, scratches, bent parts, corrosion, etc. The pilot has to find out what caused the damage and if it is safe to fly.

3. Requirements

3.1 Explanation of requirement ID

A requirement ID consists of four characters; First a letter which indicates if the requirement is a CS-23 (C), functional (F) or non-functional (N) requirement, then two numbers which are a unique indicator of the requirements, and the last letter describes if the requirement have priority A, B or C.

For instance if we have the requirement ID: F02B

This will indicate that it is a functional requirement with the unique indicator 02 and with priority B.

Table 1 shows how the requirements are set up.

ID: [ID#]	**Front/Rear:** [Front, Rear, Both]	**Priority:** [A,B,C]
Description: ***[Description of the requirement]***		
Use case: [Use Case ID]	**Source:** [Requirement set by]	**Date set:** dd.mm.yyyy

Table 1: Template for a requirement in detail

3.2 CS-23 Requirements

ID: C10A	**Front/Rear:** Both	**Priority:** A
Description: *Fasteners and their locking devices must not be adversely affected by the environmental conditions associated with the particular installation*		
Use case:	**Source:** [CS-23, 23.607 b)]	**Date set:** 02.02.2011

Table 2: C10A

ID: C11A	**Front/Rear:** Both	**Priority:** A
Description: *Each removable fastener must incorporate two retaining devices if the loss of such fastener would prelude continued safe flight and landing.*		
Use case:	**Source:** [CS-23, 23.607 a)]	**Date set:** 02.02.2011

Table 3: C11A

ID: C12A	**Front/Rear:** Both	**Priority:** A
Description: *Unless otherwise provided, a factor of safety of 1.5 must be used*		
Use case:	**Source:** [CS-23, 23.303]	**Date set:** 02.02.2011

Table 4: C12A

ID: C13A	**Front/Rear:** Both	**Priority:** A
Description: *Control surface hinges, except ball and roller bearing hinges, must have a factor of safety of not less than 6.67 with respect to the ultimate bearing strength of the softest material used as a bearing. The approved rating of the bearing may not be exceeded*		
Use case:	**Source:** [CS-23, 23.657 a),b)]	**Date set:** 02.02.2011

Table 5: C13A

ID: C14A	**Front/Rear:** Both	**Priority:** A
Description: *Control system joints (in push-pull systems) that are subjected to angular motion, except those in ball and roller bearing systems, must have a special factor of safety of not less than 3.33 with respect to the ultimate bearing strength of the softest material used as a bearing. This factor may be reduced to 2.0 for joints in cable control systems. For ball and roller bearings, the approved ratings may not be exceeded*		
Use case:	**Source:** [CS-23, 23.693]	**Date set:** 02.02.2011

Table 6: C14A

ID: C15A	**Front/Rear:** Both	**Priority:** A
Description: *Each cable, cable fitting, turn-buckle, splice and pulley used must meet approved specifications*		
Use case:	**Source:** [CS-23, 23.689 a)]	**Date set:** 02.02.2011

Table 7: C15A

ID: C16A	**Front/Rear:** Both	**Priority:** A
Description: *Each cable system must be designed so that there will be no hazardous change in cable tension throughout the range of travel under operating conditions and temperature variations*		
Use case:	**Source:** [CS-23, 23.689 a2)]	**Date set:** 02.02.2011

Table 8: C16A

ID: C17A	**Front/Rear:** Both	**Priority:** A
Description: *The limit vertical load factor must be 1.33, with the vertical ground reaction divided equally between the main wheels*		
Use case:	**Source:** [CS-23, 23.485 b)]	**Date set:** 02.02.2011

Table 9: C17A

ID: C18A	**Front/Rear:** Rear	**Priority:** A
Description: *The limit side inertia factor must be 0.83, with the side ground reaction divided between the main wheels so that:* *1) 0.5 (W) is acting inboard on one side, and* *2) 0.33 (W) is acting on the other side*		
Use case:	**Source:** [CS-23, 23.485 c)]	**Date set:** 02.02.2011

Table 10: C18A

ID: C19A	**Front/Rear:** Rear	**Priority:** A
Description: *For aft loads, the limit force component at the axle must be:* *1) A vertical component of 2.25 times the static load on the wheel; and* *2) A drag component of 0.8 times the vertical load*		
Use case:	**Source:** [CS-23, 23.499 a)]	**Date set:** 02.02.2011

Table 11: C19A

ID: C20A	**Front/Rear:** Front	**Priority:** A
Description: *For forward loads, the limit force component at the axle must be:* *1) A vertical component of 2.25 times the static load on the wheel; and* *2) A forward component of 0.4 times the vertical load*		
Use case:	**Source:** [CS-23, 23.499 b)]	**Date set:** 02.02.2011

Table 12: C20A

ID: C21A	**Front/Rear:** Both	**Priority:** A
Description: *For side loads, the limit force component at ground contact must be:* *1) A vertical component of 2.25 times the static load on the wheel; and* *2) A side component of 0.7 times the vertical load*		
Use case:	**Source:** [CS-23, 23.499 c)]	**Date set:** 02.02.2011

Table 13: C21A

ID: C22A	**Front/Rear:** Both	**Priority:** A
Description: *The pressure in the wheel braking system must not exceed the pressure specified by the brake manufacturer*		
Use case:	**Source:** [CS-23, 23.735 c)]	**Date set:** 02.02.2011

Table 14: C22A

ID: C23A	**Front/Rear:** Both	**Priority:** A
Description: *The landing brake kinetic energy capacity rating of each main wheel brake wheel assembly must not be less than the kinetic energy absorption requirements*		
Use case:	**Source:** [CS-23, 23.735 a)]	**Date set:** 02.02.2011

Table 15: C23A

ID: C24A	**Front/Rear:** Both	**Priority:** A
Description: *Brakes must be able to prevent the wheels from rolling on a paved runway with take-off power in the critical engine, but need not prevent movement of the aircraft with wheels locked*		
Use case:	**Source:** [CS-23, 23.735 b)]	**Date set:** 02.02.2011

Table 16: C24A

ID: C27A	**Front/Rear:** Both	**Priority:** A
Description: *No self locking nut may be used on any bolt subjected to rotation in operation unless a non-friction locking device is used in addition to the self-locking device*		
Use case:	**Source:** [CS-23, 23.607 c)]	**Date set:** 02.02.2011

Table 17: C27A

ID: C28A	**Front/Rear:** Both	**Priority:** A
Description: *The structure must be able to support limit loads without detrimental, permanent deformation. At any load up to limit loads, the deformation may not interfere with safe operation*		
Use case:	**Source:** [CS-23, 23.305 a)]	**Date set:** 02.02.2011

Table 18: C28A

ID: C29A	**Front/Rear:** Both	**Priority:** A
Description: *The structure must be designed, as far as practicable, to avoid points of stress concentration where variable stresses above fatigue limit are likely to occur in normal service*		
Use case:	**Source:** [CS-23, 23.627]	**Date set:** 02.02.2011

Table 19: C29A

ID: C30A	**Front/Rear:** Both	**Priority:** A
Description: *No cable smaller than 3.2 mm (1/8 in) diameter may be used in primary control systems*		
Use case:	**Source:** [CS-23, 23.689 a1)]	**Date set:** 02.02.2011

Table 20: C30A

ID: C31A	**Front/Rear:** Both	**Priority:** A
Description: *The landing gear may not fail, but may yield, in a test showing its reserve energy absorption capacity, simulating a descent velocity of 1.2 times the limit descent velocity, assuming wing lift equal to the weight of the aircraft*		
Use case:	**Source:** [CS-23, 23.723]	**Date set:** 02.02.2011

Table 21: C31A

ID: C32A	**Front/Rear:** Both	**Priority:** A
Description: *Each landing gear retracting mechanism and its structure, including the well doors, must be designed for maximum flight load factors with the gear retracted/extracted and must be designed for the combination of friction, inertia; brake torque and air loads, occurring during retraction/extraction at any airspeed up to 1.6* V_{S1} *with flaps retracted*		
Use case:	**Source:** [CS-23, 23.729 a1, a2]	**Date set:** 02.02.2011

Table 22: C32A

ID: C33A	**Front/Rear:** Both	**Priority:** A
Description: *There must be other positive means (other than hydraulic pressure) to keep the landing gear extended*		
Use case:	**Source:** [CS-23, 23.729 b)]	**Date set:** 02.02.2011

Table 23: C33A

ID: C34A	**Front/Rear:** Both	**Priority:** A
Description: *Operation test. The proper function of the retracting mechanism must be shown by operation tests*		
Use case:	**Source:** [CS-23, 23.729 d)]	**Date set:** 02.02.2011

Table 24: C34A

ID: C36A	**Front/Rear:** Both	**Priority:** A
Description: *Each tire installed on a retractable landing gear system must, at the maximum size of the tire type expected in service, have a clearance to surrounding structure and systems that is adequate to prevent contact between the tire and any part of the structure systems*		
Use case:	**Source:** [CS-23, 23.733 c)]	**Date set:** 02.02.2011

Table 25: C36A

ID: C37A	**Front/Rear:** Both	**Priority:** A
Description: *Each landing gear wheel must have a tire whose approved tire ratings (static and dynamic) are not exceeded*		
Use case:	**Source:** [CS-23, 23.733 a)]	**Date set:** 02.02.2011

Table 26: C37A

ID: C38A	**Front/Rear:** Both	**Priority:** A
Description: *There must be a landing gear position indicator (as well as necessary switches to actuate the indicator) or other means to inform the pilot that each gear is secured in extended (or retracted) position*		
Use case:	**Source:** [CS-23, 23.729 e)]	**Date set:** 02.02.2011

Table 27: C38A

ID: C09B	**Front/Rear:** Both	**Priority:** B
Description: *The RG must be designed so it is available for maintenance, inspection or other servicing*		
Use case:	**Source:** [CS-23, 23.611]	**Date set:** 02.02.2011

Table 28: C09B

ID: C14B	**Front/Rear:** Both	**Priority:** B
Description: *Each part of the RG must have design features, or must be distinctively and permanently marked, to minimize the possibility of incorrect assembly that could result in malfunction of the RG*		
Use case:	**Source:** [CS-23, 23.685 d) and the group	**Date set:** 02.02.2011

Table 29: C14B

ID: C25B	**Front/Rear:** Both	**Priority:** B
Description: *If nose/tail wheel steering is installed, it must be demonstrated that its use does not require exceptional pilot skill during take-off and landing, in cross-winds and in the event of an engine failure or its use must be limited to low speed maneuvering*		
Use case:	**Source:** [CS-23, 23.745 a)]	**Date set:** 02.02.2011

Table 30: C25B

ID: C35B	**Front/Rear:** Both	**Priority:** B
Description: *Aural landing gear warning or equally effective landing gear devices must be provided*		
Use case:	**Source:** [CS-23, 23.729 f)]	**Date set:** 02.02.2011

Table 31: C35B

ID: C26C	**Front/Rear:** Both	**Priority:** C
Description: *Each taxi and landing light must be designed and installed so that:* *1) No dangerous glare is visible to the pilots.* *2) The pilot is not seriously affected by halation.* *3) It provides enough light for night operations.* *4) It does not cause a fire hazard in any configuration.*		
Use case:	**Source:** [CS-23, 23.1383]	**Date set:** 02.02.2011

Table 32: C26C

3.3 Functional Requirements

ID: F03A	**Front/Rear:** Both	**Priority:** A
Description: *There must be an emergency landing operation system in case of failure of the primary electrical system.*		
Use case: U6	**Source:** Requirement set by Equator Aircraft Norway, CS-23, 23.729 c)	**Date set:** 18.12.2010

Table 33: F03A

ID: F05A	**Front/Rear:** Both	**Priority:** A
Description: *There must be an emergency landing operation system in case of failure of the mechanical system.*		
Use case: U6	**Source:** Requirement set by Equator Aircraft Norway, CS-23, 23.729 c)	**Date set:** 18.12.2010

Table 34: F05A

ID: F06A	**Front/Rear:** Both	**Priority:** A
Description: *The RG-system should be activated physically from the cockpit*		
Use case: U1, U3, U5, U6	**Source:** Requirement set by Equator Aircraft Norway and the project group	**Date set:** 10.12.2010

Table 35: F06A

ID: F08A	**Front/Rear:** Rear	**Priority:** A
Description: *The RG shock-absorber function must be able to absorb all the vertical energy produced when landing on land*		
Use case: U3	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 10.12.2010

Table 36: F08A

ID: F12A	**Front/Rear:** Rear	**Priority:** A
Description: *The brakes must be able to decelerate the aircraft when it reaches its maximum speed*		
Use case: U3	**Source:** Requirement set by the group	**Date set:** 01.02.2011

Table 37: F12A

ID: F13A	**Front/Rear:** Both	**Priority:** A
Description: *The aircraft must be able to taxi on rough and soft surfaces*		
Use case: U1, U3, U5	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 01.02.2011

Table 38: F13A

ID: F15A	**Front/Rear:** Both	**Priority:** A
Description: *The aircraft must be able to turn on land*		
Use case: U1, U3, U5	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 01.02.2011

Table 39: F15A

ID: F16A	**Front/Rear:** Both	**Priority:** A
Description: *When the RG is retracted and locked, the water trapped into the wheel wells must be drained*		
Use case: U2, U4, U5	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 02.02.2011

Table 40: F16A

ID: F17A	**Front/Rear:** Both	**Priority:** A
Description: *Malfunctioning of the RG system must be indicated to the pilot*		
Use case: U6	**Source:** Requirement set by the group	**Date set:** 01.02.2011

Table 41: F17A

ID: F18A	**Front/Rear:** Both	**Priority:** A
Description: *The RG must be able to deploy in water*		
Use case: U5	**Source:** Requirement set by the group	**Date set:** 01.02.2011

Table 42: F18A

ID: F19A	**Front/Rear:** Both	**Priority:** A
Description: *The RG must be able to retract in water*		
Use case: U5	**Source:** Requirement set by the group	**Date set:** 01.02.2011

Table 43: F19A

ID: F22A	**Front/Rear:** Rear	**Priority:** A
Description: *The undercarriage must withstand the forces applied to the system by landing on one wheel*		
Use case: U3, U6	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 10.12.2010

Table 44: F22A

ID: F25A	**Front/Rear:** Front	**Priority:** A
Description: *It must be possible to lock the front wheel in the linear position of the aircraft*		
Use case: U1, U3	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 01.03.2011

Table 45: F25A

ID: F27A	**Front/Rear:** Both	**Priority:** A
Description: *The nose of the aircraft should be able to lift up a maximum of 15 degrees without touching the ground with the tail of the aircraft*		
Use case: U1	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 01.03.2011

Table 46: F27A

ID: F28A	**Front/Rear:** Both	**Priority:** A
Description: *The wheels must be balanced*		
Use case: U1, U3	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 01.03.2011

Table 47: F28A

ID: F29A	**Front/Rear:** Both	**Priority:** A
Description: ***The wheel well doors are locked when they are not in motion***		
Use case: U1, U2, U3, U4, U5	**Source:** Requirement set by the group	**Date set:** 01.03.2011

Table 48: F29A

ID: F30A	**Front/Rear:** Both	**Priority:** A
Description: ***The RG is locked when it is not in motion***		
Use case: U1, U2, U3, U4, U5	**Source:** Requirement set by the group	**Date set:** 01.03.2011

Table 49: F30A

ID: F31A	**Front/Rear:** Both	**Priority:** A
Description: ***The deployed wheel well doors/wheel covers must withstand the water drag while the aircraft taxis on water***		
Use case: U5	**Source:** Requirement set by the group	**Date set:** 01.03.2011

Table 50: F31A

ID: F32A	**Front/Rear:** Both	**Priority:** A
Description: ***The RG must withstand the shocks from bouncing on waves***		
Use case: U2, U4, U5	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 01.03.2011

Table 51: F32A

ID: F33A	**Front/Rear:** Front	**Priority:** A
Description: ***The shock-absorber function must be able to absorb the weight transfer of the aircraft to the nose when decelerating***		
Use case: U3	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 01.03.2011

Table 52: F33A

ID: F34A	**Front/Rear:** Both	**Priority:** A
Description: ***The RG must withstand to be extracted when the aircraft is cruising at maximum speed***		
Use case: U6	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 01.03.2011

Table 53: F34A

ID: F35A	**Front/Rear:** Both	**Priority:** A
Description: ***The RG must withstand extended exposure to humidity***		
Use case: U2, U4, U5	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 01.03.2011

Table 54: F35A

ID: F07B	**Front/Rear:** Both	**Priority:** B
Description: ***Activating the RG-system by random touch must be disabled***		
Use case: U1, U2, U3, U4, U5, U6	**Source:** Requirement set by Equator Aircraft Norway and the project group	**Date set:** 10.12.2010

Table 55: F07B

ID: F14B	**Front/Rear:** Rear	**Priority:** B
Description: ***The RG must be able to park-brake***		
Use case: U1	**Source:** [Requirement set by]	**Date set:** 01.02.2011

Table 56: F14B

ID: F21B	**Front/Rear:** Both	**Priority:** B
Description: ***The aircraft must remain stable on land when the pilot enters the cockpit***		
Use case: U1	**Source:** Requirement set by the group	**Date set:** 01.02.2011

Table 57: F21B

ID: F26B	**Front/Rear:** Both	**Priority:** B
Description: ***The wheel covers/wheel well doors must not affect the aerodynamic of the aircraft significantly***		
Use case: U1, U3	**Source:** Requirement set by the group	**Date set:** 01.03.2011

Table 58: F26B

ID: F36B	**Front/Rear:** Both	**Priority:** B
Description: ***The wheel covers/wheel well doors must withstand to hit stones when taxiing***		
Use case: U1, U3, U5	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 01.03.2011

Table 59: F36B

ID: F09C	**Front/Rear:** Front	**Priority:** C
Description: ***The aircraft should be able to be dragged after a car***		
Use case: U1	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 10.12.2010

Table 60: F09C

ID: F10C	**Front/Rear:** Front	**Priority:** C
Description: ***The pilot should be able to steer the front wheel from the cockpit***		
Use case: U1, U3, U5	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 10.12.2010

Table 61: F10C

ID: F11C	**Front/Rear:** Both	**Priority:** C
Description: ***The RG retracting mechanism while on ground must be disabled***		
Use case: U1, U3, U5	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 01.02.2011

Table 62: F11C

ID: F20C	**Front/Rear:** Both	**Priority:** C
Description: ***Indicators must inform the pilot when the aircraft is loaded over the gross weight***		
Use case: U1, U2	**Source:** Requirement set by Equator Aircraft	**Date set:** 01.02.2011

Table 63: F20C

ID: F23C	**Front/Rear:** Both	**Priority:** C
Description: ***Indicators must inform the pilot about the aircraft's weight distribution***		
Use case: U1	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 01.03.2011

Table 64: F23C

ID: F24C	**Front/Rear:** Both	**Priority:** C
Description: ***The shock-absorbers' stiffness should affect the cockpit to minimal vibrations when the aircraft is taxiing on rough surfaces***		
Use case: U1, U3, U5	**Source:** Requirement set by the group	**Date set:** 01.03.2011

Table 65: F24C

3.4 Non-functional Requirements

ID: N02A	**Front/Rear:** Both	**Priority:** A
Description: *Both retractable gears must be salty water resistant*		
Use case:	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 10.12.2010

Table 666: N02A

ID: N03A	**Front/Rear:** Both	**Priority:** A
Description: *All electronic components must be kept dry*		
Use case:	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 10.12.2010

Table 677: N03A

ID: N09A	**Front/Rear:** Front	**Priority:** A
Description: *Maximum weight of front RG is 8.00kg (17.64lbs)*		
Use case:	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 10.12.2010

Table 68: N09A

ID: N10A	**Front/Rear:** Rear	**Priority:** A
Description: *Maximum weight of each rear RG is 6.00kg (13.23lbs)*		
Use case:	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 10.12.2010

Table 69: N10A

ID: N11A	**Front/Rear:** Both	**Priority:** A
Description: *The size of the RG must fit into the free space/volume inside the aircraft's body (wheel well)*		
Use case:	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 10.12.2010

Table 70: N11A

ID: N12A	**Front/Rear:** Both	**Priority:** A
Description: *The lowest point on the aircraft's fuselage must be at least 10cm (≈4inch) above the lowest point on the rim*		
Use case:	**Source:** Requirement set by Equator Aircraft Norway and the project group	**Date set:** 10.12.2010

Table 71: N12A

ID: N13A	**Front/Rear:** Both	**Priority:** A
Description: *The wheel size have to be small enough to fit inside the fuselage*		
Use case:	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 10.12.2010

Table 72: N13A

ID: N28A	**Front/Rear:** Front	**Priority:** A
Description: *The aircraft's front wheel must stay on the ground when accelerating*		
Use case:	**Source:** Requirement set by the group	**Date set:** 01.02.2011

Table 73: N28A

ID: N29A	**Front/Rear:** Both	**Priority:** A
Description: *The wheels remain stable when the aircraft drives at maximum speed*		
Use case:	**Source:** Requirement set by the group	**Date set:** 01.02.2011

Table 74: 29A

ID: N32A	**Front/Rear:** Both	**Priority:** A
Description: *The aircraft must be stable during turns on land*		
Use case:	**Source:** Requirement set by the group	**Date set:** 02.02.2011

Table 75: N32A

ID: N34A	**Front/Rear:** Both	**Priority:** A
Description: *The RG deploying time must be a maximum of 2 min*		
Use case:	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 01.03.2011

Table 76: N34A

ID: N35A	**Front/Rear:** Both	**Priority:** A
Description: *The RG retracting time must be a maximum of 2 min*		
Use case:	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 01.03.2011

Table 77: N35A

ID: N36A	**Front/Rear:** Both	**Priority:** A
Description: *The wheel well doors/wheel covers must be salty-water resistant*		
Use case:	**Source:** Requirement set by the group	**Date set:** 01.03.2011

Table 78: N36A

ID: N37A	**Front/Rear:** Both	**Priority:** A
Description: *The drainage of water trapped in the wheel wells should take a maximum of 20 seconds*		
Use case:	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 01.03.2011

Table 79: N37A

ID: N04B	**Front/Rear:** Both	**Priority:** B
Description: *The RG should have a robust off-road look*		
Use case:	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 10.12.2010

Table 80: N04B

ID: N05B	**Front/Rear:** Both	**Priority:** B
Description: *The RG-system should be protected against rocky surfaces*		
Use case:	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 10.12.2010

Table 81: N05B

ID: N06B	**Front/Rear:** Both	**Priority:** B
Description: *Protection of vital moving components*		
Use case:	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 10.12.2010

Table 82: N06B

ID: N07B	**Front/Rear:** Both	**Priority:** B
Description: *The RG should be able to be implemented as a self build kit*		
Use case:	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 18.12.2010

Table 83: N07B

ID: N08C	**Front/Rear:** Both	**Priority:** C
Description: *The RG-system in motion should sound smooth and ensuring*		
Use case:	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 10.12.2010

Table 84: N08C

ID: N31C	**Front/Rear:** Both	**Priority:** C
Description: *The wheels must be able to prevent puncture*		
Use case:	**Source:** Requirement set by the group	**Date set:** 02.02.2011

Table 85: N31C

ID: N33C	**Front/Rear:** Both	**Priority:** C
Description: ***The wheel covers/wheel doors should be one single part***		
Use case:	**Source:** Requirement set by Equator Aircraft Norway	**Date set:** 03.02.2011

Table 86: N33C

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Test Specification

aRGie

Retractable Gear Development Study

Buskerud University College, Department of Engineering Institute of Technology

Equator Aircraft Norway SA

Document responsible: Sigbjørn Gunnerød
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Abstract

The goal with this document is to give an overview of which tests to be performed on the product. It will show which requirements we meet from the requirement specification and how we intended to test them.

This document will constantly be updated throughout the project when changes are made, and new tests occur.

Sammendrag

Målet med dette dokumentet er å gi en oversikt over hvilke tester som skal utføres på produktet. Det vil vise hvilke krav vi møter fra kravspesifikasjonen og hvordan vi har planlagt å teste dem.

Dette dokumentet vil kontinuerlig oppdateres gjennom prosjektet når endringer blir gjort og nye tester oppstår.

Document history

Version	Date	Responsible	Changing
0.1	21.12.10	Sigbjørn Gunnerød, Sindre D- Flaten, Jeremy Marchand	First version
0.2	22.12.10	Sigbjørn Gunnerød	• Added more on the abstract • More explanation of test ID, test groups • Named all the tests • Made the list of tests • Added more to the definitions • Added more to the test plan • Added test TC02 and TC03
0.3	03.01.11	Sindre D. Flaten	• Word change in abstract • Changed description for FEM in definitions • Spelling in 1.2 Constraints • Added sentence on 2.1.1 Component testing • Spelling in 2.1.2 Integration testing • Changed sentences in 2.1.3 System testing • Spelling in 2.1.4 Acceptance testing • Spelling 3.1 Explanation of the test ID • Added SW to definitions • Spelling in test TC02
0.4	04.01.11	Sigbjørn Gunnerød	Changed the test TS04
1.0	04.01.11	Rebaz Aziz	
1.1	14.03.11	Sigbjørn Gunnerød	• Changed the logo • Made the following tests: TS17, TS18, TS19, TS20, TS21, TS22, TC05, TS23, TC07 • Removed TS12, no test to F09C or F24C • Removed TS15, was changed to TC04

			• TC06 was made by TS19, added requirement C11A, C16A, C27A, C30A and C39B • Removed TS04, the requirement N13A was put into TS02 • Removed TS18 since this was the same test as TS07 • Changed TS10, added req. C23A and C22A • Changed TS09, added F05A • Changed TS05, added F31A, F32A, F34A, F36A and all the requirement according to safety factors: C12A, C13A, C14A, C17A, C18A, C19A, C20A, C21A, C28A, C29A • Changed TS17, added F21B • Removed TS11 • Added chap. 2.3 test organizing with table
1.2	18.04.11	Stein Erik Thoen	• Changed dates on test: TC04, TC05, TC06, TC07, TS05, TS07, TS10. • Added comments on tests: TC01, TS06, TS09, TS13, TS16, TS20, TS22.
2.0	19.04.11	Sigbjørn Gunnerød	• Changed status on TS02, TS03, TS17 and TS21
2.1	03.05.11	Sigbjørn Gunnerød	• Spelling in TC01 • Translated a Norwegian sentence in TS05.
2.2	20.05.11	Jeremy Marchand	• Changed status on TS01, TC07 and TS07 • Added comment on TS02
3.0	27.05.11	Sigbjørn Gunnerød	• Updated the status on the rest of the tests • Added more to 1.2 Constraints • Added the latest test plan

Table of content

List of tests

Definitions

Abbreviation	Extension	Description
FEM	Finite Element Method	Method used in 3D modeling software for analysis in structural mechanics. Can be used to calculate strength and forces according mechanical materials.
RG	Retractable Gear	
FAT	Factory Acceptance Test	Test to see if the system works acceptably, often the last test before the product reaches the market.
EAN	Equator Aircraft Norway	Employer
SW	SolidWorks	3D modeling software

1. Introduction

1.1 Goals and objectives

The goal with the testing is to look into parts of a system to consider if the requirements of the test are met. This involves analyzing or looking into a system to control if the result corresponds to what is expected. This is to find and fix errors before the system is being taken into use. The earlier errors can be detected in a development phase, the less cost there will be for developing the product. By performing tests and evaluating the quality of the product, we will also have a good overview of how the system works and how reliable it is.

1.2 Constraints

There are several constraints that affect the tests that we describe in this document. The biggest constraint concerns stress testing on the whole RG system. When talking about stress testing, we mean testing the system with different forces applied to the whole system. We do this so we can see if the RG is able to withstand the forces that are applied to the system, when landing/take off and flying. To be able to perform stress tests on the whole system, which will give us almost the same results as when landing/take off and flying, we have to make a prototype or a full scale model in the exact same materials and components to get the right results. Since we don't have time to make a full-scale prototype in the exact materials that will be used in the finished aircraft, we have to perform these tests by using FEM analysis in SolidWorks.

Some parts that will be used in the prototype have several days of delivery time. This has to be taken under consideration when planning the testing schedule. For instance, an electrical motor for the prototype have about 4 weeks delivery time.

Since we are also working to develop the RG of an unfinished aircraft it happens constantly changes with the fuselage aswell, which also makes some tests invalid and have to be done again to be correct. In some cases we didn't have time to do this, but chose rather to make suggestions for improvements so that it can have a value for EAN later on.

2. Test plan

2.1 Test strategy

It is understood that a project developed for an aircraft contains high-risk functions. This means that parts must be perfectly well tested.

2.1.1 Component testing

Components will be tested individually. We will use FEM-analysis in Cosmos to test parts designed in SolidWorks. When testing parts, we will have to considerate the safety factor. If a part is supposed to withstand a certain amount of stress, we will have to test it so it can withstand more than it is supposed to. How much more depends on the safety factor. When it comes to electronic components these will be tested using various measuring instruments.

2.1.2 Integration testing

When component testing is fulfilled, we will test the components together as a system. We will use test cases where we describe instructions to be followed in order to find out if the functions are working correctly or not. Integration testing can be planned differently, depending on the type of project. There are several models to follow:

- *Bottom-up:*
  Begins by testing smaller modules of the system and then merging these into bigger modules, ending with the whole system.
- *Top-down:*
  Begins by testing a fictive system as a whole before dividing in smaller tests when real modules are implemented to the system.
- *Incremental testing:*
  Is a mix of bottom-up and top-down model. Begins by testing the most critical vital parts of the system, then testing the whole system.
- *Back to back:*
  If a system contains many identical modules, it consists on testing these using the same procedure and comparing the results.

2.1.3 System testing

System testing will happen when the whole system is build together. It should be simulated in the environment the system is supposed to perform.

- *Functional testing:*
  Includes testing that each function meets its requirement.
- *Interaction testing:*
  Includes testing functions against each other in order to check if they are conflictual or not.

2.1.4 Acceptance testing

Acceptance testing is the last testing performed on a system before it's delivered. We will not perform a FAT test of the finished product, as our final product will be a small-scale prototype. We can perform a test to see if the system works acceptably in the scaled form, but a drop-test will not give correct results since we most likely will not use the same materials as a full-scale prototype.

2.2 Test report document

When it is time to execute the tests that is mentioned in Chapter 3-Tests, it is important to document the test in a good way. A report like this has to contain a number of different things like; the report name, what is going to be tested, how the test is to be preformed, the persons involved in the test and of course the results of the test. Each test report will have its own name describing the test. To make it easier for us in the testing and documentation process, we have made a template for the test report. The template for our test report can be seen in Appendix 1.

2.3 Test organizing

From previous delivery we had to revise the test plan because the time has not matched with how far we had come in the project. This is the newest testplan:

Test ID	Date	Estimated time (hours)	Test responsible
Components tests			
TC01	Expires		
TC02	15.05.2011	1	Sigbjørn Gunnerød
TC03	15.05.2011	1	Sigbjørn Gunnerød
TC04	26.05.2011	7	Jeremy Marchand
TC05	26.05.2011	7	Jeremy Marchand
TC06	02.05.2011	2	Rebaz Aziz
TC07	06.05.2011	2	Jeremy Marchand
System tests			
TS01	03.05.2011	2	Sakaraiya Dahir
TS02	21.03.2011	2	Stein Erik Thoen
TS03	16.03.2011	1	Stein Erik Thoen
TS05	18.05.2011	6	Rebaz Aziz
TS06	Expires		
TS07	11.05.2011	2	Sigbjørn Gunnerød
TS08	23.05.2011	3	Sigbjørn Gunnerød
TS09	Expires		
TS10	Expires	2	Sakariya Dahir
TS13	Expires		
TS14	14.05.2011	4	Rebaz Aziz
TS16	Expires		
TS17	23.03.2011	2	Stein Erik Thoen
TS19	Expires	10	Sindre D. Flaten
TS20	Expires		
TS21	29.03.2011	1	Stein Erik Thoen
TS22	Expires		
TS23	Expires	4	Sakariya Dahir
TS24	Expires	4	Sakariya Dahir

Table 1: Test organizing

3. Tests

3.1 Explanation of the test ID

All the test requirements have a unique ID-number so we easily can keep track of them. The ID-number consists of two letters and two digits. The letters describe what kind of test it is and the digits are there to give the test a number. Table 1 shows the template we use to describe each test.

ID: [ID#]	**Covers requirement:** [ID#]	**Status:** tested/not tested (dd.mm.yyyy)
What: [What needs to be tested]		
How: [How will the test be performed]		
Comment: [Comments about the test]		
Test report: [Name of the test report]		

Table 2: Template for tests in detail

Currently, we have divided the tests into two groups:

- **Component testing**
  Shows all the tests we have to perform on the mechanical and electronic components we need for the RG. This means basically to test components before they are integrated into the system to ensure that they work properly.

  The ID-number can look like this: TC01

- **System testing**
  Shows all the tests we have to perform on parts of the system.

  The ID-number can look like this: TS01

The status tells if the test is approved or failed and whether it is completed or not. If the test is not performed or it failed, it should be a comment why this is so.

3.2 Component testing

ID: TC01	**Covers requirement:** N05B, N06B, F13A	**Status:** not tested
What: Test that vital parts of the RG-system are well protected against vibration and shocks.		
How: Component analysis against frequent stress changes and intrusion resistance. (FEM-analysis)		
Comment: Need better knowledge on how this is done with FEM analysis. This is something we don't have time to perform.		
Test report:		

Table 3: TC01

ID: TC02	**Covers requirement:**	**Status:** Tested OK 15.05.2011
What: Ensure that the power supply delivers its intentional values		
How: Measure the voltage and current of the power supply by using voltmeters and ammeters in combination with smaller test circuits.		
Comment:		
Test report: Test_report_TC02_180511.doc		

Table 4: TC02

ID: TC03	**Covers requirement:**	**Status:** Tested OK 15.05.2011
What: Ensure that every resistor, capacitor, diode, transistor and other small electronic components have right value and work as they should.		
How: Measure the value of the component using a multimeter before inserting it to the circuit.		
Comment:		
Test report: Test_report_TC03_210511.doc		

Table 5: TC03

ID: TC04	**Covers requirement:** N02A, F35A	**Status:** Tested OK 26.05.2011
What: Test that the RG withstand extended exposure to humidity		
How: • Analyze material characteristics and possible coating. • Provide that the materials we choose are salty water-resistant. • Provide that the materials we choose can be in water over a long period of time, without being affected and damaged.		
Comment:		
Test report: Test_report_TC04_260511.doc		

Table 6: TC04

ID: TC05	**Covers requirement:** C10A, C15A	**Status:** Tested OK 26.05.2011
What: Test that all RG components will not be affected by different environmental conditions (cold/warm weather, water etc.)		
How: • Analyze material characteristics and see that they withstand the temperature range and weather conditions that the RG will be used in. Looking at datasheets etc. • Analyze electrical components and see that they withstand the temperature range and weather conditions that the RG will be used in. Looking at datasheets etc.		
Comment:		
Test report: Test_report_TC05.260511.doc		

Table 7: TC05

ID: TC06	**Covers requirement:** N33C, F26B, C11A, C16A, C27A, C30A, C39B	**Status:** Tested OK 02.05.2011
What: Check all the visually requirements according to the design.		
How: • Check visually that the wheel cover/ wheel doors are one single part • Check that the front wheel is steerable. • Check that the wheel covers don't have any surfaces that affect the aerodynamic. • Check that all removable fasteners has two retaining devices		

• Check that there is no big change in cable tension when the RG is operated. • Check that no self-locking nut is used on any bolts subjected to rotation. • Check that there are no cables smaller then 3.2 mm in diameter used in the primary control system.	
Comment: Together with EAN we have agreed on not performing parts of the test because of priorities.	
Test report: Test_report_TC06_020511.doc	

Table 8: TC06

ID: TC07	**Covers requirement:** C37A	**Status:** Tested OK 06.05.2011
What: Test that the tire used in the RG system have an approved tire rating.		
How: Check the datasheet for the specific tire and find out if the tire ratings are exceeded.		
Comment:		
Test report: Test_report_TC07_060511.doc		

Table 9: TC07

3.3 System testing

ID: TS01	**Covers requirement:** N09A, N10A	**Status:** Tested FAIL 03.05.2011
What: Weigh the RGs to see that they do not exceed the maximum weight set.		
How: Use SW to perform FEM analysis to determine the weight.		
Comment: All the parts of the front RG are solid, while some parts of the rear RG are hollow. Most parts are supposed to be hollow. This will affect the result of the total mass significantly. It will be lighter in weight. The material chosen is only used for the simulation on SW. It doesn't need to be the material that will actually be used for the construction of the parts. Lighter materials can be used.		
Test report: Test_report_TS01_030511.doc		

Table 10: TS01

ID: TS02	**Covers requirement:** N11A, N13A, C36A	**Status:** Tested FAIL 21.03.2011
What: See that the size of the RG fits into the aircraft's body.		
How: Use SW to measure the total volume of the RG and compare this to the volume available inside the aircraft's body. We can also confirm this by assembling the prototype and see if the RG fits.		
Comment: The wings have been redesigned after the test report so they would be thicker. And this will not be a problem.		
Test report: Test_report_TS02_210311.doc		

Table 11: TS02

ID: TS03	**Covers requirement:** N12A	**Status:** Tested OK 16.03.2011
What: Measure that the distance between the lowest point of the aircraft's fuselage and the lowest point on the rim.		
How: Measure the distance in SW and on the small-scale prototype.		
Comment:		
Test report: Test_report_TS03_160311.doc		

Table 12: TS03

ID: TS05	**Covers requirement:** F22A, C32A, F31A, F32A, F34A, F36B, C12A, C13A, C14A, C17A, C18A, C19A, C20A, C21A, C28A, C29A	**Status:** Tested 18.05.2011
What: Test the strength of the RG system to see how much force we can apply before it break down		
How: • Use SW to perform a FEM analysis. By applying forces from different appropriate angles to the RG system, we can determine its yield strength. Do the same with the hatches to see if they withstand the force of the waterdrag. • Add a force equal to the air drag produced at max cruising speed. • Test the strength on the wheel covers by applying forces using FEM-analysis to see how much it can withstand before breakdown. • Test that there is points in the design where there are stress consentrations.		
Comment: Safety factors and load factors to use in FEM-analysis: The RG structure must be able to support all these safety factors and limits loads without getting detrimental permanent deformation. • The RG must withstand all the load factors produced when flying in an airspeed of $1.6V_{s1}$ • Safety factor of 1.5 must be used unless otherwise provided. • Minimum safety factor of 6.67 must be used on control surface hinges. • Minimum safety factor of 3.33 in control system joints. • Vertical limit load factor must be 1.33. • Limit side inertia factor must be a total of 0.83 1. 0.5 is acting inboard on one side 2. 0.33 is acting on the other side • For aft loads, the limit force component at the axle must be: 1. A vertical component of 2.25 times the static load on the wheel 2. A drag component of 0.8 times the vertical load • For forward loads, the limit force component at the axle must be: 1. A vertical component of 2.25 times the static load on the wheel 2. A forward component of 0.4 times the vertical load. • For side loads, the limit force component at ground contact must be: 1. A vertical component of 2.25 times the static load on the wheel 2. A side component of 0.7 times the vertical load		
Test report: Test_report_TS05_180511.doc		

Table 13: TS05

ID: TS06	**Covers requirement:** N34A, N35A	**Status:** not tested
What: Test the RG system and see how long it takes to release/retract.		
How: Measure the time the small-scale prototype uses when it extract/retract the gears		
Comment: Since we got the prototype in plaster, we can't connect a motor and therefore perform this test.		
Test report:		

Table 14: TS06

ID: TS07	**Covers requirement:** F16A, N37A	**Status:** Tested OK, 11.05.2011
What: Test how long time it takes to empty the wheel wells for water.		
How: Calculate the volume to the wheel well, fill equivalent amount of water in a bucket and make a hole, then see how long it takes to drain out. The hole must correspond to the opening in the wheel well for drainage of water.		
Comment: This test should be done with a full-scale prototype to provide a better result. The result of this the test is only a approximation, since a lot can influence the drainage.		
Test report: Test_report_TS07_110511.doc		

Table 15: TS07

ID: TS08	**Covers requirement:** C38A, F06A, F07B, F17A, F20C, F23C	**Status:** Tested OK 23.05.2011
What: Test the activation and indication system for the RG.		
How: • Use the activation system and see if the RG deploys when we use the deploy switch. At the same time see if the indication system works in accordance with the current position/movement of the RG. • See if the indication system shows that the RG is fully released. • Use the activation system and see if the RG retracts when we use the retract switch. At the same time see if the indication system works in accordance with the current position/movement of the RG. • See if the indication system shows that the RG is fully retracted • Test that the RG activation system cannot be activated before the security switch is activated • If the RG is malfunctioning it must be indicated to the pilot.		

Comment:	
Test report: Test_report_TS08_230511.doc	

Table 16: TS08

ID: TS09	**Covers requirement:** F03A, F05A	**Status:** not tested
What: Test that the RG system can be activated when the main electrical system and/or mechanical system are not working.		
How: On the prototype, see that the gears are falling out when the motors physically are disconnected from the rest of the system.		
Comment: To perform this test we have to have a finished prototype of the system with actuation.		
Test report:		

Table 17: TS09

ID: TS10	**Covers requirement:** C24A, F12A, C23A, C22A	**Status:** not tested
What: Test the brakes.		
How: As long as the maximum braking force needed for stopping the aircraft with maximum take-off speed is within the limit kinetic energy, the brakes are good enough. We have to calculate maximum braking force and look at the specification of the brakes by the supplier; the brakes must be strong enough to tolerate the forces we have calculated.		
Comment: Since the brakes for the RG system aren't decided yet, we can't perform this test.		
Test report: Test_report_TS10_250511.doc		

Table 18: TS10

ID: TS13	**Covers requirement:** F10C	**Status:** not tested
What: Test that the front landing wheel can be controlled from the cockpit.		
How: This is a test that has to be executed with the full-scale prototype.		
Comment: This test will not be executed because we will not make a full-scale prototype.		
Test report:		

Table 19: TS13

ID: TS14	**Covers requirement:** C09B, N04B, N07B, N08C	**Status:** Tested OK 14.05.2011
What: See if the visual and audible parts of the RG meet the customer's expectations.		
How: Perform a customer test where we ask the customer (EAN) if the system meet contract requirements and expectations.		
Comment: According to the new project goal, this test is approved		
Test report: Test_report_TS14_140511.doc		

Table 20: TS14

ID: TS16	**Covers requirement:** N03A	**Status:** not tested
What: Test that all electronic components are kept dry when the RG is exposed to water		
How: See if the box, containing the electronic components, is waterproof (without the electronic components inside).		
Comment: To perform this test we have to have a finished prototype. This will not be done because our scale prototype isn't in correct materials.		
Test report:		

Table 21: TS16

ID: TS17	**Covers requirement:** N28A, F21B	**Status:** Tested OK 23.03.2011
What: Find out where center of gravity is in the wing and place the wheel as far behind this point as possible and still have room for the whole RG in the wing.		
How: Have instructions to place it 25-30% in from the wing tip, must convert this into millimeters to find an exact distance and place the RG into the wing to see if it's room enough. As long as we place the wheel behind center of gravity, the wheel is stable when the aircraft is standing on the ground.		
Comment:		
Test report: Test_report_TS17_230311.doc		

Table 22: TS17

ID: TS19	**Covers requirement:** C34A, F15A	**Status:** not tested
What: Operation test		
How: Check that all the proper functions of the RG works. This includes the RG retracting and extracting mechanism and the indications system.		
Comment: Since we don't have a prototype that we can connect the motor and electric circuit to, we can't perform a final acceptance test. We refer to TS08 to show that the activation - and indication system works properly.		
Test report:		

Table 23: TS19

ID: TS20	**Covers requirement:** F18A, F19A	**Status:** not tested
What: Test that the RG retract/extract in water		
How: Calculate and choose an actuation method that is powerful enough withstand the resistance of the water to retract and extract the gears.		
Comment: This will not be done because our scale prototype will not be in correct materials. We choose to assume that if the actuation tolerate the resistance to retract / extract in the air with air resistance then it is also strong enough to retract / extract in water		
Test report:		

Table 24: TS20

ID: TS21	**Covers requirement:** F27A	**Status:** Tested FAIL 29.03.2011
What: Test that the tail of the aircraft don't touch the ground, when the nose is lifted with 15 degrees		
How: In SW, lift the nose of the aircraft with 15 degrees when RG is attached and extracted, and see if the tail touches the ground.		
Comment: Fuselage has been modified after this test, so this would probably be no problem.		
Test report: Test_report_TS21_290311.doc		

Table 25: TS21

ID: TS22	**Covers requirement:** F30A C33A	**Status:** not tested
What: Ensure that every locking mechanism in the system works		
How: In full scale, extract the wheels and apply a dynamic force on the RG to check that they are in a locked position. Apply the same force when the gears are retracted to check that they are locked inside.		
Comment: To perform this test we have to have a finished prototype. This will not be done because our scale prototype will not be in correct materials.		
Test report:		

Table 26: TS22

ID: TS23	**Covers requirement:** C31A	**Status:** not tested
What: Test the reserve energy absorption capacity of the RG.		
How: Simulate a descent velocity of 1,2 times limit descent velocity, and check if the landing gear fails.		
Comment: This test can't be performed before the materials are specified		
Test report: Test_report_TS23_180511.doc		

Table 27: TS23

ID: TS24	**Covers requirement:** F33A	**Status:** not tested
What: Test that the shock absorber function is able to absorb the weight transfer of the aircraft to the nose when decelerating		
How: Calculate the transmission that will affect the front RG when the aircraft is braking down. When we find this force, we inflict this on our system to see if it can withstand the strain.		
Comment: This test can't be performed before the materials are specified		
Test report: Test_report_TS24_180511.doc		

Table 28: TS24

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Abstract

The goal of this document is to give EAN a deeper insight of the possible alternatives of material that can be used for the construction of the RG mechanism.

Sammendrag

Målet med dette dokumentet er å gi EAN et dypere insykt av de mulige material alternativene som kan brukes for konstruksjonen av RG mekanismen.

Document history

Version	Date	Responsible	Changing
0.1	26.05.11	Jeremy Marchand	
0.2	27.05.11	Sindre D. Flaten	• Changed font on some of the text in chapter 2 • Added table number and name
1.0	27.05.11	Stein Erik Thoen	

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Definitions

Abbreviation	Extension	Description
EAN	Equator Aircraft Norway SA	Employer
RG	Retractable gear	
FRC	Fiber Reinforced Composites	Material structure

1. Introduction

The materials used for the RGs should combine the following properties:
- Light weight
- High strength
- Corrosion resistance
- Low price
- High flexibility

- Why light weight?

Weight is the first enemy of the aviation industry. The lighter, the better. The point is mainly to decrease the power needed to light the aircraft and hold it in the air. A weight reduction in the order of grams is worth a lot for our employer.

- Why high strength?

Bigger systems often withstand more than smaller systems. Unfortunately, the space available for the RGs is restrained, especially for the rear RG. A high tensile strength makes it possible to use little space and still be able to withstand the stresses and forces applied on the system.

- Why corrosion resistance?

The RGs will operate in water and therefore, they will have to be water and salty water resistant. This is in order to increase the reliability of the systems over time and to decrease the maintenance costs.

- Why low price?

The EqP2 is supposed to be accessible to a larger scope of customers; therefore, its price must remain low. This means also that the RGs must be lowest possible to produce, and in the same time, offer a good quality. This can be obtained by using cheap materials.

- Why high flexibility?

The damper function of both RGs is supposed to be obtained by the elasticity of the material used. Therefore, it must be flexible enough to permit this suspension.

2. Composites

Composite materials are some of the most common in today's industries and homes. These materials satisfy the need for performance, innovation and creation, while taking into account the very current ecological issues. At first sight, composites seem to have the qualities to fit the needs of our project.

The environment issues favor the use of composite material in the long term. They have ecological arguments in all steps of a product lifecycle (fabrication, construction, use, maintenance and recycling).

A fabrication phase generating less material loss and less waste is a constant preoccupation for most industries. Many aircraft producers are using composite materials instead of aluminum, which generate lots of waste.

2.1 Technical characteristics

Thanks to their qualities, composite materials have important advantages compared to traditional materials. They bring interesting combinations of functional advantages.

- Light weight (about 4 times lighter than steel)
- Good chemical and corrosion resistance without particular treatment or maintenance
- Exceptional mechanical resistance (better than steel)
- No plastic deformation (composite won't deform permanently)
- Long life material thanks to:
    - Flexibility
    - Mechanical and fatigue resistance
    - Corrosion resistance
    - Waterproof
- Improved security
    - Chock resistance
    - Thermal and electrical insulation

They also augment the possibilities of conception, lightening structures and making more complex forms that can fulfill more functions.

2.2 Material structure

A composite material is a material composed of two or more distinct phases.

- Matrix phase
- Dispersed (reinforcing) phase

The matrix phase has a continuous form, usually more ductile and less hard phase. It is used to hold the dispersed phase and shares a load with it.

The dispersed phase is embedded in the matrix in a discontinuous form. It is usually stronger than the matrix, therefore it is often called the reinforcing phase.

The two phases act together, each overcoming the deficits of the other. Whereas the matrix is strong in compressive loading and relatively weak in tensile strength, the reinforcing material is very strong in tension but have no strength against compression. By combining the two, composites resist both compressive and tensile forces well.
There are many factors that influence the properties of a composite.

- Matrix material
- Reinforcing material structure
- Anisotropy (orientation of the reinforcing structure)
- Percent (%) of reinforcing material
- Fabrication process
- Coating

Fiber Reinforced Composites (FRC) are today recognized as the best materials in order of weight to strength ratio. They also give tremendous fatigue, corrosion and wear resistance. The performance, stiffness and price vary from type to type. We have chosen to take closer look at the most effective types of FRCs:

- Glass fiber composite
- Carbon fiber composite
- Kevlar fiber composite

2.2.1 Angle and anisotropy

FRCs can be made of short discontinuous fibers (length < 100*diameter) or long continuous fibers. Fibers can be oriented in a random way, unidirectional way or bidirectional way. The two last mentioned will make the material more robust in the chosen directions (anisotropy). When a FRC consists of several layers with different fiber orientation, it is called a multilayer (angle-ply) composite. The angle between the two orientations of fibers also affects the properties of the composite.

0 degree (axial)
Makes tubes resistant to longitudinal bending and axial tension/compression

90 degree (hoop)
Resists internal/external pressure, helps a tube to stay round and provides consolidation in conventional filament winding

± 45 degree
The ideal fiber angle to resist pure torsion

Intermediate angles
Tubes seldom have only one load applied to them, therefore a tube will need at least 2 of the above angles need to be incorporated to carry the combined loads. Most combined loads can be carried with fibers at an intermediate angle.
e.g.
For Internal pressure the hoop stress is twice the longitudinal stress use approx. ± 55°.
For External pressure as above but to resist buckling use approx. ± 65°.
For Quasi-Isotropic laminate use ± 22.5° & ± 67.5° alternate layers.
For bending with torsion angles between ± 5° to ± 25° are appropriate.

2.2.2 Processes

There are a variety of manufacturing processes applicable to the production of composite tubes that could be used, especially in the context of the rear RG. The choice of process is influenced by the properties required, quantity, costs, etc.

Pre preg rolling
Layers of material are rolled around a mandrel, by hand or machine, prior to consolidation and cure.
When hard the outside diameter can be machined if required.
Ideal for smaller quantities and smaller tubes where increased material costs are less significant.

Pultrusion
A continuous process in which fibers in the form of rovings, mat or fabric are impregnated with resin and pulled through a heated die of the required shape, molding both the inside and outside diameters.
Uses raw materials in their most basic and lowest cost form, however large quantities need to be produced to justify the high tooling and set-up costs
Limited choice of fiber angle.

Filament winding
After impregnating with resin the fiber is wound onto a mandrel at the angle required to produce the mechanical properties.
Conventionally tubes produced in this way have a molded inside diameter, the outside diameter can be machined if required, after curing.

There are so many different ways of making a composite that standard properties for composite materials are not definable. Each production methods give different properties. This is by the way why the properties of composite materials are not defined in our version of Solidworks. This is also why the composite industry to this day is not well suited for mass production. Indeed, composite manufacturers usually propose to make a material that is tailored for your exact needs.

2.3 Glass fiber composites

Glass fibers reinforced composites (GRC) are characterized by the following properties:

- High strength-to-weight ratio
- High modulus of elasticity-to-weight ratio
- Good corrosion resistance
- Good insulation properties
- Low thermal resistance (as compared to metals and ceramics)

Glass fiber materials are used for manufacturing: boat hulls and marine structures, automobile and truck body panels, pressure vessels, aircraft wings and fuselage sections, housings for radar systems, swimming pools, welding helmets, roofs and pipes.

The two most common types of glass fibers are:

- **E-Glass** – the most popular and inexpensive glass fibers. The designation letter "E" means "electrical" (E-Glass is excellent insulator). The composition of E-glass ranges from 52-56% SiO2, 12-16% A1203, 16-25% CaO, and 8-13% B203.
  Modulus of elasticity: about 72,5 GPa
  Tensile strength: 2,4 GPa (typical steel: 400 MPa)
  Price: 2 $/kg
  Density: 2,58 g/cm^3

- **S-Glass** – stronger than E-Glass fibers (the letter "S" means strength). S-Glass is used in military applications and in aerospace. S-Glass consists of silica (SiO2), magnesia (MgO), alumina (Al2O3). It costs about 10 times more than E-Glass and does not always wet out clear.
  Modulus of elasticity: about 85,5 GPa
  Tensile strength: about 4,5 GPa
  Price: 20 $/kg
  Density: 2,46 g/cm^3

The most popular matrix materials for manufacturing fibreglasses are thermo sets such as unsaturated polyester (UP), epoxies (EP) and thermoplastics such as nylon (polyamide), polycarbonate (PC), polystyrene (PS), polyvinylchloride (PVC).

S-Glass being less reliable in water, we will concentrate on E-Glass.

Key properties of E glass fibers:
- Low cost
- High production rate
- High strength
- High stiffness

- Relatively low density (compared to traditional materials)
- Non flammable
- Resistant to heat
- Good chemical resistance
- Relatively insensitive to moisture
- Able to maintain strength properties over a wide range of conditions
- Good electrical insulation

Fiberglass				
Composition: Glass fibers reinforced polyester matrix composite				
Property	**Value in metric unit**		**Value in US unit**	
Density	$1.8 * 10^3$	kg/m^3	114	lb/ft^3
Tensile modulus (LW)	17.2	GPa	2500	ksi
Tensile modulus (CW)	5.5	GPa	800	ksi
Compressive modulus (LW)	17.2	GPa	2500	ksi
Compressive modulus (CW)	6.9	GPa	1000	ksi
Flexural modulus (LW)	12.4	GPa	1800	ksi
Flexural modulus (CW)	5.5	GPa	800	ksi
Tensile strength (LW)	207	MPa	30000	psi
Tensile strength (CW)	48	MPa	7000	psi
Compressive strength (LW)	207	MPa	30000	psi
Compressive strength (CW)	103	MPa	15000	psi
Flexural strength (LW)	207	MPa	30000	psi
Flexural strength (CW)	69	MPa	10000	psi
Shear strength (short beam)	31	MPa	4500	psi
Thermal expansion (20 ºC)	$8*10^{-6}$	$^oC^{-1}$	$4.4*10^{-6}$	in/(in* ºF)
Barcol hardness	45	-	45	-
Dielectric constant (60 Hz)	5	-	5	-

Table 1: Properties of fiberglass

*LW- Lengthwise direction, CW- Crosswise direction

2.4 Carbon fiber composites

Carbon fiber reinforced composites (CRC) are characterized by the following properties:

- Expensive
- Fantastic weight-to-strength ratio
- Very high modulus elasticity-to-weight ratio
- High fatigue strength
- Good corrosion resistance
- Very low coefficient of thermal expansion

- Low impact resistance
- Low abrasion resistance
- High electric conductivity

Carbon fiber is very expensive, but has a fantastic weight-to-strength ratio. Attempts to put it into mass production have so far failed, due to inadequate demand, the customized nature of most carbon fiber parts, and a lack of skilled craftsmen. The material is employed in high-quality cars, boats, bicycles, and planes, including Formula One racecars. Large commercial airplanes typically use carbon fiber composites, increasing the production, which is the decisive factor for the rapid growth of carbon fiber demand in recent years. Both private and public spaceship projects use carbon fiber as part of the craft's chassis.

Depending on the orientation of the fiber, the carbon fiber composite can be stronger in a certain direction or equally strong in all directions. A small piece can withstand an impact of many tons and still deform minimally. The complex interwoven nature of the fiber makes it very difficult to break.

In terms of weight-to-strength ratio, carbon fiber composite is currently the best material that our civilization can produce in appreciable quantities. Introducing carbon nanotubes into the fiber is currently in research stages, and may offer improved ratios of 10 times or greater – a space age material indeed. Carbon fibers are chemically “grown” on smaller frames with a high surface area, design to bond to deposited carbon atoms. The frame typically constitutes 2% of the total fiber produced.

If the cost of carbon fiber can be significantly reduced, it may become a universal material for vehicles and small products designed for extreme durability and lightness. The current strategies used for manufacture vary based on application and quantity.

2.5 Kevlar fiber composites

Kevlar is the trade name (registered by DuPont Co.) of aramid fibers.
Kevlar fibers were originally developed as a replacement of steel in automotive tires.

Distinctive features of Kevlar are high impact resistance and low density.
Kevlar fibers possess the following properties:

- High tensile strength (5 time stronger than steel)
- High modulus of elasticity
- Very low elongation up to braking point
- Light weight
- High chemical resistance
- Very low thermal expansion
- High impact resistance
- High cut resistance
- Textile processibility
- Flame resistance

The disadvantages of Kevlar are: ability to absorb moisture, difficulties in cutting, low compressive strength.

There are several modifications of Kevlar, developed for various applications:

- **Kevlar 29** – high strength (520000 psi/3600 MPa), low density (90 lb/ft³/1440 kg/m³) fibers used for manufacturing bullet-proof vests, composite armor reinforcement, helmets, ropes, cables, asbestos replacing parts.

- **Kevlar 49** – high modulus (19000 ksi/131 GPa), high strength (550000 psi/3800 MPa), low density (90 lb/ft³/1440 kg/m³) fibers used in aerospace, automotive and marine applications.

- **Kevlar 149** – ultra high modulus (27000 ksi/186 GPa), high strength (490000 psi/3400 MPa), low density (92 lb/ft³/1470 kg/m³) highly crystalline fibers used as reinforcing dispersing phase for composite aircraft components.

Kevlar filaments are produced by extrusion of the precursor through a spinner. Extrusion imparts anisotropy (increased strength in the lengthwise direction) to the filaments.

Kevlar may protect carbon fibers and improve their properties: hybrid fabric (Kevlar + Carbon fibers) combines very high tensile strength with high impact and abrasion resistance. The most popular matrix materials for manufacturing Kevlar (aramid) Fiber Reinforced Polymers are thermosets such as epoxies (EP), vinylester and phenolics (PF).

Kevlar (aramid) Fiber Reinforced Polymer				
Composition: 50% Kevlar (aramid) unidirectional fibers in epoxy matrix				
Property	**Value in metric unit**		**Value in US unit**	
Density	$1.4 * 10^3$	kg/m³	87	lb/ft³
Tensile modulus (LW)	76	GPa	11000	ksi
Tensile modulus (CW)	5.5	GPa	800	ksi
Shear modulus	2.3	GPa	330	ksi
Tensile strength (LW)	1400	MPa	203000	psi
Tensile strength (CW)	12	MPa	1700	psi
Compressive strength (LW)	235	MPa	34000	psi
Compressive strength (CW)	53	MPa	7700	psi
Shear strength (LW)	34	MPa	4900	psi
Thermal expansion (20 ºC, LW))	$-4*10^{-6}$	ºC⁻¹	$-2.2*10^{-6}$	in/(in* ºF)
Thermal expansion (20 ºC, CW)	$80*10^{-6}$	ºC⁻¹	$44*10^{-6}$	in/(in* ºF)

Table 2: Properties of Kevlar

*LW- Lengthwise direction, CW- Crosswise direction

3. Composite comparison

Glass fiber composite primary advantage is the low price, but if we assume that strength-to-weight ratio is the material property with the most grade of importance in this project, carbon fiber composite is the winners of this contest.

Carbon fiber composite and Kevlar fiber composite are quite even on tensile strength. However, carbon fiber composite is better in compressive strength. This gives carbon fiber composite a big advantage, as most our parts are subjected to compressive strength rather than tensile strength. Nevertheless, Kevlar fibers can be mixed with other fiber types in order to make a composite material with better compression strength.

Kevlar fiber composite primary advantages are:

- Resistance to fracture as they have a high ability to absorb impact energy
- Flexibility due to a low young's modulus
- Better abrasion resistance than carbon

The abrasion resistance of carbon fiber is a con compared to the one of Kevlar or glass fiber. It means that parts most subjected to important mechanical wear should not be made of carbon fiber composite unless it is coated against such wear. A solution might be carbon fiber composite protected by layers of Kevlar.

The stiffness of carbon fiber composite limits the damper function of the material that we intend to use. Glass fiber composite on the other hand can undergo more elongation before it breaks.

Below is a table that resumes the different properties of the 3 specific fiber composite we have been studying in this document.

Property	Aramid	Carbon	Glass
High Tensile Strength	B	A	B
High Tensile Modulus	B	A	C
High Compressive Strength	C	A	B
High Compressive Modulus	B	A	C
High Flexural Strength	C	A	B
High Flexural Modulus	B	A	C
High Impact Strength	A	C	B
High Interlaminar Shear Strength	B	A	A
High In-plane Shear Strength	B	A	A
Low Density	A	B	C
High Fatigue Resistance	B	A	C
High Fire Resistance	A	C	A
High Thermal Insulation	A	C	B

High Electrical Insulation	B	C	A
Low Thermal Expansion	A	A	A
Low Cost	C	C	A

Table 3: Fiber composite comparison

*(Key: C=Poor, B=Good, A=Excellent)

4. Conclusion

The fiber composites we have studied in this document can be used in the context of our project. However it is important to know where and when to use them:

- Use Glass fiber composite when price matters most.
- Use Carbon fiber composite on parts that are less probable to be afflicted chocks, parts that are less subjected to abrasion.
- Use Kevlar fiber composite on parts that require flexibility and impact strength, parts that are less subjected to compressive strength.

For the most critical parts, hybrid fabrics of Carbon + Kevlar fiber composite is the most complete solution. Kevlar and carbon fibers complete each other to combine a super composite that has both compressive and tensile strength, abrasion resistance, flexibility and impact strength.

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Economy Document

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Abstract

This report explains the budget for our project (RG), that we used during the project. We have so far spent less than we budgeted for, but we are not far away. Regarding the 3D printing, we have not received an exact amount, since this was done by an affiliate of EAN.

Sammendrag

Denne rapporten forklarer budsjett for prosjektet (RG) som vi brukte i løpet av prosjektet. Vi har foreløpig brukt noe mindre enn det vi budsjetterte til, men vi er ikke langt unna. Ang 3D printing har vi ikke fått noen eksakt sum, siden dette ble gjort av en samarbeidspartner av EAN.

Document history

Version	Date	Responsible	Changing
0.1	26.05.11	Sakariya Hassan Dahir	
0.2	26.05.11	Stein Erik Thoen	Layout and corrections.
1.0	26.05.11	Stein Erik Thoen	

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Table of figures

1. Introduction

This document should give the reader a good insight in what this projects economical situation is. The document includes the estimated budget we handed in before first presentation. This is compared with the actual amount of money we have used.
It also contains the purchasings, the different suppliers that we used and transportation costs.

2. Estimated Budget

It is specified in the contract between BUC and EAN that EAN will cover all expenses regarding the project. We have made the budget on the basis of what is used in former project. In addition, we have been doing some research on what components generally costs and organizations expenses.

Description	**Costs in NOK**
Organization	3850 NOK
Component /Material	12 000 NOK
Total	**15 850 NOK**

Table 1: Budget

The above table shows the organizations budget, which contains all of the expenses of presentations, documentation and transportation, etc. Also, it shows the components/material which cover all expenses regarding production of special parts, 3D printer prototyping and El-components.

2.1 Purchasing

After the estimated budget got approved we had little time to discuss and decide the materials that we need. The components that we needed for the prototype we ordered with Rebaz´ address, but the El-component we listed the all the component that we needed and ordered with the Sindres address. After we where to create a circuit boards layout and we needed more components, then we went to Oslo to pick up all the components that we needed from ELFA.

3. Financials

The following tables explain the suppliers and transportation that we used during the project.

3.1 Suppliers

We used two suppliers when we ordered different component during the project period. Eldevik Industri Design and ELFA.

3.1.1 Eldevik Industri Design

Equator Aircraft Norway has been working with Eldevik Industri Design before and it was natural to use them when we needed 3D print of our design.

3.1.2 ELFA

ELFA is one of the largest electronic distributions in North Europe and has 60 years of experience from electronic distribution. ELFA also has a web shop with the guarantee that they send the items same day you order if you order before 17:00.

3.2 Transportation

We have used our own cars and we agree that the Equator Aircraft will cover fuel expenses. The following table shows how we calculated the transportation expenses.

Fuel prize	Fuel consumption	Total Km	Total NOK
13 NOK	0.5 liter pr 10Km	1340.96 Km	**877.25 NOK**

Table 2: Transportation

3.3 Expenses

The following list is the budget that we used the whole project, except from the last presentation.

Date	**Kind of bills**	**Finance person**	**Amount NOK**
05.01.11	DVD+R	Rebaz Aziz	85,00 NOK
05.01.11	Book binding	Sindre D.Flaten	90,00 NOK
10.01.11	Presentation cafe	Jeremy Marchand	95,00 NOK
07.04.11	El-components	Sigbjørn G.	661,00+259,45 NOK
30.04.11	Various for 3D print	Sindre D. Flaten	132,70 NOK
03.05.11	Wood for prototype rig	Stein Erik Thoen	126,27 NOK

04.05.11	Various for 3D print	Sindre D. Flaten	71,60 NOK
05.05.11	Various for proto rig	Rebaz Aziz	61,50 NOK
11.05.11	Various for prototype	Stein Erik Thoen	69,70 NOK
16.05.11	Skruer, maling etc.	Jeremy Marchand	371,40 NOK
28.04.11	3D Print	Equator Aircraft Norway	10.000 -15.000 NOK
20.05.11	Transport/bensin		877,24 NOK
30.05.11	Printing documents	Rebaz Aziz	1443,24 NOK
Total			**14344,10 -19344,10** NOK

Table 3: Expenses

Because we do not have fixed prize of the 3D printing, we use both different prizes of total costs.

3.4 Summary

The tables below show the sum of the budget that we estimated and the amount that we spent during the whole period of the project.

Organization Budget	
Budget	3850 NOK
Used	2590,48 NOK
Rest	**1259,52 NOK**

Table 4: Organisation summary

Component budget	
Budget	12000 NOK
Used (prize of 3D printer varies)	11753,62-16753,62 NOK
Rest	**246,38 - -4753,62NOK**

Table 5: Components summary

4. Conclusion

Because we did not get Equator aircraft exact prize for the 3D printer prototype the prize of components is varies, if we use the minimum prize of 3D printer prototype that we saved 246,38 NOK, if we use the max prize, we need 4753,62 NOK extra. But we used organizations budget less then that we estimate and we saves 1259,52 NOK.

Post project evaluation

Buskerud University College, Department of Engineering Institute of Technology

Equator Aircraft Norway SA

Document responsible: Rebaz Aziz
Version 1.0
Date: 27.05.11

Internal guidance councilor: Øyvind Eek-Jensen

Rebaz Aziz	Jeremy Marchand	Stein Erik Thoen
Sindre D. Flaten	Sigbjørn Gunnerød	Sakariya H. Dahir

Abstract

Our project team has evaluated the thesis that has been carried out during the 2010/2011 semester.

It appears in the documentation that the task hasn't gone completely as desired. The parameters of the thesis have been changed during the life time of the project. This results in work being done over again, and led to frustration within the group.

Some misunderstandings during the project have resulted in us not being able to do the tasks that we originally had set for us. Which again then results in the solution may seem simple.

The part of the assignment that deals with project management was somehow vague. Something we wish we could have learned more about to practice better before the task began.

The communication with our internal and external guidance councilors has been good. The time from a question being asked until it is answered has been short, something that has helped us as a group to make decisions fast. The dialogue within the group has also been well.

Finally, we have allowed each member of the group to reveal his own views on the main project, so that no voices to go unheard.

Sammendrag

Vi har som prosjektgruppe evaluert arbeidet som er blitt gjennomført i løpet av hovedoppgave peridoen 2010/2011.

Det kommer fram av dokumentet at oppgaven ikke har gått helt som ønsket. Oppgavens parametere har stadig blitt endret underveis, noe som har ført til frustrasjon og mye omgjøring av våre løsninger.
Misforståelser i løpet av prosjektet har resultert i at vi ikke har fått gjort de oppgaver som vi opprinnelig hadde satt for oss. Noe som da igjen resulterers i at løsningen kan virke noe enkel.

Den delen av studiet som omhandler prosjektstyring, var noe vag i og med at ingen på gruppen hadde hatt et slikt studie tidligere i utdanningen, noe vi ønsker vi kunne ha lært mer om å praktisere før oppgaven ble påbegynt.

Komunikasjonen med våre interne og eksterne veildere har vært meget god. Tiden fra et spørmål var stillt til det vi fikk svar på det har vært kort, noe som har hjulpet oss å foreta avgjørelser fort. Dialogen innad i gruppen har også vært god.

Til sist har vi latt hvert enkelt medlem av gruppen få fram sitt eget synspunkt på hovedprosjektet som er gjennomført, slik at ingen stemmer skal gå uhørt.

Document history

Version	Date	Responsible	Changing
0.1	26.05.11	Stein Erik Thoen/Sindre D. Flaten	
0.2	27.05.11	Rebaz Aziz	• Controlled spelling • Added abstract
1.0	27.05.11	Rebaz Aziz	

Table of content

Definitions

Abbreviation	Extension	Description
EAN	Equator Aircraft Norway SA	Employer
EQP2	Equator P2 Excursion	The aircraft now under development by EAN
RG	Retractable Gear	
BUC	Buskerud University College	
CS-23	Certification Specifications 23	Certification Specifications for Normal, Utility, Aerobatic, and Commuter Category Airplanes.
FEM	Finite Element Method	Software method of analysis

1. Introduction

In this document we will evaluate the project, its result and the work progress. It will also include an individual evaluation from each group member. The document is an ending to the project and is made so supervisors and sensor can see our opinion of the project.

2. Evaluations

2.1 Assignment

Our project assignment was given to us by Equator Aircraft Norway (EAN). The goal of the assignment was to develop a retractable gear for a small amphibious aircraft. At first the project seemed manageable and we though that we could develop a good working prototype for both the front and the rear RG. Later on we found out that the product development phase took longer time then expected. This resulted in us having to cut down on what was going to be done in the project.

The project group consisting of students from two fields, mechatronics and product development, that had no/or little knowledge about aviation or aircraft construction. Therefore we had to start the project by reading a lot about general aviation. When developing our product, both the actuation circuit and the RG, we have used the technical knowledge that we have learned at BUC. This has been something that was important to use from the start.

The different solution and final concept for the RG system have been presented for EAN through out the project. In this way the group and EAN could discuss the different solutions and we could get an approval on which design to go further with. This form of working also gave EAN a design that they liked and saw a potential in.

The assignment has given us many challenges in both the mechanical and electrical part. We have learned a lot about aviation and how to proceed with and design and development assignment.

EAN also wanted all documentation to be done in English, this was challenging for us since we have never made a report of this size in English.

2.2 Subject

The bachelor assignment was a subject that started in the fall semester of 2010 and went on through the spring of 2011. The main load of the work was done during the spring semester, as we only had two other subjects this semester. The bachelor project period started with the internal sensor having a course in project management and methods used. This was very helpful as none of us had any real experience with project work of this size.

There could maybe have been more of this kind of lectures earlier in bachelor course. For instance to have a subject in the second year of our education that could focus more on project management would have helped a lot.

In all, the bachelor project as a subject has been exciting. We as a group have learned much about project managing and how to work in a larger group with and assignment. It has also been educational and challenging to work with a company that is under development.

2.3 Project result

There where some misunderstanding during the 3D printing, where we thought that the print was going to be in plastic, but when we received it, the parts where in plaster. We were also expecting both front and rear gear to be printed in 50% scales, the rear gear was printed in 80%. This surprised both us an EAN, and it meant that we could not run the gear up and down with a motor. The plaster will crack if affected with to much force. When we could not us the large model with the motor and controller, we decided on constructing another smaller model, which shows the principle of the motor controller and indication system. This model was just made of modified easy to get materials.

2.4 Targets

One of the targets we did not get to finish was creating a half scale working prototype. This is mainly because we did not get the prototype printed as expected, and when we found out this, we did not bother finding motors and actuation mechanism that fitted. We rather focused on creating the 3D models of actuation, and a smaller prototype, just for showing the motor controller.

2.5 Economics

The financial matter in this project has been taken care of the group members up to this point, and we have shared the expenses within the group, until we get money back. We have not had any large expensed except from the 3D printing. The components for the electrical circuit where bought in small quantity and we chose inexpensive parts.

2.6 Collaboration

This project has needed a lot of collaboration, especially during the starting phase of the project when we decided on a design. There have been loud discussions where all members where trying to get their opinion through, but we believe this have given an even better final design.

2.7 Organization

2.7.1 Internal guidance councilor

Øyvind Eek Jensen (associate professor) from the department of technology was assigned to us as our internal supervisor on this project. Øyvind teaches in computer subjects and both the group and he was not overwhelmed, that he had been assigned as our guidance councilor. The reason for this is that, our assignment is a mechanical and electrical assignment. Therefore it would have been better for the group to get a guidance councilor that has some insight in these subjects. So to get technical help at school we had to ask other teachers.
Other than that our communication with Øyvind has been good.

Øyvind has provided us with advises on the documentation, presentations and the general project management. We have tried to take this information and use it in the best possible way. Through the project we also have tried to keep Øyvind updated on what the group is doing.

2.7.2 External guidance councilor

Tomas Brødreskift has been our external guidance councilor, but other members from EAN have also helped us through the project. Knut Brødreskift have helped us whit both the electrical and mechanical part. Rajeev Lehar has helped us with questions about FEM analysis and Øyvind Berven has given us advice on aircraft related questions.

Our guidance councilors from EAN are manly located in the Oslo area, so there have been some challenges from both sides regarding meeting appointments. Much of the communication with Tomas and EAN was done over e-mail and through phone conversations. Our perception is that this communication form has worked well for both the group and EAN. E-mails with questions that we have send to Tomas has been answered quickly, something that is important when we don't have the opportunity to meet as often.

EAN's dedication to the assignments and the product we have produced, have boosted our moral and helped us stay enthusiastic about aircraft construction through the whole project.

3. Individual evaluations

3.1 Rebaz Aziz

At the beginning of this assignment, I believe the ambition level from both EAN and I was really high. But we both soon faced facts and started to realize, after we had been working with the initial papers that were supposed to be handed in before the first presentation, that this assignment is larger in both size and knowledge level, than both EAN and I had the ability to comprehend at the beginning of the collaboration.

Starting off with my task of planning the progress that the rest of the group is supposed to follow, gave me new challenges that were exiting and interesting. But I soon realized that progress planning in a project of this size takes both time and experience to master. After several attempts trying to plan the progress for both the mechanical and electrical parts of the assignment, while trying to master software that I haven't worked with before, I believe that the final result is good enough, being the first time for me.

Being the leader of this group, I haven't been able to follow up on the project plan as much as I would have liked to. There are several reasons for this; among these are that the assignment of developing a design took longer time than first estimated. Secondly I have been spending my time designing in solid works, calculating, analyzing test results and controlling work that has been made by my fellow students. I also have been spending my time delegating tasks to members of the group, so that we could work in a manner that could produce results in the shortest time possible.

I know that we haven't been able to meet the goals that our employee gave to us in the first place, but the product that we have produced is valuable to them, in the manner that when taking up the assignment of developing the landing gear for the airplane, they don't have to go through all of the work that has to be in place at the beginning of a assignment like this. We have made it easier for them thinking of requirements, use cases, possible solutions on how to solve the task for their product and ideas on what will work and not.

Thinking of the communication and cooperation within the group, we have had a good dialogue from the beginning, and given every member of the group the right to participate in decisions that has been made during the lifetime of the project. Off course it been times of discussions were the decibel level has increased significantly, but that's how it is when the participants are passionate about the assignment.

Finally I can say that overall I believe this project is a success both for us and our employee, thinking of how the project has evolved during its lifetime. At the beginning both sides didn't have much knowledge on how much work it is developing a new groundbreaking product for the aviation industry. But at the moment of hand over of documents, when we (the students), can say that we are finished with our assignment. I believe our employee is one step closer to have a final product on their airplane. And we can say that we are done with one of many iterations which it takes to develop a product like this.

3.2 Sindre D. Flaten

The Bachelor project started fall 2010 and ended 07.06.2011. The project group consisted of 6 students, three students from mechatronics and three students from product development.

Our assignment was to develop a retractable gear we initially divided the group into to parts. One half of the group would focus on the electrical system for the RG and the other part would focus on the mechanical part. We later found out that it would be much easier for us to find a design if the whole group focused on finding good design solutions. I think this was a good decision, because we came up with several designs that had big potentials. The group members communicated well through the brainstorming period of the project and we had many discussions that helped us improve the design we had come up with. We also had several discussions with EAN that I think helped the brainstorming process.

Since we used more time, than planned, to find the right design for our RG, we had less time to develop the chosen design further and also to perform the test we initially planed to do on the design and in the project.

We also used more time one the requirement specification than planned. This also gave us less time on other tings. But I feel that this could be helpful for EAN when they are developing our RG solution further. Because we now have put the requirements they had, and other requirements from CS-23, into one document it will be easier to follow them when they are building the RG for the first time.

Through out the project my main focused was on the electrical part for the RG and the actuation. Initially we all focused on the design to find the best design. On the electrical part I helped make the control circuit and write the program code for the microcontroller. The actuation systems was done in the same way that we did the design process, were we came up with different ideas and sketched them down.

I think in general the group communication was good throughout the whole project. At the beginning we decided to meet at school at 9 o'clock every day that we planned to work on the bachelor project. This did that we all knew what the other persons in the group was doing, and we could easily help each other out or have a discussion if we needed that. This agreement was over held very well through the project.

The product we have produced have a lot of potential in my mind. We have come up with a solution for an RG that I don't think already exists and it also fulfills some of the requirements that EAN gave to us.

From this project I have learned that a design process take much more time than you have planned. We always come up with "better" solutions for a product and then we often have to use some time to change the design. And it's not always we have that time to do that.

3.3 Stein Erik Thoen

The result of the project has been a design of both front and rear gear for the Equator Aircraft Excursion P2. We have come up with actuation methods and emergency operations that we are pleased with. There is still some work on detailing the actuation methods that we not had time to do. Even though in the beginning of the project our goals where somewhat higher than what we have come up with, I believe that what we have achieved the main task of the project. There where some difficulties with the determination of the design both front and rear, and this meant less time on the actuation and control system design.

In the beginning of the project I worked mainly with SolidWorks modeling. Although I am a mechatronics student I have had SolidWorks as an optional subject worked closely with the mechanical team in the design phase of the project. I have learned a lot of new features in the software and believe it has given me more knowledge in the mechanical subjects. When the design for the gear were set, I worked with the two other mechatronics student deciding on actuation method and design of a control system. The motor controller circuit and its components have been a collaboration within the mechatronics team of the group

Since our task mainly was mechanical, and our group consists of half mechanical- and half mechatronics students there where some discussions on how this will effect the project for us none mechanical student. This however was no problem once we got started, and we saw that all group members came up with suggestion on the design.

Our group manager have been running the project with a loose hand, and has gives us responsibility to finish task in time. At times there have been some delays mainly due to questions we have had, and time it took to get them answered.

3.4 Sigbjørn Gunnerød

I will first say that I am very grateful for having been allowed to work on a task like this. When we got this assignment, I didn't have much clue of how aircraft are generally designed and functions today. As time has passed, the interest has increased and I now feel I have fairly good insight of what aircraft development actually involve. It has required a lot of research on existing solutions to find the strengths and weaknesses to make our solution as good as possible. I have spent a lot of time on research which has resulted to that I have had many ideas that I have presented to the group. This has been ideas like the original sliding design, development of the electrical circuit and various actuation methods that the group further has worked with and found improvements to. After seeing how many different solutions there actually are today in according to RG, it also makes me quite proud of taking part in developing two completely new design solutions that in my opinion meets the requirements of EAN in a good way.

We used relatively long time in the concept phase, before we got the go ahead working on one front gear design and one rear gear design. This was mainly because of EAN had a wish that our concepts actually were so good that they could fit EQP2 and the vision they have for the aircraft from an early state. And when the concepts first were determined, we could concentrate more on calculations and how it could be solved according to both the electrical and mechanical. Then we split into working on more individual tasks, which led to more efficiency in the group. I started with designing the electrical circuit primarily regarding to the functional prototype. We had no specific requirements on how this should be, so I made the logic as easily as I could. After the components were ordered my job was primarily about finding good actuation solutions then wiring and troubleshooting the electrical circuit.

When it comes to problems that have come along the way, I feel we've had a good dialogue with the employer. All external resources from EAN have helped us a lot getting a good understanding and making it possible for us to progress in the process. The availability of teachers in school has in my opinion been worse. It has happened we have been stuck with some calculations on both the electrical and mechanical that some teachers probably could have helped us with, but have not been available or had time to helping us. Internal supervisor has been flexible when it comes to meetings and has given us feedback on the project and the documentation, which we also agreed from the start since he is otherwise a bit outside of the project area in terms of the technical. It has also been a challenge to work with a aircraft that isn't fully constructed, considering that things change all the time, and we must adapt ourselves for the measures of the aircraft we are given.

I believe we have achieved our goal of getting a solid product, although several things were not quite as planned from the beginning and that we unfortunately didn't get a motor on the 3D-model since it was more fragile than we expected since we got the model in plaster instead of plastic. I hope and believe that this project has had a good utility for EAN and look forward to following the development of EQP2 in the future and hopefully see our concept on the finished aircraft.

3.5 Jeremy Marchand

As a group, we have been very connected by meeting at school every weekday and work together. There have been many discussions where everybody has participated. Decisions were mostly taken by the whole group and no one has been set aside. This spirit was successful in the brainstorming and designing phase.

However, when it comes to documentation, we have met difficulties to distribute tasks in order to work effectively. After working so much in group in the first part of the project and taking decision together, I found it especially difficult to focus on my own tasks. Deadlines were not always respected. I also feel this is general for the group.

We have been quite ineffective in our documentation work, mostly, I think, because we discussed so much about our decisions and forgot to put it down on paper. It was more difficult to remember what we actually agreed on in detail, and it felt pretty unstructured. This is for me the main reason why it has been so stressful now in the end.
Else, it has been very pleasant to be in this project. I've learned to set theory in practice and learned more about how the life in a project is.

3.6 Sakariya H. Dahir

As I am mechanical students and our task was mainly design process, firstly, I worked on designing research and I collected the information through books, online and previous researches. That makes easy for our group to understand and get good ideas about the all project requirements.

Secondly, I designed the concept that we got from the group`s idea and see how it works both mechanically and actuating method, considering the EAN requirement and international aircraft requirement CS-23.

Thirdly we decide the suitable concept that we need to use. Also, I worked on design our product with other mechanical students. Finally, when we came up with our product, then I worked the calculation front gear that was the biggest challenge we had on the project assignment and to participate the rear gear calculation.

It was very big challenges for us of both front gear and rear gear that we work very hard and corporation of all groups. The most challenge that we had our task was to fulfill the EAN requirement such like actuating method, weight and place of the retractable gear.

Our group team have make easier for us to work as a team and give us responsibility that we finish the task before the deadline. I believe we reached our achievement that we had with group and the great help and advice of our respectively supervisors and sensors and EAN will satisfied the result of the task.

5. Conclusion

Although it took some time getting a final design to work further on, we believe this project have given a lot of information to EAN on a retractable gear design which they can use in the EQP2. We have come up with two designs, actuations methods for both and a motor controller (control system) with indication system.

We would have hoped to get further on the actuation methods and detailing the components but our time ran out.

6. References

6.1 Literature

Prosjekthåndbok, Høgskolen I Buskerud, Torbjørn Strøm & Olaf Hallan Graven, Avdeling for teknologi, 2010