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New Methodologies of Integrated Development in Aeronautical Structures

Implementation of a Knowledge Management Strategy in CEIIA

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Resumo

Nos dias que correm, o mercado aeronáutico e aeroespacial são ambientes extremamente competitivos que lidam com quantidades monetárias bastante consideráveis e onde o sucesso de uma organização depende da forma como esta aplica o seu conhecimento nos projectos. A boa gestão do conhecimento de uma empresa leva a que a sua aplicação seja mais eficiente e eficaz, o que se reflecte na qualidade do produto final e também nos lucros obtidos. Várias empresas de renome como a Airbus ou Boeing possuem sistemas de gestão de conhecimento aplicados ao seu modo de funcionamento e isso reflecte-se na sua performance.

Este projecto tem como objectivo estudar a melhor forma de implementação de uma estratégia de Gestão do Conhecimento na Unidade Aeronáutica do Centro para a Excelência e Inovação na Indústria Automóvel (CEIIA). A estratégia desenvolvida nesta tese visa coincidir com o modo de funcionamento da unidade, os seus objectivos e necessidades e também colmatar as dificuldades experimentadas pelos trabalhadores. Esta estratégia é apenas aplicada às áreas de Stress e de Design, pois são as que possuem maior volume de trabalho, tornando-as modelos ideais para testar a aplicabilidade da estratégia. Como primeiro passo, esta estratégia visa organizar e identificar o conhecimento gerado na unidade e também o possuído pelos colaboradores, visto que esta estratégia é a iniciação da Unidade Aeronáutica (e também do CEIIA) mundo da Gestão do Conhecimento. O custo desta implementação foi avaliado e medido em horas de trabalho, distribuídas pelas diferentes etapas e processos da estratégia.

Palavras Chave: Conhecimento, Gestão, Aeronaútica, Estruturas, CEIIA

Abstract

Nowadays, the Aerospace and Aeronautical markets are extremely competitive environments that handle with quite considerable amounts of money and where an organization's success relies on the way of how its knowledge is applied in the projects. A good Knowledge Management (KM) leads to a more efficient and effective knowledge application in a company, which is reflected in the quality of the final product and also in its profits. A great number of well known companies such as Airbus or Boeing have KM Systems applied to its methodologies which is reflected in their performance.

This project aims to study the best way of implementing a KM strategy in CEIIA's Aeronautical Unit (AU), applied to the development of Aeronautical Structures. The developed strategy in this thesis intents to match AU's way of working, goals and necessities, as well as surpass the difficulties experienced by the workers . This strategy is only directed to the company's Stress and Design areas, since these are the ones with more workload, which makes them perfect models to test the strategy's suitability. As a first step, this strategy aims to organize and identify the knowledge created by AU and also the one stored in workers, thus this is the AU's initiation (and also CEIIA's) in the KM's world. The implementation's cost was evaluated and measured in working hours distributed by the strategy's distinct phases and processes.

Keywords: Knowledge, Management, Aeronautical, Structures, CEIIA

Contents

Resumo iii

Abstract v

Contents vii

List of Acronyms xi

List of Figures xiii

List of Tables xv

1 Introduction 1

1.1 The Three Proposals . . . 1

1.1.1 Real Tests VS Virtual Tests . . . 1

1.1.2 Implementation of a Knowledge Management Strategy . . . 2

1.1.3 Implementation of an AGILE/SCRUM Methodology . . . 4

1.2 The Decision . . . 4

1.3 Structure of the Thesis . . . 5

2 Knowledge Management - State of Art 7

2.1 What is Knowledge? . . . 7

2.1.1 Explicit Knowledge . . . 8

2.1.2 Tacit Knowledge . . . 9

2.1.3 Relationship Between Tacit Knowledge and Explicit Knowledge . . . 9

2.1.4 The Importance of Knowledge . . . 10

2.2 What is Knowledge Management, and what are its advantages? . . . 11

2.3 What is the KM Cycle? . . . 12

2.3.1 Vision, Search and Control . . . 13

2.3.2 Creation . . . 14

2.3.3 Capture . . . 14

2.3.4 Transference . . . 14

2.3.5 Application . . . 15

2.4 How can Knowledge Management be implemented in an organization? . . . 15
2.4.1 Contents of a good Implementation Strategy . . . 17
2.4.2 Implementation Obstacles . . . 18
2.5 How is KM being applied in today's Aerospace and Aeronautical Organizations? . . . 20
2.5.1 Tools/ Procedures . . . 21
2.5.1.1 The intranet . . . 21
2.5.1.2 Informal Communication . . . 21
2.5.1.3 Knowledge Communities . . . 21
2.5.2 Strategies . . . 22
2.5.2.1 Benchmarking . . . 22
2.5.2.2 Mentoring . . . 22
2.5.3 Case Studies . . . 22
2.5.3.1 NASA - Lessons Learned . . . 22
2.5.3.2 DLR - Tools of the Aerogrid Porject . . . 24
2.5.3.3 inSide - Boeing's Internal Social Network . . . 25
2.5.3.4 ESA . . . 25
2.5.3.5 European Space Operation Center . . . 27

3 CEIIA's Aeronautical Unit **31**
3.1 CEIIA in the Aeronautical Industry . . . 32
3.2 The Development of Aeronautical Structures . . . 33
3.2.1 Knowledge Discrimination: Frame from Lower Fuselage . . . 35
3.2.2 Knowledge Discrimination: Rear Protection Panel from Secondary Structure . . . 36
3.3 Aeronautical Unit's Working Process . . . 36
3.4 Knowledge Management in AU . . . 42
3.4.1 CEIIA's Knowledge Tools . . . 42
3.4.1.1 i-CEIIA . . . 42
3.4.1.2 Lessons Learned . . . 43
3.4.1.3 A3 . . . 44
3.4.1.4 CEIIA Sharing Knowledge . . . 45

4 Knowledge Management Strategy **47**
4.1 The Strategy . . . 47
4.1.1 Identification . . . 50
4.1.1.1 Survey of Competences . . . 50
4.1.1.2 Knowledge Analysis . . . 50
4.1.1.3 Study of Knowledge Subprocesses . . . 51
4.1.1.4 Tools Implementation . . . 51
4.1.2 Organization . . . 51
4.1.2.1 Department's Creation . . . 52

4.1.2.2 Study of Knowledge Subprocesses . . . 53
4.1.2.3 Application . . . 53
4.1.2.4 Maintenance . . . 54
4.2 Strategy Processes . . . 54
4.2.1 Vision, Search and Control Process . . . 55
4.2.1.1 Yellow Pages System . . . 56
4.2.1.2 Quantifiers . . . 57
4.2.2 Creation Process . . . 57
4.2.3 Capture Process . . . 58
4.2.4 Transference Process . . . 59
4.3 Case Study / Possible Application . . . 61
4.4 ROI . . . 62
4.4.1 Annual Goals . . . 62
4.4.2 Estimated Time and Cost . . . 63
4.4.3 Returnable Value . . . 65

5 Conclusion **67**

Bibliography **69**

A XPS4CFD Examples of Workflow, Rules Template and Forms template **75**

B Query about CEIIA's Knowledge Processes and State **81**

C Lessons Learned Template **83**

D A3 Template **85**

List of Acronyms

AS	Aeronautical Structures
AU	Aeronautical Unit
CAD	Computer Aided Design
CEIIA	Centro para a Excelência e Inovação na Indústria Automóvel
CFD	Computer Fluid Dynamics
CSCW	Computer Supported Cooperative Work
CSK	CEIIA Sharing Knowledge
DLR	Deutsches Zentrum für Luft- und Raumfahrt
EASA	European Aviation Safety Agency
ESA	European Space Agency
ESOC	European Space Operations Center
FAA	Federal Aviation Administration
FEM	Finite Element Method
FT&A	Functional Tolerance & Annotation
IT	Information Technology
KM	Knowledge Management
KML	Knowledge Management Leader
KMO	Knowledge Management Officer
LL	Lessons Learned
NASA	National Aeronautics and Space Administration
PSS	Product Structure Software
ROI	Return Of Investment

List of Figures

2.1 Pyramid of Knowledge. 8

2.2 Relationship between Explicit and Tacit Knowledge. 10

2.3 Knowledge Management Cycle 13

2.4 Examples of metrics to use in a ROI managing of an Aerospace organization 19

2.5 Available options in inSite Menu 25

3.1 CEIIA's main Headquarters. 31

3.2 Cargo Aircraft KC-390. 35

3.3 Frame from Lower Fuselage 35

3.4 ear Protection Panel from Secondary Structure 36

3.5 AU's Working Organization Chart 37

3.6 Aeronautical workers distribution through the different areas. 37

3.7 Organization of a Project's Folder System 38

3.8 iCEIIA's main Menu 43

4.1 KM strategy, including its different parts and phases. 49

4.2 KM department inserted in the AU's structure. 52

4.3 Structure of the KM Department 53

4.4 KM Strategy Cost in Working Hours 64

4.5 Gantt chart of KM Strategy's Phases 64

4.6 Gantt chart of the Strategy's Evaluations. 66

List of Tables

3.1 List of essential knowledge to perform Design and Stress functions. **X** - High Knowledge level **0** - Basic Knowledge level 34

3.2 Root Problems and the respective knowledge phases that are affected. 40

3.3 The number of times that knowledge phases are referenced in table 3.2. 40

3.4 Root Causes and consequent difficulties that affect AU's KM Process. 41

4.1 Points that the KM Strategy intends to improve. 48

4.2 List of possible reasons to disseminate knowledge and the respective solutions. 56

4.3 Subprocess A3. 58

4.4 Subprocess Interview. 58

4.5 Subprocess LL. 59

4.6 Subprocess Documentation. 59

4.7 Subprocess Debriefing/Presentation. 60

4.8 Subprocess Mentoring. 60

4.9 Subprocess Workshop. 60

Chapter 1

Introduction

As stated in the title, this thesis intents to study the application of new methodologies in the development of Aeronautical Structures (AS), that initially were not conceived to act in this environment. The number of existing theories and its possible application to the development of AS has enough potential to do countless projects and Master Thesis. First, it is necessary to analyze and understand the role of the company CEIIA in the Aeronautical Industry, in order to choose a particular theme that shares the company's needs, the student's interest and also that possesses enough material to elaborate a Master Thesis.

After an elaborated search about this vast subject, the student along with the company's guidance, selected the following three proposals as the three more important projects to investigate, develop and apply in CEIIA's AU, taking in account the company's needs and goals in the development of AS:

1. Real Tests VS Virtual Tests;
2. Implementation of a Knowledge Management Strategy;
3. Implementation of an AGILE/SCRUM Methodology.

It is expected that the development of each of these projects would have a significant impact in AU, since their development intents to change procedures, improve the efficiency and reduce the units's costs.

In order to choose one of these themes, the student also did a restricted search to gather enough material and information to analyze the possible income advantages and procedures of each one. A brief description about the themes will be presented in the next section, along with factors that helped the decision making progress. Afterwards, a choice will be presented, followed by a succinct description of the thesis' structure.

1.1 The Three Proposals

1.1.1 Real Tests VS Virtual Tests

This first theme compares the differences, advantages and disadvantages of these two different types of tests, as well as their needs, return of investment (ROI), costs, utility, the actual roles in AU's core, among other

characteristics.

The tests are essential procedures in the aeronautical and aerospace sectors thus, it is only through them that is possible to verify if certain components or systems work properly, if they need any kind of adjustment or even if they can work properly when interacting with other components or systems.

The tests can be classified in two distinct groups: the virtual and the real ones. The virtual tests are usually cheaper and also faster than the real ones, because the situation is simulated through special computer tools, avoiding the construction of scale models and platforms. This represents an advantage to a company, turning its projects faster and also cheaper. Through the years, the use of virtual tests has been growing due to fast progress of technology and consequently, its accuracy with the real tests has improving, which makes it an important and significant tool in nowadays aeronautical industry.

Even so, the real tests are crucial in certain situations, making its execution indispensable and its replace by a virtual test, impossible. For example: the study of human feeling and sensation in a certain environment or scenario, the study of ergonomics (to assure the user's comfort), or even a final physic test to check if all the systems are working properly when working at the same time. There are also other kind of real tests that are mandatory, such as the ones demanded by the safety entities (e.g., the European Aviation Safety Agency (EASA) and the Federal Aviation Administration (FAA)). The real tests are also a way of studying, evaluate and/or certificate a new type of technology or material which the properties or behavior are unknown or even uncertain.

However, the possible replacement of real tests by virtual ones, would require a detailed analysis in order to elaborate logical procedures that needed to be approved and certificated by the safety Aeronautical entities. This conversion would require the participation of the Aeronautical safety entities and would also be very specific for just one type of test, due to the complex nature of this process.[1–8]

1.1.2 Implementation of a Knowledge Management Strategy

The second theme is based on the meaning, value and methodologies of KM along with an implementation strategy in AU. The ultimate goal of this philosophy and its methodologies is to manage the company's knowledge through policies and strategies that enable its free circulation and effective dissemination. Capturing and transmitting knowledge through company's employees allows them to store knowledge (avoiding its loss), learn from past situations and also opens the possibility of creating new knowledge. KM gathers the sufficient conditions to transform a company in a more adaptive, innovative, intelligent and sustainable one.[9]

KM is not a new theme around the companies, where its impact has been growing through these last two decades[10–14]. KM is a wide discipline and it can be applied to industries, governments, military operations, organizations, institutions, among others.[15] According to a survey made by the International Association for Contact & Commercial Management in 2009, which drew an input of 116 companies from different industries across the world, only 13% of the respondents claim to have a complete formal and documented KM system for contracting, while 28% claim to having no kind of KM system at all. The results also showed that the aerospace industry was the one which dominated this kind of system, thus 43% of interviewed companys of this industry claimed to have a "complete" formal and documented KM system.[11]

The Aeronautical industry is one of the toughest to prevail, since it is ruled by restrictive and exigent rules, intense competition, safety concerns and considerable amounts of money.[13, 16] The fact that this industry is technology and knowledge depended, makes the use of KM methodologies a big advantage, since it improves the company's performance, quality and interaction between different engineering areas.[10, 12, 15–17] KM also helps answering to one of the aerospace and aeronautical industries main problem: the loss of knowledge, either by job rotation, job reduction or even retirement.[11, 13, 16, 18–20] Big organizations like Boeing[20–24], National Aeronautics and Space Administration (NASA)[9, 25–27], German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt - DLR)[26, 28–30], ESA[25, 26, 30–33], among others, are currently using a KM System, which enables a better creation of knowledge, along with its dissemination and application.

A well succeeded KM implementation would certainly be a big acquisition for AU (and consequently CEIIA), since it would ease the identification, capture, transference, creation and application of the necessary knowledge to develop aeronautical structures, optimizing its procedures and consequently reducing its costs, improving the final products and helping to better achieve the stipulated goals, turning into a great tool and competitive advantage in the aeronautical business.[10, 12, 15–17, 27, 29, 31] However, the success of a KM Strategy Implementation relies essentially on the human factor, thus the complex and hard to transmit knowledge lies on peoples' mind. This knowledge, usually associated to experience, can only be transmitted if its possessor is willing to share it, if the dissemination is performed in the right conditions and if the receiver has the need of possessing that certain knowledge . If the employees are not motivated or if they do not fully believe in the KM System, than this is doomed to fail. Policies that promote KM should be created around the company's values and goals, while employees must be motivated to learn and work in a KM Strategy, in which they should be guided (not commanded) by their superiors.

The Information Technology (IT) also plays an import role in the KM strategy, since it allows the capture, easy access, organization and transference of some less complex knowledge. In order to fulfill its role, technology relies on tools such as organized data base (where it is easy to find the desired information in an easy and simple way), intranet or any other kind of tool that permits the user to store the acquired knowledge in order to share it with the rest of the company.

Even considering the human and technology factors, it is necessary to have the perception that KM is a complex subject and that a strategy implementation requires a exact and cared analysis of the company's situation, dimension and objectives. Even a cared analysis does not prevent an inadequacy of the strategy, which is the reason why the implementation is usually followed by a trial-error method, where the applied strategy is consequently reformulated until it is perfectly suitable to the company's needs and goals. As the company goals, the strategy might also not be constant through time, requiring an update or reformulation based on the company's vision and the industry's current perspective.

The implementation strategy has also to take into account its maintenance process along with its associated costs, and the strategy's ROI. ROI is the critical factor that decides if a strategy is worthy to apply or not, thus if the strategy maintenance and investment surpasses its benefits, it means that this strategy in not lucrative, which means it has to be reformulated or otherwise it is not worth to implement it.

1.1.3 Implementation of an AGILE/SCRUM Methodology

This last theme is based on an Implementation of an AGILE methodology - SCRUM - in an Aeronautical environment. As the name suggests, the AGILE methodologies are focused on turning the company more agile, i.e. more flexible to unpredictable happenings or last minute changes (even the significant ones) in any phase of the product development.

The SCRUM methodology has its origins in an IT environment and software development and it is focused on projects with small teams (less than 20 people). Each team has one person that leads and manages the SCRUM methodology - SCRUM Master. He, along with the team, establishes goals for short periods of time (from two weeks to one month), which are called sprints. The SCRUM Master leads a short meeting (of 15 minutes maximum) in the beginning of each day of the sprint, where he asks the following questions to each member:

- What did you do yesterday?
- What are you going to do today?
- Do you have any problem or block in what you are doing?

At the end of the sprint, the SCRUM Master evaluates the team's performance and changes or adapts the goals according to the following sprint. This methodology requires that each team member must have high individual skills along with good capacity of team working. It is also expected a full commitment and interest from each member, otherwise the implementation will be doomed to fail.

The implementation of this methodology in an aeronautical environment is a big challenge, thus it is a different environment with specific characteristics. Not all phases of an aeronautical project are suitable for this kind of implementation, which means that it is necessary to do a previous study of all phases and the SCRUM methodology with the expectation of finding the suitable phases. The implementation of SCRUM methodology has already been applied to other industries, besides software industry, such as the construction industry. [34–38]

1.2 The Decision

Each one of these proposals can lead to a numerous set of advantages that will help AU to increase its efficiency, product quality and also grow as an organization. However, these proposals affect the organization in different ways, since they also are distinct and applied to different Aeronautical departments. For instance, the application of the first proposal would improve the manufacturing, certification and would also allow the possibility to gather more important data about materials and products, affecting also the product conception phase.

On the other hand, the AGILE/SCRUM method is only suitable in certain development phases, giving a flexible strategy since it is suitable to work in unpredictable or unexperienced environments. Although it might be a powerful method, its application is limited and mainly associated to new environments/challenges, that appeal the workers' capacity of innovate.

Nevertheless, a correct and successful implementation of a KM strategy would have a significant impact in CEEIA's AU, improving the communication between departments and employees, the processes of knowledge

(such as creation, innovation or dissemination), the access to information and performance in the development of AS (better efficiency - more quality, less spent time and less costs). Besides these advantages, the implementation of this strategy in AU could be an introduction to a complete implementation through all the organization, which would improve the other units and the interaction between them.

From all three proposals, it was decided that the second one - Implementation of a Knowledge Management Strategy - would be the most fruitful to AU, helping the organization to achieve its goals in more efficient way. This proposal is also consistent with AU's priorities, which lacks of a KM strategy besides the fact of already having some tools that can be inserted in the KM strategy. In the future this strategy might also be extended to the entire CEIIA.

The following section will present this master thesis' structure, describing its chapters and associated contents.

1.3 Structure of the Thesis

Chapter 2 introduces the main theme to the reader, explaining its characteristics, advantages, weaknesses and methods. This chapter also contains real examples, situations or procedures performed by aerospace and aeronautical organizations. Its goal is to inform the reader about the role of KM in today's aerospace and aeronautical industries and to give the necessary information to understand the background of the implemented strategy on chapter 4.

Chapter 3 presents the company's work, along with its dimension, values and current strategy. This chapter intents to inform the reader about the actual situation of CEIIA's AU and also the reasons and necessity of a KM implementation strategy.

Afterwards, chapter 4 contains the implementation strategy, being the main core of this thesis.

The final chapter 5 presents the established conclusions of this thesis, as well as some measures to be taken in the future, after the strategy's implementation.

Chapter 2

Knowledge Management - State of Art

This chapter intents to inform the reader about the concept of KM, as well as its advantages, difficulties, strategies and tools when applied to the aerospace and aeronautical industries. Another of this chapter's goal is also to support the content and choices made in chapter 4, which contains the structure of the KM strategy to be implemented in AU, along with its implications, consequences, expected results, use of existing tools and creation of new ones.

The structure of this chapter intents to follow a logic sequence, starting by defining what is knowledge (thus in order to manage something with efficiency, it is crucial to first understand it) and why it is so important to protect and maintain it. Afterwards, the KM concept will be presented along with its advantages and goals, followed by the presentation of a KM cycle, where is explained all the KM phases. Next, it is presented the usual characteristics, strategies and challenges of a KM implementation in the aeronautical and aerospace industries. This chapter ends with real cases of aerospace and aeronautical companies that implemented a KM methodology, describing the used strategy and tools. Summarizing, this chapter aims to answer the following questions:

1. **What is Knowledge?**
2. **What is Knowledge Management, and what are its advantages?**
3. **What is the KM Cycle?**
4. **How can Knowledge Management be implemented in an organization?**
5. **How is KM being applied in today's Aerospace and Aeronautical Organizations?**

Each of this questions corresponds to a section of this chapter. As previously mentioned, this chapter will start by defining what is knowledge, thus, how will someone manage something that cannot fully comprehend, ignoring its properties, advantages, weak spots, among other factors? It will not, because it is simply impossible.[10]

2.1 What is Knowledge?

According to Nonaka et al, cited on [10], "Knowledge is one of those concepts that is extremely meaningful, positive, promising and hard to pin down". A good way of explain what is knowledge, is to make a distinction

between data, information, knowledge and wisdom, as presented in Figure 2.1[10]:

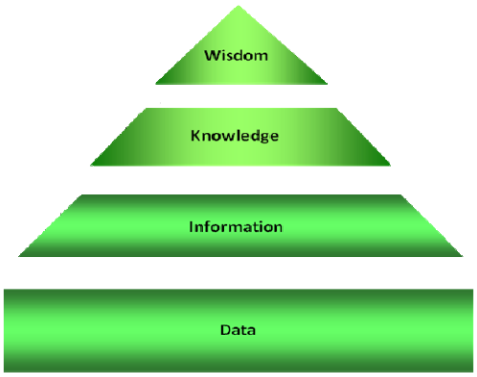

Figure 2.1: Pyramid of Knowledge.

In the bottom of the pyramid there is Data. Data is material gathered in its pure state. It can be images, videos, sounds, digital transmissions, among others. These data did not suffer any kind of treatment, i.e. interpretation, filtration, structuration or summarization. Data is usually context-free and has no meaning.

The next layer is Information. Information is made through giving meaning to Data by treating it. It collects, organizes, processes and communicates the essential core of Data. For example: a book is Data, but its summary on the back cover is Information. Information's value is subjective to its receiver, who decides if what he gets is information or noise.

Knowledge comes from the understanding and interpretation of Information and it is usually associated to its possible application. Unlike Information, Knowledge only exists within people and is constant and personal, thus in spite of Information being available to a group of people, its comprehension only depends on the personal capacity of interpretation and assimilation along with the time and context of the situation.[10, 20, 31, 39, 40] According to Cattell et al [10] "It (Knowledge) is frequently intangible and abstract, and differs in the way it operates and how it can be tracked."

Finally, wisdom lies on top. Wisdom is the application of Knowledge combined with experience and intuition, i.e. to know when and where to apply Knowledge in order to take the best possible advantage.[10, 20, 31]

Not all knowledge is equal, thus it can be captured, stored and transmitted according its characteristics. Knowledge can be classified in two distinct types: explicit knowledge and tacit knowledge. The following three sections will distinguish these two kinds of knowledge and also the possible correlation between both.

2.1.1 Explicit Knowledge

Explicit Knowledge is the kind of knowledge that can be communicated and shared through technology systems, scientific formulas or even product specification (e.g., documented concepts, procedures, laws and routines, pictures, videos, etc.), without loss of data or information. It is formal, systematic and easily captured.[9, 10, 12, 18, 30, 31, 39–42] For example: when someone reads the user manual to mount a piece of furniture from IKEA©, that person is acquiring explicit knowledge of how to mount that specific piece of furniture.

2.1.2 Tacit Knowledge

Tacit Knowledge is totally personal and hard to transfer, disseminate or preserve. Usually it is hard to express and is always associated to technical abilities or things so embedded that people take them for granted. It is often associated to the term *know-how*, i.e. the practical skill or knowledge associated with the experience - the absolute control of a specif task.(e.g. experience on human relationships, master of one specific skill, etc.).[9, 10, 12, 18, 30, 31, 39–42] For example, a good guitar player has in his possession tacit knowledge, because he practiced several hours in order to get his actual speed and technique. This kind of knowledge is consequence of experience, which makes it hard to disseminate, because it might take many time and dedication (from the receptor) to achieve the same knowledge level. Tacit knowledge is far more complex than explicit knowledge, which implies the use of different methods for capturing and disseminate it. The transference of this kind of knowledge is usually made through personal interaction (such as teaching, mentoring, among others) and its assimilation usually longer.

2.1.3 Relationship Between Tacit Knowledge and Explicit Knowledge

If an organization desires to efficiently manage its knowledge assets, then the interaction and transformation between tacit knowledge and explicit knowledge is a crucial factor.[10, 12, 29, 39, 41] This interaction allows the company to create, capture and transfer knowledge through its employees. It is possible to see in figure 2.2 (from [41]), the method proposed by Nonaka that establishes the relations between tacit knowledge and explicit knowledge.[41] The possible knowledge transference/transformations represented in figure 2.2 are:

- **Socialization** - it is usually made personally through training, mentoring or teaching. It is not a fast process, thus the person who is receiving the tacit knowledge might take some time to assimilate it.[10, 12, 29, 39, 41] Beside technical skills, the person who is transferring knowledge, also needs to have human socialization skills (such as approaching strategies or teaching methods based on human psychology) in order to disseminate it effectively and efficiently. An example of this case is the training of new employees without any professional experience, where the experienced workers have to transfer their technical knowledge to them.
- **Externalization** - tacit to explicit knowledge is the hardest transformation and transference to do of all these four, since it tries to create, store and register (making it simple and easy to assimilate) knowledge originated by an action based on experience and mastery.[10, 12, 29, 39, 41] This type of transformation performs the documentation and registration of simple actions or skills that are crucial for some function, but that people do not recognize it as knowledge because they are accustomed to do it, taking it from granted and as natural part of their habits. For example a cook has a recipe for a very tasteful dish and shares it with his fellow cooks. Although they all have the same recipe, no one can make the dish as the original cook, because he also tastes the dish while cooking it, in order to realize if it needs more condiments or ingredients. This last step, does not come in the recipe, not because the cook did not want to share it, but because it is a natural procedure to him every time he cooks something.
- **Combination** - explicit knowledge to explicit knowledge, which is done by combining isolated components of this kind, allowing the creation of a new one.[10, 12, 29, 39, 41] For example, if two documents with complement information are combined, it might be possible to create a new document (or other form of

explicit knowledge) containing the combination of both or even new knowledge.

- **Internalization** - and finally explicit knowledge to tacit knowledge, which is also very hard, because it tries to apply stored knowledge, with the intuit of becoming a skill or a practical action.[10, 12, 29, 39, 41] A good example of this transformation is the embedding of an organization's rules and values. If an organization has specific and distinct rules or procedures, employees will be costumed to those obligations through their repetition until it becomes a natural and instinctive procedure.

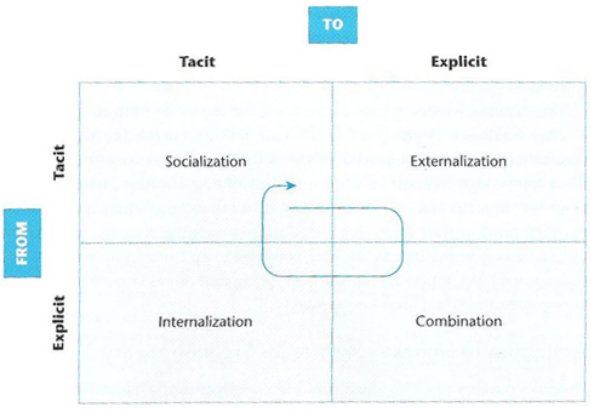

Figure 2.2: Relationship between Explicit and Tacit Knowledge.

As it is possible to see in the figure 2.2, the knowledge flow follows the previous stated order, which makes knowledge drive to a spiral of creations, captures, disseminations and conversions. This figure is known as Nonaka's Spiral of Knowledge[10, 12, 29, 39, 41].

The next subsection will explain why is knowledge so important in the aerospace and aeronautical industries.

2.1.4 The Importance of Knowledge

An organization's knowledge is measured through the knowledge of its employees. By creating, capturing and transferring their knowledge they increase the organization's knowledge, which also implies an increasing of the competitive advantages. This implication happens due to the knowledge's capacity of solving problems, i.e., by acquiring the right knowledge and mastering it, the organization might be able to solve a problem that was never solved before, or solve an already existing problem in a more efficient way, acquiring an unique knowledge.[10, 21, 43]. However, this competitive advantage also has a great tendency to leak, especially nowadays where the globalization enables an easier job rotation and the communication technology allows information to travel to the other end of the World in no time. These factors make knowledge duplication easier, lowering the advantage of having a unique knowledge.[10, 21, 43] However, there are internal and external factors in a company that aim to prevent knowledge leak and duplication. The internal factors usually tend to persuade the worker to stay in the company (giving him better conditions and incentives), to limit the worker's knowledge (working in only one section of the project, handle complex knowledge, prevent access to main knowledge) or even to make sure that the employee is forbidden, by legal mechanisms, to leak information (signing non disclosure agreements). The

external factors are normally ruled by legal mechanisms which aim to avoid knowledge duplication (legal contracts with costumers/suppliers, technical standards, patents, etc.).[10]

Knowledge is usually well protected in the aerospace and aeronautical industries, which are ruled by strict government laws and standards that not only assure national and international security, but also give the industries a secretive nature. On top of it, industries have a very competitive environment, thus knowledge advantage can lead to wining bigger projects and very profitable contracts. However, this secrecy might be harmful to the knowledge assets managing, when exaggerated. If teams work in a complete restricted environment without any access or communication with the outside or even the company's inside, then the creation and dissemination of knowledge will be much harder when compared to usual conditions. As it will be explained in subsection 2.4.2, this isolation might lead to problems in the area of knowledge. [13, 18, 28, 44]

It is also necessary to have in consideration that the loss of knowledge is one of the biggest problems in nowadays aerospace and aeronautical organizations. In these industries, the acquisition of new employees has not been continuous through time, which might lead to a big gap between generations. Since the gap is widely big, there will be a time when the elder generation will retire or change to another organization (taking precious knowledge with them) and the younger will assume the leader roles without having the proper experience. Without the proper knowledge the new generation might commit the same mistakes, wasting unnecessary time and resources if the organization had captured and disseminated it from the start.[13, 16–20, 27, 31, 33, 39, 42, 44]

Organizations from the aerospace and aeronautical industries have to be prepared to capture, conserve and disseminate the knowledge of its employees, in order to secure its advantageous position. The KM methodology, as the name indicates, allows to manage the knowledge assets in a efficient and effective way, bringing specif advantages to its users. But what is KM and what are its associated benefits? The answer lies in the next section.

2.2 What is Knowledge Management, and what are its advantages?

KM is a multidisciplinary subject which gathers fields like organizational science, cognitive science, information technology, library science, communication, human resources management and artificial intelligence. This should be the main reason why KM's vision may vary from some authors to others and why it is so hard to get a proper definition.[9, 13, 39, 41, 43, 45] According to Redmiles et al[13], there are more than 100 different and published definitions of KM. Although, between the different definitions found in the elaboration of this thesis, the one that suits it the most (relatively to its scope) is the one by Cattell et al[10]:"Knowledge management is the systematic process that supports the continuous development of individual, group and organizational learning, and involves the creation, acquisition gathering, transforming, transfer and application of knowledge to achieve organizational objectives".

By storing knowledge and performing its correct dissemination, the organization assures that it does not leave the company, assuring its continuity and the company's high level of competence, thus the more employees possess a certain knowledge, the harder it gets to loose it. This dissemination allows the reusing of organization's stored knowledge, allowing the organization to not waste time and resources searching it and also avoiding to commit past mistakes[10, 15–17, 20, 21, 27, 31, 33, 39, 40, 44], which in industries like the aeronautical and

aerospace, can be associated to human safety (crew and/or passengers)[9]. Besides these advantages, KM also promotes and develops the organization's communication and inside cooperation, enabling the development of an efficient working process and consequently the creation of conditions to improve the quality of products and services.[15, 21, 31, 33, 39] It is not just a way to preserve and share information and know-how, but also to help guarantee its own cost-effective and qualitative evolution.[33]

As a discipline and way of working, KM might enable the creation of the following advantageous situations:

- Minimization of project errors, thus a good KM plan can supply an effective technical knowledge transference between the development and operational teams;[9]
- Quicker answers and better reaction times, since a good KM plan can efficiently allow experts, who were not involved in early phases of the project, to get the correct information and interpret it for a fast and wise decision making;[9, 33]
- Ease the arrival of newcomers to a project, thus a good KM plan possesses the ability to efficiently train each new generation entering in a project, which is critical to the success of long-duration projects and missions;[9, 33]
- It can be the answer to the loss of tacit knowledge by the retirement of elder generations, since a good KM plan can address both the needs of newcomers (with project overviews, archives, and mentoring), as well as the need to capture the tacit knowledge of a retiring workforce;[9]
- It allows the engineer or project manager, to make a better decision and a better risk analysis, due to good access to all the project's information and knowledge.[18, 27, 31]

As a discipline, KM changes the behavior of an organization and can be used as an advantage which would increase the company's value and would also provide potential to evolve and expand. KM is the key driver for new knowledge, new ideas and new products - innovation.[15, 21, 31, 39] But it is only possible to take advantage of this benefits, if KM is well implemented, conducted and interiorized in the organization (the implementation of KM is discussed in section 2.4).[20, 21] Before a KM implementation it is first necessary to now how will it work in an organization and what phases should knowledge go through. The following section will explain the ideal knowledge cycle and its respective phases.

2.3 What is the KM Cycle?

Knowledge can go trough many phases/states since its creation until its application, and each of these different stages has different procedures, according to its specific needs. For example, the methods and procedures that enable knowledge creation are not the same that provide its transference or application. The combination of these phases forms a cycle, that is essential to understand in order to implement an effective and efficient KM strategy that suits the organization's goals and values.

This cycle should be freely followed by the employees, where the existence of policies and programs works as an incentive and guidance to follow the cycle's phases. Policies aim to reflect how knowledge production and integration should occur, incorporating the company's principles and beliefs (culture organization), while on the

other hand, programs are a group of actions which attempt to fulfill policies. Sometimes programs' outcomes are unpredictable and only measurable after its application, which leads to a trial-error action in order to improve, eliminate or create new programs. Since policies and programs depend on each other, it is crucial to KM success that both of them do not conflict.[43] KM should focus its programs and policies in the following areas:

- Embryology - it is based on worker's desire and motivation to learn, giving liberty to pursue their own learning ideas, goals and interests, and also organize knowledge communities through own initiative.
- Politics - it is based on politics of knowledge creation, dissemination and use.
- Intellectual Diversity - as the name suggests, it is based on the fact that different intellects have unique points of view, which ables to look to the same problem from different perspectives and propose different solutions.
- Connectedness - it is based on connectivity inside the organization and communication of its culture values.[12, 43]

As the definition of KM, the KM cycle also changes from author to author, since each one has its own version. Throughout the analysis of several versions, a KM cycle was elaborated (represented in figure 2.3), that contains the process that knowledge goes by. The developed strategy will rely on this cycle.

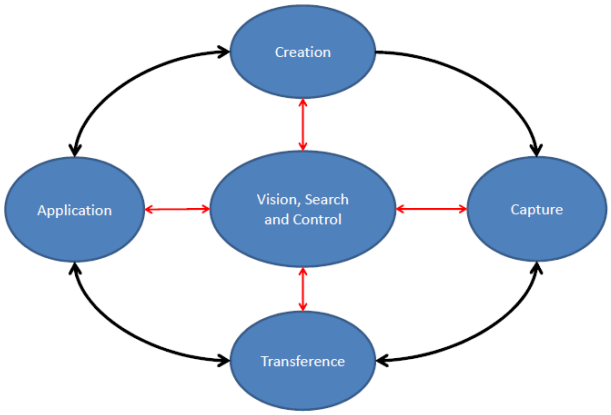

Figure 2.3: Knowledge Management Cycle

As figure 2.3 shows, this cycle is composed by five distinct phases of knowledge. In the following subsections, the description and explanation of each phase will be made.

2.3.1 Vision, Search and Control

This state is the starting point of any KM activity. It is where the organization tries to understand its actual situation by identifying the key knowledge areas, the possessed knowledge, its purpose and which knowledge can be shared and acquired with outside partners. It is also in this phase that the organization defines the situation where it wants to be and the necessary knowledge to reach it, according with the organization's values and goals. It starts by identifying the needs of the organization, stakeholders, customers, employees and industry. Afterwards, it is conducted a search for the KM tools and initiatives that will allow the company to control the applied processes in order to achieve its goals, followed by a plan elaboration, that takes in consideration the weights of the human and technological components. The principal key in this state is to elaborate a plan where the workers feel comfortable

with their tasks and are able to recognize and enjoy the respective outcomes.[10, 15, 19] It is also in this state, that IT tools should be designed according to the organization's needs, objectives and KM strategy.[16]

2.3.2 Creation

This state happens when a person or a team creates useful knowledge. The creation of knowledge occurs through the interpretation of information or other knowledge's application. For example: when someone reads a document for the first time and realizes that it contains valuable information. Here are some examples of approaches to generate knowledge: use the Research and Development department as a source of knowledge generation, ear the opinions and hunches of the employees, suppliers and costumers (thus, all of them have a different perspective of the product and can detect weaknesses in different development phases), create programs and policies that enable the knowledge generation without losing information (the employees must feel comfortable with these and become embodied with the same), create a diversified team (it may cause some disputes because different people have different perspectives, but will also contribute with a wider perspective for the team and a bigger range of options), etc.[10, 18, 39, 43] Also in this stage, there should be a system that checks the content of knowledge and validates it. Without this process, the organization might suffer the risk of capturing worthless knowledge, wasting time and resources. After the creation of knowledge, comes its application or capture to further transference (as seen in figure 2.3).

2.3.3 Capture

Knowledge must be captured and stored in order to avoid its loss. One of the benefits of storing knowledge is the possibility of accessing it whenever needed, thus sometimes knowledge is discovered and it is only needed a long time after being generated. That normally occurs because knowledge is too advanced for being used, is not suitable, its application is too expensive, or because the company/employees do not know what advantages might come with it. As explained in subsections 2.1.1 and 2.1.2, while the explicit knowledge is easily captured and stored (electronically, in text or in prototypes), the tacit knowledge requires a bigger effort to describe and its usually captured by the workers instead of being registered.[9, 10, 18, 39, 41] In this phase, methods like communities of practice, mentoring, lessons learned or documentation standards are predominant, which makes the verbal communication a crucial factor to this state (and also the Transference).

2.3.4 Transference

If the knowledge only remains stored without being transmitted, it will never have the desired impact. The company must transmit the knowledge through its employees, thus knowledge has more value shared by many than by few. These transference across the organization makes it easier to give the proper training to young employees, enabling them to learn the tacit knowledge of the elder generations.[9, 10, 18, 19, 39, 40, 43].

Although knowledge must be shared, it is also necessary to balance the number of people involved with the knowledge's nature, because a large and unwieldy network might inhibit the transferring process. One important

role of KM is to support the transference of knowledge between the following levels:

- To or from the individual;
- To or from groups;
- To or from the organization[9, 10, 18, 19, 39, 40, 43].

Cattell et al[10] states that the mechanisms providing knowledge transference are: "written reports, oral presentations, site visits, tours, job rotation, education and training programs, coaching and mentoring, conferences, business plans, cross-functional teams rather than functional teams, databases, intranets, job descriptions, work manuals, meetings, communities of practice and matrix working." Some of the previous stated mechanisms are more suited to transfer explicit knowledge, while others are more directed to disseminate tacit knowledge (the ones where the human component is more important, and verbal communication becomes essential, in order to create contact and nearness which are essential for the passing on of experience).[33, 42] Knowledge transference is usually followed by its capture (documented or by its receptors) or its application (as seen in figure 2.3).

2.3.5 Application

Application is the final state of this process and afterwards the process flows to Vision and Search to evaluate the feedback of its application (including advantages and detection of problems), restarting the cycle. All knowledge must be able to be applied, otherwise it will have no value. As stated in subsection 2.3.3, knowledge is stored with the perspective of being used in the future and besides not being in actual use, knowledge will at least be available when required. But if knowledge, by some particular reason, goes beyond company's goals, then a good solution is to license it, sold it or even throw it away. In certain situations, knowledge application may create new knowledge or originate its dissemination (see figure 2.3).[10, 18, 39, 40, 43]

The logic step after presenting the KM cycle is to investigate its implementation. What is necessary to do in order to have a successful implementation? What are the main implementation strategies? What are the main drawbacks of a KM implementation in the aerospace and aeronautical industries? The answers to these questions will be given in the next section.

2.4 How can Knowledge Management be implemented in an organization?

The main goal of a KM implementation is to spread KM's philosophy through all the organization.[9, 10] KM must become implicit, as a natural characteristic from the organization, where employees fully understand it and use it naturally in order to solve the company's problems.[10] In order to succeed, an implementation most address issues in three distinct areas:

- People - who will help people (employees, public partners, etc.) sharing their knowledge and maintain the tools and processes.

- Processes - oriented on the way in which people do their day-to-day work in the organization and how will they share their knowledge (tacit orientated).
- Technologies - ensures the availability of an IT infrastructure and necessary tools to deliver knowledge (mostly explicit) and efficient services efficiently to the end users.[9]

Each of these areas has to take into account the company's values, needs, goals, position in the industry and future necessities. However, the People area has a dominant factor in comparison to the other two, since their success is a matter of cultural acceptance.[9] Besides the incentive to use KM tools, learning conditions must also be created as well as access to knowledge, so the employees can trust the system and start using it naturally. Support and initiative from upper managers or team leaders, along with employees' cooperation, open spirit to criticism and sharing knowledge, are crucial components of a successful KM implementation. The human factor has a dominant impact, thus if a company has the best KM tools in the industry, but the workers do not feel motivated or do not believe in KM, then the system is condemned to fail.[9, 10, 12, 13, 21, 31, 39, 41]

Taking in consideration all areas and their respective weight, it is necessary to develop strategies, methods, technologies and techniques that promote knowledge, along with policies and programs that promote collaboration, continuous learning and sharing spirit between workers.[10, 12, 13, 21, 31, 39, 41] When the right tasks, routines, tools or processes have been identified, there is a need to structure them in order to be profitable to the organization, i.e. establish metrics, create a schedule and budget for the task, assigning resources, develop a prototype (or any kind of way to test it) and finally establish a service for successful pilots. The implementation also needs to take into account the spent resources and the expected outcomes. After the application of these principles, the KM implementation team should look at the requirements for specific groups at the organization, study smaller mechanisms with different necessities and adapt the strategy to each one.[9].

Based on all the needs and steps of an implementation strategy, it is possible to define a set of chronological factors to have in to account, when elaborating an implementation plan. These factors are the ones that are going to support the implementation strategy on chapter 4;

- The organization's values;
- The future situation that the organization wants to achieve along with other goals;
- The strategy to implement in order to achieve its goals , motivating employees to use and believing in the KM system, and guiding them through KM process;
- The basic business drivers, i.e. contextualize the strategy with the kind of activity of that organization along with its actual situation and impact;
- How much time will it take until the system is fully implemented;
- How much resources will be spent until that time and afterwards (with the system's maintenance);
- What is the expected outcome.

After establishing the implementation, this goes up to three stages: learning, behave, incorporate. In the first stage the employees learn the new concepts and knowledge, understanding its meaning and its application. In the second stage the new knowledge is applied, which creates new behaviors in the employees. The last stage is about dominating this vision and incorporating a KM mentality, improving its behaviors, efficiency and quality.[12]

After understanding the fundamental drivers and principles behind a KM implementation, it is necessary to see what is necessary to develop a successful strategy. This subject will be approached in the next section.

2.4.1 Contents of a good Implementation Strategy

In order to understand what guides an implementation strategy, it is necessary to first understand its definition. Strategy can be defined as "an adaptation or complex of adaptations (as of behavior, metabolism, or structure) that serves or appears to serve an important function in achieving evolutionary success" [46], which means that in this case, a strategy might be a plan elaboration of a KM structure (composed by processes, tools and policies), in order to achieve a better performance and be more competitive in nowadays industry. As stated in the previous subsection, strategies have to contain the needs and intentions of the organizations, along with the ways of achieving it and its expected outcomes. In order to be effective and efficient at the same time, there are three main characteristics that an ideal strategy needs to fulfill:

- be flexible
- be highly participatory (hit all the organization and its processes)
- be able of organizational learning[29]

As a good start, these strategies and methods can be tested in a single section or department, taking in account that, in the future, these processes should evolve and be transfered to all the organization. All strategies of implementation can be divided in two major groups: the internal strategies, which try to create, capture, reuse and apply knowledge from inside the company; and the external strategies, which aim to build, measure and improve KM's structure. In the internal strategies the more significant are: identify business challenges, obtain executive support, be patient, listen to users opinions, celebrate small wins and manage employee behavior. On the other hand, the main external strategies are: attend to KM training and conferences, benchmark, hire a knowledge management expert and establish a community/network (inside or outside the organization). There are also strategies that can be in the middle of these two areas, such as the pull mechanism strategies, where employees are encouraged to seek out knowledge for themselves inside the company (internal strategies) or outside the company (external strategies) in order to strengthen the organization knowledge its processes.[18]

Along to each strategy, comes associated a series of tools, services and processes, structured in a logical plan. As seen in section 2.3, programs and policies are able of changing employees' perspective, which makes them essential in KM implementation.[43] There are also methods which promote, incentive and regulate the company's KM structure, such as: presentations to staff meetings, executive briefs, remunerative and/or moral incentives, informal divulgation, reward and performance appraisal, adoption of Computer Support Cooperative Work (CSCW) tools (computer tools that promote communication and transference of knowledge and information through the organization), training, job shadowing and mentoring, career coaching and save knowledge in documents, electronic archives and video archives, among others.[13, 20, 33, 39, 41]

KM technological activities are usually related to the explicit knowledge and they play a important role in a KM strategy. These activities should ensure that there is a high-level user interface via an enterprise portal or web site that organizes information via role, interests and technical disciplines.[9]. However, it is also necessary

to create conditions, space and motivation processes to learn how to work with this kind of tools. It is essential to have a good coordination between the IT, Communication and the Technical Area. KM is usually confused with Information Management, which might lead to a failed implementation. Many companies of the aerospace and aeronautical industries tried to implement a KM strategy and failed, due to misunderstanding of KM concepts and other obstacles.[16]

A good and efficient KM system is achieved through the ideal implementation strategies and methods that ensure knowledge creation, dissemination, security and validation.[9] However, a KM system implementation is not an easy and quick task, because it demands complete commitment of the employees as well as an efficient use of the KM system through time[10, 12, 13, 16]. Siemens©, states that KM implementation is as hard as "changing the tires of a car while driving."[10], which can translate its high level of difficulty.

2.4.2 Implementation Obstacles

KM implementation is conditioned by numerous factors that may diminish its success or even lead to a failed implementation. This subsection intents to give a general reality of the problems that are most common nowadays, in the aerospace and aeronautical industries. These problems are enumerated in the following list:

1. Knowledge-based reward culture;
2. Decreasing labor pool of qualified talent;
3. Convincing workers and managers;
4. Engineering Culture;
5. Personal Relations;
6. Forgetting the importance of the human factor;
7. Organizations' Logistics.

The first topic is related to the fact that the employees of these aerospace and aeronautical industries, are usually rewarded according to their specialized knowledge. Since the industry adopts a very secretive behavior, their workers tend to keep the knowledge to themselves or to a small group, which interferes with knowledge dissemination. Employees feel threaten by knowledge sharing, because they believe that by sharing their knowledge, their status as unique/restricted knowledge workers will be lost and they will consequently loose value (becoming less important to the company). KM initiatives often suffer from constant tension between the company's goals to reuse knowledge and the employees' behavior to share/disseminate it through the company.[10, 11, 13, 18, 19, 31, 39, 41]

The second topic is related with the supply of engineers and specialists. The big gap between different generations might induce some drawbacks for KM implementation. The elder generation, which is near retirement and it is probably used to work according certain standards all its life, may find it difficult to change its way of thinking, working and even its priorities as knowledge workers. Another consequence of this gap is the technology adaptation problems, thus it is harder for older generations to understand and use new technologies and tools, that the young are used to.[13, 16, 18–20]

The third topic is related with the fact of convincing the workers and managers, of the advantages and uses of KM. KM is a discipline where the ROI is not quick and also not easy to measure by statistics, which in certain situa-

tions motivates concern in workers and managers, who need to have immediate results to trust the system. If they do not see the values or progressions of this discipline, they will believe that it is useless.[9, 12, 13, 19, 21, 29, 39, 40] The best way to measure ROI is by studying the evolution of the rules in the knowledge containers (strategies, processes, policies, products, services, organizational structure, company's culture and values, workers, information systems) and by measuring the changes related to the company's performance on knowledge processing. ROI such as costs and time saving are very slow and result from an indirect impact of KM. It is necessary to use the correct metrics that encourage individual decisions and also, at the same time, move the company in the direction of its long-term and short-term goals.[9, 12, 39, 40, 43] The board in Figure 2.4, represents some examples of sortable metrics to be used in a ROI measuring of an Aerospace organization.[9]

Areas	*Criteria and metrics*
Human capital	*Efficiency*: the time the staff focuses on the task they are assigned (rather than in managing or finding information) *Turnover*: the time people remain in the same job within the company *Age pyramid*: the mean age of the employees and experts
Organization capital	*Quality*: the number of anomalies (during development, test, and in flight), the number of anomalies properly resolved, the number of hours used for anomaly correction, the percentage of failures resolved, the number of lessons that are published *Knowledge production*: the number of identified expertise centers or specific experts, the number of new patents or copyrights *Knowledge sharing*: the number of patents/licenses used in the company (internal/external), the number of standards used, the number of people who access the corporate web sites, the mean time it takes to get the relevant information for employees and partners ISO 9000: the number of captured processes, the number of anomalies during (re)certification *Training*: the number of hours per employee that is spent on training annually
Customer capital	*Customer satisfaction*: the percentage of successful projects and tasks (may be decomposed to technical performance, schedule, and costs aspects), survey results from customer satisfaction polls Reputation: the number of media articles and publications, the number of sites linking to the corporate site, the citation indices of corporate authors
Financial aspects	Business: the evolution of the financial turnover and of the benefits (absolute and per employees) *Cost control*: the percentage of projects or tasks having met their completion cost targets *External expenses*: the evolution of the contractor and supplier payments

Figure 2.4: Examples of metrics to use in a ROI managing of an Aerospace organization

The fourth topic is related with the fact that engineers use knowledge to solve a particular problem, while other professions (like scientists) are used to apply knowledge to produce new one and sharing it through an informal community. Engineers creativity is usually controlled by administrative decisions, leading to an association between their identity and their employers instead of their work.[13] Besides the fact that some engineers do not feel comfortable by using other engineers' ideas[13, 18, 19], this is also a profession where the tacit knowledge is dominant, which makes it difficult to capture and transmit it.[13]

The fifth topic is related with relationships between the knowledge sender and its receiver. The fact of two persons do not getting along or having relationship problems may affect their knowledge relationship, adding difficulties to their knowledge transference. This problem often appears when the knowledge transference is made in a personal way, using tools or methods that involve a lot of communication and personal interaction, such as training, mentoring and helping.[16, 41]

The sixth topic is related to the fact that KM systems should not only focus on the IT processes and tools. In most of the cases, the desired knowledge is already inside the company but there is no effective way to capture or

transmit it. That is probably the reason why some early models of KM believed that capture, codification, storage and retrieval of knowledge were the heart of a KM system. By this model, the IT would be the main component of KM system, which is a big mistake, thus KM is composed by several disciplines (including IT) and its scope is beyond the IT scope. It is true that technology eases the communication and provides an infrastructure for storing and disseminate knowledge, but IT is the key component of data management, not knowledge. Capture and storing knowledge are processes that promote the efficiency and effectiveness of the company's flow of information and knowledge, but if the company does not disseminate this content in a proper way, the knowledge will be transformed in mere information. The data/information system will be like a warehouse of information which ignores the necessities of the knowledge workers and consequently creates worse conditions to knowledge creation, product development and incentive systems. KM needs the human factor along with technology, thus it is necessary to understand how knowledge is created, shared and disseminated through the organization - organizational learning. Employees must feel motivated and comfortable to share their knowledge, in order to get expected results from technology and consequently increase the innovation process. A method is required to establish a relation between the worker and the organization with learning processes, systems and technology which will benefit both.[10, 13, 16, 18, 31, 33, 39–41, 43, 44]

The final topic is related with company's logistics. Many aerospace and aeronautical organizations are big and spread around the world, which makes it harder to implement a KM culture, due to the long distances that separate workers and also their different mentalities and working methods.[13, 19, 20]

Some of these problems might be of AU's concern, while others have a very thin chance of happening to this organization. The following section intents to show some of the strategies, tools, services and systems used in the current aerospace and aeronautical industries.

2.5 How is KM being applied in today's Aerospace and Aeronautical Organizations?

This section will present some strategies, tools, services and systems that have been used or that are currently being used (or tested) in the aerospace and aeronautical industries. With this sort of examples it is possible to identify which tools and methods are directed for what, and which ones are more important and suitable to the KM implementation on AU. The following examples will be divided in three distinct categories , according to its nature:

1. **Tools/ Procedures** - isolated tools and procedures, common in the aerospace and aeronautical industries;
2. **Strategies** - typical strategies used by some organizations, in order to develop its KM assets;
3. **Case Studies** - more detailed examples and situations of how certain organizations implemented KM or how they manage their KM assets.

2.5.1 Tools/ Procedures

2.5.1.1 The intranet

The intranet is a common CSCW tool between aerospace and aeronautical companies (like Boeing), because it allows to share in a secure way documents, information and programs between all employees, permitting the information/knowledge to flow through the company. It is possible to create a secure intranet, even inside the company, where only certain persons have authority to access certain documents. It is very useful since many nowadays companies are spread around the world and so are their projects with teams communicating from different places. It promotes the reuse and sharing of existing information/knowledge and creation of new knowledge, due to rapid feedback and input from the users.[21]

2.5.1.2 Informal Communication

Some employees seam to prefer informal networks, usually oral communication channels, over the formal ones. It seams that they feel more comfortable sharing their opinions and seeking for each others' knowledge face to face, outside the meeting rooms, in the coffee break, by phone or even at the bar, outside the company's pressure and environment. This informal networks may contribute in knowledge's acquisition and dissemination.[12, 21, 40] This behavior was registered in Boeing's environment.[21]

2.5.1.3 Knowledge Communities

Creating a community is one of the best way of discovering the best KM tools, methodologies, strategies, benefits, implications and consequences, thus workers are able to share, discuss, exchange experiences, learn and look for solutions with other workers from the same industry (or even a different one) from inside the same organization.There are certain cases, where communities are formed by workers of different organizations(where there is a possibility of working with the competition). These communities can either be established by the organizations in a formal way or be informally formed through workers initiative, since engineers have a tendency to form informal communities when involved in the development of certain aerospace and aeronautical products.[13, 14, 18, 39, 41, 43]

These communities are usually held by informal and formal conferences or technical forums. Several institutions from California formed the Southern California Aerospace Industry Knowledge Management Exchange, which enable the participating firms to gain new insights about KM.[18] Organizations like Siemens[10],ESA[26] and the European Space Operation Center (ESOC) [33] also created a community inside its own company, while aerospace organizations like NASA, ESA, DLR, among others also created a community between them.[25, 26]

2.5.2 Strategies

2.5.2.1 Benchmarking

As a strategy, benchmarking has the objective to learn processes and methodologies from other partners or organizations, in order to further applicate in a company with a similar (or desired) environment. This strategy starts by investigating which organizations have the best practices along with their suitability and development in the company that desires them. Afterwards, it is planed a set of visits and interviews before making the implementation study, its application and recommendations. This is usually a long process that takes a considerable time covering all the details around the method and its implementation, but on the other hand, it has the possibility of not being too expensive.[11, 12, 39, 40] This methodology was used in organizations like PrattWhitney Rocketdyne, Northrop Grumman, NASA-Jet Propulsion Laboratories, Aerospace Corporation, Pepperdine University, California State University Northridge and University of California at Irvine.[18]

2.5.2.2 Mentoring

The goal of this strategy is to pass down knowledge from the elder and/or experienced workers to the fresh starters or not costumed workers, in a guided way. The mentor teaches and guides the student's path, showing the logic behind decisions, actions or methods, helping the mentored to gradually absorb the knowledge possessed by the mentor. Mentoring is usually conducted by a combination of formal evaluated phases (like milestones) along with other informal processes that together create the proper environment to learn according to the student's and also the organization's needs. This strategy also allows the participants to grow and develop a special bound, that will help them to grow both professionally and personally. [21, 39] This strategy is used by Boeing [22]and by NASA, in which the mentoring program has strong virtual component that intents to capture knowledge and dispose its content online, through tools and processes such as e-mail, threaded discussions and live collaborative sessions.[39]

2.5.3 Case Studies

2.5.3.1 NASA - Lessons Learned

In order to capture acquired knowledge from past experiences, NASA created a system named Lessons Learned. In this system, learned lessons are represented through documents (whether stored as paper or in some electronic repository) and can have various states, according to its evolution during its lifetime. By accessing knowledge and information from past experiences, workers are able to apply it to the facing problems, which leads to taking better decisions and to deal with problems faster.

A typical lesson must follow these three basic characteristics, in order to be considered worth of being stored:

- to have a significant impact on operations;
- to be factually correct;

- to be applicable since it identifies a specific design, process, or decision that reduces/eliminates the potential for failures and reinforces a positive result.

Meanwhile, beside its high success rate, back in 1992 NASA realized that despite its implemented mechanisms to capture, organize and share knowledge -such as web-based lessons learned information system, user training, and program reviews - these efforts did not fully address the following weaknesses:

- **Lessons learned collection and sharing.** Although some lessons learned did occur, these were not routinely identified, collected or shared by programs and project managers. Workers claimed that they were unfamiliar with lessons generated by other centers and programs. In addition, many employees were dissatisfied with NASA's lessons learned processes and systems.
- **Cultural barriers.** Managers identified cultural resisting to sharing knowledge and the lack of strong support from agency leaders making it difficult to implement an effective lesson learned and a knowledge sharing environment.
- **Lack of strategic framework.** Although there was a strategic plan for KM, NASA had not made a business commitment of how it would be implemented within the organization. There was no commitment from the agency to that plan for the leadership, support and resources needed for the effective KM to take place.

After the detection of the following weaknesses and its origins, NASA's administration implemented these seven recommendations:

1. Articulating the relationship between lessons learning and KM through an implementation plan for KM.
2. Designating a lessons learned manager to lead and coordinate all agency lessons learning efforts.
3. Establishing functional and technical linkages among the various center-level and program-level lessons learning systems.
4. Developing ways to broaden and implement mentoring and "storytelling" as additional mechanisms for lessons learning.
5. Identifying incentives to encourage more collection and sharing of lessons among employees and teams, such as links to performance evaluation and awards.
6. Enhancing the Lessons Learned Informatic System by coding information, soliciting user input on an ongoing basis and developing an easier search engine that allows users to identify relevant lessons.
7. Tracking and reporting on effectiveness of the agency's lessons learned efforts using objective performance metrics.[9]

According to J. Holm et al[9], in 2006 the Lessons Learned system followed a logical sequence of phases from its proposal to its validation, having a great impact in the organization. Once a lesson had been initially proposed, it was then submitted for a detailed technical assessment. If the analysis was positive, the lesson become accepted and gave rise to specif recommendations; alternatively, it could be returned for amending and resubmission. Each proposed recommendation of an accepted lesson was submitted for validation. A validated recommendation could remain as such or become an approved practice, or even, the new validated practice could be enforced in an update to the organization's standards and procedures. Once a lesson learned was approved and stored within the organization, it was made available for others to search, reuse, disseminate, and verify.[9]

2.5.3.2 DLR - Tools of the Aerogrid Porject

The AeroGrid is a German project which gathers the following organizations and institutes: DLR, Motoren- und Turbinen-Union Aero Engines GmbH, T-Systems Solutions for Research GmbH and University of Armed Forces (Munich), with the purpose of:

- Allow cooperation in research and development projects.
- Use of up-to-date program versions, data, and compute resources across all locations.
- Detailed documentation of history of a computational process that leads to a certain result - Provenance.[47]

The following paragraphs will describe the set of tools that were used in the AeroGrid Project.

DataFinder

The DataFinder was developed by DLR and it is directed to huge data sets, thus it is able to efficiently manage all the project's scientific and technical data (from climate simulations, aerodynamic simulations, stress simulations, etc.). This tool is a complex search mechanism to find data, where it is even possible to track the data's origin (simulation, test and even project). Each data file is stored on the data servers and standardized with meta-tags, making it possible to find it. This storage is defined through a hierarchy, where users with higher hierarchy have more benefits and access. Despite its complexity, the DataFinder has the advantage of being of easy and fast customization, easy installation and instant access to distributed storage resources. [48]

The DataFinder allows the user to:

- Upload and download data.
- Assign data standardized and user-defined meta-information.
- Search function allowing linkage of multiple search terms.
- Script execution for automation of tasks (e.g., for automatic up- and download or running of calculations).

This system also possesses the advantage of enabling users to use partial results or input data from other calculations already on the server for their own work, without having to generate the data all over again. The flexible metadata concept also allows users to attach additional meta-information to data on the server. [49]

XPS4CFD

DLR also developed an expert system called XPS4CFD, which assists/helps users of TAU (a kind of Computer Fluid Dynamics (CFD) code). XPS4CFD provides the best-practices and guidelines, depending on the respective problems /situations, and it is linked to a search engine which enables the user to find the relevant documents for its situation. This system has the characteristic of being maintainable and extensible by CFD experts instead of programmers, which is useful, since people inside the area have a better perception of the real and most common difficulties, because they experience it in first hand. The guidelines and best practices can be available in different formats, such as: forms and graphical editors (for adding, changing and deleting rules), flowcharts and documents with messages, rules, advices, step by step guides to certain problems, solution or even filling up

forms. A flowcharts, rule creation and form creation examples are available in the appendix A , in the respective order.[48]

2.5.3.3 inSide - Boeing's Internal Social Network

inSide is Boeing's own social network, in other words, an internal and private social network, to which only Boeing's employees have access.[22] The goal of this tool is to form a common place to all Boeing's workers there are spread around the world, where they can communicate with each others, get to know more about other workers (professionally and socially), improve their relationships, trade information and even files in a secure way, store documents among other files, express their thoughts and opinions, ask for help for a specific problem and find people based on its characteristics (such as name, skills, location and other attributes). This tool possesses the capacity to be accessed through a smartphone application.

As other social networks, every employee is allowed to create a personal profile where he describes him (as well as its function and work in Boeing), which enables the communication between other employees and the interface with all that inSide gathers. inSite also possesses a forum typical system that allows people to express their opinion or ask questions in order to get answers or comments from other employees. Figure 2.5 represents a menu that displays some functions and utilities from this private social network.[50]

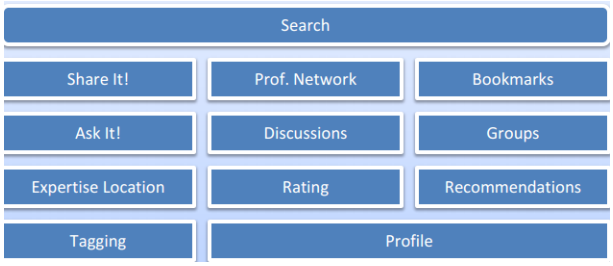

Figure 2.5: Available options in inSite Menu

Besides improving the communication and trust relationships between employees, this tool also opens the possibility to ease knowledge sharing and even create Communities of Practice (like knowledge communities). inSite has the ability to connect people besides a professional relation (which eases the knowledge dissemination) combined with the technological structure that permits to find stored explicit knowledge in a fast way, which leads to a time and resources saving along with the reduction of knowledge duplication risk. This tool is also capable of unite the company's workers, which will consequently improve their environment, reflecting on its performance and company's efficiency.[50]

2.5.3.4 ESA

ESA's KM strategy is ruled by the following objectives:

1. Facilitate knowledge sharing to increase collaboration and synergies
2. Capture, preserve and make evolve knowledge across missions and projects in order to increase efficiency of current and future operations, minimize the risks and avoid loss of expertise;

3. Set up methodologies and tools for staff to find, organize, and share knowledge.

Aiming to fulfill those objectives, ESA established a set of services such as:

- KM Officer
- Lessons Learned
- Competence Management

KM Officer

The KM Officer is an additional function for a project and can be represented as a bridge between KM and the project. This function aims to implement, control and promote KM inside the project through a set of actions such as: defining KM goals, control the processes of storing knowledge and their respective accessibility (isolated or within projects), anticipate the participation of employees, costumers and the organization, etc.. The KM Officer has also to be defined in terms of sourcing profile, since it requires a dynamic, responsible and sociable person who understands the meaning and the value of the KM system.

Lessons Learned

This service aims to investigate ways of harmonizing the lessons learned systems existing in the organization (like rules or procedures) and of fostering the spread and exchange of lessons leaned and best practices, avoiding the repetition of the mistakes committed in the past and increasing the efficiency along with the effectiveness. This service also aims to create a unique and centralized platform where all employees can share, search and access all learned lessons from ESA.

The process of validation of a Lesson Learned follows this step sequence: A public presentation should be made of every proposed Lesson Learned. After the presentation, a group of experts nominated by ESA will analyze the proposed lesson and if they agree with the recommendation, the lesson is validated and sent to ESA management board who will decide the final verdict. If the recommendation is considered useful for the organization, the ESA management board assigns an action to implement it.

The process is meant not only to improve the agreed practices within the agency, but also to proactively interface with external entities and assimilate lessons from daily operational experiences, whether they have been positive or negative ones. The outcome of this process is manifested through a modification to either:

- Procedures in Quality Management System
- Localized Management Instructions
- Training given to staff.

Competence Management

In order to match the skills and competences of its workers with the respective functions, as well as the existence or necessity of certain competencies that were missing inside ESA, the organization's KM staff established a set of processes called Competence Management:

- **Competence Requirements Definition** - this process establishes a collection of strategic and operational competence requirements related to ESA's current and/or future (predicted) competence needs.
- **Management of Competence Requirements** - this process is responsible for understanding, structuring and giving priorities to the competence requirements. The most common situations that require a Redefinition of the Competence Requirements are the change in personnel (retirement, new employment, changing function) and the evolution of technology. Usually, this management is conducted and guided by previous elaborated plans that predicted those kind of cases or by interviewing heads of units or team leaders.
- **Competence Assessment** - this process is responsible for knowing and register the individual competencies of a worker and measure them against the competence requirements identified for its assigned function. This is the most important process of the Competence Management, since it is in this process that the required and the already obtained skills are compared. This process is divided in two distinct parts:
  - Part I - Where the desired/required competence level is mapped in relation to the worker's function. This is achieved by defining and implementing a Competence Measurement Set.
  - Part II - Where the individual competence that the worker possesses (only those that are related to its role) are mapped.
- **Competence Gap Analysis and Action Proposal** - based on the outcome of the Competence Assessment, this process produces a report of the potential discrepancy between the required level of competence and the actual level that the worker possesses to execute its work. In addition to this, the report should also propose actions and plans to mitigate the identified discrepancies.
- **Mitigation Approval and Execution** - this process usually involves relevant workers (such as team leaders and/or heads of unit) to plan and activate the individual (or group) development plan. This step includes dialog not only with these individuals but also with the Human Resources unit.
- **Competence Management Improvement** - this final process ensures that the suggestions for improving the worker's competences are addressed and implemented in collaboration with the KM unit and the organization's priorities and necessities.

According with reference [33], which dates from 2012, the Competence Management program had yet not been implemented because it was still in development. One of the major preoccupations about it, was to create a unique standard tool that obeyed a specific criteria, that suited all different units and its requirements. It was also expected that the information collected by the program would need to be centrally stored and remotely accessible (e.g. Web interface). It is also predicted that the system would have access control in order to preserve the correct level of confidentiality.

2.5.3.5 European Space Operation Center

The ESOC in Darmstadt, Germany, was inaugurated in 1967 with the purpose of providing satellite control for the European Space Research Organisation, which is known today by ESA. In nowadays, ESOC is the main mission control center of ESA[42, 51], possessing a singular and distinct KM project that it is not extensive to all ESA's facilities.[33] ESOC's KM project will be described in this subsubsection.

ESOC Organization

ESOC developed a proper KM organization composed by different levels of hierarchy with distinct and specific functions assigned to each level. This hierarchy is divided in two main groups: the Technical Domains and the KM Core team. The specific and distinctive know-how of each function is gathered in the Technical Domains group, which is organized and ruled by the following roles: the Technical Domain Owner, the KM Assistant, the Knowledge Area Leaders, the experts and of course the other members. The Technical Domain Owner is responsible for managing the knowledge inside the domain with the support of the KM Assistant, while Knowledge Area leaders are responsible for managing a specific knowledge area within the domain. On the other hand, the KM Core Team is composed by representatives of all technical domains and is in charge of designing and monitoring the overall KM in ESOC. This management set up is very important for the success of KM in ESOC, since it:

- Defines the leading actors of the KM process and the people involved;
- Divides workload according to people's involvement and availability;
- Ensures clear roles and responsibilities to avoid overlaps and reorganizations

Knowledge Capture and Dissemination

The two principal methods used to capture knowledge in ESOC are: expert debriefings and interviews. A expert debriefing is a specie of forum/workshop (usually with a duration of half a day), where the expert explains his specialized knowledge (or part of it) to a larger group of participants, counting sometimes, with the assistance of a moderator, who helps guiding the debriefing and eases the orator to express its expertise. On the other hand,the interview is more suitable to describe complex subjects. These interviews are usually video-recorded and count only with the participation of the expert, a moderator (depending on the subjects complexity) and an IT member.

Both these methods are usually used to capture knowledge from a worker who is going to retire, change function or organization. These methods aim to spread the gained experience over a larger group of colleagues, with the intention to initiate further discussions and knowledge transference. Irrespective of the method, there is no basic difference for the overall structure of the procedure with respect to the preparation and its conduct, since both follow this step sequence:

1. Review of status with an inquiry
2. Plan for debriefing or interview
3. Conduct of Debriefing or documentation of tacit knowledge with the help of video-recording
4. Ongoing work to facilitate the contents of the debriefing or video in text format.

Although not being one of the principal methods to capture and disseminate knowledge, the narrative method Story Telling is worth being referenced. In this method, a worker (or a group of workers that presented the same situation) narrates its experience (either positive or negative) in order to transmit past experience to other workers. These narrative methods do not only consist of telling of occurrences, events or episodes but they also include the usage of pictures, metaphors and analogies.[33, 42]

Knowledge Sharing

The process of knowledge sharing in ESOC usually takes place through the following means:

- Voluntary and Informal Communities of Practice, which are strongly supported by ESOC.
- Sharing Best/Worst practices repositories.
- Use of the KM Portal.

Since the KM portal is a very important tool in ESOC's KM project, it is important to understand its advantages, in order to comprehend its crucial position in ESOC. The KM Portal is accessible through ESOC's intranet and it is the "entry-point" for all ESOC KM related activities and also a platform providing a simple, friendly and flexible on-line environment for storing, sharing and searching knowledge. The KM Portal is also crucial to the Communities of Practice management, since it provides a specific platform for this practices, by enabling a space in which the members of every community create, store and classify the content according to their experience, giving a new approach to access information that complements the more formal ones. This is also considered as a bottom-up approach, since the creation of communities is spontaneous and motivated by people's knowledge needs and interest. Anyone can create a community and use the platform without the need of further authorization. In this way, the KM Portal administrators are mere spectators providing a platform, and letting the information be structured and flow among the users.

KM portal is also the entry point to other features, such as the Tools Catalog, an interactive collection of tools developed, customized or simply used within ESOC. This database collects tools from any department, team or individual that is whiling to publish it. The inputs (link and basic description) are provided by the users, who are the ones who really know the resources that they are going to share.

The KM Portal is provided with a Search Engine, which enables the worker to search for any subject related to with whatever he types. Currently, the KM portal supports the following features:

- KM Project Pages
- Portal Level Blog
- Communities of practice
- Community level blogs
- Content Pages
- Wiki-like pages
- Forums
- Main Navigation Menu[33]

Chapter 3

CEIIA's Aeronautical Unit

CEIIA is an innovation and engineering center composed by the main suppliers, associations, universities and public organizations related with the Portuguese and international Automotive and Aeronautical industries. As an organization, CEIIA has the following goals in the mobility industry:

- to enhance the competitiveness of mobility through international cooperation between the university and industry, developing products and market orientated solutions;
- to promote the growth of Portuguese companies (belonging to the mobility industry) in the international supply courses;
- to become a global reference on research, design, development, manufacture and testing of products and services for mobility industries around the world.[52–55]

CEIIA was formed in Portugal on December 22 of 1999 as a non-profit private organization and was only directed to the automotive industry. However, its activity only started on the 1st of March of the following year.[56] In 2005, a facility was created in Maia (North of Portugal), with a workable area of 4000 m^2 and it has been the company headquarters since then (see figure 3.1).[52, 54, 55, 57] Besides its main headquarters, CEIIA also has one office in Lisboa (with an area of 200m^2) and teams working in Spain, France, United Kingdom, Italy and Brazil. Currently, it has a dimension of 170 workers and an associative patrimony of 1 500 000€.[52, 56]

Figure 3.1: CEIIA's main Headquarters.

Due to its scope of work and the complexity of mobility industries, CEIIA developed its internal structure based on the following three development units:

- CEIIA - this unity is focused in process and product integrated development.
- CEIIA-PP (Parcerias Público-Privadas - Public-Private Partnerships) - this unity is focused in managing the public-private initiatives of pre-competitive nature.
- CEIIA-VET (Valorização Empresarial da Tecnologia - Technology's Business Appreciation) - this unity, along with the industry and the university, is focused in supporting the technological development.[53]

The following sections will only be related with CEIIA's work in the Aeronautical industry, since the automotive industry is out of this master thesis' scope. Next section will describe CEIIA's role in the Portuguese and International Aeronautical industry, as well as its dimension and resources.

3.1 CEIIA in the Aeronautical Industry

CEIIA was created in 1999 but its entrance in the Aeronautical Industry only took place in the year of 2008, with a Research, Design and Engineering partnership with AugustaWestland.[58] Nowadays, from the 170 workers in CEIIA, 100 work in AU, located in Maia or in teams spread in Europe and Brazil. In this industry, CEIIA performs structural design and stress analysis of composite and metallic parts, aerodynamic and aeroacoustic simulations, partial and full scale testing and prototyping, as well as certification. CEIIA is certified and guided by the ISO 9001 and EN9100 standards.[54]

CEIIA's role in the national and international Aeronautical Industry can be evaluated through its current projects and partnerships. CEIIA is qualified as an Embraer design and stress supplier as well as an AugustaWestland engineering supplier.[57] The success within the past projects contributed to a good reputation and trust relationship within its partners, which consequently led to wining bigger and more complex projects. CEIIA's AU has been growing in the past few years, leading to the appearance of new necessities, hiring of more employees and creation of more working tools. AU is actually involved in the following projects from the Aeronautical industry:

- Development of central fuselage, sponson and elevator parts from the Embraer KC-390.
- Development and modification of seven military and civil helicopters from AugustaWestland.
- Partnership with AugustaWestland in European projects such as Clean Sky, Reach and Alicia.
- Development of Dassault Aviation Falcon SMS central fuselage from Daher-Socata.
- Coordination and development of a national aeronautical and defense cluster for aeronautical suppliers.
- Development of an international aeronautical RD&I (Research, Development & Implementation) program to be implemented in cooperation with the main Portuguese Universities - Instituto Superior Técnico, Universidade do Porto, Universidade do Minho, Universidade da Beira Interior - and international R&D centers, such as Von Karman Institute (Belgium), Cranfield University (United Kingdom), Instituto Tecnológico de Aeronáutica (Brazil) and Massachusetts Institute of Technology (United States of America).[54, 59–61]

It is foreseen to move all Aeronautical workers from the headquarters to an Aeronautical facility that will

be built in 2014 at Matosinhos. This facility will be responsible for coordinating and performing all the company's work in the Aeronautical industry.

After the description of CEIIA's role in the Portuguese and International Aeronautical industry, the following section will give a more detailed perspective of AU's necessary knowledge to develop AS.

3.2 The Development of Aeronautical Structures

In order to develop AS, AU needs to have in its possession a vast set of knowledge in areas such as: Design, Stress, Materials, Support and Certification. The development of these structures results from the change of information and collaboration between these areas, in order to reach an optimized result that fulfills the sum of all demands.

The Stress is focused on structural concerns such as fatigue, loads concentration, critical loads and areas, transmitting the necessary information (such as minimum dimensions) to the Design in order to model the parts. The Design interprets the Stress information and confronts it with the part's geometry, function and interaction with the other parts involved in the main assembly. Both of these areas interact in simultaneous with Materials in order to get information about the manufacturing process, the existing cares to have with the materials and the characteristics of the available raw materials. There is also interaction with support areas such as Electrical Systems or Engines that need space, safe conditions and special cares to install their systems (such as treatment of certain components). Certification is also included in this process, thus the structures have to fulfill a vast set of regulations established by the safety regulation agencies.

This exchange of information involves several iterations until it reaches the final state. It requires that workers from different areas have different knowledge to fulfill their roles. However, there is common knowledge that everyone needs to possess and, of course, not all areas have to possess the same knowledge level about a specific knowledge. For example: a Stress worker does not need to know every manufacturing processes of a certain kind of material, but he still needs to know the basic about manufacturing in order to fulfill its role and ease the iteration process.

Table 3.1 contains the necessary knowledge and its level, that both Stress and Design workers need to possess in order to fulfill their roles. The specific knowledge from the other areas is not included in this table, since the implementation strategy is only directed to these areas, because they are the more complex environment, which mean that are ideal to implement and test the KM strategy.

KNOWLEDGE	DESIGN	STRESS	DESCRIPTION
Aeronautical Documentation and Regulation	0	0	Know where to consult and how to interpret the Official Aeronautical Documentation and Regulation emitted by the FAA or EASA.
Part's Role on the Aircraft	X	X	Knowing the part's function and interfaces is essential for the good Design and Stress analysis.
Structural Mechanics	0	X	In order to perform and understand the Stress analysis.
Solid Mechanics		X	In order to perform and understand the Stress analysis.
Finite Elements Method (FEM)		X	In order to perform and understand this kind of analysis.
Fatigue Concepts		X	In order to perform and understand the Fatigue analysis.
Nastran Patran		X	Software used by the Stress workers to perform the Stress Analysis.
CATIA V5	X		Computer Aided Design (CAD) software used by the Designers.
Functional Tolerance & Annotation (FT&A)	X		Technical Drawing tool incorporated in CATIA V5, which enables the part dimensioning and tolerance inside the 3D model. This tool aims to replace the use of the 2D Technical Drawing.
Technical Drawing	X		In order to do the parts measuring and tolerance.
Manufacturing Processes	X	0	In order to do design the parts in accordance with the manufacturing procedures. These procedures take in consideration the parts function and its material, as well as interaction with the manufacture.
Assembly Processes and Hardware	X	0	In order to do design the parts in accordance with the assembly procedures and the characteristics of the used hardware (such as rivets, bolts, nuts ,etc.).
Product Structure Software (PSS)	X	X	Intranet tool that possesses the physical model of all parts (either individually or in assembly), as well as its stress and design characteristics. It also eases the workers in the knowledge iterations.
Part List	X		Knowledge related with a tool that elaborates the document containing all the important information of the part for manufacture, such as the type of material, dimensions, treatments, norms, assemblies, etc.
Part's Treatments and Cares	X		It is necessary to know the part's function and interfaces in order to know which are the necessary and more indicated measures and cares to include in the Part List.
Microsoft Office Tools	X	X	In order to make documents such as presentations, calculus sheets among others.
Soft Skills	X	X	Skills such as communication, organization, group work among others that are necessary to interact either between the same area or between different areas.

Table 3.1: List of essential knowledge to perform Design and Stress functions. **X** - High Knowledge level **0** - Basic Knowledge level

The following subsections aim to demonstrate specific examples of applied knowledge when performing the Design and Stress analysis of real aeronautical structure components. The given examples are usual components from primary and secondary AS of cargo airplanes such as KC-390, that is represented in figure 3.2[62].

Figure 3.2: Cargo Aircraft KC-390.

3.2.1 Knowledge Discrimination: Frame from Lower Fuselage

This component (represent on figure 3.3[63]), made from a special league of aluminum (7085-T7451), belongs to the lower central fuselage (a primary aeronautical structure) and has interfaces with other components from the lower central fuselage (such as stringers, frames, skin, etc.), upper central fuselage (such as stringers, frames, skin, etc.) and other systems (such as electric, support and oxygen systems). Since this component is inserted in the lower fuselage, it is necessary to have a special care with the supported load and fatigue (which tends to be bigger than in other parts) and also the suffered detrition, thus this place is more propitious to the accumulation of wastes and liquids. In order to prevent the part's deterioration, a special polyurethane paint layer (proper for metallic parts) is applied, along with an epoxy primer paint layer, in order to protect the part against corrosion.

In order to elaborate this component it is necessary to have specific knowledge regarding the component's function, its manufacturing processes and and also its treatments. Besides this knowledge, it is also necessary to understand and know the component's location, existing interfaces, the respective assemblies and PSS related knowledge in order to perform a good Stress Analysis and Design. It is also necessary to know and interpret the aeronautical regulation to check if the component is fulfilling the mandatory requirements. The specific Stress knowledge that is necessary to elaborate this component is: structural mechanics, solid mechanics, FEM modulation, Nastran Patran and fatigue concepts related knowledge. In order to Design this component, it is necessary to possess specific Design knowledge such as: CATIA V5 design, FT&A, technical drawing and tolerance related knowledge.

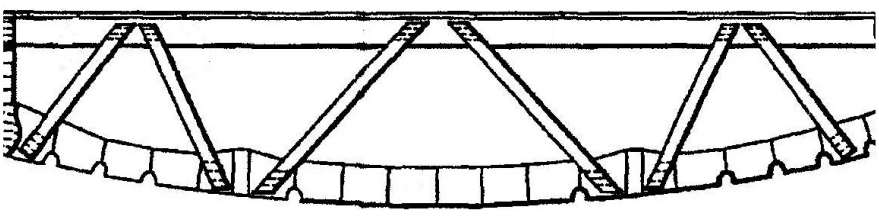

Figure 3.3: Frame from Lower Fuselage

3.2.2 Knowledge Discrimination: Rear Protection Panel from Secondary Structure

This component (represent on figure 3.4[64]), made out of composite AS4 carbon fiber (where in some zones is used a honeycomb configuration), belongs to a secondary structure located in the lower rear and has interfaces with other components from this structure (such as latches, frames, panels, etc.), panels from the primary structure and other systems (such as hydraulic and electric). Besides the aerodynamic loads supported by this component (due to its function and localization), it is also necessary to take in consideration the suffered detrition, thus this place is more propitious to the accumulation of wastes and liquids. In order to prevent the part's deterioration, a special polyurethane paint layer (proper for composites parts) is applied, along with an epoxy primer paint layer, in order to protect the part against corrosion.

In order to elaborate this component it is necessary to have specific knowledge regarding the part's function, its manufacturing processes and also its treatments. Besides this knowledge, it is also necessary to understand and know the component's location, existing interfaces, the respective assemblies and PSS related knowledge in order to perform a good Stress Analysis and Design. The specific Stress knowledge that is necessary to elaborate this component is: structural mechanics, solid mechanics, FEM modulation, Nastran Patran and fatigue concepts related knowledge. In order to Design this component, it is necessary to possess specific Design knowledge such as: CATIA V5 design, FT&A, technical drawing, tolerance and part list related knowledge.

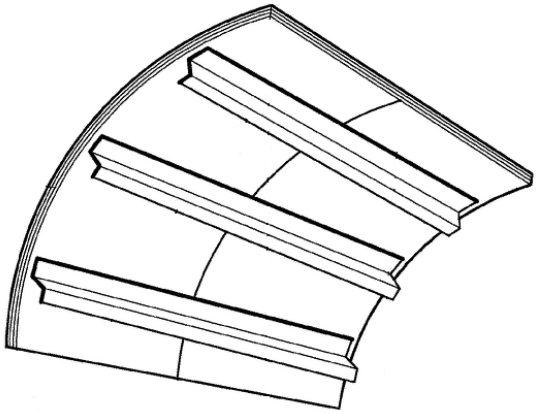

Figure 3.4: ear Protection Panel from Secondary Structure

The next section will present AU's working process, as well as its organization, flow of information and usual procedures.

3.3 Aeronautical Unit's Working Process

The Working Organization Chart of AU is represented in figure 3.5 where is possible to identify the different areas that compose this unit[65]. Meanwhile, figure 3.6 represents the distribution of AU's employees through its different areas.

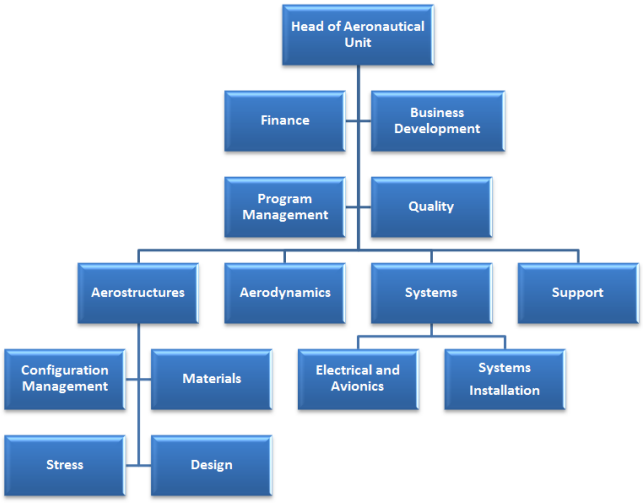

Figure 3.5: AU's Working Organization Chart

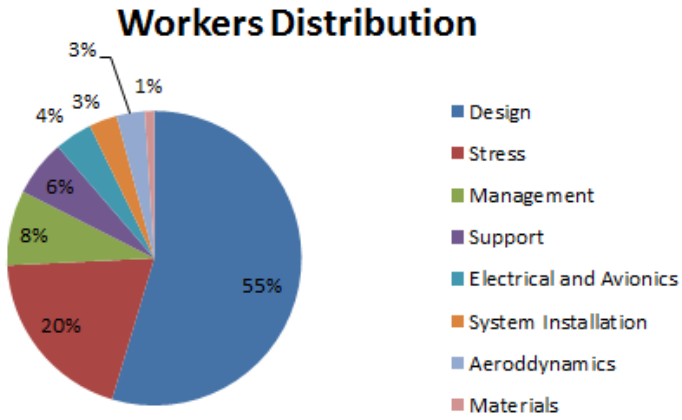

Figure 3.6: Aeronautical workers distribution through the different areas.

This organization is structured with the objective of achieving product realization and customer satisfaction. Areas such as Finances, Business Development, Program Management and Quality are support areas that work together with the Head of Unit on project's development and technical areas activities. Each of the technical areas has at least one team. Each team is led by a Team Leader and all of them are guided by a project Technical Manager. The project technical managers of each area communicate between each in order to exchange information and data related to the project.

When working in projects, all the relevant data (where it can be also included CFD files, CAD files, Stress Analysis files, etc.) and information is usually stored in the project's folder system that it is located on a specific location in the intranet dedicated exclusively to AU. The usual structure of this folder system is represented in figure 3.7

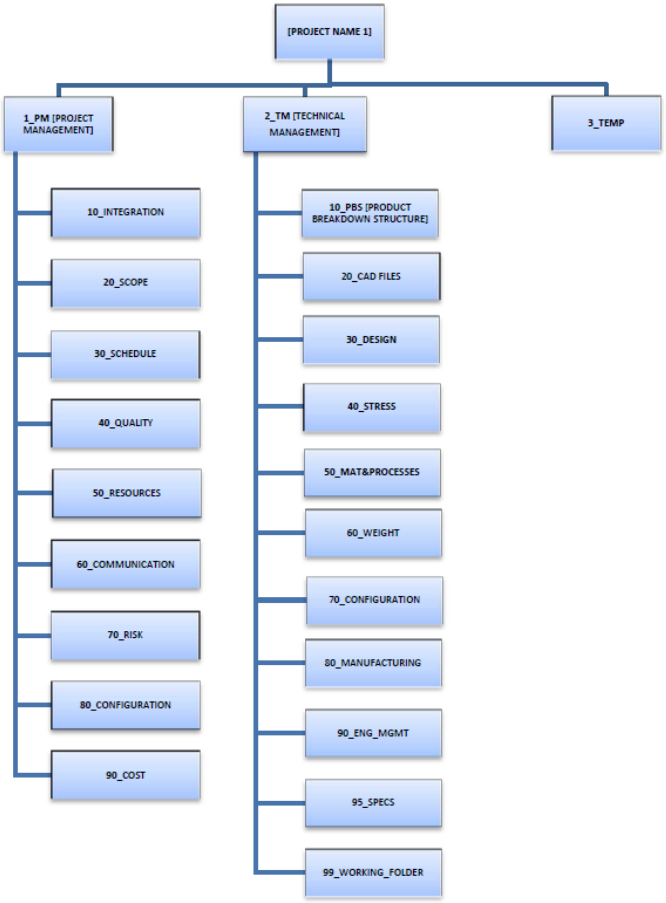

Figure 3.7: Organization of a Project's Folder System

Only the workers involved in the project, have access to the project documentation. Not all of these folders need to have content, since not all projects in AU are obliged to have all the technical areas working.[66] Usually an organization chart of the project's folder system is created (by the superiors, who decide the hierarchy and the vital information) and presented to the workers in a "kick-off" meeting, during the beginning of the project, with the objective of informing and clarifying everyone about the correct use of the system as well as the vital information.

The insertion of new documentation, information or changes in the system (such as creation of new folders, merging of folders, alterations in documentation, etc.) is usually notified to the workers involved in project through e-mail. Sometimes the adding of some minor details or alterations that are not registered, are also communicated through email. The usual procedures to store and capture explicit knowledge may change from project to project and even from technical area to technical area. The exchanged information with clients is controlled through a document called "Control Sheet", where it is registered the information asked by AU, if the client has already answered and the answered information. Sometimes knowledge is also captured with the help of other tools that follow up specific procedures and methods, but this subject will be discussed with more detail in the next subsection (3.4). It is also relevant to clarify that the access to this information and explicit knowledge it is not quantified.

It is possible to say that all employees contribute to the process of capturing and transmitting explicit knowledge in AU's projects, since everybody wants the project to be successful, which motivates workers to not compromise the explicit knowledge cycle.

Meanwhile, the tacit knowledge is gained through experience, by committing errors, achieving success, through socialization (knowing the worker and its limits), meetings, exchange of experiences and information (done in an informal way), through presentations with guidelines or by guidance of those who are more experienced (usually the elders guide and teach the young or those who are new in the organization/area). At the end of each project, a meeting is made, with the intention of discussing what went wrong and right, its causes and also what can be avoided, repeated or improved in future projects.

The exchange of information and explicit knowledge between different sectors is usually done: in an informal way through oral communication or discussion, through reports and documents (sometimes read by curiosity and/or interest); or in a more formal way through reports, documents meetings, emails.

It was elaborated a brief interview with a query of open answer (Appendix B) to some of AU's employees, in order to find out which where worker's main difficulties, complains and problems when leading with knowledge's search, capture and dissemination. There were selected 5 experienced workers from Stress, Design, Aerodynamics, Quality and Electrical and Avionic Systems. This selection aims to identify not just the local difficulties, complains and problems, but also the ones that are common to different areas. The following list possesses the identified difficulties, complains and problems:

- Lack of Communication between workers (inside and outside sectors)
- Organization of Data and Information should improve
- Lack of guidance and supervision of the daily activities (from the elders to the young/new)
- The nonexistence of standard procedures of how disseminate information and explicit knowledge through the team
- Find out who knows what (inside and outside sectors).
- Know where the information is stored.
- Fear of committing mistakes and ask "dumb" questions or look like one - Non valorization of the mistake.
- Ensure knowledge disposal and fixation, with the perspective of having it accessible and understandable by anyone who might enter in a latter phase in the project, easing the project follow up by the new participants.
- Big amount of work, making it harder to share and transmit knowledge and also to socialize.
- Find matching time between different sectors (each sector has specif priorities, functions and even some sectors have different working schedule).
- Miscarrying about other sectors priorities, obligations and necessities.
- Different procedures, workflows, perspectives, use of tools to capture and disseminate knowledge and goals between different sectors.
- Afraid of sharing tacit knowledge and becoming expendable.
- Some knowledge is took from granted and it is not registered or its possessor does not gives its deserved value.
- Know and structure what knowledge the worker possesses.
- Know the Knowledge level of the new guys, in order to have a better idea what knowledge is crucial to transfer.
- Lack of structure and means to access information.
- Being aware of everything that happens in a project.

The root causes of these problems are identified and listed in table 3.4. These root causes have direct impact in certain phases of the KM cycle (represented previously in figure 2.3). The affected phases are represent in the tables 3.2 and 3.3.

ROOT CAUSE	AFFECTED KM PHASES
Communication	Transference Vision, Search and Control
Organization	Capture Transference Vision, Search and Control
Work Culture	Creation Capture Transference
Knowledge Complexity	Capture Transference Application
Knowledge Spectrum	Transference

Table 3.2: Root Problems and the respective knowledge phases that are affected.

AFFECTED KNOWLEDGE PHASES	NUMBER OF REFERENCES
Transference	5
Capture	3
Vision, Search and Control	2
Creation	1
Application	1

Table 3.3: The number of times that knowledge phases are referenced in table 3.2.

Table 3.3 allows to realize which are the most affected phases of the KM cycle that AU needs to focus, in order to improve its weakest components .

Since the organization working process is explained, it is necessary to analyze the presence and impact of KM in AU - its process, its strategy and its tools. The following section will be about KM's role in the organization.

ROOT CAUSE	LIST OF PROBLEM
COMMUNICATION	- Know where the information is stored.
	- Lack of Communication between workers (inside and outside sectors).
	- Being aware of everything that happens in a project.
	- Find out who knows what (inside and outside sectors).
	- Ensure knowledge disposal and fixation with the perspective of having it accessible and understandable by anyone who might enter in a latter phase in the project, easing the project follow up by new participants.
ORGANIZATION	- Organization of Data and Information should improve.
	- The nonexistence of standard procedures of how disseminate information and explicit knowledge through the team.
	- Know where the information is stored.
	- Big amount of work, making it harder to share knowledge, transmit it and also to socialize.
	- Find matching time between different sectors (each sector has specif priorities, functions and even some sectors have different working schedule).
	- Being aware of everything that happens in a project.
	- Ensure knowledge disposal and fixation with the perspective of having it accessible and understandable by anyone who might enter in a latter phase in the project, easing the project follow up by new participants.
	- Lack of structure and means to access information.
	- Find out who knows what (inside and outside sectors).
	- Know the Knowledge level of the new guys, in order to have a better idea what knowledge is crucial to transfer.
	- Different procedures, workflows, perspectives, use of tools to capture and disseminate knowledge and goals between different sectors.
WORK CULTURE	- Fear of committing mistakes and ask 'dumb' questions or look like one - Non valorization of the mistake.
	- Miscarrying about other sectors priorities, obligations and necessities.
	- Afraid of sharing tacit knowledge and becoming expendable.
KNOWLEDGE COMPLEXITY	- Some knowledge is took from granted and it is not registered or its possessor does not gives its deserved value.
	- Know the Knowledge level of the new guys, in order to have a better idea what knowledge is crucial to transfer.
	- Ensure knowledge disposal and fixation with the perspective of having it accessible and understandable by anyone who might enter in a latter phase in the project, easing the project follow up by new participants.
KNOWLEDGE SPECTRUM	- Miscarrying about other sectors priorities, obligations and necessities.
	- Know the Knowledge level of the new guys, in order to have a better idea what knowledge is crucial to transfer.

Table 3.4: Root Causes and consequent difficulties that affect AU's KM Process.

3.4 Knowledge Management in AU

As already stated in this thesis: AU (as well as CEIIA) does not have any kind of KM strategy implemented. Its quest for knowledge is based on the necessity of solving problems. However, employees know what is KM and comprehend the advantages of knowledge dissemination, which is only done by employees initiative instead of company's deployed processes. They use knowledge tools and methods, based on common sense, experience and mimic (from other companies). These tools are used in an unorganized way without obeying to any kind of order or standard procedures, which in fact is also a workers' complain. However some of these tools can be inserted in the KM strategy.

3.4.1 CEIIA's Knowledge Tools

As any organization with this dimension, CEIIA has to use a vast number of tools, in order to process knowledge through the company. The exact tools used by CEIIA in this process are: meetings, training, presentations, emails, document sharing processes, data bases, intranet, informal networks (such as coffee break talk) and benchmarking. Also, in a closer future, AU is planning the introduction of Manuals for its employees. From this set of tools, there are four that deserve a more detailed look, thus its understanding and correct application is crucial to knowledge creation, capture and dissemination inside the organization. These critical tools are:

- i-CEIIA
- Lessons Learned (LL)
- A3
- CEIIA Sharing Knowledge (CSK)

All of these tools are transversal to all units and were developed by CEIIA as response to its internal necessities, aiming to help solving problems, organize knowledge, transfer knowledge and face the daily difficulties. The following subsubsections will explain the characteristics, use and functions of these tools.

3.4.1.1 i-CEIIA

This is CEIIA's portal to access specific documentation outside projects and CEIIA's social network. Besides that, it is also a mean of communication between different areas. Figure 3.8 represents the main menu of this portal.

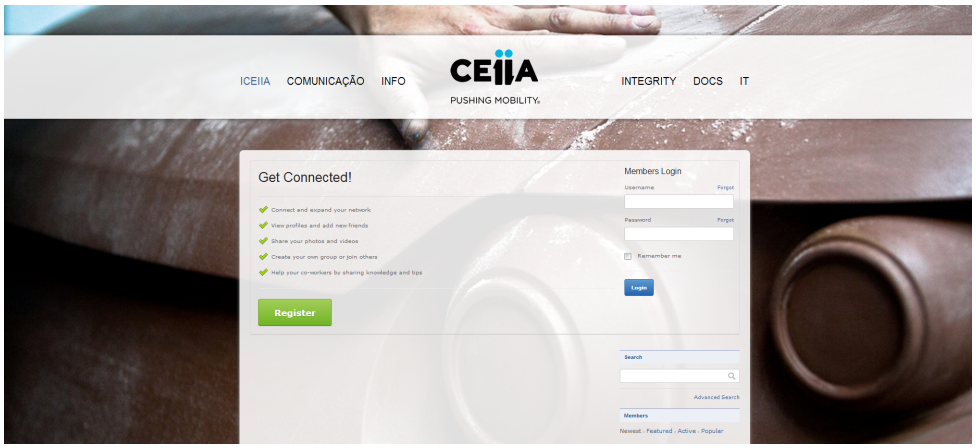

Figure 3.8: iCEIIA's main Menu

As it is possible to see in figure 3.8, iCEIIA's main Menu possesses 6 different submenus, from which only four are actually available:

1. ICEIIA
2. Comunicação
3. DOCS
4. IT

The first submenu accesses the company's social network, to which users describe it as company's internal Facebook. Every employee is able to create a personal profile page where he writes a description of its job. He is also free to describe himself, his hobbies and his personal life, as well as to upload one picture in his profile. Workers are also free to write messages, post videos, photos or other documents for other workers, being the content work related or not.

The second submenu is a storage for all the press articles or public documentation that are related to CEIIA's activities. Each documentation and article is referenced with its emission data and source.

The third submenu is also a storage of documentation, where the internal documentation from all units is stored. This submenu also possess portals to access other tools, such as data/information bases, LL portal (in development), CSK portal and others. DOCS also allows to: store articles and other documents (data base), so employees can access them; announce news, meetings, trainings, presentations and other events; and to expose problems in order to get help from other employees.

The last submenu is dedicated to the IT department, allowing the user to access CEIIA's webmail or to fill or control an IT ticket (special form dedicated to report software and hardware malfunctions to the IT department).

The remaining submenus are still in developing stage and are not accessible by the workers

3.4.1.2 Lessons Learned

This KM tool aims to develop, organize and disseminate knowledge through CEIIA. It is only used after the problem has been solved, with the purpose of registering the problem's way of solving. It can be used as future

reference or help to avoid past mistakes and wasting time reinventing solutions that were already found.

LL follows some specific steps since its preparation until its final state. When the engineer, team leader, manager, or other person related to the project wants to register a solution, it is necessary to fill a specific form (see appendix C) and wait for an approval from a superior (as the project technical manager). The fulfillment of this template might also come from a superior suggestion/order to capture and/or disseminate knowledge. After approval, the LL is uploaded in a proper portal on i-CEIIA and the information about a new LL is communicated to the people in the same area. The final steps consist in a merit evaluation performed by the human resources and superiors (taking in consideration the value and importance of the LL), followed by a reward to the employee.

This tool has is still under development[67] and has some similarities with NASA'sand ESA's services, presented in subsubsections 2.5.3.1 and 2.5.3.4, respectively.

3.4.1.3 A3

This KM tool aims to describe the main characteristics of a faced problem, as well as its future resolution or attempt. It is used when the employee is facing a problem, enabling its analysis and solution searching. It is a verification tool which allows to structure thoughts and develop solutions.

This tool is an A3 paper sheet with seven text boxes, where each box represents a field of the problem. The boxes have the following tittles in the respective order:

- Background - What the user is talking about and why.
- Current Conditions - The user actual situation. What is the problem or what indicates its presence.
- Target/Goal(s) - What the user wants to solve or get .
- Analysis - The reason of the problem. What is impending the user to achieve its goals.
- Proposed Countermeasures - What to do to solve it.
- Plan - How to do it and what it will require. Implementation Process.
- Follow Up - How to secure the plan's success and how to measure it, what possible outcomes should be expected and how to share the obtained knowledge with other areas.

By filling up each of these fields the user describes all steps since the problem's origin to its possible solution - it elaborates a plan or methodology. After filled up and approved by a superior, the A3 becomes available in a specific portal in i-CEIIA, where it can be accessed. It is a useful tool, taken in consideration that it can be consulted when facing a similar problem or obstacle.

Usually the A3 goes through several versions until it reaches its final, since the user fills it up in order to better understand the problems main causes and rewrites a new version afterward, in order to explore a new possibility of main causes and its resolution. It is a tool that enables the user to create knowledge and register its creation process. A copy of this tool is available in appendix D.[68]

3.4.1.4 CEIIA Sharing Knowledge

This KM tool consists on a presentation to all company of a new method, knowledge or solution that was created. If an employee (or a team) has in its possession some kind of knowledge, method or solution that he thinks that is valuable and suitable to the company, he may organize a session of CSK.

First, the employee has to ask permission to its superior to present it or even the superior might suggest a CSK session. The proposal gets through a light evaluation from the superior, without any kind of formalities. After granted permission, the CSK session is announced on i-CEIIA and all company members can assist. This session is made in an auditorium, where the worker makes a 40 minute presentation about its subject, its advantages and its wide applications. When the presentation finishes, a 20 minute discussion begins, where audience's participation is encouraged while the worker is available to answer the audience questions, as well as to ear their opinions and suggestions. While the presentation promotes knowledge creation, capture and transference, this discussion promotes its application and also creation. This has some similarities with ESOC's story telling presented in subsubsection 2.5.3.5.

With the tools that the company already has and the right strategy, a KM methodology could be incorporated in the aeronautical section, which would conduce to all the advantages described in section 2.2. The next chapter will define a suitable strategy for AU, as well as the right implementation method, taking in consideration the company's dimension, working process, goals and values.

Chapter 4

Knowledge Management Strategy

This chapter aims to elaborate a KM strategy that fulfills AU's needs. It will start by establishing the priority of the root causes (identified in the previous chapter on table 3.4), in order to elaborate an effective and realistic strategy. It will also describe the KM strategy, including its goals and established phases.

The second section will describe in a detailed way, the proposed processes that compose the KM strategy phases, as well as their place in the KM cycle, taking into account its duration, number of participants and the subprocesses that constitute them.

The last section will analyze the strategy's ROI, confronting the implementation cost of the proposed measures with its outcome. This analysis intends to establish quantitative goals that will allow to control the strategy's outcome and duration.

4.1 The Strategy

The strategy and all the solutions that compose it are based in only one main root cause: Organization. This choice is justified through the analysis of the tables 3.2 to 3.4 (in which lies the collected data from the query), where it is possible to understand that this root cause generates more problems than the others (possessing a great number of problems in common with other root causes) and is also the one that affects more phases of the KM cycle (tied with Work Culture and Knowledge Complexity, which also affect 3 phases). In addition to these facts, Work Culture and Communication are causes that are more related with the social sciences (which are subjects that get out of the scope of an Engineering Master thesis), while the Complexity of Knowledge is a permanent characteristic that can only be fought when there is a solid knowledge structure behind it, which makes the Organization the obvious choice to be the main target of this strategy. By attacking this root cause, the strategy will have bigger impact on the following phases of the KM cycle (presented in section 2.3): Vision, Search and Control, Capture and Transference.

The issues related with the main root Organization that lie in table 3.4 where reorganized and transformed in points to be improved, which are the foundation of these strategy. These points are enlisted in table 4.1

ORGANIZATION	- Organization of Data and Information should improve.
	- The nonexistence of standard procedures to disseminate information and explicit knowledge through the team.
	- Knowing where the information is stored.
	- Being aware of everything that happens in a project.
	- Ensure knowledge disposal and fixation with the perspective of having it accessible and understandable by anyone who might enter in a latter phase in the project, easing the project follow up by new participants.
	- Lacking of structure and means to access information.
	- Find out who knows what (inside and outside sectors).
	- Knowing the Knowledge level of the new guys, in order to have a better idea what knowledge is crucial to transfer.

Table 4.1: Points that the KM Strategy intends to improve.

Some of these points share resemblances, which means they can be fought with similar methods in the strategy. This resemblances makes it possible to divide the identified points in two distinct parts:

- **Organization** - which intents to improve the organization of the stored knowledge.
- **Identification** - which intents to identify the existent knowledge (primarily the tacit knowledge) inside AU and the best way to transfer and capture it.

These parts are going to constitute the main core of the strategy, since each action will be based on one (or both) parts. Each of these parts possesses its specific goals (represented on 4.1) and 4 phases each (having one phase in common), which will occur in a specific order. The structure of this strategy, along with the phases that constitute each part and their respective weight in the strategy, is represented in figure 4.1.

Since it is the first time that a KM structure is being inserted on AU (and even on CEIIA), it is necessary to first apply the strategy to a portion of the workers, in order to test it and calibrate it before applying it to the whole AU. The target areas of these strategy will be the Design and Stress, since these are the areas with bigger workload and number of workers (as seen on figure 3.6), which makes them ideal environments to test and adjust the strategy adequacy. In this way, the strategy will try to identify and organize two distinct (but connected) sources of knowledge that are essential for the development of AS.

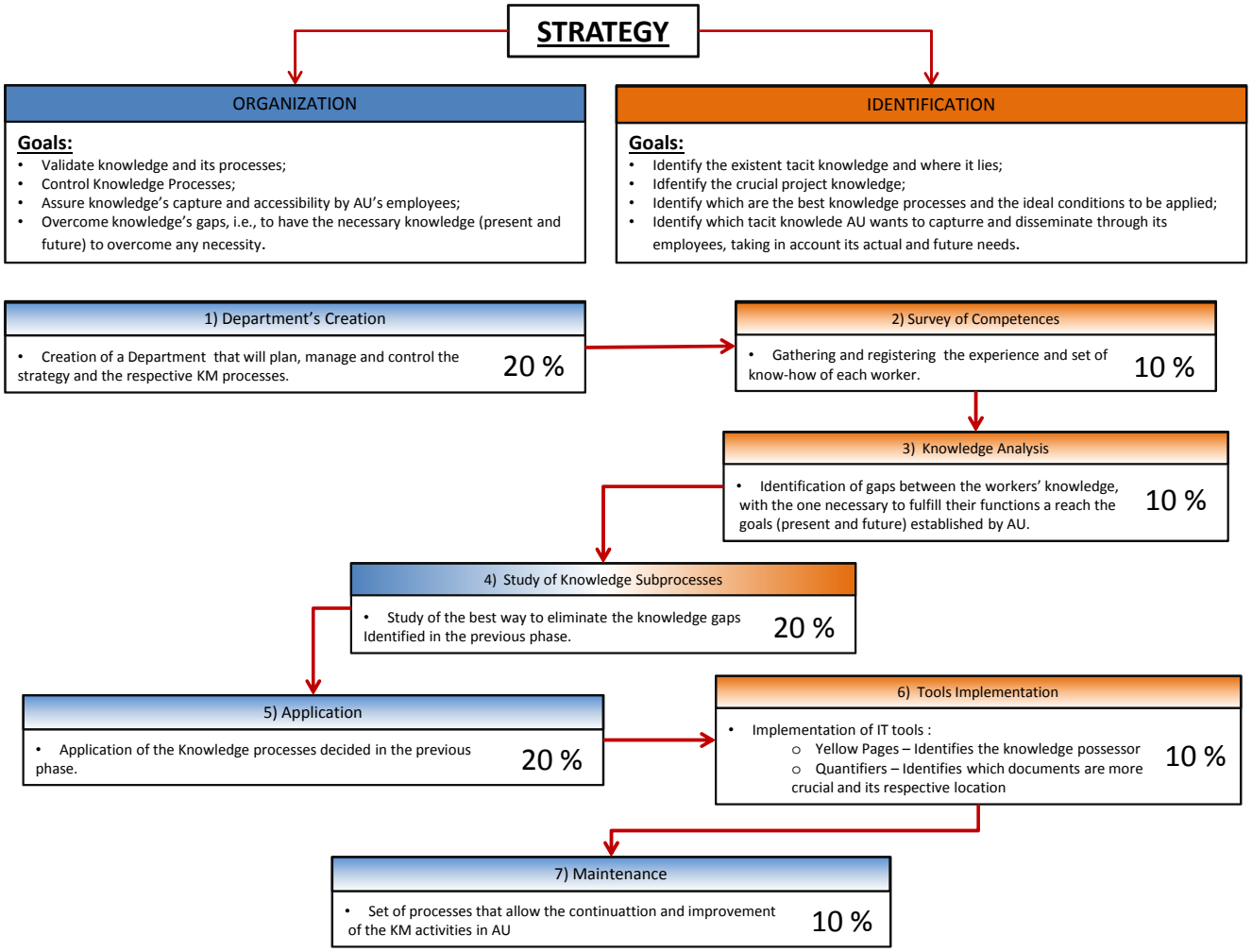

Figure 4.1: KM strategy, including its different parts and phases.

The following subsections will describe each part of the strategy, including its goals and phases, weight in the global strategy and duration.

4.1.1 Identification

This part aims to fulfill the following goals, through a set of 4 distinct phases, each one with a crucial role and purpose in the established strategy:

- Identify the existent tacit knowledge and where it lies;
- Identify the crucial project knowledge;
- Identify which are the best knowledge processes and the ideal conditions to be applied;
- Identify which tacit knowledge AU wants to capture and disseminate through its employees, taking in account its actual and future needs .

4.1.1.1 Survey of Competences

The first phase intents to collect the employees past experiences in projects (inside and outside CEIIA), skills (e.g. experience in CATIA V5), performed functions, studies and important aspects that would help to characterize a worker's knowledge profile. This information will be registered in iCEIIA's personal profile, which already possesses the ideal structure to store this information. Despite the existing conditions, the success of this phase (and of course, the whole strategy) depends on the initiative and participation of the employees to fulfill their personal profile in a correct way. It is precisely because of that factor, that this process will be controlled and validated by the Knowledge Management Officers (KMO; charge incorporated in the first phase of the Organization part's strategy and described in subsubsection 4.1.2.1). The KMO's will assure that all profiles are correctly filled until the end of this phase. It is predicted to have a duration of 2 weeks, where each worker would take 1,5 hour to fill its profile and the KMO would take 1 hour to check and validate the profile.

4.1.1.2 Knowledge Analysis

In the second phase, a comparison is made, through the analysis of the iCEEIA's profile information, between the workers knowledge and the required knowledge to fulfill the respective roles in an efficient way. This phase allows to identify which tacit knowledge lies on AU and who possess it and is able to transfer it. This analysis is made taking into account AU's actual and future needs and it is performed by the KMO's. During this phase the profiles are organized through many characteristics, such as working clients, past experiences, specializations, etc., in order to prepare the developing of the Yellow Pages tool by the IT department (this tool will be presented in subsubsection 4.2.1.1). This phase is estimated to have a duration of 1 month, since a KMO would take 2 hour to analyze a single profile and that would be necessary that 6 persons analyze approximately 75 profiles.

4.1.1.3 Study of Knowledge Subprocesses

The third phase analyzes which is the best way to capture or transfer the knowledge identified in the previous phase, taking into account the situation of the knowledge possessor. In other words, if the knowledge possessor is leaving the company, he will have a completely different attitude while disseminating knowledge than another one who plans to stay. It is also necessary to take in consideration the number of workers who need to capture this knowledge, as well as the complexity of it. The participants of this phase will be the KMO's, since they are the ones in charge of analyzing and decide which is the best way to transfer or capture knowledge in each situation. The processes of knowledge capture and transference will be presented in a detailed way in section 4.2.

The estimated duration of this phase is 2 weeks, taking into account a scenario where 50% of the Design and Stress areas are need to overcome knowledge gaps and that 2 hour would be necessary for a KMO to analyze, individually, the best way to transfer or capture knowledge.

4.1.1.4 Tools Implementation

The fourth phase consists in the implementation of two IT tools: the Yellow Pages and the Quantifier. The goal of the Yellow Pages is to be able to find a worker in the organization through its functions, working projects (passed and current), specializations, among other factors. This tool allows to find who knows what inside AU, in order to help solving problems, perform workshops, or disseminate knowledge in any other way. This tool will be described in more detail in subsubsection 4.2.1.1. The Quantifier is a tool that permits to count the times that a certain document has been useful for project information, in order to determinate which knowledge is crucial inside a project and where it is located. This tool would be described in subsubsection 4.2.1.2.

Both of these tools are expected to be developed by CEIIA's IT department and monitored by the KMO's who know how it works and promotes its use to the other workers. The estimated time do develop the Quantifier tool is of 55 days (including one test week), while the Yellow Pages tool is of 30 days (also including one test week). However, while Quantifiers can be developed from the project's start, the Yellow pages can only start being developed after phase 2 - Survey of Competences - have ended, thus this one organizes all the necessary information for developing this tool. The KMO should communicate with the IT department, in case of finding any inconsistency with these tools.

4.1.2 Organization

This part aims to fulfill the following goals, through a set of 4 distinct phases, each one with a crucial role and purpose in the established strategy:

- Validate knowledge and its processes;
- Control Knowledge Processes;
- Assure knowledge's capture and accessibility by AU's employees;
- Overcome knowledge gaps, i.e., to have the necessary knowledge (present and future) to overcome any necessity.

4.1.2.1 Department's Creation

The first phase of the Organization is to create a KM department (as shown in figure 4.2) in order to validate, apply and control the strategy development along with AU's knowledge. This department would be formed by experience workers who are used to AU's working process and will be in charge of monitoring each implemented tool and measure along with its application and respective output. The structure of this department is based in ESOC's and ESA's Organization (described in subsubsections 2.5.3.5 and 2.5.3.4).

Figure 4.2: KM department inserted in the AU's structure.

This department would possess 2 distinct roles, vertically organized by the following order:

- Knowledge Management Leader (KML)
- KMO

The KML would be the Head of the KM Department, in charge of controlling and managing the entire KM strategy in a global scale. He would be responsible for validating knowledge processes (such as knowledge capture or transference processes), evaluating the strategy's efficiency, expenses and outcomes and consequently, any necessary alteration in order achieve the strategy's goals.

The KMO would act only in a single area (Stress or Design), being responsible for the area knowledge in a specific project,controlling the internal KM processes and also easing the transference of knowledge and information between different areas. The KMO would need to be fully aware of the projects development and understand the implemented tools and methodologies along with its objectives, in order to promote its use. This role would be also responsible for knowing which knowledge it is necessary for the project, if it is stored in AU and what is the best way to capture or transfer it. Besides these functions, the KMO would be responsible for validating the area knowledge and to decide which are the best ways to capture, transfer or generate area knowledge inside the project. The internal structure of the KM unit is represented in figure 4.3.

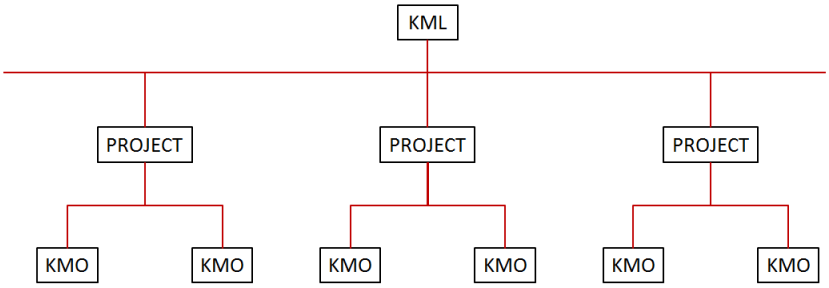

Figure 4.3: Structure of the KM Department

In addition to the described functions of the previous roles, there will be some extra local functions in the different phases of this strategy. Taking into account that AU is actually involved in three projects, the KM Unit should be formed by a total of 7 workers - one KML and 6 KMO's (2 for each project).

After creating the department and decide which members should integrate it, the first step would be to call a meeting to discuss the following topics:

1. Clarify roles and functions;
2. Align and clarify the strategy details;
3. Establish Knowledge's processes and its applicability;
4. Establish deadlines between phases;

This first meeting would occur in the first week of the implementation. These type of meetings are crucial to the strategy's development, since they allow to control the strategy's course and its details. It is estimated a duration of 4 hours for each meeting. The periodicity of these meetings should be settled by the KM Department, taking into account their current necessities (it should not be longer than 1 week).

4.1.2.2 Study of Knowledge Subprocesses

The second phase of the Organization is also the third phase of the Identification (described in subsubsection 4.1.1.3. Besides identifying the best way to disseminate and capture knowledge according to each situation, this phase also intents to organize those methods in order to apply them in similar situations that might occur in the future. It is necessary to keep track of the methods and organize them through reasons and conditions that led to their application. The table 4.2, on subsection 4.2.1 contains the identified knowledge transference and capture methods, organized through their knowledge nature (explicit or tacit) and the reason why is necessary to apply the same method.

As described in subsubsection 4.1.1.3, the participants of this phase will be the KMO's, since they are the ones in charge of analyzing and decide which is the best way to transfer or capture knowledge in each situation.

4.1.2.3 Application

This phase intends to put in action all the planed processes that were established in the previous phase. As in phase 3, the KMO's are the ones who control the established processes, assuring that their success is achieved.

They evaluate the processes and propose alterations or the inclusion of new ones to the KML (responsible for validating knowledge processes).

The duration of this phase would depend of the applied subprocesses (described on 4.2). But taking in account the estimated participants of the previous phase, the Application would have a maximum duration of 3 weeks. It is also necessary to take in consideration that after overcoming the knowledge GAPS, the user have to update their profile in iCEIIA, in order to have a real description about their know-how. This process is also controlled by the KMO's, who have to verify if the profiles are updated. It is estimated that the update of each profile will take 0,5 hour to be updated by the worker and 0,5 to be checked by the KMO.

4.1.2.4 Maintenance

The final phase of the Organization aims to control all the established processes in the previous phases, in order to have an agile strategy that is able to adapt to what the future will bring. As maintenance processes the KM department would have to:

- Update the workers information about their knowledge every time that a worker obtains a new skill, captures a specific knowledge or that the profile information is outdated (e.g. project participation, frequented workshop, etc.).
- Verify that iCEIIA's personal profile is filled every time that a new employee enters in AU.
- To perform a Comparison phase every time a new project is started, in order to find out if there is any necessary knowledge that the workers are missing and that is crucial to the project.
- KMO and Team Leaders must be aware of the knowledge level in their areas, in order to identify if it is necessary to disseminate any kind of knowledge and what is the best way to do it.
- Verify the efficiency of the knowledge processes and update or change it according to its necessities.
- Control the inserted tools usage and performance and communicate problems to the IT department.

This maintenance process might require even more actions, depending on the workers feedback, the strategy adequacy to the Stress and Design areas and the existence of unpredicted situations that might occur. The necessary interventions and maintenance processes are decided by the KM department who is responsible for the strategy's success.

4.2 Strategy Processes

This is a knowledge based strategy, which implies that all the established phases and respective processes are also knowledge based. The processes' knowledge based nature also implies their insertion in the established KM Cycle (see figure 2.3), since each process is associated to one of its phases. Due to this factor, it is possible do divide the processes according to their nature:

- Vision, Search and Control Process
- Creation Process

- Capture Process
- Transference Process

Although the focus of this strategy aims for the first three phases of the KM Cycle, the phase of "Vision, Search and Control" also has a part on it. This phase occurs each time that a decision has to be made (such as which knowledge should be captured or need to be created), taking in consideration AU's needs and goals, which makes it a linking element between the other phases that eases the transition between them, being crucial for strategy's success.

The following subsections will describe these processes, along with the included subprocesses and respective participants.

4.2.1 Vision, Search and Control Process

This process is formed by a set of subprocesses that intents to control the KM strategy and perform connections between the different phases of the KM process, making a crucial element of this strategy. This process is inserted in phases 1, 3, 4, 6 and 7 from the strategy and aims to achieve the following goals from Identification and Organization parts:

- Identify the crucial project knowledge;
- Identify which are the best knowledge processes and the ideal conditions to be applied;
- Identify which tacit knowledge AU wants to capture and disseminate through its employees, taking in account its actual and future needs;
- Overcome knowledge gaps, i. e., to have necessary knowledge (present and future) to overcome any necessity;
- Control Knowledge Processes.

This process is formed by the following set of three subprocesses:

1. Control Meetings
2. Knowledge Analysis
3. Identification Tools

The first subprocess match exactly with the control meetings performed by the KM Department, that were presented and described (in the previous section) in phase 1 (and its maintenance on phase 7) of the KM strategy, while the second subprocess is represented by phases 3 and 4 (and its maintenance on phase 7) of the KM strategy(see figure 4.1). As described on the precious section, this subprocess aims to identify the existent knowledge gaps as well as their respective solution, either being through the creation of nonexistent knowledge or through knowledge dissemination inside AU. The desired knowledge involved in this processes depends of two factors: its complexity and the situation of the knowledge possessor. These factors have a direct influence on the processes of creation, capture and transference, since different situations (such as retirement of the knowledge possessor,

changing company, project necessity, etc.) require different methods, each one more suitable for a particular case. Table 4.2 represents a set of different possible cases along with its respective possible and more suitable solutions.

KNOWLEDGE	SITUATION	SOLUTION
Tacit	Retirement	Mentoring Interview
	Change of Function inside AU or changing unit	Mentoring Interview
	Leaving CEIIA	Mentoring
	Critical Project Knowledge	Mentoring Workshop/Training Interview
	Difficulty in surpassing Problems (create Knowledge)	A3
Explicit	Useful Knowledge inside AU	Debriefing Presentation Documents Access

Table 4.2: List of possible reasons to disseminate knowledge and the respective solutions.

The third subprocess is represented by phase 6 of the KM strategy, which consists on the implementation of two CSCW tools, developed by CEIIA's IT department: Yellow Pages and Quantifiers. Both of these tools, as well as their respective use, will be explained in the following subsubsections.

4.2.1.1 Yellow Pages System

This tool consists in the creation of a system that captures the main know-how and experience of each worker (profession, clients, projects, skills, etc.), enabling to find the employees (by categories or with the help of a search engine) who have a specific knowledge in their possession. For example, if some employee has a problem leading with composites, he could look on the Yellow Pages for someone who has the experience in that matter, in order to have someone who can guide him in the right direction. The Yellow Pages system is supposed to be developed by CEIIA's IT department.

This tool would manage to find any work through it's name, projects participation (inside and outside CEIIA), clients that he worked with, performed functions, performed studies, belonging area (or former area(s)), working tools (e.g. CATIA V5, ANSYS, etc.) skills (e.g. knowledge in composites manufacturing procedures) and others (such as mentoring of Master Thesis or information about some article that the employee wrote for a scientific journal). This tool would take advantage of iCEIIA's structure, since it is prepared to register all this information.

This tool would be able to find workers through a search engine which contains a filter with the following fields: name, clients, projects, tools, skills, functions and area. Besides this search engine, the user will also be

able to navigate through a menu were he can select one or more of the mentioned fields in order to focus his search in a more specific parameter. For example, if the user selects CLIENT_X as client and CATIA V5 as tool, it will appear a list of everyone who has worked with CLIENT_X and also used CATIA V5.

The Yellow Pages system has the potential to ease knowledge transference between workers, along with time saving when looking for the right solution and tracking where is and who has the specific knowledge. CEIIA's IT department estimated that this tool would take 8 days to be developed and 2 more days to be tested.

4.2.1.2 Quantifiers

This tool has the potential of quantifying the useful access to certain documents/files, in order to determinate which ones are more consulted and important to the project, area or even unit. These allows to recognize which information/knowledge is more crucial in a project and also which one the new guys should consult/acquire. By having access to this information, AU can optimize the data and information organization and also to determinate which is the best way to disseminate that knowledge through its employees.

This tool consists on a pop-up window that would appear each time that a closed document (a document which is in its final state and that would not suffer any further content change) is closed, where the user has the option to mark one of these two options:

1. The documents/file was useful, taking in consideration my intentions .
2. The document/file was not useful, taking in consideration my intentions.

The results would be stored in a proper data repository, where this tool could also perform charts with the most useful documents/files. CEIIA's IT department estimated that this tool would take 15 days to be developed and 3 more days to be tested.

4.2.2 Creation Process

By analyzing AU's goals and ambitions, the KM Department is able to determinate which knowledge can be created in AU in order to achieve its objectives in a more effective and efficient way. This process is formed by a set of measures that will be established by the KM Department, in order to obtain the desired knowledge. This process is inserted on phases 5 and 7 from the strategy (see 4.1) contributes to achieve the following goal of the Identification part: "Identify which tacit knowledge AU wants to capture and disseminate through its employees, taking in account its actual and future needs."

One identified subprocess that constitutes the Creation Process is the A3 (described in subsubsection 3.4.1.3). When facing a particular problem that has an unknown root cause, a superior worker (such as a Team Leader, Technical Manager or KMO) should propose the other worker to do an A3 template, in order to try to overcome the problem. This proposed has to be communicated to the respective KMO, since this is the one who is going to validate the process. The A3 can also be auto proposed, but it always needs to have the permission of both Team Leader (or Technical Manager) and KMO. The A3 subprocess is described succinctly in table 4.3.

Subprocess	A3
Description	Template used by a single worker, in order to realize what is the real source of the problem he is facing and how to surpass it - acquiring of know-how (presented in subsubsection 3.4.1.3).
Number and Nature of Participant(s) / Duration	Single Worker / 5 hours
Subprocess Validator(s) / Duration	KMO / 5 hours
Output taker	- The worker increases its knowledge spectrum - The filled A3 is stored in a specific section of GSD - Update of iCEIIA's profile

Table 4.3: Subprocess A3.

4.2.3 Capture Process

The capture process intents to capture and store two different things: explicit knowledge and the past experience of the worker (in order to know its specializations, skills and know-how areas). This process also aims to fulfill the following goals:

- Identify the existent explicit knowledge and where it lies;
- Control Knowledge Processes;
- Assure knowledge's capture and accessibility by AU's employees.

The capture of the worker's past experience is a subprocess represented and described on phase 2 of the KM Strategy, while the capture of explicit knowledge is represented on phase 5 and can be split in three subprocesses (that are fully described on tables 4.4 - 4.6):

1. Interview
2. LL
3. Documentation

Subprocess	Interview
Description	This subprocess is used to capture a routine, a story or a lot of not complex knowledge through an interview performed by the worker as the interviewed and by the KMO as the moderator. This interview can be filmed, audio recorded or written and it will be edited by the IT and approved by the KMO.
Number and Nature of Participant(s) / Duration	Single Worker, KMO and IT worker / 5 hours, 5 hours, 3 hours
Subprocess Validator(s) / Duration	KMO/ 3 hours
Output taker	- The filled A3 is stored in a specific section of GSD - Update of iCEIIA's profile

Table 4.4: Subprocess Interview.

Subprocess	LL
Description	Template used by a single worker, in order to capture the solution to solve a particular problem (presented in subsubsection 3.4.1.2).
Number and Nature of Participant(s) / Duration	Single Worker / 2 hours
Subprocess Validator(s) / Duration	KMO / 1 hours
Output taker	- The filled LL is stored in a specific section of GSD - Update of iCEIIA's profile

Table 4.5: Subprocess LL.

Subprocess	Documentation
Description	Capture of explicit knowledge through documents such as slide shows, technical reports, presentations, etc..
Number and Nature of Participant(s) / Duration	Single Worker / 3 hours
Subprocess Validator(s) / Duration	KMO / 1.5 hours
Output taker	- The document is stored in a specific section of GSD. - Update of iCEIIA's profile

Table 4.6: Subprocess Documentation.

4.2.4 Transference Process

The transfer process takes place after the control process has established which knowledge is necessary inside AU, who is going to transmit it and on which way. This process is represented in phase 5 of the KM strategy (see figure 4.1) and aims to achieve the following goals:

- Assure knowledge's capture and accessibility by AU's employees;
- Overcome knowledge gaps, i.e., to have the necessary knowledge (present and future) to overcome any necessity.

The knowledge transference allows to level AU's knowledge and also to capture inside each individual in order to be transmitted later when necessary. This process is composed by three different subprocesses (that are fully described on tables 4.7 - 4.9):

1. Debriefing / Presentation
2. Mentoring
3. Workshop / Training

Subprocess	Debriefing/ Presentation
Description	Ideal method to transfer explicit knowledge to a vast number of receptors, where someone or a small group, explain and present a certain theory, knowledge, procedure to the audience.
Number and Nature of Participant(s) / Duration	Audience (10-40 workers) and Knowledge Possessor / 1-3 hours (each)
Subprocess Validator(s) / Duration	KMO with the Team Leader or Technical Manager's feedback/ -
Output taker	- The worker increases its knowledge spectrum - Update of iCEIIA's profile

Table 4.7: Subprocess Debriefing/Presentation.

Subprocess	Mentoring
Description	Subprocess of transference involving complex knowledge, where a single collaborator follows and works in collaboration with a more experienced one, with the purpose of learn and absorb the maximum possible knowledge. (described on subsubsection 2.5.2.2).
Number and Nature of Participant(s) / Duration	Single Worker and Knowledge Possessor / 1 month (40 hours of usefull time)
Subprocess Validator(s) / Duration	KMO with the Team Leader or Technical Manager's feedback (if possible) / -
Output taker	- The worker increases its knowledge spectrum - Update of iCEIIA's profile

Table 4.8: Subprocess Mentoring.

Subprocess	Workshop / Training
Description	Transference of complex knowledge to a small group, that requires participation of the knowledge receptors in order to be effective.
Number and Nature of Participant(s) / Duration	Small group of workers (5-10) and Knowledge Possessor/ 5-10 hours (each)
Subprocess Validator(s) / Duration	KMO with the Team Leader or Technical Manager's feedback / -
Output taker	- The worker increases its knowledge spectrum - Update of iCEIIA's profile

Table 4.9: Subprocess Workshop.

4.3 Case Study / Possible Application

This section intents to demonstrate how AU would react to a possible new project, applying the delineated strategy on this chapter. In this pictured scenario, AU would have already implemented the KM strategy in the past, which means that phases *1) Department's Creation*, *2) Survey of Competences* and *6) Tool Implementation* would have already occurred. In other words, this scenario already contains: a KM unit who manages the KM activities of both Design and Stress areas; the iCEIIA profiles of all workers are correctly filled, which means that the organization knows the existent knowledge in its workers; and that the implemented tools Yellow Pages and Quantifiers are already familiar and currently used by the workers.

Hypothetical supposing that AU takes a new project such as developing the design and stress of the primary structures of a certain aircraft, the first step to follow in the strategy is phase number *3) Knowledge Analysis*. In this phase, the necessary knowledge to fulfill the project is identified and compared to the one existent in AU. The necessary knowledge to perform a project such as this is the same knowledge that is identified in section 3.2. Through the knowledge comparison, lets suppose that AU faces the following problems:

1. Lack on Knowledge in FT&A;
2. Lack of Knowledge in PSS;
3. Lack of Workers.
4. Lack of specific knowledge regarding the client's norms, rules and way of working.

The following step on the strategy is to follow phase *4) Study of Knowledge Processes*, which aims to find out the best way to overcome the knowledge gaps the were detected in the previous phase. Each knowledge gap solution will be addressed individually.

Since the FT&A is a new tool that is starting to appear in the Aeronautical Projects, it is common that the major parts of the organizations do not have experience in this tool. Since the use of this tool is a requirement of the client, this means that the client might also possess this kind of knowledge. If this is the case, the proper solution should be to negotiate with the client, in order to disseminate this knowledge through AU. In case of this knowledge not be in the client's possession, it is necessary that AU hires one or more experienced workers that might be able to disseminate through the rest of the workers. Besides the presence of some experienced worker(s), this knowledge is also going to be obtained through experience (learning on job) and can also be complemented with documents such as training, presentations or learning manuals.

The PSS system differs from client to client since each one has each own, that is why is necessary to have some client representative that is used to work with the software in order to pass that knowledge to AU's workers. As the FT&A the knowledge of this tool is also gained by experience (learning on job) and can also be complemented with documents such as presentations or learning manuals. These proposed solutions are the exactly the same ones that are proposed to overcome the lack of specific knowledge regarding the Client's norms, rules and way of working, thus the conditions of both problems are very similar.

The lack of workers can be overcome through the simultaneous hiring of two types of workers: junior and senior, hiring more juniors (that might need a initial training given by AU) than seniors. The teams will also

be formed with more junior members than seniors, which will allow the seniors to guide and disseminate their knowledge through the juniors (Mentoring). In this way, knowledge would also be captured by the juniors which represents the capture and and maintenance of knowledge in AU. Beside the seniors guidance, the juniors will also learn by experience (learning on job) and by consulting documents such as presentations, international norms or manuals.

After comes phase *5) Application*, where all the measures that where decide in phase *4* are implemented. Finally comes phase *7) Maintenance*, which assures that the knowledge is being disseminated in the right way, that the workers have enough knowledge to achieve AU's goals and that knowledge is being applied in the right way. In this specific case, phase *7* would assure that:

1. The proposed measures to overcome the knowledge gaps were successful;
2. The overcome of new or even remaining gaps;
3. The workers were following and answering to the needs and goals that keep coming through the project development.
4. The iCEIIA profiles were correctly updated every time that was necessary, in order to have the most recent possible information;
5. The Yellow Pages and Quantifiers tools were being correctly used and understood by AU's employees;
6. The unexpected drawbacks and anomalies are solved in order to assure the strategy's suitability.

4.4 ROI

This section aims to establish real measurable goals to the strategy (and all its processes),as well as its duration and returnable value.

4.4.1 Annual Goals

In order to have a quantitative target in the KM Strategy, it is necessary to establish quantitative goals and milestones, so that the KM Department can keep track on the strategy's development and suitability to the actual facing situation. These goals will serve as reference points allowing the KM Department to compare its initial predictions with the reality that they are facing it, giving the perception if the strategy is suitable or if it is being conducted in the most efficient way. The established goals are predicted values for the strategy's outcome after a year starting from the first implementation day:

- Having a minimum of 70% of the iCEIIA profiles correctly filled and updated.
- The IT tools Yellow Pages and Quantifiers have to be completely functional and without flaws, six months after the first day of implementation, in most.
- At least 50% of the workers have to understand and work with the IT tools Yellow Pages and Quantifiers.
- More than 65% of the detected flaws were attempted to solve.
- At least 50% of the detected flaws were successively solved.
- Understand if the strategy is effective to AU's actual situation.

4.4.2 Estimated Time and Cost

In order to estimate the strategy's implementation time and cost it is necessary to determinate what is going to happen in the Application phase. Since this one depends on the outcome of the previous phases, a hypothetical scenario will be considered, with the purpose of estimating the duration of this phase. In this hypothetical scenario, the Application phase is formed by:

- Training in CATIA V5 of 5 Junior employees with a duration o 1 month;
- Training in Nastran Patran of 5 Junior employees with a duration o 1 month;
- Training in FT&A of 15 workers with a duration of one week;
- 3 Workshops in Product Structure Software, each one with the participation of 12 workers and one moderator. Estimated duration of 10 hours.
- Workshop of Leadership with the participation of 15 workers and one moderator. Estimated duration of 4 hours.
- One presentation of 4 hours, regarding interpretation and appliance of Certification and Regulation, with the participation of 36 workers and one moderator.
- Presentation of 5 hours regarding support systems, with the participation of 36 workers and one moderator.
- 2 Mentoring Process with a Stress Project Technical Managers (2 different projects) with a duration of 1 months.
- 2 Mentoring Process with a Stress Project Technical Managers (2 different projects) with the duration of 1 months.

With this scenario it is possible to calculate the cost of of the whole strategy in working hours, which is represented on figure 4.4. In this calculation, it was added a safety factor of 30% to the sum of working hours, in order to cover delays, unpredicted or unexpected situations and strategy's adjustments.

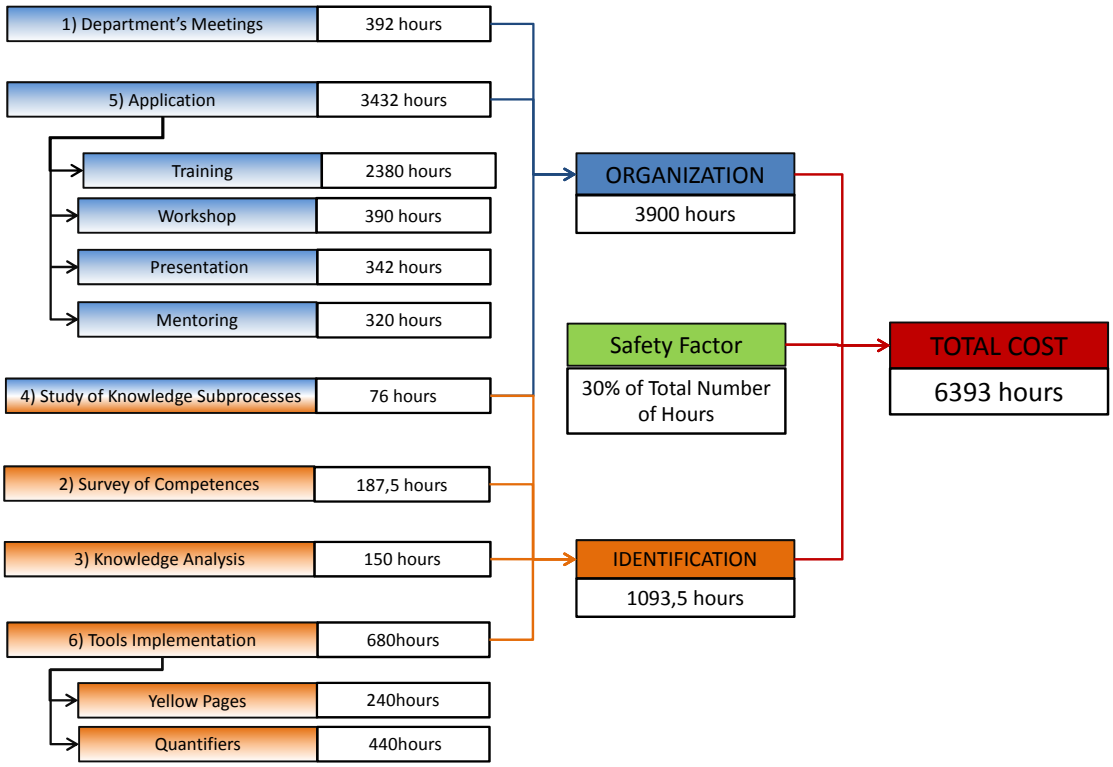

Figure 4.4: KM Strategy Cost in Working Hours

With the previous calculated hours and the established duration of each KM strategy's phases (predicted in section 4.1), it is estimated that the total duration of this implementation (from phase 1 to 6) should be of 18 weeks, i.e., 4,5 months. The following figure 4.5 represents a Gantt chart of the strategy's phases, showing the duration and chronological order of each one. As well as the cost in working hours, a safety factor of 30% was also added to the strategy's duration.

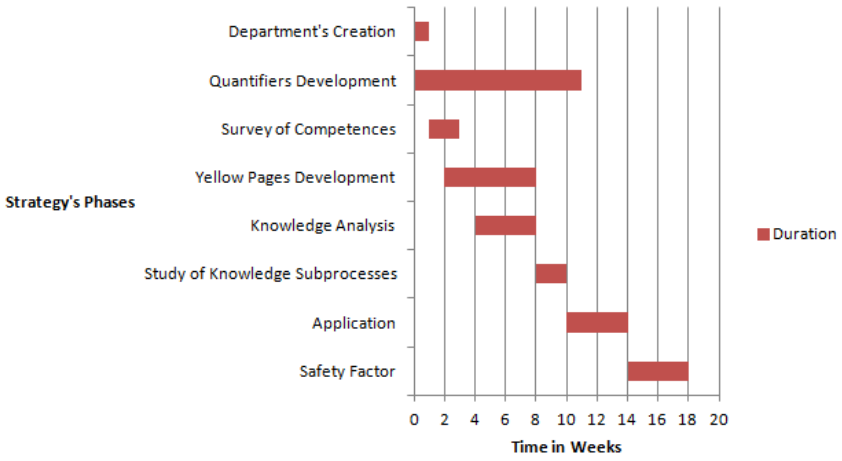

Figure 4.5: Gantt chart of KM Strategy's Phases

4.4.3 Returnable Value

The implementation of this strategy will allow AU to develop a unit only dedicated to KM, which it will be responsible of tracking which knowledge lies in AU, where it lies (either documented knowledge or worker's tacit knowledge), which knowledge is missing in AU, where are the knowledge gaps and what are the best ways to surpass those gaps. This unit will be responsible for organizing knowledge and all its associated processes, making CEIIA a more organized company and consequently a more efficient one. It is quite difficult to predict quantitative outcomes when the subject is something so complex and abstract as knowledge, however this strategy was conceived in a way where it is possible to track AU's situation in order to have a quantitative perception if the organization is achieving its goals in an efficient and effective way.

However, after its implementation it is possible to measure the ROI with more precision, using the metrics presented in 2.4. Not all of these metrics are suitable to evaluate this strategy since its goal is to identify and organize AU's knowledge. The metrics and criteria that can be used in a future ROI evaluation are:

- Efficiency - analyze the evolution of employees' consumed time when performing their tasks.
- Quality - analyze the evolution of the product's quality.
- Knowledge sharing - analyze the number of workers who participate in the knowledge sharing processes, the evolution of knowledge level since the introduction of KM and compare the use of external knowledge *VS.* internal knowledge (created inside the organization).
- ISO 9000 - the number of anomalies during certification
- Training - analyze the cost related with the employee's training.
- Customer satisfaction - analyze the level of the client's satisfaction with the performed job.
- Reputation - analyze the company's reputation.
- Business - the evolution of business, verifying if there was a positive or negative financial turnover.
- Cost Control - analyze if the established KM strategy, as well as other internal project and functional costs have exceed the predicted budget.

As the annual goals, ROI should also be calculated annually, thus KM does not produce immediate results right after its implementation and ROI's calculation requires mature information in order to be reliable. With the data gathered from the calculation of the first ROI, it is possible to elaborate a more quantitative prediction and judgment about the KM's role in AU. However, it is necessary to establish intermediate evaluations, that allow studying the strategy's evolution. Unlike the meetings referred in 4.1.2.1 that only gather data and control the strategy's processes, the evaluations are responsible for evaluating the strategy's suitability and changing it, so it can accomplish it's goals.

Figure 4.6 represents the strategy's intermediate evaluations (with a duration of one week), until it's final evaluation, where ROI is calculated for the first time. The fist intermediate evaluation will occur 6 months after the first week of implementation (week 24), in order to evaluate the strategy's implementation and assure that the strategy is running on the established conditions. The second intermediate evaluation will occur 6 months after the first one (week 48), with the goal of evaluate the strategy's suitability and take actions to guarantee its success. At last, the final evaluation will occur one year after the implementation have ended (week 66 - 1 year and 4,5 months

after the implementation started), where the first ROI will be calculated, enabling to gathering of reliable data to study the strategy's evolution, impact, outcomes and also to predict the strategy's outcome for the following year.

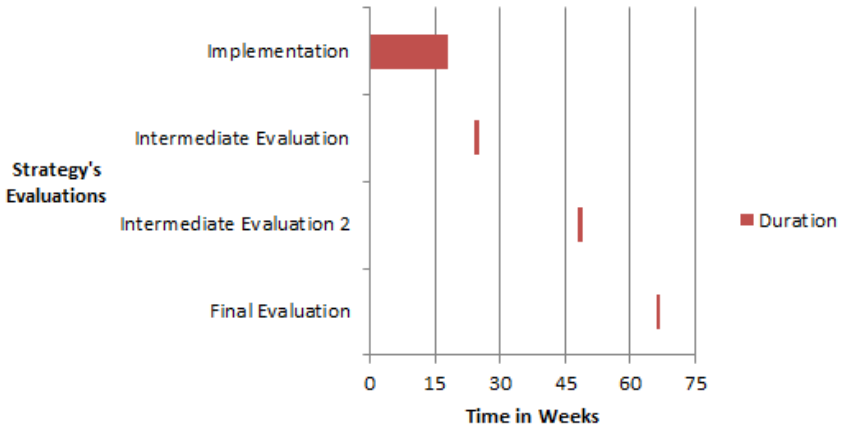

Figure 4.6: Gantt chart of the Strategy's Evaluations.

Chapter 5

Conclusion

The primary goal of this thesis was to implement a KM strategy to the development of aeronautical structures in CEIIA's AU . First, it was conducted a bibliographic search in order to understand the meaning of KM, its integrating processes and its role in nowadays aeronautical and aerospace industries.

Afterwards, it was gathered enough material in order to understand AU's actual situation: its workload, way of working, available resources and knowledge related difficulty's. The gathering of this information was essential for the strategy's planning since AU does not have any kind of KM structure implemented i.e. this strategy will be the first step of AU (and even CEIIA) in the KM world and has to be synchronized with the organization and answer to its needs, in order to be as flawless as possible.

The developed strategy is concentrated in the AU's knowledge Organization, thus apart of being the main root of AU's knowledge difficulties, it is also the foundation of each KM structure, since an organization can only seek to innovate and improve its knowledge after identifying and organizing the one that already possesses. It is predicted that the implementation of the elaborated strategy would imply in the following advantages/benefits to AU:

- Identification and Organization of AU's knowledge (either tacit or explicit);
- Identification of Knowledge Gaps among workers, as well as the best way to surpass them;
- Improvement of access to knowledge or knowledge possessors;
- Faster knowledge dissemination and application;
- Decrease the Knowledge discrepancy among employees;
- Increase the worker's knowledge level;
- Faster Development of AS;
- Increase of AS's quality;
- Reduction of the Development's cost.

This strategy will primarily be applied only to the Stress and Design areas (the areas with more workload) in order to study and evaluate its impact and suitability.

Due to the abstract and complex nature of knowledge, predict the quantitative outcome of a KM strategy becomes an inaccurate and unpredictable job. However, a set of measurable goals were established (along with a

respective deadline), that will help to evaluate the strategy's effectiveness and suitable to its real situation. It was also possible to measure the cost of the strategy implementation and also the cost of some maintenance processes and subprocesses in working hours: 6393 hours. It is not possible to make a more quantitative prediction without any kind of background data regarding these type activities.

It is impossible to obtain immediately outcome of this strategy, due to its content's nature. One year after the implementation is finished, is the minimum time to recover proper data that will allow to evaluate the strategy's suitability and also to make a more quantitative prediction for future ROI. Since the total implementation time is 4,5 months, the evaluation of the strategy should be made 1 year and 4,5 months after the first implementation day, this is, if the strategy does not suffer any kind of significant drawback that would delay the established processes.

This thesis does not present the outcome of this strategy, since the strategy's application and data gathering to perform a reliable ROI calculation would consume almost 1,5 year which already gets out of the established time to perform a Master Thesis.

However, the strategy's implementation and respective intermediate evaluations are future work to be done, where it is expected that the strategy might suffer changes in the future, since it must adapt to the upcoming eventualities, such as: strategy's suitability, unforeseen situations (that are only perceived in practice), industry's demands, changing of AU's necessities and goals or technology's progress. It is necessary to change it until it reaches success and is able to accomplish its goals.

After proving that the strategy is successful, it is necessary to evolve it, either by aiming to improve/solve the remaining difficulties addressed by the workers (in table 3.3), searching for new challenges or looking for other goals inside KM (such as innovation methods). Finally, the strategy's target should increase its scope and become addressed to all AU or even all organization, turning CEIIA in a complete KM working company. This would have to take in consideration each different area and its goals as well as its own way of working, because the same strategy that is applied to AU might not be suitable to the Automotive Unit. It is necessary to adjust the strategy to the current necessities and future objectives in the different areas and adapt it through the changes and the upcoming scenarios, thus KM is a constant necessity that evolves through time. As stated in reference [10] "KM is a journey not a destination".

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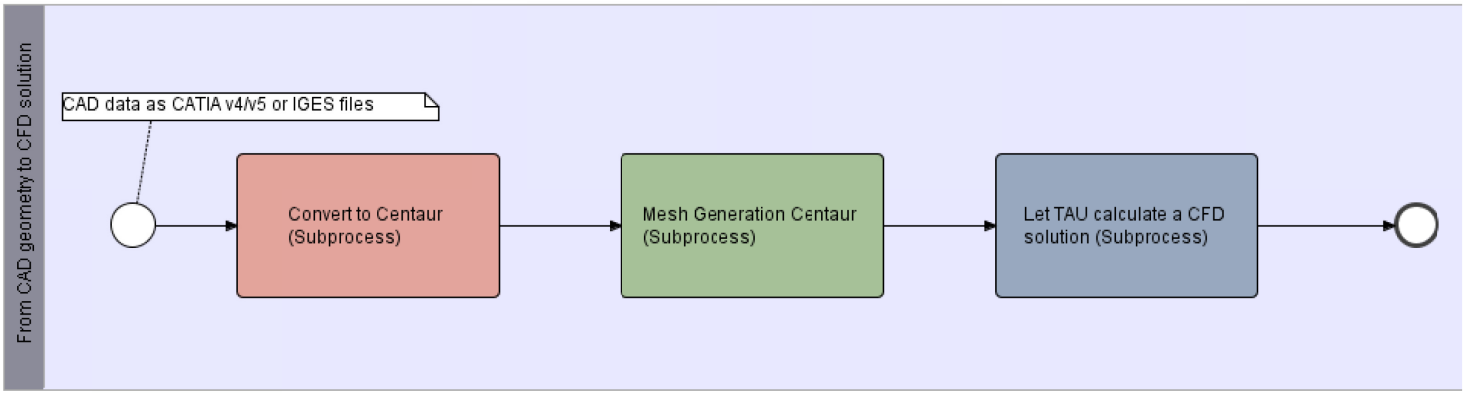
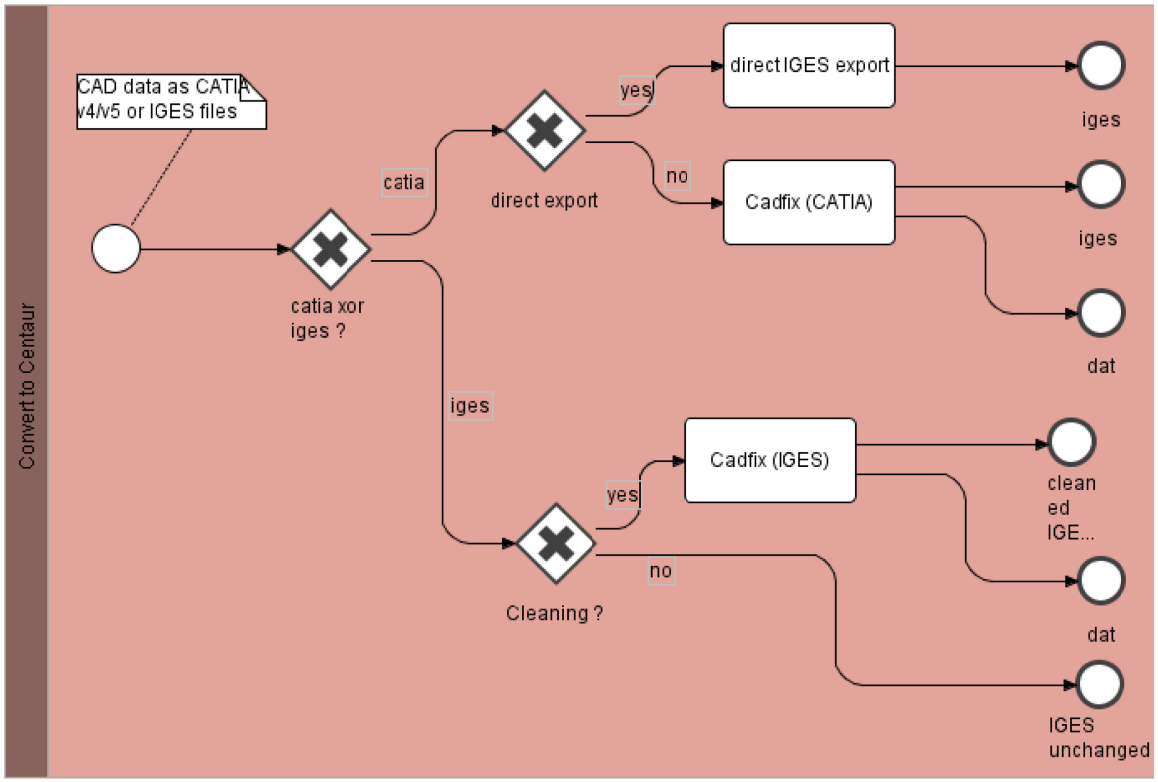
Appendix A

XPS4CFD Examples of Workflow, Rules Template and Forms template

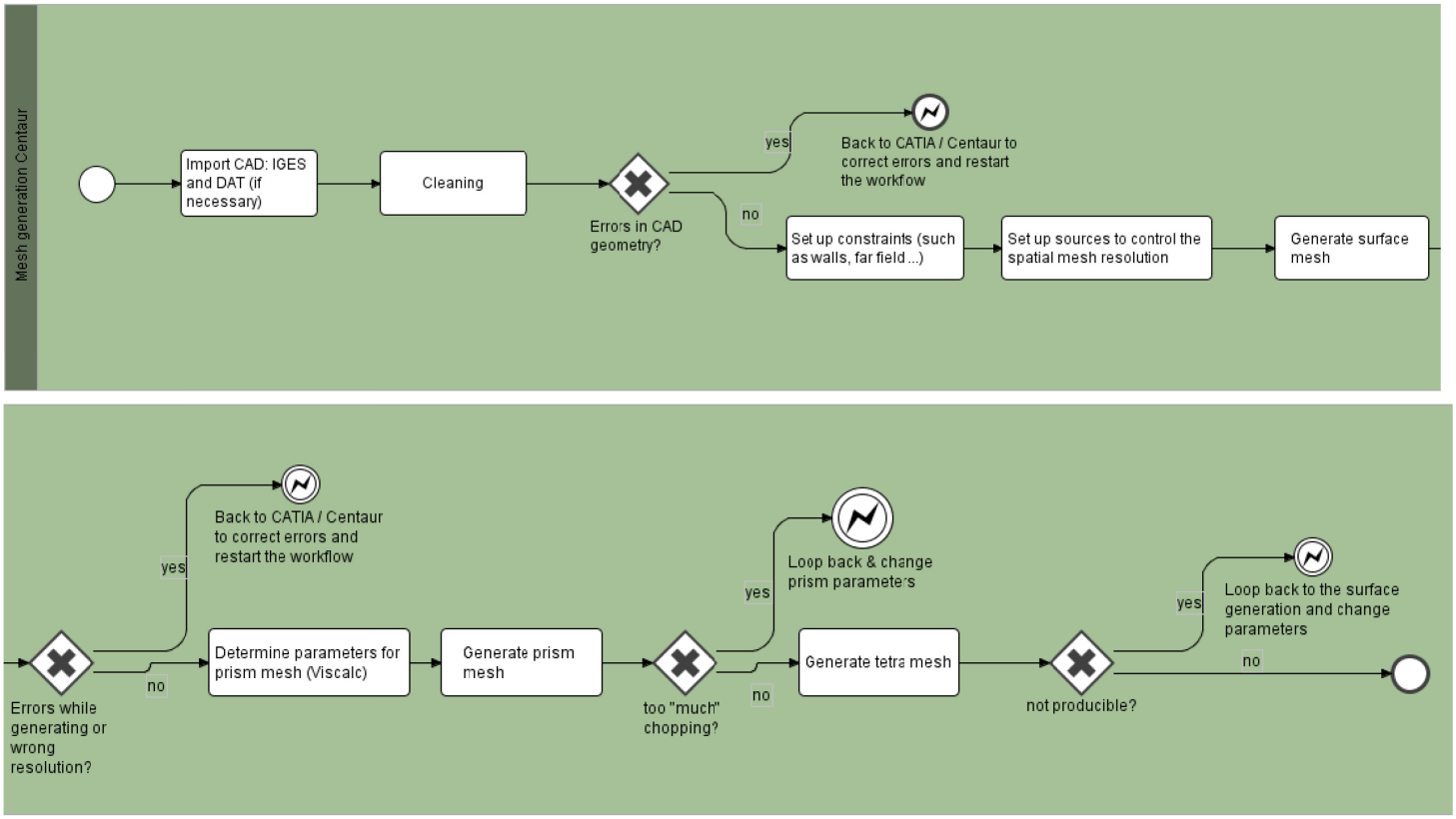
Guiding Users Through a TAU Workflow (1)



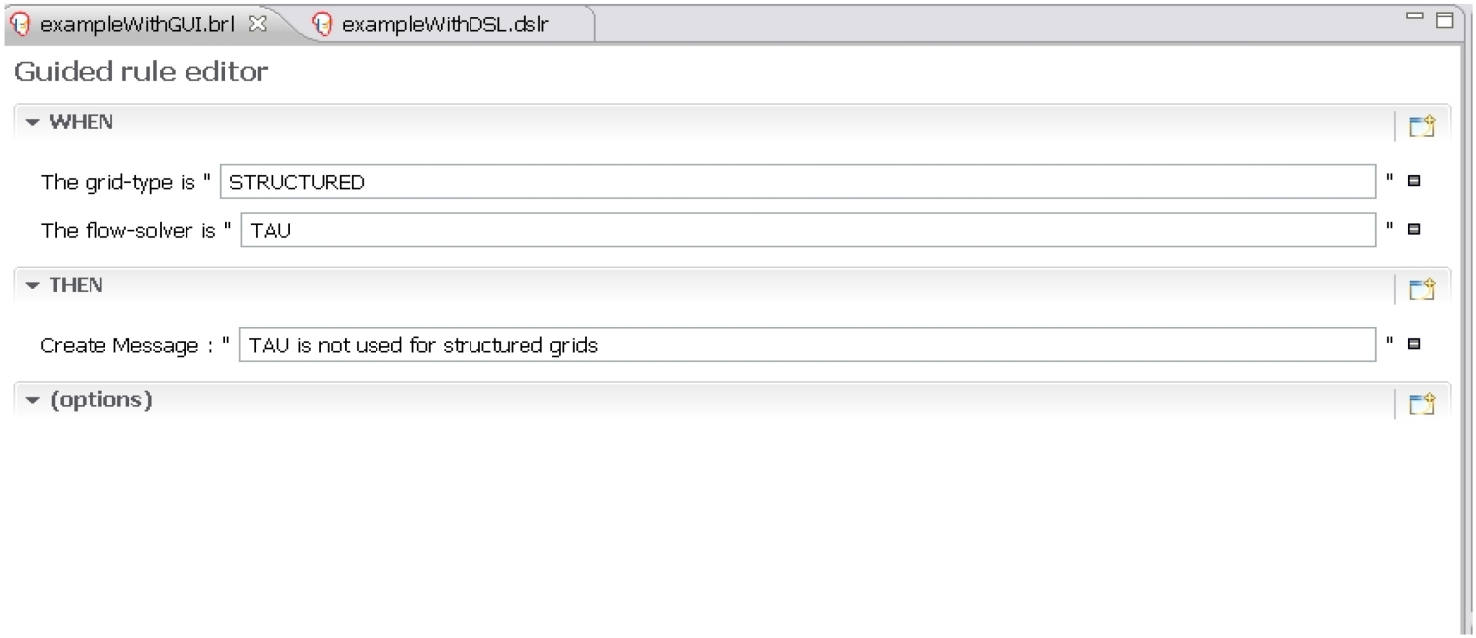
Guiding Users Through a TAU Workflow (2)



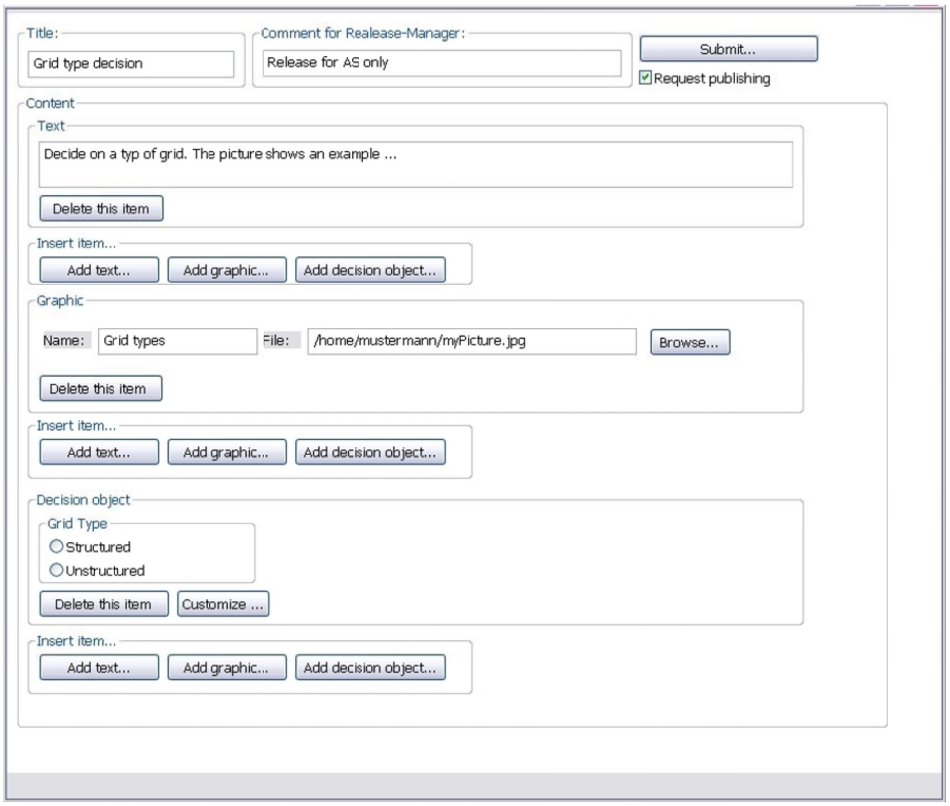
Guiding Users Through a TAU Workflow (3)



Creating Rules



Creating Forms



Appendix B

Query about CEIIA's Knowledge Processes and State

1. **How and where is the project's explicit knowledge stored?**
2. **What are the performed procedures to store it?**
3. **Do the workers usually follow these procedures?**
4. **What are the main difficulties/problems concerning these procedures?**
5. **Is there any type of quantification concerning the capture of explicit knowledge?**
6. **How is the tacit knowledge transmitted and captured inside CEIIA?**
7. **Are these activities/procedures registered?**
8. **What are the main difficulties/problems concerning these procedures?**
9. **How is the knowledge disseminated between different areas?**
10. **What are the main difficulties/problems concerning these procedures?**

Appendix C

Lessons Learned Template

LESSONS LEARNED CEIIA

Title (120chars)		Author	Role	Dept	Date
Remoção rápida de fillets e furos		André Silva	Eng CAE	PAR – Estruturas e Mats	25-4-2012
REF	**Area**	**Approved by**	**Role**	**Dept**	**Date**
LL-CAE-PAR-2012-001	**CAE**	Bernardo Marques	RA CAE	PAR – Estruturas e Mats	30-4-2012
Distribution	~~**Public**~~ **/ Restricted**	**Importance**	~~High/Med/~~ Low	**__campo 3**	

Issue	Solution / Lesson Learned	Keywords
• Tarefa de remoção de fillets e furos para modelo de elementos finitos é morosa e complicada	• Utilizar a função defeature no Hypermesh	• Fillets • Hypermesh • Altair • FEM • Preparação Geometria
Impact	**Observations**	
• Redução no tempo de preparação do modelo • Mais iterações no mesmo tempo	• Apenas para utilizadores experientes • Ficheiro CAD tem de estar OK	

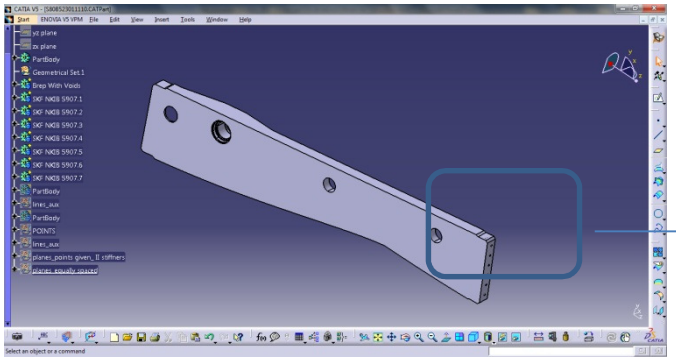


Imagem Representativa do Problema ou Lição Aprendida

Appendix D

A3 Template

Title: What change or improvement are you talking about?

Owner/Date

1. Background: What are you talking about and why?

What is the purpose, the business reason for choosing this issue?

What specific perfomance measure needs to be improved?

What is the strategic, operational, historical, or organizational context of the situation?

2. Current Conditions: Where do things stand now?

What is the problem or need—the gap in performance?

What is happening now versus what you want or needs to be happening?

Have you been to the gemba?

What facts or data indicate there is a problem?

What specific conditions indicate that you have a problem or need?

Where and how much? Can you break the problem into smaller pieces?

➞ Show facts and processes visually using charts, graphs, maps, etc.

3. Goal: What specific outcome is required?

What specific improvement(s) in performance do you need to achieve?

➞ Show visually how much, by when, and with what impact.

➞ Don't state a countermeasure as a goal!

4. Analysis: Why does the problem or need exist?

What do the specifics of the issues in work processes (location, patterns, trends, factors) indicate about why the performance gap or need exists?

What conditions or occurances are preventing you from achieving the goals?

Why do they exist? What is (are) their cause(s)?

➞ Use the simplest problem-analysis tool that will suffice to show cause-and-effect down to root cause. From 5 Whys to 7 QC tools (fishbones, analysis trees, Pareto charts) to more sophisticated SPC, 6 Sigma, and other tools as needed.

➞ Test the cause-and-effect logic by asking "why?" downward and stating "therefore" upward.

5. Recommendations: What do you propose and why?

What are the options for addressing the gaps and improving performance in the current situation?

➞ Always start with two or three alternatives to evaluate.

How do they compare in effectiveness, feasibility, and potential disruption?

What are their relative costs and benefits?

Which do you recommend and why?

➞ Show how your proposed actions will address the specific causes of the gaps or constraints you identified in your analysis. The link should be clear and explicit!

6. Plan: How will you implement? (4Ws, 1H)

What will be the main actions and outcomes in the implementation process and in what sequence?

What support and resources will be required?

Who will be responsible for what, when, and how much?

How will you measure effectiveness?

When will progress be reviewed and by whom?

➞ Use a Gantt chart (or similar diagram) to display actions, steps, outcomes, timelines, and roles.

7. Followup: How will you ensure ongoing PDCA?

How and when will you know if plans have been followed and the actions have had the impact planned and needed?

How will you know if you meet your targets?

How will you know if you reduced the gap in performance?

What related issues or unintended consequences do you anticipate?

What contingencies can you anticipate?

What processes will you use to enable, assure, and sustain success?

How will you share your learnings with other areas?

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