THOR
TACTICAL HEAD-MOUNTED OPERATIONAL RESOURCE

Författare: Oskar Varland

Maskiningenjörsprogrammet
Högskolan i Halmstad

Handledare: Lars Bååth

Examinator: Aron Chibba

Halmstad den 24 maj 2011
Abstract

By 2017 a program called Future Soldier will be implemented in the Swedish armed forces. Future Soldier is a program that will focus on making the soldier a more effective and better unit. What makes the THOR-system unique is that it is built around the soldier instead of building the system for the soldier. The user is the one in focus and everything has been adapted for the soldier and not the other way around.

By using the latest materials and technology the THOR-system will be more effective and modern than helmets used today. The system will allow the army to use fewer soldier but more effectively. Users can also feel safe since higher ballistic protection is achieved with the THOR-system.

The THOR-system will be exhibited at the Future Defense & Security exhibition in Stockholm in December 2011.
Foreword

THOR is a bachelor thesis carried out by Oskar Varland, a student in mechanical engineering at Högskolan i Halmstad. The thesis has been done in collaboration with Tenderteq AB.

A big thanks to everybody who has helped making this thesis a big success. First of all Petter Hegnelius at Tenderteq AB for this opportunity and helping with resources and knowledge.

Paulo Kiefe at Creativetools AB for help with developing a full scale prototype.

A big thanks to everybody at Högskolan i Halmstad and especially Lars Bååth who has been my mentor during this thesis.

This project has been an incredible journey to conduct where I have gained new knowledge; especially in how complicated it is to design a new system and how time consuming different tasks are. A great insight has been how important it is to have a good social network.

_____________________

Oskar Varland
## Table of Contents

1. Introduction .......................................................................................................... 1  
   1.1 Background .................................................................................................... 1  
   1.2 Company presentation ................................................................................... 1  
   1.3 Problem description ....................................................................................... 1  
      1.3.1 Weight ..................................................................................................... 2  
      1.3.2 Mobility .................................................................................................. 2  
      1.3.3 Function .................................................................................................. 2  
      1.3.4 Comfort ................................................................................................... 2  
      1.3.5 Protection ................................................................................................ 3  
   1.4 Aim ............................................................................................................... 3  
   1.5 Objective ........................................................................................................ 3  
   1.6 Scope .............................................................................................................. 3  

2. Project description ............................................................................................... 4  
   2.1 Stakeholders ................................................................................................... 4  
      2.1.1 Primary Stakeholders .............................................................................. 4  
      2.1.2 Secondary Stakeholders .......................................................................... 4  
   2.2 Requirements ................................................................................................. 4  
   2.3 Financing & ownership .................................................................................. 4  
   2.4 Project organization ....................................................................................... 5  
      2.4.1 Project members ..................................................................................... 5  
      2.4.2 Supervisors .............................................................................................. 5  
      2.4.3 Suppliers ................................................................................................. 5  
   2.5 Schedule ......................................................................................................... 5  
   2.6 Risks ............................................................................................................... 5  

3. Methodology ........................................................................................................ 6  
   3.1 Fact Gathering ................................................................................................ 6  
      3.1.1 Novelty search ........................................................................................ 6
3.1.2 Interviews

3.1.3 Need assessment

3.1.4 Guidance & meetings

3.2 Communication

3.3 Idea generation

3.4 Specification of requirements

3.5 Materials

3.6 Prototype development

3.7 Tests

3.8 Tools

3.8.1 SWOT

3.9 Reconciliation

3.9.1 Supervisor meeting

3.9.2 Company

4. Market Analysis

4.1 Market

4.2 Interviews

5. Specification of requirements

5.3.1 Weight

5.3.2 Design

5.3.3 Comfort

5.3.4 Technical

5.3.5 Ballistic

6 Design

6.1 Design propositions

6.1.1 Proposition 1

6.1.2 Proposition 2

6.1.3 Proposition 3
9. Results................................................................................................................ 29
  9.1 Design .......................................................................................................... 29
  9.2 Components ................................................................................................. 29
  9.3 Material ........................................................................................................ 29
10. Conclusion ....................................................................................................... 30
11. Discussion and recommendation ................................................................. 31
12. Critical Review ................................................................................................ 32

Appendixes

Appendix 1 Product definition  
Appendix 2 System Requirements  
Appendix 3 Functional Requirements  
Appendix 4 Performance Requirements  
Appendix 5 Project Organization  
Appendix 6 Gantt Chart  
Appendix 7 Need Assessment  
Appendix 8 SWOT  
Appendix 9 Ops-core  
Appendix 10 Gentex  
Appendix 11 Rabintex  
Appendix 12 Land Warrior  
Appendix 13 FIST  
Appendix 14 FELIN  
Appendix 15 MARKUS  
Appendix 16 Drawing 001  
Appendix 17 Drawing 002  
Appendix 18 Drawing 003  
Appendix 19 Drawing 004  
Appendix 20 References
1. Introduction

1.1 Background

In collaboration with Tenderteq AB a new helmet system which keeps the user in focus has been designed. By keeping the user in focus when developing features and the design, a much more effective and user friendly helmet can be achieved. The helmet system is a new high technology system that uses the latest materials and components to take the soldier into a new era in tactical operations.

Helmets of today are outdated and ineffective which makes new helmet system a high priority for the armed forces all over the world.

Sweden’s police force and armed forces are in absolute need of a new helmet which can aid and protect them in difficult situations. So a new helmet system which implements new high technology functions is a well needed product.

1.2 Company presentation

Tenderteq AB has its main office in Älmhult, Sweden with a second office located in Malmö, Sweden. Tenderteq AB is a consultancy firm and its main task is to help foreign companies enter bids for contracts to FMV, Sweden’s Defense Material Administration and other contractors. They have close contact with Sweden’s armed forces, police and task forces since they provide them with the state of the art protection and tactical gear. Tenderteq AB is an authorized reseller for many foreign dealers, which sells modern protection gear and tactical equipment.

1.3 Problem description

Today’s helmets are outdated with one function: protect the user against shrapnel, explosions and gun fire. The weight and ergonomics of today’s helmets are substandard and the users experience neck pains, discomfort and pressure to the skull.

Beyond these problems the overall design of the helmets today are old-fashioned and does not use the helmet form factor to its favor.
1.3.1 Weight
A big problem with the helmets today is their weight, as an example a helmet today can weigh 1.5 kg, which puts a significant strain on the user’s neck and back during long periods of wearing the helmet. Heavy helmets also contribute to more excessive injuries upon an impact, several cases of whiplash injuries has been recorded by the Swedish police.
Reference: Petter Hegnelius Tendertiq AB

1.3.2 Mobility
A soldier in combat must be able to quickly and effectively adapt to the situations they are in, whether it means ducking for cover, breaching a building or strolling through a village. Helmets today are big and bulky which can prevent the soldier from reaching a safe point or to stay unnoticed.

1.3.3 Function
The helmets primary function is to protect the user and everything else comes in second hand. More and more functions, such as integrated cameras, Wi-Fi, GPS etc, are being used by the armed forces and today’s helmets are not built for these functions.

1.3.4 Comfort
Many of the helmets today are uncomfortable for the user to wear for long periods of time, since it has not been adapted to the user’s specific head size. In warm surroundings the helmet will act as an oven and the user can easily become overheated and while in cold surroundings the helmet will not keep the user warm.
1.3.5 Protection
Helmets today gives the user a good protection but at the cost of weight. Most helmets today are NIJ level III certified. More information about the helmets used today can be read in appendix 9, 10, 11.

1.4 Aim
THOR – Tactical Head-mounted Operational Resource will offer extraordinary protection and give the soldier higher awareness of the surrounding situation. Keeping the soldier calm and on alert with vital pieces of information will aid them in making only the right decisions.

1.5 Objective
The following objectives have been established for the THOR-system.
- In may 2011 have a system proposition that will act as a base for further development
- In May 2011 have an full scale prototype
- Compatible with existing accessories
- Be implemented in the Swedish MARKUS program
- Keep the THOR helmet system simple and with few components
- Achieve a lower weight and a higher ballistic protection

1.6 Scope
This thesis will focus on developing a new helmet for the Swedish armed forces and their conditions. A full system for how the helmet will function and a new design proposition will be presented which later on can be developed further.

Main focus is to develop a new unique helmet with new clever functions and a revolutionary design which uses state-of-the-art materials to achieve light weight with extraordinary protection. The main point when developing this helmet will lie on not to think of the helmet as only a helmet, but more of a unit that can aid the user in difficult situations.
Focus will not lie on how the components in the helmet will function or what brand of the components will be used. How the helmet will be manufactured will also not be taken in to consideration.

2. Project description

2.1 Stakeholders

2.1.1 Primary Stakeholders
Petter Hegnelius (Tenderteq AB) is the main stakeholder since they are funding this project with money, knowledge and time. Their goal is to sell the THOR-system to the armed forces when it is finished.

2.1.2 Secondary Stakeholders
Högskolan i Halmstad and Lars Bååth has supported this project with their knowledge and time. Paulo Kiefe (Creativetools) has an interest in this project since the prototype is developed with their 3D-printers, which will give them an opportunity to show off their capabilities.

2.2 Requirements
This thesis is to result in a new helmet system called THOR – Tactical Head-mounted Operational Resource. In addition to the THOR-system, a CAD-model in Catia v5 and a full scale prototype were developed where the design concept is illustrated. Features that are to be included in the THOR-system will be illustrated and listed via the thesis and will not be developed as prototypes.

2.3 Financing & ownership
This project has been fully conducted in collaboration with Tenderteq AB under the supervision of Petter Hegnelius. Tenderteq AB has contributed with the necessary resources to ensure an excellent result of this project. So the results achieved in this thesis will be devolved to Tenderteq AB and Petter Hegnelius. Development of the full scale prototype has cost Tenderteq AB 8000 SEK.
Costs that has occurred during this thesis is a commuter card between Halmstad and Tenderteq AB office in Malmö and the development of a full scale prototype.

2.4 Project organization

The project organization consists of the project members, supervisors and suppliers. For more information see appendix 5.

2.4.1 Project members
This project has been carried out by Oskar Varland a mechanical engineer student at Högskolan i Halmstad. The programs main focus is on mechanical construction using CAD-programs for illustration and calculations.

2.4.2 Supervisors
Petter Hegnelius (Tenderteq AB) has contributed, in collaboration with Lars Bååth (Högskolan i Halmstad), with guidance regarding the project.

2.4.3 Suppliers
Paulo Kiefe (Creativetools AB) has contributed with their workshop to develop a full scale model using the latest technology in 3D-printing.

2.5 Schedule
The thesis has elapsed from 1 January 2011 to 28 May 2011. A strict time schedule has been followed throughout this project with regular status reports and meetings with the supervisors. A Gantt chart has been made to easily illustrate the time schedule and vital dates. For further details see appendix 6.

2.6 Risks
The risks that would affect the project the most would be if Tenderteq AB for some reason would cancel our collaboration. This would mean that the project could not receive the resources needed. Other risks are that the development of the prototype is delayed and cannot be showed at the UTEXPO.
3. Methodology

3.1 Fact Gathering

3.1.1 Novelty search
A novelty search has been conducted in order to scan the market of existing products. By determining the strengths and weaknesses of existing helmets and future soldier systems the THOR-system can draw lessons from them. In order to know what components and accessories exists on the market today and what is to come in the future a novelty search is a must.

3.1.2 Interviews
In order to get insight in how the current helmets within the police and armed forces perform today simple interviews have been conducted. The input from current user is a vital piece of information in order to avoid mistakes made by helmet manufactures today. Interview with the police and armed forces is crucial since they will be the end-user of the THOR-system.

3.1.3 Need assessment
A need assessment was carried out in order to determine the need of a new helmet on the market. For further information see appendix 7.

3.1.4 Guidance & meetings
Tenderteq AB has contributed with their knowledge in the field, providing vital information in order to keep the project in motion. Lars Bååth has also contributed with his knowledge. Meetings with the suppliers have helped the project to reach its goal in developing a prototype.
3.2 Communication
A solid communication with supervisors and suppliers has been critical to ensure
good results, avoid misunderstandings and to ensure that products are delivered on
time.

3.3 Idea generation
In order to start at the right end of the project the BAD – PAD – MAD – CAD
(Stig Ottosson, 2006) method has been applied.
This method starts with a stage an Idea stage, Brain Aided Design. The ideas are
visualized in Pencil Aided Design, Model Aided Design and Computer Aided
Design.

3.4 Specification of requirements
To get an overview of what demands are going to be set on the THOR-system a
specification of requirements has been established. The demands and preferences
have been set by users and the project members.
The specification of requirements has been broken down in to subdivisions which
can be read about in appendix 2, 3 and 4.

3.5 Materials
Since the THOR-system will depend on the latest materials it is a must to research
what material are available and what materials are to come in the future.

3.6 Prototype development
A crucial part in this thesis is to visualize the design made in CatiaV5 in a full
scale prototype. When using Catia V5 to model the helmet it is easy to lose
perspective on how big or small different components are. A full scale prototype
will provide useful information regarding the design and overall feel of the
helmet.

3.7 Tests
Tests will be conducted using the full scale model to analyze the size and feel of
the helmet in proportion to a normal size human head.
3.8 Tools

3.8.1 SWOT
A SWOT analysis (Kotler, 2006) has been conducted for the finished product, in order to visualize the strengths, weaknesses, opportunities and threats with the THOR-system.
See Appendix 8

3.9 Reconciliation

3.9.1 Supervisor meeting
The project group has had continuous weekly meetings with the supervisor, Lars Bååth and Petter Hegnelius. These meetings have helped the project to stay in the right direction and not become stagnant. They have also contributed to the project with new ideas and opportunities.

3.9.2 Company
Throughout the project there has been constant contact with several companies via e-mail, telephone and meetings.
Contact has been with Rabintex and MKU, in order to use their knowledge in how to design and manufacture a helmet.
4. Market Analysis

4.1 Market

A big part of this thesis has been to analyze the existing products on the market. Information about the existing products has been gathered through internet, books, folders and information from Petter Hegnelius via Tenderteq AB. Since Petter Hegnelius, Tenderteq AB has a very close connection to the Swedish police and armed forces he has helped out by providing vital information about user experiences using today’s helmets.

Helmets that are used by the Swedish army are Rabintex Attack helmet and Protech helmets.

Reference: Petter Hegnelius, Tenderteq AB

The helmets most used today have been looked closer at. Fact has been gathered from the helmet manufactures specific website and via brochures provided by Tenderteq AB. The manufactures that has been looked at are;

- Ops-core’s FAST Ballistic Helmet
- Gentexcorp’s USMC Lightweight Helmet and U.S Army ACH
- Rabintex’s RBH 303 AU

See appendix 9, 10, 11.

Since the THOR-system is intended to be implemented in Sweden’s future soldier program in 2017 it has been crucial to also look at other country’s future soldier programs, especially their helmet development. Future soldier programs that have been looked at are;

- Land Warrior Integrated Modular Fighting System, USA
- FIST - Future Infantry Soldier Technology, United Kingdom
- FELIN - Fantassin à Équipements et Liaisons Intégrés, France
- MARKUS, Markstrids utrustad soldat, Sweden

See appendix 12, 13, 14, 15

4.2 Interviews

A critical step in this thesis is to find out what the users think of the current helmets. Interviews with the armed forces and police have been conducted, via the help of Tenderteq AB.
The users at the armed forces and police force was gathered at two separate times and a brainstorming session was conducted were they were asked what the problems with today’s helmet are and what functions the wish for in a new helmet. This information has been used throughout the entire design process of the THOR-system. For the full information from these two sessions see Appendix 7.

5. Specification of requirements

The following requirements and preferences has been the foundation that THOR has been developed on. Below some of them are described, the rest is located in appendix 2, 3, 4.

5.3.1 Weight
Tough weight requirements have been established for the THOR-system since it is the biggest problem with helmets today. Today’s helmets weigh 1.4-1.5 kg in a standard state which strains the user’s neck and spine during long periods of wearing the helmet. The biggest goal with THOR is to decrease the weight while increasing the ballistic protection. See appendix 9, 10, 11.

5.3.2 Design
The helmets used today have had the same form and appearance for a long time and they have not been adapted to the modern war fields today. THOR will have a revolutionary design which protects the users head and face without affecting the users mobility.

5.3.3 Comfort
THOR must be comfortable to wear during long periods of time. The helmet shall also be adaptable to a specific users head, for a perfect fit.
5.3.4 Technical
The THOR-system shall be able to be fitted with standardized rail systems and vas shrouds used by the armed forces today. These rail systems and vas shrouds are used to attach different components, such as flashlights, cameras, gasmasks etc.

5.3.5 Ballistic
A high level of ballistic protection will be demanded of the THOR-system. THOR shall be certified with the American standard NIJ level IV which is the highest level today.
6 Design

Many sketches have been made before the design was finalized. Below some of the sketches are shown, also the final design is shown.

6.1 Design propositions

6.1.1 Proposition 1
Propositions 1 is a basically a slimmed down version of a motorcycle helmet with some exceptions. The helmet is one piece with a face visor that can be removed. Ventilation is connected to the back of the helmet via a tube and is controlled by a unit on the users arm.

Figure 6.1
6.1.2 Proposition 2
This proposition is based on the sloped armor principal used by tanks. By having the armor in an angle the effective thickness increases. The helmet is in one piece with a small visor.

Figure 6.2

Figure 6.3
6.1.3 Proposition 3
In this proposition the helmet is split in half with a face plate that is attached. By this method the helmet is able to have a tight fit around the neck and give the user protection from shrapnel. The face plate has an integrated visor.
Cons with this method is that the structural integrity of the helmet is severely weakened and the difficulty to design a locking system that is strong enough to hold the pieces together without breaking under pressure.

Figure 6.4

Figure 6.5
6.1.4 Proposition 4
In this proposition the lower chin protections can be removed. This allows the user to use the helmet as a “normal” helmet and add the chin protection when needed. Overall a traditional design.

Figure 6.6
6.1.5 Proposition 5

Proposition 5A

This final proposition is based on a normal military helmet but with some extra features. The user can choose to wear the helmet with only the head protection or add the side and front protectors for higher protection ability. The helmet has a built in visor which can be used with or without the side and front protection.

Figure 6.7

Figure 6.8

Figure 6.9
Proposition 5B
This is another version of proposition 5. Here once again sloped armor is used.

6.1.6 Proposition 6
Here propositions of the helmet in a cutaway view to show how the helmet will be structured. An outer shell will protect against bullet, shrapnel and blows while the inner shell will absorb shocks and have built in ventilation channels. Personal pads will be applied inside of the inner shell for the best personalization.
6.2 Design evaluation

The evaluation process has been conducted entirely by experience and knowledge gathered from Tenderteq AB, Rabintex and the supervisors. No tests or calculations have been conducted.

Since the visor made of a flexible OLED-display with a protective layer is hard to get a high ballistic protection on, it is better to keep the visor as small as possible. So proposition 1 and 4 were therefore not relevant to pursue further.

Proposition 3 has a severe loss in structural integrity since it is split in half, also developing a locking mechanism to keep the two halves together will be hard.

Proposition 5 has a more traditional design with an exception, the chin protection. The chin protection is a feature that the user can chose to use for extra protection. The chin protection is snapped on to the helmet and kept in place with locking mechanisms. In this proposition the chin protection is split in half, this is unnecessary.
6.3 Final design

The final design is a combination of all the propositions. First an outer shell for ballistic protection will be used then an inner shell which is shock absorbing and personal pads that are adjusted to the user. The chin protection shall be fitted to the outer shell when needed by the user.

6.3.1 Outer shell

This shell will be the protection against bullets, shrapnel, shocks and blows. Rail systems used by the army today can be fitted with accessories to adapt the helmet to a certain surrounding and mission.

The outer shell will have the highest level of ballistic protection possible.
6.3.2 Inner shell
The inner shell has been designed to absorb shocks and have integrated ventilation channels that keep the user cool or warm depending on the surrounding. In order to get the inner shell to absorb as much force as possible, a honeycomb structure will be used. At the base of the inner shell, a small connection for the ventilation tube is placed.

Figure 6.17

Figure 6.18
6.3.3 Visor
The visor will be attached to the outer shell and can be retracted. The visor will serve as a light ballistic protection and a heads-up display providing the user with vital information right before their eyes. The visor will be made of a flexible OLED-display with a protection layer.
Example of information that can be shown is; a map, objectives, vital status, weapon information and so forth, there are no limitations.
If a night vision camera is mounted on the helmet the image can be projected directly on the visor, so the user can switch easily between different views via the small computer on the arm.
The possibilities are endless, if a camera is attached to the weapon and the image projected to the visor it will allow the user to literally see around corner or over obstacles without putting their life at risk.
6.3.4 Chin protection

The use of a chin protection was developed in order to stand out from other helmet manufactures and to add extra protection.

The chin protection will give the users face a ballistic protection and can also serve as a gasmask if needed.

Several different types of chin protections will be developed so depending on what kind of surrounding and mission different chin protections can be used.

The chin protection is attached to the outer shell via a nylon strap with a locking mechanism at the end. Further information about the locking mechanism can be seen in appendix 18.

Example of Chin Protectors:

- A chin protection with a gasmask integrated
- A chin protection that is light and fully ventilated
- A chin protection with high ballistic protection
6.3.5 Complete helmet
Down below the helmet in its complete state is displayed.

Figure 6.23
Figure 6.24
Figure 6.25
7. Material

7.1 Material propositions

Here a summary of materials that is possible to use for the components in THOR are listed.

7.1.1 Aramid fiber

Aramid fibers are a class of strong and heat-resistant fibers which are used in many different types of applications. The aramid fibers are divided into two different types, Meta aramid (Nomex) and Para aramid (Kevlar) which are the most common types.\(^4\)

**Kevlar, Para-aramid**

Kevlar was first introduced by the American company Du Pont in 1973 and have since then been used as reinforcement in car tires, composites and also for ballistic protection gear.\(^5\)

“Fibers of Kevlar\textsuperscript{®} consist of long molecular chains produced from poly-paraphenylene terephthalamide. The chains are highly oriented with strong interchain bonding, which results in a unique combination of properties.”\(^6\)

- General properties of Kevlar\textsuperscript{®}:
  - High Modulus
  - High LASE (Load At Specified Elongation)
  - High Tensile Strength at Low Weight
  - Low Elongation to Break High Modulus (Structural Rigidity)
  - Low Electrical Conductivity
  - High Chemical Resistance
  - Low Thermal Shrinkage
  - High Toughness (Work-To-Break)
  - Excellent Dimensional Stability
  - High Cut Resistance
  - Flame Resistant, Self-Extinguishing

\textit{Kevlar made by DuPont\textsuperscript{20}}
Nomex, Meta-aramid

Nomex is made of meta-aramid fibers that are medium strength fibers that are mostly used for fire resistant clothing and to some extent protective clothing.

“NOMEX® meta-aramid, poly (meta-phenyleneisophthalamide), is prepared from meta-phenylenediamine and isophthaloyl chloride in an amide solvent. It is a long chain polyamide in which at least 85% of the amide linkages are attached directly to two aromatic rings. The meta oriented phenylene forms bends in the polymer chain, reducing chain rigidity as compared to the para orientation in the chemically similar KEVLAR® para-aramid chain.”

7.1.2 Thermoplastic Composite Materials

Old thermoplastics have not been suitable to use for protective gear since the right compound not has been found. But a company called FiberForge describes the new thermoplastic composites like this:

“Forget everything you know about composites. Slow processing times, high scrap rates, brittleness and high cost are a thing of the past. Today's thermoplastic composites are tougher, lighter, stiffer, have infinite shelf life, can be recycled and perform better in every multi-impact, highly demanding environment. And cost is coming down fast.”

The new Enhanced Combat Helmet (ECH), which is to replace the Advance Combat Helmet (ACH) used by the U.S army today, comprises a carbon-fiber inner cage overmolded with a preform made from Spectra ultrahigh-molecular-weight polyethylene (UHMWPE).

The test results have been very good and further development of the material will result in even better results. According to an article found on the internet the ECH is already far better than the old ACH;

“A CH, Advanced Combat Helmet introduced in 2002, is able to resist a 9mm bullet at point blank range and rifle bullets from longer range, the ECH has been tested to resist 7.26mm rounds along with rifle bullets from point blank range. According to size the ECH can also be up to 4 ounces lighter than the ACH.”

This is an improvement in both ballistic protection and weight which is exactly what the THOR-system depends on.
8. THOR-system components

8.1 THOR components

The THOR-system consists of six individual components:

- (001) Outer shell
- (002) Chin protection
- (003) Visor
- (004) Inner Shell
- (006) Pads
- (007) Retention system

Components 001, 002, 003 and 004 have been developed using Catia V5, while 006 and 007 will be bought from an existing supplier.

In order to come up with the final design that has been made in Catia V5 the method BAD – PAD – MAD – CAD (Stig Ottosson, 2006) has been applied.

8.1.1 BAD – Brain Aided Design

This is the ideation stage, where the goal is to come up with as many ideas as you can in your mind. When developing the different helmet components brainstorming has been used as to not restrict the idea generation process.

8.1.2 PAD – Pencil Aided Design

Here you use a pencil to get your ideas on paper. Many sketches were made during this process in order to come up with the final design, which later was made in CAD. Sketches can be found in 4.4 Design propositions page 12.

8.1.3 MAD – Model Aided Design

With the sketches as references, a model is made in this stage. A simple model of clay was made in order to get the shape of an actual male head to get an idea of the shape and size needed.
8.1.4 CAD – Computer Aided Design
With the other stages done a model can now be created in a 3D program, Catia V5 in this case, to visualize the final model. The final design of all the components was created in Catia V5. Pictures can be found in 4.6 Final designs page 198.

8.2 Components
Here components that can be used with the THOR-system are shown.
- Night vision camera
- Thermal camera
- Gasmask, a gasmask from Avon protection will be integrated in one version of the chin protection\(^\text{10}\)
- Sensors that monitor the user vital signs and the surrounding
- Wi-Fi
- Data connection
- GPS
- Intercom system with a microphone and headphones
The user will control all of the components via a small computer attached to the arm. The user can easily switch between night vision, thermal vision or a normal vision since image recorded by the cameras will be shown on the heads-up display in real time.

8.3 Retention system
The retention system will be bought from an existing supplier to Tenderteq AB and adapted to the THOR-system.

8.4 Pad system
The pad system that will be used in the THOR-system will be bought from a supplier to Tenderteq AB.
8.5 Prototype development
The goal since the beginning has been to develop a full scale prototype using the CAD model.
In an early stage of the project, contact was made with two different companies that specialize in 3D printing. Information about the different materials, delivery times and a price estimate was collected from the two companies.
When the CAD model was finished, 1 May 2011, it was sent to the companies for a precise pricing.
Tenders were received about a week later and it was up to Tenderteq AB to choose which tender to accept.
The company chosen was Creativetools AB which is located in Halmstad. They agreed to deliver a full scale prototype at a cheap price since it is for a bachelor thesis.
Delivery of the prototype was set to take place no later than 23 May 2011 since the thesis is to be presented 24 May 2011.

8.6 Tests
Using the full scale model several tests were conducted. Since the prototype is made of plaster with an epoxy coating no ballistic or blow tests has been conducted.

8.6.1 Fitting & size
The overall size of the helmet is good but some minor adjustments must be done. Size could be better and here adjustments have to been done in order to get a perfect fit.

8.6.2 Attachment
The attachment system that is used does its job and thanks to the pads on the chin protection and grooves in the outer shell they align fine.
For an even stronger attachment it is recommended to use one more retention system.

8.6.3 Design
The design is satisfying and shows a new futuristic look of the helmet. The feature with the attachable chin protection really makes the helmet stand out.
9. Results

Great results have been achieved in this bachelor thesis where a new helmet system called THOR, Tactical Head-mounted Operational Resource, has been developed. The THOR-system consists of many different complex components which have been compiled into a futuristic system that hopefully will be used by the Swedish armed forces.

9.1 Design

Many different types of design propositions has been made throughout this thesis but only one made it through all the way. The chosen design, figure 9.1, has a futuristic and revolutionary design that will make it stand out from the existing products on the market. The chin protection is what really makes the helmet unique since it offers the user, if needed, an extra level of protection that can be adapted depending on the environment and mission.

9.2 Components

The THOR-system consists of six different components were four of them has been design just for the THOR-system, 001 Outer shell, 002 Chin protection, 003 Visor and 004 Inner shell. The 006 pad system and 007 retention system will be bought from existing suppliers to Tenderteq AB. The chin protection will be attached to the outer shell via two straps that will connect to a rail system. Grooves and Pads will keep the chin protection aligned. For a more detailed view see appendix 17, 18, 19, 20.

9.3 Material

The material that stands out the most right now is the Thermoplastic composite materials, more can be read about these at page 24 in this thesis.
This is also the material that at the time has been chosen for the THOR-system to be produced in. This material will be applied to 001 Outer Shell, 002 Chin Protection and 004 Inner shell. The 003 visor will be, as mentioned before, made of a Flexible OLED-display with a protective layer.

10. Conclusion

On page three in this thesis the objectives for this bachelor thesis can be read. Below a conclusion of which objectives for the THOR-system has been met.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Conclusion</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>• In may 2011 have a system proposition that will act as a base for further development</td>
<td>This objective has been met to its fullest. A system called THOR has been achieved with this thesis.</td>
<td>A good base has been developed. But further research is needed in order to get the system fully functional.</td>
</tr>
<tr>
<td>• In May 2011 have an full scale prototype</td>
<td>This objective has been met. A full scale prototype has been developed.</td>
<td>This was an important objective since it gives the thesis a totally different perspective.</td>
</tr>
<tr>
<td>• Compatible with existing accessories</td>
<td>This objective has been met. The accessories in question fits on the THOR-system.</td>
<td></td>
</tr>
<tr>
<td>• In the future be implemented in the Swedish MARKUS program</td>
<td>This objective has not been met at the present time.</td>
<td>This is a goal that the project members are hopeful about and will most definitely be met in the future.</td>
</tr>
<tr>
<td>• Keep the THOR helmet system easy and with few components</td>
<td>This objective has been partially met. The system is complicated but the components are easy and straight forward.</td>
<td>Much work still remains with the different components.</td>
</tr>
</tbody>
</table>
• Achieve a lower weight and a higher ballistic protection

This objective is a hard to determine. A material proposition has been made that most likely will make a strong and light helmet. But no concrete tests have been made.

This is a goal that will be achieved in the future. Much more research about the material is needed.

11. Discussion and recommendation

This thesis has been a great success since the most important goals has been met and a complete helmet system called THOR has been developed. The THOR-system is an excellent base to continue the research on since a complete design proposition has been developed.

Much work still remains with the THOR-system, each component must be looked much closer at and define their properties on a more detailed level.

My recommendation is to continue with the research with the THOR-system since a solid base has been done and I predict that it will be sellable to the Swedish armed forces by 2015. The interest for these kinds of systems are very sought after and will give Tenderteq AB publicity since they are one of few companies in Sweden that has started to research this kind of system.
12. Critical Review

When working with this thesis many different methods have been followed, Freddy Ohlsson (1995), Stig Ottosson (2005). It has been helpful to follow these methods since it has provided a structure to work with. The Gantt chart that was made in the beginning of the thesis has been useful and most of the deadlines have been met, although a more detailed Gantt chart could have been done.

I have learned that it often takes longer time then expected to get components delivered and for people to reply via email. So in future projects contact with companies will occur much earlier in the process.

I have learned that having a solid and broad social network is crucial when trying to develop a new system or product. Much information is received directly from companies and through contacts. So being able to use Tenderteq AB’s social network and knowledge has been crucial for this project in order to make it a success.

So for future projects I will conduct a more detailed time schedule and contact with the involved companies will be made in an earlier stage. Overall the execution of this bachelor thesis has given me much experience that will help me in future projects.
Appendixes

Appendix 1 Product definition

1 General

1.1 Aim and proportions
This specification of requirements is valid for Tactical Head-mounted Operational Resource (THOR) for the Swedish Armed Forces.

The specification will cover the technical requirements, conditions and functions that are demanded for the Tactical Helmet. It will also later include requirements for the system safety, operations safety, maintenance, documentation and training.

1.2 Fulfillment of the requirements
The manufacture will agree to meet these requirements

1.3 Stock designation number
Product number for THOR:s different parts.
- 001 Outer Shell
- 002 Chin Protection
- 003 Visor
- 004 Inner Shell
- 006 Pad system
- 007 Retention system

1.4 Definitions
The following definitions are used in this specification:
THOR - Tactical Head-mounted Operational Resource
Appendix 2 System requirements

2.1. Scope
Tactical Head-mounted Operational Resource should aid, protect and facilitate the user. Primarily providing a high ballistic protection without interfering with the user. All the information that the user needs should be easy accessed through the heads-up display and integrated intercom. The helmet must adapt to the environment and keep the user comfortable at all times.
The helmets interior must be designed with the user in absolute focus, ergonomic. The helmets outside should be designed with the Swedish Armed Forces and Police requirements in mind.
Different accessories must be able to be attached to the helmet by using a modular system.
THOR will adapt to the surroundings temperature through a cooling and heating system.
In its entirety, THOR should be designed to meet the applicable standards for all the Swedish Armed Forces.

2.2 System philosophy
Thor is intended to be used in various conditions by soldiers and police and withstand the tough surroundings. THOR will permit a flexible head protection that will sustain high velocity ballistics and shrapnel without affecting the user’s ability. Suitable for Scandinavian Armed forces in every aspect.
THOR will be a modular system where the user can alter the use of the helmet by adding or removing different accessories, e.g. flashlights, camera.
THOR is to provide the user an optimal combination of ballistic protection, mobility and comfort.

2.3 Development capability
THOR’s software shall be easy to upgrade if necessary without affecting the system. To some extent the exterior and interior shall be upgradable without affecting the ballistics protection or the ergonomics.
2.4 Main tasks

- THOR shall contribute to the soldier’s ability to perform and execute tasks in tactical operations.
- Protect against fragmentations and shrapnel
- Protect against all projectiles
- Protect against blows and shocks
- Keep the user updated with needed information
- Aid the user to correct measure of action
- Keep the user alert and comfortable
Appendix 3 Functional requirements

3.1 Design requirements
3.1.1 THOR shall admit unimpeded use of sight
3.1.2 THOR shall be able to use all year round, in temperatures from -40° to +50° Celsius
3.1.3 THOR shall not affect the user in a negative way
3.1.4 THOR shall be capable of holding external accessories/devices
3.1.5 THOR shall be constructed of a modular system
3.1.6 THOR shall be light weight

3.2 Handling Times
Handling times, i.e. time spent mounting accessories, replacing damaged component, putting the helmet on and adjusting. Below are guide values for how long each operation should take. The values are to be achieved after an introduction to the system and while wearing standard combat gloves.
3.2.1 General fitting of THOR; max. 5 minutes
3.2.2 Mounting Chin protection max. 1 minute
3.2.3 Mounting accessories; max. 1 seconds
3.2.4 Replacing a damaged component; max. 1 minute
3.2.5 Changing visor; max. 1 minute

3.3 Comfort and mobility
3.3.1 THOR shall not interfere with the other equipment worn by the user, such as a combat suite.
3.3.2 THOR shall not prevent the user from entering narrow spaces

3.4 Interface requirement
THOR shall be able to use with all the existing gear and vehicles used by the Swedish armed forces and the Swedish police force.
Appendix 4 Performance requirements

4.1 Technical Requirements
4.1.1 THOR shall be able to be fitted with one standard Vas shroud
4.1.2 THOR shall be able to be fitted with two standard Rail systems
4.1.3 THOR shall be able to be fitted with tailor made accessories

4.2 Ballistic protection requirements
Incl. knife, spike, blow and shock
4.2.1 THOR shall protect against level IV in NIJ standard, American standard
4.2.2 THOR shall protect against level

4.3 Weight Requirements
4.3.1 THOR-system shall not weigh more than 1.3 kg.
4.3.2 THOR, Outer shell (001) shall not weigh more than 0.8 kg in its standard state.
4.3.3 THOR, Inner shell (004) shall not weigh more than 0.2 kg
4.3.4 THOR, Chin protection (002) shall not weigh more than 0.2 kg
4.3.5 THOR, Visor (003) shall not weigh more than 0.05 kg

4.4 Material
4.4.1 The choice of material for all parts of THOR shall be such that the characteristics of the system are not affected negatively in a maritime environment. That means that the material shall be resistant to rot and corrosion, and not be damaged by sea water, perspiration, oil or fungal attack.
4.4.2 THOR shall be built using a material that is strong enough to meet the ballistic and weight requirements.

4.5 Other requirements
Size
THOR shall be developed in three different sizes: Large, Medium and Small. The straps shall be made in different sizes to fit different users.

Color
THOR shall be made in the standard color required by the Swedish armed forces and police force.
Appendix 5 Project Organization

Tenderteq AB

Supervisor
Lars Bååth

Supervisor
Petter Hegnelius

Creativetools AB
Appendix 7 Need Assessment

Need assessment

Meeting called by: Oskar Varland
Facilitator: Tenderteq AB
Attendees: Police and armed forces

Type of Meeting: Need assessment
Note taker: Oskar Varland

Agenda Items

Topic

- Functions
- Properties
- Ergonomics
- Weight
- Design
- Components
1. Functions
   − Heads-up display
   − Night vision
   − Thermal camera
   − Information in visor
   − Sensors
   − Wi-Fi
   − GPS
   − Intercom, noise reduction

2. Properties
   − Heat resistant
   − Cold resistant
   − High ballistic protection
   − Shock absorbing
   − Adjustable
   − Customizable
   − Water proof
   − Full head protection

3. Ergonomics
   − Easy to put on and off
   − Easy retention system
   − Exchangeable pads
   − Temperature adjustable
   − Adjustable retentions system
4. **Weight**
   - As light as possible
   - MAX 1.2 kg

5. **Design**
   - Futuristic design
   - Appealing design
   - Camouflage paint
Appendix 8 SWOT

**Strengths**
- Experienced supervisors
- Knowledge bank
- New product
- New Design

**Weaknesses**
- Lack of time
- One person
- Lack of experience

**Opportunities**
- Gain experience
- Sell product
- Job offering

**Threats**
- Lack of time
- Lack of funding
- Suppliers delayed
Appendix 9 Ops-core FAST Ballistic Helmet

The FAST ballistic helmet is the most popular helmet today and is primarily used by the US military. The helmet is lightweight, multi-impact, comfortable and still NIJ IIIA classified. It is also fitted with a ventilated liner with adjustable EPP impact pads and LDV closed-cell comfort foam that is not affected by temperature, altitude, or moisture.\textsuperscript{11}

<table>
<thead>
<tr>
<th>WEIGHT</th>
<th>S/M</th>
<th>M/L</th>
<th>L/XL</th>
</tr>
</thead>
<tbody>
<tr>
<td>As shown in photos,</td>
<td>2.67 lbs (1211g)</td>
<td>2.93 lbs (1328g)</td>
<td>3.18 lbs (1445g)</td>
</tr>
<tr>
<td>including VAS Shroud</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>and rails</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 9.1 weight of Ops-core FAST ballistic helmet.

The ops-core ballistic helmet is NIJ level IIIA certified.
Appendix 10 Gentex Force Protection Helmet

USMC Lightweight Helmet

USMC Lightweight Helmet is an advanced helmet system which is designed for the U.S Marine Corps with provides an improved performance by reduced weight, better materials and protection.

The USMC helmet uses a water resistant pad suspension in combination with a four point retention system. This gives the helmet a good adjustability and a tight fit\textsuperscript{12}.

<table>
<thead>
<tr>
<th>Size</th>
<th>Part Number</th>
<th>NSN</th>
<th>Total Weight (oz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-Small</td>
<td>A12769-1</td>
<td>8470-01-560-2866</td>
<td>46 (1.3 kg)</td>
</tr>
<tr>
<td>Small</td>
<td>A12769-2</td>
<td>8470-01-506-3267</td>
<td>48 (1.36 kg)</td>
</tr>
<tr>
<td>Medium</td>
<td>A12769-3</td>
<td>8470-01-506-3076</td>
<td>49 (1.39 kg)</td>
</tr>
<tr>
<td>Large</td>
<td>A12769-4</td>
<td>8470-01-506-3270</td>
<td>52 (1.47 kg)</td>
</tr>
<tr>
<td>X-Large</td>
<td>A12769-1</td>
<td>8470-01-506-3271</td>
<td>62 (1.75 kg)</td>
</tr>
</tbody>
</table>

Figure 10.1 weight of USMC Lightweight ballistic helmet.

The Gentex USMC lightweight helmet is NIJ level IIIA certified\textsuperscript{13}. 

![Gentex USMC Lightweight Helmet](image)
U.S. Army Advanced Combat Helmet (ACH)
This helmet is today used by the U.S army. Gentex describes the helmet as following:

“The Advanced Combat Helmet (ACH) and TBH-II Army Version are based on the latest performance requirements of the U.S. Army for ballistics, impact, retention and other protective upgrades. The helmets are lighter than the previous PASGT infantry helmet and include a pre-drilled Night Vision Goggle Bracket hole. The shell trim eliminates the beak and has a higher side trim than the PASGT. The helmet also includes an improved 4-Point Retention and Pad Suspension System.”¹⁴

The U.S. Army Advanced Combat Helmet (ACH) is NIJ level IIIA certified.¹⁵
Appendix 11 Rabintex RBH 303 AU
The Rabintex RBH 303 AU is the helmet used by the Swedish army today. Rabintex describes the helmet as following:

"The RBH 303 AU is a high-protection combat helmet based on the American MICH helmet shape. The RBH 303 AU has a special harness which ensures maximum comfort along with high ballistic protection (level IIIA according to NIJ 0108.01 and NIJ 0106.01)."

<table>
<thead>
<tr>
<th>Size</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>1,200 kg</td>
</tr>
<tr>
<td>Medium</td>
<td>1,250 kg</td>
</tr>
<tr>
<td>Large</td>
<td>1,300 kg</td>
</tr>
<tr>
<td>X-large</td>
<td>1,500 kg</td>
</tr>
</tbody>
</table>

Figure 11.1 weight of Rabintex RBH 303 AU helmet.

The Rabintex RBH 303 AU is NIJ level IIIA certified.
Appendix 12 Land Warrior Integrated Modular Fighting System, USA

The Land Warrior project was launched in 1994 by the US Army. Land Warrior is an integrated fighting system for individual infantry soldiers and is supposed to enhance tactical awareness, lethality and survivability of the soldier. The Land Warrior system will be deployed by infantry, and combat support soldiers, including rangers, airborne, air assault, light and mechanized infantry soldiers.

The Land Warrior programs main areas are:

- **HELMET**
  - Weight 4.5lb (2.04 kg)
  - Wireless local area network antenna
  - Helmet mounted display
  - Radio microphone and earpiece

- **SOLDIER CONTROL SYSTEM**
  - Joystick
  - Mouse buttons
  - Programmable buttons
  - SIM Card Reader

- **FIGHTING LOAD VEST**
  - GPS1
  - Dead reckoning system
  - Batteries, rechargeable, weight 2.5lb (1.1 kg)
  - Batteries, disposable, weight 2.5lb (1.1 kg)
  - Ports in Hub
  - Computer operating system Windows 2000
  - Radio Multi-band intra and inter team

- **WEAPON**
  - M4 Carbine caliber .223
  - Magazine 30 rounds
  - Daylight scope
  - Day video scope zoom1.5x to 6x
  - Thermal weapon Scope
  - Laser
  - Programmable buttons
Appendix 13 FIST - Future Infantry Soldier Technology, United Kingdom

UK Ministry of Defense Procurement Agency at Abbey Wood, Bristo is managing the FIST program. FIST is expected to be in operations between 2015 and 2020 and the first major experimental assessment phase took place in January 2005. A total of 70 soldiers took part and was equipped with experimental FIST-gear. Effectiveness was assessed by comparing the results with the conventional gear.

The data gathered in the test was analyzed and taken in consideration when FIST V2 was designed.

The FIST programs main areas are:

- C4I, Command, control, communications, computers and intelligence
- Lethality: Weapons and sights
- Mobility: Navigation, and small size and weight of equipment
- Survivability: Clothing, stealth, body armor
- Sustainability: Logistics
FELIN is the French future infantry soldier system which will be integrated with the French army’s future air and land network centric system. The system is said to provide the soldiers with improved close-combat capabilities with focus on lethality, survivability, mobility and C4I (command, control, computers, communications and information.)

2010 will all French infantry troops be equipped with FELIN V1 and by 2015 production of FELIN V2 is planned to start.

The FELIN programs main areas are:
- Weapons
- Weapon sights
- Day and night sights
- Voice and data communications
- Personal communications
- Clothing
- Ballistic helmet
- Armor protection

**FELIN ballistic helmet**

A new helmet will be introduced with the FELIN system. The helmet is lightweight and will provide ballistic protection. It is also fitted with Sagem’s monocular oculaire de vision déportée (OVD) optronic system with light intensifying camera and two LED displays, each 3cm²
Appendix 15 MARKUS - Markstridsutrustad Soldat, Sweden

Sweden’s future soldier program is meant to be implemented in 2015-2017 to the army. The aim is to make the soldiers more effective and aware. 20,000 units is required with includes reserves.

Markus main areas are:

− C3I
− Weapons
− Survivability
− Ergonometric
− Maintenance
− Portable power sources

Figure taken from FMV
This drawing is our property. It can't be reproduced or communicated without our written agreement.

THOR

001 Outer Shell

<table>
<thead>
<tr>
<th>DRAWN BY</th>
<th>DATE</th>
<th>CHECKED BY</th>
<th>DATE</th>
<th>DESIGNED BY</th>
<th>DATE</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>SIZE</th>
<th>DRAWING NUMBER</th>
<th>SCALE</th>
<th>WEIGHT(kg)</th>
<th>SHEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>A4</td>
<td>001</td>
<td>1:2</td>
<td>XXX</td>
<td>1/1</td>
</tr>
</tbody>
</table>

Front View
Scale: 1:2
This drawing is our property. It can't be reproduced or communicated without our written agreement.

THOR

002 Chin Protection

<table>
<thead>
<tr>
<th>DRAWN BY</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varland</td>
<td>2011-05-18</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CHECKED BY</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varland</td>
<td>2011-05-18</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DESIGNED BY</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varland</td>
<td>2011-05-09</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DRAWING TITLE</th>
<th>SIZE</th>
<th>DRAWING NUMBER</th>
<th>REV</th>
</tr>
</thead>
<tbody>
<tr>
<td>002 Chin Protection</td>
<td>A4</td>
<td>002</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SCALE</th>
<th>WEIGHT(kg)</th>
<th>SHEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:2</td>
<td>XXX</td>
<td>1/1</td>
</tr>
</tbody>
</table>

Front View
Scale: 1:2

Left View
Scale: 1:2

Detail A
Scale: 1:1

THOR

Appendix 17

209

214

This drawing is our property. It can't be reproduced or communicated without our written agreement.
THOR

DRAWING TITLE

003 Visor

<table>
<thead>
<tr>
<th>DRAWN BY</th>
<th>DATE</th>
<th>CHECKED BY</th>
<th>DATE</th>
<th>DESIGNED BY</th>
<th>DATE</th>
</tr>
</thead>
</table>

SIZE    DRAWING NUMBER REV
A4      003           0

SCALE  WEIGHT(kg) SHEET
1:2     XXX           1/1

This drawing is our property.
It can't be reproduced
or communicated without
our written agreement.
**THOR**

<table>
<thead>
<tr>
<th>DRAWING TITLE</th>
<th>SIZE</th>
<th>DRAWING NUMBER</th>
<th>REV</th>
</tr>
</thead>
<tbody>
<tr>
<td>004 Inner Shell</td>
<td>A4</td>
<td>004</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SCALE</th>
<th>WEIGHT(kg)</th>
<th>SHEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:2</td>
<td>XXX</td>
<td>1/1</td>
</tr>
</tbody>
</table>

This drawing is our property. It can't be reproduced or communicated without our written agreement.

**Drawn By:** Varland  
**Date:** 2011-05-18

**Checked By:** Varland  
**Date:** 2011-05-18

**Designed By:** Varland  
**Date:** 2011-05-09
Appendix 20 References

WWW References
2. Stig Ottosson 2006, Handbok in Innovation and management URL:
3. Kotler 2006, Marketing Management URL:
   http://www.mig.se/tasks/sites/default/assets/File/Sammanfattning_av_Philip_Kotler_-_Marketing_Management.pdf page 40
4. National Encylopedin, Armid URI:
   http://www.ne.se/lang/aramid
5. National Encylopedin, Armid URI:
   http://www.ne.se/lang/aramid
6. Dupont Kevlar, Kevlar Tech Info URL:
7. National Encylopedin, Armid URI:
   http://www.ne.se/lang/aramid
8. Dupont Nomex, Technical Guide Nomex URL:
9. Military headgear, The enhanced combat helmet the next big thing in helmets URL:
10. Avon Protection, Protection URI:
    http://www.avon-protection.com/Protection%20US/protection-home-us.htm
11. Ops-Core, FAST ballistic helmet URL:
    http://www.ops-core.com/FAST_Ballistic_Helmet_P7C20.cfm
12. Gentex Corp, USMC Lightweight Helmet (LWH) URL:
13. Gentex Corp, USMC Lightweight Helmet (LWH) Data sheet URL:
22. Fiberforge, URL: http://www.fiberforge.com/
23. Compositesworld, Hybrid enhanced combat helmet enters final testing phase, URL: http://www.compositesworld.com/articles/hybrid-enhanced-combat-helmet-enters-final-testing-phase

Tenderteq AB References

24. Bilaga_2_MS_struktur_avseende_Soldatsystem_MARKUS_[Skrivskyddad]-1.pdf
25. RFI_avseende_Integrera_Soldatsystem_MARKUS_version_1_0_MALIF_2011-03-23-1.pdf