Application of Platform-Based Product Development to Complex Products and Systems: a multi-case study of some Saab’s Systems

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Abstract

The processes involved in the development of new products inside companies is challenging, and internal competition for resources (human, financial and top-management support) between the different projects within a firm occurs with loss of consistency and focus. For this reason, the adoption of a platform-based development is an essential enabler both for bringing up to date existing products and for generating entirely novel products. (Sköld and Karlsson, 2013)

When high cost and high engineering Complex Products and Systems (CoPS) are considered, the importance of the platform perspective for product innovation increases, reflected on the number of custom-built components, the scope of knowledge and skills necessary and the degree of new knowledge involved in the production (Hobday, 1997).

For singular cases like military equipment, the CoPS’ acquisition processes are usually different from the assumptions of the market theory. For weapons acquisition, the market tends to be duopolistic or even monopolistic, highly bureaucratized, politicized and regulated, with almost none private financing. They also have a strong role of the buyer (as user and specifier of weapons systems and as a procurement actor) and with the pricing-definition largely defined before the design of the equipment for each specific transaction. (Hobday, 1997; Templin, 1994)

Aligned with these concepts, the purpose of this thesis is to explore the management decisions related to CoPS platforms over time, through a study of several product platforms, including its derivatives, improvements, additions to product family and the evolution between generations.

A multiple case study of five product platforms within the context of the Swedish defense industry were conducted to answer the purpose of the research. The systems (Carl-Gustaf, AT4, BILL, NLAW, and Gripen) were selected with knowledgeable representatives from Saab. One important criterion is that the platforms have been continuously modernized and improved to fulfill different armed forces’ needs, in highly demanding environments. The research is qualitative and based on retrospective semi-structured interviews, with knowledgeable representatives about the product platforms.

The results of this thesis indicate that the translation of platform methods to CoPS is not easily made, in particular for military products and systems with all peculiarities of the Defense Industry (such as sovereignty power of users and limited market). However, CoPS firms can have advantages from applying platform strategies, such as the standardization and use of off-the-shelf components and subsystems and the adoption of modularity with the segregation of critical functions in separated modules. In this sense, CoPS can be designed and produced using a product platform approach to reduce the life cycle costs while keeping the CoPS updated with new technologies to meet new and old customer needs.

Keywords: Platform-Based Products, Complex Products and Systems, Customer-Supplier Relationship, Strategic Management, Defense Systems
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Linköping, August 2017

Rafael Hidalgo Olivieri
### List of Acronyms and Definitions

<table>
<thead>
<tr>
<th>TERM</th>
<th>DEFINITION</th>
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<tbody>
<tr>
<td>ASTROS</td>
<td>Artillery Saturation Rocket System</td>
</tr>
<tr>
<td>AT4</td>
<td>Family of disposable and single-soldier-operated 84mm support weapons</td>
</tr>
<tr>
<td>ATGW</td>
<td>Anti-Tank Guided Weapon</td>
</tr>
<tr>
<td>BILL</td>
<td>Bofors Infantry Light and Lethal anti-tank missile</td>
</tr>
<tr>
<td>BUGC</td>
<td>Business Unit Ground Combat</td>
</tr>
<tr>
<td>CG</td>
<td>Carl-Gustaf</td>
</tr>
<tr>
<td>COPAC</td>
<td>Comissão Coordenadora do Programa Aeronave de Combate (Portuguese: Coordinating Committee of the Combat Aircraft Program) is a Brazilian Air Force (FAB) organization responsible for the management of Defense System Projects for FAB.</td>
</tr>
<tr>
<td>CoPS</td>
<td>Complex Products and Systems</td>
</tr>
<tr>
<td>CS</td>
<td>Confined Space</td>
</tr>
<tr>
<td>ERA</td>
<td>Explosive Reactive Armor</td>
</tr>
<tr>
<td>FAB</td>
<td>Força Aérea Brasileira (Portuguese: Brazilian Air Force)</td>
</tr>
<tr>
<td>FMV</td>
<td>Försvarets Materielverk (Swedish: Swedish Defense Material Administration) is a governmental procurement agency acting under the Swedish Ministry of Defense</td>
</tr>
<tr>
<td>FOI</td>
<td>Totalförsvarets forskningsinstitut - Swedish Defense Research Agency is a government agency in Sweden for defense research that reports to the Swedish Ministry of Defense</td>
</tr>
<tr>
<td>HEAT</td>
<td>High Explosive Anti-Tank</td>
</tr>
<tr>
<td>JAS</td>
<td>Jakt, Attack och Spaning (Swedish: Fighter, Attack, and Reconnaissance)</td>
</tr>
<tr>
<td>KAFT</td>
<td>Kungliga Armeförvaltningens Tygavdelning (Swedish: Royal Swedish Army Material Administration). In 1968, it became FMV</td>
</tr>
<tr>
<td>MBSE</td>
<td>Model-Based Systems Engineering</td>
</tr>
<tr>
<td>MBT</td>
<td>Main Battle Tank</td>
</tr>
<tr>
<td>Mk or M</td>
<td>Mark. It is a manner of designating the version of a specific product. It is usually abbreviated as Mk or M and is followed by a number showing the version.</td>
</tr>
<tr>
<td>MLU</td>
<td>Mid-life Update or Mid-life Upgrade</td>
</tr>
<tr>
<td>MOUT</td>
<td>Military Operations on Urban Terrain</td>
</tr>
<tr>
<td>MS</td>
<td>Material System</td>
</tr>
<tr>
<td>NATO</td>
<td>North Atlantic Treaty Organization</td>
</tr>
<tr>
<td>NG</td>
<td>New Generation</td>
</tr>
<tr>
<td>NLA W</td>
<td>Next generation Light Anti-tank Weapon</td>
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<tr>
<td>NPD</td>
<td>New Product Development</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<td>--------------</td>
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<tr>
<td>OTA</td>
<td>Overfly top attack</td>
</tr>
<tr>
<td>PAL</td>
<td>Panzerabwehrlenkwaffe (German: Anti-tank missile)</td>
</tr>
<tr>
<td>PLOS</td>
<td>Predicted Line of Sight</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
</tr>
<tr>
<td>RFI</td>
<td>Request for Information</td>
</tr>
<tr>
<td>RFP</td>
<td>Request for Proposal</td>
</tr>
<tr>
<td>SACLOS</td>
<td>Semi-automatic Command to Line of Sight missile guidance method</td>
</tr>
<tr>
<td>SAF</td>
<td>Swedish Armed Forces</td>
</tr>
<tr>
<td>SDI</td>
<td>Swedish Defense Industry</td>
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<tr>
<td>SI</td>
<td>Systems Integrator</td>
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<tr>
<td>SSKP</td>
<td>Single Shot Kill Probability</td>
</tr>
<tr>
<td>SwAF</td>
<td>Swedish Air Force</td>
</tr>
<tr>
<td>UN</td>
<td>United Nations</td>
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</table>
1 Introduction

1.1 Background

The processes involved in the development of new products inside companies is challenging, and internal competition for resources (human, financial and top-management support) between the different projects within a firm sometimes occurs with loss of consistency and focus. For this reason, the adoption of a platform-based development is an essential enabler both for bringing up to date existing products and for generating entirely novel products. (Sköld and Karlsson, 2013)

Platforms, in general, offer substantial competitive advantage and possibilities to foster market penetration. However, many enterprises consistently underinvest in them, mainly because of reduced perception of the strategic value of platforms by management. This way, these firms fail to create well-planned platform projects. (Wheelwright and Clark, 1992)

In this sense, the use of platform projects, a group of subsystems and interfaces that form a shared structure that can be used efficiently to develop and produce derivative products, represent the foundation for the long-standing success of a company (Meyer and Lehnerd, 1997). It covers a broad scope of new-generation products, additions to product families, by-products, and improved products. The investigation of how this development occurs in different strategic circumstances and with different aims shows how combinations of innovations in components and architecture represent a crucial differentiator (Sköld and Karlsson, 2013).

When Complex Products and Systems (CoPS) are considered, the importance of the platform perspective for product innovation increases. CoPS are products and systems characterized by a high cost and high engineering demand, reflected on the number of custom-built components, the scope of knowledge and skills necessary and the degree of new knowledge involved in the production (Hobday, 1997). On the same path, the adoption of CoPS often consists of a long-term commitment where the cost and risk of failure are high and whose buying process is usually long-lasting, and the adoption may take some years from the first proposal to the first products and systems in operational use (Tidd and Bessant, 2013).

For singular cases like military equipment, the CoPS’ acquisition processes are usually different from the assumptions of the market theory. For weapons acquisition, the market tends to be duopolistic or even monopolistic¹, highly bureaucratized, politicized and regulated, with almost none private financing. They also have a strong role of the buyer (as user and specifier of weapons systems and as a procurement actor) and with the pricing-definition largely defined before the design of the equipment for each specific transaction. (Hobday, 1997; Templin, 1994)

To analyze the particular case of platform-based development in CoPS, the study was performed to understand how management decisions on Defense Industries, as manufacturers of CoPS platforms, influence their business areas and products with the aim of adapting, innovating, incorporating and rearranging internal and external organizational skills and

1 “A monopolistic market is a theoretical construct in which only one company may offer products and services to the public.” (Investopedia, 2006)
functional capabilities (Davies and Brady, 2000) to meet changing customers’ needs. Strategic management is of central relevance for firms in general as it is responsible for recognizing, supporting and building essential capabilities so that a company can adjust and shape its surroundings and take advantage of new business opportunities (Davies and Brady, 2000) through the time. In the Defense Sector, these aspects are even more noticeable as the demands for defense products are evolving regarding new threats, regulations, geographical markets, geopolitical shifts, systems complexity and technology developments in different areas, ranging from military vehicles and weapon systems\(^2\) to combat aircrafts.

1.2 Problem discussion

In the past, companies usually designed and developed only one product at a time, which have made new products from these firms to compete against other internal projects for resources (human, financial and support) and to have to continuously defend its existence to reach the stage of development and commercialization (Halman, Hofer and Van Vuuren, 2003; Meyer and Lechner, 1997).

In contrast to this previous procedure, many enterprises are implementing a platform-based approach to the development, manufacturing and commercialization of product families with the objective of increasing the number of products (customization), satisfying different customer needs, shortening time to market, and reducing costs (economies of scale), while maximizing economies of operation (Halman, Hofer and Van Vuuren, 2003; Simpson, Siddique and Jiao, 2006a). Thomas, Autio, and Gann (2014) consider platform development of vital importance for the strategic management of companies with some researchers suggesting that they are among the crucial decisions that an organization makes (Robertson and Ulrich, 1998).

On the same path, firms in many industries are taking into account platform-based approaches to try to reduce the complexity of the product development process (Simpson, Siddique and Jiao, 2006a), although the development of CoPS has not received the same attention by researchers as product platform development and the use of product platforms within CoPS is challenging (Alblas, 2011).

The inherent complexity of this type of product often call for extra engineering work, especially on the early phases of development and, therefore, it will have a continuous evolution after delivery to the customer. In addition, CoPS normally have long life cycles, which lead to a constant relation between development, engineering, production, and service, as well as, involves an ability to adapt and implement innovations in new and existing products quickly. (Alblas, 2011)

This is of great importance for military equipment and systems that have high costs and engineering demands (Tidd and Bessant, 2013), are constantly dealing with new threats and doctrines, changes in politics and public opinion, innovative technologies (Templin, 1994), and have a lifespan of several decades (Davies and Hobday, 2005).

In this sense, as mentioned by Hofer and Halman (2005), there is gap in the literature regarding the application of the platform concept for CoPS what brings an opportunity to study on how

\(^2\) Weapon System is the set of weapon, ammunitions and the components necessary to its proper function, such as targeting and guidance devices (Dictionary.com, 2016).
product platform strategies could fulfill the needs of CoPS manufacturers, in special, the role of strategic management to deal with the increasing complexity of one-off\(^3\) products (Alblas, 2011) while adjusting, combining and rearranging internal and external organizational competencies and functional capabilities to handle changes in external conditions (Davies and Brady, 2000).

Therefore, the study was carried out to analyze the management decisions of the Platform-Based Product Development of CoPS within some systems of the Swedish company Saab that in its 80 years of history has faced many challenges to keep its military equipment and systems in the state-of-the-art to fulfill different defense forces in high demanding environments in a very politicized and regulated market (Hobday, 1998).

1.3 Purpose

Aligned with these concepts, the purpose of this thesis is to explore the management decisions related to CoPS platforms over time, through a study of several product platforms, including its derivatives, improvements, additions to product family and the evolution between generations, aimed to answer the following research questions:

I. How strategic was the evolvement of the product platform (for example, accidental and, only understood at a later stage or based on a clear strategy from the outset)?

II. What were the management and technical factors behind the emergence of each platform?

III. What key management decisions enabled the emergence of each respective platform?

1.4 Delimitations

This study is focused on the product development processes of five Saab’s systems from two different Business Units within the company, as shown in Table 1 and the derivative products, new products originated from the family and the next generations enhancements that were based on the same platforms.

Table 1: Saab’s Systems analyzed in this study

<table>
<thead>
<tr>
<th>Business Unit</th>
<th>System</th>
</tr>
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<tbody>
<tr>
<td>Saab Dynamics – Ground Combat Weapon Systems</td>
<td>Carl-Gustaf (CG)</td>
</tr>
<tr>
<td></td>
<td>AT4</td>
</tr>
<tr>
<td></td>
<td>BILL</td>
</tr>
<tr>
<td></td>
<td>NLAW</td>
</tr>
<tr>
<td>Saab Aeronautics</td>
<td>Gripen</td>
</tr>
</tbody>
</table>

Nevertheless, it does not cover in detail all the aspects of the products’ development processes as some of the available data are considered classified, such as technical specifications and performance charts. The focus of this work is to examine the management decisions performed during the product development process of these systems to understand how the concept of

\(^3\) One-off: limited to a single time, occasion, or instance.
platform-based products and which aspects fostered or hindered the product development processes of these CoPS.

1.5 Structure of the thesis

This thesis briefly initiates with an overview on the topic of this study followed by a Methodology section with in-depth information on the methodology of the research, data collection techniques, and how data analysis was performed, including validity and reliability issues, research ethics and some limitations of this work. The subsequent section, Theoretical Background, covers the literature studies about the subject that helped on the development of an analytical framework of the problem. In the next part, a small summary about Saab and the systems that were analyzed gives a general idea of them and their key features. Later in the Empirical section, the data gathered during this research is presented considering the perspective of the formulated analytical framework. The analysis section yields a critical analysis of the empirical evidence based on the theory and proposed analytical framework. The following part examines the results and comprises the conclusions of the study with some general discussions and suggestions for further studies linked with the present research.
2 Methodology

This chapter presents the overall methodology used in this research connecting the general method theory with the practical approaches in conducting the study of several product platforms to explore strategic and management decisions related to complex product platforms over time.

2.1 Prior Knowledge

The author has a background in Mechanical and Armament Engineering and is a Brazilian Army officer. He worked with the maintenance of a CoPS platform (the Artillery Saturation Rocket Systems – ASTROS - manufactured by the Brazilian company Avibras) in close relation to the supplier and also with the procurement of military equipment (he was a member of the committee that was specifying the main requirements of the new version of the ASTROS vehicles for the Brazilian Army) for ten years.

Thus, the author has previous knowledge regarding military equipment development, defense industry, and innovation that helped him to get more insights from the interviews and the secondary data and to have a better understanding of the implications of the Defense Industry market on the development choices of the analyzed systems. On the other hand, this previous knowledge biased the author’s analysis, as he had pre-concepts about the evolution of weapons, and tried to compare to the system that he had worked previously.

2.2 Research Process

This research had the purpose of exploring the management decisions related to CoPS over time, especially related to the long-term strategy of the acquiring organization and the supplying organization. For that reason, a qualitative study based on interviews was a good choice to examine a real-world phenomenon capturing the contextual richness of it and potentially generating new ideas and concepts (Yin, 2011), especially for research in management (Gummesson, 2000).

In this study, a case study approach is proposed. Case study research involves the examination of a phenomenon in its natural setting (Yin, 2014). The method is particularly suitable for exploratory research with a focus on “how”, “what” or “why” questions providing a better understanding of the development of CoPS based on Platform-based product development. The method is also suitable for situations where it is possible to collect relevant data under the real perspectives in which the collaborations have occurred.

Qualitative methodology and case studies offer great tools for research in management including corporate strategy, management decisions (Gummesson, 2000), and the customer-supplier relationship among others.

The study was initially proposed by delimiting the problem to be examined through some meetings with Saab, the author, and the master’s thesis supervisor. The meetings were followed by literature studies, the first draft of the research questions that were adjusted during the research, as suggested by Eisenhardt (1989), and preparations for data collection (semi-structured interviews with pre-selected staff by Saab). These meetings also set the selection of the cases of the research.
The research was based on the choice of multiple cases instead of a single case study due to the possibilities to have a broader exploration of the research questions what gives more substantial, generalizable and verifiable results (Eisenhardt & Graebner, 2007). However, as multiple case studies demand more time and resources to be performed (Yin, 2014), the researcher decided on selecting five cases from two specific areas (explained in more details in section 2.4) to analyze with the intention of getting more robust results while limited to the academic period available to carry out this study.

The collected data were categorized, interpreted and analyzed with additional literature studies to provide interactive cycles and the necessary adjustments on the research questions, lined up with the research purpose. Later the data analyzed were used to understand the empirical findings via a pattern corresponding procedure, where the empirical findings are compared to existing theoretical propositions accessible on prior studies (Yin, 2014), that was the basis to elicit conclusions regarding the study’s purpose. A simplified version with the different steps for the development of this research is depicted in Figure 1.

![Figure 1: Research Process](image)

2.3 Literature Study

To support a better understanding of the problem, to be capable of elaborating a theoretical framework of the case, to establish a research protocol for the data collection through semi-structured interviews and to link the collected data with theory, literature studies were performed. These studies also supplied the researcher with knowledge to identify a research gap concerning the application of the platform concept for CoPS and propose research questions to accomplish the purpose of this study (Eisenhardt and Graebner, 2007).

They were focused on scientific articles and books in databases such as Scopus, Google Scholar, and Linköping University Library website where keywords that are connected to the purpose of the study, and combinations of them, such as platform-based products, new product development (NPD), Complex Products and Systems (CoPS), Management Strategies, Customer-supplier relationship, Weapon System Design and Development were used. The method is based on searching for the keywords and choosing the most cited articles that were used to support the literature studies. Furthermore, they helped on further searches as these articles refer to the most relevant authors on those fields, which aided on narrowing down the scope of the additional search. Moreover, these databases were used to search for articles, books
and websites relating to the Saab systems studied to give a better understanding of the systems and to have a secondary set of data to support the analysis.

As the theoretical framework could be continuously improved, the author has carried out additional literature studies through the entire process of writing the thesis. Johansson and Svedner (2010) state that a study can benefit from an early version of the final work as it creates awareness about possible missing theory. Therefore, the theory part has been updated and revised continuously through the duration of this research, as portrayed in Figure 1.

2.4 Case Study Selection

Selection of cases is an important aspect of choosing case study as a research strategy. This selection is related to how the research questions are outlined and must allow appropriate access to the essential data by interviews, reports and written documents or observations in the field (Yin, 2014).

For this reason, a first draft of the research questions was discussed with a Saab representative to delimit the scope of the study and which systems would be explored. As participation in qualitative research demands considerable time, and the quality of the data is related to the willingness to be interviewed (Polkinghorne, 2005), it was also discussed which systems would be easier to have access to the necessary information and would have people interested in participating in the research. The previous background of the author as a Brazilian Army Mechanical and Armament Engineer was also considered in the choice of the cases due to his familiarity with the terms and the systems themselves.

The research involved a multiple case study with a single set of "cross-case" analysis since the conclusions from multiple cases are considered more convincing, and it makes the study more robust (Yin, 2014). Nevertheless, as it was only one researcher performing the study, it demanded more time, which has influenced the depth of the study compared to a single case study.

The study was executed within the context of the Swedish Defense Industry (SDI), specifically two Business Units of Saab (Saab Dynamics – Ground Combat Weapon Systems, dealing with anti-tank recoilless rifles and missiles, and Saab Aeronautics, dealing with combat aircraft). From these two Business Units, five platforms (five cases as depicted in Table 1) were selected for the study: AT4, BILL, Carl-Gustaf, NLAW, and Gripen, and were carefully chosen together with knowledgeable representatives from Saab. One important criterion was that the platforms had been continuously modernized and improved to fulfill different armed forces’ needs, in highly demanding environments, except for the NLAW that is in its first version.

Lastly, the selected cases offer an excellent opportunity for investigation, linking the cases with the base theory on focus since the systems can be seen as successful examples of platform-based CoPS.

2.5 Data collection

In qualitative studies, the relevant information is not easily available and ready to be collected by the researcher; some effort needs to be put to find from all the available sources of information (interviews, observations, documents, and artifacts) the ones that the researcher can learn and gain experiential accounts (Polkinghorne, 2005). Different sources can provide a case study with relevant evidence (Yin, 2014) and it is essential to understand how the case is
in its real-life environment, influencing and being affected by its context (Rose, Spinks and Canhoto, 2015).

This study was largely based on retrospective semi-structured interviews with knowledgeable representatives about the product platforms. Ideally, different representatives would be interviewed for each platform, providing complementary perspectives (Polkinghorne, 2005) and considering different periods in time, including the supplying organization’s as well as the acquiring organization’s perspective. The interviewees were carefully selected, as the platform evolvement stretches extended periods of time.

Additionally, visits to museums and an extensive search for reports, articles, books, and websites linked to the systems in the study not only to have more knowledge about these systems but also to get an additional set of evidence to support the analysis of the cases.

In this sense, since this work is a qualitative research, the interviewees, and documents (such as reports, articles, and websites) were not chosen because they represent a statistical distribution of the cases under analysis but because they can provide relevant descriptions of these cases (Polkinghorne, 2005) with detailed historical data and knowledge with contextual nuances of the systems (Given, 2008).

2.5.1 Preparation for Data Collection

As the principal source of data in the study was semi-structured interviews, to help on the selection of the employees that were interviewed, a first draft of the questions was elaborated to guarantee that the right people were interviewed. These predetermined questions were set based on open-ended questions to try to get much information as possible (Jacob and Furgerson, 2012; Gill et al., 2008). Both the supervisor and the opponent verified this draft of the questions and gave suggestions to improve them. It was also necessary to prepare a schedule for the interviews, as some of the interviewees are located in different cities in Sweden.

2.5.2 Primary data

The purpose of the research interview is to discover the perspectives, knowledge, views, doing processes and/or motivations of key informants in their own language on the specific topic that is under investigation (Gill et al., 2008; Woodside, 2010), so that the investigator can get enough information from the participants to answer the research questions (Polkinghorne, 2005). The best use of an interview is to get unexpected and unanticipated facets of what is being studied which enrich the set of data and can be explored further by the researcher (Polkinghorne, 2005), especially interpersonal relationships and the contextual framework in which the key actors are involved (Given, 2008). For that reason, the interviewees were selected from experienced and knowledgeable key actors that worked (are working) with the Saab’s systems studied who can provide relevant descriptions (Polkinghorne, 2005) about the management decisions related to the systems over time, some with more than 20 years of experience with the systems. Table 2 presents some general information about the interviews that were conducted.

With the aim of getting both a comprehensive and deep knowledge about the cases (Yin, 2014), the interviews were semi-structured with open-ended questions. This way, the researcher had some control over the topics of the interviews but without fixing the range of the answers to each question (Given, 2008) allowing a free thinking by the interviewees.
Table 2: Information about the interviews in the analyzed cases

<table>
<thead>
<tr>
<th>CASE</th>
<th>Participant Position</th>
<th>Years working with the CoPS</th>
<th>Collection Method</th>
<th>Volume of Data</th>
<th>Length of interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>CG</td>
<td>Director of Product Planning Ground Combat Weapon Systems – Saab Dynamics</td>
<td>22 years</td>
<td>Face-to-face interview</td>
<td>14 pages</td>
<td>96 min</td>
</tr>
<tr>
<td>AT4</td>
<td>Former Colonel and Chief Scientist of SAF - Head of R&amp;D – Working for Innovair</td>
<td>7 years</td>
<td>Face-to-face interview</td>
<td>19 pages</td>
<td>97 min</td>
</tr>
<tr>
<td>BILL</td>
<td>Pilot and Gripen Program Manager within the SwAF – Working for Innovair</td>
<td>17 years</td>
<td>Written interview</td>
<td>4 pages*</td>
<td>---</td>
</tr>
<tr>
<td>NLA</td>
<td>Project Manager - Saab Aeronautics</td>
<td>35 years</td>
<td>Face-to-face interview</td>
<td>10 pages</td>
<td>68 min</td>
</tr>
<tr>
<td>Gripen</td>
<td>Project Manager- FMV</td>
<td>22 years</td>
<td>Face-to-face interview</td>
<td>4 pages**</td>
<td>75 min</td>
</tr>
</tbody>
</table>

Notes: * Interview via e-mail; ** No audio recording of the interview.

The interviews’ questions concentrated on strategic and management issues (not on technical aspects) that are essential to understand the evolvement of CoPS platforms over time. Questions asked covered the following broad areas and are available in Appendix 1 - Interview Questions:

- General background of the interviewee
- Role in the product platform(s) central to the study
- Implementations of the platform(s) over time
- Technical and management aspects behind the emergence of each platform
- Strategic aspects and decisions related to the platform(s)
- Management of the complexities related to the platform(s)
- Role of the customer and the supplying organization
- Platform-based products and possibilities to innovate
- Drivers and barriers for the development of platform-based products
- Management of platform-based product development
- Reflections and recommendations for the future

The participants were informed about the study purpose and main ideas of the questions before the interviews through a two-page summary of the research that gave them some idea of what to expect during the interview (Gill et al., 2008). During these first contacts, the schedule (date and time) of the interviews and the locations were also set so that the interviews were conducted in areas free from disturbances and at the best suitable places and time for both the participants and the researcher (Gill et al., 2008).

With the intention of later perform in-depth analysis of the interviews (Given, 2008), the interviews were audio recorded with prior permission from participants before recording them (Given, 2008). This fact guaranteed that the researcher did not lose valuable insights during the interview. However, two interviews were not recorded: one that was conducted via e-mail and other where it was not allowed to record, as shown in Table 2.

Later on, the recordings were transcribed into written form and sent to the interviewees so that they could check if there were any misunderstanding during the transcription process, increasing the internal validity of the research, although some non-written information existing
in the audio recordings is lost in this process, like intonation and emphasis (Polkinghorne, 2005).

By a snowball sampling approach, the first interviewees suggested new key persons (Yin, 2014) that would be of particular interest for the study and two of the respondents were selected through this approach.

The extent of interviews depends on the topic, but especially on the researcher and interviewee previous knowledge of the subject, their interest in the topic (Gill et al., 2008) and the interviewer’s participation and way of conduction the interview; how he or she pays attention, listens and finishes responses (Polkinghorne, 2005). For the present study, as presented in Table 2, the average interview time was around 85 minutes.

In summary, the resulting text of the interview can be seen as an informal teamwork between the researcher and the respondent (Given, 2008).

2.5.3 Secondary data

For case study research, the use of secondary data is a way to support the primary data sources and to extend the number of evidence that can bring up new knowledge about the cases under study (Yin, 2014; Given, 2008; Polkinghorne, 2005). The use of multiple sources of information also allows the triangulation of the findings in a way to approach the systems studied through different perspectives and trying to find patterns and contradictions (Rose, Spinks and Canhoto, 2015; Polkinghorne, 2005).

The secondary data were collected from visits to the Robotmuseum (Missile Museum) in Arboga and the Flygvapnmuseum (Air Force Museum) in Linköping, the Saab’s website (product’s datasheet, seminars, and presentations), reports about Saab and its products from consultancy companies, from specialized media reports and magazines regarding military equipment and defense industry and from books, like the online book A Journey of Change in the Aircraft Industry (available at http://saabaircraftindustry.com/en/the-driving-forces-behind-the-journey/a-journey/) which gives a historical description of Gripen development and was written by Martin Hjelm that worked at Saab for 33 years.

The use of secondary data also helped the researcher to increase its knowledge regarding the systems and the SDI context which was useful during the interviews, assisted in the process of confirming some findings from the primary data (triangulation), which increased the validity of the study, and also supplemented useful data that were not possible to get from the interviews, in special for the Ground Weapons Systems.

2.6 Data analysis

Data analysis is an essential part of a qualitative research and is the foundation to link the literature and the cases data to increase understanding of theory, connecting the researcher’s findings with different concepts (Given, 2008). Data analysis is the process of examining, classifying and combining the available evidence to seek out patterns, perceptions or concepts that therefore may result in empirical findings (Yin, 2014).

This phase of the research initiated with the transcription of the interviews ipsis litteris in narrative text, from the audio recordings. In a few cases, the information given by the interviewees were so relevant that they were quoted as exactly presented by the respondents.
After the transcription, the data of each case were labeled according to a classification and categorization of the themes to facilitate the analysis, what was called as “coding” by Voss et al. (2002). Once the classification and coding steps were done, the data gathered in the cases were analyzed within each case and in a cross-case comparison after the analysis of each single case (Eisenhardt, 1989; Yin, 2014; Rose, Spinks and Canhoto, 2015). The analysis of each case provides close expertise about each case and the appearance of patterns for each case as an individual unit, whereas the cross-case analysis presents possible parallels and differences between the cases (Eisenhardt, 1989), which converges and clarifies the cases, and helps to increase the internal validity of the study (Voss, et al., 2002).

2.7 Validity and Reliability

The validity and reliability of a study are aspects that are used to judge the quality of the performed research and must be kept in mind when establishing the research design (Yin, 2014). The validity concept is focused on whether the question or data in fact measures or explains what it was proposed to do that can be increased by the use of particular specified and well-established techniques and strategies (Given, 2008). Reliability is reached when similar results can be obtained by other researchers when they apply the same research process what makes it necessary to adopt a systematic way of work (Given, 2008).

2.7.1 Validity

Along with reliability, validity is a crucial indicator of the quality of a study. Validity is regularly described in general as being reliant on the level to which a research truly measures what it intends to measure (Given, 2008).

This concept can be divided in construct validity, internal validity, and external validity (Yin, 2014). The first looks at if the right operational measures were set up for the topic under study (Voss, et al., 2002). Internal validity concentrates on the findings of the research if they correspond to the reality or if non-examined factors that could influence the outcomes exists (Yin, 2014). The last one, external validity, describes to what extent the results of the study can be generalizable to other situations (Yin, 2014).

To increase the construct validity, the researcher made use of multiple sources of evidence (Yin, 2014), such as interviewees and secondary data (reports, books, and articles) including different perspectives. Likewise, an extensive literature study grounded the theoretical background, which assisted on the description of a set of procedures lined up with the research questions and with a definition concerning what has being examined under the platform-based development of CoPS topics and what has not.

Similarly, the extensive literature review guaranteed the internal validity of the study, since it provided the starting point for the definition of the dimensions and aspects used to examine the platform-based development of CoPS, considering recognized previous studies that analyze this subject from several points of view. The study used a well-accepted method (case study), and the interviews were audio-recorded and transcribed to help to perform a cross-case analysis, what supports to make a pattern matching between the studied cases and the existing theory to present a clear interpretation of the results (Yin, 2014).

A framework of the relevant theory regarding platform-based products and CoPS have been proposed to make sure and support the internal validity of the study, which according to Yin (2014) assist researchers in collecting pertinent information for the project.
Considering external validity, differently from the quantitative studies where the generalizability is assessed through sampling techniques (from sample to population) (Given, 2008; Yin, 2014), the generalization of qualitative results in a broader sense goes beyond a particular case under study. In this way, the adoption of multiple case studies increased the external validity of this research since it allowed more robust outcomes based on the replication logic (Eisenhardt, 1989). Thus, the study has a higher external validity compared to a single case study. However, the research was focused on systems from a specific firm in Sweden in a very specialized industry, what could restrict the application of these results to a different context. Despite this, a good support of data and a comprehensive portrayal of the context of the cases under investigation allowed to extend the results and make an evaluation with comparable cases.

2.7.2 Reliability

Considering the research arena, reliability can be described as the dependability, constancy, and repeatability of a study’s collection, interpretation, and analysis of data (Given, 2008). In other words, as stated by Yin (2014), it is the capability that the procedures of a study – such as data collection processes – can be repeated with the same results if other researchers adopt them.

A good explanation of the planned steps in the research and what was achieved, a thorough description of the data collection and an assessment about the carried out interviews guaranteed the reliability of this study.

The questions of the interviews are presented in Appendix 1 - Interview Questions to make sure that the gathered data are replicable. However, a qualitative study is somewhat difficult to be replicable due to different answers to the same questions by different employees as each human being has a unique perspective on its surroundings (Yin, 2014), what can affect the reliability of this work.

In this way, it is expected that another researcher performing the same study would probably get comparable results on what factors influence the platform-based development of CoPS. On the other hand, the previous knowledge of the researcher about the cases analyzed and his familiarity with weapon systems’ terminology will insert a subjective opinion regarding data interpretation that can incur on different perspectives about the same topic by another researcher.

2.8 Research Ethics

Regarding ethics, the first step in the thesis was a meeting with a Saab employee to understand the proposal and try to delimit the scope of the study. He also provided the contact of the researcher with the first interviewees. All the respondents received initially a proposal of the research with a brief introduction of the study, the interview procedures with some main ideas about the interview questions and how the given information would be used to avoid any misleading or misunderstanding. All the respondents agreed voluntarily to participate in the research.

All the interviewees’ identifications were removed from the empirical data to ensure confidentiality at the necessary level agreed by them. Although no technical details about the systems were the focus of the study, the researcher looked at the primary data to remove any possible classified information that should not be public.
2.9 Limitations

Even with all the qualities presented in the literature regarding case studies it has its limitations (Rose, Spinks and Canhoto, 2015), for example, from generalization to time demanding issues. Different aspects presented in the study may bias its outcomes. The researcher prior knowledge about the different weapon systems and some knowledge about CoPS platforms might have influenced the author’s subjective opinion, as well as, the selection of the cases can bias the findings of the research, since they may favor cases that are supporting the theoretical background (Rose, Spinks and Canhoto, 2015).

As the research involves multiple cases, the ideal situation would be to have a uniform way of recording data to assist both with the analysis and the reliability of the study along with reducing the complexity of field research (Rose, Spinks and Canhoto, 2015). However, for different reasons, three separate methods of collecting data were used.

The number of secondary data available for the systems, in particular for Gripen, regarding a historical perspective, is considerable. However, the majority of them are in Swedish what limited the scope of available secondary data in English. Although, some of the available data in electronic format in Swedish were translated into English with the use of Google Translate website, which inserted translations issues to the utilization of these data and was time-consuming to check the translations.

Furthermore, the availability of secondary data is not evenly distributed through the five systems. Gripen, Carl-Gustaf, and AT4 have much more secondary data available than NLAW and BILL (the last one being the system with less secondary data available). One explanation for this limitation is that NLAW and BILL have a small number of users and BILL has not been tested in real combat. BILL is also the system with fewer data available from the interview.

One limitation concerning validity is that Saab initially selected the interviewees what, somehow, imposed a bias to the answers, especially for the Ground Support Weapons Systems that just one interview was performed. For Gripen, it was possible to get the names and contact information of some knowledgeable interviewees after adopting a snowball approach to the initial ones. However, in many cases, it was tough to access them with a small response rate reducing the number of interviews.

Another validity limitation was that the interviews were conducted in English. Although all the respondents and the author speak English, it is not their mother language, which can inhibit a complete free thinking of the interviewees and impose some misunderstandings by the interviewer.


3 Theoretical Background

This section includes a description of platform-based products theory, the special case of complex products and systems, the strategic management decisions that are involved in the development of CoPS platforms and the aspects related with the customer-supplier (buyer-seller) relationship of the specific case of CoPS in the military field. In the end, an analytical framework is proposed to analyze the collected data.

3.1 Platform-Based Product

In a competitive and globalized world where companies from different countries compete against each other for customers with nearly individual needs, the use of product platforms has spread (Simpson, Siddique and Jiao, 2006a) changing the focus from a single product to a multi-product focus, while preserving the crucial economies of scale within design and manufacturing (Simpson, Siddique and Jiao, 2006a).

Different definitions in the literature exist. Robertson and Ulrich (1998) define platform in general terms as a series of assets that are common in a group of products regarding components, processes, knowledge or relationships (people). Meyer and Lehnerd (1997) have a more product-oriented perspective where a product platform is a group of subsystems and interfaces that form a shared structure that can be used effectively to develop and produce derivative products. Gawer (2011) has her focus more on industry ecosystems and technology platforms where the products, services or technologies, like personal computers or operational systems, are designed and developed by a single or a set of companies, and this platform is used as the base where other firms build additional products, services or technologies, such as applications for smartphones.

In other words, platform-based products can be defined as a set of components and modules developed with the aim of building a foundation (the platform), for the successive design and development of derivative products (product family) (Sköld and Karlsson, 2013; Chai et al., 2012).

Meyer and Lehnerd (1997) define product family as “a set of individual products that share common technology and address a related set of market applications.” The design process of a product family is not fixed to a specific formula or model available on the literature. A common beginning of a product family development process relies on its customer requirements and market needs (Ohvanainen and Hietikko, 2012). Moreover, it relies on a whole core of assets including processes (design, engineering, and manufacturing), customer segmentation, brand positioning, logistics (supply and distribution) (Halman, Hofer and Van Vuuren, 2003) and after sales support.

Platform-based products developments are primarily based on multifunctionality, which brings greater flexibility in product design and a better product development. The platform concept is related to reuse of subsystems, modules, and components through diverse products that at the end point out to a core element (platform) from where each specific product is originated (Halman et al., 2003).

The arrangement of these subsystems, components, and interfaces outlines the architecture of any single product (Meyer and Lehnerd, 1997). Ulrich (1995) defines product architecture as “the scheme by which the function of a product is allocated to physical components.” In other words, it means how the functional elements of a product are arranged, how they are related to
physical components and how their interfaces interact with physical components (Ulrich, 1995). All products have a particular architecture, and it is an important part of the product concept; the objective with platform thinking is to design an architecture that is common across many products and can be the basis for making several derivative products. (Meyer and Lehnerd, 1997)

Therefore, the key aspects of a product platform include some level of modularity to permit decoupling of components (with some customization) and the standardizing of part of the product architecture (Halman et al., 2003). Figure 2 describes these aspects showing the product platform strategy of Volkswagen (in the case the Golf platform) with standard parts (like chassis and engine) and customized components (such as seats and exterior parts).

![Figure 2: Volkswagen’s Product Platform Strategy adapted from (Winterkorn and Pötsch, 2012)](image)

Henderson and Clark (1990) in their work regarding Architectural Innovation proposed a two-dimensional framework that captures innovation impacts on components (horizontal axis) and the linkages and interfaces between components (vertical axis). Similarly, Sköld and Karlsson (2013) summarized the key features of platform development in four different types that are focused on the component and architectural aspects, as presented in Table 3.

The incremental platform development supports derivative and improvement development as it is focused on minor changes in components. This type of development demands normal line of resources within functional units, with line management coordination and almost no direct top management involvement. (Sköld and Karlsson, 2013)

Also on the component focus, Modular platform development enables new products to product families as the changes are mainly targeting the components, rather than the architecture. Knowledge in handling complex technologies and specialized Research and Development (R&D) are required resources, demanding a management style concerning coordination of new component technology through a medium or long-term cycle. (Sköld and Karlsson, 2013)

Architectural platform development involves changes in architecture enabling new generations of a product platform. It demands resources to integrate R&D and manufacturing, with cross-functional management and senior management involvement as the important management styles. (Sköld and Karlsson, 2013)

The last one, radical platform development similarly involves changes in architecture as well as with components to enable next-generation product development. It requires extensive R&D resources with long time cycles and cross-functional groups handling complex processes with top management and senior management as the main changes in management styles. (Sköld and Karlsson, 2013)
Table 3: Characteristics of Platform Development adapted from (Sköld and Karlsson, 2013)

<table>
<thead>
<tr>
<th>Platform development variant</th>
<th>Incremental platform development</th>
<th>Modular platform development</th>
<th>Architectural platform development</th>
<th>Radical platform development</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Components Focus</strong></td>
<td><strong>Architectural Focus</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Changes in architecture (A) and components (C)</td>
<td>(A): No</td>
<td>(C): Small</td>
<td>(A): Yes</td>
<td>(A): Yes</td>
</tr>
<tr>
<td>Time length (relative)</td>
<td>• Short time or Short-time cycles</td>
<td>• Mid- or long-time cycle</td>
<td>• Long time</td>
<td>• Very long time</td>
</tr>
</tbody>
</table>

Requirements

| Resources                      | • Normal line resources          | • Specialized R&D Complex technologies | • Product development departments | • Extensive R&D resources |
|                               | • Various specialists            | • Systems engineering                | • Manufacturing integration       | • Several functional technology areas |
| Principles for organizing     | • Within functional units        | • Cross-functional project organization | • Cross-functional project organization | • Cross-functional teams |
|                               | • Lightweight team               | • Heavyweight team                   | • Autonomous team                 | • Autonomous team |
| Management styles             | • Line management coordination   | • Technology coordination            | • Mid- or long-time cycle         | • Complex processes |
|                               | • Little or no direct top management involvement | • Senior coordinating technology managers | • Senior management involvement | • Senior and top management ownership and involvement |

3.1.1 Advantages and Disadvantages of Platform-Based Products

Companies are progressively moving toward a platform-based approach to reduce complexity and costs in product development, as well as, in manufacturing and marketing (Halman, Hofer and Van Vuuren, 2003).

Applying the platform-based approach can speed up the product development process. Further, it contributes to the reduction of resources (human, money and time) in all phases of product development. As previous tested components and subsystems are used, the knowledge gained through this process will enhance the design of products with better performance (Halman et al., 2003; Simpson et al., 2006). Therefore, this process must be continuously renewed as new technologies are available (Simpson et al., 2006), making the product platforms that are carefully planned and executed offer significant enhancements in cost, quality, and performance compared to previous generations (Wheelwright and Clark, 1992).

These new generations can also be based on either an addition to the product platform or on a completely new product platform (Meyer and Lehnerd, 1997). Although, if the common platform has a bad design, it will weaken the competitiveness of the product family, making many products lose attractiveness (Halman et al., 2003).
Some advantages that the adoption of a platform approach presents are a formalized development process, knowledge-sharing across platform-based products, stability of development teams, and, sometimes, the existence of champions during platform-based product development, in particular on the early stages of development. Similarly to R&D and production in higher volumes, logistics (distribution channels and maintenance services) enables platforms to obtain economies of scale (Baldwin and Woodard, 2009; Mäkinen, Seppänen and Ortt, 2014). The common practice in many industries is to design product families that make use of commonality to gain economies of scale and scope at the same time as to fulfill the requirements of different market segments. (Simpson et al., 2006)

On the other hand, these competencies may create some disadvantages, such as a more platform-based rigid design and manufacturing process, and delivering a less innovative solution to the user, as the innovations are limited by the platform (Mäkinen, Seppänen and Ortt, 2014). Another drawback is the increased potential for the lack of product distinctiveness due to commonalities within each platform (Robertson and Ulrich 1998) which can impact financial return of a company with lower-end models cannibalizing sales of the higher-end models as well as affecting costs due to overdesign of low-end products (Simpson, Siddique and Jiao, 2006a). Also on the financial side, the developing costs of a product platform, as found by Ulrich and Eppinger (2004, cited in Simpson, Siddique and Jiao, 2006a), can be two to ten times more expensive than the development of a single product, making a platform-based product development not always profitable (Alizon et al., 2007). This fact is more noticeable for those platforms with low volumes of production.

3.1.2 Drivers and Barriers to Platform-Based Products

Platform-based thinking assists on the innovation process in new product development, since new product versions match the platform design and in this manner, deliver additional value to end users. In contrast, a platform-based thinking may hinder the ability to develop new products that would require radical changes in the platform. For instance, if some parts of the platform (components, modules or subsystems) or even the architecture need to be changed radically, the platform as a whole may need to be altered, modified, or abandoned. (Mäkinen, Seppänen and Ortt, 2014)

Standardization of previously parts and subsystems tailored to specific customers is an important strategy to have production learning, cost reduction and continuous innovation (Hobday, Rush and Tidd, 2000). The standardization of the main subsystems (and their components) across a product family can thus enhance product performance and reduce costs. (Meyer and Lehnerd, 1997)

Companies adopting platform-based products face some barriers to keep with this approach. First is how to maintain the platform compatible with components and subsystem that are also facing technological innovations and are part of other firms’ strategy. Moreover is how to foster platform improvements keeping compatibility with old components and subsystems. (Cusumano and Gawer, 2002)

Sometimes, companies that have a successful platform can be so tied to some specific technologies that it becomes tough to advance their platforms. They need to look beyond their current business as well as the technical features of one product or component. (Cusumano and Gawer, 2002)
Platforms development demand a high level of resources, so it is usually suggested that existing product platforms are exploited to its full potential to the maximum extent possible. However, this fact imposes a conflict of interests, since product platforms can be used to increase product diversity and foster short-term innovation while the money invested on the platform makes pressure to reuse the platform as much as possible. This way, the platform itself may act as a barrier to future improvements requiring a renewal of the whole product architecture. (Simpson et al., 2006)

3.1.3 Strategies for Platform-Based Products

The adoption of a platform development strategy is a crucial factor for both upgrading existing products and creating entirely new solutions. Planning families of products involves extra attention, as these products compete for market shares with competitor products as well as with products within the family (Simpson et al., 2006). In this manner, the design of a product platform and its corresponding family of products is challenging as it involves all the difficulties of product design with the complexities of coordinating the design of multiple products in order to increase commonality within this product family conciliating their distinctiveness (Simpson et al., 2006; Simpson, Siddique and Jiao, 2006b).

Modularity and product architecture allow firms to merge their capabilities and technologies to answer a wide-ranging number of different customer needs. With platforms it is possible to a company to put on the market global portfolios of products while dealing with regional differences regarding design, styling, regulations (Simpson et al., 2006), geographical (environment and climate) and cultural aspects.

Development of cohesive and flexible product architectures are required to implement a successful platform strategy. The platform should be the origin and the focus of an internal product roadmap that shapes future capabilities and functionalities at the same time serving as a target in the overall corporate vision. Platforms are based on supporting building blocks such as common architecture, components, and subsystem. This way, the platforms can be designed for a specific market segment and then be easily modified for different market tiers within the same segment. (Marion and Simpson, 2006)

In this way, Figure 3 describes a product family roadmap through time based on three generations of a product platform (Marion and Simpson, 2006). This roadmap shows how product platform developments can lead a company into the future through transitions in technology as well as market needs. It illustrates the development of a product platform based on a single product family, followed by continuous improvements to the main product and processes of that platform, with derivative products within each generation. (Meyer and Lehnerd, 1997)

At the same time as product platforms are the basis for the development of many derivative products, they should not be seen as something static (Meyer and Lehnerd, 1997). When competitors’ products are surpassing product derivatives or market needs are shifting, a platform renovation has to be performed (Ohvanainen and Hietikko, 2012). Well-managed product platforms are always evolving as new market knowledge, and new technologies are integrated into products and production processes. (Meyer and Lehnerd, 1997)
To obtain continuous success in new product development, a company needs to maintain its platform architecture and manufacturing processes updated by incorporating innovations into the platform and to its processes, both internally and externally. By constantly obsoleting its products with better ones, a firm keeps its products up to date with competitors and guarantees the continuity of the company. (Meyer and Lehnerd, 1997)

The rewards from a platform design take years to recognize since the total benefits from a successful platform can only be calculated at the end of the platform life cycle, which can take several product generations. To evaluate these rewards, rather during the development process is challenging. (Simpson et al., 2006)

Measuring the benefits and drawbacks of platform thinking is essential, but at the same time, it is difficult due to inherent uncertainties in model and market. Because of these uncertainties, platforms have to be robust and flexible to answer in a better way to future customers and market needs, such as new functions, new technologies, and changes in regulations or the extension into new markets. Product platforms usually have life cycles that surpass the lifetime of each product variant, and this issue makes the quantifying of advantages and disadvantages both challenging and important. (Simpson et al., 2006)

Platform strategy serves as a top-down planning line of attack to exploit market advantage from common technology and simplify portfolios. In Figure 4, the vertical axis reflects different tiers regarding both price and performance. Meyer and Lehnerd (1997) portrayed this market segmentation grid to assist marketing and engineering in recognizing potential platform leveraging strategies for a product family at the same time as it is being developed.

The gain of using a horizontal leverage strategy (Figure 5) is that a firm can introduce streams of new products through several related customer groups not needing to start the development from the ground for each group. Leverage can be reached albeit the platform as a whole is not used in neighboring segments. Essential components or subsystems of the platform not only will be appropriated but also are the most usual form of horizontal leverage of common technology. Moreover, leverage follows the degree that the key components and subsystems of a product platform are modified for use within several market segments. (Meyer and Lehnerd, 1997)
Vertical scaling (Figure 5) a platform gives a company the ability to leverage its knowledge about any specific market segment to develop products for each tier of price-performance without the need to develop a new platform or product for each market tier (Meyer and Lehnerd, 1997).

The full potential of product platforms is augmented when horizontal leveraging with upward vertical scaling are merged. This leveraging strategy is called the beachhead approach, as shown in Figure 5. (Meyer, 1997)

A potential risk of both horizontal and vertical leveraging is that a common low quality or poorly designed platform can undermine performance and competitiveness of the entire platform in multiple market segments. (Meyer and Lehnerd, 1997; Marion and Simpson, 2006)

With this in mind, to develop thriving new product platforms and services, companies need to precisely listen to and recognize the needs and expectations of each market segment and tier. This information, related to the product platform strategy, can help improve the market segmentation grid. (Marion and Simpson, 2006)

Another strategy to leverage platforms is what Eisenmann, Parker and Van Alstyne (2011) called as platform envelopment. Platform manufacturers, supplying different markets, sometimes make use of similar components and share the user bases within these markets. In this sense, the idea of envelopment is to cross over the limits of its current markets by bundling
the company’s platform functionality with that of the boundary markets to leverage the firm’s platform through shared user relationships, reputation, technology and common components (Eisenmann, Parker and Van Alstyne, 2011; Gawer and Cusumano, 2008).

One platform that dominates its market can be a distribution mechanism for contesting other markets if this platform can bundle technologies, use the same distribution channels or create distinctive complementarities to the new market (Gawer and Cusumano, 2008). For example, Apple’s iPhone/iPad/iPod platform has enveloped platform providers in many different markets, bundling the functionalities of personal digital assistants, video games, eBook readers, mobile phones, photography, PCs, media players and even payment systems. (Eisenmann, Parker and Van Alstyne, 2011)

Because platform-based product development involves more resources, more people, and more products with more functions than single product development, it can be regarded as a particular form of complex development work (Chai et al., 2012). It is similarly important to understand and focus on the different organizational contexts that platforms and product families are applied (Halman, Hofer and Van Vuuren, 2003).

3.2 Complex Products and Systems (CoPS)

Hobday (1997) defines Complex Products and Systems (CoPS) as those products that have a high cost of development, are engineering-intensive, and demand some different technological capabilities to be developed. For Davies and Brady (2000) “CoPS are high-technology and high-value capital goods,” ranging from high-speed trains to intelligent buildings and weapon systems. They are called complex to express the number of tailored components and modules, the extent of knowledge (part of it new) and skills involved in their production, along with other critical dimensions (Hobday, 1997).

For some CoPS, like airplanes, the subsystems (such as aircraft engines and avionics) are also complex products and systems, tailored to specific requirements and with a high cost (Hobday, 1998). These subsystems are sometimes equal or more complex than the system they are part, as, for example, the guidance system of a missile.

CoPS are typically challenging to produce, based on multi-firm projects, and customized for corporations, government and institutional customers usually under one (or more) formal contracts (Davies and Hobday, 2005). The number of selling orders is irregular, large in value and long in duration (Hobday, 1997). As CoPS are large investment products or services which operational life cycles spread out over many years, decisions to put money in these projects may take months or even years (Davies and Hobday, 2005) and, in some cases, innovation often goes in parallel with long life cycle of the product (Hobday, 1997).

Some examples of CoPS include telecommunications stations, satellite systems, aircraft engines, software packages, chemical plants, baggage-handling systems, offshore oil equipment, and systems for electricity grids (Hobday, Rush and Tidd, 2000; Davies et al., 2011), representing a substantial amount of industrial output (Hobday, 1998) of many countries.

As high technology tailored capital goods, CoPS are manufactured in one-off projects or small volumes (Hobday, 1997; Hobday, Rush and Tidd, 2000) differing from mass-production of consumer goods. Undoubtedly, there are a number of products that are manufactured initially in small lots and then shifted towards mass production, as for instance, new consumer products that are, in some cases, manufactured first in small batches and later expanded to mass
production volumes when there is market demand (Acha et al., 2004). CoPS are designed and produced on a one-off project basis or in small customized lots to meet specific customer needs (Davies and Hobday, 2005). Hobday (1997) considers that they are never mass-produced. Acha et al. (2004) have a slightly different approach where they state that CoPS are rarely manufactured thinking on mass production batches; some products are initially planned as CoPS and then, following market demands and cost reductions in their manufacturing processes become over time mass-produced. Some examples are the mobile phones and computers that initially were very expensive and with limited markets and then became mass-produced goods (from CoPS to non-CoPS production) (Acha et al., 2004).

Many other differences exist between CoPS and mass-produced goods. At the product level, CoPS are formed of lots of tailored, sometimes unique, interrelated control units, subsystems and components (Hobday, 1997), making it difficult to have commonality and economies of scale in products that fulfill very specific customer needs and that usually differ greatly from one contract to the other (Farrell and Simpson, 2003). These factors lead to a high cost of design, development, and production, and long and uncertain time to market (Farrell and Simpson, 2003). In mass-production, the products have mainly standardized parts and subsystems and are mostly the same from contract-to-contract, making it easier to design and manufacture and reducing costs and production time.

In mass production, product development is concluded before taking the product into manufacture, later followed by marketing, distribution and, finally, selling to final users (Davies et al., 2011). For CoPS the sequence usually starts in the pre-design phase, winning a bidding process and securing an order from the customer, with later development of components and subsystems, adjusting the design in the course of production to meet changing customer requirements, and delivering an integrated system solution at the end (Davies et al., 2011; Davies and Brady, 2000).

In CoPS production, the user’s voice and knowledge about the product or system have more influence than in commodity goods (Hobday, 1998; Davies and Brady, 2000). The user’s involvement in CoPS takes place in all steps of the product’s life cycle distinguishing it from simple production goods, where direct user involvement occurs (if it occurs) at the early stages (Hobday, 1997). As CoPS have a high cost and a long lifespan (Hobday, 1997), customers, users, and operators are usually intimately involved with suppliers in R&D and during production, along with operation, maintenance, updating, re-design (Davies and Hobday, 2005) and for some case, decommissioning, continuously feeding back information to the supplier (Hobday, 1997). The close collaboration between customers and producers allow users to feed their needs directly into the steps of product development of CoPS (specification, design, development, and manufacture) (Hobday, 1998). In reality, due to the customer’s knowledge about the product and the specific demands, it is common that new ideas originate with the customer (Davies and Hobday, 2005). In contrast, although some mass-produced products can present significant user-producer interaction at the early stages of product development, this interaction is scaled down over time due to standardization of components and to a reduced influence of the customer as the markets for the product expand. (Hobday, 1997)

The design and construction of CoPS usually demand a high level of coordination skills, not only because CoPS involves a large number of different components, knowledge, and skills but also because many sub-suppliers and other organizational units of the producer frequently share duties and responsibilities during production (Hobday, 1997; Hobday, Rush and Tidd, 2000).
A considerable part of this coordination process is to deal with feedback loops from users and other stakeholders like sub-suppliers and governments (as a regulator) (Hobday, 1998).

Another coordination problem is related to the degree of user involvement and how well was the translation of user requirements into the product design and vice-versa. Sometimes, a user is not very sure about its demands, or its requirements can change as the product development process evolves (Hobday, 1997). These feedback loops are very common in military systems where the requirements are set prior to the design of the systems, and the buyers have an in-depth involvement in the monitoring and control of changes in the specifications that may occur during product development, as the user requirements evolve (Davies and Hobday, 2005). Likewise, the degree of supplier involvement can further affect the coordination of the product development. Also, the higher the number of companies that are involved in product specification, design and manufacture, the higher will be the complexity of coordination. Regulatory and sovereignty issues, like safety purposes, standardization and national interests, can also influence CoPS development. (Hobday, 1997)

Moreover, the breadth of skills and technologies required has a great impact on the coordination process (Hobday, 1998). It is directly proportional to the level of complexity of the CoPS, as well as to the number of firms involved in the CoPS design, development, and production as can be seen on railway systems where knowledge bases from different fields (such as software and Information Technology – IT, communication, mechanical systems, and logistics) need to be integrated. If the number of firms involved is high, the coordination task will be more complex (Davies and Brady, 2000). Likewise, if the CoPS is more complex than it will need a wider range of skills and capabilities for pre-design, bidding, design, development, and manufacture (Hobday, 1998) compared to a simple product. For example, CoPS suppliers need to keep some design knowledge of main components and subsystems in-house to be able to outsource efficiently (Hobday, Rush and Tidd, 2000). In addition to this, the main part of this required knowledge (skills and capabilities) are within people (tacit knowledge) and cannot be easily translated to written form (Hobday, 1998). In the course of the main production steps of a CoPS, some intangible skills, like leadership, communications, and spirit de corps are essential to a good performance of this CoPS (Hobday, Rush and Tidd, 2000).

The learning process within products and from prior generations is higher in simpler goods than in CoPS due to the volume of production (learning by doing) and the knowledge in written formal procedures (Hobday, 1998). In CoPS, this learning process is more accidental (unplanned) as a result of the inherent challenges of transferring knowledge from one project to the next, with different customer needs and a high degree of component customization (Hobday, 1997). This learning process is critically dependent on tacit knowledge embodied on the employees and project team, contrasting with the more explicit knowledge (in codifiable format) necessary to the large volume rate of simpler goods (Hobday, 1998; Davies and Hobday, 2005). Another common problem for CoPS is that the project teams are many times shut down after completion of the project, having negative implications for knowledge transfer inside the organization from one project to another (Hobday, 1998) and also within the employees, as they will get part of the knowledge with them. Undoubtedly, it represents a challenge to maintain a capability level from project to project, since there is a clear risk that the tacit knowledge embedded in employees will be dissipated and lost to new CoPS and probably the same mistakes will be repeated (Davies and Brady, 2000) and the time for design and manufacture will increase.
Furthermore, CoPS prototyping and experimentation can be extremely costly or even impossible to produce (Hobday, 1997). Errors and wrong design at early stages can be costly and difficult to correct. This way, due to impossibilities to make field tests and due to feedback loops from later to earlier stages, a process of continuous learning during CoPS development is expected to be crucial to their design, manufacture, and installation (Hobday, 1997). Moreover, lessons learned from previous projects are essential to the success of subsequent projects, leading to functional changes in CoPS producers’ organization and contributing to major shifts in the strategic direction of these companies. (Davies and Brady, 2000)

Consequently, CoPS suppliers can reduce their costs and achieve improvements in product efficiency, referred as ‘economies of repetition’, by managing changes, routines and learning processes inside the firm to the execution of an increasing number of comparable bids or projects within cost, time and the required specifications (Davies and Brady, 2000). When projects are repeated, familiar patterns of organizational behavior are likely to arise indicating potential routines and procedures a company could adopt to effectively deliver new similar projects (Davies and Brady, 2000). Instead of starting from the ground, CoPS producers can present repeatable solutions using prior experience from other bids or products in the same type of business (Davies and Brady, 2000). Sometimes, they can also use knowledge from one product to aid the development of another business unit (Davies and Brady, 2000), like the development of KC-390 Military Aircraft from the Brazilian firm Embraer that has used many technological solutions employed in its E-series of civilian aircrafts (Embraer, 2007).

For the CoPS supplier, the emphasis on front-end activities, which involves a close collaboration between the supplier and users (Davies and Brady, 2000), requires more competitive strategies, and management skills focused on efficiency and effectiveness in design and pre-design, bidding, and development than economies of scale in manufacturing as occurs with mass-produced goods (Hobday, 1998). Although CoPS may not have high volumes, the use of batch production and changes in its design architecture (to increase the number of standardized components and subsystems) (Hobday, Rush and Tidd, 2000) can provide substantial development and production economies, in particular for those products planned as platforms (Hobday, 1998). One example of this approach is the development of the E-series of aircrafts from Embraer. The commonality rate among subsystems (such as engine, avionics, and high-level components) and components for its four models (E-170, E-175, E-190, and E-195) is around 85% (Simpson, Siddique and Jiao, 2006b). Even though planned as product platforms, these CoPS always have some degree of customization (Hobday, 1998).

Evolution in CoPS has the purpose to overcome product limitations and to adapt to increasing demands on performance, capabilities, and reliability (Hobday, 1997) by adding new functions (Davies and Hobday, 2005) or correcting problems in the design. This evolution frequently increases system complexity from one generation to the next, even though some factors are used to try to simplify, such as the modularization of systems and standardization of previously tailored components (Davies and Hobday, 2005). For instance, the standardization of formerly customized parts and subsystems is an important management strategy that can reduce costs, generate innovations and allow production learning (Hobday, Rush and Tidd, 2000). Likewise, with modularization, it is possible to decouple components and subsystems to build an information structure to obtain entrenched coordination and to increase the firm’s flexibility (Magnusson and Pasche, 2014).
This way, many CoPS have become larger, with highly elaborated architectures and thousands of components (Hobday, 1997), more costly and more technologically intensive through time (Davies and Hobday, 2005). Emerging and non-planned properties also occur from generation to generation, as small changes in one part of a system’s design (as a result of, for example, feedback from users or new market needs) can lead to larger changes in other parts, requiring new control systems and, in some cases, new materials (Hobday, Rush and Tidd, 2000).

For CoPS suppliers, it is necessary to have a deep Systems Integrator (SI) capability to compete (Davies and Hobday, 2005) on the market. CoPS producers are not only involved in the fabrication of components, they mostly add value to parts and subsystems, and establish how these components and subsystems are integrated into a coherent form as a whole (product architecture) (Hobday, 1997). This way, they regularly define the design rules of specific components and their technical specifications (Acha et al., 2004). However, the number of possible product architectures can create important coordination problems for the different suppliers of the CoPS, particularly when the SI, the customers, the users, and regulators have to agree (Hobday, 1997). Therefore, CoPS suppliers’ key production capabilities as SI are systems design, project management, systems engineering and integration, differently from manufacturing processes focused on volume, like design for manufacturing, which is crucial to have a competitive mass-produced good (Hobday, 1997). Likewise, users and regulators (government agencies), also need some knowledge about systems integration and, occasionally, specific capabilities (Davies and Hobday, 2005).

CoPS development and use have changed through time with the increasing use of computers and software. The extent of embedded software and IT in CoPS has become a core integrative activity. The use of state-of-the-art software within CoPS, stimulated by low-cost increasing computer power, has enhanced the control and performance of various systems (Davies and Hobday, 2005) being the main task in systems like flight simulators, military systems, telecommunications exchanges, avionics, among other complex products (Davies and Hobday, 2005). Integration of embedded software and IT within components and subsystems and, in particular between firms, is an uncertain and risky activity (Hobday, 1997). In this sense, it demands more coordination to avoid the possible obstacles that embedded software and IT present to a smooth, on time and budget CoPS project (Hobday, 1997).

Considering Industry perspective, CoPS Industries are usually duopolistic (bilateral oligopolies) with a small number of large suppliers and large demanding customers that are very knowledgeable about the products and system they are demanding (such as airport operators, oil companies, electric power suppliers and armed forces) (Davies et al., 2011). These transactions are highly institutionalized, involving complicated and detailed price formulas that, sometimes, are unique for each single contract (Hobday, 1998).

CoPS, as occurs with mass-produced goods, are not ‘all the same’ (Davies and Hobday, 2005). It is clever to analyze CoPS bearing in mind the markets where they are embedded, considering that their main characteristics can only be understood when the requirements and peculiarities of their specific markets are taken into account (Hobday, 1998). Products and systems for military applications, for example, regularly merge characteristics of product development and projects implementation, as exemplified by fighter jets, submarines and radar systems that continuously widen the boundaries of technology (Davies and Brady, 2000). For instance, considering defense equipment, they enclose high-complexity core technologies that demand extensive investments in R&D which increases costs of development and are challenging to
deliver on an economy of scale (Lee and Yoon, 2015) since they have low volume of production and have governments as their major regulators, sponsors and final customers for these CoPS (Hobday, Rush and Tidd, 2000; Davies et al., 2011; Heidenkamp, Louth and Taylor, 2013)

CoPS has a long life cycle that extend over decades (Hobday, 1997) and will have to meet new requirements and offer new solutions (Holmberg, 2003) which brings difficulties to have a clear picture of market niches⁴ and design requirements since future needs and demands may be significantly different from the past (Farrell and Simpson, 2003). In this way, the problem of delimitating design options for CoPS can be overwhelming, notably in circumstances where there are rapid technological changes, unknown user demands and many tailored components (Hobday, 1997). Therefore, CoPS’ architecture has to be designed such that yet-unknown requirements and design parameters could be integrated in the future while the architecture remains unchanged (Holmberg, 2003). Nevertheless, what may be seen as incremental evolution at the product and system performance level, can be a radical change at the component level (Hobday, 1998; Davies and Hobday, 2005).

3.3 Strategic Management of CoPS platforms

Management strategies and decisions actively draw the direction a firm should follow to achieve and sustain competitive advantage (Teece, Pisano and Shuen, 1997) taking into account how the company can affect the market it is involved in and how this market may influence the firm (Freeman, 1984). Management is in charge of recognizing, supporting and building essential capabilities to a firm be able to adapt to and to mold its environment (Davies and Brady, 2000).

Radical changes in the firm’s Industry and market can push the company to a renewal of its capabilities and internal organization. Management is responsible for distributing human and financial resources and for carrying out long-term strategies to maintain, renovate and expand a firm’s organizational capabilities in response to technological changes and market transformations. (Davies and Brady, 2000)

Capabilities, in this sense, refer to the role of management in being able to adapt, integrate, and redesign organizational skills (both internally and externally), resources and functional competencies to contest the new demands of a changing environment (Teece, Pisano and Shuen, 1997) more quickly and efficiently, than its competitors. (Davies and Brady, 2000).

As market conditions change, a company needs to adapt its internal capabilities and processes to continue effective (Davies and Brady, 2000). Nevertheless, this necessity for organizational change remains through the time as the company changes its capabilities and processes from the first projects to an increasing number of similar projects (Davies and Brady, 2000) based on the same product platform. Therefore, management of the development of a product platform concerning changes in the platform components and architecture appears to be crucial for managers. (Sköld and Karlsson, 2013)

Platforms, in general, offer substantial competitive advantage and possibilities to foster market penetration. However, many enterprises consistently underinvest in them, mainly because of

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⁴ A market niche is defined as a particular area of a market area where price and performance requirements are unique. (Marion and Simpson, 2006)
reduced perception of the strategic value of platforms by management. This way, these firms fail to create well-planned platform projects. (Wheelwright and Clark, 1992)

For this reason, platform development is considered to be a phenomenon of vital importance for the strategic management of companies (Thomas, Autio and Gann, 2014) with some researchers suggesting that they are among the crucial decisions that an organization makes (Robertson and Ulrich, 1998). Platforms to thrive among competitors require significant up-front planning and the participation of not only R&D but likewise marketing, manufacturing (Wheelwright and Clark, 1992) and especially from a great support from the top management (Wheelwright and Clark, 1992; Ohvanainen and Hietikko, 2012).

In this sense, robust product platforms are not perceived as the result of lucky companies. In contrast, they are the outcomes of methods, practices, and strategies for designing, developing, manufacturing, selling and renovating them through time (Meyer, 1997). Therefore, platform decisions implies an enterprise’s flexibility to respond to technological or market changes (Halman, Hofer and Van Vuuren, 2003). A high level of formalization (strict rules and procedures) may be valuable to maintain platforms stable, and with clear and instantly recognizable interfaces, thus simplifying coordination process. On the other hand, if the product family structure is too formal and rigid, it may act as a barrier to a successful generation of derivative products. (Magnusson and Pasche, 2014)

Robertson and Ulrich (1998) see top management central steering and strong role as essential to platform planning since platform decisions often affect many product lines or intra-organizational units, they are cross-functional and call for complex tradeoffs among different business areas. On the same path, Meyer and Lehnerd (1997) advocate that those platform strategies require having a top-down planning approach to gain the benefits of commonality and technology leverage. Moreover, senior management needs to be closely related to the process of platform revitalization, managing human resources between teams and providing support as projects shift from the design stage into commercialization (Meyer, 1997).

Therefore, it is mainly a top-down responsibility to realize a close alignment between the different business units and the strategic planning of the firms as a whole (Davies and Brady, 2000). Top management is accountable to build shared values throughout an organization, to manage connections across business units, and to develop strategies for acquiring and improving capabilities (Davies and Brady, 2000). Moreover, the adoption of a product platform development demands a centralized top-down implementation process to gain advantages on economies of scale and scope (Magnusson and Pasche, 2014)

 Likewise, continuous updates of a platform’s architecture and manufacturing process are crucial to secure a long-term success and competitive advantage in the market (Meyer and Lehnerd, 1997; Ohvanainen and Hietikko, 2012). The focus must be on the platform life cycle, not on each single product lifespan; the platforms need to be managed as progressing entities (Meyer and Lehnerd, 1997). New customer needs and decreasing competitiveness are indicators that an upgraded version of a platform is needed. Therefore, managers need to respond to platform obsolescence by replacing the current platform (Meyer and Lehnerd, 1997; Simpson et al., 2006). Revitalization of the product platform must be part of the culture of the company (Meyer and Lehnerd, 1997). Choices on new modules and module derivatives have to be made, while at the same time guaranteeing commonalities within the product family (Weiser et al., 2016) and the older generations.
Hence, two approaches to product family design can be adopted. On the first (top-down), a firm strategically manages and design a product family based on a product platform and its derivatives (Simpson, Maier and Mistree, 2001). The design decisions are made in advance, for example, a module-based product family design in which the design is based on modules that can be easily modified and updated. An example of this approach is the Sony Walkman’s product family, in the 1970-1980’s, that was designed from the beginning as a platform and had more than 160 variations based on this robust platform with an average of one new derivative product per month for eleven years (Meyer and Lehnerd, 1997).

On the other (bottom-up), a company, after the first versions of distinct products are on the market, redesigns or merges products of this group to standardize components to get cost reductions by economies of scale (Simpson, Maier and Mistree, 2001). As an example of this approach, since 2007, Ford Motor Company is adopting what it dubbed as “Global Platform Consolidation” where the company is consolidating its portfolio in fewer platforms as shown in Figure 6, although being able to introduce more products at a faster rate (Ford, 2015).

Additionally, modularity and upgradability of a system are important characteristics to obtain economies of substitution. It can be achieved through a well-planned decentralization of decision-making power and, with less coordination (Halman, Hofer and Van Vuuren, 2003) and customization costs via the adoption of defined interfaces (Magnusson and Pasche, 2014). In other words, they decrease the integration costs of a brand new designed component into an existing system (Garud and Kumaraswamy, 1995). Modularization also has aimed to increase the level of reuse in R&D, along with decreasing the total number of components by standardizing parts and subsystems. Many distinct modules are to be common within and among the product families (Magnusson and Pasche, 2014).

Hence, an important management decision is to choose which elements should be included in the platform (the common subsystems and components) to take full advantage of standardization without compromising the performance of the product derivatives in the family. For example, employees training, user manuals, spare parts, and systems integration of components are some areas where it is possible to have some savings with standardization. (Corl, Kokkolaras and Parsons, 2007)

However, the translation of platform methods to CoPS cannot be easily made. CoPS firms usually have few products from which to get advantages from applying platform strategies.
Moreover, within a CoPS family, new generations of products, subsystems or components are produced and, as a result, the platform is changed through the life cycle of this family. Likewise, as the product development is also often highly complex and science-based, it demands that new scientific discoveries should be rapidly implemented into new products. These facts afterward lead to changes to subsystems and components that could be reused from previous generations or products in a platform. (Alblas, 2011)

In this sense, although facing more complexities, like modularity and cross-firm coordination (Alblas, 2011), CoPS products can be designed and produced to reduce development costs by using a product platform approach, and by doing so the production volume is increased compared to the expected low rate of a CoPS product (Wong, 2011), allowing the firm to leverage platform advantages (Alblas, 2011).

3.4 Customer-supplier relationship in Platform Development of military CoPS

A special issue regarding the product platform field is the relationship between the customer/user and the supplier in new product development processes. The users are not seen as a passive recipient of the solutions presented by the supplier, but they have an active role in the design, evaluation, and choice of platform-based offerings (Mäkinen, Seppänen and Ortt, 2014). Adopting a platform approach requires a clear and accurate comprehension of customer needs and market demands (Halman, Hofer, and van Vuuren, 2003). Global product platforms also have to take into account the differences in needs of users in different parts of the planet. (Meyer and Lehnerd, 1997)

Meyer and Lehnerd (1997) put in the same level of importance the intimate knowledge of customer needs with each break-through technology a firm can achieve. The positioning of customers as the center point of value creation for a company and their involvement in the product development are what pushes a product family design and development. (Jiao, Simpson and Siddique, 2007)

Frequently, the customer is at the top of the pyramid, spreading its necessities down the supply chain and becoming closely engaged in the product development process. This user involvement is more intense in CoPS, and it occurs in every step of the product’s life cycle (from pre-design to decommissioning) distinguishing complex from simple goods (Davies and Brady, 2000; Davies and Hobday, 2005).

For some CoPS users, it is necessary to learn and absorb systems design skills and some knowledge of the architecture of the CoPS to be effective in their specific business (Hobday, 1997). This close relation between customer and producer enables the user to be directly involved in the product development, allowing the buyers to feed its requirements and demands into the early stages of the CoPS development process (Davies and Hobday, 2005) as well as to continuously feedback critics and suggestions on the late stages for further improvements.

The more complex and higher the cost of a CoPS, the fewer the number of available suppliers which leads to a more irregular market transaction (oligopolistic market). Without a direct competition, the price is not as important as other factors like previous experiences, performance maintainability and reputation. (Davies and Hobday, 2005; Tidd and Bessant, 2013)

When complex military systems like fighters and missiles are involved, the market is even more limited to one or a few suppliers, with in some cases having a bilateral monopoly with just one
buyer and one seller (Templin, 1994). In the Defense Industry, suppliers are completely reliant on and reactive to the requirements and demands of the military users, and they make their profit through a very close relationship with the users (Dombrowski and Gholz, 2006a).

For military equipment, the customers are usually governments, represented by their Armed Forces or Law-Enforcement Agencies. They are related to the Defense Industry in three different ways: as users of military equipment, as their funders and as their regulators (Heidenkamp, Louth and Taylor, 2013).

A government purchase military products and services to equip its Armed Forces for security reasons at domestic industries or abroad, as “there are no real substitutes to the manufacture of defense systems” (MarketLine, 2015a). However, the government does not give up of its sovereignty, which makes it a particular customer not following economic reasons alone (Templin, 1994), with imports only occurring if there are no technical capacity at national firms (MarketLine, 2014).

Governments have different levels of financial power depending on the wealth of their economy and the governmental policies towards military expenses, depending on political changes and social pressures (Templin, 1994; MarketLine, 2014), especially for high-cost orders where the number of countries that could participate in this market tier is limited. It can also make some buyers choose a more cost-effective product (MarketLine, 2014). In some cases, it is difficult to defend these investments on military power instead of investing in health or education as the military threats are not perceived by the taxpayers (MarketLine, 2014), particularly after the end of the Cold War.

For some specific products like fighters, submarines and artillery systems, the firm’s national government may be the only buyer, since it is hard to export a product that its own country does not have in its military inventory (Heidenkamp, Louth and Taylor, 2013).

Simultaneously, the government normally play a role as sponsor, by government’s commitment and support to promote defense industries through government funding (private financing for defense firms is negligible) and through specific policies (Heidenkamp, Louth and Taylor, 2013). Moreover, governments act as marketing actors to military products and services via official government organizations such as embassies and commercial and exports boards and by successful utilizations of this equipment in combat (combat proven). Another important way to support the Defense Industry is through state funding research at universities and some institutes that can create a collaborative environment of actors from government, academia and industry that fosters trust, innovation, problem-solving capability and increases the interest for military studies within academia with the potential to produce new ideas and knowledge (Axelson, Johansson and Lundmark, 2013).

As regulators, the government can influence the Defense Industry by its sovereign power to deny the export of controlled technology and information (Heidenkamp, Louth and Taylor, 2013) due to security concerns. Moreover through different State Policies (accounting rules and safety requirements (MarketLine, 2015a)) and International Agreements, like The Convention on Cluster Munitions (that bans all use, storage, production and transfer of cluster munitions), and United Nations (UN) sanctions. The regulator power of governments also affect the ownership of firms (restrictions to foreign-owned companies to have control of national defense companies) and define some limits to the powers of shareholders (Heidenkamp, Louth and
Taylor, 2013) (some governments have what is dubbed as a “golden share” of the defense firms where they have a veto power).

On the other side are the suppliers mainly as SI, which play an important task in the coordination of the development of complex military equipment (Lazaric, Mérindol and Rochhia, 2011) while at the same time they deal with the regulatory limitations of this Industry (Dombrowski and Gholz, 2006a) and political and electoral idiosyncrasies that can cause instabilities, cost growth and inefficiencies (Templin, 1994).

Systems integration is crucial for complex military products and systems as they deal with many tradeoffs between technical alternatives and establish connections among different equipment so that parts and subsystems of various companies can operate together (Dombrowski and Gholz, 2006b). It is also a core competency of an SI how well familiar it is with the components and subsystems designs and technologies of a particular product which are directly proportional to how suited the SI will work with them (Dombrowski and Gholz, 2006b). In a broader perspective, these firms can be seen as systems-of-systems integrators as they have to be able to integrate components and subsystems that, in many cases, are as much complex as the main system or even more complex.

To be successful as a system-of-systems integrator, it is fundamental to understand the military environment with all the particularities of each branch (Army, Navy and Air Force), their long history and traditions, organizational culture and battlefield experiences (Dombrowski and Gholz, 2006b). In this sense, military suppliers must prove military commanders that they understand the requirements for new defense products and that the firms have the capability to deliver the defense equipment demanded (Dombrowski and Gholz, 2006a). The previous military products from a company that had good performance is also a way to gain trust from military leaders (Dombrowski and Gholz, 2006a).

Therefore, an SI has to continuously improve its military-operational knowledge base by monitoring lessons learned from latest military operations, along with changes in doctrine and national strategy (Dombrowski and Gholz, 2006b). Participation in war games, military training exercises, and seminars are good opportunities to test new operational concepts and discuss future threats and challenges that will foster the development of new military products or will impose changes to the current defense CoPS. It also helps to create a mutual trust between the militaries and the Defense Industry.

On the same path, it is common for defense suppliers to hire retired military personnel as employees in their strategic planning departments or as consultants due to their military background and their networking with those militaries that continue on active duty (Dombrowski and Gholz, 2006a; b). Those contacts are of particular importance during the pre-design and bidding phases where the final specifications and requirements are not decided, and there is a period of intense change of knowledge and cooperation between Defense Industry and customers (Davies and Brady, 2000).

Unfortunately, the buyer-seller relationship in defense acquisitions can lead military personnel to defend the point of view of the industry rather than the public interest (Dombrowski and Gholz, 2006b). It can also result in transforming the seller in a company that is just focused on supplying the current needs of its customer, hindering innovation and creating a high dependency between the buyer and the supplier. To overcome this problem, both sides must self-consciously differentiate between collaboration and customer understanding from a
friendship relation that might block changes (Dombrowski and Gholz, 2006b) or will try to hide potential errors in specification and design. Fortunately, the potential to become a public scandal and the fierce competition from other national or foreign defense firms may inhibit and help to prevent this type of relationship (Dombrowski and Gholz, 2006b).

As a result, defense acquisition is a unique process that mixes military analysis (like threats and doctrines), political pressure (political/electoral priorities versus military needs), and technological innovations (Dombrowski and Gholz, 2006a). That does not follow the assumptions of market theory demanding a high volume of financing (generally public funding) and presenting the uncertainties associated with the acquisition process (like changing threats, technology, politics, strategies, and costs) (Templin, 1994).

3.5 Analytical framework

Platforms serve as a base for new product developments covering a broad scope including new products generation, new members to product families, and derivative and improved products. Therefore, platform development is a critical enabler both for improving existing products and for creating new products from the ground (Simpson, Siddique and Jiao, 2006a; Meyer and Lehnerd, 1997). From a strategic perspective, it is important to observe the evolution of a product platform and its family of derivative products with the aim of bringing to light the markets, laws and regulations, and technologies that have been guiding its evolution and recognize new opportunities for technological advancement and leveraging. (Simpson, Siddique and Jiao, 2006a)

However, with its specific characteristics like high costs, high level of customization, low volume of production, long life cycle and engineering-intensive (Hobday, 1997), CoPS have been neglected in the research and discussion of platform concepts (Hofer and Halman, 2005) where CoPS are seen as a peculiarity where the regular or commonly accepted theories of Platform-Based Products are not applicable (Wong, 2011). Although facing more complexities, like modularity and cross-firm coordination, CoPS manufacturers can still obtain benefits from platform usage (Alblas, 2011). In the specific case of military CoPS, other aspects, similarly, influence the evolution of these products and systems through time, like the usually duopolistic relationship between customers and suppliers (Templin, 1994) and the change of the theater of operations (new scenarios and threats) of these CoPS.

In this sense, this study focused on understanding from empirical cases how product platform strategies could fulfill the needs of CoPS manufacturers, in special, the role of strategic management to deal with the increasing complexity of these one-off products (Alblas, 2011) while adjusting, combining and rearranging internal and external organizational competencies and functional capabilities to handle changes in external conditions (Davies and Brady, 2000).

Based on the presented theory about platform-based products with the CoPS point of view and considering the particular case of military equipment, an analytical framework is proposed, taking into account the critical factors (dimensions) that influence the development of CoPS platforms of military equipment (weapon systems).

3.5.1 Management dimension

The Management dimension refers to management aspects that influenced the development of each weapon system like differences in management styles and their impact on the evolution of each system, the role of top management (Sköld and Karlsson, 2013), cross-firm coordination
(Alblas, 2011), some management skills and strategies (Hobday, Rush and Tidd, 2000) and how regional differences regarding design, styling, regulations (Simpson et al., 2006), geographical and cultural aspects had an impact on the development path of the systems studied.

3.5.2 Knowledge and technology dimension

This dimension refers to how knowledge is gained from previous products, components, and systems and used for improvements in design (Halman et al., 2003; Simpson et al., 2006), how to handle a wide scope and diversity of technologies and specialized R&D (Hobday, 1997; Sköld and Karlsson, 2013) with sometimes innovative solutions never tested before that are continuously widening the boundaries of technology (Davies and Brady, 2000). Other aspects are the knowledge-sharing process within and across the systems (tacit and explicit knowledge transfer) (Hobday, 1997; Davies and Brady, 2000)) as well as from the users experience with the products. Moreover, differently from a mass-produced platform, a CoPS platform of military systems demands continuously update of its military-operational knowledge base (Dombrowski and Gholz, 2006b).

3.5.3 Customer-seller relationship dimension

The last dimension of the proposed framework analysis the particular aspects of the customer-seller relationship on the restricted market of military products, taking into account the role of the customer as sponsor, regulator and user. The customers in this case, normally governments, represented by their Armed Forces, are very knowledgeable about the products and systems they are demanding (Davies et al., 2011), and they take into consideration military analysis (like threats and doctrines), political pressure (political/electoral priorities versus military needs), and technological innovations (Dombrowski and Gholz, 2006a) as well as not giving up its sovereignty power to not follow economic reasons alone (Templin, 1994). Moreover, how changes in these markets through time (Davies and Brady, 2000) have influenced/are influencing the management and evolution of these systems.
4 Empirical Data

This chapter presents the most relevant aspects of the empirical data to answer the proposed research questions. These data were collected from the interviews with key informants about the management decisions related to the systems over time and the secondary sources for each system under investigation, including a contextualized description of Saab and a brief historical perspective of each system.

4.1 Saab in brief

Tracing back its origins to 1936, Saab is the result of a choice by the Swedish Government that to keep the country’s neutrality, Sweden should have its defense industry almost totally self-sufficient (Axelson, Johansson and Lundmark, 2013), including a capability to plan and manufacture its military aircrafts (Hellenius, 2014). As it was difficult on the edge of a World War to obtain armaments from other countries (MarketLine, 2015b) and keep its neutral stance, the Swedish government was a very demanding customer and a long-term funder of the SDI (Axelson, Johansson and Lundmark, 2013). In this sense, Saab was considered not only as an asset for national security but also as a significant employer, that would promote development and economic growth (Hagelin, 2009).

Through this 80-years history, Saab became an international defense, security, and technology firm that develops, produces and sells solutions that go from military defense to civilian security applications (Hjelm, 2016; Saab, 2016a) with operations on all continents. Figure 7 presents a picture of the company’s product portfolio.

![Product Portfolio of Saab](image)

Figure 7: Shares of Saab AB’s total sales revenues in 2014 adapted from (Hjelm, 2016)

Saab’s leading client is the Swedish Armed Forces (SAF), which is far from being a heavy consumer of military products (MarketLine, 2014) and is a decreasing market especially after the end of the Cold War (Hagelin, 2009; Lundmark, 2013; Saab, 2014a). This fact together with a continuous focus on advanced military technologies has made Saab more and more dependent on exports. It includes the leasing of weapon systems to foreign nations (Hagelin, 2009), as the Gripen fighters for Hungary and the Czech Republic, the licensed production of AT4s in the USA by Alliant Tech Systems (Lindahl, 2007) and technology transfer programs and co-
development with Brazilian Air Force (FAB) and Embraer of the Gripen E/F. However, a new Swedish arms exports law to be proposed in 2017 may restrict the Saab’s expansion for countries outside European Union (EU) and Western Countries (O’Dwyer, 2017).

Another factor that is moving Saab to be a more international company is the new defense acquisition strategy adopted by the Swedish Government since 2007 to reduce costs of development. With this strategy, SAF should try, in a decreasing prioritization order, to upgrade existing defense equipment, to purchase already operative equipment, to develop in a multinational partnership and, just in exceptional situations, develop new defense material within SDI, except for jet fighters and submarines considered as of strategic national security interest. This new strategy is a shift from the previous pattern of fostering the SDI and is further supported by current reforms in the EU in the direction of establishing an open and equal EU defense market (Lundmark, 2013).

This internationalization is also expressed through the development of new products according to foreign customers (like different versions of the AT4 for France and United States and the NLAW (based on British requirements)). Moreover, the SAF are not the first users for some Saab products as the CG M4 version that has the Slovak Republic as the initial user in 2015. Saab has also foreign governments funding new product development such as Gripen F by FAB. Although Saab has the world as its market, the research, development, and production are carried out mainly in its Swedish facilities (Saab, 2011). The company has around 14,000 employees, total annual sales of SEK 27 billion and with circa 20 per cent of its turnover reinvested in R&D (Saab, 2016a).

The concentration of R&D and production in Sweden together with the long-term relationship between SAF, Försvarets Materielverk (FMV, the Swedish Defense Material Administration) and Academia has contributed to the development of a high innovation capability inside Saab to deal with technological demands (Axelson, Johansson and Lundmark, 2013) and perform a continuous evolution of its products and systems.

Considering a product platform thinking, Saab is continuously developing, adapting and improving new technologies to meet customers’ high demanding changing needs over the years (MarketLine, 2015b; Saab, 2016a) with some of its products and systems being independent platforms where Saab’s and other firms products and systems can be integrated (Hjelm, 2016).

4.2 Ground Combat Weapon Systems

4.2.1 Carl-Gustaf Weapon System

Built on tradition and technological development of almost 70 years of battle-proven experience since the introduction of the M1 models in 1948, Saab’s Carl-Gustaf (CG) is a recoilless multirole weapon system employing a variety of ammunition types, as described in Figure 8 (Saab, 2016d; Exército Brasileiro, 1998b) and that have a higher capacity for sustained fire: it can be reloaded and fired again. It is currently in service in more than 40 countries worldwide.

The CG allows dismounted soldiers to handle different scenarios in complex combat environments – from peacekeeping operations to neutralizing armored tanks or enemy troops. It offers compatibility with future innovations, as demonstrated by the use of new ammunitions by the previous versions of the weapon that gives the system a combat flexibility (Saab, 2015e).
The CG’s development can be tracked back to 1942 during World War II where the Swedish Government, by the Royal Swedish Material Administration (KAFT), found out that there was a need to have anti-tank capability since tanks were one of the main innovations in warfare during that period. The first design was a 20mm anti-armor rifle, as shown in Figure 9. This weapon had almost the same working principle as CG has today and two types of ammunition—one anti-armor tracer and one high-explosive.

Based on the lessons learned from this first design and on the armor protection of the tanks of that period, the KAFT set some key requirements to further development: 150mm of armor penetration, 300 m distance range against moving targets and lighter than 15 kg, to be portable. On the same way, based on the development of shaped charges⁵ for ammunitions in the 1940s, for a 150mm penetration, the caliber of the weapon should be at least 75mm.

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⁵ “A shaped charge is an explosive device used to penetrate thick targets using a high velocity jet. A typical shaped charge contains explosive material behind a conical hollow. The hollow is lined with a compliant material, such as copper. Extremely high stresses caused by the detonation of the explosive have a focusing effect on the liner, turning it into a long, slender, stretching jet with a tip speed of up to 12km s⁻¹.” (Poole, 2005, p.Abstract)
At the same time, Sweden was increasing its northern defenses at the Bodens Fästning. For that reason, they were upgrading their cannons to weapons with bigger calibers making a significant number of barrels of the 84mm Cannon m/94 (Figure 10) available. That is why CG has an 84mm caliber. The M1 version used a tube and most of its parts made primarily of steel and with a linear rifling of the barrel (same angle of rifling through the entire barrel).

![Figure 10: 84mm Cannon m/94 that were used to make the first prototypes of the CG (Hammarström, 2017)](image)

When the first foreign customer started to order CG, in the 1960s, Saab (Bofors at that time) had to change two things in the design due to the use of the weapon in countries with hotter temperatures, where the higher temperature when firing an ammunition with powder implicate on a higher internal pressure inside the barrel. The first change was to increase the thickness of the barrel. The second one was to change from linear rifling to progressive rifling to reduce tear at the beginning of the barrel. The M2 version also has some parts made from high-strength aluminum instead of steel to reduce weight.

Foreign customers’ requirements also led the company to new ammunitions: a new high explosive round to replace the original M48, a new high explosive anti-tank (HEAT) and a new smoke grenade. Thus, the CG turned into a support weapon rather than just an anti-tank weapon.

Following the feedback and new demands from users, as well as technology improvements, the M3 version entered service in the late 1980s, with a great weight reduction from 14 to 10 kg. This weight reduction relies on the use of glass fiber composites that became common, cheaper and with a capacity to resist the high pressures of the firing. This way, the weapon changed from a steel barrel to one with glass fiber composites on the outside with thin internal steel liner containing the rifling, and the other steel parts made from light aluminum alloys or plastics.

The newer and up-to-date version, the M4 from 2014, had a focus mainly on weight reduction. The adoption of new materials and changes in its ballistics to make the barrel shorter was essential in the weight reduction, a requirement from some Special Operations units. The barrel has a titanium liner with carbon fiber composites casing, maintaining the 1000-round expected durability, and the total length is below 1m, making the weapon more suitable for special forces and military operations on urban terrain (MOUT) (Valpolini, 2014). Also, this version is more ergonomic and compatible with smart sights for future programmable ammunitions.
Other two great improvements from the previous versions were implemented. One was an integrated shot counter, meaning a safer use of the weapon without removing it from service due to a lack in taking notes every time the weapon is fired. The other is that now the weapon can be carried safely loaded and ready to be fired enabling the soldier in the field to act faster. All these enhancements were based on feedback from the users of the M2 and M3 generations.

Figure 11 portrays the development over time of CG from the first version to the newest version.

From Figure 8 and following the development shown in Figure 11 and the words of the interviewee, it is possible to consider the CG’s ammunitions as different applications for the firing platform (the recoilless rifle). For example, the HEAT 751 is a HEAT round with a tandem warhead\(^6\), effective against explosive reactive armor (ERA)\(^7\) or with more penetration solid armor, a demanded further development of the HEAT 551 single warhead due to the evolution of the armor protection of tanks while the high explosive dual-purpose HEDP 502 is especially designed against light armored vehicles and anti-structure applications. As a result of a more urbanized battlefield where confined spaces (CS)\(^8\) are common, the firm developed the 655 CS that is anti-tank ammunition optimized for use in CS. For tactical support on the

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\(^6\) Tandem warhead is a type of ammunition which warhead has two or more stages of detonation. It is generally used against armored vehicles with Explosive Reactive Armor (ERA) with two shaped charges in the same warhead.

\(^7\) Explosive Reactive Armor (ERA) is a weight-efficient form of add-on armor that enables an increase in the level of armored protection against HEAT warheads, without an equivalent increase in the weight in many armored combat vehicles, like MBT. High explosives are inserted between add-on armor modules, called tiles, made from thin metal plates. When these plates are hit by the warheads, they explode in an outward direction reducing the penetrability of a shaped charge jet. (Hazell, 2008).

\(^8\) Confined spaces (CS) are areas that have enough room to a soldier enter and execute a military mission with limited or restricted access (entry and exit) for a very short period. Military operations in these areas expose the troops to many hazards, like noise, vibration, backblast, oxygen richness/deficiency, air flammability and presence of toxic gases. (Noble and Allen, 2004)
battlefield, Saab manufactures a smoke (469C) and illumination (545C) ammunitions, as well as the firm, has two inert training rounds: one with and one without tracer.

This ammunition’s catalog has been growing through the years and has been upgrading with some improvements to the different ammunition types, due to changes in the requirements from the users. These new battlefield scenarios also have made Saab obsolete previous ammunitions. However, the firm is not able to obsolete completely older generations of some specific ammunitions, as, for example, is the case of the 441D round (fourth generation) where there is some customer still buying the 441B version. For some customers, a change for a newer ammunition represents a great cost in training and safety and operational certifications. Saab has to keep the production line able to manufacture the older and newer versions (maintain drawing sets and manufacturing techniques for two different articles within the same category) which also represents a cost to the company.

Each grenade has been developed with its first customer in mind, some internally financed and others sponsored by the customer. In the past, SAF were the focus for CG specifications, but now their influence is decreasing as CG is not of national strategic interest and consequently SAF are not allowed to fund development of CG anymore (new procurement policy since 2007) and are buying only from the shelf, although very interested and well knowledgeable about CG’s developments.

These ammunitions developments are based on a very trustful relationship among Saab and its customers and on the company’s practice to see feedback from the users as an opportunity to improve and innovate. For example, the smoke ammunition 469C is a consequence of Brazilian Army feedback. The B-version was not suitable for rainforest scenarios (hot climate and high moisture). Brazil as the first customer having rainforest environments had problems with the ammunitions not working properly after some time in storage. The C-version was introduced to solve this issue using a tighter sealing and better welding. Another success factor is the close collaboration with US Army that is a good sponsor for the development of improvements for the CG platform. Moreover, US soldiers have been using CG many times in real combat situations, and the feedback from the field and the new demands from US Army have been one of the pushing forces towards the development and improvement of CG System.

Although the CG platform has more than 70 years, Saab Dynamics does not see it retiring soon (Valpolini, 2014). Saab says that the company wants to develop this battle-proven platform continuously so that it always meets the demands of modern battlefields (Saab, 2016d). The M4 design allows the integration of future technologies (Saab, 2015e) and the company tries to have backward and forward compatibility with older versions with the launchers being able to fire older or new ammunition (Militærteknikk, 2014; Hughes, 2016b) what can represent considerable savings to customers (Militærteknikk, 2014), regarding training and ammunition certifications.

Some new R&D is under development around CG and AT4, internally funded or sponsored by customers. Saab is developing a new ammunition that was initially intended for the M4, but it is available for the AT4, dubbed as High Explosive Modular Grenade (HEMG). It is funded by Saab’s R&D budget (Hughes, 2016a) and the term “modular” refers to its use for both CG and AT4 (Hughes, 2016b). The HEMG is designed as an anti-personnel ammunition. However, it can be used in air burst mode in urban fighting situations with a more cost-effective regarding consumption of ammunition expenditure compared to the current HE 441D round (Hughes,
This warhead is also a close derivative of the AT4 CS HE ammunition (Valpolini, 2014).

The firm has also proceeded on the development of an advanced programmable guided multirole ammunition concept to provide a long firing range (1500 to 2000 m) with high-precision capability to CG and AT4 to expand their possible applications and potential markets (Hughes, 2016a; Militærteknikk, 2014), as shown in Figure 12. The ultra-light missile (ULM), as it has been called, is also funded by Saab and it is in its early stages of development (Valpolini, 2014) with technical specifications under development.

Moreover, the R&D US Defense Advanced Research Projects Agency (DARPA) has selected and has been sponsoring Saab for the development of an “advanced precision engagement capability” for shoulder-launched weapons using its CG and AT4 (currently in use by US Army), the “DARPA/TTO Research Opportunity: Massive Overmatch Assault Round (MOAR) Study” (Hughes, 2016a). The study explores new possibilities to increase the firing power of small combat units (mounted or dismounted) with a multirole precise-engagement weapon that would merge the low weight and portability of shoulder-launched weapons, like CG and AT4, with the efficiency of larger, heavier and more expensive missiles systems. (Eshel, 2016; Saab, 2016b)

![Carl-Gustaf’s Ultra Light Missile (mock-up)](Valpolini, 2014)

In this way,

“Analysing already-established platforms allows the research to remain focused on the munition itself. Rather than developing a completely new solution, we are seeking to apply improved capabilities to existing systems - and that would translate to lower costs and faster availability.”

(Saab, 2016b).

These words from the head of Saab Dynamics, Görgen Johansson, summarize how Saab is foreseeing the future of this longevous weapon system.

### 4.2.2 AT4 Light Anti-armor Weapon

The AT4 family is a series of 84mm unguided, man-portable, single-shot (disposable), recoilless smoothbore⁹ (stabilization of the round via pop-out fins) weapons. The weapons range from anti-armor and anti-structure to anti-personnel/high explosive roles, based on the same launching platform (Saab, 2015a). Its name derives from playing with the letters AT, from anti-tank (the weapon’s original role), and the caliber of the weapon, 84mm (Hewish, 1982).

The AT4 history started with the 74mm Pansarskott M/68 Miniman weapon (Figure 13) in the 1960s, which was the precursor of the AT4, mainly sold to Sweden and small volumes to other

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⁹ A smoothbore weapon is one that has an unrifled barrel.
countries. In the 1970s, SAF realized that the M/68 was not able to defeat the main Soviet tanks from that period (Military Today, 2016a). Thus, there was a need to have an improved weapon.

The AT4 development started in 1976 at the Ordnance Division of Förenade Fabriksverken (FFV), a Swedish state-owned armament company (Hewish, 1982) (now owned by Saab), with a Miniman upsized version with 84mm caliber, better warhead and propellant, and a new gun tube (Military Today, 2016a). For the interviewee and from the literature, the availability of fiberglass at a reasonable cost and with technical capabilities to resist the high pressures of firing the gun was what made AT4 possible and successful, since before that the weapons had barrels made of steel making it heavy to be carried by a soldier.

Figure 13: 74mm Pansarskott M68/Miniman precursor of AT4 (Hammarström, 2017)

At the same time, US Army had an urgent requirement to replace its 66mm M72 LAW anti-tank rocket launcher that had proven not satisfactory against tanks and buildings during the Vietnam War (Military Today, 2016a) and the AT4 was one of six weapons evaluated in 1983 (Army Technology, 2011a) and formally selected in the same year. To fulfill US requirements, some changes were introduced to the final version of the AT4 HEAT (Figure 14) that, in the end, were also adopted by the SAF (Army Technology, 2011a; Military Today, 2016a). The weapons have also been licensed-manufactured in the USA by Alliant Tech Systems (Lindahl, 2007), with US Army as AT4’s largest user and combat proven in Panama in 1989.

Figure 14: FFV AT4 Light Anti-Tank Weapon Brochure, pages 01 to 03 (FFV, 1983)
Later, in the early 1990s, France was rebuilding its anti-armor capabilities replacing the LRAC system with main demand for high armor penetration. Therefore, instead of having a bimetal liner in the warhead, this one has a heavier warhead and a somewhat redesigned shaped charge cone, with pure copper that gives high penetration although less after armor effect. Another requirement was to make AT4 suitable to use in restricted areas because of the large backblast\(^{10}\) behind this type of weapon (as shown in Figure 15). Saab introduced an innovative solution that uses salt water counter mass (a simple spray of steam upon firing) to absorb the backblast, slow down the pressure wave and help to reduce the launch signature (Army Technology, 2011a). This way the second version of the weapon called AT4CS HP had high penetration (HP) and CS capabilities with France as the first user. This backblast solution was later replicated to Carl Gustaf’s HEAT 655 CS ammunition.

![Figure 15: Backblast formed after US Army soldiers firing AT4 in April 2007 (Military Today, 2016a)](image)

After the end of Cold War, the requirement sets changed from firing at military vehicles in open terrain to lower levels of conflict in MOUT. As a result, Saab designed an anti-structure tandem ammunition (AST) to AT4 (AT4CS AST). This ammunition has a warhead that is more adapted to urban targets and firing through walls and buildings with enhanced blast effect. Developed during 2005 to 2009 for US Army but there are also other customers, like Sweden.

With a different focus, developed in the early 2000s, the company worked on the development of a Confined Space/Reduced Sensitivity (CS/RS) version with improved sensitivity ammunition capabilities, satisfying US requirements. The AT4CS RS also has a bimetal liner that gives huge behind armor effect. The first user is the USA, both bought from Sweden and license-manufactured in the USA, in high numbers (estimations of more than 30000 units).

Saab thought that it had a good catalog of anti-tank warfare. However, Saab received a Request for Information (RFI) five years ago for the Roquette NG procurement for the Next Generation shoulder-launched weapon system for the three branches of French Armed Forces. The procurement wanted a multi-target capability (anti-personal effect, anti-armor effect, and anti-structure effect) while from disposable weapons (2 to 4 different disposable weapon systems).

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\(^{10}\) Backblast means “a rearward discharge of gases from the breech of a recoilless weapon when the weapon is fired.” (Morris, 1992, p. 202)
and Saab did not have anything off-the-shelf\textsuperscript{11} that met these requirements. Saab had the AT4CS HP that was filling these requirements, except that it was necessary to increase the range, the HEAT round, and a warhead from the tests that was in ongoing development. For the anti-structure version, there was available the AT4CS AST developed for US Army. However, differently from the US version that focused on low weight, the French procurement was more sensitive to cost. This way, the US version (a high-end product) were redesigned to lower the weight requirements while also lowering the price. These new versions are also compatible with smart sights due to the increased range of the rounds demanding the aid from a smart sight to increase the accuracy.

With these new rounds, Saab won the bidding process, in 2014, and has been awarded a contract by the Direction Générale de l'Armement (DGA), the French Ministry of Defense procurement agency. In this contract, Saab is in partnership with NEXTER Munitions in Bourges, France, for engineering and logistics support during the contract. (Saab, 2014b).

These new French AT4 versions are somehow competing with the US versions. The company does not see a converging to only one solution in a short-term as the USA have qualified their AT4CS AST version and done all the safety tests, and furthermore, they weight sensitive. For this reason, both versions will live side-by-side. Saab expects and wants that new customers choose the French solution to have it to be the larger volume version and US version specific for customers that are not price-sensitive but are weight-sensitive (for example, Special Forces and Elite Squads). Therefore, to some extent, it makes sense to have both running.

Figure 16 summarizes the development of AT4 over time from the first version to the newest version.

There are also training versions of the AT-4, they are reloadable and match the same ballistic pattern of the standard AT-4 round. One is based on a 9mm round with a longer case and larger propellant charge. The others are a 20mm round and a reloadable smoke cartridge that simulates the backblast and noise of a real AT-4 firing. (Exército Brasileiro, 1998a)

\textsuperscript{11} Off-the-shelf is a product or service “made according to a standardized format; not developed for specialized or individual needs; ready-made.” (Dictionary.com, 2017b)
As the AT4 is an 84mm caliber, it is reasonable to associate it to CG and that they can share all the development resources and efforts regarding ammunition. However, it is not the reality. Some Saab customers have financed the development of its weapon systems. This way, if they want a new round for the AT4 system, the company would focus only on making a new round for the AT4 system, with no thinking of developing a family of 84mm anti-tank weapons.

Since a couple of years, this situation has been changing as Saab has been self-funding its development, and the company is working on making the AT4 and the CG product lines come together. The idea in the near future is to have a launch system for the AT4 system that can fire, to some extent, every CG round with minor modifications. In this sense, if a customer wants a bunker defeating ammunition from a disposable weapon, then Saab will need just a couple of months to adapt and evaluate the CG ammunition to AT4. In the words of the interviewee: “Every cent to be spent in development will have benefits in both the Carl-Gustaf and AT4.”

Saab’s idea is to integrate the development of CG and AT4 to make them an 84mm support weapon family, basically differing from a disposable or reloadable launching tube. The external ballistics, the warhead evaluation, the production, and the logistics: almost everything is common, although the rotational rounds (ammunition from CG that uses the rifling from the barrel to stabilize its flight towards the target) will not be able to fire from both. However the fins-stabilized will be.

Saab also wants to emphasize AT4 position as the most successful disposable shoulder-launched support weapon on the market. This way, the company is developing some research as mentioned in section 4.2.1 and is making some studies towards the US Army Individual Assault Munition (IAM) program (Vassallo, Wahlström and Haster, 2016). The idea is to merge current weapon systems in US Army inventory (like AT4, M72 LAW, and M141 BDM) to fight and defeat light armored vehicles as well as structures in one single weapon that will weigh between 5 and 7kg and measure less than 1m in length (Hughes, 2017).

4.2.3 BILL Anti-Tank Guided Weapon (ATGW)

The BILL (an acronym of Bofors Infantry Light and Lethal) is the first overfly top attack (OTA) man-portable, tube-launched, medium range Anti-Tank Guided Weapon (ATGW)\(^\text{12}\) designed to be fired from the ground or mounted to vehicles against moving and static targets up to 2200 meters (Saab, 2015b). The system consists of a wire-guided missile, a tripod, a disposable launch container, and a sighting unit as can be seen in Figures 17 and 18. It has three variants RBS 56A BILL 1 (BILL 1 – first generation), RBS 56B BILL 2 (BILL 2 – second generation) and PAL 2000 (Panzerabwehrleinkwaffe PAL 2000 – a mounted version of BILL 2). BILL 1 is currently in use in five countries, while the newer version has four operators. It is estimated that more than 15000 BILL 1 missiles had been manufactured (Military Today, 2016b).

The background to this missile is some studies in the late 1970s to the development of a light anti-tank missile for the SAF to first deliveries in the early 1990s. BILL 1 had a short production time (less than ten years), and FMV decided that the improved BILL 2 would replace the remaining deliveries of BILL 1, and after the deliveries of the remaining BILL 1’s orders, it

\(^{12}\) Anti-tank guided weapons (ATGWs) are small missile-launching systems designed mainly to disable heavily armored vehicles, but that can also be used against other targets, such as hardened bunkers and buildings. They differ from rocket launchers or recoilless rifles, like Carl-Gustaf and AT4, because the ammunition (the missile) is steered, or guided, to the target after launch.
was phased out of production. There was a demand from the Austrian Armed Forces for a mounted version of BILL 2, the PAL 2000 (*Panzerabwehrwaffe* 2000), that was developed and manufactured under license in Austria and only for the Austrian Armed Forces. SAF was the first user of both versions and funded the development of the weapon.

![Figure 17: BILL 1 missile and its tripod and launch container at the Arboga Robotmuseum](image1)

BILL main feature is its warhead, especially since it was the first ATGW to use an OTA pattern. The two versions of BILL are similar on the exterior. However, the second generation has some enhancements like day/night capabilities and some miniaturization of electronics. BILL 2, has an improved tandem shaped charge with a precursor warhead, to overcome ERA of new Main Battle Tanks (MBT)\(^\text{13}\), differently from the BILL 1 that has a single warhead. It has now three different firing modes (as can be seen in Figure 19) that give a multi-mission capability to increase the array of possible targets, from MBT to non-armored targets and soft targets (anti-personnel).

\(^{13}\) Main Battle Tank (MBT) can be seen as a heavily armored self-propelled all-terrain (tracked) combat vehicle that can sustain firepower using a heavy weapon and are not designed mainly to transport soldiers. They are the main weapon system of an Army’s tank forces.
Furthermore, the third firing mode is reprogrammable to counter future threat scenarios and to be customized according to user requirements. (Army Technology, 2011b; Military Today, 2016b, Saab, 1998)

4.2.4 NLAW - Next Generation Light Anti-tank Weapon

The Main Battle Tank and Light Armor Weapon (MBT LAW) or Next Generation Light Anti-Tank Weapon (NLAW) is a highly portable, single-use (disposable), shoulder-launched, anti-tank missile system designed for a single soldier in the battlefield, as can be seen in Figure 20. As mentioned during the interview regarding NLAW, the missile gives a single infantry soldier the capability to defeat an MBT: “One soldier, one tank.”. It fills the gap between the light anti-armor systems that are not optimized for defeating tanks and the heavier crew operated systems more specific for combat groups and not for a single soldier.

Figure 20: NLAW Next Generation Light Anti-Tank Missile (Miranda, 2009)

Figure 21: NLAW’s main targets with its two attack modes adapted from (Saab, 2003)
The first and foremost purpose of this weapon is against armored targets (MBT) with add-on armor, in OTA mode (Figure 21, on the left part). It is also designed to be effective against non-armored targets, in Direct Attack mode, such as light vehicles or enemies inside buildings as depicted in Figure 21 (center and right).

The NLAW development started after an RFI from the UK where there was a plan was to replace existing LAW 80 system with a weapon system that, among other features, was portable (lightweight), disposable (the launcher is discarded after firing), had anti-tank, CS and fire-and-forget capabilities, low-life cycle cost and should be not necessarily off-the-shelf but with some ongoing development. Saab had 22 months after the reply to the RFI to perform a demonstration where should be a static firing of warheads and live firings of a dummy missile that should have everything working apart from the warhead.

However, there was no such system under development at Saab at that moment, and the most similar weapon from the company’s catalog was the BILL system that has a different guidance system (wire-guided). The warhead, the logics and inertial measurements of the BILL missile were comparable to NLAW as well as the launching tube. The guidance system was changed for a fire-and-forget system while the aerodynamics of the missile was kept unaltered during this period due to the short time before field tests.

The results from the firing tests were successful. With the green light from the UK in 2002, further development of the NLAW started using key qualities of other Saab Systems. From AT4 CS HP, NLAW got its CS capability and good insensitivity ammunition properties that allow the system to be ready to use. From the BILL Missile, it got the OTA pattern (Figure 21, left part) and the warhead. However, for the NLAW, there was no room for a two shaped charge warhead (tandem warhead), so it has an improved single warhead, that incorporates a dynamically compensated shaped and copper lined charge (Army Technology, 2011c) to keep the same penetration characteristics as the BILL, guaranteeing a high single shot kill probability (SSKP). Following the positive results for the British procurement, FMV awarded a contract to Saab, in December 2005 (Army Technology, 2011c). Finland and Luxembourg are the other operators.

Although the missile has many features from the BILL, its guidance principle is different. To have fire-and-forget capability, NLAW uses a Predicted Line Of Sight guidance (PLOS\textsuperscript{14}), patented by Saab (EP1218685 (A1) - 2002-07-03 (Christer, 2002)).

The disposable missile system is a co-development and co-production between Sweden (Saab Dynamics, as prime contractor) and the United Kingdom (UK) (Thales Air Defence, the main British subcontractor with more 14 British subcontractors), to fulfill the requirements of UK Defense Procurement Agency. Saab and Thales have a marketing agreement allowing that any possible customer can procure the system from either Saab or Thales (Saab, 2011).

As the wars after the end of the Cold War are mainly fought in urban terrain, it is also possible to engage light vehicles, troops inside buildings and bunkers by NLAW’s Direct Attack mode (Figure 21, center and right part) as the missile is optimized to fighting in urban terrain. This

\textsuperscript{14} The PLOS guidance delivers accuracy and high SSKP. In this way, the soldier tracks the target from two to four seconds before firing. If it is a static target, it will correct its path and try to continue on a straight line independently of wind or other disturbances. For moving targets, the missile’s guidance system will extrapolate the movement of the target to predict its position and will correct the flight path of the missile toward the target even when the target is partially concealed or have a small area.
way the missile flies directly along its line of sight with its fuse system off and detonates upon hitting the target after a short delay (Army Technology, 2011c; Saab, 2015d).

To fulfill more requirements of the conflicts in urban terrain, the missile has a soft launch feature where it is ejected from the launch tube before igniting its rocket motor, reducing the missile profile during launch and allowing it to be fired from confined spaces (CS).

As there were demands from the users to increase the range of NLAW and using test data from production and firing tests, Saab worked on an optimization of the guidance system by a software fine-tuning of the PLOS system. This software update increased the effective range from the originally designed 600m to 800m ("NLAWi") (Vassallo, Wahlström and Haster, 2016) against static targets, which can be applied to the existing weapons. On the same path, a 1000m version with some hardware changes has been developed, though not yet qualified (Donald, 2015; Saab, 2015d).

One of the main features of this project is that the missile is easy to train and use. The interviewee exemplified it by showing that potential new customers during visits to Saab Dynamics at Karlskoga received training from morning until lunch. After that, they could fire and hit targets at 800 m. It means that even conscripts with minimum training could have the capability of taking out an MBT. It is a “non-expert weapon” compared to the BILL system where there is an expert soldier on that system with only one purpose.

In the same way, it has a low life cycle cost because it demands almost no maintenance, needing just one battery change during its whole lifetime, reducing logistics costs and increasing the system’s availability.

For the interviewee, considering the NLAW, Saab has “really taking our heritage and using it.” The company have reused technology from other systems and reused some hardware in the first prototypes and demonstrations, particularly from the BILL missile. Although NLAW and BILL share, for example, proximity fuse and same OTA principle, they do not have so many common parts.

4.2.5 Business Unit Ground Combat (BUGC)

This section highlights the relevant information regarding the Ground Combat Weapon Systems in its Business Unit, since the four systems studied share some commonalities such as the manufacturing plant and testing facilities (these products are designed, produced and tested in Karlskoga, Sweden), marketing area and some management decisions, as well as they can compete within the same market niches as described in Table 4.

This Business Unit heritage goes back to AB Bofors, which was founded in 1873 and the Swedish state-owned armament company FFV Ordnance established during the Second World War. In 1991, the merger of these two companies formed the Swedish Ordnance owned by the Celsius Group. Later in 1999, Saab purchased the Celsius Group, and in September 2000, United Defense Industries (UDI) bought Bofors Weapon Systems from Saab (heavy artillery ammunition) while Saab kept missile and anti-tank systems. (Sutton, 2000)

Changes in ownership and merging processes can bring synergies as well as create cultural differences (communication and identification) among employees that can affect the overall performance of the company as presented by Kleppestø (1998) in his work about the cultural clashes on the merging process of AB Bofors and FFV Ordnance. He showed that the two firms
did not reach agreement on each other’s identities, leading to communication problems and a not trustful relationship at the beginning of the new company.

Table 4: Ground Combat Weapon Systems main features adapted from (Saab, 2015d)

<table>
<thead>
<tr>
<th>CAPABILITY/FEATURE</th>
<th>Carl-Gustaf</th>
<th>AT4</th>
<th>NLAW</th>
<th>BILL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combat range</td>
<td>Munition-dependent</td>
<td>20-400 m</td>
<td>20-600 m</td>
<td>150-2200 m</td>
</tr>
<tr>
<td>Main targets</td>
<td>Munition-dependent (MBT, anti-structure, etc.)</td>
<td>Armored vehicles and troops inside buildings/breach-hole capability</td>
<td>MBT (all aspects)</td>
<td>MBT (all aspects)</td>
</tr>
<tr>
<td>Confined space</td>
<td>HEAT round</td>
<td>Yes (CS version)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Single soldier/crew</td>
<td>Crew</td>
<td>Single soldier</td>
<td>Single soldier</td>
<td>Crew</td>
</tr>
<tr>
<td>Guided/Non-guided</td>
<td>Non-guided</td>
<td>Non-guided</td>
<td>PLOS (Fire &amp; Forget)</td>
<td>SACLOS(^\text{15}) (Wire Guided)</td>
</tr>
<tr>
<td>Night Vision capability</td>
<td>NVS interface available</td>
<td>Goggles compatible</td>
<td>NVS (Tl and II) Goggles compatible</td>
<td>NVS (Tl)</td>
</tr>
<tr>
<td>Disposable weapon</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Key: Night Vision Sight (NVS), Thermal Imager (Tl), Image Intensifier (II)

Regarding the emergence of the platforms, they were more incidental than planned. None of these products has been thought at the beginning as a platform. For example, the 84mm caliber products (AT4 and CG) had some of their derivative products from the 1990s as the results of one customer demanding for one specific application. There was no strategic planning to it.

On the other hand, product platform is a known concept within the BUGC. The interviewee gave the example of the 84mm caliber products that are based on a core knowledge: internal ballistics, handling of the soldier experiences when uses it, fuses and warheads.

The platform-based products for BUGC are limited to the market niche, portable weapons, although BILL can be mounted in vehicles. In a broader sense, installed weapons usually have heavier or longer rounds with a higher firing rate, demanding different capabilities compared to BUGC capabilities (portable weapons). In this sense, super calibers like in the RPG-7\(^\text{16}\), where there is a warhead with a larger caliber outside the tube, is not possible for Saab. That is one restriction to the platform. However, in the past, a super caliber of 135mm was planned for CG (Hewish, 1982), as can be seen in Figure 22.

\(^{15}\) Semi-automatic command to line of sight (SACLOS) is a method of guidance of missiles where the operator (like an infantry soldier or an aircraft pilot) has to keep aiming a sighting device at the target during the missile’s flight, establishing a line-of-sight (LOS) between the launching unit and the target, guiding the missile to the target. The sighting device and the missile normally work by one of these methods: wire-guided, radio-guided, or beam-riding.

\(^{16}\) The RPG-series is one of the most famous rocket-propelled grenade (RPG) families in use. It is a Russian designed man-portable, reloadable, unguided, shoulder-launched, anti-tank weapon family with a warhead caliber bigger than the caliber of the rocket propelling it. (Rottman, 2011)
Saab has a portfolio where it can supply products to meet some market tiers although with less volume of sales (for example, AT4CS AST in high-end market) and some products, on the same platform, that has huge volume and are providing Saab the money (for example, AT4CS RS, regular soldiers). Some customers have a mixture of them. For Elite Squads they have the high-end products, and for the regular soldiers where the customers will buy in higher volume, they choose lower cost products. Moreover, Saab tries to create a fidelity within customers by keeping the production of the older generations of its platforms and trying to make that new ammunitions can be used with the older platforms as mentioned in section 4.2.1.

The Swedish customer (FMV) and user (SAF) have been very trustful through the years. However, its role as a customer and user has changed a little since the procurement procedures in Sweden were revised in 2007 as described in section 4.1. It brought some culture conflict in the beginning. Nevertheless, it is settling now, and FMV/SAF are trusting Saab and are well interested and well knowledgeable in the firm’s products, although not paying (financing development) as in the past.

This type of product requires many firing tests during its development and before delivering to the customers (weapon acceptance tests). Therefore, it is a great asset to Saab to have a facility area (Saab Bofors Test Center) five-minute drive from the manufacturing plant to test and evaluate the weapons. Moreover, the company also has a micro-firing range at the same place of manufacturing. This way, the office (design), the manufacturing plant, and the micro-firing range are less than 50 m from each other, allowing Saab to have a rapid development process.

The way the company is organized, the strategic questions of Ground Combat Weapons Systems are living within BUGC. For the interviewee, long-term strategic thinking started to happen or get reborn around ten years ago when FMV stopped financing development. Before this change in the procurement regulations in Sweden, the strategy within the BUGC was to develop just when the firm was asked to do so and only to fulfill what was asked. The respondent considered that there is no sense in having a strategy when the company still does what the customers say every time. However, since Saab has started financing its developments, the firm has strategic planning with a 20-year horizon to take the firm where it wants to be in this timeframe.

On the same path, Saab manages complexities of CoPS through the development of critical subsystems beforehand. This way, the company has a lower risk in the critical subsystems when it starts developing a new round, for example. Another strategy is trying to separate subsystems
by their functions. Ideally, in the respondent’s words, “one subsystem should only do one thing.”. There should not have cross-coupling between functions and subsystems, a modularized system. For the interviewee, if the design would be optimized to every single component and subsystem, the performance of the product would be better using an integrated process than a modular system. However, that comes with an increase in the costs of development and time to have the product on the market. For this reason, the company sees the modular system as a way to make product development quicker. Otherwise, it would not be able to push out new products the rate the firm is developing. It is also a way to get value for R&D funds, by diluting the costs of development through the generations as well as making it easier to customize the products to each specific customer.

These platform developments and modularization are not seen as barriers to innovation inside the company. It is more an asset than an obstacle. Saab sees that there is much space to innovate inside the domain of the Ground Combat Weapon Systems and the knowledge about the subject is increased by keeping the same platform. For instance, in the case of the 84mm products, there is some research by competitors with different calibers and solutions. However, there is no room on Saab’s budget to invest R&D in these new solutions if there is still space to grow inside the 84mm platform, as mentioned in sections 4.2.1 and 4.2.2.

The process of incorporating new technologies into the existing products is mostly driven by customer requirements (market-driven) and technology improvements (engineering-driven). One example is how the company decided to use titanium liner for the GC M4. As a demand from users to reduce the weight of CG, Saab was running three parallel types of research for a new barrel: two varieties of high-strength steel and one with titanium. To reduce risk, the firm kept these three paths as the long-term properties of titanium were not known, and no one had tried firing a thousand rounds from a titanium weapon. Titanium liner worked well allowing a weight reduction around 30% from CG M3 to M4 with no loss of the barrel’s lifetime. Another example is the adoption of tandem warheads to overcome ERA of MBT during Cold War.

Considering cross-firm coordination, Saab has some critical suppliers, even more on the missile systems, where the firm does not develop the majority of the components. The company buys some subsystems directly from suppliers who have developed them or sometimes buys standard products. For the CG and AT4, for example, propellants, explosives, and other components are purchased from suppliers, and other parts are developed in-house.

For some of Saab’s suppliers, the company has a strategic collaboration, which means that there are meetings in regular basis between managers from both sides. When these suppliers are going to expand or change their businesses, they inform Saab beforehand. It is beneficial for the firm because it creates a mutual dependency between Saab and its suppliers through this robust and close collaboration. Nevertheless, for some subsystems and components, Saab demands are not big enough to get the attention from the supplier. Some other companies buy many times more than Saab. For these situations, Saab has a spare supplier, and for some critical subsystems, the firm has both external suppliers and in-house production.

Considering knowledge the respondent sees human resources as the most important factor; it is the networking that he could create through the company after more than 20 years inside the firm. In his words, it is important to know people inside the company that knows specific issues, as well as, to know people that know who knows about some topic, creating quite a large family. This way, as people are usually working in two or even three projects in parallel, they share tacit knowledge through on project to the other. Also, after one project is done, the project team
spends some days getting the team’s experience and writing reports about the project. Between different units, knowledge is usually spread both informal through meetings and through internal documentations such as reports and magazines.

Regarding the stability of the project team, during the concept phases, people tend to change position a bit. However, when full-scale development starts, there is a core team (also valid to project managers) where almost no movement at all occurs. Of course, there are people on the outside that are changing, but they are just feeding the project with person-hours.

According to the interviewee, there were (are) champions in the product development of these four products. He gave the example of a 72 years old employee that invented the guidance principle for NLAW and who has influenced the design of other products. Moreover, another employee is very knowledgeable about system safety. His reputation is so good that when Saab delivers a new product to the Swedish customer, he could just make a phone call and say: that the product is safe and the customer has the confidence the product is safe with less bureaucracy. However, the presence of “gurus” presents benefits and weaknesses. The good aspects are that today the firm can get products to the market faster and the champions are knowledgeable about some design decisions and the products themselves. On the other side, one problem is that ten years later when the company is supposed to send this product to another customer, they might not have confidence in him and then Saab will have to start this work from the ground since no one inside the company will recall why some design decisions were made. It can be costly and time-consuming. Quoting the respondent’s words: “In Swedish, there's a saying that ‘large trees cast a large shadow,’ meaning that if someone is extremely good at something, there’s a risk that no one gets light enough to keep to grow.”. For him, the presence of champions can hinder not only opportunities of growth for other employees but also for new ideas and solutions.

Regarding cross-functionality for the development of these products, Saab has steering groups with representatives from different departments and periodic design reviews where the product development is discussed. In cases of extreme problems or delays, the firm uses some cross-functional task forces to tackle these problems.

Within the same product, it is common to reuse subsystems and modules and to keep the interfaces unchanged from one generation to the next. However, between different products reusability is not so common. On the technology level and the development level, yes. But not for subsystems and modules. Each product tends to live their own lives. Although for the CG and AT4 it is not true as the company sees them in the future as an 84mm support weapon family. On the component level, the firm tries to increase commonality, as, for example, the different fuses have many common components, and the number of types of explosives is small.

At the level of screws and nuts, they are almost totally off-the-shelf. Electronic components and possibly consumables that are standardized are also off-the-shelf. However, at component and subsystem level, most are Saab’s design.

For future platform-based product development, the respondent suggests that cultural shift is fundamental. A company that adopts platform-thinking needs to reprogram people into a modular way of working, and to try to reuse or adapt modules and components before design new ones. Engineers should not only solve the tasks at their hands in the best way but also provide the company with an article that can be reused in the long run that can be both improved and reused to fit for future requirements as well and for future products.
4.3 Gripen

As a neutral country with a long history of providing for its defense (Hagelin, 2009), Sweden also has a long tradition of building high-performance combat aircrafts with Gripen being the sixth and newest generation\(^{17}\) of Swedish jet combat aircrafts (Andersson, 1989).

Flexibility and multirole capability is the central point of this aircraft (Andersson, 1989), which official name adopted by Swedish Air Force (SwAF) is JAS 39 Gripen. For its turn, JAS is a Swedish acronym for “Jakt, Attack och Spaning,” meaning the multiple roles of the aircraft: fighter (air-to-air combat), attack (air-to-ground) and reconnaissance, as described in Figure 23.

![Figure 23: A 1980s sketch of a Gripen A multirole capability (Ivarsson, 2014)](image)

The Gripen product family is currently in its third generation with Gripen E (single-seat) and F (double-seat) under development. It started in the 1980s with Gripen A (single-seat) and B (double-seat) for the SwAF. On the 1990s the second generation came up with more focus on exports (this fact was corroborated from all interviews) with newly built Gripen C (single-seat) and D (double-seat) and some aircrafts that were updated using the first generation as the basis. At this moment, it is in service within six users (Sweden, South Africa, Czech Republic, Hungary, ETPS – UK, and Thailand, with Brazil entering the group in 2019) as shown further in Figure 31).

The aircraft’s development and design were planned with the Cold War period in mind. Surrounded by North Atlantic Treaty Organization (NATO) countries and members of the Warsaw Pact during that time, Sweden needed an Air Force that could protect its neutral stance in the event of a massive attack (Cook, 1998). Defending the Swedish territory required a fighter that could execute air-to-air, air-to-surface and reconnaissance missions in the same sortie, without the need to go back to base for reconfiguration (Saab, 2015c).

From 1971, FMV financed, with considered part of its budget, a project called Flygplan 80 (Aircraft 80) (Keijser, 2003), which was projected to be the main element of Swedish Air Power, replacing Saab 35 Draken and 37 Viggen aircrafts (Hunter, 2014) with initial

\(^{17}\) The term generation here is different from the context of jet fighter generations in which Gripen is considered a 4\(^{th}\) generation fighter.
manufacturing in early 1980s and entering in service with SwAF in the second half of the decade (Keijser, 2003). This project was canceled, and in 1979 the Swedish government issued additional instructions to the Commander-in-Chief of SAF to find an aircraft, even from overseas, with a multirole capability similar to the US General Dynamics F-16 (Keijser, 2003).

In 1980, a consortium, Industri Gruppen Jakt, Attack, Spanning (IG-JAS) was formed to design, develop and produce numerous components and subsystems of the aircraft (Keijser, 2003; Alex, 2016). Differently from all previous contracts between FMV and the Swedish aircraft industry, it was the first time that the SDI took the risk of developing the aircraft and not the procurement agency (Keijser, 2003). Each member of the group had a role in the project, with Saab being responsible for airframe design, final assembly, digital fly-by-wire control system, marketing and sales as the major partner in the IG-JAS. This way the consortium is often treated only as Saab.

In 1980, FMV sent a Request for Proposal (RFP) for modified versions of foreign aircrafts and Saab’s proposal (Hjelm, 2016). Two main requirements were rigid: the aircraft’s weight could not exceed 50% of Viggen’s weight, and it could not cost more than 65% of Viggen (Hjelm, 2016). The bids were submitted in the spring of 1981 with the final decision at the end of the same year choosing Gripen, although it could be a little more expensive than the foreigner offers (Keijser, 2003). To compensate the extra cost, the decision was based on the fact that the SDI would be involved in the production of the aircraft with some highly technical jobs created and keeping the Swedish policy of neutrality (Keijser, 2003).

American and French options did not fulfill all the SwAF requirements. The F/A-18 Hornet was more suitable to meet SwAF requirements, but due to its two-engine design, it was also expensive to buy and operate. Another idea was to join an international aircraft program, though attractive financially because of shared costs of development, it was rejected as a result of the unavoidable compromises characteristic of the design and operational capabilities of a multinational fighter that could not meet SwAF operational needs. (Keijser, 2003)

There was a political debate in Sweden regarding the increasing cost trend of military projects, in particular, taking into account the cost trend from previous Saab’s aircrafts (Hjelm, 2016). In comparison with other aircraft manufacturers (like McDonell Douglas and Dassault), it was challenging to keep Gripen’s unit price down, since Sweden was a non-alliance State with very strict weapons export legislations that reduced the potential customer base for Swedish aircraft making Saab rely only on SwAF buys with any exports considered as a bonus. (Keijser, 2003). Consequently, Saab needed to show Parliament, taxpayers, and FMV that the new jet fighter could, somehow, break the cost curve trend (Cook, 1998), as illustrated in Figure 24.

This way, a low life cycle cost is inherent to Gripen’s DNA (Hunter, 2014). Some of the factors that made this possible were the recently available fly-by-wire flight control system, state-of-the-art avionics and a reliable and efficient engine (Cook, 1998). Moreover, the extensive use of composite materials throughout the aircraft was one of the reason that even with half the size of a Viggen, Gripen was able to carry the same amount of weapons (Keijser, 2003).

Additionally, with the aim of reducing costs of the program, Gripen A, except for the Israeli IAI Lavi aircraft, was the only fourth-generation18 fighter that did not have a specific

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18 The characterization of fighter generations has been extensively debated although with no final definition. Tirpak (2009) presents a good picture about this classification.
technology demonstrator built (Keijsper, 2003). Instead, the program used two Viggens (one of them shown in Figure 25) to test avionics and other equipment to accelerate the development (Keijsper, 2003) and reduce costs, as technology demonstrators can be a source of possible future product solutions as well as the bed for the evaluation of new technologies (Hjelm, 2016).

![Figure 24: Saab Fighter's Cost Curve adapted from (Nilsson, 2016)](image)

![Figure 25: The ESS (Electric Control System) Viggen 37-52 used as a technology demonstrator for the Gripen program in 1982 adapted from (Keijsper, 2003)](image)

Also with cost in mind, the criteria for selection of overseas suppliers for Gripen’s subsystems was that they should perform better or equal as Swedish suppliers and for a lower price (Keijsper, 2003). Moreover, it was/is also an opportunity to apply offset\(^{19}\) agreements that are present in many military purchases. For example, Figure 26 shows the nationalities of the suppliers of subsystems in the South Africa purchase including some South African companies.

The engine chosen for the Gripen versions A/B/C and D was the General Electric F404J. It has been selected due to its reliability (used in the F/A-18 Hornet fighter with a great number of engines produced), lower airframe and less restriction to transfer of technology. The engine was license-produced in Sweden by Volvo Flygmotor with some modifications dubbed as the RM12 engine which allowed a more customized engine with a lower cost of acquisition and with a good maintenance support (Keijsper, 2003).

\(^{19}\) Offsets are contracted obligations normally presented in defense bidding processes (Dehoff et al., 2014), where the country that is offering the military product “compensates” the money invested in this product by industrial cooperation and technology transfer that can be directly related to the product or related to other areas of interest of the buying country.
One of the main critics against Gripen is the use of a single-engine and the safety issues of having a failure with this engine. To overcome any possible failure in the single-engine with a cost-effective solution, Saab designed the use of an auxiliary power unit (APU). In the case of emergency, the APU has a duty to make it possible for the Gripen pilot to glide and make an emergency landing. This APU is also important to reduce the logistical footprint of Gripen, as less ground-support equipment is necessary when the fighter is operating from dispersed road bases, and it is the main source of electric power for the aircraft on the ground. (Keijser, 2003).

Gripen, as a Cold War project, was designed to fulfill the Swedish policy to operate in road bases dispersed across Sweden, at runways only 16x800 meters in length (Saab, 2015c), as shown in Figure 27. Therefore, Gripen has a flexible deployment with a small logistical footprint, corroborated on the interviews. Easy maintenance was also essential, since “turnaround teams,” consisting of five conscripts (with only ten weeks of training) and a single professional (Cook, 1998), would be responsible for the maintenance, usually in winter conditions and isolated areas. One example of this easy maintenance and small mean time to repair (MTTR) is that the engine can be changed in the field in 60 min (Cook, 1998). However, this point was not a selling point to foreign countries since they do not normally use road bases.
Gripen maiden flight was on December 9th, 1988 with first deliveries of Gripen A to SwAF starting in 1993 and entered operational service in 1997. For Gripen B its debut flight was on April 29th, 1996 with first deliveries at the end of 1997. It was a Swedish solution for Swedish demands and standards. (Keijser, 2003)

With the end of the Cold War and the dismantling of the Warsaw Pact, countries in Europe and the USA cut their defense budgets. Sweden, on the other hand, was skeptical of reducing too much its military forces since the situation in Russia was unstable (Keijser, 2003). However, Swedish purchases alone were not enough to sustain main defense companies (Hagelin, 2009). For this reason, at the end of the 1990s, the Gripen C/D models were developed with exports and interoperability in mind, enabling the participation in joint operations under UN or NATO command, also with improved electronics, NATO-standards, air refueling, and lower radar signatures (Keijser, 2003). One example of standardization given during the interviews was the adoption of the Link-16 Datalink (NATO-standard) substituting the Swedish advanced datalink system called tactical radio system TARAS that was considered even better than the NATO model, as quoted in (Hjelm, 2016) by the aviation journalist Bill Sweetman: “Sweden has since forgotten more about datalinks than anybody else has ever known.”

However, following heavy budget cuts in 1999, SwAF had to prioritize which Gripen enhancements it should put money in. The cost/benefits of adopting thrust vectoring were not considered as something that would worth the money on R&D and in the future, if necessary, the technology could be bought off-the-shelf, being removed from the short-term prioritization list (Keijser, 2003). On the same path, the Swedish government was progressively reconsidering the total number of aircrafts necessary to keep Sweden’s sovereignty since there was the opinion that in a future conflict, the country would not fight alone. This way, in 2001, the SwAF announced that it would not need all fighters previously ordered (Keijser, 2003). The new emphasis on exploring exports possibilities from the Swedish Government (Hagelin, 2009) and this decrease in the number of total aircrafts in service created the opportunity to lease Gripen C/D for Hungary and Czech Republic.

Gripen C/D, from the outside, is almost the same as the original Gripen A/B; all the main upgrades were made underneath the fuselage. Due to its high cost, the engine was kept the same with some improvements on the flame holder and FADEC (Full Authority Digital Engine Control) to improve durability and reduce cost. (Keijser, 2003)

The lifespan of combat aircrafts is around 30-40 years or more, and they are required to perform better than before as operational needs evolve and new technology opportunities are available. This fact makes obsolescence a reality to any military product. To tackle this issue, Saab has adopted its development philosophy for fighter’s upgrades differing from other aircraft manufacturers (Wallén, 2016; Robinson, 2016). As an alternative to using major and costly mid-life upgrades (MLU)20 typical to most fighters after 10 to 15 years of operation, Saab, in close cooperation with its customers, gives them the opportunity to improve the aircraft continuously (Hjelm, 2016; Wallén, 2016). These short cycles (2 to 3 years upgrade cycles) (Saab, 2016c), dubbed Material System (MS), provides stepwise enhancements, as described in Figure 28 since many generations of avionics technology and weapons systems will follow

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20 Mid-life update or upgrade, in the defense context, is the maintenance or overhauling of a military equipment planned to prolong the utility and capability of a product. Generally, it occurs 10 to 15 years after the product had entered service.
during the lifespan of an aircraft (Hjelm, 2016). These MS make sure that the fighter is always up-to-date and that the upgrades are adapted to changing requirements from customers. In this way, the customers feel that they are part of the aircraft’s development and can have customized solutions to their specific needs (Wallén, 2016). Moreover, the development costs are spread out over an extended period, and the upgrades can be implemented according to the budget and military needs of each customer (Hjelm, 2016; Saab, 2015c).

For example, the latest MS20 update for Gripen C/D will adapt the platform to be closer in performance to the new Gripen E/F (Wallén, 2016). The upgrades include a whole series of new functions and capabilities for weapons, communication, radar, auxiliary support and training systems, among others (Wallén, 2016). Three of the respondents emphasized that this last MS is mostly based on software upgrades, display systems, and computers changes, like new processors and data storage. Furthermore, two of them mentioned that these 2 to 3-year short upgrade cycles would be mostly software updates, which increases electronics equipment capabilities by small algorithms, as, for example, the significant increase in performance of the nose radar by a software update.

Another key point highlighted on the interviews towards the adoption of these continuous upgrades procedure was related to knowledge and human resources. US Armed Forces and Aircraft manufacturers adopt MLU since these companies have a scale of production where the manufacturing lines of fighters are always busy and thinking about developments for their products based on new customers (internal and export base are big), new customer needs and feedback from the users. For the Swedish situation with a small volume of orders, to keep its engineers occupied all the time, Saab adopted this short update cycle approach. If Saab had adopted the MLU approach, after the delivery of the aircrafts, it would pass 10 to 15 before the MLU. However, it is cost prohibitive to keep engineers and technicians without a program, and they would probably go to other industries taking all the tacit knowledge, specific training and different skills with them. Also, when it would be the time to perform the MLU, there would be no skilled employees to work, and it would be necessary to spend time and money to rehire and retrain workers. This way, through MS upgrades, Saab can keep its engineering always thinking of new improvements to the aircraft.

Sometimes the major focus is on avionics, others in aerodynamics. From the user perspective, it is also an advantage since SwAF does not have to ground the fighters in the maintenance shop for a long time and it is possible to adapt the aircraft to what is happening in the world, from a new kind of electronic warfare system to a new tactical software to deal with a new type of
threat. It was also a desire from the Ministry of Defense to keep its aircraft always updated to handle changing demands and a necessity to preserve a national aircraft industry mostly dependent on the domestic market. The continuous upgrades are also perceived as opportunities to attract new human resources from Universities as these upgrades are dependent on researches that start at Swedish Universities, like Linköping University, KTH (Royal Institute of Technology) in Stockholm and Chalmers in Gothenburg, which are financed by the National Aeronautics Research program that is supported by government and industry together.

On one of the interviews, it was underlined the spin out effect of having a national provider. A number of good engineers enter into the SDI, and they eventually spin out to smaller industries. Based on a study from professor Gunnar Eliasson of KTH, the spillover aggregated effect of the JAS 39 Gripen Program generated benefits back to the whole Swedish society that worth 2.6 times more than the value that has been invested in this military purchase (Eliasson, 2010).

Gripen design adopts a modular approach, which enhances its capacity to adapt. As one of the interviewees stated: “A design of the platform that can handle new requirements, avoiding integrated solutions.”. The mentioned MS upgrades are much based on this modular approach where the aircraft can be updated to deal with new threats and to add new capabilities that are available due to new technologies. It has been a requirement to move away from the heavily integrated subsystems to have a very modularized design that can have a subsystem replaced without having to change other parts. Moreover, it was a business strategy from Saab as a way to make the aircraft more exportable. It is a way to customize the aircraft to each customer that has slightly different requirements without having to build a completely new fighter.

Also, by using off-the-shelf components and subsystems and integrating them into an open architecture, Saab can increase the flexibility of the aircraft development process. It allows that the customer countries participate in the development of Gripen as part of offsets obligations through industrial cooperation or technology transfers (Saab, 2015c), as previously shown in Figure 26, additionally, extending Saab’s supplier base. Moreover, potential offsets has been a critical enabler and an advantage in many military biddings (Dehoff, Dowdy and Kwon, 2014), as for example, the Coordinating Committee of the Combat Aircraft Program (COPAC) from FAB considered technology transfer as one of the most important aspects of its F-X2 program that chose Gripen in the end of 2013 (Coelho, 2014).

Similar to the first generation of Gripen, before the development of the new Gripen E, Saab, in collaboration with FMV, used a technology demonstrator aircraft based on a Gripen D two-seat aircraft, called Gripen Demo initiative (Gripen Demo NG). This jet fighter has been used since 2008 to reduce risks, costs and lead time, and to help on decisions for the development of Gripen E program, testing future military capabilities for the project in advance to the main development acquisition contracts (Hjelm, 2016; Hunter, 2014) such as increase in range and payload, and room to install an improved radar. It is also used as a way to evaluate in advance if at least part of the customer requirements could be reached. The C/D versions will also benefit from these developments as some of these improvements can be incorporated to them (Hjelm, 2016). The Demonstrator can be seen in Figure 29 where it was under flight tests with new missiles and bombs that will be part of Gripen E weapons inventory.

One of the respondents explained how was the decision-making process of choosing Gripen E for Sweden. It was centered on a lower cost to develop, build and operate compared to Gripen C, regardless of doing more or less everything better. The major task for FMV and SwAF was
to investigate the future development of the Gripen system, which way to go: update the Gripen C or go for a completely new aircraft system. The Swedish Ministry of Defense conducted some simulations on four distinct options for the Gripen NG, as it was called at that time. Option A was an off-the-shelf purchase from a foreign supplier, like Joint Strike Fighter (F-35), Super-Hornet F/A-18, Rafale, and Eurofighter. Option B examined the possibility of keeping the existing Gripen C/D airframe and engine and upgrading the avionics. Option C1 proposed a redesigned airframe for Gripen, with a new engine and new avionics technology, based on the knowledge from the Gripen Demo. The last option, C2, involved a new airframe, new engine and all-new technology (like stealth, thrust vectoring and even unmanned). (Hunter, 2014)

These four options were computer modeled, and many simulations were performed to see how well these different options would behave towards the known expected opponents and threats of 2025 and beyond. Data from various military reports, like Jane’s Defense and other open sources as well as from Swedish intelligence service, were used to support these simulations.

In the end, it was not that Gripen E was best in every aspect. The main reason to opt for the Option C1 was life cycle cost. When a country is procuring new advanced systems for its Armed Forces, it looks at the purchasing price. However, if this product or system is expected to have a lifetime of 30 to 40 years, it is necessary to make reasonable assumptions and calculations over the whole life cycle, considering the cost to maintain the system, to replace the essential parts, how hard-wired is the system and the degree of modularization.

From the tactical requirements, the need for longer endurance with bigger internal tanks was one of the reasons not for just upgrade Gripen C/D. It demanded a reconstruction of the airframe to accommodate more fuel internally and to adapt a new bigger engine and other components.

On the same path, one of the respondents explained that the choice for Gripen E also had a procurement regulation perspective. To renovate an aircraft and rebuild it there is no need to tender internationally in the procurement law. On the other hand, to purchase an entirely new system there is a need to prepare a bid based on the desired specifications.

One of the trade-offs during this process was the benefits and the costs of adopting stealth. The costs to operate a stealth fighter are much higher compared to Gripen’s estimated life cycle cost. Moreover, a stealth aircraft platform hinders the flexibility to use different types of weapons and sensors since they need to be carried in internal bays inside the fighter. Also, with

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21 Hardwired: “built into a computer's hardware and thus not readily changed.” (Dictionary.com, 2017a)
the development of new sensors capable of detecting stealth aircrafts, the tactical and operational advantages of stealth are decreased. Moreover, unlike the F-35, that depends on stealth to operate in a contested combat environment, Gripen relies on its electronic warfare systems to hide, confuse and decoy the opponent (Robinson, 2016).

Although the choice of Gripen E was made taking into account SwAF requirements, the economic calculations of this process always considered at least one strategic partner (another country) to share the costs of development. Initially, the potential partner was Switzerland, but following the Swiss Law, the purchase was submitted to a referendum and was rejected by the society in 2014, even though Gripen has won this bidding process. Luckily and unexpectedly, on the same year, Brazil signed the contract to buy Gripen E and co-develop Gripen F.

One problem with a strategic partner is that due to national security issues, some critical electronic warfare systems must be customized. This way, Saab adopted a standardized modularized construction, where it is possible to fit in different equipment. Gripen E is the first fighter with open architecture and separation of criticality in avionics (Hjelm, 2016). Saab has developed a distributed integrated modular avionics system that splits the flight management system (10%) from the tactical systems (90%) (Robinson, 2016). As well as Robinson (2016), two interviewees explained that Saab designed the tactical system to be mostly non-hardware dependent and with the flight software separated from the tactical system.

This way, the tactical management part works like a smartphone with apps that can be opened and closed according to a specific mission and new apps (such as radars, sensors or new weapons integration) can be “downloaded” without interfering with any critical flight function. Consequently, there is no need to re-certify critical flight systems, which is costly, grounds the fighter, makes upgrades of tactical systems easier, cheaper and quicker to be implemented and enables the use of third-party equipment. Also, because of potential restrictions in further exporting of some subsystems like weaponry and radar, it is possible to fit another radar or another weapon on the aircraft without interfering with flight safety.

Another development advance on Gripen E is the adoption of the Model-Based Systems Engineering (MBSE) that uses computers to test and verify complex aircraft systems using simulation tools and computer-aided design (CAD). This single digital model replaced around 50,000 paper documents and technical drawings. The method gives an overall picture of the whole project and allows Saab to rectify errors on the development in shorter time and to reduce sharply the flight tests (many tests can be done in simulators), although part of this reduction is based on the use of previous components and subsystems from the older Gripen generations. (Robinson, 2016; Saab, 2016c).

For example, Saab expects that the standard time of 'learning how to produce an aircraft at optimum efficiency' will reduce from the common 180 aircrafts (T180) to around 30 aircraft (T30) by the use of the MBSE (Robinson, 2016) and with this model, Gripen E could be updated with new tactical functions in a timeframe of days instead of years.

Saab and Embraer in Brazil, as a requirement from FAB, will develop together the Gripen F, the two-seater version of Gripen E. It is intended mainly for training, since differently from Sweden that, at this moment, will not purchase any unit of Gripen F because of economic reasons, FAB does not have Gripen D available for training. For the combat role, from the standpoint of being versatile and being able to expand tactical operations, the aircraft can be optimized to enable different tasks like air battle management, including jamming, information
warfare, and network attack capabilities. Weapon System Officer (WSO) and Electronic War (EW) roles can also be executed (Saab, 2015c) corroborated by three of the interviews. One small study was done by SwAF to have either this two-seater with one pilot there with a completely different equipment or use that space to pack more advanced equipment.

Focusing on new markets to Gripen, Saab has performed a concept evaluation regarding a maritime version of Gripen E (Figure 30) (Ahlqvist and Smith, 2017). It incorporates features that are ideal for aircraft carrier operations like folding wings and improved landing gear.

Figure 30: Gripen Maritime Concept taking off from an aircraft carrier adapted from (Ahlqvist and Smith, 2017)

Many States with both larger and smaller air forces will drive the military aviation market in the near future. Their old fleet will be replaced by new generation fighter aircrafts that deliver better performance, superior flexibility and the lowest total cost of ownership possible (Hjelm, 2016). Other relevant aspects of this market are the membership to different organizations, such as NATO, potential threats and political and electoral considerations, like military sanctions to some countries (Hjelm, 2016) and changes in the government that can redirect priorities regarding military expenses.

Saab foresees that the jet fighter market will have demand for both Gripen E/F (higher tier of the market) and Gripen C/D (lower tier) (Robinson, 2016; Ahlqvist and Smith, 2017), as described in Figure 31, where the current and potential Gripen users are shown. Two of the interviewees expressed the same opinion. In this sense, the company has decided to adopt a strategy where two generations of Gripen will be developed and modernized in parallel (Nilsson, 2015), as can be seen in Figures 32 and 33. Consequently, they will share as much as possible the same capabilities and will benefit from each other in future developments, except for those enhancements that are based on the new airframe of Gripen E such as extra fuel, new engine and more weapons payload (Wallén, 2016; Robinson, 2016; Ahlqvist and Smith, 2017).

Figure 31: Gripen forecasted market and current users (Ahlqvist and Smith, 2017)
Much of the successful development of the Gripen Family is based on process and practices of Saab Aeronautics. This Business Unit has its main activities grouped within a radius of around 500 meters, facilitating network and knowledge-sharing among employees. This closeness and speed of communication create cross-functional trustful relationships. (Hjelm, 2016)

Supplier collaboration is built on a win-win relationship between Saab and its many suppliers (Hjelm, 2016). From the interviews, it is possible to say that Saab is very much an SI company. The firm does not make every component or subsystem internally. Saab tries to buy what is available on the market or to specify a particular part that is not on the market. After this, the company integrates it to the aircraft. Therefore, it is crucial to Saab to have a good work relationship with its major suppliers, like, for example, engine, weapons, and sensors manufacturers. This way, the working procedures within Saab tries to integrate the supplier with both product development and sales activities (Hjelm, 2016). As Saab starts the development of a new aircraft version, the firm tries to involve the suppliers on the early stages of development to understand what is their roadmaps, to understand when or if they will have the next version of their components available. The company does not want to end up in a situation where the new version of the aircraft is designed containing old equipment.

Consequently, as the aircraft is being developed, the components and subsystems are developed in parallel. Most of this coordination is based on regular meetings between management at Saab
and suppliers, but the main points are based on written contracts. As the company gets an order for aircrafts, Saab issues contracts to its suppliers. Since the aircrafts have a long life cycle, including long planning and development times, Saab and the suppliers create a close, long-term relationship based on confidence and respect, openness in the business relationship and the development of excellent working procedures (Hjelm, 2016).

From the point of view of the customer, FMV’s role is related to customization, co-development, and procurement. In general, FMV’s roles are long-term planning, design, bidding (procurement), validating the platform, financing the development, evaluating and paying for the delivered units. When procuring a weapon system like a fighter jet, FMV considers the life cycle model with phases from concept to decommissioning. FMV translates the requirements of the user (SwAF) to the procurement so that the industry could present a solution that would fulfill the user needs. It tries to balance between engineering and user-driven aspects.

There is no clear adoption of the concept of platform within FMV. FMV sees the platform developments as a process to have a fighter system that is always in the state-of-the-art but accomplishing with the SAF budget and mission. FMV’s concept of platform is more related to the continuous updates of the aircraft to keep meeting SwAF requirements from today and trying to forecast the needs of the future. If for any reason one task of the fighter could be done in a better way by another weapon system, FMV could reduce the requirements for the aircraft platform, and vice-versa.

At the same time, FMV tries to whenever possible to reuse subsystems, modules or interfaces of the platform as a way to reduce costs of acquisition, costs in logistics (inventory management), and to decrease the number of different types of possible configurations within the platform. Regarding the suppliers of these subsystems and components, FMV role is more about risk management, as some of these subsystems and components are critical to the functioning of the aircraft and any shortage of supplies or any restriction from the supplier’s government to buy can ground the fighters.

As there was minimum competition on this platform development, FMV and Saab’s relationship is based on a long-term relationship based on trust. However, to guarantee that the platform development is good for both sides, FMV has access to Saab’s price and cost calculations.

Inside FMV, regarding Gripen, in general terms, the project team was stable with people working for many years with the platform giving a good knowledge base about the fighter. For example, the interviewee cited his case where he has worked with the Viggen aircraft within FMV before working with Gripen project. His previous knowledge regarding the older fighter helped him to have a better understanding of the customer needs and to foresee future needs. He also explained that the knowledge sharing process through the project team are both informal and through documents like reports and newsletters and made a comment about the generations issues; younger generations of employees want to change more frequently from their jobs (less stability), although it is not so common for military products in special for aircrafts.

At the same time, the Swedish Government (SwAF, FMV, and FOI), together with the SDI and Academia, is thinking on the Air warfare for 2040. The Parliamentary Investigation of Air Defense 2040 (Lutförsvarsutredningen 2040) analyses future scenarios, proposes possible
solutions and prioritizes technology opportunities having already in mind the requirements and threats of the air combat in the 2040s and beyond.

From the point of view of the user, the SwAF does not have a strategy to have Gripen as a product platform, although it has a strategy of continues upgrades. Gripen was originally designed from the SwAF high-level requirements. SwAF traditionally works close with FMV and Saab in Integrated Project Teams (IPT) during weapon systems development to explain the user’s perspective and to validate different design proposals for various functions, particularly Human-Machine Interface (HMI) and tactical missions.

For one of the interviewees, the Gripen versions (A to F) could be considered as different products as well as each export versions is seen as a unique version of Gripen. For instance, the Gripen E for FAB will have a Wide-Area Display (WAD) that will not be present on the Swedish aircrafts.

Within Saab, there were some champions on the platform in the earlier steps of the product development, and as the teams are quite stable, there are many people that have a great experience on Gripen since they have been working with this platform from the first generation. In the first steps of the development some people had more influence on the design that could be treated as individuals that are very knowledgeable about Gripen, but as the time passed and new versions of the platform were designed and delivered, this knowledge has spread out through the team. However, inside each specific subsystem, it is possible to find some specialists that have much knowledge about their area.

The development of the new generation of Gripen (Gripen E/F) is a significant enhancement to the Gripen family and ensures it will be in service after 2040 (FMV, 2014). The continuous studies of the Air Warfare in the future like Luftförsvarsutredningen 2040, the research on new technologies and the feedback from users will be the driving forces that will mold Gripen’s evolution through its lifetime.

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22 Wide Area Display (WAD) is large display on the cockpit of the fighter “integrating tactical data, mission planning and flight information into a complete situational picture responding to specific mission phase and pilot controls” (Eshel, 2012). The Swedish Gripen E will have three display performing these tasks.
5 Analysis

In this chapter, the researcher analyzed and compared the theoretical views with the findings from the interviews based on the analytical framework to present an understanding of the management decisions that were involved in the development of these five CoPS over time.

5.1 Ground Combat Weapon Systems

This section presents management aspects that influenced the weapon systems studied with specificities highlighted in each weapon section while some of the management aspects are common to all Ground Combat Weapon Systems and are presented in section 5.1.5.

5.1.1 Carl-Gustaf Weapon System

Based on the empirical data regarding CG and the Product Platform and Family evolution proposed by Meyer and Lehnerd (1997) it was possible to establish Carl-Gustaf’s development over time (Figure 34). It shows the evolution of CG platform from the previous platform to the latest version (M4) with all the derivative products (ammunitions) within each generation.

5.1.1.1 Management dimension

CG is a 70-year platform with more than 40 countries using the system and, as shown in Figure 34, with many derivative products in its family, although it was not planned as a platform in the 1940’s; it was designed to only defeat MBT with the Second World War context according to the requirements of SAF.

Following the development shown in Figure 11, CG can be seen as a weapon system where the various types of ammunitions are derivative products that can be used with the firing platform (the recoilless rifle).

The number of new applications for the ammunitions has been growing and the previous versions have been updated. However, Saab needs to keep the production of older versions of some ammunitions due to demands from customers that do not want or do not have budget to
recertify the ammunitions and retrain soldiers, which can be a drawback since there is a potential for the lack of product distinctiveness due to commonalities within the platform (Robertson and Ulrich 1998). For example, some customers are buying the HE 441B ammunition although Saab is offering the new HE 441D (that has a better performance) which can have an impact on the financial return of the firm with lower-end models cannibalizing sales of the higher-end models (Simpson, Siddique and Jiao, 2006a).

As a very successful product, Saab wants to make continuous upgrades to the platform. For instance, the newest generation (M4) has been designed to receive future technologies and future ammo that will keep commonalities with the older generations (M2 and M3), although with fewer functionalities. Instead of starting a new platform, Saab Dynamics is focusing on applying improved capabilities to the existing system that would reduce development costs and decrease time to market.

5.1.1.2 Knowledge and Technology dimension
CG development started with the 20mm anti-armor rifle, from where it got its working principle (recoilless weapon) and the first two types of ammunition. The lessons learned from this first design, the technical requirements to overcome armor of MBTs and the availability of barrels of 84mm Cannon m/94 as shown in 4.2.1 were essential to the success of the M1 version (Davies and Brady, 2000).

On the same path, new customer needs, especially after the first exports of the weapon in the 1960’s, and new technologies, like fiberglass composites and the use of titanium, makes CG a well-managed product platform that is constantly evolving as new market knowledge and new technologies are integrated into products and production processes (Meyer and Lehnerd, 1997).

Although this support weapon has a great portfolio of ammunitions covering almost all the possible applications for a support weapon, ranging from anti-armor to soft targets, as depicted in Figures 8 and 11, Saab is developing, internally funded or sponsored by customers, new types of ammunition widening the boundaries of technology (Davies and Brady, 2000). One of the researches involves a new ammunition that could be used in both CG and AT4 (Hughes, 2016b) in a bottom-up approach trying to standardize components to get cost reductions by economies of scale (Simpson, Maier and Mistree, 2001) as well as to create an 84mm support weapon product family through a platform envelopment strategy (Eisenmann, Parker and Van Alstyne, 2011). Another internally funded development refers to give a new capability to CG and AT4 to have an ammunition with long range and high precision, as shown in Figure 12, which is a platform envelopment strategy of shoulder launched missiles, as the ULM would probably meet the same customer needs of BILL.

Also a platform envelopment strategy, the other research, sponsored by US DARPA, focus on the development of an innovative solution that would merge the low weight and portability of shoulder-launched weapons with the efficiency of larger, heavier and more expensive missiles systems.

5.1.1.3 Customer-seller relationship dimension
Carl-Gustaf’s platform evolution is mostly based on a close relationship with the customers and on the company’s practice to see feedback from the users as an opportunity to improve and innovate, especially with SAF and US Army. The latter is a good sponsor for the development of improvements for the CG platform (new ammunitions development were/are financed by
Pentagon’s budget) and is an excellent source of feedback from the battlefield, presenting new demands and suggestions to the improvement of CG. (Halman, Hofer, and van Vuuren, 2003)

On the same path as a global product platform (Meyer and Lehnerd, 1997), Saab takes into account the differences in needs of users in different parts of the planet, like the development of the smoke ammunition 469C as a consequence of Brazilian Army’s feedback due to problems with hot weather and humidity (rainforest scenarios).

Similarly, CG’s portfolio has been growing through its life cycle and updated due to changes in the requirements from the users and a need to increase competitiveness. Changes on the battlefield scenarios additionally have made Saab put out of the market some of the previous ammunitions, with CG being managed as a progressing entity similarly as shown on Meyer and Lehnerd (1997) and Simpson et al., (2006) researches. However, the firm is not able to obsolesce entirely older generations of some specific ammunitions, as, for example, the case of the 441D round previously cited, since there are some customers still buying the 441B version. As suggested by Weiser et al. (2016), choices on new modules and components have to be made, while at the same time assuring commonalities within the product family.

5.1.2 AT4

In the same way as CG’s analysis section, Figure 35 presents Meyer and Lehnerd's (1997) Product Platform and Family evolution of AT4 over time also from the previous platform to the latest version with all derivative products (ammunitions) within each generation.

![Figure 35: AT4 development](image)

5.1.2.1 Management dimension

The AT4 is a 35-year weapon system platform with more than 15 countries using its different versions. It was initially designed to defeat Soviet MBT with Cold War context to substitute the M68/Miniman (Military Today, 2016a) according to the requirements of SAF.

From the development presented in Figure 16, the number of new applications for the ammunitions has been growing and with new versions being updated ammunitions from previous versions. This way, the platform can be designed for a specific market segment and then be easily modified for different market tiers within the same segment (Marion and Simpson, 2006).

Nevertheless, Saab needs to keep the production of the older ammunitions due to demands from customers that do not want or do not have budget to recertify the ammunitions and retrain
soldiers, which can be a drawback since there is a potential for the lack of product distinctiveness due to commonalities within the platform (Robertson and Ulrich 1998). This fact also applies to the existence of new ammunitions that are focusing on different market tiers. For instance, the AT4CS AST for Special Forces and the AT4CS RS and the French AT4 NG Roquette with its three derivatives for regular soldiers. The lack of distinctiveness among these ammunition can impact Saab’s financial return as lower-end models might cannibalize sales of the higher-end model as well as affect costs since lower-end versions may be more expensive to produce due to overdesigned components (Simpson, Siddique and Jiao, 2006a).

Although having the same 84mm caliber, AT4 and CG do not share all the development resources and efforts regarding ammunition. Customers have financed AT4 versions, and this way, the development effort is on designing a new round for the AT4 system, not thinking of developing an ammunition for an 84mm family. However, as explained by the interviewee, this situation has been changing as the company has been self-funding the development of some of its new products. This way, the company is working on making the AT4 and the CG product lines come together through a bottom-up approach with standardization of components to get cost reductions by economies of scale (Simpson, Maier and Mistree, 2001).

5.1.2.2 Knowledge and Technology dimension
The AT4 development started in 1976 based on a Miniman upsized version with 84mm caliber, better warhead and propellant, and a new gun tube (Military Today, 2016a). For the interviewee and from the literature, the availability of fiberglass at a realistic cost and with mechanical properties to resist the high pressures of firing the gun was what made AT4 possible and successful since before this breakthrough technology, the weapons had steel barrels making it heavy to be carried by a single soldier.

On the same path, to make AT4 suitable to use in restricted areas, Saab introduced an innovative solution that uses salt water counter mass to absorb the backblast (Figure 15), slow down the pressure wave and help to reduce the launch signature (Army Technology, 2011a) that later was replicated to CG showing one example of knowledge sharing process within this Business Unit. Saab is developing some research to improve AT4’s capabilities as mentioned in section 5.1.1 and is making some studies towards the US Army Individual Assault Munition (IAM) program (Vassallo, Wahlström and Haster, 2016) as mentioned in section 4.2.2.

5.1.2.3 Customer-seller relationship dimension
Similarly to CG, AT4’s platform evolution is mostly based on a close relationship with the customers and on Saab’s practice to use feedback from the users as an opportunity to improve and innovate. The new ammunitions are mainly the result of the development of some specific needs of a customer. There was no strategic planning to push an entirely new solution to the market without any specific customer need.

Regarding AT4, Saab has a very close relationship with its customers, in particular, USA, France, and Sweden, which facilitates a clear comprehension of customer needs and market demands (Halman, Hofer, and van Vuuren, 2003).

On the same path, as a global product platform and following the works of Meyer and Lehnerd (1997) and Davies and Brady (2000), Saab takes into account the differences in needs of users in different parts of the planet and changes in these markets through time on AT4’s platform evolution. This way, the firm developed new AT4 versions to meet French requirements with emphasis on cost although having a previous US version with similar capabilities with a focus
on the weapon’s weight. The company does not see a converging to only one solution in a short-
term with both versions living side-by-side, as well as the older generations as some customers
do not have money to retrain their soldiers or do not want to make all the certifications
procedures to the newer models.

5.1.3 BILL Anti-Tank Guided Weapon (ATGW)

5.1.3.1 Management dimension

Similar to the two previous weapon systems, Figure 36 presents the development of BILL over
time based on the work of Meyer and Lehnerd (1997). There was no previous platform as well
as there is only one derivative, in the second generation.

The evolution from BILL 1 to the next generation did not change the architecture, as the
functional elements of the product and their interfaces are the same (Ulrich, 1995) with
improvements mainly on the missile with a new warhead (modular platform development
(Sköld and Karlsson, 2013)) and enhancements like day/night capabilities and some
miniaturization of electronics in an incremental platform development (Sköld and Karlsson,
2013). However, what may be seen as incremental evolution at the product and system
performance level can be a radical change at the component level (Hobday, 1998) like the new
warhead (improved tandem shaped charge with a precursor).

Although the company incorporates innovations into the platform to try to make this product
up to date (Meyer and Lehnerd, 1997), it seems that there is no much development on this
platform even with the adoption of a mounted version by Austrian Armed Forces (derivative
product). This adoption was not a horizontal leveraging strategy (Meyer and Lehnerd, 1997)
adopted by Saab; it was more a specific demand of one customer.

5.1.3.2 Knowledge and Technology dimension

Differently from the other systems studied, this weapon had no previous product or platform
from where it would be possible to get some components or systems to foster its development,
as similarly Halman et al. (2003) and Simpson et al. (2006) suggested to the development of
platforms. In this sense, contrarily to Hobday (1997) and Davies and Brady (2000) approaches,
there was no clear knowledge sharing process within and across other systems. The background
to this missile is some studies in the late 1970s to the development of a light anti-tank missile
for the SAF to first deliveries in the early 1990s. And as a new development, BILL’s warhead
widened the boundaries of technology (Davies and Brady, 2000) for missiles as it was the first
ATGW to use an OTA pattern.
The two versions of BILL are similar on the exterior. However, the second generation has some enhancements to overcome product limitations and to adapt to increasing demands on performance, capabilities, and reliability (Hobday, 1997) by adding new functions (Davies and Hobday, 2005) or correcting problems in the design. This evolution can be exemplified by the day/night capabilities and the improved tandem shaped charge warhead, to overcome ERA of new MBT (update of its military-operational knowledge base (Dombrowski and Gholz, 2006b)).

Moreover, the second generation became more costly and more technologically intensive (Davies and Hobday, 2005) through its new sighting system, the multi-mission capability to increase the array of possible targets, and reprogrammable firing mode to counter future threat scenarios and to be customized according to user requirements. These last two aspects represent, in some way, a modularization of systems and standardization of previously tailored components (Davies and Hobday, 2005) which can reduce costs, generate innovations and allow production learning (Hobday, Rush and Tidd, 2000) for new derivative products or even for a new generation.

5.1.3.3 Customer-seller relationship dimension
As mentioned earlier, this system was a direct demand from SAF in the 1970’s with a very specific task (anti-tank missile), as shown by the small number of users (four). SAF was the first user of both versions and funded the development of the weapon, being, in this case, a user, funder, and regulator (export control) of this system (Heidenkamp, Louth and Taylor, 2013).

The derivative version to the Austrian Armed Forces (mounted version) was a clear and accurate comprehension of customer needs (Halman, Hofer, and van Vuuren, 2003). However, this derivative product was a specific demand of only one user, and the system does not seem to have taken into account the needs of more users in different parts of the world (Meyer and Lehnerd, 1997). One possible explanation could be that the system was designed to meet SAF needs for a theater of operations where the main target would be MBT and this scenario changed after the end of the Cold War for a less intensive scenario in urban terrain.

5.1.4 NLAW
NLAW is the newest weapon studied in this research and has only one product with no derivatives. It is early to consider it as a consolidated platform or as a Product Family. Its timeframe is less than ten years and the rewards from a platform design take years to recognize (Simpson et al., 2006). In order to compare to the other systems, the Product Platform and Family evolution proposed by Meyer and Lehnerd (1997) for NLAW is presented in Figure 37.
5.1.4.1 Management dimension

The NLAW development started after an RFI from the UK as mentioned on 4.2.4, which is considered as a common beginning of a product family (customer requirements and market needs) (Ohvanainen and Hietikko, 2012). It has a low life cycle cost demanding just one battery change during its whole lifetime, reducing logistics costs and increasing the system’s availability.

The disposable missile system is a co-development and co-production between Saab Dynamics, as prime contractor and Thales Air Defence (the main British subcontractor with more 14 British subcontractors) which demands a good cross-firm coordination capability from Saab (Alblas, 2011). One example is that the two companies have a marketing agreement allowing that any possible customer can procure the system from either Saab or Thales.

5.1.4.2 Knowledge and Technology dimension

Saab had only 22 months to develop this weapon before replying to the British RFI for a weapon between the light anti-armor systems that are not optimized for defeating tanks and the heavier crew operated systems more specific for combat groups and not for a single soldier. To overcome this short lead-time, the firm based this new weapon on previously tested components and subsystems like OTA pattern form BILL and CS capability from AT4. In the interviewee’s words, Saab has “really taking our heritage and using it” on this system. The knowledge gained through this process helped on the design of products with better performance, shortening time to market, and reducing costs (economies of scale) (Halman et al., 2003; Simpson et al., 2006).

Although NLAW and BILL share, for example, proximity fuse and same OTA principle, they do not have so many common parts. Their product architecture is different not making NLAW a derivative product from BILL (Meyer and Lehnerd, 1997).

Based on the demands for a weapon with conflicts in urban terrain as its main scenario (Dombrowski and Gholz, 2006b), Saab has developed some innovative features specific for MOUT (Davies and Brady, 2000). The missile has a soft launch feature where it is ejected from the launch tube before igniting its rocket motor, reducing the missile profile during launch and allowing it to be fired from confined spaces (CS).

5.1.4.3 Customer-seller relationship dimension

As the wars after the end of the Cold War are mainly fought in urban terrain, NLAW was developed considering threats and doctrines of MOUT (Dombrowski and Gholz, 2006a). NLAW was also developed with the soldier at the battlefield in mind. The missile is easy to train and use (“non-expert weapon”) with even conscripts with minimum training having the capability of taking out an MBT.

The system is in service for less than ten years, but it has four countries using it, including Sweden that, in this case, is a normal user not having the role as funder of this system as FMV and SAF had with other systems.

Although the system is new, there are demands from the users to increase the range of NLAW. Saab has been working on a software update to increase the effective range from the originally designed 600m to 800m (“NLAWi”) which can be seen as the first indication that a new version or a derivative from the original missile will be part of this product family.
5.1.5 Business Unit Ground Combat

This section presents the analysis of the common management aspects of CG, AT4, BILL and NLAW within the Ground Combat Weapon Systems in its Business Unit.

5.1.5.1 Management dimension

Saab’s Ground Combat Weapon Systems share the same manufacturing plant, testing facilities and marketing area which helps on the knowledge sharing among different products and enables the possibility to have a co-development of these weapons with the use, whenever possible, of common modules and components to obtain economies of scale. For example, in the future, the idea is to make an 84mm product family with CG and AT4 (share ammunition development although based on different launching platforms. However, this advantage for knowledge sharing can hinder innovation as the R&D team for these weapons are the same which creates natural barriers to the acceptance of ideas from outside.

At the same time, as shown in Table 4, the four systems analyzed may compete for market share in the same market niches, that demands a careful planning of the families of these products to avoid cannibalization of sales (Simpson et al., 2006) which, in a sense, corroborates the idea of a common 84mm product family.

The company has a facility area (Saab Bofors Test Center) five-minute drive from the manufacturing plant to test and evaluate the weapons. Moreover, the firm also has a micro-firing range at the same place of manufacturing. This way, the office (design), the manufacturing plant, and the micro-firing range are less than 50 m from each other, allowing Saab to have a rapid development process and decrease development costs which contradict the general perception that CoPS prototyping and experimentation can be extremely costly or even impossible to produce (Hobday, 1997).

Saab Dynamics also applies some leveraging strategies to its products through new derivatives or new versions of these weapons through several related customer groups not needing to start the development from the ground for each product (Meyer and Lehnerd, 1997). For example, new ammunitions that fulfill new demands from military forces while keeping the same platforms (horizontal leverage) like the increasing portfolio of CG’s ammunitions. By the same token, new ammunitions supplying different market tiers within the same platform (vertical leverage) like AT4CS AST that is designed for elite groups while the AT4CS RS and the new AT4 versions designed to the French NG Roquette that are focusing on the regular soldier.

Considering Eisenmann, Parker and Van Alstyne’s (2011) leverage strategy, the possible future 84mm product family, and the researches of new smart ammunitions for CG and AT4 can be seen as a platform envelopment with a bundling of CG and AT4 platforms’ functionalities with that of the boundary markets (short range missiles) to leverage the 84mm platform through shared user relationships, reputation, technology and common components (Eisenmann, Parker and Van Alstyne, 2011; Gawer and Cusumano, 2008).

Saab’s idea is to combine the development of CG and AT4 to make them an 84mm support weapon family, differing from a disposable or reloadable launching tube. In the words of the interviewee: “Every cent to be spent in development will have benefits in both the Carl-Gustaf and AT4.”, exploiting this platform in its full potential to the maximum extent possible due to the high level of resources demanded by a platform development (Simpson et al., 2006).
The top management central steering and strong role in this business unit are crucial to platform planning since platform decisions often affect many product lines or intra-organizational units, they are cross-functional and call for complex tradeoffs among different business areas, (Robertson and Ulrich, 1998). Moreover, top-down planning is essential to gain the benefits of commonality and technology leverage (Meyer and Lehnerd, 1997) getting advantages on economies of scale and scope (Magnusson and Pasche, 2014).

Moreover, senior management needs to be closely related to the process of platform revitalization and renewal, managing human resources between teams and providing support as projects shift from the design stage into commercialization (Meyer, 1997). However, for the support weapons, this strategic thinking of the weapons systems as product platforms is something new or was reintroduced recently to BUGC. The common practice was to develop new products (and its derivatives) only when potential users demanded (as shown in the initial development of the four weapons systems studied) and only to fulfill the specific need requested. There was no planning in future versions or to keep the systems continuously updated. This fact changed since Saab has started financing its developments, with a strategic planning with a 20-year horizon.

On the other hand, continuous updates of a platform’s architecture and manufacturing process are crucial to secure a long-term success and competitive advantage in the market (Meyer and Lehnerd, 1997; Ohvanaïnen and Hietikko, 2012). Although not having a strategic planning, the company used feedback from users and their new demands to renew its platforms and keep them updated through the choice of new modules and derivatives, while at the same time guaranteeing commonalities within the product family (Weiser et al., 2016) and the older generations (for example, CG’s new ammunitions are designed to be also used with the old barrels from second and third generations).

CoPS are designed and produced on a one-off project basis or in small customized lots to meet specific customer needs (Davies and Hobday, 2005). However, for the support weapons, this perspective needs to be adjusted. They are rarely manufactured thinking on mass-production lots, but due to high volume production, compared to regular CoPS, they follow a CoPS to non-CoPS production where they were initially planned as CoPS and then, following market demands and cost reductions in their manufacturing processes become over time mass-produced (Acha et al., 2004).

To achieve these cost reduction the firm tries to use off-the-shelf products whenever possible, especially for small components and consumables, since the core modules and subsystem of these four weapons are mainly in-house manufactured.

5.1.5.2 Knowledge and Technology dimension

According to the interviewee, the process of knowledge sharing (from previous generations or platforms) is both formal (through reports and official documentation) and informal within the employees. The main part of this knowledge is within people (tacit knowledge) that cannot be easily translated to written form (Hobday, 1998). The tacit knowledge is represented by a good project team stability as, for example, the interviewee has been working at Saab for more than 20 years and he highlighted networking inside the company as a benefit from team stability. Moreover, by the presence of “champions” or gurus, which are people inside this Business Unit that are very knowledgeable about the four weapons systems.
For the interviewee, the presence of “gurus” presents benefits and weaknesses. It can make the firm to get new products to the market faster as the champions have knowledge regarding some design decisions and the products themselves. On the other side, it can be costly and time-consuming to prepare a new employee to the same level of the “guru.” Moreover, for the respondent, the presence of a champion can hinder not only opportunities for growth for other employees but also new ideas and solutions.

The platforms’ evolutions within BUGC are based mostly on either an addition to the product platform (such as the new ammunitions for CG and AT4) or on an entirely new product platform. Moreover, they are always evolving as new market knowledge and new technologies are integrated into products and production processes (Meyer and Lehnerd, 1997). The development of NLA\textup{W} based on BILL and some components of other systems is an example of how the lessons learned from previous products or bidding processes are crucial to the success of the new platforms/generations, leading to functional changes in CoPS producers’ organization and contributing to major changes in the strategic direction of these companies (Davies and Brady, 2000).

However, as the platform-based products for BUGC are limited to the market niche portable weapons, this design rigidity will deliver a less innovative solution to the user, as the innovations are limited by the platform (Mäkinen, Seppänen and Ortt, 2014). In a broader sense, installed weapons usually have heavier or longer rounds with a higher firing rate, demanding different capabilities compared to portable weapons. In this sense, super calibers ammunitions, as the planned FFV 597 HEAT (Figure 22), is not considered by Saab, which restricts the platform.

The interviewee did not highlight any issue regarding the changes in ownership and merging processes of this Business Unit that could have brought synergies as well as created cultural differences (communication and identification) among employees that could have affected the overall performance of the company as presented by Kleppestø (1998). One possible explanation is that after more than ten years since the last change of ownership, the employees see themselves as part of the same team with no more cultural clashes because of the changing and merging processes.

Considering the breadth of skills and technologies required, the core subsystems are made by Saab, with some components being outsourced demanding some coordinating skills with the suppliers (Hobday, 1998). The new generations of products, subsystems or components are produced following the requirements of users as well as new technologies available, like the fiberglass for AT4 and the titanium barrel for CG, with these improvements changing the platforms through the life cycle of each product family. Likewise, as the product development is also often highly complex and science-based, it demands that new scientific discoveries should be implemented into new products or to improve old products, afterward leading to changes to subsystems and components that could be reused from previous generations or products in a platform (Alblas, 2011).

\textbf{5.1.5.3 Customer-seller relationship dimension}

As mentioned on each weapon section, the developments inside BUGC are mostly based on a trustful relationship with the customers allowing them to feed their needs directly into the steps of product development of CoPS. Moreover, as the customers are very knowledgeable about the products and their specific demands, it is common that new ideas originate with the customers (Davies and Hobday, 2005). Additionally, these ideas frequently come from Saab’s
continuous improvement of its military-operational knowledge base by monitoring lessons learned from latest military operations, along with changes in doctrines and national strategies (Dombrowski and Gholz, 2006b).

As a result, the selling process of these weapons is a distinctive process that mixes military analysis (for example increased relevance of MOUT after the end of the Cold War), political pressure (reduction of military budgets and the change of the procurement law in Sweden), and technological innovations (Dombrowski and Gholz, 2006a). Moreover, it demands a high volume of financing (generally public) (Templin, 1994), although Saab is trying to self-fund its R&D.

The different versions of CG, AT4 and NLAW for specific users and the evolution of these weapons over time show that Saab, in a similar way as proposed by Halman, Hofer, and van Vuuren (2003), is adopting a platform approach to these systems through a clear and accurate comprehension of customer needs and market demands, considering the differences in needs of each user (Meyer and Lehnerd, 1997), and the characteristics of each platform.

5.2 Gripen

The Product Platform and Family evolution proposed by Meyer and Lehnerd (1997) to Gripen is depicted in Figure 38. It illustrates the evolution of Gripen platform from the Viggen (including the Technology Demonstrator) to the under development Gripen E/F.

![Gripen development](Figure 38: Gripen development)

5.2.1 Management dimension

One of the most important management decisions that supported not only the evolution of the platform (especially from versions C/D to E/F) but also the emergence of Gripen is to focus its design and development with a low life cycle cost as the main core of the aircraft. It was one of the points to choose Gripen instead of a foreign fighter on the first and third generations, with Figure 24 presenting the breaking of the trend of increasing costs of development and operation of previous Saab’s combat aircrafts.

Regarding platform strategy, Saab adopted a vertical scaling on Gripen when it is considered that Gripen E/F will focus on the higher tier of the market and C/D focus on countries that do not have high military needs or budget. These versions will share as much as possible the same capabilities and will benefit from each other in future developments without the need to develop a new platform or product for each market tier. (Meyer and Lehnerd, 1997)
This new strategy adopted by Saab to focus on two different market-tiers as presented in Figures 31 and 32 need to be carefully planned, as Gripen C/D and E/F compete for market shares with competitor products as well as with products within the family (Simpson et al., 2006)

The company also is using a horizontal leverage strategy as the fighter can handle new missions through the addition of modules or software updates. This strategy does not have a clear customer in mind, but from the interviews, it was possible to see new applications for the aircraft, in particular for the two-seat versions besides its common task of pilot training, for example, as an electronic warfare aircraft. (Meyer and Lehnerd, 1997)

Gripen’s production volume is low. Therefore, Saab tries to use whenever possible off-the-shelf components and subsystems, as suggested by Hobday, Rush and Tidd (2000) study, to increase the number of standardized items to get substantial development and production economies (Hobday, 1998). The most significant example to illustrate this search for standardization of components is the use of a modified version of the engine of the F/A-18 Hornet for Gripen A/B/C/D and the engine of the F/A-18 E/F Super Hornet for Gripen E/F. They were/are produced in high volume (considering a CoPS perspective), reducing the cost of acquisition and nearly eliminating any development cost of a specific engine for Gripen. Moreover, the standardization of components and subsystems lead to internationalization (exports) and interoperability, enabling the participation in joint operations under UN or NATO command. One example of standardization given during the interviews was the adoption of the Link-16 Datalink (NATO-standard) substituting the Swedish system TARAS even with the worst performance of the Link-16 compared to TARAS.

On the same path, the use of modularity allows Saab to merge its capabilities and technologies toward answering a wide-ranging number of different customer needs from defending frozen Sweden to hot and humid Thailand. With platform thinking it is possible to Saab to put on the market an aircraft that is tailored to each customer, dealing with regional differences regarding design, styling, and regulations what is corroborate by Simpson et al. (2006) in their research regarding Platform-Based Design and Development. Saab has also to deal with some environmental and cultural aspects considering the platform design.

A fundamental aspect of this approach is Gripen’s modular and open avionics architecture. The platform should be the same, but it should be able to fit in other customized modules which enable the integration of off-the-shelf products wherever possible, as well as the continuous development of new functions to meet future needs, as shown by the new MS 20 that updated Gripen C/D functions and capabilities to meet current and future air combat scenarios.

The design and construction of CoPS usually demand a high level of coordination skills, not only because CoPS involves a large number of different components, knowledge, and skills but also because many sub-suppliers and other organizational units of the producer frequently share duties and responsibilities during production (Hobday, 1997; Hobday, Rush and Tidd, 2000) which is the case with Gripen. Since the aircrafts have a long life cycle, supplier collaboration is built on a long-term win-win relationship. Saab acts mostly as an SI company not making every component or subsystem internally. This way, Saab tries to integrate the supplier with both product development and sales activities to involve the suppliers on the early stages of development to understand their roadmaps to have a parallel development of the aircraft and its components and subsystems. The company does not want to end up in a situation where the new version of the aircraft is designed containing old equipment. Choices on new modules and module derivatives go in parallel with the long life cycle of the product (Hobday, 1997).
Regarding market conditions change, Saab is continuously adapting its internal capabilities and processes to remain effective (Davies and Brady, 2000) as can be seen in the adoption of Model-Based Systems Engineering (MBSE) that uses computers to test and verify complex aircraft systems using computer-aided design (CAD) and simulation tools. This digital model allows Saab to rectify errors on the development in shorter time and to reduce the flight tests sharply that in the end represent a shrinkage in the cost of development and a shorter time to market.

Gripen is one of the most important products inside Saab having great support from Top Management, with a top-down planning approach to this platform since beginning to gain the benefits of commonality and technology leverage (Meyer and Lehnerd, 1997). Moreover, senior management is closely related to the process of platform revitalization, and providing support to studies on future improvements of the aircraft (Meyer, 1997).

Although there was no planning of Gripen as a platform from beginning, this platform renewal is part of the culture of the company (Meyer and Lehnerd, 1997) and it is crucial to secure a long-term success and competitive advantage in the market (Meyer and Lehnerd, 1997; Ohvanainen and Hietikko, 2012) and keep Gripen updated to face new scenarios and threats, particularly as Gripen’s operational life cycle spreads out over many years.

5.2.2 Knowledge and Technology dimension

In a broader perspective, regarding Gripen, Saab can be seen as systems-of-systems integrators as it integrates components and subsystems that, in many cases, are as much complex as the main system or even more complex, like jet engines and radars. In this sense, it requires design knowledge of main components and subsystems in-house to be able to outsource efficiently (Hobday, Rush and Tidd, 2000). In the same way, the knowledge from previous generations is also important to understand design decisions on the platform. Lessons learned from previous projects, and bidding processes (successful or failed) are essential to the success of subsequent projects (Davies and Brady, 2000).

The process of knowledge sharing is both formal (through reports and official documentation) and informal within the employees. This tacit knowledge is represented by a good project team stability (some employees are working with Gripen for more than 30 years) as well as through the presence of the dubbed “champions,” workers that are very knowledgeable about Gripen.

Sometimes, they can also use knowledge from one business to aid the development of another business unit (Davies and Brady, 2000) or from previous platforms as was the case with Gripen A/B that used a Viggen aircraft and Gripen E/F that used Gripen D as technology demonstrators (Figures 25 and 29). The benefits were the reuse of design and parts, with less cost, keeping previous design experience, reducing development risk, bridging the gap between R&D and production.

As a result, it was possible to build a new aircraft with a low life cycle cost breaking the cost curve as shown in Figure 24. Other factors that made this possible were/are new technologies (like fly-by-wire flight control system for Gripen A/B and MBSE and increasing computer power for Gripen E/F). Moreover, the extensive use of composite materials throughout the aircraft was one of the reasons that even with half the size of a Viggen, Gripen was able to carry the same amount of weapons (Keijsper, 2003).

On the same path, Gripen is always evolving as new market knowledge and new technologies are integrated into the aircraft (Meyer and Lehnerd, 1997). However, this evolution is not
uniform among the different system and components. As a system of systems, each part of Gripen has a different pattern of evolution that is described in Figure 39.

Systems and components that are related to shape, aerodynamics, airframe, and engine, which are more related to hardware and materials, are less likely to be changed through Gripen’s life cycle with changes more incremental than radical (Sköld and Karlsson, 2013). These systems are expensive to change and demand some new flight tests and certifications as well as they might ground the fighters for a long time. They could be considered as the main platform (stable and long lasting) of Gripen’s platform.

On the other hand, the flying and tactical systems that are mostly software and IT dependent have a more frequent cycle of upgrades, following the changing of customer needs (new threats), new weapons and sensors availability and the miniaturization of electronics and increasing computing power (Davies and Hobday, 2005). Moreover, to be able to have an aircraft that is always updated to face the demands of the air forces, Gripen has an open architecture with separation of criticality in avionics (Hjelm, 2016). Saab has developed a distributed integrated modular avionics system that splits the flight management system (10%) from the tactical systems (90%) (Robinson, 2016).

This way Saab can have a jet fighter that can have its tactical capabilities constantly updated, as seen in Figure 39, although not having to pass through all flight safety certifications that would ground the aircrafts for long time. The tactical system works similar to a smartphone where apps are opened and closed according to a specific military mission (air superiority, reconnaissance or ground attack, for example), and new apps (such as radars, sensors or new missiles) can be “downloaded” with minimum interference with any critical flight function. Moreover, the development costs are spread out over the life cycle of the aircraft, and the upgrades can be implemented customized and adapted to each customer budget and military needs.

This way of working with continuous upgrades is also related to knowledge and human resources management. Differently from the US Armed Forces and Aircraft manufacturers that
adopt MLU due to the high volume of production, Saab faces a situation with a small volume of orders. To keep its engineers occupied all the time, Saab adopted this short update cycle approach since it is cost prohibitive to keep engineers and technicians without a project after the delivery of the aircrafts, as it would pass 10 to 15 years before the MLU. They would go to other industries or even competitors taking all the tacit knowledge, specific training, and different skills with them. Additionally, there would be no skilled employees to work, and it would be necessary to spend time and money to rehire and retrain workers when it would be the time to perform the MLU. This way, through MS upgrades, Saab can keep its engineering always thinking of new improvements to the aircraft.

5.2.3 Customer-seller relationship dimension

Saab’s customer-seller relationship relating to Gripen is mostly based on the long-term relationship with SwAF that goes back to the origins of the firm 80 years ago. The Swedish customer is related to Saab as users of the aircraft, as their funders and as their regulators (Heidenkamp, Louth and Taylor, 2013).

As a user, the SwAF demanded an aircraft with a low life cycle that could operate from road bases dispersed across Sweden with a low logistics footprint (Cook, 1998). These characteristics influenced the design parameters of the aircraft like being a small, single-engine fighter with a great level of modularization of systems and standardization of components to reduce MTTR during operation from road bases, which helps to minimize the complexity of the design (Davies and Hobday, 2005).

As sponsor, Swedish government support Gripen’s development by the R&D program INNOVAIR (Axelson, Johansson and Lundmark, 2013), considering Gripen as of national strategic interest for the procurement law, through the participation in military operations (Sweden mission in Libya in 2011), and through financing export and specific policies (Heidenkamp, Louth and Taylor, 2013).

Regulatory and sovereignty issues by the Swedish Government, like safety purposes, standardization and national interests have influenced the development (Hobday, 1997) of this platform over foreign fighters both with Gripen A/B and with the E versions, even with a higher cost of acquisition (Templin, 1994). Another example is the agreement of the Swedish Government to authorize a contract for transfer of technology with Brazil which was one of the most important factors of the FAB bidding program. Although the need of a strategic partner was part of the economic calculations of the Gripen E project.

Another important aspect of this trustful customer-seller relationship with the Swedish customer is Saab’s participation in war games, military training exercises, and seminars like the Parliamentary Investigation of Air Defense 2040 (Luftförsvarsutredningen 2040). These are opportunities to test new operational concepts and discuss future threats and challenges that will enhance Gripen’s development (Dombrowski and Gholz, 2006a) and also increase the trust among the firm and its main customer.

Furthermore, the previous good performance of Viggen and Drakken was also a way to gain trust from military leaders (Dombrowski and Gholz, 2006a) and favor Gripen over foreign aircrafts.

Moreover, after the internationalization of Gripen with the first export contract for South Africa other user’s needs also influenced the evolution of Gripen. This export focus from Gripen C/D
and beyond made Saab standardize modules and components (NATO standard) and increase the modularity within the aircraft to overcome the possible restriction of exporting some components (like radar and missiles). Additionally, this modularization of Gripen allows Saab to diversify its supplier base as well as offer potential offsets that have been a critical enabler and an advantage in many military biddings (Dehoff, Dowdy and Kwon, 2014), as exemplified on Figure 26. Also, it enables that Gripen can be a global platform customized to the specific needs of each country (Meyer and Lehnerd, 1997), with one of the interviewees considering this each customized aircraft as a derivative of Gripen.

5.3 Cross-case Analysis

To analyze the possible correspondences and differences between the cases (Eisenhardt, 1989), what converges and clarifies the cases, and to increase the internal validity of the study (Voss, et al., 2002), a cross-case analysis of the systems was performed based on the analytical framework proposed.

5.3.1 Management dimension

Differently from Saab Aeronautics that has been controlled by Saab since beginning, the Saab Dynamics is relatively a new business within Saab Group. The BUGC has a diverse background from different companies, although with no cultural clashes presented today.

Modularity and product architecture allow firms to merge their capabilities and technologies to answer a wide-ranging number of different customer needs. In this sense, Gripen is a more modular system with an open architecture and separation of tactical and flight systems compared to the support weapons. It is also explained by the fact that in Gripen Saab acts like a system of systems integrator combining complex components into the aircraft while for the support weapons the core of those systems is the ammunition that is mainly a Saab product but also having an SI capability. These differences in the level of modularity can also be shown with the possibilities to customize Gripen for each user without having to create a new product (although one of the interviewees consider this customization as a new derivative). For the support weapons, any significant customization will demand the development of a new derivative product such as AT4’s development for France that was based on the US versions but had to be a new version of the weapon.

Although platforms can offer substantial competitive advantage and possibilities to foster market penetration (Wheelwright and Clark, 1992) with four of these Saab’s systems being successful platforms, platform concept is a new thing at Saab.

The first generations of all the systems studied were not seen as a platform since beginning with no top-down strategy for design decisions in advance (Meyer and Lehnerd, 1997). They have a bottom-up approach with standardization of components to get cost reductions by economies of scale (Simpson, Maier and Mistree, 2001). However, for the new generations, the product families design are more planned and based on modules that can be easily modified and updated (Meyer and Lehnerd, 1997), showing the new thinking of the company on adopting a top-down approach as can be clearly seen in Figure 32 showing the development path of a Gripen family. On the other hand, the planned integration of a family of 84mm support weapon (CG and AT4) is a bottom-up approach where the idea is to mutually leverage CG and AT4 markets through a platform envelopment where they will share user relationships, reputation, technology and common components (Eisenmann, Parker and Van Alstyne, 2011; Gawer and Cusumano,
The ULM research can also be seen as a platform envelopment strategy to cross over BILL market by giving the same functionality of BILL through using of CG or AT4 platforms.

CoPS are designed and produced on a one-off project basis or in small customized lots to meet specific customer needs (Davies and Hobday, 2005). Gripen is a classic example of this approach with no mass-production perspective (Hobday, 1997). For the support weapons, this point of view cannot be totally adopted. Although they are CoPS that are rarely manufactured thinking on mass-production lots, they follow a CoPS to non-CoPS production where they were initially planned as CoPS and then, following market demands and cost reductions in their manufacturing processes become over time mass-produced, compared to a regular CoPS (Acha et al., 2004). Therefore, if the aircraft is seen as a system of systems, as described in Figure 39, then each specific subsystem can have more or less the same approach suggested by Acha et al. (2004), for example, Gripen’s engine that is similar to the F/A-18 engine which have a high number of engines produced (for each F/A-18 there is a need for two engines and the aircraft is in use by the US Marines, US Navy and other Air Forces around the world).

5.3.2 Knowledge and Technology dimension

Regarding knowledge dimension, all the systems are based on knowledge sharing within and between businesses units of the company and from one generation (or even a previous product) to the next or to a derivative product. This process is both formal (through reports and official documentation) and informal from the employees. This tacit knowledge is represented by a good project team stability for each system as well as by the presence of the so-called “champions,” workers that are very knowledgeable about the systems.

Adaptability to new threats and new technologies over the long lifespan of the military equipment was also presented among these systems (Meyer and Lehnerd, 1997), with more or less intensity. CG evolved from an anti-tank weapon to a support weapon with multiple applications, adapting the platform to the new demands of the users and to the new technologies available. For its turn, Gripen evolved from a Swedish aircraft for the Swedish needs to a multirole customized international fighter that is in the state-of-the-art in the military aviation market, based on new threats (like the end of Cold War and multinational operations) and technology enhancements such as increasing computer power and improved radar capability.

Although not planned as platforms from the beginning, the systems’ architectures were designed in a way that they can be updated to handle not yet known requirements from the users (Holmberg, 2003) or deal with new threats while keeping the architecture mostly unchanged. On the support weapons, it can be seen, for example, on the array of new ammunitions for CG and AT4, and the several researches on these two systems. On Gripen, it is even more evident with the continuous upgrades of the fighter. Moreover, Gripen’s modular and open architecture (separation of tactical and flight systems within the aircraft) and the increasing dependency on software/computer power allows the aircraft to be updated in shorter cycles to meet customer needs.

The continuous updates (MS) in Gripen is also a knowledge management strategy as Saab can keep its engineering always thinking of new improvements to the aircraft differently from MLU where the demand for updates is from cycles of 10 to 15 years. In addition, it is cost prohibitive to keep engineers and technicians without a program, and they would probably go to other industries taking all the tacit knowledge, specific training and different skills with them, and it would be costly to rehire or retrain workers. For the support weapons, this way of thinking is
not necessary as the production of the weapons systems have some mass-produced characteristics as mentioned in the previous section like a high volume of production, compared to regular CoPS. Moreover, the low cost of prototyping and experimentation that allows innovations or adjustment, like new sealing for CG’s 469B ammunition, occurs without interfering on the user’s military capabilities.

5.3.3 Customer-seller relationship dimension

One of the most important characteristic of a defense company is its ability to maintain a close relationship with its customers (Armed Forces, R&D organizations and procurement agencies), allowing the firm to understand customer needs and present the solutions that users want, while dealing with all the intrinsic political, economic and regulatory issues of Defense bidding processes (Dombrowski and Gholz, 2006a). They are related to the Defense Industry in three different ways: as users of military equipment, as their funders and as their regulators (Heidenkamp, Louth and Taylor, 2013). From the interviews, it was possible to see that Saab and its customers, particularly FMV and SAF, have a very close relationship with a mutual trustful relationship where Saab is seen as a partner on the development of military solutions for these customers. The different researches conducted by Saab with DARPA in USA for the support weapons and the participation of the company on the Parliamentary Investigation of Air Defense 2040 (Luftförsvarsutredningen 2040) with SwAF, FMV, and FOI, are some of the examples presented in chapter 4 of this close relationship with customers.

Simultaneously, through the different examples of government finance of R&D of new types of ammunition for the support weapons and the Gripen E/F development by Sweden and Brazil, the customer can play a role as sponsor, by government’s commitment and support to promote defense industries through government funding (private financing for defense firms is negligible) and through specific policies (Heidenkamp, Louth and Taylor, 2013).

Regulatory and sovereignty issues, like safety purposes, standardization and national interests, can also influence CoPS development (Hobday, 1997). However, they are treated differently for support weapons and combat aircrafts. Gripen is considered of national strategic interest and, together with submarines, can have its development funded by the Swedish government. For support weapons, following the new procurement law in Sweden, they should be bought on open bidding processes without any specific financial sponsorship from the government.

Moreover, a typical aspect regarding platform-based thinking from the user perspective is the reduction of costs and time with certifications and training. Certifications can be exempted or just be amended if the platform is kept almost stable. It is one reason why Saab has to keep old ammunitions for CG and AT4 in its portfolio. For its turn, training can be simplified, as the platform is nearly the same, which occurs in the case of Gripen, where Sweden will not buy the F-version for pilot training, as the training will be performed on the D-version.

In opposition to these benefits of keeping the platform stable, it may hinder the ability to develop new products that would require radical changes in the platform. For instance, if some parts of the platform (components, modules or subsystems) or even the architecture need to be changed radically, the platform as a whole may need to be altered, modified, or abandoned (Mäkinen, Seppänen and Ortt, 2014). This fact might lead to some conflicts with users, as they may not be willing to retrain and recertify their inventories.
6 Conclusion

Platform development is considered to be a phenomenon of vital importance for the strategic management of companies (Thomas, Autio and Gann, 2014). However, the translation of platform methods to CoPS cannot be easily made, especially when complex military systems like fighters and missiles are involved, since the market is limited to one or a few suppliers taking into account political and sovereignty issues along with economic reasons.

Thus, this thesis tried to enlighten management decisions related to CoPS platforms over time through a study of five product platforms in the context of the Swedish Defense Industry, aimed to answer three research questions:

I. How strategic was the evolvement of the product platform (for example, accidental and, only understood at a later stage or based on a clear strategy from the outset)?
II. What were the management and technical factors behind the emergence of each platform?
III. What key management decisions enabled the emergence of each respective platform?

Therefore, the five cases were analyzed based on the relevant literature regarding Platform-Based Product, CoPS, strategic management of CoPS Platforms and the special issue of customer-supplier relationship of military CoPS from where an analytical framework was proposed. The three dimensions proposed on the analytical framework raise the main aspects that, in a broader perspective, influence the management of a CoPS platform within the Defense Industry context.

In this sense, even though no system studied were strategically planned as a platform from the beginning, it is clear that robust product platforms are not seen as the result of a lucky company. Saab has applied/applies a set of methods, practices and strategies for designing, developing, manufacturing, selling and renovating the platforms through time in a similar way as proposed by Meyer (1997) in his paper. All the platforms are based on a great level of diversity of technologies and specialized R&D (Hobday, 1997; Sköld and Karlsson, 2013), knowledge sharing process within platforms and from other products on Saab’s portfolio (Hobday, 1997; Davies and Brady, 2000) and on a trustful and long-term relationship with its customers (Dombrowski and Gholz, 2006b).

From the analysis, it was clear that Saab has been traditionally a technology-driven and engineering-driven company. In this way, Saab’s strength is based on its capability to deliver cost-effective and high-quality solutions, under fierce competition, changing customer needs and strict requirements on low life cycle costs to its products and systems, also trying to deliver whenever possible specific solutions to each customer. This strength is supported by core capabilities in systems integration, project management, team stability, knowledge sharing, continuous investment in R&D (self-funded and sponsored by customers), long-standing relationships with operators, and a good understanding of the different organizational and market contexts in which each system is applied.

Regarding management dimension, the company adopts both a top-down approach to the new derivatives of the platforms showing that they are planned as platforms and based on modules that can be easily modified and updated. For the older products, Saab uses a bottom-up approach trying to standardize technologies and components to gain economies of scale. The management of suppliers is smooth with regular meetings and a parallel roadmap of the components with Saab’s CoPS, as the company act as an SI, combining components and
systems outsourced and internally manufactured. Moreover, in order to achieve cost reductions, Saab tries to use whenever possible off-the-shelf products and systems and to modularize the platforms which allows the company to customize the platforms for each customer in its specific context, to decrease the time to market of new derivative products (reducing complexities) and to enable the separation of tactical systems from the critical flight systems for Gripen.

Top management has an important role in supporting the development of these platforms as continuous updates of a platform’s architecture and manufacturing process are crucial to secure a long-term success and competitive advantage in the market (Meyer and Lehnerd, 1997; Ohvanainen and Hietikko, 2012). In this sense, the firm adopts a vertical scaling strategy where Saab can reach both higher and lower tiers of its markets, a platform envelopment strategy to bundle some of the company’s platforms functionalities and a horizontal leveraging within new types of ammunitions for CG and new missions for Gripen.

On the knowledge and technology dimension, knowledge from previous products components and systems are shared through both reports and official documentation, and informal from the employees with the presence of knowledgeable employees, dubbed “gurus,” within each platform. Moreover, the tacit knowledge is also based on a good team stability. By transferring knowledge from previous products, the company can improve its project performance and competitiveness. The firm presents a good capacity to handle new threats and technologies with both governmental and self-funding of R&D that brought some innovative solutions that widened the boundaries of technology (Davies and Brady, 2000). Furthermore, the analysis showed the importance of continuously updating the platforms as a knowledge management strategy. Since CoPS have long life cycles and low volume of production, it is cost prohibitive to keep trained employees in cycles of more than ten years for upgrades. From the user’s perspective, it is also beneficial to have shorter cycles of innovations, as the user’s platform can be always in the state-of-the-art and incorporate new technologies available.

The last dimension can be seen as one of the symbols of a successful defense company: it is its ability to keep a close customer-seller relationship with its customers allowing the firm to listen, understand and present solutions that meet the customers’ needs. The customer is related to the Defense Industry in three different ways: as users of military equipment, as their funders and as their regulators (Heidenkamp, Louth and Taylor, 2013). In this sense, it is important to consider all of these facets. On military analysis (like threats and doctrines), it involves understanding the military needs from participation in war games, military training exercises, seminars and bidding processes. Regarding the political side (political/electoral priorities versus military needs), it includes modularization of the platform allowing the participation of suppliers from the customer’s country and to have different derivative products within a platform that meet both higher and lower tiers of the market.

Moreover, differently from Hobday (1997) that considers that CoPS are never mass-produced, this study found more similarities to Acha et al. (2004) approach where CoPS are rarely manufactured thinking of mass production lots; they are initially planned as CoPS and then, following market demands and cost reductions in their manufacturing processes some of them become over time mass-produced. Considering the support weapons, they follow this CoPS to non-CoPS production path, having all the characteristics of a CoPS during the design phase, however changing to a more volume intensive production (compared to regular CoPS) where it is possible to apply platform strategies to gain some economies of substitution and scale. In the case of Gripen, with a very low production volume, this approach is true only when the aircraft
is seen as one system of systems and each system is analyzed separately. For example, the adoption of components and modules that are used in other CoPS, like the engine that is similar to the engines of the F/A-18, is one way of getting the benefits of economy of scale.

Furthermore, this study presented some management decisions that can foster product platform strategies for CoPS under the Swedish Defense Industry context. Thus, some research on other settings could bring new perspectives regarding CoPS platforms that could fill up the lack of theory regarding the special issue of applying product platform strategies to the development of CoPS.
7 References


Appendices

Appendix 1 - Interview Questions

Background
- Name, Age, Current Position, General Background
- In which Saab Systems do you work/ (have you worked) and for how many years?

Role in the product platform(s) central to the study
- What was your role in the mentioned Systems through the time?
- Is a Product platform a known concept and applied within the company? What is your and the company’s understanding of this concept?

Implementations of the platform(s) over time
- How was the implementation of the platform(s) over time?
- Has the product platform design enabled to accommodate several products, which are regarded as one product family?
- Have the products been designed as platforms since beginning? Was it a response to a demand from customers to the first generation of the product?
- During the development of the system, which procedures have been adopted, considering a Platform-Based perspective?
- A variety of design tools for NPD exists. How was/is their implementation? Any of them specific to platform-based products?

Crucial factors behind the emergence of each platform
- Which crucial factors or incidents could you identify behind the emergence of this platform?

Strategic aspects and decisions related to the platform(s)
- How was the process of incorporating new technologies to the existing platforms of the systems (critical incidents, important aspects)?
- How is your perception or thinking of platform on this (these) Product Development process(es)?
- What products have been derived and commercialized from this platform? Why have they been chosen? Were any Platform Strategy adopted (top-down or bottom-up)?

Management of the complexities related to the platform(s)
- How has the company dealt with all the complexities of the NPD of CoPS?
- What are the advantages and disadvantages of adopting Platform-Based Product Development to CoPS, given the one-off nature of CoPS projects?

Role of the customer and the supplying organization
- What was the role of customers’ needs/market requirements on the NPD of a Platform-Based product?
- What was the role of the customer on the NPD of a Platform-Based product? Customization, Co-Development, or another one that could you identify?
- How to guarantee that the platform and family of the system are “ideal” for Saab and its customers?
- How was the user/customer involvement on the NPD of the system and in the products derived from this common platform?
- How was the cross-firm coordination (high, medium, low) with different suppliers, in terms of monitoring, meetings, responsibilities, etc.?

**Platform-based products and possibilities to innovate**
- How do you perceive platform-Based product related to innovation? Barrier or driver?
- What could you identify as drivers and barriers for innovation on platform-based products?

**Drivers and barriers for the development of platform-based products**
- What could you identify as drivers and barriers for the development of platform-based products?
- What are some limitations to the adoption of a platform-based product development?

**Management of platform-based product development**
- Have you worked in different divisions inside Saab? How has your knowledge from previous tasks helped on or disturbed the Platform-Based product development?
- How was the stability of the project team during the NPD? Have the managers and team members remained on the project from one product to the derived products from this platform? How has this fact influenced the NPD?
- How was the knowledge sharing process through the project team? Informal or through documents (e.g., reports, newsletters)? And with different product lines within Saab?
- Has this team been responsible/accountable for the products derived from this platform?
- How do you see the role of the project manager and from the top management in the NPD of this Platform-Based product?
- Was there a champion (or champions) in the product development of this platform? What was his/her role and how has he or she made the difference for the NPD of this platform?
- How was the cross-functional organization through the development of this Platform-Based product?
- How was the level of reusability of subsystems, modules and/or interfaces of platform-based products between generations and the degree of commonality between different products in the system?
- How was the reusability of subsystems, modules and/or interfaces of the platform-based products?
- Was there a design strategy where common functional modules are used in several products derived from this platform?
- How is the use of “off the shelf” functional modules in different products from this platform?

**Reflections and recommendations for the future**
- What could you suggest as recommendations for future platform-based product developments?
- Could you suggest more people that would be interesting to interview to support this research?

Would you like to add anything more?