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MODEL DESIGN RECOMMENDATIONS FOR TREATING ROGUE UNITS

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no mundo tereis aflições, mas tende bom ânimo, eu venci o mundo.”.

(João 16:33)

“I have told you these things, so that in me you may have peace.

In this world, you will have trouble. But take heart! I have overcome the world.”

(John 16:33)

Abstract

Logistical support is usually relegated to a second step during the development of projects or products. However, this practice leads to a logistically immature product at the time of delivery to the first operator. One of those issues goes back to the management of Rogue Units, a subset of components whose failure rates differ from other identical items. This phenomenon leads to a decrease in reliability, availability, maintainability, safety and readiness of the involved systems. This work develop a prescriptive model to identify, prevent, and treat problems regarding Rogue Units to during preparation, development and production, to be applied during in-service life cycle phase. The methodology proposed is to delimit the study case thru a full literature review, list the most relevant ILS elements throughout the specialist's opinion and content analysis, deduce recommendations, and validate the recommendations with Focus Group. The contributions of this work include the academy, with a generalisable model for generating recommendations, the industry, with its own generated list, and the Government, with safe guidance on how to improve their acquisition processes by verifying the application of the recommendations generated.

Resumo

O suporte logístico é geralmente relegado a uma segunda etapa durante o desenvolvimento de projetos ou produtos. No entanto, essa prática leva a um produto logisticamente imaturo no momento da entrega ao primeiro operador. Um desses problemas remonta ao gerenciamento de Unidades *Rogue*, um subconjunto de componentes cujas taxas de falha diferem de outros itens idênticos. Este fenômeno leva a uma diminuição na confiabilidade, disponibilidade, manutenibilidade, segurança e prontidão dos sistemas envolvidos. Este trabalho se propõe a desenvolver um modelo prescritivo, a ser aplicado durante a preparação, desenvolvimento e produção, para identificar, prevenir e tratar problemas relacionados a Unidades *Rogue* durante a fase do ciclo de vida em serviço. A metodologia proposta é delimitar o caso de estudo por meio de uma revisão completa da literatura, listar os elementos ILS mais relevantes através da opinião de especialistas e de análise de conteúdo, deduzir recomendações e validar as recomendações com Grupo Focal. As contribuições deste trabalho incluem a academia, com um modelo generalizável de geração de recomendações, a indústria, com a própria lista gerada, e o Governo, com orientações seguras sobre como melhorar seus processos de aquisição verificando a aplicação das recomendações geradas.

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List of Abbreviations and Acronyms

AIA	Aerospace Industries Association of America
ANOVA	Analysis Of Variance
ASD	Aerospace of the Defence Industries Association of Europe
BCA	Business Case Analysis
BIT	Built-in Test
BITE	Built-in Test Equipment
CDR	Critical Design Review
CDRL	Contract Data Requirement List
CMMS	Computerized Maintenance Management System
CONOPS	Concept of Operation
CR	Computer Resources
CTE	Ciências e Tecnologias Espaciais
D&PHM	Diagnostics Prognostics Health Management
DAG	Defense Acquisition Guidebook
DAU	Defense Acquisition University
DI	Design Influence
DOA	Dead-on-Arrival
DOD or DoD	Department of Defense
EMD	Engineering and Manufacturing Development phase
F&I	Facilities and Infrastructure
FRP&D	Full-Rate Production and Deployment phase
IATA	International Air Transport Association, previously the Air Transport Association (ATA)

ILS	Integrated Logistic Support
INCOSE	International Council On Systems Engineering
IPS	Integrated Product Support
ISMO	In-Service Maintenance Optimization
ITA	Instituto Tecnológico de Aeronáutica
LCC	Life Cycle Cost
LCSP	Life Cycle Sustainment Plan
LORA	Level Of Repair Analysis
LRU	Line Replaceable Unit
LSA GC	Logistic Support Analysis Guidance Conference
LSA	Logistic Support Analysis
M&P	Manpower and Personnel
MDA	Milestone Decision Authority
MRO	Maintenance Repair and Overhaul
MSA	Material Solution Analysis phase
MTBUR	Mean Time Between Removals
MTNC	Maintenance
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organisation
NFF	No Fault Found
O&S	Operating and Support phase
O&S	Operation and Service
OCCAR	Organization Conjointe de Coopéracion en matière d'Armament
OEM	Original Equipment Manufacturer
PHS&T	Packaging, Handling, Storage and Transportation
PM	Project Manager

PSM	Product Support Management
PSMGR	Product Support Manager
RAMS	Reliability, Availability, Maintainability and Safety
RAMST	Reliability, Availability, Maintainability, Safety, Security and Testability
REMM	Reliability Enhancement Methodology and Modelling
REMM2	2nd stage of REMM
RFP	Request For Proposal
SE	Systems Engineering
SENG	Sustaining Engineering
SEP	System Engineering Plan
SEQ	Support Equipment
SLR	Systematic Literature Review
SMA	Scheduled Maintenance Analysis
SOW	Statement Of Work
SS	Supply Support
SSA	Software Support Analysis
SSM	Soft Systems Methodology
STAC	Subject to Aircraft Check
T&TS	Training and Training Support
TECHD	Technical Data
TMRR	Technology Maturation and Risk Reduction phase
TNA	Training Needs Analysis
USA	United States of America
V&V	Verification and Validation

Summary

1 Introduction

1.1 Contextualisation

In a complex aeronautical system, during the life cycle stage so-called operation, the main drivers for cost, regarding the whole life cycle, are maintenance and supply chain. At this same stage, around 63%-68% of the total life cycle costs are concentrated (UNITED STATES, 2014). Therefore, reasonable inventory control and maintenance is always an important measure to reduce costs, ensure availability and avoid wastage of financial resources.

In supply management, there is a subset of individuals that have slightly lower reliability than expected, called Rogue Units. These individuals have long been infesting material stocks, causing losses, decreasing availability and rework.

Although problematic, they are challenging to identify and, probably are a consequence of the lack of logistic support maturity of complex systems in new and legacy products (CARROLL III, 2005, 2008; MORTADA et al., 2012).

1.2 Problem definition

When problems similar to those of Rogue Units arise during operation life cycle phase, a typical solution is to try to solve it locally without looking back in the early stages of life cycle development and finding the best systemic approach to the case. Observing the beginning of the project, that is, before the first delivery, may be possible to understand and act to satisfy these new requirements.

Therefore, the systems continue to present problems due to the lack of correct management of Integrated Logistic Support (ILS) throughout the life cycle phases. There is a lack of tools to identify the problem and the consequent lack of support for the first operators. Added to this, diagnostic errors further enhance the problem of resource mismanagement, and the erroneous solution orientation can be repeated (SÖDERHOLM, 2007).

Furthermore, the current literature is not clear regarding the definition of the term Rogue Unit, which leads us to a theoretical gap that has not yet been resolved. We also noticed an absence of a robust methodology for generating such a definition.

In addition, the works researched in all databases do not demonstrate clear solutions to the problem. The approaches in the literature found on Rogue Unit are conflicting with each other, precisely because of the absence of a correct definition. We have a practical approach applied by the industry (identification and disposal) that does not seem to be the most appropriate. There is also a lack of adherence to existing normative standards, in which the cause has not yet been clearly identified.

Rogue Units can oversize, over cost and generate great complexity in availability, maintainability, reliability, and safety management. The systems supported by the contamination of such anomaly do not respond to the usual management practices. Additionally, there is a lack of tools to identify Rogue parts precisely, which can potentialise the support poverty for the first operator. (CARROLL III, 2005), (MORTADA et al., 2012). Briefly, it affects the cost, awareness, readiness, safety, and availability of a complex system.

The current problem is the lack of a systemic and practical approach to direct actions during the concept, development and production life cycle phases to ensure that the new system will be logistically mature at the time of the first delivery to the operator.

1.3 Objective

This work develops a model of recommendations able to look back and deal with the problems related to the case study in a comprehensive way. The model addresses not only the immediate consequences but identify the most relevant actions to be taken during **preparation, development and production life cycle phases.** Additionally, assimilate the life cycle phases and the ILS elements involved in the **identification**, **prevention** and **solution,** of any support problem identified in the case study, and create a more mature product capable of autonomously deal with Rogue Units problem during In-Service life cycle phase. It applies to legacy systems and, mainly, to new systems.

The practical and applied benefits are recommended actions for problems, similar to the case study, and the integral management of the procurement processes involved. A defined set based on the experience and effort of the industry is applied, together with the academy, in a triple-helix environment, as proposed in the main axes of the National Defence Strategy, the National Defence Policy and the Strategic Design - Air Force 100 (BRASIL, 2005, 2008, 2018).

The academic benefits of this work are the systematic review of the literature on the case study, the formulation of a more precise definition of Rogue Unit and the development of better ways to study the intricacies of developing the supportability of a complex space system.

1.3.1 Specific Objectives

To achieve the general objective specific objectives were identified:

I. Propose a definition of Rogue Unit (SO I);
II. Establish which elements of Integrated Logistic Support are a priority for the construction of the model during **preparation, development and production life cycle phases** (SO II);
III. Produce the recommendations according to the premises established in Specific Objective II. (SO, III); and
IV. Validate the recommendations of Specific Objective III. (SO IV).

1.3.2 Justifications

Although the literature presents vast material on the No-Fault Found phenomenon (NFF), little is said about the Rogue Units, and this little still seems to conflict with definitions, as it currently happens with the NFF. (KHAN; FARNSWORTH; ERKOYUNCU, 2017).

With this premise, this thesis is ready to clarify the gaps of the other works of literature regarding the construction of definitions, inaugurating the development of a new approach, facing a new conceptual paradigm, for the case of Rogue Units.

Moreover the cost with NFF, within the aerospace industry, can overcome more than 90% of total maintenance cost related to electronics (WILLIAMS et al., 1998), or, by an Air Transport Association (ATA, nowadays IATA) example, airlines expend $100 million annually with only 4500 NFF events (BENIAMINY; JOSEPH, 2002). These figures do not address Rogue Units specifically, but it may increase those expenditures (JONES; HAYES, 2001; SÖDERHOLM, 2007).

1.3.3 Resources and methods

To achieve each specific objective, a resource is proposed, together with a method.

To fulfil Specific Objective I (SO I), the available research bases that best suit the theme are used as a material through the Systematic Literature Review method (DRESCH; LACERDA; ANTUNES JÚNIOR, 2015).

To fulfil Specific Objective II (SO II), the Delphi method combined with Content Analysis method is employed to rank the most critical elements of the ILS. Next, Friedman's test will be used to analyse the ranks raised from the Delphi method and Content Analysis Method and decide which ones are the most significant for the model. The material is supported by a plethora of specialists from the productive, aeronautical and industrial sectors, and from the Maintenance, Repair and Overhaul sector, which indicates the principal axes of Integrated Logistic Support (ILS) and the literature used in this work. (ABRAHÃO, 1998; BROWN, 1968; KINDVALL et al., 2017)

To fulfil Specific Objective III (SO III), the Deductive method is used with a combination of the material available in the international standards, the vast literature available and the contribution from specialists. (DRESCH; LACERDA; ANTUNES JÚNIOR, 2015)

To fulfil Specific Objective IV (SO IV), using the material obtained with SO III, the confirmatory Focus Group method is applied. (DRESCH; LACERDA; ANTUNES JÚNIOR, 2015; TREMBLAY; HEVNER; BERNDT, 2010)

1.4 Structure

This research is organised as follows: A literature review and bibliography are presented next, in chapter 2, with the context that explains the research problem and the theoretical base to clarify the study case. Chapter 3 provides the methodology applied in the analysis of the problem and the strategies to give the model and the recommendations related. Chapter 4 presents the method application and its results. A discussion is also provided to come up with the recommendations, that are part of the model, and its validations discussion. Finally, chapter 5 concludes the work described in previous chapters and presents limitations found and future work related to this research.

2 Literature Review

The purposes of this chapter are: in subtitle one explain the Systematic Literature Review (SLR) protocol applied, characterise the object of study, distinguish and analyse how the literature is dealing with the study case; subtitle two present the aspects of the methodologies that will be proposed to support the thesis and, finally, subtitle three identify the research gap and the contribution of this thesis.

2.1 Bibliographic literature review

2.1.1 Protocol for Systematic Literature Review (SLR)

To organise the search for publications to support this research, a Systematic Literature Review, under the orientations of design science research (DRESCH; LACERDA; ANTUNES JÚNIOR, 2015) was applied.

To achieve the objectives of the SLR, some formal steps are established to ensure the accuracy and traceability of the process conclusions. The model to be used in this review is the one proposed by Dresch, Lacerda and Antunes Júnior (2015), whose script goes through the definition of the research problem, elaboration of the conceptual framework, search strategy, search, eligibility and coding, quality evaluation, synthesis and presentation of results. Each of the mentioned points is discussed below.

2.1.1.1 Definition of the research problem

This definition was thoroughly discussed in chapter one. Here we present a brief description to fulfil the requirements of the research protocol.

The current problem is the lack of a systemic and practical approach to direct actions during the concept, development and production life cycle phases to ensure that the new system will be logistically mature at the time of the first delivery to the operator.

2.1.1.2 Elaboration of the conceptual framework

Data extracted from the primary studies (more heterogeneous among themselves) will be explored and interpreted throughout the development to obtain a theory (inductive method). The goal of the literature review, in this case, is the adjustment of many results in a “coherent theoretical rendering”(DRESCH; LACERDA; ANTUNES JÚNIOR, 2015, p. 147).

This kind of conceptual framework aims to a configurative literature review where the conjunction of results will provide the best answers to solve the research problem. Until this stage, the conceptual "drivers" that guide the solution of the problem are not clear. It is precisely in this case that the configurative review gains strength and importance.

2.1.1.3 Search strategy

This part of the research protocol ties up the search for the classic answers of a literature review: what to look for, where, how to reduce bias, which documents to consider and how much to look for. Correct preparation will lead to a result that will not only answer the questions but will also serve as the basis for the proper confluence of the conceptual framework.

Primarily the term “rogue item” was searched, but mismatched results were obtained. Then, the terms explained below were selected via an interview with specialists (mostly professors from post-graduation) that suggested the use of “rogue unit” and “rogue component” instead.

Four search terms were used:

1 - “Rogue Unit” (the use of double quotation marks restricts the search to the exact phrase in almost databases used);

2- “rogue component*” (the use of asterisk returns the variants of the term component);

3- “rogue”; and

4 - “Rogue Unit*”. The use of asterisk for this last term was motivated by the analysis of the results, which showed different results when using just the name “Rogue Unit”.

The objective was to exhaust the databases and search for the texts that best suited the research. Table 2.1 summarises the bases and results found. Although it may seem that the search terms overlap, it was empirically verified that the results obtained differed. For example, when searching for the word “Rogue”, all terms with "Rogue Unit" were expected; however, this did not occur. Therefore, the search, for the exhaustion of the results, was used with both terms.

Table 2.1 Databases and results.

Database	Results without filtering	After filtering	Primary results
Aerospace Research Central (ARC)	254	79	0
American Society of Mechanical Engineers (ASME)	489	52	0
Compendex (Engineering Village – Elsevier)	2,837	31	0
Derwent Innovations Index (Web of Science)	973	214	1
EBSCO	6,606	2744	0
Emerald	1,457	83	0
IEEE Xplore (Institute of Electrical and Electronics Engineers)	599	40	0
(ITA) – Integrated library research – EBSCO	355,487	117	3
National Aeronautics and Space Agency (NASA)	846	35	0
ProQuest	35,508	207	6
Scholar Google	77,265	1188	3
Science Direct (Elsevier)	11,558	2507	12
Scientific Electronic Library Online (SciELO)	5	5	0
Scopus (Elsevier)	49,038	256	0
Web of Science	6,681	98	0
Total	549,603	7656	25

The complete execution of the search strategy, with terms, sources (bases), inclusion and exclusion criteria, extension, tactics to minimise bias and their results are contained in Appendix 1.

2.1.1.4 Search, eligibility, and coding

The search strategy elucidated a small number of primary studies to start the eligibility and coding process so that all the prior studies found were selected for the analysis of the full texts, not only from title and from the abstract analysis.

Additionally, the bibliographic references of the papers were used to increase the possibility to better contribute to the characterisation of the study object.

The aim was to elucidate what concepts and strategies were being used to cover the study case. In other words, the approach adopted was a configurative literature review were the ideas of the framework arise from the analysis of the primary studies. (DRESCH; LACERDA; ANTUNES JÚNIOR, 2015)

2.1.1.5 Quality evaluation

Most of the studies found were classified via criteria: “Primary study does not meet the framework but characterises the object of study”. Only a patent (YACOUT; SALAMANCA; MORTADA, 2017) was classified via criteria: “Primary study partially meets the framework.”

Most of the studies were discarded via criteria: “Primary study does not meet the framework nor characterise the object of study”. Only one (BURCHELL, 2007) was discarded via criteria: “Primary study with low impact or not available for download (no citation on the horizon)” (see Appendix 1 for more details).

Due to the scarcity of the results found in the primary studies, no sensitivity analysis strategy was implemented. Instead, all primary results were used to compose the assignment. Note that this procedure differs substantially from the one recommended by Dresch, Lacerda and Antunes Júnior (2015) that makes use of a pre-selection in which the title and the abstract are used for the selection of the primary results. In this case, there is an innovation in the proposed protocol, in which a more refined search (**analysis of the entire content of the articles**) (bolds added) is applied, generating more reliable results and discarding those with low impact or low academic robustness.

2.1.1.6 Synthesis and presentation of results

A thorough and extensive search was made in the presented research bases to clarify to what extent the Rogue Unit problem was dealt with until the present.

As each database has specificities in performing searches, at first, the characteristics of each searcher were studied, and it was verified whether the search term was suitable for it. It was found that most search engines accepted the terms in their original forms; however, when necessary, adaptations to the use of special characters were made. This personalised adaptation for each search engine ensured the correct elucidation of the results presented. Whenever necessary, advanced search options were used to minimise the possibility of bias. All the tailoring for each database is available in Appendix A.

With the initial results in search, the individualised analysis of the articles found was carried out to select the correct search filters. A didactic example of this filter selection can be found in the search for the term "Rogue Unit" in the ITA's integrated research database, described below.

From the initial results (330 articles) there was a large number of articles dealing with "rogue states" referring to belligerent states, peoples or nations considered "rogue". To eliminate such results, the NOT operator was used in the advanced search to restrict the results with "state". Following a new search and analysis (in 49 articles), the NOT operator was applied to the term "waves" and, successively repeating the process for the other words "fitness", "trader" and "nation" which resulted in forty articles. These articles were read, and the 14^{th} result selected: “Aging avionics-what causes it and how to respond”. This article presents an explanation about No Fault Found problem that may be useful, so it was selected because it does not meet the framework but may characterise the object of study.

The process above was repeated for every single term and database.

In total, 7656 articles rose after applying the filters. Each one was read briefly to get an idea of what contribution it could bring in its wake, for the application in the aggregative framework as shown above. After this last scrutiny, a total of twenty-five articles were selected to compose a rendered base of the information.

With this initial base, in a continuation of the research protocol, a search was done for new publications in the bibliographic references presented at the initial 25 results. As expected, only two new publications were listed.

The first one was an article from Thomas Carrol (CARROLL III, 2008) presented in The Maintenance and Reliability Conference-MARCON 2008 conference, which was not listed in the databases. The second one was “Guidelines for Reduction of No Fault Found (Nff)” (AERONAUTICAL RADIO, 2008) which is a standard for the industry.

The analysis of the references showed that the results previously found or related had already been listed. This fact corroborates and **shows how deep and complete the search for the research protocol is** (bolds added).

In the last phase of analysis, during the in-depth reading, two articles were removed, and one will not be thoroughly analysed. The first one was “Cases studies in system burn-in” (JENSEN, 1982). Although the term "rogue" appears several times, it is considered as "early failures" whose description has already been well narrated in the preceding articles and has little added innovation in the definition and scope of the work. The following article "The Carroll-Hung method for component reliability mapping in aircraft maintenance" (LEUNG et al., 2007) deals with a statistical method. It is not significant for the development of the thesis because it uses the definition of Carroll (2005), but will be cited for his academic contribution to reinforcing theories of his contemporaneity. Finally, Mortada's (2011) doctoral thesis was also removed because it contains three articles, among which, one published *a posteriori* (MORTADA et al., 2012) that is analysed in detail, would soon be a redundancy of information. Such inconsistency of date regarding Mortada (2011) and Mortada et al. (2012) is a consequence of the peer review process, established by the publishers, which led the article to be published after the thesis in which it is used for support.

Finally, citations raised from the readings were checked, if available, and added to the reference list.

Once the research protocol is presented, there will be a detailed discussion of the articles found and the establishment of fundamental definitions.

2.1.2 Rogue Unit

This item is intended to present the bibliographic literature review and the analysis of the Rogue Unit and parallel with the No-Fault Found (NFF) phenomenon. The topics address historic, maturity, and, in the end, the contemporaneity of the subject is presented with a proposal for a new definition.

2.1.2.1 Historic

This sub-item aims to present the literature considered a precursor to the problem of the Rogue Unit. Didactically travels through the first publication found that mentions the Rogue Unit and goes on until the review article by Söderholm (2007).

2.1.2.1.1 Beginnings

As explained at the research protocol, there was no time limit imposed to find the primary studies. In 1966, during the Microelectronics Lecture Course, Mackintosh (1966) first mentioned “rogue” or “freaks” devices, referring to the reliability of integrated circuits. It was told that these devices were a conjunction of failures derived from the manufacturing process and would not comply with the main failure distribution. This approach considered that the faults were inherent to the devices, and they were doomed to fail, in consequence, would be scrapped. It is also pointed out that due to the growth of reliability during those days, a fail was becoming very hard to occur, and predict those failures, was more than impractical.

Another punctuated feature is about the relative ease for the identification and elimination of the Rogue Unit. As the symptoms related to the type of “rogues” are rapidly rising, these are revealed in the first moments of use. **Although unavoidable** (bolds added), they cause many problems because of their early failure, due to manufacturing errors that are beyond quality control, declines the reliability of the system. Therefore, a more rigorous posture in quality control is urgent to increase reliability. In this sense, the application of a pre-stress technique, called burn-in, is very efficient to generate a deliberate failure in these fragile items and to evidence their exit from the factories. The most intriguing in this case is the determination of the correct level of burn-in without causing excessive ageing in healthy units.

Mackintosh (1966) concludes by eliciting the current need for accurate pre-stress techniques, combined with research on reliability and usage data, should be used to increase the quality control of items that currently have meagre failure rates. It can be seen in these beginnings presented above that there was already an incipient idea about the harmful effects of non-compliant items.

Almost ten years later, the Rogue Unit was present and active in the issue of system reliability (MEAD, 1975). The process of "natural selection" of the weakest followed, through the burn-in process, as the best way to identify and survey defective components. The small change in concept introduced was that these items of exacerbated fragility were slightly above the average of the others and, consequently, were more challenging to purge in forced wear out. Such resilience was culminating in a need to increase the forced wear out of the item population to reveal the "rogues".

Even so, although primitively, a new approach to production was established in which the premise of avoiding defects was more advantageous and less costly than correcting them after delivery of the product. The novelty was the recognition of who would first feel the effects of imperfections would be the customer and economically viable measures for the solution should be taken. Another valid argument is that this balance between the level of testing required and the possibility of providing a warranty for defective items should be considered (MEAD, 1975).

Almost contemporary, the branch of electronics for the production of semiconductors encapsulated in plastic, also had a view on Rogue Units (KING, 1977), although similar to the papers previously presented. In this approach, the inference is that the units with low life expectancy would be classified as "early rogues" or "infant mortality"(KING, 1977). To counteract these flaws, the author proposes the creation of quality control classes to defer the time spent in the identification and purging tests of Rogue Units. However, there remains a doubt as to how much wear should be promoted in the tests. The forced ageing processes presented were based on exposure to high temperatures and humidity while covered by electrical currents. The routines presented by King (1977), the methods and the description of the tests are not within the scope of this dissertation.

Advancing in time, the term rogue is differentiated from the term of infant mortality. In the analysis proposed by Møltoft (1983) of a new "bathtub curve" he establishes that, for the analysed items, the "freaks" (used randomly to replace the term rogue) fail, according to his experience, typically between 1000 and 2000 hours of operation, while infant mortality occurs around 200 hours of operation. However, the view remains that the flaws pointed out until then, are related to lots of equipment. There is a statistical treatment approach for burning defective components. One advancement mentioned, for example, is the suggestion of changes in the design of pieces to make them more tolerant to failures, since the purging process can become economically unfeasible. To achieve this goal, the author suggests the more intense adoption of reliability indicator methods.

The term Rogue remains silent for another five years before being used again with a new application. It is unprecedentedly used to characterise a failure mode in blades discs of centrifugal compressor turbines (AFOLABI, 1988). Rogue failure, as described by the author, is caused by the action of Rogue blades, that is, components that had small variations in mass concentration or variations in stiffness during their manufacture. Such variations in the physical composition of the compressor blade cause a new type of failure, different from the already known isolated Rogue blade failure (STRATFORD,1986 apud AFOLABI, 1988) The latter is related to fatigue failure or damage caused by a foreign object. In this new case mentioned (Rogue failure) the severe vibration between two neighbouring blades can trigger a generalised loss in the entire disk. The article reports the techniques of identification of mistuning. However, it does not address any mention of improvement in design, production techniques or development, attributing to the stochastic nature of manufacture the possible causes for "rogue failure".

After the mention above, as far as the restriction of the bibliographic search allows, there is a gap of fifteen years until a new and straightforward notation is made on Rogue Units.

In a study by Shawlee and Humphrey (2001) on the ageing of avionics, the long operational duration achieved by aeronautical equipment is verified. In this type of equipment, the ageing of embedded electronics is not well known because it starts in production and continues inexorably, despite preventive interventions, **since the deterioration process can occur even at the molecular level** (bolds added). Despite efforts to correctly identify, the deterioration (decay) of electronic items can take years to manifest, and these same items can populate the spares pool over time.

It is pointed out that the shared parts repository, when inflated by items with occluded failures, leads to ineffective management of the spare parts inventory. These items, when crammed into shared stocks, will eventually return to the operational line causing more problems than solutions, for which they were initially proposed. The authors state that, from that point on, the only possible solution is to purge these malicious items and purchase new items. In a continuous act they indicate that such a drastic measure may not be possible for items "out of production" and, although it looks gruesome, it is what must be done (SHAWLEE; HUMPHREY, 2001).

The safety inferences made in the design are considered for the estimation of the avionics life cycle and a correct prediction for the retirement of the items. They reinforce that little has been done for the analysis of wire wear, which the authors indicate as a critical point to be addressed to minimise the effects of ageing, and also propose clear prospect of the measures to be used in the operation phase of the product's life cycle (SHAWLEE; HUMPHREY, 2001).

2.1.2.1.2 Trend change

When looking for fundamentals about the evolution of the concept of Rogue Unit, as established in 2.1.1.4, there is no way to depart from the concept of No Fault Found (NFF). The texts analysed so far made little mention of the NFF phenomenon (a term used by BAEK, 2016; KHAN, 2015; SÖDERHOLM, 2007). This position begins to change with the study conducted by a consortium, between the aeronautical industry, the government of the United Kingdom and the academy, called Reliability Enhancement Methodology and Modelling (REMM) (JAMES et al., 2003).

The main objective of the REMM project in its second stage (REMM2), narrated at the 2003 Annual Reliability and Maintainability Symposium, is to propose a practical guide for engineers to reduce the incidence of NFF removals for current and legacy projects. With this new philosophy, it is possible to observe an increasing trend in the identification and to combat the root causes of the NFF. The conformist attitude towards the hitherto "insoluble" problem is abandoned and proactive attitudes to mitigate or eliminate the trial begin. The solutions shown by the authors for the NFF, in a certain way, carry a parallel with the possible explanations for the Rogue Units, since, until then, one has not distanced itself from the other.

One of the drivers of this new onslaught is the change in the positioning of customers in the aerospace industry who are beginning to demand a new type of commercial relationship, in which “servitisation” takes centre stage. Contracts for the supply of inputs gradually migrate to the supply of operational availability, also known as "power-by-the-hour". Note that in this configuration the superlative availability indices represent a higher profit margin for the supplier/manufacturer (original equipment manufacturer - OEM), as it reflects a lower maintenance cost, lower unscheduled fines and, possibly, performance bonuses.

REMM's work (JAMES et al., 2003) proposes to embrace the variables of the problem highlighted to the NFF, identifying which obstacles are common to the participants, which are the root causes derived from the analysis of the collected data and modelling of the problems considered managerial. For that purpose, influence diagrams were used intensively, compiled from interviews and meetings.

Firstly, the research points to the **need to change** the NFF rating to **Fault Not Found** (bolds added). This little alliteration suggests that, although the piece has been tested and reported without failure, there is the premise that it still requires a more in-depth analysis of the correct identification of the root cause. In continuation, three situations are placed as preponderant: troubleshooting, system design and fault isolation manual.

Troubleshooting (bolds added) training is also pointed out as one of the contributing factors to the causes of NFF. A misinterpretation of the failure symptoms generates an inadequate recoil, consequently a negative failure. What can lead to poor troubleshooting was subdivided into company policy, the process itself and the tools used for execution (a manual for example). However, the article is not conclusive about this sub-classification, inferring the need for more research.

When designing built-in test equipment (BITE), the manufacturer can induce an extremely **sensitive alarm** (bolds added) level that corroborates the difficulty in correctly identifying the failing system. When the environmental operating conditions are not properly planned, the alarms, for the various limits considered, will be triggered simultaneously. On the other hand, a large tolerance in the limits will imply the occurrence of the fault without alarms. Besides, there is a preponderant human factor in the correct analysis of the reports (JAMES et al., 2003).

Another main issue is the induced NFF due to maintenance procedures. When handling the systems and their connectors, it is possible to create false NFF, as well as false Rogue Units (underline added), just by doing a mismatch in the connections or forcing a wrong plug attachment. Eliminate connection failures or short-circuits induced in the item is considered an effective way of reducing NFF.

When analysing managerial problems, the authors point out that the correct identification of Rogue components is preponderant, **defining them as units that are routinely removed during an NFF classification** (bolds added). No further enhancement of the qualification of the concept of Rogue is made. The solution commonly adopted for the case is to purge the unit, regardless of the cost of the decision. In the end, they inform that future work will seek to identify the processes that generate truly rogue items to provide indications for the correct treatment of the problem (JAMES et al., 2003).

Although they have proposed to present solutions and ideas for the design of new projects and the current ones, the article lends itself to offering a taxonomy for the causes, without any indication of practical applications. In the search for the result of the REMM2 research, proposed for 2005, no articles were found within the protocol.

2.1.2.1.3 Maturity of NFF

The year 2005 pointed out as being the most active in producing studies on the Rogue Unit, until then. The papers by Carroll (2005), Ramsey (2005), Leung et al. (2007), which repeats Carroll’s postulates, and Söderholm (2007) (the last two published in 2007, although made in 2005) shed more light on the urgent and costly problem.

Carroll (2005) defines the Rogue Unit, changing the example of its predecessors, as an individual who presents repeated visits to the workshop, with the same type of defect and whose replacement in the main system closes the problem of this. This new definition, which excludes the problem generated in batches, changes the treatment previously given to the theme. The creation of the Rogue Unit stems from the inability of the test benches to simulate the operating environment and, concomitantly, the fact that they are designed to identify only the failure modes known in the design, there are also failure modes entirely ignored by the designer. Therefore, a bench will never be able to recognise a failure in which its designers did not prepare or were unaware of it. Based on this principle, the **author states that any component can become a Rogue if it suffices to have an unforeseen failure or an unknown failure** (bold added).

Following the **consequences** (bolds added) of the existence of Rogue Units, the most damaging considered is the pollution of the spare pool with items whose flaws have not been identified. These items eventually return to the operation to replace a failed item, which directly implies performing bizarre troubleshooting. This is called the Rogue Unit effect which affects "operational and dispatch reliability, aircraft systems, maintenance effectiveness, aircraft/OEM engineering, maintenance support, training programs, the repair facility, spare levels, component ‘quarantine’ programs, and others components as well” (CARROLL III, 2005, p. 1). At this point, the author approaches the definition of the NFF where he makes it explicit that the Rogue Unit, although acting as the individual, that is, the given serial number, the process of generating the failure follows the same model as the NFF items (CARROLL III, 2005). The sum of maintenance costs, including logistics and management, can reach $ 50,000, considering a cycle of six maintenance for a typical Rogue item, excluding operating expenses (delays and cancellations).

The proposed solution involves the correct identification and tracking of the Rogue Unit in addition to a policy of sharing information between logistics agents. However, it is not mentioned of any suggestion of implementing procedures for the OEM or the supplier to mitigate the problem that weighs on the operator's pocket and the manufacturers' reputation (CARROLL III, 2005).

Ramsey (2005) brings an insight into numbers and expands the possible causes of NFF by correlating with behavioural factors, directly linked to maintenance management. Points such as training, pressure for availability, communication and complacency explain the perpetuation of the NFF.

Although dealing more specifically with avionics, the author states that the NFF rate can range from thirty-five per cent to sixty per cent, where incorrect failure identification procedures generated two-thirds of the repair service. The causes of this misidentification are the ambiguity in reporting the failure by the pilot, inadequate training and the culture that "gotta change something "(RAMSEY, 2005, p. 2). The latter is understandable when the guarantee period has not yet expired; nonetheless, it generates a continuous increase in the costs of contracting new insurance. The author reports on a view of the airline that believes it is cheaper to send a currently good part to repair than to miss an exit or cancel a flight.

Communication takes centre stage (bolds added) in identifying the problem. OEMs, when receiving items for repair, need a complete description of how the failure occurred; otherwise, they only test the basic functioning of the component. Atmospheric conditions similar to the flight environment will only be simulated if the failure report has any indication for this. Besides, aged pieces usually tend to have a higher failure rate or borderline performance. Furthermore, it states that during the design, not much attention is given to the development of troubleshooting procedures, or others designed for mechanics, as necessary (RAMSEY, 2005).

The **practical solutions put forward addresses** (bolds added) the correct identification and screening of the Rogue Unit, training procedures, provided by OEM's, warranty contracts and operator bonus for NFF reduction. For the proper identification, establishing a policy of "waiting on the shelf", before sending it to the workshop, where the doubtful piece is used again and a data analysis policy. The increase of quality in the communication of facts is performed via training. An exchange of operating data between the manufacturer/workshop and the operator is usually a critical operation, but beneficial to both when properly interlaced thru warranty contracts. Lastly, a parts loan policy, while causes of failure are investigated in-depth (RAMSEY, 2005).

Once again, the **absence of a standard for qualification and definition of Rogue Units is registered** (bolds added). As a matter of fact, the correct meaning of the term has not yet been established by the industry or even by academia, until then. Additionally, among the standard practices listed by Ramsey (2005), the effects mitigation measures of the Rogue Unit persevere during the operation phase of the product life cycle.

2.1.2.1.3.1 A system view of the NFF phenomenon

Given the importance of the information presented in this review article, it is necessary to separate this sub-paragraph for a better analysis of its content and offer an in-depth approach.

Closing this period of maturity, Peter Söderholm (2007), from Luleå University of Technology, produces a review paper on the NFF and, consequently, addresses several points of prominence on the Rogue Unit treated below.

In his approach, based on a holistic analysis of the exploratory study of the literature, the author aims to a relationship between the phases of the life cycle, availability factors and stakeholders with the causes and solutions identified.

Based on a definition that the Rogue Unit is a recurring NFF or Dead-on-Arrival (DOA), he establishes gaps in terms of **terminology**, NFF **occurrence**, **consequences**, **causes** and **improvement** of NFF management (bolds added).

As for the **terminology**, the **lack of consensus on all the available literature is clear in a single and irrefutable definition of the NFF** (bolds added), although there is a predominance of the aeronautical sector as the one that mostly refers to the problem. Consequently, a convergence of ideas was expected for the unification of meaning. This convergence, therefore, impacts the definition of Rogue Unit.

By the middle of the two thousand decade, the **occurrences of NFF were mixed with those of the Rogue Unit** (bolds added), since Rogue was included as a subclass of NFF. Söderholm (2007) mentions, by several other authors, that in the aeronautical industry, 50% of the pickups, during the operation and support phase, are classified as No Fault Found. If more specific areas of the aeronautical sector are observed, such as military aviation, the rates can go up to 50%. Specifically "an analysis of the number of times a unit fails, with and without an NFF, but where the previous failure was an NFF, can indicate the frequency of Rogue Units. Such an analysis shows that an NFF occurs after a previous NFF almost as often a real fault is identified." (SÖDERHOLM, 2007, p. 4)

Proceeding with his analysis (SÖDERHOLM, 2007) the following approach deals with the harmful **consequences** (bolds added) of an unidentified failure where the affected individuals are closely related, either by the operator, the repairer or the manufacturer. The impact related to the increase in cost applies to the operation, the maintenance of inventories, the manpower and the work. More specifically, the cost reported by the ATA (currently the International Air Transport Association - IATA) in 1995 with 4500 occurrences of NFF was $ 100 million per year, not including delays and cancellations (BENIAMINY; JOSEPH, 2002;), and the NFF contribute to more 90% of all maintenance costs related to electronics (WILLIAMS et al., 1998). The author reinforces that the problem of Rogue Units can enhance these costs since the search for root causes is not happening correctly. The other two subsequent impacts are dependability, positively affected by the increase o Mean Time Between Removals (MTBUR) and safety that last, but not least, analysis refers to the risk of operating with an item of unknown reliability.

When dealing with the possible **causes** (bold added) of NFF by Söderholm (2007), actions are pointed out to mitigate the effects in the in-service life cycle phase and identify the roots in the preparation and development life cycle phases and will be dealt below.

In very general terms, during the in-service phase, the leading causes are attributed to intermittent failures (connection and corrosion problems), environmental differences, errors in the identification of failures (both in the lack of training and in the absence of experience for the troubleshooting), lack of test standardisation and ineffective decision support tools. Moreover, Söderholm(2007) points out that the relationship between the manufacturer and the testing workshop, and the operator with the supporter, have been the biggest generator of Rogue Units, as they usually conflict between standardisation of procedures, lack of communication, outdated and error-prone documentation and inconsistency in the failure report.

Regarding preparation and development phases, the NFF roots are pointed out to the unbalance between in development of tests and new technologies. Redundancy is added to counterbalance the drop in reliability, caused by the introduction of new components (immature technology). This redundancy increase complexity, leading to the use of more complex BIT and BITE, providing the environment for the growth of errors in tests. This technological loop is challenging to be broke. Even the improvement in reliability may become a cause. When designing new test software for a new, and improved item, and the requisite documentation for the item is not consulted, creating a software design that does not meet the operator requirements or violation of any design restrictions. Common in projects with low production volume, such as the military. Rogue Units and NFF are indicated as a symptom of inadequate test coverage (SÖDERHOLM, 2007).

Concerning the **improvement** (bolds added) of NFF management, Söderholm (2007) gather the literature recommendations and present it regarding each life cycle phases, emphasising that most of the causes can be traced during preparation and development phases. The improvement guidelines raised focus mainly on reducing the causes of NFF, and therefore the Rogue Unit. Such a paradigm works with the possibility of elimination and does not indicate measures to cope with the problem. Throughout the text, **the author's intention in the emphasis on eradication is clear** (bolds added), based on the analysis of improved reliability, maintainability and maintenance support for the concept, design and operation phases.

The conclusion reached points out that the problem is still expanding, in line with the expansion of the complexity of systems and technology. Also concludes the tracing and control of Rogue Units are essential, the different levels of testing (OEM, MRO, shops) must be closely linked from the design and information switching should be improved at all stages of the product life cycle.

2.1.2.2 Contemporary applications

After reaching maturity in dealing with the NFF, characterised by the identification of the problem, models for cost estimation, suggestions for the implementation of controls and tools, it is possible to see that the differentiation on the phenomenon of Rogue Units begins to take hold.

At first, we have a more straightforward definition of Rogue Units with the establishment of removal pattern (in general 3) in a given period (KHAN *et al.*, 2014; KHAN; FARNSWORTH; ERKOYUNCU, 2017; AERONAUTICAL RADIO, 2008). Then there was a counterbalance to affirm that the term would apply to the component that presented repeated returns to the workshop, with the same failure mode, whose identification was outside the spectrum of the tests developed (CARROLL III, 2008; HOCKLEY; LACEY, 2017; LEJEUNE et al., 2019; MORTADA, 2010; MORTADA et al., 2012; YACOUT; SALAMANCA; MORTADA, 2017). In a broader concept, the idea that it is a component that has multiple removals (AHMET ERKOYUNCU et al., 2016; BAEK, 2016; KHAN, 2015; KHAN; FARNSWORTH; ERKOYUNCU, 2017) has been expanded to any component that has anomalous behaviour concerning the standard (LAKE; MCCULLOUGH; CHAPMAN, 2016).

It is interesting to note the position of Khan *et al.* (2014b) regarding the change of vision about the NFF. After criticising a failure in the academy for not perceiving the systemic interconnection of the No-Fault Found problem and treating it repeatedly as a one-off event, it suggests a change of approach. In this new delimitation, to give more emphasis to the systemic character, he proposes to change the nomenclature, according to Khan *et al.* (2012) and James *et al.* (2003), for Fault Not Found, as already mentioned above.

Additionally, Khan *et al.* (2014b) suggest that a multi-disciplinary integration for design solutions and cross-discipline features should be implemented in the engineering creation processes for the NFF solution. Particularly this last statement can be directly transposed to the solution of the Rogue Units.

Through the researched literature, three classes of procedures were identified to deal with the Rogue Units defined above: quarantine processes, computerised tracking systems and application of artificial intelligence (AI).

The quarantine processes suggested (also known as subject to aircraft check – STAC) (AERONAUICAL RADIO, 2008; BAEK, 2016; HOCKLEY; LACEY, 2017; HOCKLEY; PHILLIPS, 2012), for the most part, consider that the correct identification of Rogue Units was made *a priori*, without taking into account the possible difficulty of carrying out this initial step. Therefore, such measures apply to propose a suggestion to deal with Rogue Units. This measure has some validity because it allows an LRU, removed under suspicion, the victim of an incorrect procedure or test, to end up being considered Rogue incorrectly. Although it is still presented in the most recent literature (BAEK, 2016; HOCKLEY; LACEY, 2017), this measure *per se* does not indicate an optimised path for the correct treatment of the case study, due to its simplicity of destination, disposal.

Computerised tracking systems suggested were differentiated from AI because these solutions are mainly focused on statistics procedures or event controllers. Among the models found in the literature (CARROLL III, 2008; KHAN, 2015; KHAN et al., 2014a; KHAN; FARNSWORTH; ERKOYUNCU, 2017; LAKE; MCCULLOUGH; CHAPMAN, 2016), the only mention was made of project requirements to be implemented, generic and inconclusive guidelines. However, they gain cogency due to their applicability and effectiveness in the correct identification of Rogue Units. Carroll (2008) begins with a system in which items are searched for by serial number, in its broader set (aircraft, for example) or installed subsystem, with a comprehensive description of its history of operation, removal and repair, together with the respective acceptance criteria as Rogue. Khan (2014a) follows the same pattern; however, it does not establish more refined acceptance criteria and considers only the disposal of the unit identified as an anomaly. Finally, Lake, McCullough and Chapman (2016) propose a computerised tool to identify and provide at least one action for the identified Rogue Unit.

The application of artificial intelligence found in the researched literature follows the line of studies of the Department of Industrial engineering at *Ecole Polytechnique de Montreal*, starting in 2010 with Mortada's doctoral thesis (MORTADA, 2010) and subsequent publications (LEJEUNE et al., 2019; MORTADA et al., 2012; YACOUT; SALAMANCA; MORTADA, 2017). In this application, the concepts of Carroll (2008) are used as a basis in the "education" of machine learning for the identification of Rogue patterns. This technique is still contemporary (LEJEUNE et al., 2019) because it can filter results, it finds anomalies more efficiently and because it is an algorithm of "white box" type, allowing the tracking of the decision taken automatically. Nevertheless, this AI did not seek to provide solutions to deal with the Rogue Unit found.

Regarding the cost evaluation, the model proposed by Erkoyuncu *et al.* (2016) was found, which uses the Soft Systems Methodology (SSM) to acquire the main cost generators for the NFF. Based on the classification of Khan *et al.* (2014b), it addresses only the NFF problem generated by an inappropriate system design, which combines operational feedback, performance indicators, inherent costs and diagnosis as part of the design.

Finally, none of the publications found reported suggestions, models or even recommendations for Rogue Units specifically for the preparation, development or production phases of the life cycle. Khan and Khan, Farnsworth & Erkoyuncu (2015; 2017) are categorical in stating that most manufacturers, OEMs and users **do not have clear and defined plans to deal with NFF, not even Rogue Units** (bolds added). Although blunt, this statement can still be contested without the due and careful analysis to follow, on a new definition of what Rogue Units are.

2.1.2.3 A new definition of Rogue Unit

Throughout the exhaustive search process for Rogue Units definition, some idiosyncrasies can be perceived in the descriptions and applications presented. Although not conflicting, **they fail** (bolds added) to outline the Rogue Unit properly.

At the beginning of the mentions presented in 2.1.2.1.1, the Rogue Unit was confused with the items of infant mortality, eliminated with the purge or burn-in (KING, 1977; MACKINTOSH, 1966; MEAD, 1975), although for Mead (1975) Møltoft (1983) they were more resistant items.

Then the term Rogue is presented for several types of problems in which the fault behaviour is anomalous (AFOLABI, 1988), but considered a hidden fault or an effect from ageing (SHAWLEE; HUMPHREY, 2001) or an item which exhibits a non-stop rejection cycle (JAMES et al., 2003). For Ramsey (2005) **it still not clear on one definition** (bolds added) for Rogue Units.

Carroll (2005) begins to change the definition adding **the impossibility to avoid** (bolds added) the Rogue Unit (CARROLL III, 2008), establishing four identification criteria and highlighting the importance of fighting it. Even so, **it does not differentiate it from the NFF** (bolds added) in all his future work (LEUNG et al., 2007; MORTADA et al., 2012).

Söderholm (2007) **is definitive and conclusive in pointing out that until now there is no consensus around the NFF** (bolds added), in parallel, there **is also no consensus about the Rogue Unit** (bolds added). Even in the new applications mentioned in 2.1.2.2, the definition changes a little to a more generic form where Rogue refers to the component that has a history of operation that deviates from the other typical components (LAKE; MCCULLOUGH; CHAPMAN, 2016), but **still does not differentiate from the NFF** (bolds added).

Thus, the concepts presented do not consider all facets of the Rogue Unit, namely:

a) The item that has a failure rate different from the standard component;

In this part, the evolution of the concepts of Rogue Units is equal to that proposed, except for the possibility of a beneficial Rogue item, that is, fail less than the standard;

b) Possibility of use even if its failure mode is known, whose correction of such failure mode does not eliminate the more ephemeral character of the item.

Even knowing the failure mode for the Rogue Unit, it should be better used due to its added value, that is, disposal is not an economically or operationally viable solution;

c) An approach that considers the improvement and worsens the anomalous condition, regardless of the ageing of the item;

d) Differentiation of the NFF phenomenon.

The item that acts as NFF is no longer problematic when its failure mode is discovered and corrected. This approach is not possible for a Rogue Unit;

e) The mutative capacity of a Rogue Unit.

An item may become Rogue for poorly performed maintenance; it may cease to be Rogue for a manufacturer that improves the condition or updates it with modification and may continue Rogue until its disposal at the end of the life cycle. It will depend on the given treatment; and

f) The added value of the item (complex component);

There is no point in considering Rogue an item that has a low replacement or consumable cost. Special treatment and classification are linked to the degree of complexity and the ease (economic and operational) of obtaining the item.

Therefore, to address such peculiar aspects, we propose the following definition:

Rogue Unit is a complex item of relevant added value, belonging to a complex system, whose failure rate differs from other similar items, which cannot be avoided and has a known or unknown failure mode.

With this definition, Specific Objective I (SO I) is achieved.

After the presentation of the definition, we started to discuss the entire theoretical basis that will support the development of the methodology.

2.2 Theoretical Fundaments

This subtitle proposes to present the entire theoretical basis applied in the various phases of the methodology, analysis of the results and conclusion. It is not in the scope of this work to demonstrate or deepen the origin of the theories presented. However, it undertakes to address what is necessary for the understanding of their subsequent applications.

2.2.1 Systems Engineering

Systems Engineering (SE) in words of Blanchard and Blyler is

> …the orderly process of bringing a system into being and the subsequent effective and efficient operation and support of that system throughout its projected life cycle. It constitutes an interdisciplinary approach and means for enabling the realisation and the follow-on deployment of a successful system (BLANCHARD; BLYLER, 2016, p. 1).

Thru International Council On Systems Engineering (INCOSE):

> Systems Engineering is a transdisciplinary and integrative approach to enable the successful realisation, use, and retirement of engineered systems, using systems principles and concepts, and scientific, technological, and management methods. (INCOSE, 2020)

SE establishes the intricate relationship between the means of production, people, knowledge and equipment to provide, in the most organised and effective way, the path to satisfy the operating requirements of a system, whose function is to meet a need. (BLANCHARD; BLYLER, 2016; DEFENSE ACQUISITION UNIVERSITY, 2020a)

The SE plays a crucial role in delineating the stages of development where it provides a schematic organisation for the analysis of the possible measures of identification, prevention and treatment in the study of Rogue Units.

2.2.2 Integrated Logistic Support (ILS)

The concept of Integrated Logistic Support was born in the 1960s out of a need by the United States Department of Defence (DoD) to improve the procurement and cost management process for military projects. (BLANCHARD; BLYLER, 2016)

It is considered a managerial function that addresses a series of aspects (called elements of integrated logistical support) iteratively and, mainly integrated, to optimise the use of resources from the design of the project until its withdrawal from service.

Although started in defence projects, the concept has been widely used by the industry as a way of improving the product. According to the Aerospace and Defence Industries Association of Europe and Aerospace Industries Association of America (ASD/AIA) "is the management and the technical process of support activities for a Product throughout its life cycle" (AEROSPACE AND DEFENCE INDUSTRIES ASSOCIATION OF EUROPE, 2018).

Nowadays, DoD uses the term Integrated Product Support (IPS) to designate the concept. This change aimed at improving the image of product support and adding two new elements to the existing ten (KOBREN, 2014).

According to the concepts brought from DoD (through the Defence Acquisition University - DAU) other organisations, governmental or not, have also adopted similar ILS implementation processes through standards, such as JPS 886 volume 7 and Def Stan 00-600, both United Kingdom, the US Army regulation 700-127, the Integrated Logistic Support Plan Template (Florida’s Statewide Sys. Eng. Mgt. Plan Template), US Coast Guard System Integrated Logistic Support Policy Manual, the NASA (National Aeronautics Space Administration) Policy Directive Program and Project Life-Cycle Logistic Support Policy and the NATO ALP-10 (North Atlantic Treaty Organization) (ASD;AIA, 2018).

Each standard adopts different divisions and terms. One point that distinguishes the standards are the divisions and definitions of each phase of the life cycle such as NATO AAP-20, US DoD Instruction 5000.02, NASA / SP-2007-6105 Rev 1 (System Engineering Handbook), OCCAR OMP 1 (Organization Conjointe de Coopération en matière d'Armament / Organization for Joint Armament Co-operation - OCCAR) (OCCAR, 2020) and ISO/IEC TR 19760: 2003. For this work purpose, the definitions presented in the International guide for the use of the S-Series Integrated Logistic Support (ILS) specifications (SX000i) of the ASD/AIA 2018 (ASD;AIA, 2018) will be used, namely:

a) Preparation phase: During this phase, initial studies of the product or project to be developed take place. Starting from a Concept of Operation (CONOPS), the requirements are identified and analysed. Feasibility and risk analysis studies are also conducted to prepare for the launch of the next phase, development.
b) Development phase: Product development begins. The aim is to meet project requirements, with a focus on minimising the logistical footprint and on accessible and executable manufacturing.

c) Production phase: In this phase, the series production is started, together with the first operation tests and the first users.
d) In service phase: This is the most lasting of the life cycle phases. Corresponds to the daily life of the product, operation and support. Evaluations continue to ensure project performance and continuity. Modifications can be planned to extend the usage or update it.
e) Disposal phase: It is the nightfall of the product for its withdrawal from service. In this step, the plans and tests aim at the complete closure of the operation and support.

ILS serves the most diverse stakeholders such as OEM, resellers, suppliers and customers. From the beginning of the concept of the product or service to the withdrawal of service the correct identification of logistical requirements (whether they are original from the interested parties or derived from the analysis of the former), the support planning and choosing the various elements that will be employed must be planned. It should be noted that in the customization process, not all tools may be necessary, and it is up to those involved to analyse and decide the intensity of ILS to be applied (ASD;AIA, 2018). In other words, the proper level of ILS must be planned for each and single project.

Given that the opportunities to reduce the cost of living are much more significant in the early stages of design, so does product support planning (BLANCHARD; BLYLER, 2016; DEFENSE ACQUISITION UNIVERSITY, 2019b, 2020a, 2020b; INCOSE, 2015; UNITED STATES, 2014). The actions provided for in the ILS must be initiated in conjunction with the product or system development project and mature with it, influencing and acting, whenever possible, to make it more settled for the first user (DEFENSE ACQUISITION UNIVERSITY, 2020a). In the DoD metrics it should start at the Milestone Decision Authority (MDA) when the need for material is decided to meet a capacity requirement, that is, even before a formal establishment of a project (DEFENSE ACQUISITION UNIVERSITY, 2020b).

Figure 2.1 shows how the opportunities for cost reduction degrade and how the cost evolves according to the life cycle phases. It is easy to notice that the driver cost for a life cycle is the operation, and after in-service entry, project changes may increase the project cost dramatically.

Finally, it is added that the objectives of the ILS may be broader than the initial goals of the project. While a project can stick to the design, development and production phases, ILS can influence the original directions going much further by analysing the entire life cycle and, therefore, to optimize costs and the requirements of the performance.

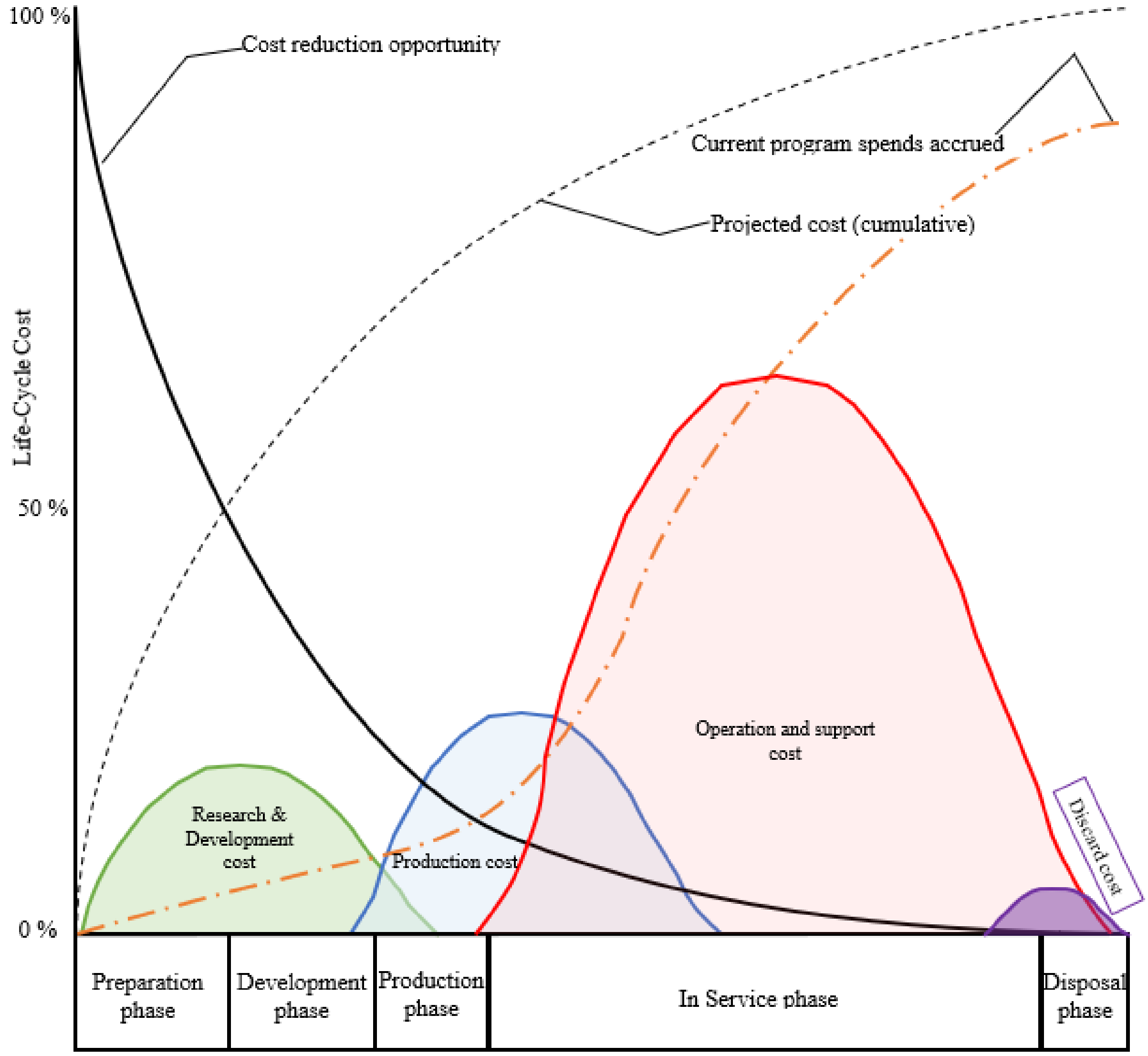

Figure 1 Commitment of life-cycle cost. Adapted from (ASD;AIA, 2014; BLANCHARD; BLYLER, 2016; UNITED STATES, 2014)

2.2.2.1 ILS Elements

As aforementioned, the aspects of ILS are described as twelve elements which comprise a unique function of support, whose integration is the most important, to guarantee the maturity of the support in the product life cycle. The definitions for each element are (ASD;AIA, 2018; DEFENSE ACQUISITION UNIVERSITY, 2019a):

a) Computer Resources (CR): The objective is to act in every possible scope that relates to software and hardware in the life cycle of the system or product.

Whether with personnel, installations, software life cycle and hardware to support their operation, as well as security and safety, as prevention from cyber-attacks. Its importance lies in the fact that any complex system no longer operates without the integration of a massive computer system;

b) Design Influence (DI): This element brings together design decisions, made throughout the life cycle, which will directly impact from conception to disposal in terms of reliability, availability, maintainability, safety, security, testability (RAMST), effectiveness, cost, man-machine integration, among others. It is vitally essential for all types of systems because it is the technical link that will amalgamate the other initiatives of the other elements. Although the responsibility for coordination lies with Product Support Management, DI is the activity conducive to achieving the objectives of integrated support.

c) Facilities and Infrastructure (F&I): It refers to the actions necessary for the acquisition, construction, reassignment, lease, maintenance and adaptation (including environmental) of real property assets of interest to support the product's life cycle. It aims to meet the product support requirements from its manufacture (prototype production, development laboratories, training, supply, testing, maintenance, network and communication systems, hazardous materials storage, etc.) to disposal. Since its implementation involves a considerable funding, with long lead time, it should be planned preferably from the beginning of the preparation phase.

d) Maintenance (MTNC): This element has a significant impact on the life cycle because its planning and development influence the decision making of all the other elements. Through Maintenance, maintenance requirements and concepts are designed to define repairs, scheduling, personnel skills, and supplies support for the operation of the system or product. It is also related to health management, prognosis and diagnosis, development and improvement of preventive maintenance.

e) Manpower and Personnel (M&P): It is the design for the acquisition or construction of the body of human endeavour needed to develop a specific task or mission and its set of intellectual skills, physical and psychological combined.

f) Packaging, Handling, Storage and Transportation (PHS&T): It involves all processes that refer to the safe transportation, handling and the correct accommodation in stock of the items that will guarantee the availability of the system (including training) or product. It is also related to ensuring the proper environmental analysis for the performance of the relevant actions, the rescue, servicing, towing and the statistical control of the use of the product (or its supply).

g) Product Support Management (PSM): It is the integrating element in the broadest possible spectrum within the ILS. Through the action of the Product Support Manager (PSMGR), is responsible for the entire conduct of the project from cradle to grave, that is, cost and performance. It has decisive actions in the design when it integrates the requirements with the diverse tasks of the other elements (ILS plan). In the development, it is responsible for guaranteeing the economic and logistic viability. When in-service it accompanies the use, ripening and ageing of the product and provides, in the end, removal from service.

h) Supply Support (SS): It consists of management actions to establish the requirements for acquisition, cataloguing, receipt, stock, transfer for use and disposal of spare parts, repair parts and consumables.

> This means having the right spares, repair parts, and all classes of supplies available, in the right quantities **and qualities** (bolds added), at the right place, at the right time, at the right price. The process includes provisioning for initial support, as well as acquiring, distributing, and replenishing inventories. (DEFENSE ACQUISITION UNIVERSITY, 2019a, p. 118)

i) Support Equipment (SEQ): It consists of actions to plan, acquire, relocate, rent, and hire all equipment (whether mobile or fixed) that supports the operation and conservation of the system or product. The PSMGR is responsible for preventing the growth of the Support Equipment inventory by analysing the legacy material and implementing its use and routines in the new product or system.

j) Sustaining Engineering (SENG): This element is intended to provide technical support for the operation of the system or product through the analysis of engineering metrics and the development of product improvement. It is heavily influenced by the design interface and continues its activities. It also may affect initial phases thru Engineering Change Requests from legacy projects (ASD;AIA, 2018, p. 87);

k) Technical Data (TECHD): It is the congregation, in a traceable way, on any format, of all the planning and production of technical information about the product or service, from design to disposal. Information related to the operation of software (use and installation manuals), contractual information and management information are excluded from the treatment of this element.

l) Training and Training Support (T&TS): This element is responsible for analysing, planning and executing all the necessary actions for the proper initial training, updating and review of the knowledge mandatory for the immediate and safe operation of the product or service. It also includes analysis of the equipment, materials and facilities needed to conduct the training. Given the complexity involved in the necessary means and processes dedicated to teaching, this element sometimes requires a specific management chain.

After analysing the concepts and elements of the ILS, we now describe the standards to be used in this work.

2.2.2.2 Defense Acquisition University (DAU)

The Defense Acquisition University is a corporate university created in October 1991 by the Department of Defense o United States of America (DOD) to “Provides for a senior course, as a part of a Senior Acquisition Education Program, as a substitute for, and equivalent to, existing senior professional military education” (UNITED STATES, 1991, p. 1). This purpose serves the mission of training personnel to serve as procurement professionals and to develop research related to the procurement theme.

With a wide variety of courses and online materials, this academy provides a plethora of educational resources that condense, in an organized and didactic way, the regulations issued by the United States of America (USA) Government. Some of these materials will be used in this research and are described below.

2.2.2.2.1 Defense Acquisition Guidebook

Defense Acquisition Guide Book (DAG) is an e-book reference, published by DAU, which explains and complement the policy documents from DoD to perform program management.

Within its ten chapters, it is possible to understand and go deeper thru the parts involved during a program. The chapters are Program management, Analysis of Alternatives, cost estimating & reporting, System Engineering, Life cycle Sustainment, Manpower planning &

human systems integration, Information technology & business systems, Intelligence support & acquisition, Test & Evaluation, Program protection and Acquisition of services.

From the analysis of the chapters, it was identified that two are more related to the research topic: Chapter 3 Systems Engineering and Chapter 4 Life Cycle Sustainment, analysed below.

2.2.2.2.1.1 Chapter 3 Systems Engineering

In this chapter, the DAG describes how SE processes, required and standardized by the DoD to achieve the desired capabilities of a product or service, are used. All steps of creating and planning the product life cycle are presented over four subtitles.

The first indicates the purpose of the chapter.

The second presents the theoretical background going through the definition of SE, the processes, policy and guidance, plan (System Engineering Plan - SEP), Systems Level Considerations, tools, techniques and lessons learned, engineering resources, certifications and the role in contracts.

The third focuses on business practices addressing life cycle expectations, SE activities in the life cycle, and finally, audits and technical reviews. It is noted that the SE activities and technical reviews, dedicated to the verification and validation (V&V) of the system are scrutinized so that no aspect of the development is neglected.

In the fourth subtitle, additional planning considerations that address technical management processes, technical processes and design considerations are exposed. It outlines how SE processes should be customized for each type of project or each of the six DoD acquisition models. Besides, in design considerations, it addresses themes peculiar to each project such as accessibility, affordability, anti-counterfeiting, commercial off-the-shelf, corrosion prevention and control, critical safety item, demilitarization and disposal, diminishing manufacturing sources and material shortages, environment, safety and occupational health, human systems integration, insensitive munitions, intelligence (Life-Cycle Mission Data Plan), interoperability and dependencies, item unique identification, modular design, operational energy, PHS&T, producibility, quality and manufacturing readiness, reliability and maintainability engineering, spectrum management, standardization, supportability, survivability and susceptibility and system security engineering.

Concerning this last subtitle, it is worth highlight and distinguish some aspects that are similar to the elements of the ILS. At this point, a concern of the authors is perceived with the perfect integration between the areas of support design and design. More specifically, there is apprehension, apparently identified with the experience, that the Project Manager (PM) will carefully read the DAG and, mainly of chapter 3, however, it will delegate the specific support duties to the Product Support Manager (PSMGR). However, given the importance of some aspects of the support, these are replicated in the subtitle under discussion. For example, corrosion control and PHS&T are treated under Maintenance and PHS&T ILS Elements, respectively. Nevertheless, they are again "remembered" in items 4.3.5 and 4.3.17, preventing such support topics from being neglected in the project and having an extra layer of warning, for each phase of the life cycle.

As aforementioned, Systems Engineering has a significant impact on the planning and division of activities of the logistical support for the identification, prevention and treatment of Rogue Units.

2.2.2.2.1.2 Chapter 4 Life Cycle Sustainment DAU

Chapter 4 discusses Life Cycle Sustainment Planning in all its breadth. Life Cycle Sustainment Plan - LCSP addresses the entire planning, implementation and operation of product support activities, so does the recommendations for dealing with Rogues. Its undeniable benefits are maximized when employed in the tenders' stages of the development of any product or system. The main objective of life cycle support planning is to deliver the highest readiness within the proposed operational requirements. The practices proposed by the DoD to achieve the goals described above are presented in four subtitles and compared with SX000i standard.

The first and second subtitles are introductory and dedicated to presenting the foundations of the LCSP, the main actors and the legal references of the DoD.

The third subtitle describes the business plan for planning sustainability through the phases of a product's life cycle for major capability acquisition. As previously seen in item 2.2.2, the DoD has its definition for the life cycle phases, (ASD;AIA, 2018; DEFENSE ACQUISITION UNIVERSITY, 2020c) as well as several acquisition models with peculiar life cycles to each model as shown in figure 2.2. The acquisition models provide for several modalities, with varying duration and stages, depending on the complexity and the type of capacity to be acquired (presented here in a broad spectrum, meaning purchase or development).

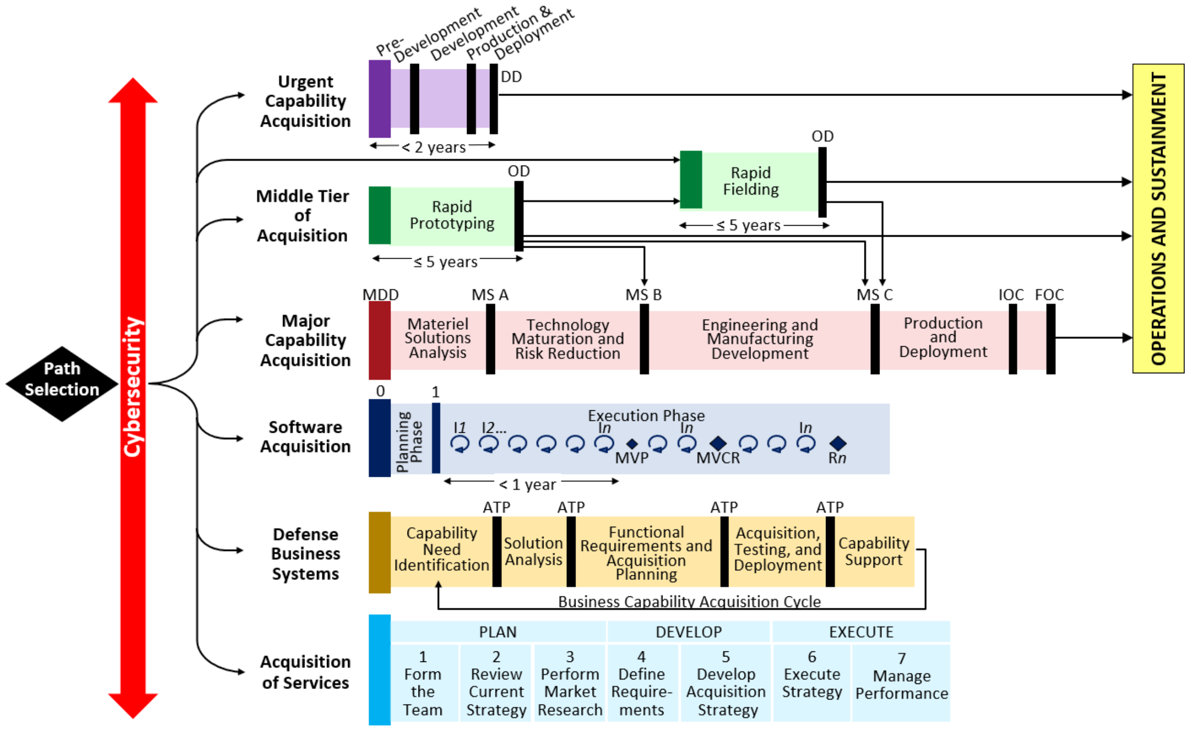

Figure 2 Major Capability Acquisition pathway (DEFENSE ACQUISITION UNIVERSITY, 2020c)

Considering a Major Capability Acquisition, there are five phases, Materiel Solution Analysis (MSA), Technology Maturation and Risk Reduction (TMRR), Engineering and Manufacturing Development (EMD), Full-Rate Production and Deployment (FRP&D) and Operating and Support (O&S). These life cycle phases are equivalent to the ones proposed in 2.2.2, as shown in the table below.

Table 2.2 Life cycle phases. Adapted from (ASD;AIA, 2018)

SX000i	Preparation phase		Development phase	Production phase	In-Service phase	Disposal phase
DoD	Material Solution Analysis phase	Technology Maturation and Risk Reduction phase	Engineering and Manufacturing Development phase	Full Rate Production and Deployment phase	Operating and Support phase	

Each DoD's Life cycle phase will be addressed below according to the intrinsic characteristics of this work.

MSA is where the product or service life cycle begins. It is at this stage that the purchase or development of the capacity is decided. Thus, should be noted the recommendations so that the planning of supportability also occurs in this phase, such as the cost-benefit analysis, maintenance analysis, and design interface processes analysis, which must be completed by milestone A, which ends the phase. All of these initial reviews support the launch of the Life Cycle Sustainment Plan - LCSP (or ILS Plan on the SX000i model)

TMRR is the phase in which a large part of the integrated support is planned, concentrated and refined, from the beginning until the end of the life of the product or service. Support Strategy, Supportability design requirements, Intellectual Property Strategy and Supportability Analysis (or Logistic Support Analysis – LSA) are some activities developed. It is also in this phase that the Request For Proposal (RFP) with the Contract Data Requirements List (CDRL) is released.

In the EMD phase, the product or service is developed, and the prototypes are produced. Regarding support, it is planned to develop the tests and deliver the product support to the first operator. This is a phase focused on the construction of RAMST metrics, for the case analysis the and for the cost-benefit ratio analysis of the measures taken about the support, such as Business Case Analysis (BCA). The Critical Design Review (CDR) is one of the critical steps completed at EMD. In this Review, the configurations are frozen, at the lowest possible level, and according to the prototypes and models built, the final assessments of sustainability are made, and sufficient maturity is given for the start of manufacturing.

It is worth noting at this point, the difference found between the Supportability Analysis reported in the DAG and the Logistic Support Analysis (LSA) of the SX000i (ASD;AIA, 2014, 2018). Although both have the same purpose, to analyse in detail the elements of support and to plan the development of the product or service throughout the life cycle, they are described in different phases and processes**. For semantic precision, they are considered synonymous and will be distinguished when necessary** (bold added).

The FRP&D is the phase in which the product or system will be delivered to the first operator. In this step, controls and metrics of supportability (RAMST) are intensified to ensure that support requirements are being met or at which point they need to be improved.

Operating and Support phase is the current life of the product or service. In this most significant phase of the life cycle, the total operational capacity is checked, the operating conditions are monitored to monitor the evolution of the product, minor adjustments are made for the improvement and, finally, its withdrawal from service. Concerning the life cycle presented by the SX000i, this phase condenses the Disposal phase.

The last subtitle of chapter 4 presents additional considerations to the planning, such as the acquisition models, the description of the activities in each milestone and specific acquisitions (ships, aircraft, space, ammunition, information systems and modification programs).

2.2.2.2.2 Product Support Manager (PSMGR) Guidebook

This guide is a tool generated by DAU to lead the activities of the procurement and logistics workers, condensing the DoD rules, with acceptable practices and with the knowledge generated in the academy. It goes through all aspects of governance when developing, purchasing or upgrading a product or service. As a guide, it should be used as such, that is, each chapter is described independently of the others and can be consulted separately.

It consists of six chapters and ten appendices which addresses all the functions in which the PSMGR can or should act. In the expenditure of its reading, it points out several items in which the PSMGR has a decisive impact on the identification, prevention and treatment of the Rogue Unit. Such actions will be covered in more detail in chapter four of this work.

2.2.2.2.3 Integrated Product Support (IPS) Guidebook

This training tool proposes to bring together all descriptions related to the elements of integrated logistical support in a single location. Unlike ASD/AIA standards, this guide arranges each chapter describing each one of the Elements according to the following structure: Objective and description, overview, the importance of the Element, PSMGR activities about this Element, main activities for each phase of the cycle resources, training resources, among others. The other processes are linked explicitly to the DoD acquisition bureaucracy and are specific to internal processes.

2.2.2.3 AeroSpace and Defence Industries Association of Europe/ ASD-STAN and Aerospace Industries Association International guide for the use of the S-Series Integrated Logistics Support (ILS) specifications (SX000i)

The standard S-series is an initiative of aerospace manufacturers of Europe and the United States of America to provide industry and customer-driven semantic and process commonality when dealing with Integrated Logistic Support, centred on achievements. It also provides a reduction in the complexity of projects through a broad coverage on all aspects related to ILS within the product life cycle, a contractual basis, a straightforward provider of mutual contributions and knowledge transfer and, finally, efficiency.

It is based on the actions developed by Working Groups and Steering Committees that keep updated with the best practices and provide the necessary corrections.

There are currently twelve publications:

> "- S1000D - International specification for technical publications using a common source database;
> - S2000M - International specification for material management - Integrated data processing for military equipment;
> - S3000L - International procedure specification for Logistics Support Analysis (LSA);
> - S4000P - International specification for developing and continuously improving preventive maintenance;
> - S5000F - International specification for in-service data feedback;
> - S6000T - International specification for training analysis and design;
> - SX000i - International Guide for the use of the S-Series Integrated Logistic Support (ILS) specifications;
> - SX001G - Glossary for the S-Series ILS specifications;
> - SX002D - Common Data Model for the S-Series ILS specifications;
> - SX003X - Compatibility matrix for the S-Series ILS specifications;
> - SX004G - Unified Modelling Language (UML) model reader's guidance;
> - SX005G - S-Series ILS specification XML schema implementation guidance." (ASD;AIA, 2018, p. 8).

The SX000i is the publication responsible for integrating all other standards, ordering them in time and synthesizing their contents. It is the starting point for understanding other publications. Figure 2.3 shows how each of its publication covers S-Series processes. Note that it is not a one to one publication, although it covers a significant part of the approach suggested. The codes used are:

a) F – full in-depth coverage: the corresponding publication completely covers this activity;
b) P – partial in-depth coverage: the related publication does not entirely cover this activity
c) I – just information to perform the activity;
d) S – the specification provides support for the activity, but it is not described;
e) T – top-level coverage: high-level information only;
f) (blank) – no coverage.

Table 2.3 Activity-specification mapping table. Adapted (ASD;AIA, 2018, p. 100)

ILS Element	Activities	ASD specifications coverage									
		S1000D	S2000M	S3000L	S4000P	S5000F	S6000T	SX000i	SX001G	SX002D	STE-100
CR	Perform CR Analysis			P		I		T			
	Provide CR							T			
DI	Perform RAM Analysis			I	I	I		T			
	Perform LSA		S	F	I	I		T		S	
	Perform LCC Analysis (BCA or Affordability)			P		I		T			
F&I	Perform F&I Analysis			P		I		T			
	Provide F&I					I		T			
MTNC	Develop MTNC Concept			F	S			T			
	Perform LORA			F		I		T			
	Develop MTNC Plan		S	F	I	I		T			
	Execute MTNC tasks	S	S			I		T			
	Perform SSA					I		T			
	Develop and continuously improve preventive MTNC			I	F	I		T			
	Perform schedule MTNC analysis				F	I		T			
	Perform Diagnostics, Prognostics and health management (D&PHM) analysis					I		T			
	Perform Software MTNC analysis			F				T			
M&P	Perform M&P analysis			P		I		T			
PHS&T	Analyse PHS&T requirements		S	I		I		T			
PSM	Manage contract					I		T			
	Capture product support requirement		S	P				T			
	Develop ILS plan		S			I		P			
	Perform obsolescence management		S	F		I		T			
SS	Provide provisioning data		F			I		T		S	
	Perform Material Supply		F			I		T			
SEQ	Analyse SEQ requirements			P		I					
	Provide SEQ		I								
SENG	Perform engineering technical analysis			P		I		T		S	
	Develop & provide engineering disposition & recommend design changes	S	S	P	P	I		T			
TECHD	Develop Technical Data Package		I			I		T		S	
	Produce Technical Publications	F	I			I		T			S
T&TS	Perform Training Need Analysis (TNA)						F	T			
	Develop Training Plan	S					F	T			
	Perform Training Development	F					I	T			
	Deploy Training	S						T			
Other Activities (not covered in first SX000i issue)	Manage In-service ILS activities Perform		S			I					
	Perform in-service maintenance optimization (ISMO)				F	I					
	Operational suitability evaluation					I					
	Fleet management					F					
	Manage stocks/stores		I			I					
	Manage warranty		I	P		I					
	Disposal		S	P							

The use of S-series specifications must be weighted thru the tailoring process required for every single project. Each project with its uniqueness must be customized for the application according to its degree of complexity. Such individualization processes are described throughout the SX000i, considering all other specifications. Each project must measure how much of each ILS element will be applied. The point to be reached is the satisfaction of the requirements presented.

According to the specification, the central role in defining how each element of the integrated support will be applied lies with the PSMRG. It must carefully observe "project requirements, involved parties, ILS activities on the project, the added value of the publications, available tools, risks and opportunities" and "interoperability of specifications and ILS products." (ASD;AIA, 2018, p. 103).

2.2.2.4 International specification for Logistic Support Analysis – LSA (S3000L)

As part of the S-Series information suite and as shown in table 2.3 above, the S3000L covers the entire Logistic Support Analysis process. The LSA is one of the most critical activities in the whole ILS as it is the primary database provider for other activities. Specifically, the LSA meets the design needs of RAMST and the definition of needs for phase In-service.

In the same way as the other specifications in the series, it is managed by a Working Group responsible for updating and adapting to the different standards of the suite.

The S3000L intends to cover the entire scope related to LSA activities such as product breakdown, specific analysis, how to use the analysis, interface between LSA and RAMST engineering and interface between LSA and ILS elements. Pg10.

Specific Analyses are those used and documented in the LSA program to populate the logistical database for the performance of the other ILS items. As the processes are listed in the SX000i, the list of activities must be individualized for the project to meet the requirements. A great effort to analyse all aspects can cause an increase in costs, which may be minimized through candidate item selection. Potential analysis activities that can be developed are: the identification of general LSA needs, comparative, human factors, configuration evaluation, reliability evaluation, maintainability, testability, FMEA, FMECA, damages, special events, scheduled maintenance, LORA, maintenance tasks, software support, simulation of operational scenarios and TNA.

2.2.2.5 Guidelines for reduction of no fault found (NFF). ARINC Report 672

This standard is an initiative of Aeronautical Radio Inc. (ARINC) that brings together the knowledge and good practices acquired in the aviation industry to standardize techniques for the production of embedded electronic equipment.

Although it doesn't report directly to ILS elements, it is addressed in this subtitle due to its commonality with terms and practices.

As explained in item 2.1.2.3 above, the NFF theme permeates the Rogue Unit, and many of the measures taken for the mitigation and solution of NFF are applicable in Rogue Units (reported here as chronic) problems as well.

This guide is peculiar because it addresses measures in a comprehensive and multidisciplinary view to try to solve the No-Fault Found phenomenon, from the Preparation to the In-service life cycle phase. It is equal to other standards mentioned because it emphasizes the need to customize the listed processes according to the type of product or service designed.

Its usage algorithm is based on the query of three tables. The first one contains the possible causes, the second solutions related to the causes and the third the implementation. Note that the solutions, although directed to the Preparation and Development phases, rely on facts narrated from the In-service phase, that is, although it is possible to use the recommendations in the Preparation, the generating point came from the In-service.

It should be noted that several recommendations, feedback and experience, derived from the shop floor, are well recognized and indicated. The exchange of information in the field is considered a robust tool for the reduction of related problems and whenever possible, should be included in the formal training processes.

2.2.3 Solution Methods

In this subtitle, the theoretical bases for the solutions adopted in the methodology will be addressed. The explanation of how they applied to the method is explained in chapter three.

2.2.3.1 Systematic literature review (SLR)

A Systematic literature review is a separate study on the content to be searched for "mapping, finding, critically evaluating, consolidating and aggregating the results of relevant primary studies on a specific research question or topic, as well as identifying the gaps to be filled, resulting in a current report or a summary.” (DRESCH; LACERDA; ANTUNES JÚNIOR, 2015, p. 142). Systematic reviews provide knowledge through the aggregation of the result obtained, the academic background necessary to avoid wasting time, the lack of representativeness of the research topic or even ethical inconsistency.

It is possible to benefit from the systematic review by starting from analyses supported by a wide range of publications, mitigating the possibility of bias and generating comprehensive and robust results (DRESCH; LACERDA; ANTUNES JÚNIOR, 2015).

Depending on the type of question to be answered in the research, an appropriate systematic review should be adopted. Reviews intended to answer questions that seek to prove a theory and are based on more quantitative data are more focused on the aggregative version. On the other hand, when they try to understand a phenomenon that is not yet clearly identified and are based on more qualitative data, they are more focused on the configurative version. (DRESCH; LACERDA; ANTUNES JÚNIOR, 2015)

The steps to be followed to obtain a systematic review of the literature are the establishment of a work project, choice of the work team, selection of the search strategy, eligibility and coding of the results, quality assessment, synthesis of the results and presentation (DRESCH; LACERDA; ANTUNES JÚNIOR, 2015).

The work project is intended to guide the methodological steps of the systematic review; following it is of fundamental importance to prevent research bias. The search strategy should stick to what was discussed above with the addition that, in the case of configurative reviews, exhausting the search will be more advantageous. Eligibility and coding are elements described in the work plan and prevent bias. The other steps of the systematic review follow the same pattern commonly adopted in the scientific process.

Particularly the systematic review of the literature carried out in item 2.1.1 already addressed the necessary practices, due to the protocol used in the research explained by Dresh, Lacerda e Antunes Júnior (2015).

2.2.3.2 Delphi Method

Forecasts are a constant in any system or development, especially for technologies, as they seek to "clarify" a little more of the future, many times, based on past information. Knowing the trends allows guiding the state-of-the-art in a direction that will be followed or that will be supported in the future. They are also essential to assist decision making in the face of risky or critical situations. Nevertheless, many forms of forecasting have already been tried, and still, many will be (KINDVALL et al., 2017).

The Delphi method has its origin in the 1960s narrated through the RAND project (a contraction of research and development), by USA Air Force, in which it sought to elicit the opinion of panellists through questionnaires to make forecasts, and it remains current (BROWN, 1968; KINDVALL et al., 2017; LINSTONE; TUROFF, 2002).

This technique consists of surveying rounds (at least two) of anonymous questionnaires answered, followed by subsequent replies to the first, to try to establish a consensus on the topic studied (KINDVALL et al., 2017). The literature on the subject indicates that the format of the questionnaire, number of participants, the maximum number of rounds and execution time is quite variable, with the need for anonymity and the minimum number of two rounds being constant (BROWN, 1968; DIAS, 2007; LINSTONE; TUROFF, 2002).

Anonymity guarantees the independence of responses by panellists as they are not under pressure to agree with other opinions, sometimes seen as being issued by more competent professionals. In other words, it seeks to remove the pressure from the face-to-face debate and allow the respondent to reach more individualized conclusions. For the second round, conflicting opinions will be confronted, and consensus will be tried.(BROWN, 1968; DIAS, 2007; MARQUES; FREITAS, 2018)

Another crucial point is the iteration between the response rounds. This process guarantees the discussion of conflicting ideas and allows the survey of new concepts, which are the main objective of the research. It is also at this moment of iteration that the respondent can change his opinion. Although the consensus is sought, it is not always possible to leave it to researchers to adopt the measures provided for in the initial protocol to decide when to stop the rounds (BROWN, 1968; DIAS, 2007; MARQUES; FREITAS, 2018).

The process begins with the establishment of the research protocol where the control parameters (levels of agreement or consensus) are stipulated, forms of execution, criteria for stopping rounds, criteria for the construction of a questionnaire and replica shipment and how it will be reported. Given that the process allows several flexibilities for the execution, it is vital to establish and strictly follow the research protocol to guarantee the possibility of traceability of the obtained data (DIAS, 2007; MARQUES; FREITAS, 2018).

The second stage consists of choosing the participants. It should be guided by the search for the elements that are most appropriate and that have a notorious knowledge about the subject that will be forecast. It is worth mentioning that more critical than the number of participants is their quality for Delphi. However, the addition of more participants reduces the possibility of error; it is not recommended to go beyond thirty (DIAS, 2007). Usually, it is done by indicating peers that work in the same branch. It is essential to consider that heterogeneity among participants tends to produce "solutions of higher quality and acceptance" (MARQUES; FREITAS, 2018, p. 7).

The third stage consists of preparing, sending and replying to the questionnaires, that is, the operation of the method. In this stage, we identified the main problems such as the high abandonment of the survey by respondents, delay in responding, difficulty not to force consensus, non-bias of the questionnaire or replies, and, finally, corporate view of the expert's responses and not the individual (DIAS, 2007; MARQUES; FREITAS, 2018).

Finally, the results are analysed and presented.

It is worth mentioning that the Delphi method has a precise application for the prospecting of ideas and strategies for proposing organizational policies and, together with the other opinion prospecting methods (panel of experts, scenario building, brainstorming, SWOT analysis) are dedicated to the study of future and the technological development. The Delphi method, however, **is the most suitable for this research because it is ideal for anticipating future possibilities, based on an unstructured iteration of complex problems, with a lack of historical data or diffuse knowledge, or for knowledge prospecting** (bold added) (DIAS, 2007; MARQUES; FREITAS, 2018).

2.2.3.3 Content Analysis

This research method seeks to identify in a discourse (text), analytically, impressions, intuitions, interpretations and strict textual analyses. The type of application and technique used depends on the result sought. In general terms, it can be differentiated in quantitative and qualitative analysis (HSIEH; SHANNON, 2005).

In quantitative analysis, document analysis is used where it is identified how the quantity of terms (codes) shapes the content of the text. It is not the initial objective to infer meaning but to understand the content through the use of words (HSIEH; SHANNON, 2005; SANTOS, 2012).

In qualitative analysis, the search is for meaning, for the message transmitted through the nuances of the characters, the heart of the written or unwritten content. This technique is best indicated when looking for content from different messages such as interviews, videos, photos, symbols that are implied or subliminal (HSIEH; SHANNON, 2005; SANTOS, 2012).

Every qualitative analysis goes through a quantitative analysis. But inferences can be made from quantitative analyses using statistical methods (SANTOS, 2012)

2.2.3.4 Friedman test

It is a non-parametric test applied for comparing more than two samples, related or depended, and the normality assumptions are not guaranteed or when variances are different from population to population. Its parametric equivalent test is the repeated measures Analysis Of Variance (ANOVA), and it is based on the analysis of ranks instead of raw data for the calculation of statistics (F_r). (CORDER; FOREMAN, 2009; PORTAL ACTION, 2020)

The hypotheses are constructed based on population medians, θ_i, where H_0 means that the samples are similar and H_1 at least one of the samples is different from the others. However, the Friedman Test does not identify which of the samples is different, and for that, *post hoc* tests should be performed to observe the significant differences. (CORDER; FOREMAN, 2009)

To calculate the F_r statistic first, a table with the data (subjects) in rows (n) is organized, and they are ranked according to each line, that is, across the row. The evaluation conditions are placed in the columns (k). If there is no tie in the ranking

$$Fr = \left[\frac{12}{nk(k+1)}\sum_{i=1}^{k} R_i^2\right] - 3n(k+1) \tag{2.1}$$

Where R_i is the sum of the ranks from column or condition i. In the event of a tie

$$Fr = \frac{n(k-1)\left[\sum_{j=1}^{k}\frac{R_i^2}{n} - C_F\right]}{\sum r_{ij}^2 - C_F} \tag{2.2}$$

"Where n is the number of rows or subjects, k is the number of columns or conditions R_i is the sum of the ranks of the column or condition i " […] "and r_{ij} is the rank corresponding to subject j in column i." (CORDER; FOREMAN, 2009, p. 80). C_F is the tie correction given by

$$CF = \left(\frac{1}{4}\right) nk(k+1)$$

(2.3)

The degrees of freedom are given by

$$df = k - 1$$

(2.4)

"Where *df* is the degrees of freedom and *k* is the number of groups" (CORDER; FOREMAN, 2009, p. 80), columns, or conditions.

"As the sample distribution of the calculated F_r statistic is approximate to a Chi-square distribution with *k-1* degrees of freedom, the probability associated with the occurrence of H_0 will be significant if it is greater than the probability found" (SIEGEL, 1975, p. 191) in the model distribution. If the F_r statistic is not significant, then there is no difference between the reported conditions. (CORDER; FOREMAN, 2009)

However, if there is the significance, there are at least two samples that differ from each other and, for their correct identification, multiple pairwise comparisons must be performed. The problem with multiple comparisons is that the Type I error rate tends to be inflated. More modern tests that seek to reduce the Type I error are proposals that tend to adjust the *p-value* from the test statistics, among them the method of Holm, Simes, Hochberg, Hommel and Rom, which are improvements of the technique employed initially by Bonferroni. (SANTOS, 2013).

The method of multiple comparisons for the Friedman test is the one based on the Nemenyi model that better controls family-wise error in tests of multiple hypotheses (DEMŠAR, 2006). For the analysis, the critical difference given by

$$\left|R_i - R_j\right| \geq Z_{\left(\frac{\alpha}{k(k-1)}\right)} \sqrt{\frac{n.k(k+1)}{6}}$$

(2.5)

Where R_i and R_j are the sum of the ranks regarding *i* and *j* groups compared; | $R_i - R_j$ | is the observed difference; *k* is the number of groups; *α* is the level of significance desired; *n* is the number of rows. If (2.5) occurs, we conclude that the observed difference is significant. For *k* groups, the number of comparisons must be $k(k-1)/2$. The value of α/2 was represented after adjusted for multiple comparisons, as indicated by Bonferroni ($\alpha/k(k-1)$). (DEMŠAR, 2006, p. 12; PORTAL ACTION, 2020; HOLLANDER; WOLFE; CHICKEN, 2014, p. 323)

2.2.3.5 Deductive Method

The scientific method is a structured planning for the construction of knowledge from a theoretical gap, a practical problem or the direct observation of a phenomenon which one wishes to explain, describe, explore or predict. The approach given to the scientific method may vary according to the research objective and maybe inductive, deductive, hypothetical-deductive or abductive. (DRESCH; LACERDA; ANTUNES JÚNIOR, 2015)

The inductive method is the most suitable when the observed phenomenon is not known, and it is necessary to describe it, make inferences about its behaviour, generalize it or even propose a universal law that explains it. It is based on exhaustive experimentation and impartial observation of the phenomenon. (DRESCH; LACERDA; ANTUNES JÚNIOR, 2015)

The deductive method is the use of premises (laws or theories that can come from the inductive method) for the construction of new knowledge that can explain or predict phenomena. The use of logic is the main instrument of the process, mainly for the construction of conceptual models in the area of management research. The deductivist causal link arises from the confirmation of hypotheses logically, systematically conjectured and faced with reality, from its results, the explanations are constructed. (DRESCH; LACERDA; ANTUNES JÚNIOR, 2015)

The hypothetical-deductive method is linked to the deductive as it uses the knowledge gained to propose hypotheses and put them to the test. If refuted, they are considered null, if confirmed they reinforce the initial understanding. The abductive method is linked to the creative process in which the facts are studied, and an explanatory theory is proposed for them, that is, it suggests what may be. Proof of the hypotheses in the abductive method can be done using the methods mentioned above. (DRESCH; LACERDA; ANTUNES JÚNIOR, 2015)

2.2.3.6 Focus Group

Focus Group is a discussion section, implemented by a moderator whose function is to keep the audience on the topic of interest. It can be done with a defined theme and a questionnaire script, for the case of the confirmatory Focus Group. Or, it can be done with a free theme in which the opinion of each participant will lead the direction for sharing ideas and analysing the behaviour of the participants, for the exploratory Focus Group. (TREMBLAY; HEVNER; BERNDT, 2010)

It is a method of collecting or analysing qualitative data in which a panel of experts, confronting each other, exposes their opinions in depth. It allows flexibility in the formatting of the interviews, direct interaction with experts on the subject, produces a large amount of data from the panellists' responses and allows the construction of knowledge based on the opinion of others. (DRESCH; LACERDA; ANTUNES JÚNIOR, 2015; TREMBLAY; HEVNER; BERNDT, 2010)

The exploratory Focus Group is one that provides a quick outline of the topic to be addressed, seeking, in the specialists' opinion, limits and points to be discussed in the research or even for the construction of other Focus Groups. The confirmatory Focus Group is the one used to verify and demonstrate the usefulness of the artefact generated in the research. (DRESCH; LACERDA; ANTUNES JÚNIOR, 2015; TREMBLAY; HEVNER; BERNDT, 2010)

Given its flexibility, the number of sections or participants must be appropriate to the theme and the desired depth of research. The difficulties presented by the method are the time for the specialists to meet, recruitment, number of sections to be carried out, the rigorous interpretation and coding of the data required for the interviews and the preparation of the mediator. All restrictors will be driven by the cost and time limitations of the survey. (TREMBLAY; HEVNER; BERNDT, 2010)

2.3 Gap analysis

This item summarizes the analysis made in 2.1.2 on Rogue Unit and its parallel with the No Fault Found phenomenon and position the contribution of this work facing the gap found.

The Systematic Literature Review returned twenty-five publications that were presented in sub-item 2.1.2., mentioned above and thoroughly analysed. Moreover, specific recommendations for identification, treatment and prevention of Rogue Units are restricted to a few, as well as a clear definition (analysed in 2.1.2.3).

To better visualize this panorama, Table 2.4 presents a summary of the proposed Rogue Units definitions and the recommendations found in the Concept, Development, Production and In-Service phases. The cells marked in green have at least one recommendation regarding Rogue Units. The other recommendations refer to the NFF phenomenon. In the end, the improvement proposals of this work are positioned.

Table 2.4 Synoptic Table

Publications	Rogue definition	Preparation phase	Development phase	Production phase	In-Service phase
(MACKINTOSH, 1966)	ER			BIP	
(MEAD, 1975)	ER	attention and imagination		BIP	
(KING, 1977)	ER			BIP	
(MØLTOFT, 1983)	Freak		RYI	RYI	
(AFOLABI, 1988)	Rogue failure				
(SHAWLEE; HUMPHREY, 2001)	Aged Rogue				DIS
(JAMES et al., 2003)	LOR				TRI, DIS and RYI
(CARROLL III, 2005)	Unrepairable Rogue				IDF, TSI and DIS
(RAMSEY, 2005)	LOR				Tag, TSI, return in warranty, TRI and DIS
(SÖDERHOLM, 2007)	NFF Rogue	RYI, MNI and MSI	RYI, MNI and MSI		RYI, MNI, MSI and DIS
(RADIO, 2008)	Chronic, LOR		Documentation improvement, MNG, TRI, TSI, RYI	Documentation improvement, MNG, TRI, TSI, RYI	Documentation improvement, MNG, TRI, TSI, RYI
(CARROLL III, 2008)	Unrepairable Rogue				IDF and DIS
(MORTADA et al., 2012)	Unrepairable Rogue				IDF and DIS
(HOCKLEY; PHILLIPS, 2012)	NFF Rogue	RYI and Develop a standard	TSI		STAC, RYI, MNG, MSI
(KHAN et al., 2014a) (KHAN et al., 2014b)	LOR	RYI and Sustaining Engineering improvement			RYI, TSI and Supply Support improvement.
(KHAN, 2015)	LOR				TSI
(BAEK, 2016)	NFF Rogue				RYI, TRI, and TSI
(LAKE; MCCULLOUGH; CHAPMAN, 2016)	Divergent Rogue				Parameterization, Identification, Alert, Classification, Analysis, Prioritization, Action suggestion and Comparison with similar items
(AHMET ERKOYUNCU et al., 2016)	Not defined				Cost control improvement
(KHAN; FARNSWORTH; ERKOYUNCU, 2017)	Not defined				RYI and MNG
(HOCKLEY; LACEY, 2017)	NFF Rogue				STAC, MNG, TSI and TRI
(YACOUT; SALAMANCA; MORTADA, 2017)	Unrepairable Rogue				IDF and DIS
(LEJEUNE et al., 2019)	Unrepairable Rogue				IDF
IRIGON, 2020	New	New	New	New	

Legend:

a) ER – Early Rogue

b) BIP – Burn-in process
c) LOR – Loop Rogue
d) DIS – Discard Rogue
e) TRI – Training improvements
f) IDF – Identify Rogue
g) RYI – Reliability improvement
h) MNI – Maintainability improvement
i) MNG – Management improvement
j) MSI – Maintenance support improvement
k) TSI – Testing improvement
l) STAC – Subject to aircraft check

Furthermore, there is a clear trend towards reactive processes (CARROLL III, 2008; MORTADA et al., 2012); therefore, the possible recommendations are concentrated in the In-Service life cycle phase. Even so, the most frequent recommendations are identification and disposal, except by a few of them. The first exception is the work of Lake, McCullough and Chapman (2016) whose core is, for the In-Service phase, with the adoption of at least one suggestion of action (disposal, selective use of the item, re-analysis by the workshop or requiring warranty) to deal with the Rogue Unit. The second exception is the burn-in process during production is suggested by Mackintosh (1966) Mead (1975), and King (1977). The third exception is the Subject to Aircraft Check (STAC) proposed by Hockley & Phillips (2012) and Hockley & Lacey (2017).

Once the academic research gap has been analysed, the proposed methodologies for addressing the research problem will be discussed.

3 Materials and methods

After Specific Objective I achievement, a suggestion of a new definition for the Rogue Unit and the academic gap identification, with the highlighted exceptions, this chapter is dedicated to explaining the entire methodology to be used for the achievement of Specific Objectives II, III and IV, as well as the materials to be used.

The chapter is divided into six subtitles, namely Systematic Literature Review, Delphi method, Content Analysis method, Friedman test, Deduction method and Focus Group method.

3.1 Systematic literature review

Although located in this subtitle, the entire protocol, theoretical support and materials used for the Systematic Literature Review have already been covered in subtitle 2.1 and teased in Appendix A. For the sake of maintaining the logic of development of the work, this topic has not been removed.

It should be ratified that Specific Objective I, will serve as a semantic (material) basis for the development of the other Specific Objectives.

3.2 Delphi method

The Delphi method will be employed to achieve part of Specific Objective II.

The Delphi method was chosen to raise, among a panel of experts, which elements of the ILS are most important for the identification, prevention and solution of support problems arising from the existence of Rogue Units among complex systems. Additionally, as aforementioned in 2.2.3.2, **it is the most indicated method of this type of research** (bold added).

The process begins with a round of questions sent by email to the selected participants. On the first round, participants are invited to analyse a list of twelve ILS Elements where they are asked about the importance of the respective Element regarding identification, prevention and treatment of Rogue Units. In this first round, it is possible to add Elements to the list, modify it or remove Elements according to the panellist’s opinion. Finally, suggestions for implementing the item are requested, not compulsorily. For this questionnaire, the specialists are provided with a fictitious example of completion, definitions of the life cycle stages and descriptions of each element of the ILS based on SX000i (ASD;AIA, 2018). It is open to the expert to resolve any doubts about completing the survey with the moderator, vetoing contact with any other research participant.

The purpose of this first round is to open the spectrum of possibilities regarding the case study. While there is a possibility to change the presented list, after the first round, it may be redone, remand for further analysis by the experts, until a consensus is reached on the items belonging to it. The consensus is considered achieved when there is a difference less than or equal to one-third of the opinions. Until then, the rounds for selecting the items on the list will be redone.

For the second and subsequent rounds, an analysis of the responses of all participants is made. The experts are presented with a new questionnaire containing their answer of the previous round, the percentage of "yes" answers, the justifications presented for these answers and the justifications for "no" answers. Then the participant is asked to re-analyse their first response based on the opinion of the other participants, deciding whether to add, change or discard any element. They are required to justify their changes in answers related to round one. The field for suggestions and actions to implement the respective elements remain.

After reaching the proposed consensus limit, participants are invited to start the next stage, rank the elements on the list and describe actions to implement each of the elements on the list. Additionally, the results of the consensus of the previous rounds are presented in the form of percentiles.

The second part of the process consists of choosing the participants. This part takes place through consultation with members of the academy who will be invited to nominate peers from the different branches of the productive, aeronautical and industrial sectors, and from the Maintenance, Repair and Overhaul (MRO) sector, which indicates the main axes of Integrated Logistic Support. All questionnaires models can be found in Appendix C.

3.3 Content Analysis method

The second part of Specific Objective II is achieved using the Content Analysis method.

The objective of using this method is the same as Delphi identifying, in the researched literature, which elements of ILS are most important for the identification, prevention and solution of support problems, related to the existence of Rogue Units in complex systems.

Nevertheless, the use of the Content Analysis method complements the Delphi method. In the first, we have the academic bias on the subject, while the second covers the more pragmatic, operational discrimination.

The data used for thematic categorical analysis (classificatory) quantitatively is provided by the entire literature review, standards and manuals.

Excerpts that mention the twelve elements of the ILS will be highlighted, added by category and ranked according to the number of citations.

The MAXQDA Analytics Pro 2020 Demo software will be used to aid Content Analysis. License (4C4C4544-0047-5010-8036-B9C04F584C31). All tables, materials and remarks from Content Analysis are available in Appendix E and Appendix F.

3.4 Friedman test

The Friedman test is used in the rankings obtained from the Delphi method and the Content Analysis method to complete Specific Objective II.

After analysing the data obtained with the Friedman test and deciding which elements are a priority for the construction of the recommendations model, they are used as a basis for the achievement of Specific Objective III with the Deductive method. If necessary, multiple comparison method is applied. All non-parametric tests are available in Appendix G.

3.5 Deductive method

The Deductive method is employed to achieve Specific Objective III.

First, a careful analysis of all the texts presented throughout chapter 2, all notes generated by the reading, the output of the excerpts generated in the Content Analysis method and the recommendations raised from Delphi method are carried out (premises). Next, the possibilities of recommendations for the case study are highlighted on each publication and opinion from Delphi.

Finally, each recommendation proposal found is faced against the other publications analysed in a way that generates a robust theoretical framework (hypothesis) justifying its use. Note that the analysed texts already give the proper support because valid assumptions (best practices) were established for the generation of the model. Mendeley Desktop software is used to prepare the notes and remarks in every single piece of work used as a reference. All notes generated are available in Appendix H.

The Focus Group method is used to validate the composition of the recommendations and confront reality.

3.6 Focus Group method

The confirmatory Focus Group method is employed to achieve the Specific Objective IV. The purpose of using this methodology is to demonstrate the validity of the hypotheses generated from **SO III**.

The method starts with the preparation of the questionnaire to the participants. It is structured in Rogue Unit definition explanation, as stipulated in **SO I**, and the theoretical reasoning of the recommendations generated. Next, the recommendations are presented, categorized by life cycle stage, with the ILS Element(s) correlated, the original bibliographic source and specific and complete reasoning for each. The last part of the questionnaire will be dedicated to the result of the consensus among the participants. The consensus formulation proposal comes from the tailoring process for the application of ILS, proposed in the SX000i, for every single project teased in 2.2.2.3.

The second step consists of the preparation of the mediator, who should be able to clarify the doubts of the specialists and provide their focus on carrying out the work. As the focus group's objective is validation, this should be pursued throughout the session.

The third step is the choice of participants. Those who are most familiar with the case study are chosen from the participants of the Delphi rounds, considering the suggestions and interactions presented and curriculum analysis. If there are not enough interactions by Delphi participants, they are individually invited to join the Focus Group or to nominate another peer. It should be noted that one of the restrictions of the method is precisely the difficulty of finding specialists on the subject to be discussed; for this reason, the participants of the Delphi rounds are invited.

Each session is guided by the presentation of the questionnaire, in the terms described above. After the explanation of the recommendation, then the participants must pronounce their votes simultaneously, without being aware of the other votes cast. Each vote is based on three concepts: Relevant, some Relevance and not Relevant, of which only one will be pronounced at a time if the participants were unanimous in their decision the session proceeds to explain the subsequent recommendation further. If they disagree, the participants describe their votes, and a new election is made. Mediator interaction is also possible to resolve possible doubts. The process is repeated until unanimous opinions.

There are as many sections as necessary for the complete evaluation of all recommendations. Any contributions made may be included in the model if submitted to the same ballot. In the end, data obtained during sections are gathered, and the results are presented in a report next chapter, item 4.6.

3.7 Synthesis of Methodological Flow

The methodological flow can be synthesized according to the steps outlined throughout chapter three.

The start is the Configurative Systematic Bibliographic Review, which produced the Rogue Unit definition and fulfilled specific objective one. At this stage, a coherent theoretical rendering was able to understand how the literature dealt with the case study and its bias. It also produced the notes and ideas to feed the Deductive Method

A second step is a supposition that is applying Delphi, Content Analysis and Friedman's we will be able to identify which elements of ILS are the most crucial to compose the Model of Recommendations. At this point, specific objective two is fulfilled. Opinions, suggestions, notes and ideas feed the Deductive Method.

With the Deductive Method, we will raise the Model of recommendations establishing specific objective three.

Confirmatory Focus group validate the Model of Recommendations, and specific objective four is achieved.

Figure 3 represents the pictorial description of the methodology presented in chapter 3.

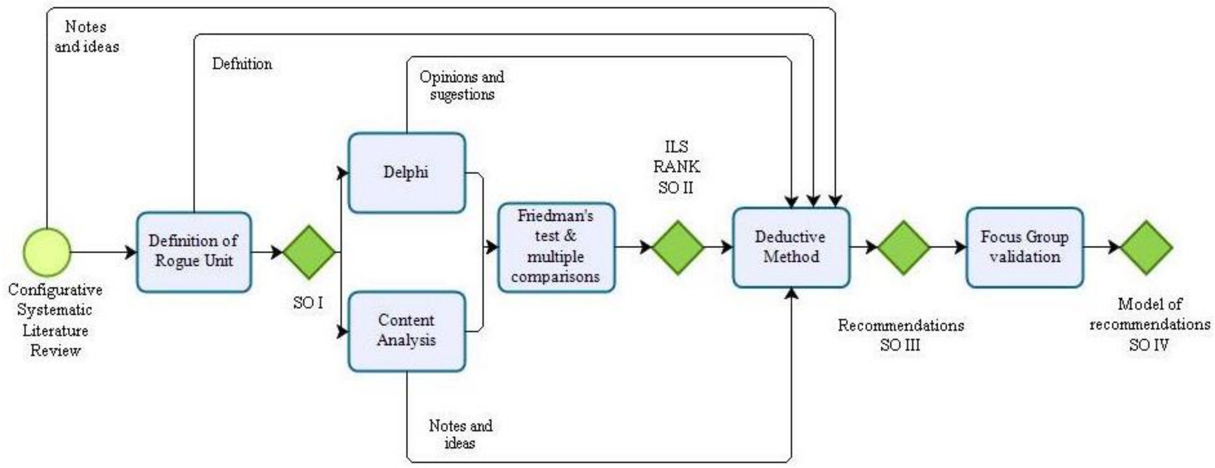

Figure 3 Methodology flow

4 Analysis and discussion

This chapter proposes to present, analyse and discuss the results of the methodology described in Chapter 3. Besides, it makes an analytical assessment of the results according to the method's restrictions for achieving the model. Throughout the chapter, eventually, for each methodology, parallel aspects are highlighted. Those aspects are also results found with the development of the research.

The Chapter is divided into six subtitles Systematic Literature Review results, Delphi results, Content Analysis results, nom-parametric tests results, Recommendation model and Focus Group validation results.

4.1 Systematic literature review (SLR) results

Similar to Chapter 3, results, protocol and materials used in the SLR were presented in item 2.1 and teased in Appendix A. For the sake of maintaining the logic of development of the work, this item has not been removed.

The main result of the method was the proposed new definition:

Rogue Unit is a complex item of relevant added value, belonging to a complex system, whose failure rate differs from other similar items, which cannot be avoided and has a known or unknown failure mode.

4.2 Delphi method

This item is dedicated to describing the entire development of the Delphi method, as presented in Chapter 3, the results and its analysis.

4.2.1 Preparation

Temporally positioning the facts in the research the method started at the beginning of November of 2019 with the preparation of the thesis abstract that would be used to guide the initial steps.

The second part was the quest for specialists. Due to the characteristics of the problem firstly, postgraduate professors from ITA were asked to indicate peers with notorious knowledge in the industrial, aeronautical and MRO areas. This knowledge area choice was based on the findings of the SLR that demonstrated a strong predominance of the aeronautics and defence sector when it came to Rogue Units. For each nominee contacted (via e-mail or phone), another peer was requested. The entire peer quest process ended on February 13, with a total of ten confirmed participants, and no other requests were met. For each participant, a curriculum vitae included in Appendix B was requested. As agreed, the identities were kept confidential and uncharacterized in the respective curricula.

Even after confirmed, one of the specialists gave up on the research, did not respond to the communication attempts and was completely exceeded, remaining only nine.

The scarcity of participants, the delay in responding (three months length) and the withdrawal confirms one of the main difficulties of the method presented in the literature (BROWN, 1968; DIAS, 2007).

At the same time, the quest for specialists, the preparation of the questionnaire model for the first round began. It was tabulated in a spreadsheet containing sixteen folders, named as follows: Survey, Example, Definitions, Abstract and the others as the respective name of each ILS element in acronyms. The acronyms were captioned in the Survey folder.

The Survey folder was the cover of the survey where the primary information, and which could help participants with the answer, were placed. Links were also created for the other folders named above. The models of the developed questionnaires can be found in Appendix C.

With the participants confirmed, e-mails for the first round were sent on February 17th with an expected response by February 21st. The text of all emails sent (explanatory, reminders, doubt solutions and questionnaires) can be found in Appendix D.

4.2.2 Round 1 result

The last reply from round 1 was received on March 10th, 2020. Participant J was excluded, as explained above.

With all the responses to the questionnaire, table 4.1 was structured to summarize the reactions of the participants. Neither Elements nor concepts were added to the proposed list, and the consensus was not reached to remove any of the ILS Elements presented.

There was unanimity that the elements, Design Influence (DI), Maintenance (MTNC) and Manpower & Personnel (M&P), are essential for the identification, prevention and treatment of the Rogue Unit during the preparation, development and production phases. There was a consensus that the other elements are important, except for Product Support Management (PSM).

Table 4.1 Round 1 answer

ILS ELEMENTS	A	B	C	D	E	F	G	H	I	J
Computer Resources (CR)	Y	N	Y	Y	Y	Y	Y	Y	Y	
Design Influence (DI)	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Facilities and Infrastructure (F&I)	Y	Y	Y	N	Y	N	Y	Y	N	
Maintenance (MTNC)	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Manpower & Personnel (M&P)	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Packaging, Handling, Storage and Transportation (PHS&T)	Y	Y	Y	Y	Y	Y	N	Y	N	
Product Support Management (PSM)	Y	N	Y	Y	N	N	N	Y	Y	
Supply Support (SS)	Y	Y	Y	Y	N	N	Y	Y	N	
Support Equipment (SEQ)	Y	Y	Y	N	Y	Y	Y	Y	Y	
Sustaining Engineering (SENG)	Y	Y	Y	N	Y	Y	Y	Y	Y	
Technical Data (TECHD)	Y	Y	Y	N	Y	Y	Y	Y	Y	
Training and Training Support (T&TS)	Y	Y	Y	N	Y	Y	Y	Y	Y	

After the responses compilation and analysis from the first round, the second questionnaire was launched on March 19th prospect of ending by March 27th.

4.2.3 Round 2 results

The last reply from round 2 was received on May 7th, 2020. With all the all responses, Table 4.2 was structured to summarize the reactions of the participants. No other elements or concepts were added to the proposed list, and a consensus to remove the element PSM was reached.

There was unanimity that the elements Design Influence (DI), Maintenance (MTNC), Manpower & Personnel (M&P), Support Equipment (SEQ) and Sustaining Engineering (SENG) are important for the identification, prevention and treatment of the Rogue Unit during the preparation, development and production phases. There was a consensus that the other elements are important, except PSM.

Table 4.2 Round 2 answers

ILS ELEMENTS	A	B	C	D	E	F	G	H	I
Computer Resources (CR)	Y	N	Y	Y	Y	Y	Y	Y	Y
Design Influence (DI)	Y	Y	Y	Y	Y	Y	Y	Y	Y
Facilities and Infrastructure (F&I)	Y	N	Y	Y	Y	N	Y	Y	Y
Maintenance (MTNC)	Y	Y	Y	Y	Y	Y	Y	Y	Y
Manpower & Personnel (M&P)	Y	Y	Y	Y	Y	Y	Y	Y	Y
Packaging, Handling, Storage and Transportation (PHS&T)	Y	Y	Y	Y	Y	Y	N	Y	Y
Product Support Management (PSM)	N	N	N	Y	N	N	N	Y	Y
Supply Support (SS)	Y	Y	Y	Y	N	Y	Y	Y	N
Support Equipment (SEQ)	Y	Y	Y	Y	Y	Y	Y	Y	Y
Sustaining Engineering (SENG)	Y	Y	Y	Y	Y	Y	Y	Y	Y
Technical Data (TECHD)	Y	Y	Y	N	Y	Y	Y	Y	Y
Training and Training Support (T&TS)	Y	Y	Y	N	Y	Y	Y	Y	Y

After the responses compilation and analysis from the second round, the second stage (only round) questionnaire was launched on May 12th prospect of ending by May 18th.

4.2.4 Second Stage answers

In the second stage, first stage results were presented to the participants, in terms of percentiles, each panellist was asked to score rank all Elements, in a degree of importance, between 1 and 12 (1 being the most important), without repetition.

The panellists' responses that were inconsistent with the previous stages were questioned and clarified. For example, a panellist considered the PSM element as not relevant during stage one (rounds one and two) to the case study and classified it with a grade other than 12 (lower importance). In this case, an e-mail was sent questioning the panellist to explain his choice. After clarification, the ranking was redone. The last response regarding the ranking, and the due completion of the method, occurred on June 8th, 2020.

The ranking sum obtained from the panel of experts is summarized in Table 4.3. In a sum of the ranks, we can see that the order of importance of the elements, chosen by the panellists, is shown in table 4.4. Nevertheless, this classification must be subjected to statistical analysis to verify whether the classes (ranks) formed are significantly distant from each other; that is if they are distinct. This statistical analysis will be presented in item 4.4.

Table 4.3 Ranking sum result

ILS ELEMENTS	A	B	C	D	E	F	G	H	I	Absolute Rank Sum
Computer Resources (CR)	11	12	9	3	4	9	2	7	10	67
Design Influence (DI)	4	5	1	1	1	2	1	9	1	25
Facilities and Infrastructure (F&I)	10	9	11	10	10	11	3	12	7	83
Maintenance (MTNC)	2	1	5	6	5	1	4	3	2	29
Manpower & Personnel (M&P)	5	2	4	4	6	5	5	1	4	36
Packaging, Handling, Storage and Transportation (PHS&T)	9	7	8	11	11	8	12	10	6	82
Product Support Management (PSM)	12	10	12	5	12	12	11	8	12	94
Supply Support (SS)	3	11	7	7	9	10	9	11	11	78
Support Equipment (SEQ)	7	4	3	8	3	4	10	6	5	50
Sustaining Engineering (SENG)	8	3	2	2	2	3	8	4	9	41
Technical Data (TECHD)	6	6	6	12	7	7	7	5	3	59
Training and Training Support (T&TS)	1	8	10	9	8	6	6	2	8	58

Table 4.4 Order of importance from Delphi

ILS ELEMENTS	Absolute Rank Sum	Classification
Design Influence (DI)	25	1
Maintenance (MTNC)	29	2
Manpower & Personnel (M&P)	36	3
Sustaining Engineering (SENG)	41	4
Support Equipment (SEQ)	50	5
Training and Training Support (T&TS)	58	6
Technical Data (TECHD)	59	7
Computer Resources (CR)	67	8
Supply Support (SS)	78	9
Packaging, Handling, Storage and Transportation (PHS&T)	82	10
Facilities and Infrastructure (F&I)	83	11
Product Support Management (PSM)	94	12

4.2.5 Discussion

Initially, the method's shortcomings regarding the participants' response time were proven. The total response time of the survey, between the first submission and the last response, was one hundred and twelve days (almost four months).

The second finding that the method provided was the panel's understanding that the PSM Element is not important for the case study. This understanding can be, to some extent, corroborated by the tailoring recommendation of the ILS Plan (ASD;AIA, 2018, p. 56;101). As mentioned in the ILS analysis, not all Elements apply to specific projects and must be evaluated according to a precise cost-benefit ratio.

However, the discarded element is a central and integrating element. It was a surprise that most justifications for the exclusion considered the Element only crucial for the In-Service phase. This same opinion reinforces the findings in the literature that the measures to solve the Rogue Units are only thought reactively.

Confronting the opinions with the curricula of the participants, we observed that most of the respondents, who were against maintaining the PSM in the initial phases, are designers. In other words, those most used to the initial phases of complex projects relegated Product Support Management.

Ultimately, a particular bias was noticed as to the correct definition of the Rogue Unit. As well as the literature presented in Chapter 2, the majority respondents, have in mind the view that Rogue Units are related to the NFF phenomenon and indicated implementation measures quite similar to those found in the literature.

Lastly, it was possible to verify, even at the end of the research that some participants did not spell the term rogue correctly, using rouge or rough instead. Moreover, for them, the idea of connecting the Rogue Unit with the NFF was stronger.

A comprehensive analysis of the measures suggested and adopted for the case study will be carried out in item 4.5.

4.3 Content Analysis (CA) method results

This item describes the protocol used, results and discussion of the Content Analysis method.

4.3.1 Protocol and results

The analysis made on top of the bibliography analysed in the development of the text. Support citations, for example, those used throughout the text to identify the sources or support some definitions, such as web pages, were excluded from the analysis. An example of this differentiation is Brown’s (1968) text on the Delphi Method that was excluded from CA. The complete list with the material used can be found in Appendix E

When starting the method, for each Element of the ILS, some keywords were chosen for the MAXQDA 2020 software lexical search tool. This search mode returns the "search term" with the excerpt in the vicinity for the acceptance or refusal analysis. This option can be customized to return a proximity sentence, a paragraph or even a certain number of words in the search. The configuration used was to return the sentence around the entry term. The tool proved to be very useful because it was possible to access the original document, with the result presented, in a very agile way, which facilitated to decide the permanence or rejection of the search output.

When entering the keyword for the lexical search, a dialogue box presents a window where the excerpts for highlighting were chosen. When ending the selection (permanence or rejection) with the previous keyword, a new keyword was inserted, and the process was repeated until all the keywords were analysed. When the keyword returned many biased results, some operators (AND & NOT) were used to restrict the excess of analysed results. (21979 excerpts)

Then the highlighted content (11393 excerpts) was read, on each original document, and any replications of the quotes (double selection in the same word) were excluded. On table 4.5, it is possible to see the keywords, primary results, filtered and final results.

Table 4.5 Filtering results

ILS Element	Keywords	Primary results	Filtered results	Final results	Rank
(CR)	Computer resource, Software, Hardware, CMMS, AMMS	915	611	578	8
(DI)	Design, Design Influence	5887	2147	2107	2
(F&I)	Facilities, Infrastructure	1428	641	608	7
(MTNC)	Maintenance, Maintenance plan, Maintenance - NOT centred, Maintenance - NOT based	5014	2202	2165	1
(M&P)	Manpower, Personnel, Human Resource, Personnel Training	1415	1111	1101	3
(PHS&T)	Packaging, Handling, Storage, Transportation, PHS&T	836	513	505	10
(PSM)	Product Support, Product Support Management	1135	1013	945	5
(SS)	Supply, Supply Support	822	545	497	11
(SEQ)	Support Equipment, Test Equipment - NOT support, Special Tools	602	508	519	9
(SENG)	Sustaining Engineering, Sustaining - NOT Engineering, Engineering - NOT Sustaining, Engineering -NOT Manufacturing, Engineering -NOT System?	944	228	227	12
(TECHD)	Technical Data, Technical Publications - NOT Data, Manuals, Troubleshooting, Data	998	761	759	6
(T&TS)	Training, Training Strategy, Training Needs Analysis, Training Equipment	1983	1113	1033	4
Totals		21979	11393	11044	---

The last column represents the position of the element based only on the number of excerpts reported in the previous column. The complete spreadsheet with all the resulting coding can be found in Appendix F.

As above mentioned, this classification must be subjected to statistical analysis to verify whether the classes (ranks) formed are significantly distant from each other; that is if they are distinct. This statistical analysis will be presented in item 4.4. Table 4.6, as well as table 4.4, shows the order of importance extracted from Content Analysis.

Table 4.6 Order of importance from Content Analysis

ILS ELEMENTS	Rank
Maintenance (MTNC)	1
Design Influence (DI)	2
Manpower & Personnel (M&P)	3
Training and Training Support (T&TS)	4
Product Support Management (PSM)	5
Technical Data (TECHD)	6
Facilities and Infrastructure (F&I)	7
Computer Resources (CR)	8
Support Equipment (SEQ)	9
Packaging, Handling, Storage and Transportation (PHS&T)	10
Supply Support (SS)	11
Sustaining Engineering (SENG)	12

4.3.2 Discussion

The materials used generated a ranking biased by the data in the manuals *versus* the SLR papers. However, this was already expected due to the volume of pages and the peculiarity of the manuals regarding the direct approach to the elements of the ILS.

Nevertheless, to minimize the bias, codifications were considered in the papers whose, applied thematic categorical analysis returned indirect results, but which, in content, represented the element or a mention of it.

Some convergence with the results of the Delphi round could be seen, and it was indeed expected, as opinions are expected to be somewhat aligned with current knowledge about Rogue Units.

However, table 4.6 is not absolute as it does not correctly correlate each excerpt with its relative position of the Element for each publication. For example, the PSM Element appears in the fifth position, influenced by the number of returns, probably from the publication PSMGR Guidebook (DEFENSE ACQUISITION UNIVERSITY, 2019b).

4.4 Non-parametric tests results

This item is dedicated to present the Friedman test, as described in Chapter 3, with the results and its analysis.

As presented in 2.2.3.4, we have for the results of the Delphi method and Content Analysis, several samples, ranked with categories and treatments. To evaluate the rankings obtained concerning their degree of differentiation, the Friedman Test will be applied.

For such test, the null hypothesis (H_0) is that the rankings do not differ and an alternative (H_1) that at least one of the samples is different from the others. In case of a difference, it will be placed a critical difference analysis (DEMŠAR, 2006) as noted in (2.5).

Firstly, the Delphi results will be analysed, after the Content Analysis results, then we will discuss them.

4.4.1 Delphi

We want to determine if each element analysed by a specialist has the same rank or not.

H_0: each category block is equal ranked

H_1: at least one of the rankings are different.

Decision: reject the null hypothesis at α level if F_r is significant

The level of confidence was set to α=0,05.

To complete the task, the Excel® supplement Action Stat Demo version 3.7 was used to calculate F_r statistic where n = 9; k = 12. The formulations applied in the supplement were analysed and compared with manual calculations and returned, as expected, the same results. The advantage of using the analysis tool is clear concerning the time required for manual accounting, the possibility of applying simultaneous Type I family-wise error rate methods and compare among them and the case of errors in the input. The tabulation required by the technology was different from that organized for manual calculation and is presented in Appendix G.

The result is F_r = 49,08547009, df = 11, p-value = $9{,}13363 \times 10^{-7}$

Decision: at α =0,05 we reject the null hypothesis that each category block is equally rank.

To find out to what extent they are unequal, the combination, pair by pair, of $k(k-1)/2$ is performed, resulting in 66 multiple comparisons. Table 4.6 presents the grouping table. To reduce Type I error the Bonferroni, Simes-Hochberg, Holm, and Hommel methods were applied. However, none of the grouping tables changed. All the result tables can be found in Appendix G

Table 4.7 Delphi Grouping Table

ILS elements	Rank Sum	Groups
Design Influence (DI)	25	A
Maintenance (MTNC)	29	AB
Manpower & Personnel (M&P)	36	ABC
Sustaining Engineering (SENG)	41	ABCD
Support Equipment (SEQ)	50	BCDE
Training and Training Support (T&TS)	58	CDEF
Technical Data (TECHD)	59	DEF
Computer Resources (CR)	67	EFG
Supply Support (SS)	78	FGH
Packaging, Handling, Storage and Transportation (PHS&T)	82	GH
Facilities and Infrastructure (F&I)	83	GH
Product Support Management (PSM)	94	H

4.4.2 Content Analysis

We want to determine if each element ranked by the Content Analysis result has the same rank or not.

H_0: each category block is equal ranked

H_1: at least one of the rankings are different.

Decision: reject the null hypothesis at α level if F_r is significant

The level of confidence was set to α=0,05.

To complete the task the Excel® supplement Action Stat Demo version 3.7 was used to calculate F_r statistic where $n = 36$; $k = 12$.

The result is $F_r = 126{,}307745$, $df = 11$, p-value = $9{,}7078 \times 10^{-22}$

Decision: at α =0,05 we reject the null hypothesis that each category block is equally ranked.

To find out to what extent they are unequal, the combination, pair by pair, of $k(k-1)/2$ is performed, resulting in 66 multiple comparisons. Table 4.7 presents the grouping table. To reduce Type I error the Bonferroni, Holm, Simes-Hochberg and methods were applied. However, none of the grouping tables changed. All the result tables can be found in Appendix G

Table 4.8 Content Analysis Grouping Table

ILS Elements	Rank Sum	Groups
Maintenance (MTNC)	360	A
Design Influence (DI)	324,5	AB
Training & Training support (T&TS)	285	BC
Manpower & Personnel (M&P)	266	C
Supply Support (SS)	217,5	D
Sustaining Engineering (SENG)	217,5	D
Support Equipment (SEQ)	212,5	DE
Technical Data (TECHD)	204,5	DEF
Packaging, Handling, Storage and Transportation (PHS&T)	201	DEF
Computer Resources (CR)	182	DEF
Product Support Management (PSM)	170,5	EF
Facilities & Infrastructure (F&I)	167	F

4.4.3 Discussion

Non-parametric tests revealed that the categories formed (from A to H for Delphi and A to F for CA) were quite similar.

Once the Content Analysis had more samples (n = 36), the ability for test differentiation was bigger than Delphi (n = 9) (six groups against eight). (CORDER; FOREMAN, 2009)

For Delphi DI, MTNC, M&P, SENG, SEQ, T&TS were classified as group A, B or C and for Content Analysis MTNC, DI, T&TS and M&P only. Those categories could be identified of high importance. Categories D and E can be categorized as important, and F, G &H some importance.

Nevertheless, the formation of categories showed that all elements are poorly differentiated from each other. Therefore, the recommendation model will seek to use all Elements of the ILS. Once again, it is proven that the integration part (Integrated) is very important in the philosophy of logistical support.

With this statement, we achieved Specific Objective II (SO II)

After establishing the priority among the ILS Elements, we will proceed to the construction of the Recommendations Model.

4.5 Recommendation Model

This item is dedicated to present the Recommendation Model using the premises established in Specific Objective II (SOII).

The process of deducting the recommendations was the most extended work. The recommendations were the first expected result, and this has been pursued since the first reading. With this objective in mind, each excerpt analysed, which could potentially be converted into a recommendation, was catalogued, analysed and thoroughly compared with the other publications read, in a movement of conference and review until all possible relationships were analysed. Mendeley Desktop Software, version 1.19.4 was used to highlight the excerpts and to fulfil this task. All data generated and highlighted can be found in Appendix H. Subsequently, a second analysis was made in which each potential recommendation was compared with similar ones, redundancies were excluded, the text was delimited and the correlation with the Elements of the ILS, when not originating from the definitions themselves, was made. After the Delphi rounds, the recommendations suggested by the panellists were also integrated into the tailoring analysis loop.

Then, the forty-four recommendations generated were grouped according to their application in the life cycle and justified according to the basis of literature, for the Preparation, Development and Production phases. The indicative number of the recommendation has no relation to the order of application or priority over the others in the same life cycle. The source or explanation, when necessary, of each recommendation, is presented in sequence. Due to the scope of the work, the recommendations are not aimed at implementing the model below.

4.5.1 Preparation phase

It is well known that the concept of support is neglected for the later stages of project development, after the main factors associated with the mission's performance criteria. For perfect integration of all phases of the life cycle, recommendations for Rogue Units are addressed from the Preparation phase. In this stage, the premises of the maintenance and support concepts are established and will form fertile land for the beginning of the Development phase (BLANCHARD; BLYLER, 2016, p. 76).

Recommendation 1:

Include the identification, prevention and treatment of the Rogue Unit as a supportability requirement.

“Each supportability requirement must be based on an operational requirement” derived from a CONOPS, “and that relationship must be identified. If the basis for the supportability requirement is not clear, that requirement must be regarded with suspicion.” (ASD, 2018, p. 88; BLANCHARD; BLYLER, 2016, p. 232). The design should include derived requirements that support maintainability. (DEFENSE ACQUISITION UNIVERSITY, 2020b). DI is related due to supportability design, PSM is the element related to capturing support requirement, and SENG is related to monitoring the performance of the requirement during the operation.

Recommendation 2:

Develop a Computerized Maintenance Management System (CMMS) with the logistic requirements (assessment metrics) for identification, prevention and treatment. Including auto analysis of affordability for repair, discard, refurbish or manage the item (this info may come from Business Case Analysis).

Analysis of repair or upgrade versus disposal or retirement regards SENG and PSM (obsolescence management) (BLANCHARD; BLYLER, 2016, p. 134; DEFENSE ACQUISITION UNIVERSITY, 2019b, p. 73). Software Impact Analysis refers to MTNC, Business Case Analysis is related to PSM, resource software is about CR is and completing paperwork for statistical purposes (assessment metrics) is associated with PHS&T (ASD;AIA, 2018, p. 35).

Recommendation 3:

Commit the Original Equipment Manufacturers (OEM) of Line Replacement Units (LRU) the use Computer Resources to trace/track the log life of an item. Also, prevent counterfeit parts.

Blockchain technology may be applied to solve the tracking problem. Recommendation deducted from PSMGR Guidebook, Appendix A item 4.17, Delphi panel and ARINC 672, appendix B item 4.1. (AERONAUICAL RADIO, 2008; DEFENSE ACQUISITION UNIVERSITY, 2019b). Elements related are CR and SS.

Recommendation 4:

Design bench tests with higher test capabilities and ensures test coverage to diminish ambiguity.

Greater capacity for differentiation provides greater power for identification of the Rogue Unit. Recommendation derived from ARINC 672, appendix B, item 1.5. SX000i and

Delphi panel. (AERONAUICAL RADIO, 2008; ASD;AIA, 2018, p. 40). Elements related DI and SEQ.

Recommendation 5:

Design the product in a way that ambiguous failures could be straightforwardly identified in the troubleshooting process and discard the possibility of a Rogue Unit.

Sometimes an incorrect troubleshooting procedure can generate a Rogue Unit. An improvement in the accuracy of the course can better identify the Rogue Unit. Recommendation derived from ARINC 672, appendix B, item 1.5 and Delphi panel. (AERONAUICAL RADIO, 2008). Elements related DI, MTNC and TECHD. (ASD;AIA, 2018)

Recommendation 6:

Establish Rogue Units assessment metrics for contracts in Business Case Analysis (BCA).

A BCA is a thorough analysis of a situation to identify, as much as possible, the risks, costs, advantages in the adopted support solution and integrate it into the other elements. The objective of this recommendation is to assist the PSMGR in the elaboration of supply contracts with contractual warranties. This recommendation derives from PSMGR Guidebook, item 3.6.2, and S3000L (ASD;AIA, 2014, p. 293; DEFENSE ACQUISITION UNIVERSITY, 2019b). Elements related are TECHD and PSM. Note that the assessment metrics are documentations regarding development. (ASD;AIA, 2018)

Recommendation 7:

Establish, based on logistic requirements, which data shall be collected to enable the analysis of Rogue Units (Intellectual property as well). Use of Engineering Changes Requests (ECR) and Contract Data Requirement's List (CDRL).

> "As a basic result of the LSA GC (guidance conference), the contractor and customer must agree to the principles of how to use the data coming from the logistic analysis activities. The documentation of data within a logistic database must define the purpose of collecting the data. Therefore, it is strongly recommended to carefully select which data elements will be documented in a logistic database and then link the data with its corresponding purpose. This also applies to the logistic analysis activities. The selection must consider technical and economic aspects, especially for very extensive analysis. Examples can be the following: − Detailed or simplified Level of Repair Analysis (LORA) − Optimization methods, such as via simulation runs − Detailed Scheduled Maintenance Analysis (SMA)." (ASD;AIA, 2014, p. 29) S3000L ch2 item 2.4.5.1.

Engineering changes requests are products of SENG as in SX000i "This provides feedback information, evaluations and recommendations to design in the form of engineering changes that address any design shortfalls or that enhance supportability design factors." (ASD;AIA, 2018, p. 78).

> "As early as the TMRR phase, the program can address O&S Cost management through a series of CDRL requirements. The Program Office could use reports required in the RFP and SOW to track part consumption trends, cost drivers, and failure causes to improve training, redesign when necessary, increase reliability, and decrease O&S Cost." (DEFENSE ACQUISITION UNIVERSITY, 2020b, pp. 25, 27) DAG CH4 item 3.2.3.4 and item 3.2.4.1.1 Intellectual Property Strategy

Others Elements related are TECHD, PHS&T and PSM. (ASD;AIA, 2018)

Recommendation 8:

Implementation of an automatic reengineering analysis process after discarded Rogue Unit hypotheses to compensate the no fault found (NFF) phenomena.

Once with a failure that develops an NFF scenario, a reengineering analysis is recommended, this involvement is related to DI.

On both publications, SENG relates to post-deployment, but design changes requests are from SENG (ASD;AIA, 2018). Recommendation derived from PSMGR Guidebook and SX000i. (ASD;AIA, 2018, p. 93; DEFENSE ACQUISITION UNIVERSITY, 2019b, p. 27)

Recommendation 9:

Integrate Logistic Support Analysis (LSA) team to Rogue Unit identification, prevention and treatment requirements.

It is derived from S3000L, Ch. 2, item 2.6 “The LSA manager” and Delphi panel. Related elements are PSM and DI. (ASD;AIA, 2014, p. 33; BLANCHARD; BLYLER, 2016, p. 297)

Recommendation 10:

Submit only those items that have been selected by the Logistic Support Analysis (LSA) to the Rogue Unit candidate analysis.

It is derived from S3000L and SX000i item 2.3.2.8. Elements related DI and PSM. (ASD;AIA, 2014, p. 21, 2018, p. 33)

Recommendation 11:

Use the Modular Open Systems Approach (MOSA) concept during design to facilitate other assessment metrics usage or software, to prevent, identify or deal with Rogue Units.

The use of MOSA provides the best interaction and openness to the use of Artificial Intelligence in identification (MORTADA et al., 2012; YACOUT; SALAMANCA; MORTADA, 2017).

> "The key enabler for MOSA is the adoption of an open business model that requires doing business in a transparent way that leverages the collaborative innovation of numerous participants across the enterprise, permitting shared risk, maximized reuse of assets and reduced total ownership costs." DAG Ch3 item 2.4.1 (DEFENSE ACQUISITION UNIVERSITY, 2020a, p. 24)

Elements related are CR and DI.

Recommendation 12:

Include a clear statement in the Request For Proposal (vendors' survey) about Rogue Unit aspects: warranty, data management, reliability aspects and limits.

During the preparation phase, the logistic requirements identified must be communicated to vendors. DAG Ch 3, table 11(DEFENSE ACQUISITION UNIVERSITY, 2020a, p. 41). The element related is PSM.

Recommendation 13:

If, due to a high mission performance requirement, an item was developed with lower supportability requirement propose an enhanced Logistic Support Analysis for that item.

It is derived from S3000L, Ch3 item 10.3 LSA Candidate selection flowchart. A high operational performance item, such as radar, may have a high failure rate given its inherent logistical immaturity. For this item, a more specific LSA, whose incidence of “rogues” may be higher, is indicated (ASD;AIA, 2014, p. 103). In balancing design alternatives, functional requirements must be balanced against support requirements (BLANCHARD; BLYLER, 2016, p. 279). Elements related DI and PSM.

Recommendation 14:

Include in Life Cycle Sustainment Plan (LCSP) the requirements to treat, identify and prevent Rogue Unit or alternatives for a solution.

It is derived from DAG Ch 4. PSMGR should coordinate the inclusions needed (DEFENSE ACQUISITION UNIVERSITY, 2020b, p. 7). The Element related is PSM.

Recommendation 15:

Special rules for LRU's maintenance manuals change. Usually, the test sequence differs when the parts are modified.

Maintenance manuals change without changing test manuals (KHAN, 2015, p. 3). These procedures may increase the appearance of false Rogue Units. It is derived from ARINC 672 (AERONAUICAL RADIO, 2008, p. 31,37). The Element related is TECHD. (ASD;AIA, 2018)

Recommendation 16:

Include in the independent logistic assessment (ILA, before milestone B, end of preparation/TMRR phase) the verification of the management requirements of the Rogue Units.

Derived directly from DAG Ch4 item 4.1.2.2 Independent Logistics Assessment: "Conducting the ILA early in the program phase where the design can be influenced is critical to fielding a sustainable system. The ILA should then be re-done at each milestone and periodically thereafter as the design matures." (DEFENSE ACQUISITION UNIVERSITY, 2020b, p. 46). The Element related is PSM.

Recommendation 17:

Include special rules for Rogue Units when establishing performance and product design data. Special rules establishing penalties or rewards regulations for warranty clauses regarding the management of Rogue Units. Potential systematic failures would be analysed after the return in service of a new part. The OEM and the user must agree to provide enough data to solve the problem.

Derived from S3000L, Ch3, item 3.3.4 and DAG Ch3, table 11, section H

> "When special rules are established, the related conditions and related values must be well defined in order to avoid uncertainty: − Establishment of penalty regulations concerning failed specified LSA significant data − Establishment of rewards in case of exceeding specified LSA significant data."(ASD;AIA, 2014, p. 51)

Elements related MTNC, PSM, DI and TECHD (ASD;AIA, 2018; DEFENSE ACQUISITION UNIVERSITY, 2019b, p. 74).

Recommendation 18:

Develop maintenance concepts where Rogue Units are considered.

This recommendation was derived from Delphi panel, and it is based on the fact that the maintenance concept, designed with the possibility of Rogue Units, can effectively reduce its impacts on the In-Service phase. Elements related are MTNC, PSM and TECHD (ASD;AIA, 2014, p. 33).

Recommendation 19:

Take considerations regarding obsolescence and ageing when developing maintenance concept for Rogue Units.

PSMGR is responsible for managing obsolescence thought should think about Rogue Units on his plans. This recommendation was derived from Delphi panel. The Elements related are PSM and MTNC (ASD;AIA, 2018, p. 37; BLANCHARD; BLYLER, 2016, p. 220).

Recommendation 20:

Design the product considering Rogue Units experiences from legacy projects or suppliers.

The objective of Sustaining Engineering is mostly influencing the design throughout Engineering Changes Request and improve new products. The Elements related are DI and MTNC (LSA). (ASD;AIA, 2014, p. 180, 2018, p. 66,77,78,87)

Recommendation 21:

Pay attention to the accounting control on mitigation measures for Rogue Units within BCA, estimating possible savings with LCC.

It is derived from Delphi panel, PSMGR Guidebook and IPS Elements Guidebook. The cost-benefit analysis should be tailored to the requirements of the program or project. The Element related is PSM. (DEFENSE ACQUISITION UNIVERSITY, 2019a, p. 27, 2019b, p. 28)

4.5.2 Development phase

In this step, the premises of the regular maintenance and support concepts are implemented and verified. The resulting recommendations aim to guarantee and monitor the development process. It enables the product to meet the designed supportability requirements and delivers a logistically mature product for the first operator.

The knowledge started in the previous phase is applied in the prototypes and must be assimilated and analysed in this phase.

Recommendation 22:

Integrate the logistic chain in-depth, with vendors, to establish the correct level of testability, providing the proper level of adequacy to the Rogue Unit policy.

It is derived directly from S3000L. PSMGR (LSA manager) should participate the suppliers with the design changes and ensure proper follow on (ASD;AIA, 2014, p. 34). The Elements involved are DI, TECHD and PSM. (ASD;AIA, 2018)

Recommendation 23:

Deeply analyse events with prototypes that misled to the wrong usage of the troubleshooting (human factor analysis). Develop troubleshooting procedures.

It is derived from ARINC 672. Just after the development of maintenance tasks, Training needs analysis (TNA) must be performed and comprises Rogue Unit problems. The Elements related are PSM, T&TS, SENG, DI, TECHD and MTNC (AERONAUICAL RADIO, 2008, p. 27; ASD;AIA, 2014, 2018).

Recommendation 24:

Establish, develop or improve the feedback process to support the Rogue Unit treatment or troubleshooting.

It is derived from SX000i. Maintenance concept related. Treatment and troubleshooting define requisites for knowledge bases on M&P. Sustaining engineering is responsible for analysing possible upgrades to correct the Rogues throughout the Engineering Change Proposal (ECP). During development, the same team of designers may execute tasks related to SENG. The Elements related are SENG, DI, M&P, PSM and MTNC (ASD;AIA, 2018, p. 66,77,78,87).

Recommendation 25:

Develop and test a communication system focused on the Rogue Unit troubleshooting for entry to service. Establish priority communications channels with first operators (or first upgrade operators) to receive rapidly feedback on a Rogue situation and share information.

It is derived from ARINC 672 and Delphi panel. It is crucial to establish a system for sharing information regarding Rogues, especially for the first operators, thru the whole life cycle. This action focuses specifically on the first operator or the first delivery. The Elements related are PSM, SENG, DI, T&TS and MTNC (AERONAUICAL RADIO, 2008, p. 27; ASD;AIA, 2018)

Recommendation 26:

Utilization of tags to correctly identify the Rogue Units on the inventory. It might be used smart tags as well (RFID, QR code, bar code…) or a special transponder.

It is derived from ARINC 672 and PSMGR Guidebook. The correct collection of information in the entire system benefits the identification of the Rogue Unit patterns automatically. The Elements related are SS, DI, TECHD and CR (AERONAUICAL RADIO, 2008, p. 33; DEFENSE ACQUISITION UNIVERSITY, 2019b, p. 27).

Recommendation 27:

Establish a proper model to follow up the evolution, regression or stabilization of reliability of the Rogue Unit. Diagnostics, prognostics and health management (D&PHM). Special transponder.

It is derived from SX000i. D&PHM are concerned to Maintenance element. After the correct identification of the Rogue Unit, its behaviour is followed to verify the reliability evolution. This thorough monitoring will serve as input for decision making regarding the destination of the Rogue Unit. This model is typical of the Development phase because it uses the data collected from the prototypes as material (Training of Artificial Intelligence tools). The Elements related are DI and MTNC. (ASD;AIA, 2018)

Recommendation 28:

Implementation of a trigger to change the current inventory control model, once the Rogue Unit was identified. Conventional inventory control models can cause a significant increase in units since they are contaminated with Rogue Units. (Differentiate from NFF)

Derived from Mortada et al. (2012). Non identified Rogue Units might lead to a phantom supply chain, causing an increase in the cost of supply. The Element related is SS.

Recommendation 29:

Procure affordable (rigs models) test bench with higher test capabilities or agree on proper acceptance tests levels. Upgrade existing test benches when possible.

It is the task of PSMGR to search in the inventory of Support Equipment available to be used in the new project. Propose its upgrade or purchase new equipment. In the Development phase, rigs with adapters are typically used for various measurements (DEFENSE ACQUISITION UNIVERSITY, 2019b, p. 27). The Elements related are SEQ and PSM (ASD;AIA, 2018).

Recommendation 30:

Analyse the possibility of using Rogue Unit as a safety level for inventory control.

This recommendation is derived from the author's experience with inventory control in identified Rogue Units. With this information, the Rogue Units are separated by tags (physical or electronic) and mark a fundamental level of alert in the control of stock. When applying the Rogue Unit in operation, we have a strong indication that the supply chain needs to be provoked so that new replacements are urgently provided. The Elements Related are SS and DI (responsible for the due LSA that supports this recommendation).

Recommendation 31:

Develop the possibility of optimizing allocation the Rogue Unit thru the echelons of the supply structure.

In continuation to the previous recommendation, the analysis initiated in Development should also infer the correct allocation of the Rogue Unit in the different levels of the maintenance structure (Where to put the Rogue Unit? On a very operational base, on a less active base, in the workshop or at the Depot?) From the operation of the prototypes, this analysis can be fed, and its implementation proposed. The Elements related are CR and SS.

Recommendation 32:

Adoption of a design and support checklist to the Critical Design Review (CDR) meeting, regarding Rogue Units.

- **Data parameters regarding Rogue Units identification were completely identified:**
- **Parameter list of data-driven from contracts**
- **Parameter list of data-driven from requirements**
- **Parameter list of data-driven from other products documents**
- **Were Rogue Units acceptance rules well described?**
- **Were tolerances establish?**
- **Were compensation rules establish, if applied?**
- **Were project values agreed/accepted with costumers?**
- **Were penalties or compensations rules establish?**

It is derived directly from S3000L, Ch 3, Item 3.5.1. The Elements related are DI and PSM. (ASD;AIA, 2014, p. 52)

Recommendation 33:

Identify in TNA the skills necessary to deal with Rogue Units considering the new product not only for maintainers but for engineers as well.

It is derived from Delphi panel and SX000i, Ch2, item 4.2.12. TNA is related to T&TS with training requirements identified during LSA (DI) and applied to M&P. Sustaining engineers must be trained to recognize Rogue Unit possibilities. The relevance of this recommendation rests in the absence of reports of the need for training for engineers (the paradigm of the perfect project). The Elements related are DI, M&P, SENG and T&TS. (ASD;AIA, 2018, p. 46)

Recommendation 34:

Adopt in-house experience with a prototype to create additional test procedures for Rogue Units.

It is derived from ARINC 672. Experiments with prototypes should be used to improve the product, including Rogue Units concerns. The Elements related are MTNC, DI, SEQ and TECHD. (AERONAUICAL RADIO, 2008, p. 35)

Recommendation 35:

Test the PHS&T options with the prototypes to study the possible failure modes induced by their misuse.

Derived from Delphi panel and related to transportation test. The Elements related are PHS&T, DI and PSM. (ASD:AIA, 2018)

Recommendation 36:

Test the support equipment (designed or used one) to identify possible induced failure modes by their misuse

It is derived from Delphi panel. This recommendation propose is similar to the previous one, to test with the prototype the use of Support Equipment. The Elements related are SEQ, PSM and DI

Recommendation 37:

Transcribe to the maintenance manuals and TNA all experiences obtained with development regarding Rogue Unit identification, prevention and management.

It is derived from Delphi panel. The knowledge acquired with the development is applied to improve the product in the first delivery. The Elements related are TECHD, PSM, T&TS, MTNC.

Recommendation 38:

Develop simulations on Rogue Units cases to evaluate CMMS and design solutions

It is derived from Delphi panel and IPS Elements Guidebook, item 1.4. Supportability Test and Evaluation. Simulate occurrences of Rogue Units to validate methods during development or change design flaws. The Elements related are CR, MTNC, PSM, SENG and TECHD (DEFENSE ACQUISITION UNIVERSITY, 2019a, p. 24)

Recommendation 39:

Analyse/Test F&I regarding storage procedures to identify failure modes generated by misuse.

It is derived from Delphi panel and IPS Elements Guidebook, item 1.4. Supportability Test and Evaluation. Specific storage occurrences, like environmental controls, may lead to an unknown failure mode and should be tested. The Elements related are PHS&T, PMS and F&I (DEFENSE ACQUISITION UNIVERSITY, 2019a, p. 24)

4.5.3 Production phase

At this stage of the life cycle, supplier contracts, initial reliability metrics, and serial production have already been defined. The uncertainties in this phase are already lower, and so are the possibilities for the redesign. The recommendations are related to the check and validation of previously established procedures.

Recommendation 40:

Initial training program to correctly identify the Rogue Units which comprises since from the operator training. Requirements from training carry out from LSA.

It is derived from ARINC 672, SX000i and DAG Ch4. Up to date training program with the best practices, and enhancer of the maintainer's experience, to better identify the Rogue Units, apply the troubleshooting, derive from it, or ignore it (once the Rogue Unit is identified, the use of normal troubleshooting is no longer recommended for that specific unit). LSA is related to Design influence. The Elements related are T&TS and DI. (AERONAUICAL RADIO, 2008, pp. 28, 32, 33; DEFENSE ACQUISITION UNIVERSITY, 2020b, p. 39)

Recommendation 41:

Check the communication channels opened during development regarding Rogue Units

It is derived from ARINC 672, and it is a cross-check for recommendation 25. The Elements related are SENG and PSM. (AERONAUICAL RADIO, 2008, p. 27,32)

Recommendation 42:

Establish new acceptance tests on new deliveries. Batch tests (may increase cost) and monitor the supply chain to verify the effectiveness of the measures adopted in the preparation and development.

It was derived from Delphi panel and PSMGR Guidebook. “Supply chain performance should be closely monitored during this phase since it is the first real ‘stress test’ the supply chain has faced.” (DEFENSE ACQUISITION UNIVERSITY, 2019b, p. 60) It is an essential step in identifying Rogue Units. The Elements related are PSM and SS.

Recommendation 43:

Verify the needs for Engineering Change Proposal (ECP) related to Rogue Units to propose a requirement list to contractors to decide whether to repair, remanufacture or manage the Rogue Unit.

It is derived from DAG Ch4. This recommendation is a new analysis of the list of SENG actions through the ECP to verify the contractual clauses. It is a cross-check with recommendations 6 and 7. The Elements related are PSM, SENG and DI. (DEFENSE ACQUISITION UNIVERSITY, 2020b, p. 40)

Recommendation 44:

If necessary, implement the use of more accurate test benches (surveyed in other projects during the production phase) for the identification of Rogue Units.

It is derived from PSMGR Guidebook item 3.4.1. Take advantage of In-service options to identify Rogues if the designed one presents failures. After the development and acquisition steps, while the test benches still do not conform, it is up to the PSMGR to use other projects to try to identify the Rogue Units. Although in the production phase, it is a recommendation that can easily be extended to the In-Service. PSM Guidebook item 5.2.4.1

4.5.4 Discussion

One of the main findings at the end of the preparation of the recommendations was that the PSM Element stood out from the rest, contrary to its positioning in the ranking of the Delphi and Content Analysis method, as mentioned in 4.2.5 and 4.3.2. Table 4.9 summarizes how many contributions each element made to the recommendations. Elements DI, MTNC, SENG and SS also highlighted. On the other hand, the M&P Element dropped in importance.

As previously presented, the results of the ranking methods may have indicated a lack of knowledge about the importance of PSM. As one of the most recently implemented, together with SENG, it is believed that its contribution is more relevant in the In-Service phase. This position was corroborated by Delphi panellists who, for several opportunities, mentioned that this Element was only more critical for the operational phase. However, reading revealed just the opposite of the participants' perception.

Table 4.9 Contributions per ILS Element

ILS ELEMENTS	Contributions
Product Support Management (PSM)	23
Design Influence (DI)	21
Maintenance (MTNC)	13
Technical Data (TECHD)	11
Sustaining Engineering (SENG)	11
Supply Support (SS)	6
Training and Training Support (T&TS)	5
Computer Resources (CR)	5
Support Equipment (SEQ)	5
Packaging, Handling, Storage and Transportation (PHS&T)	4
Manpower & Personnel (M&P)	2
Facilities and Infrastructure (F&I)	1

It should also be noted that most of the recommendations rested on DI, as expected, and MTNC (Central element in the LSA, where all the necessary data for the significant logistical support decisions come from).

As can be seen, most recommendations are direct applications of a customization process derived from the standards. However, they are of great importance because they directly contribute to a gap found, as far as it was possible to research given the limitations of a master's thesis, not seen similar in the literature.

With the presentation of the recommendations, we achieved Specific Objective III (SOIII). Then the model will be validated using the Confirmatory Focus Group technique.

4.6 Focus Group validation results

This item is dedicated to present the Confirmatory Focus Group, as described in Chapter 3, with the results and its analysis.

The process was organized in three consecutive live sections, according to the protocol described in 3.6. Among the 44 recommendations analysed, only three were of some relevance, and all the rest were considered relevant.

The three participants were chosen from five panellists of the Delphi method, who accepted the invitation for this stage and who stood out among the others as to the clarity and depth of the responses related to the case study. It is noteworthy that the participant “D” has, according to the curriculum presented in Appendix B, experience with steering groups of other standards. In total, they add together 96 years of aeronautical knowledge.

4.6.1 Recommendation Analysis

The discussions generated throughout the section will be described below, only for recommendations that were not consensually considered relevant in the first round of voting, or the comments made on each recommendation.

Recommendation 3: panellist D reinforced the contemporary nature of the recommendation. Relevant.

Recommendation 5: first round, not consensual. Panellist A and D argue that recommendation four cover recommendation 5. Panellist F discusses the viability of the recommendation. It was explained that the troubleshooting precedes the test bench procedure, and, in this case, it applies to maintenance at the organic level. Panellist F requires to relate with the TECHD element. Panellist D argues the importance of the recommendation for innovating in the paradigm shift. "When you are designing, you are overly optimistic and disregard the possibility of failure. If you consider it, perhaps the result of the work will be different." The mediator reinforces the definition that the Rogue Unit will not be avoided, so the recommendations for prevention are adopted. Relevant.

Recommendation 6: panellist A explained the critical analysis concept and argued if it is related. Panellist D argued that the recommendation refers to the contract’s facts. Panellist F had the same understanding. Some relevance.

Recommendation 7: Considered Some relevance. Panellist D argued that this recommendation is more related to contracts than technical.

Recommendation 11: Panellist F questions the application of MOSA. It was explained that the use of an open modular design allows the implementation of better Artificial Intelligence techniques. An example can be found in Mortada et al. (2012).

Recommendation 13: All participants questioned the need for this recommendation. It was explained that some items with low supportability maturity are allowed in the product. The relationship between cost (high demand for support) and benefit (high operational capacity/state-of-the-art) is advantageous if support solutions have been previously thought. Relevant.

Recommendation 18: Panellist F suggests including the Element TECHD. Relevant.

Recommendation 25: Explained that this recommendation differs from the 24 by applying to the check with the first operator.

Recommendation 26: Panellist D questions if the TAG would be applied to all units, not only Rogues. The TAG system was explained to be beneficial to all parts produced. Relevant.

Recommendation 30: Panellist D questions the possibility of keeping a Rogue Unit in stock by analysing the level of stock security. It was explained that the Rogue Unit reliability is known, and, during the Development phase, an attempt is being made to develop a possibility of using Rogue as a Safety level. Panellist A makes a comparison with the application of a KanBan technique. There was no consensus. Panellist D extended that this measure does not contribute to the solution of the Rogue Unit, but an inventory problem. It was explained that the minimization or resolution of the Rogue Unit is not the focus of the recommendations, since it, by definition (SO I) cannot be avoided. This recommendation is for the treatment of the Rogue Unit. Panellist A questions whether it will be used as an inventory risk indicator. It was explained that it represents the "bottom of the well". This analysis for using the Rogue Unit as a stock indicator is only possible from the Development stage because, in this stage, we will have data on the lead time, repair time and small operation. This analysis continues in the Production and In-Service phases. Panellist D infers that it would be a definition, starting from the Development of how to manage the life of the Rogue Unit and agrees that the recommendation is relevant. **Here we see the paradigm of the perfect project. Panellist D did not immediately conceive the possibility of coexistence with the Rogue Unit, as it will be "solved".** Relevant.

Recommendation 33: Panellist F suggests checking if S6000T contributes to the recommendation. There are no additions with the inclusion of the S6000T as the review process will use the recommendation as input to generate new training "Collect data on propose performance needs: Performance needs of a new system, including mission/business goals, maintenance plans, operating parameters, logistical requirements, and high-level training goals, etc., of the new system, are gathered during this step in the process" (ASD;AIA, 2020, p. 47). Relevant.

Recommendation 35: Panellist A commented on the importance of this recommendation. Relevant.

Recommendation 40: Panellist A questions the difference between communication and registration and asks for clarification. Recommendation 25 was recalled. Panellist A mentions the procedure of the First Article Inspection and asks if it was considered, explains that it is a thorough process of checking the quality of the item. It was explained that this is not the case with the recommendation. The alleged test is in the communication channel, not in product quality. Panellist D reinforces that it is a certification of the communication channel. Relevant.

Recommendation 42: Panellist A reports that the procedure “skip batches” are used in automobility and house appliance industry. Relevant.

Recommendation 43: Panellist A requested the re-reading of recommendations 6 and 7, which are references for 43. Some relevance.

4.6.2 Discussion

Each section was fifty minutes long, with a ten-minute break and strictly followed the proposed protocol. The need for new sections was not verified, and the participants informed that they were not in doubt of the recommendations.

Panellist D emphasized that the collection and compilation of the standards made in the recommendations is something new.

The Focus Group Confirmatory reached its goal to analyse and to argue with each recommendation generated in the Specific Objective III (SOIII). The vast majority of the recommendations were consensually considered relevant without discussion in the first round of voting. This consensus is derived from the self-explanatory and direct character of most of the texts presented for analysis.

Recommendations 6, 7 and 43 were considered to be of some relevance because they deal with contractual aspects of the treatment of the Rogue Unit. Conversely, such aspects can contribute to the precise definition of roles, responsibilities, cooperation and decrease long and expensive legal disputes.

With the completion of validation through the Confirmatory Focus Group, Specific Objective IV (SO IV) was achieved. The conclusions of the work will be presented below.

5 Conclusion

This chapter is presented in five subtitles whose purpose is to summarize the work, demonstrate the conclusions, show the contributions achieved, give the research boundaries and indicate research topics for future works.

5.1 Summary of steps

Initially, the research problem was established in an academic, institutional, and operational gap. When raising the question of Rogue Units, it was possible to realize that little had been reported and measures to mitigate operating costs were scarce and not integrated.

For that, a model of recommendations was proposed to present a systemic and practical approach to the case study that integrated the designer's view, comprehensively, to the Elements of Integrated Logistic Support.

The work started with a Systematic Literature Review, followed by the ordering of importance of the Elements of the ILS through the Delphi and Content Analysis methods, with these materials the recommendations were deduced, which were then validated by specialists.

5.2 Conclusions achieved

Starting with Systematic Review of Literature, up to the limit of this research, all available literature on Rogue Units was obtained. Marked by the aerospace industry, the review showed that there was no consensus on the definition of Rogue Units and, still, there was great confusion with the NFF Phenomenon.

In the end, Specific Objective I (SO I) was achieved by presenting a new definition

Rogue Unit is a complex item of relevant added value, belonging to a complex system, whose failure rate differs from other similar items, which cannot be avoided and has a known or unknown failure mode.

The second conclusion reached in Specific Objective II (SO II) was that the ILS Elements have a strong integration regarding the case study and were, in part, little differentiated.

With the previous materials (SO I and SO II), a model of recommendations were derived with 44 recommendations for the Preparation, Development and Production phases.

It was also possible to see that the panellists are surrounded by a paradigm in which the projects, designed by them, are not theoretically subject to unknown flaws. This paradigm prevented, for several moments, that specialists were able to generate solutions to mitigate the problems as presented by the Rogue Units.

It was well known that the Product Support Management Element stood out among the others in the incidence of contributions to the model. This finding was against the rankings developed in SO II.

Finally, the recommendation model proved to be robust when it was practically fully validated as being relevant, except for three of the forty-four recommendations.

5.3 Main contributions

Although laborious, the methodological model proposed in work proved to be efficient for generating the recommendations model (artefact) for a complex problem, validated, which contributed to cover the academic, institutional and operational gap, clearly traceable, robust and with scientific rigour.

It provides contributions to the industry as the application of the recommendations generates a more mature product in terms of supportability.

It provides contributions to the customer, who by using the model, improves their ability to discern the level of support expected from suppliers, and Original Equipment Manufacturers.

It provides contributions to the logistics chain that can clearly understand the needs for improving processes and the degree of quality expected.

It provides contributions to the Academy by establishing yet another robust analysis methodology, generalizable and capable of feeding back the knowledge base.

5.4 Research boundaries

The first restriction imposed on the work was the amount of database sought. To elucidate the main research bases to be included, a preliminary interview was done with library science professionals who indicated a vast and comprehensive (fifteen) database, known worldwide, as well as the patent repository base.

The second one regards the participant’s experience. Following the model proposed by Dias (2007), they were indicated by their peers, considering the first ones selected. For first ones, an indication was sought through the knowledge of ITA professors who pointed out the initial contacts until the network of volunteers with experience in the subject was formed.

Furthermore, the focus of the research is applied to the aeronautical sector, whose researched literature presented a more significant number of results, in addition to greater relevance to the research program studied.

5.5 Future work

This research was not intended to delimit the process of implementing the model as pointed out in 4.5, so some recommendations for future work are present.

Firstly, it is suggested to study the reasons why the available standards do not adhere to the daily routine of the industry. It was observed that such recommendations have no reach in the operational community (concept engineers). This statement, however, is not confirmed for standards that imply safety.

Second, studies can be suggested for the correct assessment of the costs of not managing Rogue Units during the operation, as well as a model for implementing the recommendations generated in this work.

Finally, an optimization analysis of the Rogue Unit in the supply brackets is suggested to minimize costs and maximize availability rates.

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Appendix A – Systematic Review Protocol

This protocol was adapted from the model proposed by Dresch, Lacerda and Antunes Júnior (2015).

A.1 Conceptual Framework

Configurative review: model a process that may identify, prevent and deal with the Rogue Unit during preparation, development and production life cycle phases;

A.2 Horizon

This research will not be limited in the time horizon, observing all the results obtained in the searched bases. The initial results will be analysed before establishing the filters applied, to avoid biased results.

A.3 Languages

Portuguese and English

A.4 Research problem

When problems similar to those of Rogue Units arise during operation life cycle phase, a typical solution is to try to solve it locally without looking back in the early stages of life cycle development and finding the best systemic approach to the case. Observing the beginning of the project, that is, before the first delivery, may be possible to understand and act to satisfy these new requirements.

Therefore, the systems continue to present problems due to the lack of correct management of Integrated Logistic Support (ILS) throughout the life cycle phases. There is a lack of tools to identify the problem and the consequent lack of support for the first operators. Added to this, diagnostic errors further enhance the problem of resource mismanagement, and the erroneous solution orientation can be repeated (SÖDERHOLM, 2007).

Rogue Units can oversize, over cost and generate great complexity in availability, maintainability, reliability and safety management. The systems supported by the contamination of such anomaly do not respond to the usual management practices. Additionally, there is a lack of tools to identify rogue parts precisely, which can potentialize the support poverty for the first operator. (CARROLL III, 2005), (MORTADA et al., 2012). Briefly, it affects the cost, awareness, safety, and availability of a complex system.

The current problem is the lack of a systemic and practical approach to direct actions during the concept, development and production life cycle phases to ensure that the new system will be logistically mature at the time of the first delivery to the operator.

A.5 Strategy

Configurative

A.6 Search criteria

A.6.1 Inclusion

1. Primary study fully meets the framework;
2. Primary study partially meets the framework;
3. Primary study does not meet the framework, but characterizes the object of study;

A.6.2 Exclusion

1. Primary study does not meet the framework nor characterize the object of study;
2. Primary study not conclusive (contemplative);
3. Primary study with low impact or not available for download (no citation on the horizon);

A.7 Search terms

1. "Rogue Unit" (the use of "" restrict the search to the exact term in almost databases used)
2. "rogue component*" (the use of * return the variants of the term component)
3. "rogue"
4. "Rogue Unit*"

A.8 Databases

A.8.1 Aerospace Research Central (ARC)

This database refers to the American Institute of Aeronautics and Astronautics (AIAA) work

Term: “Rogue Unit”, results founded (R) = 0

Term: “rogue component*”, R = 0

Term: “rogue”, R = 256

Filter applied: NOT asteroid NOT satellite NOT wave NOT vibration NOT aircraft R = 79. This final filter string was obtained by analysing each result from the previous search. For example: to obtain the restriction “asteroid” the results from “rogue” were analysed. To obtain the restriction “satellite” the results from “‘rogue’ NOT asteroids” were analysed and so on. This process will repeat throughout the protocol, showing only the last string results.

All the results were analysed and discarded by exclusion criteria A.6.2.1

Term: “Rogue Unit*”, R = 0

All the results were analysed and discarded by exclusion criteria A.6.2.1.

Search ended.

A.8.2 America Society of Mechanical Engineers (ASME)

Term: “Rogue Unit”, R = 0

Term: “rogue component*”, R = 0

Term: “rogue”, R = 489

Filter applied: NOT waves NOT particles NOT buckle NOT blade, R = 46

All the results were analysed and discarded by exclusion criteria A.6.2.1

Term: “Rogue Unit*”, R = 0

Filter applied: NOT waves NOT particles NOT blade NOT buckle NOT data, R=6

All the results were analysed and discarded by exclusion criteria A.6.2.1

A.8.3 National Aeronautics and Space Administration (NASA) Technical Reports Server (NTRS)

Term: “Rogue Unit”, R=0

Term: “rogue component”, R = 353

Filter applied: AND NOT GPS AND NOT waves AND NOT point AND NOT particle* AND NOT aircraft, R = 0

Term: “rogue”, R=493

Filter applied: AND NOT waves AND NOT point AND NOT particle* AND NOT aircraft, R=35

All the results were analysed and discarded by exclusion criteria A.6.2.1

Term: “Rogue Unit*”, R = 0

Search ended.

A.8.4 Instituto Tecnológico de Aeronáutica (ITA) integrated library base research - EBSCO

This base uses the library index and an integrated search in EBSCO Discovery Service (EDS)

Term: “Rogue Unit”, R = 330

Filter applied: NOT state NOT waves NOT fitness NOT trader NOT nation, no limits to the research using the advanced search tool, R= 40

#14 – Aging avionics-what causes it and how to respond. Selected by criteria A.6.1.3;

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Term: “rogue component*”, R = 59

Filter applied: NOT state NOT waves NOT fitness NOT trader NOT nation, R = 29

#1 - Rogue components: their effect and control using logical analysis of data. Selected by criteria A.6.1.3;

#2 – Repeated for #1

#16 - Investigating no fault found in the aerospace industry. Selected by criteria A.6.1.3;

Term: “rogue”, R= 354,746

Filter applied: NOT state NOT waves NOT fitness NOT trader NOT nation NOT GPS NOT nodes NOT drones NOT wireless, R = 55,757

All the results presented had the “subject filter” analysed and it was possible to notice that none was related to the theme. All discarded by exclusion criteria A.6.2.1

Term: “Rogue Unit*”, R = 352

Filter applied: NOT state NOT waves NOT fitness NOT trader NOT nation NOT GPS NOT nodes NOT drones NOT wireless, R = 48

#13 – Repeated: Aging avionics-what causes it and how to respond. Selected by criteria A.6.1.3.

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Search ended.

A.8.5 Science Direct (Elsevier)

Term: “Rogue Unit”, R=13

#2 A system view of the No Fault Found (NFF) phenomenon. Selected by criteria A.6.1.3;

#3 A novel approach for No Fault Found decision-making. Selected by criteria A.6.1.3;

#4 No Fault Found events in maintenance engineering Part 2: Root causes, technical developments, and future research. Selected by criteria A.6.1.3;

#6 A Research study of No Fault Found (NFF) in the Royal Air Force. Selected by criteria A.6.1.3;

#8 No Fault Found events in maintenance engineering Part 1: Current trends, implications, and organizational practices. Selected by criteria A.6.1.3;

#9 A framework to estimate the cost of No-Fault Found events. Selected by criteria A.6.1.3;

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Term: “rogue component” (the research mechanism from Science Direct does not support wildcats “*”), R = 23

#1 Cases study in system burn-in. Selected by criteria A.6.1.3;

#6 Recent advances in the theory and practice of Logical Analysis of Data. Selected by criteria A.6.1.3;

#10 Reliability growth of electronic equipment. Selected by criteria A.6.1.3;

#13 Behind the “bathtub”-curve A new model and its consequences. Selected by criteria A.6.1.3;

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Term: “rogue”, R = 11,525

Filter applied: -waves -nation -cell -access -server –particles – trader R = 2,471

#9 Excluded: A note on the rogue failure of turbine blades. Excluded by criteria A.6.2.1;

#71 Repeated: Cases study in system burn-in. Selected by criteria A.6.1.3;

#100 The reliability of integrated circuits. Selected by criteria A.6.1.3;

#971 Repeated: Behind the “bathtub”-curve A new model and its consequences. Selected by criteria A.6.1.3;

#992 Repeated: Reliability growth of electronic equipment. Selected by criteria A.6.1.3;

#1454 Quality control and screening in the production of plastic encapsulated semiconductor devices (PEDs). Selected by criteria A.6.1.3;

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Term: “Rogue Unit*” Not supported

Search ended

A.8.6 Scopus (Elsevier)

Term: “Rogue Unit”, all fields, R= 9

#4 Excluded: Portable diagnostic reasoning for improved avionics maintenance and information capture & continuity. Analysed. Not available for download. This refers to a solution to reduce ambiguity in failure detection. Do not adequate for the framework. It is not possible to conclude the absence of Rogue Unit definition. Excluded.

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Term: “rogue component*”, all fields, R = 19

#4 – Repeated: Rogue components: their effect and control using logical analysis of data. Selected by criteria A.6.1.3;

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Term: “rogue”, all fields, R= 29,854

Filter applied: AND NOT state AND NOT waves AND NOT fitness AND NOT trader AND NOT point AND NOT nation AND NOT particles AND NOT GPS AND NOT drone AND NOT wireless AND NOT network, R = 3,165

Filter applied: Limit to Subject area “Engineering”, Documentation type: “Article”, “Review”, “Conference Paper” and “Conference Review”, R = 205

Filter applied: Exclude: Physics and Astronomy, Mathematics, Social Sciences, Energy, Environmental Science, Earth and Planetary Sciences, R = 131

#17 – Repeated: A Research study of No Fault Found (NFF) in the Royal Air Force. Selected by criteria A.6.1.3;

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Term: Rogue Unit*, all fields, R=19,156

Filter applied: AND NOT state AND NOT waves AND NOT fitness AND NOT trader AND NOT point AND NOT nation AND NOT particles AND NOT GPS, R=1,202

Filter applied: Subject area “Engineering”, Documentation type: “Article”, “Review”, “Conference Paper” and Conference Review”, R=97

#38 Repeated: A Research study of No Fault Found (NFF) in the Royal Air Force. Selected by criteria A.6.1.3;

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Search ended

A.8.7 EBSCO

Term: “Rogue Unit”, R = 5

All results were analysed and discarded by exclusion criteria A.6.2.1

Term: “rogue component*”, R = 0

Term: “rogue”, R = 6,594

Filter applied: NOT state NOT waves NOT fitness NOT trader NOT point NOT nation NOT particles NOT GPS, R = 2,732

All results presented had the “subject filter” analysed and it was possible to identify that none was related to the theme. All discarded by exclusion criteria A.6.2.1

Term: “Rogue Unit*”, R = 7

All results were analysed and discarded by exclusion criteria A.6.2.1

Search ended

A.8.8 Scientific Electronic Library Online (SciELO)

Term: “Rogue Unit”, R = 0

Term: “rogue component*”, R = 0

Term: “rogue”, R = 5

All the results were analysed and discarded by exclusion criteria A.6.2.1

Term: “Rogue Unit*”, R = 0

A.8.9 Web of science

Term: ALL= (Rogue Unit), R = 167

Filter applied: Categories Web of Science: Restrict to MULTIDISCIPLINARY SCIENCES, ENGINEERING MECHANICAL, ENGINEERING AEROSPACE, ENGINEERING MANUFACTURING, ENGINEERING MULTIDISCIPLINARY, R = 15

All results were analysed and discarded by exclusion criteria A.6.2.1

Term: ALL= (rogue component*), R = 300

Filter applied: Categories Web of Science: Restrict to MULTIDISCIPLINARY SCIENCES, ENGINEERING MECHANICAL, ENGINEERING AEROSPACE,

ENGINEERING MANUFACTURING, ENGINEERING MULTIDISCIPLINARY, MANAGEMENT, OPERATIONS RESEARCH MANAGEMENT SCIENCE, R = 42

#28 Repeated: Rogue components: their effect and control using logical analysis of data. Selected by criteria A.6.1.3;

#33 Discarded by criteria A.6.2.1

#38 Discarded by criteria A.6.2.1

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Term: ALL=(rogue), R = 5,632

Filter Applied: Categories Web of Science: Restrict to MECHANICS, MULTIDISCIPLINARY SCIENCES, ENGINEERING MECHANICAL, ENGINEERING AEROSPACE, ENGINEERING MANUFACTURING, ENGINEERING MULTIDISCIPLINARY, MANAGEMENT, R = 29

#7 Discarded by criteria A.6.2.1

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Term: ALL= (Rogue Unit*), R = 582

Filter Applied: Categories Web of Science: Restrict to MECHANICS, MULTIDISCIPLINARY SCIENCES, ENGINEERING MECHANICAL, ENGINEERING AEROSPACE, ENGINEERING MANUFACTURING, ENGINEERING MULTIDISCIPLINARY, MANAGEMENT, OPERATIONS RESEARCH MANAGEMENT SCIENCE, R = 57

Filters removed

Filter applied: ALL= (Rogue Unit*) NOT TS=wave*, R = 486

Filter Applied: Categories Web of Science: Restrict to MECHANICS, MULTIDISCIPLINARY SCIENCES, ENGINEERING MECHANICAL, ENGINEERING AEROSPACE, ENGINEERING MANUFACTURING, MANAGEMENT, OPERATIONS RESEARCH MANAGEMENT SCIENCE, R = 12

All results were analysed and discarded by exclusion criteria A.6.2.1

A.8.10 Derwent Innovations Index (Web of Science)

Term: “Rogue Unit”, R = 2

All results were analysed and discarded by exclusion criteria A.6.2.1

Term: “rogue component*”, R = 2

#2 Method for enhancing performance of e.g. propulsion system, of aircraft by identifying rogue component, involves comparing operating parameter to predefined baseline for component, and determining whether component is rogue component. Patent No.: 9,327,846 B2. Selected criteria A.6.1.2

The other result was analysed and discarded by exclusion criteria A.6.2.1

Term: “rogue”, R = 967

Filter applied: NOT state NOT waves NOT fitness NOT trader NOT point NOT nation NOT particles NOT GPS, NOT user, NOT network, R = 208

Filter applied: Knowledge area: Restrict to ENGINEERING, R = 208

#121 Repeated: Method for enhancing performance of e.g. propulsion system, of aircraft by identifying rogue component, involves comparing operating parameter to predefined baseline for component, and determining whether component is rogue component. Patent No.: 9,327,846 B2. Selected criteria A.6.1.2

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Term: “Rogue Unit*” R = 2

All results were analysed and discarded by exclusion criteria A.6.2.1

A.8.11 ProQuest

Term: “Rogue Unit”, R = 18

#3 Rogue Units: Focus on cost containment. Selected criteria A.6.1.3;

#8 Repeated: Aging avionics-what causes it and how to respond. Selected criteria A.6.1.3;

#9 A study of no fault found phenomenon. Selected criteria A.6.1.3;

#13 Repeated #8

#10 No Fault Found: Everyone agrees NFF poses numerous problems, but supplying a clear answer evades the industry. Burchell, Bill. Overhaul & Maintenance; Washington Vol. 13, Ed. 2, (Feb 2007): 24. Not available for download. Magazine Article. Discarded by exclusion criteria A.6.2.3

#17 Avoiding NFF. Selected criteria A.6.1.3;

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Term: “rogue component*”, R = 39

#1 Repeated: Rogue components: their effect and control using logical analysis of data. Selected by criteria A.6.1.3;

#8 Repeated: Rogue Units: Focus on cost containment. Selected criteria A.6.1.3;

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Term: “rogue”, R = 35,414

Filter applied: Source type: restrict to: Journals (Periódicos Acadêmicos), Proceedings (trabalhos de conferência), thesis (dissertações e teses), books (Livros), government (Publicações Governamentais e Enciclopédias), R = 9,474

Filter applied: Subject: restrict to armed forces, research, statistical analysis, management, statistics, R = 113.

All results were analysed and discarded by exclusion criteria A.6.2.1

Terms: “Rogue Unit*”, R = 37

#3 Repeated: Rogue Units: Focus on cost containment. Selected criteria A.6.1.3;

#4 Repeated: Aging avionics-what causes it and how to respond. Selected criteria A.6.1.3;

#9 The impact of no fault found on through-life engineering services. Selected criteria A.6.1.3;

#10 Repeated: A study if no fault found phenomenon. Selected criteria A.6.1.3;

#13 Repeated: 17 Avoiding NFF. Selected criteria A.6.1.3;

#14 Research study from industry-university collaboration on “No Fault Found” events. Selected criteria A.6.1.3;

#34 Repeated #4

#35 Repeated #4

#36 Repeated #4

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Search ended

A.8.12 Emerald

Term: “Rogue Unit”, R = 12

#1 Repeated: The impact of no fault found on through-life engineering services. Selected criteria A.6.1.3;

#2 Repeated: Research study from industry-university collaboration on “No Fault Found” events. Selected criteria A.6.1.3.

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Term: “rogue component*”, R = 15

All results were analysed and discarded by exclusion criteria A.6.2.1

Term: “rogue”, R = 1418

Filter applied: NOT state NOT waves NOT fitness NOT trader NOT point NOT nation NOT particles NOT GPS, NOT user, R = 44

All results were analysed and discarded by exclusion criteria A.6.2.1

Term: “Rogue Unit*”, R = 12 (retrieve the same results for “Rogue Unit”)

Search ended

A.8.13 Compendex (Engineering Village – Elsevier)

Term: “Rogue Unit”, R = 0

Term: “rogue component*”, R = 2

#1 discarded by exclusion criteria A.6.2.1

#2 repeated: Rogue components: their effect and control using logical analysis of data. Selected by criteria A.6.1.3;

Term: “rogue”, R = 2,834

Filter applied: NOT state NOT waves NOT fitness NOT trader NOT point NOT nation NOT particles NOT GPS, NOT user, NOT node*, R = 347

Filter applied: Controlled Vocabulary: restrict to IEEE Standards, Supply Chains, Engineering, Aircraft Engines, Data Acquisition, Data Mining, Maintenance, Sensitivity Analysis, Statistics, R = 29

#1 repeated: Rogue components: their effect and control using logical analysis of data. Selected by criteria A.6.1.3;

#11 Repeated: A Research study of No Fault Found (NFF) in the Royal Air Force. Selected by criteria A.6.1.3;

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Term: “Rogue Unit*”, R = 0

Search ended

A.8.14 IEEE Xplore (Institute of Electrical and Electronics Engineers)

Term: “Rogue Unit”, R = 1

#1 Repeated: Aging avionics-what causes it and how to respond. Selected by criteria A.6.1.3;

Term: “rogue component*”, R = 2

All results were analysed and discarded by exclusion criteria A.6.2.1

Term: “rogue”, R = 594

Filter applied: index terms: restrict to learning (artificial intelligence), statistical analysis, R = 35

All results were analysed and discarded by exclusion criteria A.6.2.1

Term: “Rogue Unit*”, R = 2

#1 Repeated: Aging avionics-what causes it and how to respond. Selected by criteria A.6.1.3;

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Search ended

A.8.15 Scholar Google

Term: “Rogue Unit”, R = 171

#20 Repeated: Aging avionics-what causes it and how to respond. Selected by criteria A.6.1.3;

#36 Repeated: A study of no fault found phenomenon. Selected by A.6.1.3;

#48 The Carroll-Hung method for component reliability mapping in aircraft maintenance. Selected by criteria A.6.1.3;

#57 Repeated: No Fault Found events in maintenance engineering Part 2: Root causes, technical developments and future research. Selected by criteria A.6.1.3;

#71 Repeated: A novel approach for No Fault Found decision-making. Selected by criteria A.6.1.3;

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Term: “rogue component*”, R = 106

#1 Repeated: Rogue components: their effect and control using logical analysis of data. Selected by criteria A.6.1.3

#3 Repeated: The Carroll-Hung method for component reliability mapping in aircraft maintenance. Selected by criteria A.6.1.3;

#12 Repeated: Fleet performance optimization tool enhancement. Selected by criteria A.6.1.3;

#13 Repeated: Behind the “bathtub”-curve A new model and its consequences. Selected by criteria A.6.1.3;

#44 Applicability and Interpretability of Logical Analysis Of Data in Condition Based Maintenance. Selected by criteria A.6.1.3;

#47 Tool and Method for fault detection of devices by condition based maintenance. Selected by criteria A.6.1.3;

#48 Repeated: Fleet performance optimization tool enhancement. Selected by criteria A.6.1.3;

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Term: “rogue” R = 76.800

Filter applied: without the words: state, waves, fitness, trader, point, nation, particles, GPS, user, node*, flow, gene, seals, one, river, robots, valley, asteroids, R = 2,080

All filters removed

Filter applied: article title, R = 3,580

Filter applied: without the words: state, states, wave, waves, fitness, trader, point, points, nation, nations, particle, particles, GPS, user, node, nodes, flows, gene, genes, seals, AP, aid, R = 1,600

Filter applied: with, at least: component, unit, item, failure, R = 0

Filter removed: article title, R = 886

#330 Repeated: The Impact of No Fault Found (NFF) on Through Life Engineering Services. Accepted by criteria A.6.1.3;

All the other results were analysed and discarded by exclusion criteria A.6.2.1

Term: “Rogue Unit*”, R = 188.

Filter applied: without the words: state, wave, R = 25

All results were analysed and discarded by exclusion criteria A.6.2.1

A.9 Results

Total results found 548,996

Total results analysed after filters application: 7656

Articles separated for reading:

1. A framework to estimate the cost of No-Fault Found events
2. A note on the rogue failure of turbine blades
3. A novel approach for No Fault Found decision-making
4. A Research study of No Fault Found (NFF) in the Royal Air Force
5. A study of no fault found phenomenon
6. A system view of the No Fault Found (NFF) phenomenon
7. Aging avionics-what causes it and how to respond.
8. Applicability and Interpretability of Logical Analysis of Data in Condition Based Maintenance
9. Avoiding NFF
10. Behind the “bathtub”-curve A new model and its consequences
11. Cases study in system burn-in

12. Investigating no fault found in the aerospace industry
13. Method for enhancing performance of e.g. propulsion system, of aircraft by identifying rogue component, involves comparing operating parameter to predefined baseline for component, and determining whether component is rogue component, Patent No.: 9,327,846 B2.
14. No Fault Found events in maintenance engineering Part 1: Current trends, implications and organizational practices
15. No Fault Found events in maintenance engineering Part 2: Root causes, technical developments and future research
16. Quality control and screening in the production of plastic encapsulated semiconductor devices (PEDs)
17. Recent advances in the theory and practice of Logical Analysis of Data
18. Reliability growth of electronic equipment
19. Research study from industry-university collaboration on "No Fault Found" events
20. Rogue components: their effect and control using logical analysis of data
21. Rogue Units: Focus on cost containment
22. The Carroll-Hung method for component reliability mapping in aircraft maintenance
23. The impact of no fault found on through-life engineering services
24. The reliability of integrated circuits
25. Tool and Method for fault detection of devices by condition based maintenance.

Appendix B – Specialist's *Curriculum Vitae*

This appendix will present the *Curriculum Vitae* (CV) from Delphi and Focus Group participants. These CVs were requested before the start of the Delphi rounds, and the participants' anonymity was guaranteed. The personal data entrusted will be under the responsibility of the author and have been audited by the research supervisor. The presentation order does not follow any specific criteria, place any importance on participation and were transcript as it is, with a mischaracterization of personal data.

Participants selected for Focus Group Validation are marked with "*".

B.1 Participant A*

Electrical and Occupational Safety Engineer, with 29 years of experience, having worked for 25 years in the industry.

Worked in the field of electrical wires and cables, in areas such as Development, Statistical Studies (Weibull), Quality System, Field Support and Suppliers, serving markets such as White Line, Automotive, Energy Concessionaires, among others, for 10 years;

In the branch of the White line, Washers and Dishwashers worked in Product, Process, Reliability and Quality System Audits. Developed activities to reduce field failure rates for electronic components for five years

In the Metallurgical, Industrial Refrigeration and Comfort (HVAC) equipment, worked as Operations and support, Plant Controlling, Project and design, Program, Production, Process, Quality and Guarantee (Field support), for ten years.

B.2 Participant B

Head of “Aircraft Manufacturing Company X” Competence Centre ILS, Senior Technical Information Manager, Company X 2001-until now, Section manager ILS, Project leader Technical Information, Business Coordinator Technical Information and aviation services, System engineer UAVE, Technical writer and instructor, Aeronautical Engineer, Aircraft Maintenance Technician Civilian/military fixed-wing, 22 years of experience within aeronautical engineering

B.3 Participant C

Graduated in Electronic Technology and post-graduated in Production Management

Company “A” from Nov / 2015 until now as a Specialist Platform Engineering, leading cost and quality projects for electronic control and electrical components, technically responsible for validation projects and implementation of parts imported from China

Company “B” from 04/97 to 08/15 Monitoring of quality results after product implantation. Specialist in Supplies from August/12 until April/14. Leading the electronics supplier quality development team (SQD), responsible for the quality of electronic suppliers in the Latin American region, focusing on the introduction of new products (NPI) and improvement of the ECM process. Participated in the global team for the creation of internal standard (GES168) that defines controls in the manufacturing process. The team leader of Quality / Industrialization / Hardware Development teams. Responsible for electronics quality (Quality Front End. Senior Electronic Technologist (Electronic Design Center) from January /00 until April/04 accountable for the application of OPEX tools for continuous improvement in electronic controls, team leader of the project quality team since 2002. Quality Analyst - Quality Engineering from April /97 until December/99, responsible for quality improvement actions in electronic laundry components, Supply Support in the Certification of Productive Processes of suppliers and performance in IRC reduction groups identifying root cause in failure analysis.

Gathered 23 years of experience in the home appliance industry.

B.4 Participant D*

Electrical Engineer, Electronics option, graduated in 1974 at UFRGS, Porto Alegre, RS.

Experience in Aircraft Electrical Systems, Electricity Generation and Distribution, Lighting, EWIS, with an emphasis on Lightning Protection and EMI. Design, development, testing and certification of aircraft systems. Project management, coaching, training and monitoring of specialists.

Active participation in regulatory committees such as SAE, IEC, COBEI and ARACs FAA. Currently chairman of the IEC TC107 - Process Management of Avionics committee - 2015 to 2021). Chairman of the mirror committee of IEC TC107 with COBEI and committee CE 03: 107.01 since 2013.

Career:

"BRASILIAN AIRLINE COMPANY" - Engineering Intern - 1972 to 1974.

"BRASILIAN AIRLINE COMPANY" - Aircraft Maintenance Engineer - 1975 to 1979.

"Aircraft Manufacturing Company Y" - Product Development Engineer and Manager - 1979 to 2017.

"Engineering Company X" - Engineering Consultant and President - 2017 to current.

Accredited Professional of ANAC Project (RCE and PCP of Electrical Systems) - 1984 to 2017.

Autonomous PCP ANAC (Electrical Systems) - 2017 to 2021.

Main training:

- Microprocessors in Control, Process and Data Acquisition - Inst. Of Physics, UFRGS, 1978 - 68 hrs.
- Fundamental Avionics / Reliability - The University of Kansas, 1998 - 35 hrs.
- HIRF Workshop - ERA Technology, UK, 1995 - 30 hrs.
- Lightning Protection of Aircraft - Lightning Technologies, Inc, USA, 1996 - 36 hrs.
- Lightning Protection of Avionics - Lightning Technologies, Inc, USA, 1996 - 36 hrs.

ACTIVITIES such as AEP (Accredited Engineering Professional) ANAC:

Active participation in aircraft certification processes "Aircraft Manufacturing Company X" for over 34 years.

In the last two years, with emphasis on testimony test and analysis of the analytical substance in the areas of Aircraft Protection against the effects of Lightning and EMI / HIRF, such as Autonomous AEP from the “Regional Commercial Jet X” and "KC390" programs.

He accumulated forty-six years of experience.

B.5 Participant E

Mechanical Engineer with four years of experience in the defence and aerospace industry, working on the development of Integrated Logistic Support for ammunition and customer training (maintenance management).

Eighteen years of experience in the automotive sector (body shop, painting and final assembly industrial processes; including equipment maintenance planning and management), extensive experience in the use of Computerized Maintenance Management Systems (including implementation and systems management), FMEA, TPM and RCM.

Twelve years of experience in Lean Manufacturing (TPM, 5S, Poka Yoke, Kaizen, etc.). Five years of experience as a Regional Maintenance Leader in South America.

"Aerospace Industry X" (3 years, eight months)

Development Engineer (2016-current):

• Member of the Tactical Missile Project (TMP) management and development team;

• Responsible for the development of Integrated Logistic Support (ILS) of TMP - Reliability and Maintenance Engineering, Supply Support, Test and Support Equipment, Training and Instructional Aids, Logistic Operation and Technical Documentation.

After-sales technical instructor (Mechanics and Maintenance Management) (2016-2016):

• Training of the final consumer in the "Artillery Saturation Rocket System" operation, maintenance and maintenance management;

• Preparation of courses on the operation, maintenance and management;

• Technical support to the Quality area;

• Technical review of product manuals.

"Automobile Industry X" (19 years old)

Senior Manufacturing Engineer (2010-2016)

• Regional Maintenance Leader for South America and member of the Global Maintenance Team;

• Management and implementation of MAXIMO 7 CMMS in factories in South America (9 plants);

• Participation in the first World Maintenance Meeting, the launch of the Global Lean Maintenance program - Austria, January 2013;

• Regional coordinator of best practices for Preventive and Predictive Maintenance;

• Regional Coordinator of Throughput Improvement (Theory of Constraints);

• Validation of Colmotores Plant to receive the new automotive project (Lean Manufacturing and Throughput audit) - Colombia, June 2010.

Senior Manufacturing Engineer (2008-2010)

Manufacturing Technical Assistance:

• Implementation and management of the Throughput Improvement Process in manufacturing units in South America;

• Technical support in the implementation of Lean Manufacturing in South America.

Manufacturing Engineer (2001-2008)

"YYYY Production Unit Maintenance":

• Development of suppliers and technical products, as well as coordination of contracting, inspection and payment for outsourced services;

• Implementation of the MAXIMO maintenance system in the São José dos Campos Industrial Complex and assistance in other plants in Brazil / Mercosul;

• Coordination of ISO 9000 in Maintenance and internal auditor of the Industrial Complex;

• Coordinator of Preventive and Predictive maintenance of the unit (Body Shop, Painting and Final Assembly);

• Maintenance technical leader in the implementation of “Vehicles A”, “B” and “C” projects

• TPM coordinator at the unit;

• Audit and technical monitoring of fire protection systems with the IRI (Industrial Risk Insurers) and the Complex's Board of Directors;

• Coordination of the Internal Energy Conservation Commission of the plant;

• Support for the implementation of Lean Manufacturing in the factory;

• Advice and technical support to the Quality Department (CEP implementation, Capability, Systems Reliability, etc.).

Jr Manufacturing Engineer (1998-2000)

Central Maintenance:

• Planning of industrial maintenance and utilities;

• Technical support and assistance for the maintenance of the Trucks & Commercial Factory (“truck F” / “truck G”) and Machining 3 (Manufacturing of Family Motors 3);

• Coordination and monitoring of building expansion projects (15,000 m²);

• IT Coordinator in Manufacturing in the Complex;

• Internal Auditor of ISO 9000;

• Projects of industrial ventilation systems and steam pipes.

Engineering Intern (1997-1997)

Central Maintenance:

• Projects of industrial ventilation systems and steam pipes;

• Digitalization of drawings and projects for AutoCAD;

• Support and monitoring of industrial expansions in the Complex.

B.6 Participant F*

He holds a degree in Aeronautical Engineering and a master's degree in Space Sciences and Technologies. He is currently a consultant at an "Institute of Logistics Sciences", working mainly on the following topics: reliability, maintenance program and logistics.

Career:

"Flight research and testing Institute" (2004-2010)

Testing engineer: Specialized technical services, Test Engineering Section, Supplemental Type Certification; Armaments Integration; Flight Simulator Receipt; Flight Qualification Check; Flight Test Campaign Planning and Management

"Maintenance Repair and Overhaul Company": Technical advisor for "Aircraft T", Technical support for "Aircraft T", aircraft engineering modifications design, preparation of technical bulletins and management of maintenance contracts for fleet repairs.

"Institute of Logistics Sciences": Head of consulting subdivision.

He has accumulated 21 years of experience in Aeronautical Sector.

B.7 Participant G

Project Manager, system integrator, Senior Product Manager, availability performance and ILS characteristics.

Career:

"Aircraft Manufacturing Company X":

Senior Product Manager, availability performance and ILS characteristics from 01/08/2018 until now;

Project manager, System development ILS, "Military Aircraft G/E" from 01/01/2013 until 01/07/2018;

Systems engineering manager, availability performance and characteristics from 01/05/2011 until 01/01/2013;

Project manager, "Military Aircraft G/E" maintenance system from 01/02/2009 until 30/04/2011;

Project manager ILS, Preliminary Definition Phase of "Military Aircraft G/E" block XX from 01/03/2008 until 31/01/2009

Project manager, "Military Aircraft G/E" Aircrew Equipment Assembly from 01/08/2007 until 01/01/2008;

Project manager, "Military Aircraft G/E" modifications from 01/06/2005 until 01/08/2007;

Section manager ILS from 01/01/2004 until now;

"Military Aircraft G/E" Field Service Representative (FSR) from 01/02/1993 until 01/06/2005;

Flight Test Engineer from 02/07/1992 until 01/02/1993;

LSA manager from 01/01/1991 until 01/07/1992;

Maintenance engineer from 15/02/1989 until 21/12/1990.

Thirty years of experience of Military Aircraft Development and In-Service Support

B.8 Participant H

Aeronautics Engineer graduated in 1981 and later post-graduated in Administration from IBMEC.

Career:

"Airline Company C" from November 2019 until now, as Maintenance Director

"Airline Company L": where he held various positions in the aeronautical maintenance area in the Embraer 110, Fokker 27, 50 and 100 fleets, Airbus A320,330e 350 and Boeing 767 and 777, from 1985 until 2019.

On this company stayed about, twenty years as Director of Engineering and Maintenance, lead aircraft specification and delivery teams as well as Engineering, Planning, Line and Base Maintenance teams. He contributed to the development and subsequent operation of the MRO in "City C", now qualified for Airbus aircraft, Boeing, Embraer and ATR, adding a park of workshops capable of repairing and overhauling more than 5,000 different aircraft component PNs.

"Airline Company T": maintenance engineer for aeronautical structures from 1982 to 1985;

He has accumulated more than thirty-six years of aeronautical experience.

B.9 Participant I

Master of Science in Industrial Engineering and Management and Certified Project Management Professional. Head of Logistics Engineering at Support & Services of "Aircraft Manufacturing Company X" "Military Aircraft G/E" Support and Line Manager.

Career:

"IT Consulting Company A" from 2000-2002

"Aircraft Manufacturing Company X" from 1997 until 2000 and from 2002 until now:

Head of Logistics (and Maintenance) Engineering.

Project Manager "Military Aircraft E" Maintenance Solution, "Military Aircraft C/D" Maintenance System, "Military Aircraft 11" Maintenance System ("Military Aircraft C/D")

Deputy Project Manager ("Military Aircraft C/D")

ILS Manager and Technical Manager ILS TMS

Project Manager ILS-DB

Logistics Analyst

Graduate Engineer Saab AB

Twenty-three years of experience

B.10 Experience gathered

More than two-hundred and sixty years of experience.

Appendix C – Delphi questionnaires

C.1 Round 1 questionnaire

Folder Survey

Forewords:

This survey propose to gather substantial information herein specialist's knowledge. Your contribution will be very important to the development of this master research. Your personal information will remain confidential throughout this process and will reflect only your personal opinion.

The master project aims to identify the most relevant actions to be taken, during **preparation, development and production life cycle phases**, in order to **identify, prevent and deal** with rogue units. You will find some definitions in the next spreadsheets, an example to fill the survey and an abstract of the thesis. All definitions were transcribed from SX000i, issue 1.2 (2018) chapter 2, item 4.2. Available at www.sx000i.org, when not specified.

The following survey is composed, at least, by three stages. The first one evaluates a broader sample of possibilities related to the topic. You will be kindly asked to analyse this initial list of categories with freedom to add, modify, change, copy and paste, and discard items. The second stage refers to ranking the list of categories formerly set, according to the relevance of each item. The next stages will be explained, if necessary. Do not comment your answers with others participans of this research.

Please return this survey until February 21st. In case you need an extended deadline, please let me know.

I appreciate your time and availability to contribute to this research.

Stage 1 instructions: The following items display potential elements of Integrated Logistic Support (ILS) regarding the identification, prevention and treatment of a rogue unit. You are invited to analyse this initial list with freedom to modify, add, discard or change classification of the items.

Definition of Rogue Unit, preparation phase, development phase and production phase.

Example

	ILS Elements (alphabetic order)	Do you consider this element important for **identification, prevention and treatment** of the rogue unit during **preparation, development and production phases**? Yes (Y) or No (N)	Would you Add(A), Change (C), Discard (D) or Modify (M)? Please leave it blank if you already agree.	If there is any modification, please, briefly explain it.	Suggested actions to implement the element (Not obligatory, however will be very welcome)
1	Computer resources (CR)				
2	Design influence (DI)				
3	Facilities and infrastructure (F&I)				
4	Maintenance (MTNC)				
5	Manpower & personnel (M & P)				
6	Packing, Handling, Storage and Transportation (PHS&T)				
7	Product support management (PSM)				
8	Supply support (SS)				
9	Support equipment (SEQ)				
10	Sustaining engineering (SENG)				
11	Technical Data (TECHD)				
12	Training and trainig support (T&TS)				

Folder Example

Fictional Example

Back to survey

Stage 1: The following items display potential elements Integrated Logistic Support (ILS) regarding the identification, prevention and treatment of a rogue unit. You are invited to analyse this initial list with freedom to modify, add, discard or change classification of the items.

Not obligatory, however will be very

	ILS Elements	Do you consider this element important for identification, prevention and treatment of the rogur unit? Yes (Y) or No (N)	Would you Add(A), Change (C), Discard (D) or Modify (M)? Please leave it blank if you already agree.	If there is any modification, please, briefly explain it.	Suggested actions to implement the element
1	Computer resources	N	M	"Instead ou using a computer we should use abacus"	"Buy a lot of abacus"
2	Design influence	Y			
3	Facilities and infrastructure	Y			
4	Maintenance	Y			
5	Manpower & personnel	Y			
6	Packing, Handling, Storage and Transportation (PHS&T)	Y			
7	Product support management	Y			
8	Supply support	N	D	"I CAN'T SEE ANY CONNECTION WITH THE PROBLEM"	
9	Support equipment	Y			
10	Sustaining engineering	Y			
11	Technical Data	Y			
12	Training and trainig support	Y			

Folder definitions

Rogue unit (component): "defined as an individual repairable component, which repeatedly experiences consecutive short in-service periods, manifests the same mechanical system fault each time it is installed, and when it is removed from service, the mechanical system fault is corrected. The reason a component develops a rogue failure is because its repair and/or overhaul tests do not address 100% of the component's operating functions, characteristics or environment."
A rogue unit maybe tested as a no fault found (NFF), but it cannot be predicted if, when and where it will occur.
It particularly differs from usual NFF phenomena. First because not all components of the population may develop the same failure mode, however any part number population has the potential to develop rogue failures, second it is mostly derived from an alignment of mishaps during manufacturing and finally it may occur that the fault can be correctly identified but the unit still presents lower reliability.(AERONAUTICAL RADIO, 2008; MORTADA et al., 2012)

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Preparation phase: Identification of the user needs; development of requirements; assess potential material solution; identify and reduce technology risks through studies, experiments and engineering models; establish a business case including analysis of alternatives, cost estimate (Life Cycle Cost – LCC) for the launch of the development phase.

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Development phase: Develop a product that meets user requirements and can be produced, tested, evaluated, operated, supported and retired; develop an affordable and executable manufacturing process; ensure operational supportability with particular attention to minimizing the logistic footprint.

Production phase: produce or manufacture the product; test the product; conduct the product acceptance to confirm that it satisfies the requirements.

Folder Abstract

Thesis abstract

Spare part management is a well-known studied subject in aerospace industry and in military. However, there are countless problems regarding its application on corrective maintenance, which still needs a closer look from academia and industry. One of those issues goes back to the management of rogue units, a subset of components who unknown failure modes are applied. This phenomenon leads to a decrease in reliability, availability, maintainability, safety and readiness of the involved systems. This work propose to develop a prescriptive model in order to identify, prevent, and solve problems regarding rogue units during preparation, development and production phases. The methodology proposed is to delimit the study case thru a robust literature review, apply a system approach encompassing: list of problems implications, list of ILS elements impacts, list of Life Cycle Phase requirements, combination of ILS and Life Cycle Phase alternatives to the problem and, finally, to model a solution content analysis focused on specialist's opinion .

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Folder CR

Computer resources: "The objective of the ILS element computer resources is to identify, plan and resource facilities, hardware, software, documentations, manpower and personnel necessary for planning and management of mission critical computer hardware and/or software systems. Computer resources encompasses the facilities, hardware, software, documentation, manpower and personnel needed to operate, support mission critical computer hardware/software systems". The activities related are, perform computer resource analysis and provide computer resources

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Folder DI

Design influence: "Participating in the systems engineering process to impact the design from its inception thru the Product life cycle to facilitate supportability and optimize the design for availability, effectiveness and ownership costs.
Design influence is the integration of the quantitative design characteristics of systems engineering (eg. Reliability, Availability, Mantenability, Testability (RAMT), supportability, affordability) with the functional ILS elements. Design influence reflects the driving relationship of Product design parameters to Product support resource requirements.
These design parameters are expressed in operational terms rather than as inherent values and specifically relate to Product requirements. Thus, Product support requirements are derived to ensure that the Product meets its availability goals and design costs, and that support costs of the Product are effectively balanced." Activities related are, perform Life Cycle Cost (LCC) (affordability) Analysis, perform Logistic Support Analysis (LSA) and perform RAMT analysis.

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Folder F&I

Facilities and infrastructure (F&I): "…consists of the permanent and semi-permanent real property assets or mobile facilities required to integrate support and operate a Product. It includes studies to define types of facilities (eg, training, equipment storage, maintenance, supply storage, hazardous goods storage, computer hardware/software systems, network and communications systems) or facility improvements, location, space needs, environmental and security requirements and equipment.
Due to the potential long lead time in funding, acquisition or construction, planning F&I requirements must be considered as early as possible in the Product life cycle." Activities related are, perform F&I analysis and provide F&I.

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Folder MTNC

Maintenance: "…establish maintenance concepts and requirements for the life cycle of the Product. This element has a great impact on the planning, development, and acquisition of other logistics support elements.
The objective of maintenance is to identify, plan, resource, and implement maintenance concepts and requirements and to execute the maintenance to ensure the best possible equipment/capability is available at the lowest possible cost. For that purpose, nine activities are performed": develop the maintenance concept, develop maintenance plan, execute maintenance tasks, perform Diagnostics, Prognostics and Health Management (D&PHM) analysis, perform Level Of Repair Analysis (LORA), perform Maintenance Task Analysis (MTA), develop and continuously improve preventive maintenance, perform Software Impact Analysis (SIA) and perform Supportability Safety Analysis (SSA)

Back to survey

Folder M&P

Manpower & personnel: "The objective of Manpower and Personnel is to identify, plan and resource personnel, which have necessary qualifications and skills.
Qualifications and skills are required to:
- Operate equipment and product, to effectively complete the missions, and support the operations.
- Provide adequate logistics and to ensure the best capability is available.

Manpower represents the number of personnel of positions required to perform a specific task. Personnel, on the other hand, indicate those human aptitudes and capabilities, knowledge, skills, abilities, and experience levels that are needed to properly perform a task. For that purpose, a manpower and personnel analysis is performed."

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Folder PHS&T

Packing, Handling, Storage and Transportation (PHS&T): "As well as the activities associated with the maintenance and repair of a Product, the are additional aspects concerning the operation and the handling that must be considered. This ILS element covers tasks, which cannot be assigned to an area of direct operation and maintenance of a Product. However, these tasks can be important for the proper use of a Product. For this purpose, a PHS&T requirements analysis is carried out. This analysis includes the identification of PHS&T tasks and the related requirements concerning personnel, support, equipment, consumables, spare parts, facilities and training. The outcomes are documented in the PHS&T Plan."

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Folder PSM

Product support management: "… function consists of elaborating the Support concept, the ILS plan and providing Obsolescence Report. For that purpose, four activities are performed": capture Product support requirements, develop the ILS plan, perform obsolescence management and manage contract.

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Folder SS

Supply support: The objective is "to identify, plan for, resource, and implement management actions to acquire repairs parts, spares, and all classes of supply to ensure best capability is available to support at the lowest possible cycle cost.
This means having the right spares, repair parts and supplies avaible, in the right quantities and quality, at the right place, at the right time, at the right price.
Supply support consists of all management actions, procedures, and techniques necessary to determine requirements do acquire, catalog, receive, store, transfer, issue and dispose of spares, repair parts, and supplies. The process includes provisioning for initial support, as well as acquiring, distributing, and replenishing inventories. For that purpose, two activities are undertaken", provide provisioning data and perform material supply.

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Folder SEQ

Support equipment: "…identify, plan, resource and implement management actions to acquire and support the equipment (mobile or fixed) required to sustain the operation, maintenance and supply of the Product to ensure that the Product is available to the user when it is needed at the lowest life cycle cost.
During the acquisition of Products, program management are expected to decrease the proliferation of support equipment into the inventory by minimizing the development of new support equipment and giving more attention to the use of existing equipment. For that purpose two activities are performed", analyse support equipment requirements and provide support equipment.

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Folder SENG

Sustaining engineering: "… supports Products in their operational environments. This effort spans those technical tasks (eg, engineering and logistics investigations and analysis) to ensure continued operation and maintenance of a Product.
It also involves the identification, review, assessment, and resolution of deficiencies throughout a Product´s life cycle.
It returns a Product to its baselined configuration and capability, while identifying opportunities for performance and capability enhancement. It includes the measurement, identification, and verification of technical and supportability deficiencies, associated root cause analyses, evaluation of the potential for deficiency and the development of a range of corrective actions options.
Sustaining Engineering also includes the implementation of selected corrective actions to include configuration or maintenance processes and the monitoring of a key sustainment health metrics. For that purpose two activities are performed", perform engineering technical analysis, and develop/provide engineering disposition and recommend design changes.

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Folder TECHD

Technical data: "… is recorded information, regardless of the form or method of the recording, of a scientific or technical nature including documentation. Technical data does not include computer software or contract administration data like financial or management information.
The objective of this ILS Element is on hand to identify, plan, validate, resource and implement actions to develop, acquire and maintain information and on the other hand to plan, develop, produce and maintain technical publication. For that purpose two activities are performed", develop technical data package and produce technical publications.

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Folder T&TS

Training and training support: "identify, plan and resource training support and implement a training strategy and to train personnel to operate, maintain and support the Product throughout its life cycle to assure optimum performance and radiness of the Product.

To ensure that the correct training for the use of a Product is delivered, a Training Needs Analysis (TNA) must be carried out in accordance with the training requirements mainly derived from LSA results.

Training and Training support consists of processes, procedures, techniques, training devices and equipment, use to train personnel to operate, maintain and support a Product, as determined by the TNA.

The training system integrates training concepts and strategies and elements of logistics support to satisfy personnel performance levels that are required to operate, maintain, and support the training systems. It includes the tools used to provide learning experiences such as computer-based interactive courseware, simulators, and the Product itself (including embedded training capabilities on actual equipment), job performance aids, and Interactive Electronic Technical Publication (IETP). It is critical that any changes are evaluated to ensure that the impact on the training program is kept to a minimum and that Product design and the training program remain aligned. The training products themselves can require separate configuration management and supportability.

Two phases of training can be identified:

- Initial Training (…)
- Sustainment Training (…)

On each phase, four categories of training can take place:

- Operator Training (…)
- Maintenance Training (…)
- Supervisor Training (…)
- Instructor Training (…)

The overall concept of training personnel, who will operate and maintain a Product, is developed in the early phases of the acquisition cycle.

Training Requirements are identified by the TNA, which must align the subject matter that personnel will be trained.

Than a training Plan (or Program) must be defined which identifies:

- A training curriculum which identifies the number of sessions required to perform initial training of all personnel, by course type
- For each type of course:

o Training Methods (…)

o Training Materials (…)

o Training Support, which includes:

□ Instructors

□ Facilities (…)

□ Training Equipment (…)"

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C.2 Round 2 questionnaire

In this questionnaire, only the Folder Survey was modified. The others were repeated.

Folder Survey

Forewords:

This survey propose to gather substantial information herein specialist's knowledge. Your contribution will be very important to the development of this master research. Your personal information will remain confidential throughout this process and will reflect only your personal opinion.

The master project aims to identify the most relevant actions to be taken, during **preparation, development and production life cycle phases**, in order to **identify, prevent and deal** with rogue units **during operation life cycle phase**. You will find some definitions in the next spreadsheets, an example to fill the survey and an abstract of the thesis. All definitions were transcribed from SX000i, issue 1.2 (2018) chapter 2, item 4.2. Available at www.sx000i.org, when not specified.

The following survey is composed, at least, by three stages. The first one evaluates a broader sample of possibilities related to the topic. You will be kindly asked to analyse this initial list of categories with freedom to add, modify, change, copy and paste, and discard items. The second stage refers to ranking the list of categories formerly set, according to the relevance of each item. The next stages will be explained, if necessary. Do not comment your answers with others participants of this research.

Please return this survey until March 20th. In case you need an extended deadline, please let me know.

I appreciate your time and availability to contribute to this research.

Stage 1 instructions: The following items display potential elements of Integrated Logistic Support (ILS) regarding the identification, prevention and treatment of a rogue unit. You are invited to analyse this initial list with freedom to modify, add, discard or change classification of the items. A **"yes answer"** means that the mentioned element is important **at least in** one phase (preparation, development or production); A "**no answer**" means that the mentioned element is not important to any phase.

Definition of Rogue Unit, preparation phase, development phase and production phase. | Example

	ILS Elements (alphabetic order)	Do you consider this element important for **identification, prevention and treatment** of the rogue unit during **preparation, development and production phases**? Yes (Y) or No (N). **Your answer on round 1 was:**	Participants "yes" answers	Justifications for the "yes" answers	Justifications for the "no" answers	Would you Add(A), Change (C), Discard (D) or Modify (M) **your answer based in others participant's opinion**? Please leave it blank if you already agree.	If there is **any modification on YOUR ANSWER**, please, briefly explain it.	Suggested actions to implement the element (Not obligatory, however will be very welcome)
1	Computer resources (CR)	Y	88,89%	This element embraces the development of the Computer Management System (CMS) which directs collaborate for the identification of rogue patterns	there was not justifications			
2	Design influence (DI)	Y	100%	CONSENSUS		N/A		
3	Facilities and infrastructure (F&I)	Y	66,67%	This element embraces the acquisition of permanent and semi-permanent real properties in order to integrate the efforts for identification, prevention and treatment of the rogue units.	Discard: It is irrelevant for the study case; It is an important economic aspect for the life cycle of the unit during the operation phase, but has not great impact in the avoidance of rogue unit development during the preparation, development and production phases. It becomes of great importance after the unit is classified as a rogue unit, but does not avoid it.			

1	Computer resources (CR)	Y	88,89%	This element embraces the development of the Computer Management System (CMS) which directs collaborate for the identification of rogue patterns	there was not justifications	
2	Design influence (DI)	Y	100%	CONSENSUS		N/A
3	Facilities and infrastructure (F&I)	Y	66,67%	This element embraces the acquisition of permanent and semi-permanent real properties in order to integrate the efforts for identification, prevention and treatment of the rogue units.	Discard: It is irrelevant for the study case; It is an important economic aspect for the life cycle of the unit during the operation phase, but has not great impact in the avoidance of rogue unit development during the preparation, development and production phases. It becomes of great importance after the unit is classified as a rogue unit, but does not avoid it.	
4	Maintenance (MTNC)	Y	100%	CONSENSUS		N/A
5	Manpower & personnel (M & P)	Y	100%	CONSENSUS		N/A
5	Manpower & personnel (M & P)	Y	100%	CONSENSUS		N/A
6	Packing, Handling, Storage and Transportation (PHS&T)	Y	77,78%	This element embraces the tasks, which cannot be assigned to an area of the direct operation and maintenance of a Product. Completing paperwork for statistical purposes is one of them.	Probably not* (*the participant did not explained if an addition, change, discard or modification is necessary. Note from researcher)	
7	Product support management (PSM)	Y	55,56%	This element embraces the function of integrating all the others elements thru all life cycle phases. During production phase will be responsible for stablishing supply support contracts with others vendors to OEM	Discard: I don't see a relationship because the Manager is at a more planning level; Only important for treatment (spare parts, consumables and special tools acquisition) after deployment to the client.	

7	Product support management (PSM)	Y	55,56%	This element embraces the function of integrating all the others elements thru all life cycle phases. During production phase will be responsible for stablishing supply support contracts with others vendors to OEM	Discard: I don't see a relationship because the Manager is at a more planning level; Only important for treatment (spare parts, consumables and special tools acquisition) after deployment to the client.	
8	Supply support (SS)	Y	66,67%	This element is responsible for management of all actions, procedures and techniques necessary to determine requirements to acquire spares, repair parts and supplies. Including the requirements for treatment of rogue units.	Discard: I don't see relation to this element; Only important for treatment (spare parts, consumables and special tools acquisition) after deployment to the client.	
9	Support equipment (SEQ)	Y	88,89%	This element is responsible for the test benches that will identify the rogue unit. Its requirements should be analysed during preparation and development phases.	Discard: Although very important for the operation phases, it will not add value in the preparation, development and production phases.	

9	Support equipment (SEQ)	Y	88,89%	This element is responsible for the test benches that will identify the rogue unit. Its requirements should be analysed during preparation and development phases.	Discard: Although very important for the operation phases, it will not add value in the preparation, development and production phases.	

10	Sustaining engineering (SENG)	Y	88,89%	This element is important to determine the requirements (development phase) for the assessment of a rogue condition during operation phase.	Discard: Although very important for the operation phases, it will not add value in the preparation, development and production phases.	
11	Technical Data (TECHD)	Y	88,89%	This element, during development phase must plan how to update publications when the new rogue unit behaviour was found. Also need to determine how vendors publications will be updated without creating new rogue unties by a maintenance procedure change.	Discard: Although very important for the operation phases, it will not add value in the preparation, development and production phases.	

11	Technical Data (TECHD)	Y	88,89%	This element, during development phase must plan how to update publications when the new rogue unit behaviour was found. Also need to determine how vendors publications will be updated without creating new rogue unties by a maintenance procedure change.	Discard: Although very important for the operation phases, it will not add value in the preparation, development and production phases.	
12	Training and training support (T&TS)	Y	88,89%	Plan the training for rogue unit identification is one of the ways of prevention	Discard: Although very important for the operation phases, it will not add value in the preparation, development and production phases.	

C.3 Stage 2 only round questionnaire

Forewords:

This survey propose to gather substantial information herein specialist's knowledge. Your contribution will be very important to the development of this master research. Your contribution will be very important to the development of this master research. Taking part of this survey means that your personal information will remain confidential throughout this process and will reflect only your personal opinion.

The master project aims to identify the most relevant actions to be taken, during **preparation, development and production life cycle phases**, in order to **identify, prevent and deal** with rogue units **during operation life cycle phase**. You will find some definitions in the next spreadsheets, an example to fill the survey and an abstract of the thesis. All definitions were transcribed from SX000i, issue 1.2 (2018) chapter 2, item 4.2. Available at www.sx000i.org, when not specified.

The following survey is composed, at least, by **three stages**. The **first one** evaluates a broader sample of possibilities related to the topic in order to establish a consensus among the participants as to wich elements should remain or not. The first stage **has, necessarily, at least two rounds** so that the participants can know the responses of others, according to a proportional sample (percentile) and decide whether to maintain or change their opinion. **The second stage** refers to ranking the list of categories formerly set, according to the relevance of each item, and has only one round. **The eventual third** stage is the validation of the recommendations issued, according to a focus group (this stage is still incipient due to the deadline) and **will tend to live activity**. Do not comment your answers with others participants of this research.

Please return this survey until May, 18th. **In case you need an extended deadline, please let me know**.

I appreciate your time and availability to contribute to this research.

Stage 2 instructions: The following items display potential elements of Integrated Logistic Support (ILS) regarding the identification, prevention and treatment of a rogue unit. You are invited to analyse this list and

Stage 2 instructions: The following items display potential elements of Integrated Logistic Support (ILS) regarding the identification, prevention and treatment of a rogue unit. You are invited to analyse this list and Rank from 1 (most important) until 12 (less important) and suggest some actions for implementing the item in the preparation, development and production phases.

Definition of Rogue Unit, preparation phase, development phase and production phase	Example

ILS Elements (alphabetic order)	Rank from 1 (most important) until 12 (less important)	Actions to implement this item.	Results from stage 1 round 2
Computer resources (CR)			Important 88,89%
Design influence (DI)			Important 100%
Facilities and infrastructure (F&I)			Important 77,78%
Maintenance (MTNC)			Important 100%
Manpower & personnel (M & P)			Important 100%
Packing, Handling, Storage and Transportation			Important 88,89%
Product support management (PSM)			Important 33,33%
Supply support (SS)			Important 77,78%
Support equipment (SEQ)			Important 100%
Sustaining engineering (SENG)			Important 100%
Technical Data (TECHD)			Important 88,89%
Training and training support (T&TS)			Important 88,89%

Appendix D – Delphi e-mails

Round 1. Started February 17th, deadline February 21st

Good morning gentleman,

This is the first round of the survey.

Please read the instructions carefully before taking the questionnaire.

The average reading time for all content (including all definitions) is approximately 15 min. The definitions are for consultation and their reading can be omitted if the participant is used to the terms.

For your convenience, the questionnaire can be completed in English or Portuguese.

Please acknowledge receipt of this email.

Best Regards

Round 1 participant doubt solution

Dear participant,

Thank you very much for your first answer.

As an interactive process we should clarify any doubt that about the content.

One of the participants arise a doubt about the survey that may suit to others.

At the affirmative: "Do you consider this element important for identification, prevention and treatment of the Rogue Unit during preparation, development and production phases? Yes (Y) or No (N)", please consider:

1- A "yes answer" means that the mentioned element is important at least in one phase (preparation, development or production);

2- A "no answer" means that the mentioned element is not important to any phase.

3- This research aims to identify the most relevant actions to be taken, during preparation, development and production life cycle phases, in order to identify, prevent and deal with Rogue Units during operation life cycle phase.

If you had the same doubt and want to revise your answer, please let me know as soon as possible.

Best regards

Round 2. Started on March 19th, deadline March 27th

Good morning gentleman,

This is the second round of the survey.

Please read the instructions carefully before taking the questionnaire.

The average reading time for all content (including all definitions) is approximately 15 min. The definitions are for consultation and their reading can be omitted, if the participant is used to the terms.

Although I have tried to avoid any defects resulting from the different versions of Excel, I ask you to note that some text, inside each cell, may be hidden. To view the full text, please select the cell or increase its size.

For your convenience, the questionnaire can be completed in English or Portuguese.

If you have any doubt, or need an extended deadline, please let me know!

Please acknowledge receipt of this email.

Best Regards

Round 2 participant doubt solution on April 1st (only one answer previously received)

Dear participant,

A doubt was posted by one of you.

As required by the method I'm replying to all.

Research is defined by stages. In the first stage, we will establish a consensus among the participants as to which elements should remain or not.

This first stage has, necessarily, at least two rounds so that the participants can know the responses of the others, according to a proportional sample (percentile) and decide whether to maintain or change their opinion.

The second stage is the ranking, which has only one round.

The eventual third stage is the validation of the recommendations issued, according to a focus group (this stage is still incipient) and will tend to live activity.

I hope I have clarified your doubt, as it may also be that of others.

I am eagerly waiting for your answer!

Obrigado por perguntar!

A pesquisa é definida por estágios, no primeiro estágio estabeleceremos um consenso entre os participantes de quais elementos devem permanecer ou não.

Este primeiro estágio têm, necessariamente no mínimo, dois rounds para que os participantes possam conhecer a respostas dos demais, segundo uma amostragem proporcional (percentil) e decidir se mantêm ou muda sua opinião.

O segundo estágio é o ranqueamento, que tem somente um round.

O eventual terceiro estágio é a validação das recomendações emitidas, segundo um grupo focal (este estágio ainda está incipiente) e tenderá para atividade ao vivo.

Espero ter esclarecido sua dúvida, pois também pode ser a dos demais.

Aguardo ansiosamente sua resposta

Respeitosamente

Best Regards

Round 2 Survey reminder. May 6th

Caro participante,

Espero que estejas bem e em segurança.

Obrigado por ter me acompanhado até o momento.

Tenha a certeza de que sua valorosa ajuda muito contribuiu para o engrandecimento desta pesquisa.

Escrevo-lhe para manter o contato enquanto aguardo uma última resposta de um dos participantes.

Muito em breve vou lhe encaminhar uma nova parte do trabalho para continuarmos a pesquisa. Como estamos em reta final solicito-vos certa diligência para as próximas respostas.

Confiante de que sairemos melhores deste período de dificuldades despeço-me, desejando-lhe paz e bem.

Respeitosamente

Dear participant,

I hope you are well and safe.

Thank you for having accompanied me so far.

Rest assured that your valued help greatly contributed to the growth of this research.

I am writing to keep in touch while I await a final response from one of the participants.

Very soon I will send you a new part of the work to continue the research. As we are in the final stretch, I ask you for some diligence for the next answers.

Confident that we will get better out of this difficult period, I say goodbye, wishing you peace and well.

Respectfully

Stage 2, only round, May 12th. Deadline May, 18th

Bom dia Participante!

Esta é a única rodada do segundo estágio da pesquisa.

Por favor, leia as instruções cuidadosamente antes de responder ao questionário.

O tempo médio de leitura de todo o conteúdo (incluindo todas as definições) é de aproximadamente 15 minutos. As definições são para consulta e sua leitura pode ser omitida, se o participante estiver acostumado com os termos.

Embora tenha tentado evitar defeitos resultantes das diferentes versões do Excel, peço que observe que algum texto, dentro de cada célula, pode estar oculto. Para visualizar o texto completo, selecione a célula ou aumente seu tamanho.

Para sua comodidade, o questionário pode ser preenchido em inglês ou português.

Caso tenha alguma dúvida ou precisar de uma extensão de prazo, entre em contato!

Por favor confirme o recebimento deste e-mail.

Respeitosamente

Good morning Participant!

This is the only round of the second stage of the survey.

Please read the instructions carefully before taking the questionnaire.

The average reading time for all content (including all definitions) is approximately 15 min. The definitions are for consultation and their reading can be omitted, if the participant is used to the terms.

Although I have tried to avoid any defects resulting from the different versions of Excel, I ask you to note that some text, inside each cell, may be hidden. To view the full text, please select the cell or increase its size.

For your convenience, the questionnaire can be completed in English or Portuguese.

If you have any doubt, or need an extended deadline, please let me know!

Please acknowledge receipt of this email.

Best Regards

Stage 2, only round doubt solution about participants answers. May 18th, 19th 20th and June 5th

Good morning Mr. XXX

Thank you for taking the survey on time.

Analysing your answer now and comparing with the previous questionnaires I realized that you classified the item "PSM" (Product support management) in position 12 and the item "SS" (supply support) in position 11, while in the last round of the first stage the only item marked as non-contributor was (SS).

Could you please explain your understanding better with this position?

I attach your answers for comparison.

Feel free to contact me if you desire.

Regards

Bom dia ZZZZ,

Muito obrigado pela sua excelente resposta!

Fiz uma análise do seu ranking e percebi que um item elencado por você no round 2 como contribuinte ficou em penúltimo (PHS&T) e o outro item elencado com não contribuinte ficou em nono colocado (Supply support). Poderias por favor explicar melhor seu entendimento com este posicionamento?

Em anexo encaminho suas respostas para comparação.

Desde já agradeço

Respeitosamente

Boa tarde Sr YYYY,

Obrigado por seguir respondendo à pesquisa!

Entendi que sua resposta final de ranqueamento foi influenciada pelo resultado final apresentado na última coluna.

Solicito, se possível, reconsiderar sua resposta de acordo com suas convicções pessoais. Esta divergência de idéias impacta diretamente no protocolo de pesquisa para a próxima análise estatística dos resultados, seja para a convergência ou para a divergência. Por isso sua análise pessoal, desconsiderando a resposta do grupo, é a mais desejada no momento para a pesquisa.

Fico a disposição para qualquer esclarecimento, à qualquer hora do dia!

Respeitosamente

Bom dia Sr. PPPPPP!

Obrigado pela sua resposta completa!

Analisando sua planilha percebi que o Sr adotou mesmo valor para alguns dos elementos do ILS. Entendo que considera-os com mesma importância. No entanto, creio que por um erro na minha explicação sobre os critérios, solicito que, se possível o senhor analise novamente os itens e lhes conceda graus sem repeti-los.

Também fiquei em dúvida sobre qual o significado da sigla DFMEA. Para que não haja nenhuma assunção da minha parte sobre o significado, solicito que o senhor, por favor, defina o significado.

Estou à disposição 24/7 para qualquer dúvida. Se preferir pode me ligar.

Respeitosamente

Hi NNNNN!

Thank you for your answer and your participation in the survey, your opinion is very important!

Analysing your last questionnaire I realized that you placed the Computer Resource in 4th place, but in the previous rounds you pointed out as not contributing.

To keep the research clear, could you please explain your position regarding these responses.

To facilitate forwarding I attach the files you sent me.

If possible, answer me by June 8th. If you need an extension, let me know. I'm too tight with the deadline.

Best Regards

Stage 2, only round, reminder e-mail. May, 25th

Boa Tarde!

Espero que estejas bem e em segurança.

Encaminho este e-mail para informar que até a presente data não recebi sua resposta do segundo estágio da pesquisa, round único.

Poderias por favor reenviar até o final desta semana?

Se ainda não terminou poderias, por favor informar um prazo para o envio.

Sua resposta é muito importante para a conclusão da pesquisa!

Respeitosamente

Good afternoon!

I hope you are well and safe.

I forward this e-mail to inform you that to date, I have not received your response from the single round, second stage, of the survey.

Could you please resend by the end of this week?

If you have not yet finished, please provide a deadline for submission.

Your answer is very important for completing the survey!

Respectfully

The last answer received on June 8th 03:45 PM.

Appendix E – Content Analysis material

Considered bibliography for content analysis. An extract from references.

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Appendix F – Coded Segments spreadsheet

See file on CD.

Appendix G – Non-parametric tests tables

Tabulation example for the manual calculation of the Friedman test

	A	B	C	D	E	F	G	H	I		
(CR)	8	9	5,5	2	3	5,5	1	4	7		
(DI)	7	8	3	3	3	6	3	9	3	Rij^2=	3377
(F&I)	5	3	7,5	5	5	7,5	1	9	2	Cf	270
(MTNC)	3,5	1,5	7,5	9	7,5	1,5	6	5	3,5		
(M & P)	7	2	4	4	9	7	7	1	4		
(PHS&T)	5	2	3,5	7,5	7,5	3,5	9	6	1		
(PSM)	7	3	7	1	7	7	4	2	7		
(SS)	1	8	2,5	2,5	4,5	6	4,5	8	8		
(SEQ)	7	3,5	1,5	8	1,5	3,5	9	6	5		
(SENG)	7,5	4,5	2	2	2	4,5	7,5	6	9		
(TECHD)	4	4	4	9	7	7	7	2	1		
(T&TS)	1	6	9	8	6	3,5	3,5	2	6		
Rank sum	63	54,5	57	61	63	62,5	62,5	60	56,5		
Rank sum squared	3969	2970,25	3249	3721	3969	3906,25	3906,25	3600	3192,25		
H0	same										
H1	at least 1 different										
k	9										
n	12	Q crítico=	2,733								
Q	493,4869649	=(n*(k-1)*((((soma(Q42:Y42))/2)-AA30))/AA29-AA30'									
p-value	1,756E-101	=DIST.QUIQUA.CD(Q;K-1)'									
The null hypothesis is rejected at 5% significance, that is, there is difference between the evaluators for each element of the ILS											

Tabulation example of technology

Groups	Specialist	Answers
CR	1	11
CR	2	12
CR	3	9
CR	4	3
CR	5	4
CR	6	9
CR	7	2
CR	8	7
CR	9	10
DI	1	4
DI	2	5
DI	3	1
DI	4	1
DI	5	1
DI	6	2
DI	7	1
DI	8	9
DI	9	1
F&I	1	10
F&I	2	9
F&I	3	11
F&I	4	10
F&I	5	10
F&I	6	11
F&I	7	3
F&I	8	12
F&I	9	7
MTNC	1	2
MTNC	2	1
MTNC	3	5
MTNC	4	6
MTNC	5	5
MTNC	6	1
MTNC	7	4
MTNC	8	3
MTNC	9	2

Groups	Specialist	Answers
M&P	1	5
M&P	2	2
M&P	3	4
M&P	4	4
M&P	5	6
M&P	6	5
M&P	7	5
M&P	8	1
M&P	9	4
PHS&T	1	9
PHS&T	2	7
PHS&T	3	8
PHS&T	4	11
PHS&T	5	11
PHS&T	6	8
PHS&T	7	12
PHS&T	8	10
PHS&T	9	6
PSM	1	12
PSM	2	10
PSM	3	12
PSM	4	5
PSM	5	12
PSM	6	12
PSM	7	11
PSM	8	8
PSM	9	12
SS	1	3
SS	2	11
SS	3	7
SS	4	7
SS	5	9
SS	6	10
SS	7	9
SS	8	11
SS	9	11

Groups	Specialist	Answers
SEQ	1	7
SEQ	2	4
SEQ	3	3
SEQ	4	8
SEQ	5	3
SEQ	6	4
SEQ	7	10
SEQ	8	6
SEQ	9	5
SENG	1	8
SENG	2	3
SENG	3	2
SENG	4	2
SENG	5	2
SENG	6	3
SENG	7	8
SENG	8	4
SENG	9	9
TECHD	1	6
TECHD	2	6
TECHD	3	6
TECHD	4	12
TECHD	5	7
TECHD	6	7
TECHD	7	7
TECHD	8	5
TECHD	9	3
T&TS	1	1
T&TS	2	8
T&TS	3	10
T&TS	4	9
T&TS	5	8
T&TS	6	6
T&TS	7	6
T&TS	8	2
T&TS	9	8

Multiple comparison table Delphi - FWER (Bonferroni)					
ILS Elements	***Observed difference***	***Critical difference***	***Statistic***	***P-value***	***Adjusted P-value***
CR - DI	42	51,51815547	2,745625892	0,006039559	0,398610897
CR - F&I	16	51,51815547	1,045952721	0,295582862	1
CR - M&P	38	51,51815547	2,484137712	0,012986558	0,8571128
CR - MTNC	31	51,51815547	2,026533396	0,042710154	1
CR - PHS&T	15	51,51815547	0,980580676	0,326799568	1
CR - PSM	27	51,51815547	1,765045216	0,077556167	1
CR - SENG	11	51,51815547	0,719092496	0,472083931	1
CR - SEQ	17	51,51815547	1,111324766	0,266428583	1
CR - SS	26	51,51815547	1,699673171	0,089192418	1
CR - T&TS	8	51,51815547	0,52297636	0,600990704	1
CR - TECHD	9	51,51815547	0,588348405	0,556298461	1
DI - F&I	58	51,51815547	3,791578613	0,000149693	0,009879721
DI - M&P	4	51,51815547	0,26148818	0,793716063	1
DI - MTNC	11	51,51815547	0,719092496	0,472083931	1
DI - PHS&T	57	51,51815547	3,726206568	0,000194383	0,012829286
DI - PSM	69	51,51815547	4,510671108	6,46228E-06	0,000426511
DI - SENG	53	51,51815547	3,464718387	0,000530787	0,035031941
DI - SEQ	25	51,51815547	1,634301126	0,102195637	1
DI - SS	16	51,51815547	1,045952721	0,295582862	1
DI - T&TS	34	51,51815547	2,222649532	0,026239441	1
DI - TECHD	33	51,51815547	2,157277487	0,03098405	1
F&I - M&P	54	51,51815547	3,530090432	0,000415418	0,027417565
F&I - MTNC	47	51,51815547	3,072486117	0,002122837	0,140107247
F&I - PHS&T	1	51,51815547	0,065372045	0,947877781	1
F&I - PSM	11	51,51815547	0,719092496	0,472083931	1
F&I - SENG	5	51,51815547	0,326860225	0,743773606	1
F&I - SEQ	33	51,51815547	2,157277487	0,03098405	1
F&I - SS	42	51,51815547	2,745625892	0,006039559	0,398610897
F&I - T&TS	24	51,51815547	1,568929081	0,116664465	1
F&I - TECHD	25	51,51815547	1,634301126	0,102195637	1
M&P - MTNC	7	51,51815547	0,457604315	0,647236743	1
M&P - PHS&T	53	51,51815547	3,464718387	0,000530787	0,035031941
M&P - PSM	65	51,51815547	4,249182928	2,14552E-05	0,001416041
M&P - SENG	49	51,51815547	3,203230207	0,001358953	0,0896909
M&P - SEQ	21	51,51815547	1,372812946	0,169810505	1
M&P - SS	12	51,51815547	0,784464541	0,432767581	1
M&P - T&TS	30	51,51815547	1,961161351	0,049860204	1
M&P - TECHD	29	51,51815547	1,895789306	0,05798791	1
MTNC - PHS&T	46	51,51815547	3,007114072	0,002637408	0,17406891
MTNC - PSM	58	51,51815547	3,791578613	0,000149693	0,009879721
MTNC - SENG	42	51,51815547	2,745625892	0,006039559	0,398610897
MTNC - SEQ	14	51,51815547	0,915208631	0,360082115	1
MTNC - SS	5	51,51815547	0,326860225	0,743773606	1
MTNC - T&TS	23	51,51815547	1,503557036	0,132695461	1
MTNC - TECHD	22	51,51815547	1,438184991	0,150381573	1
PHS&T - PSM	12	51,51815547	0,784464541	0,432767581	1
PHS&T - SENG	4	51,51815547	0,26148818	0,793716063	1
PHS&T - SEQ	32	51,51815547	2,091905441	0,036446975	1
PHS&T - SS	41	51,51815547	2,680253847	0,007356635	0,485537899
PHS&T - T&TS	23	51,51815547	1,503557036	0,132695461	1
PHS&T - TECHD	24	51,51815547	1,568929081	0,116664465	1

Multiple comparison table Delphi - FWER (Bonferroni)Continuation					
ILS Elements	Observed difference	Critical difference	Statistic	P-value	Adjusted P-value
PSM - SENG	16	51,51815547	1,045952721	0,295582862	1
PSM - SEQ	44	51,51815547	2,876369982	0,004022779	0,265503404
PSM - SS	53	51,51815547	3,464718387	0,000530787	0,035031941
PSM - T&TS	35	51,51815547	2,288021577	0,022136265	1
PSM - TECHD	36	51,51815547	2,353393622	0,01860293	1
SENG - SEQ	28	51,51815547	1,830417261	0,067187569	1
SENG - SS	37	51,51815547	2,418765667	0,015573269	1
SENG - T&TS	19	51,51815547	1,242068856	0,214211158	1
SENG - TECHD	20	51,51815547	1,307440901	0,191063014	1
SEQ - SS	9	51,51815547	0,588348405	0,556298461	1
SEQ - T&TS	9	51,51815547	0,588348405	0,556298461	1
SEQ - TECHD	8	51,51815547	0,52297636	0,600990704	1
SS - T&TS	18	51,51815547	1,176696811	0,239316541	1
SS - TECHD	17	51,51815547	1,111324766	0,266428583	1
T&TS - TECHD	1	51,51815547	0,065372045	0,947877781	1

Multiple comparison table Delphi - FWER (Simes-Hochberg)					
ILS Elements	Observed difference	Critical difference	Statistic	P-value	Adjusted P-value
CR - DI	42	51,51815547	2,745625892	0,006039559	0,308017511
CR - F&I	16	51,51815547	1,045952721	0,295582862	0,947877781
CR - M&P	38	51,51815547	2,484137712	0,012986558	0,636341321
CR - MTNC	31	51,51815547	2,026533396	0,042710154	0,947877781
CR - PHS&T	15	51,51815547	0,980580676	0,326799568	0,947877781
CR - PSM	27	51,51815547	1,765045216	0,077556167	0,947877781
CR - SENG	11	51,51815547	0,719092496	0,472083931	0,947877781
CR - SEQ	17	51,51815547	1,111324766	0,266428583	0,947877781
CR - SS	26	51,51815547	1,699673171	0,089192418	0,947877781
CR - T&TS	8	51,51815547	0,52297636	0,600990704	0,947877781
CR - TECHD	9	51,51815547	0,588348405	0,556298461	0,947877781
DI - F&I	58	51,51815547	3,791578613	0,000149693	0,009430643
DI - M&P	4	51,51815547	0,26148818	0,793716063	0,947877781
DI - MTNC	11	51,51815547	0,719092496	0,472083931	0,947877781
DI - PHS&T	57	51,51815547	3,726206568	0,000194383	0,012051754
DI - PSM	69	51,51815547	4,510671108	6,46228E-06	0,000426511
DI - SENG	53	51,51815547	3,464718387	0,000530787	0,030785645
DI - SEQ	25	51,51815547	1,634301126	0,102195637	0,947877781
DI - SS	16	51,51815547	1,045952721	0,295582862	0,947877781
DI - T&TS	34	51,51815547	2,222649532	0,026239441	0,947877781
DI - TECHD	33	51,51815547	2,157277487	0,03098405	0,947877781
F&I - M&P	54	51,51815547	3,530090432	0,000415418	0,025340477
F&I - MTNC	47	51,51815547	3,072486117	0,002122837	0,118878876
F&I - PHS&T	1	51,51815547	0,065372045	0,947877781	0,947877781
F&I - PSM	11	51,51815547	0,719092496	0,472083931	0,947877781
F&I - SENG	5	51,51815547	0,326860225	0,743773606	0,947877781
F&I - SEQ	33	51,51815547	2,157277487	0,03098405	0,947877781
F&I - SS	42	51,51815547	2,745625892	0,006039559	0,308017511
F&I - T&TS	24	51,51815547	1,568929081	0,116664465	0,947877781
F&I - TECHD	25	51,51815547	1,634301126	0,102195637	0,947877781

Multiple comparison table Delphi - FWER (Simes-Hochberg) Continuation					
ILS Elements	***Observed difference***	***Critical difference***	***Statistic***	***P-value***	***Adjusted P-value***
M&P - MTNC	7	51,51815547	0,457604315	0,647236743	0,947877781
M&P - PHS&T	53	51,51815547	3,464718387	0,000530787	0,030785645
M&P - PSM	65	51,51815547	4,249182928	2,14552E-05	0,001394586
M&P - SENG	49	51,51815547	3,203230207	0,001358953	0,077460323
M&P - SEQ	21	51,51815547	1,372812946	0,169810505	0,947877781
M&P - SS	12	51,51815547	0,784464541	0,432767581	0,947877781
M&P - T&TS	30	51,51815547	1,961161351	0,049860204	0,947877781
M&P - TECHD	29	51,51815547	1,895789306	0,05798791	0,947877781
MTNC - PHS&T	46	51,51815547	3,007114072	0,002637408	0,145057425
MTNC - PSM	58	51,51815547	3,791578613	0,000149693	0,009430643
MTNC - SENG	42	51,51815547	2,745625892	0,006039559	0,308017511
MTNC - SEQ	14	51,51815547	0,915208631	0,360082115	0,947877781
MTNC - SS	5	51,51815547	0,326860225	0,743773606	0,947877781
MTNC - T&TS	23	51,51815547	1,503557036	0,132695461	0,947877781
MTNC - TECHD	22	51,51815547	1,438184991	0,150381573	0,947877781
PHS&T - PSM	12	51,51815547	0,784464541	0,432767581	0,947877781
PHS&T - SENG	4	51,51815547	0,26148818	0,793716063	0,947877781
PHS&T - SEQ	32	51,51815547	2,091905441	0,036446975	0,947877781
PHS&T - SS	41	51,51815547	2,680253847	0,007356635	0,367831742
PHS&T - T&TS	23	51,51815547	1,503557036	0,132695461	0,947877781
PHS&T - TECHD	24	51,51815547	1,568929081	0,116664465	0,947877781
PSM - SENG	16	51,51815547	1,045952721	0,295582862	0,947877781
PSM - SEQ	44	51,51815547	2,876369982	0,004022779	0,217230058
PSM - SS	53	51,51815547	3,464718387	0,000530787	0,030785645
PSM - T&TS	35	51,51815547	2,288021577	0,022136265	0,947877781
PSM - TECHD	36	51,51815547	2,353393622	0,01860293	0,874337705
SENG - SEQ	28	51,51815547	1,830417261	0,067187569	0,947877781
SENG - SS	37	51,51815547	2,418765667	0,015573269	0,74751691
SENG - T&TS	19	51,51815547	1,242068856	0,214211158	0,947877781
SENG - TECHD	20	51,51815547	1,307440901	0,191063014	0,947877781
SEQ - SS	9	51,51815547	0,588348405	0,556298461	0,947877781
SEQ - T&TS	9	51,51815547	0,588348405	0,556298461	0,947877781
SEQ - TECHD	8	51,51815547	0,52297636	0,600990704	0,947877781
SS - T&TS	18	51,51815547	1,176696811	0,239316541	0,947877781
SS - TECHD	17	51,51815547	1,111324766	0,266428583	0,947877781
T&TS - TECHD	1	51,51815547	0,065372045	0,947877781	0,947877781

Multiple comparison table Delphi - FWER (Holm)					
ILS Elements	***Observed difference***	***Critical difference***	***Statistic***	***P-value***	***Adjusted P-value***
CR - DI	42	51,51815547	2,745625892	0,006039559	0,32009663
CR - F&I	16	51,51815547	1,045952721	0,295582862	1
CR - M&P	38	51,51815547	2,484137712	0,012986558	0,636341321
CR - MTNC	31	51,51815547	2,026533396	0,042710154	1
CR - PHS&T	15	51,51815547	0,980580676	0,326799568	1
CR - PSM	27	51,51815547	1,765045216	0,077556167	1
CR - SENG	11	51,51815547	0,719092496	0,472083931	1
CR - SEQ	17	51,51815547	1,111324766	0,266428583	1
CR - SS	26	51,51815547	1,699673171	0,089192418	1
CR - T&TS	8	51,51815547	0,52297636	0,600990704	1
CR - TECHD	9	51,51815547	0,588348405	0,556298461	1
DI - F&I	58	51,51815547	3,791578613	0,000149693	0,009580336
DI - M&P	4	51,51815547	0,26148818	0,793716063	1
DI - MTNC	11	51,51815547	0,719092496	0,472083931	1

Multiple comparison table Delphi - FWER (Holm) Continuation					
ILS Elements	***Observed difference***	***Critical difference***	***Statistic***	***P-value***	***Adjusted P-value***
DI - PHS&T	57	51,51815547	3,726206568	0,000194383	0,012051754
DI - PSM	69	51,51815547	4,510671108	6,46228E-06	0,000426511
DI - SENG	53	51,51815547	3,464718387	0,000530787	0,031847219
DI - SEQ	25	51,51815547	1,634301126	0,102195637	1
DI - SS	16	51,51815547	1,045952721	0,295582862	1
DI - T&TS	34	51,51815547	2,222649532	0,026239441	1
DI - TECHD	33	51,51815547	2,157277487	0,03098405	1
F&I - M&P	54	51,51815547	3,530090432	0,000415418	0,025340477
F&I - MTNC	47	51,51815547	3,072486117	0,002122837	0,118878876
F&I - PHS&T	1	51,51815547	0,065372045	0,947877781	1
F&I - PSM	11	51,51815547	0,719092496	0,472083931	1
F&I - SENG	5	51,51815547	0,326860225	0,743773606	1
F&I - SEQ	33	51,51815547	2,157277487	0,03098405	1
F&I - SS	42	51,51815547	2,745625892	0,006039559	0,32009663
F&I - T&TS	24	51,51815547	1,568929081	0,116664465	1
F&I - TECHD	25	51,51815547	1,634301126	0,102195637	1
M&P - MTNC	7	51,51815547	0,457604315	0,647236743	1
M&P - PHS&T	53	51,51815547	3,464718387	0,000530787	0,031847219
M&P - PSM	65	51,51815547	4,249182928	2,14552E-05	0,001394586
M&P - SENG	49	51,51815547	3,203230207	0,001358953	0,077460323
M&P - SEQ	21	51,51815547	1,372812946	0,169810505	1
M&P - SS	12	51,51815547	0,784464541	0,432767581	1
M&P - T&TS	30	51,51815547	1,961161351	0,049860204	1
M&P - TECHD	29	51,51815547	1,895789306	0,05798791	1
MTNC - PHS&T	46	51,51815547	3,007114072	0,002637408	0,145057425
MTNC - PSM	58	51,51815547	3,791578613	0,000149693	0,009580336
MTNC - SENG	42	51,51815547	2,745625892	0,006039559	0,32009663
MTNC - SEQ	14	51,51815547	0,915208631	0,360082115	1
MTNC - SS	5	51,51815547	0,326860225	0,743773606	1
MTNC - T&TS	23	51,51815547	1,503557036	0,132695461	1
MTNC - TECHD	22	51,51815547	1,438184991	0,150381573	1
PHS&T - PSM	12	51,51815547	0,784464541	0,432767581	1
PHS&T - SENG	4	51,51815547	0,26148818	0,793716063	1
PHS&T - SEQ	32	51,51815547	2,091905441	0,036446975	1
PHS&T - SS	41	51,51815547	2,680253847	0,007356635	0,367831742
PHS&T - T&TS	23	51,51815547	1,503557036	0,132695461	1
PHS&T - TECHD	24	51,51815547	1,568929081	0,116664465	1
PSM - SENG	16	51,51815547	1,045952721	0,295582862	1
PSM - SEQ	44	51,51815547	2,876369982	0,004022779	0,217230058
PSM - SS	53	51,51815547	3,464718387	0,000530787	0,031847219
PSM - T&TS	35	51,51815547	2,288021577	0,022136265	1
PSM - TECHD	36	51,51815547	2,353393622	0,01860293	0,874337705
SENG - SEQ	28	51,51815547	1,830417261	0,067187569	1
SENG - SS	37	51,51815547	2,418765667	0,015573269	0,74751691
SENG - T&TS	19	51,51815547	1,242068856	0,214211158	1
SENG - TECHD	20	51,51815547	1,307440901	0,191063014	1
SEQ - SS	9	51,51815547	0,588348405	0,556298461	1
SEQ - T&TS	9	51,51815547	0,588348405	0,556298461	1
SEQ - TECHD	8	51,51815547	0,52297636	0,600990704	1
SS - T&TS	18	51,51815547	1,176696811	0,239316541	1
SS - TECHD	17	51,51815547	1,111324766	0,266428583	1
T&TS - TECHD	1	51,51815547	0,065372045	0,947877781	1

Multiple comparison table Delphi - FWER (Hommel)					
ILS Elements	***Observed difference***	***Critical difference***	***Statistic***	***P-value***	***Adjusted P-value***
CR - DI	42	51,51815547	2,745625892	0,006039559	0,283859275
CR - F&I	16	51,51815547	1,045952721	0,295582862	0,947877781
CR - M&P	38	51,51815547	2,484137712	0,012986558	0,506475745
CR - MTNC	31	51,51815547	2,026533396	0,042710154	0,877265123
CR - PHS&T	15	51,51815547	0,980580676	0,326799568	0,947877781
CR - PSM	27	51,51815547	1,765045216	0,077556167	0,938028075
CR - SENG	11	51,51815547	0,719092496	0,472083931	0,947877781
CR - SEQ	17	51,51815547	1,111324766	0,266428583	0,947877781
CR - SS	26	51,51815547	1,699673171	0,089192418	0,947877781
CR - T&TS	8	51,51815547	0,52297636	0,600990704	0,947877781
CR - TECHD	9	51,51815547	0,588348405	0,556298461	0,947877781
DI - F&I	58	51,51815547	3,791578613	0,000149693	0,008981565
DI - M&P	4	51,51815547	0,26148818	0,793716063	0,947877781
DI - MTNC	11	51,51815547	0,719092496	0,472083931	0,947877781
DI - PHS&T	57	51,51815547	3,726206568	0,000194383	0,011468604
DI - PSM	69	51,51815547	4,510671108	6,46228E-06	0,000426511
DI - SENG	53	51,51815547	3,464718387	0,000530787	0,030785645
DI - SEQ	25	51,51815547	1,634301126	0,102195637	0,947877781
DI - SS	16	51,51815547	1,045952721	0,295582862	0,947877781
DI - T&TS	34	51,51815547	2,222649532	0,026239441	0,783900918
DI - TECHD	33	51,51815547	2,157277487	0,03098405	0,81133745
F&I - M&P	54	51,51815547	3,530090432	0,000415418	0,024094224
F&I - MTNC	47	51,51815547	3,072486117	0,002122837	0,110387528
F&I - PHS&T	1	51,51815547	0,065372045	0,947877781	0,947877781
F&I - PSM	11	51,51815547	0,719092496	0,472083931	0,947877781
F&I - SENG	5	51,51815547	0,326860225	0,743773606	0,947877781
F&I - SEQ	33	51,51815547	2,157277487	0,03098405	0,81133745
F&I - SS	42	51,51815547	2,745625892	0,006039559	0,283859275
F&I - T&TS	24	51,51815547	1,568929081	0,116664465	0,947877781
F&I - TECHD	25	51,51815547	1,634301126	0,102195637	0,947877781
M&P - MTNC	7	51,51815547	0,457604315	0,647236743	0,947877781
M&P - PHS&T	53	51,51815547	3,464718387	0,000530787	0,030785645
M&P - PSM	65	51,51815547	4,249182928	2,14552E-05	0,001394586
M&P - SENG	49	51,51815547	3,203230207	0,001358953	0,073383464
M&P - SEQ	21	51,51815547	1,372812946	0,169810505	0,947877781
M&P - SS	12	51,51815547	0,784464541	0,432767581	0,947877781
M&P - T&TS	30	51,51815547	1,961161351	0,049860204	0,892930571
M&P - TECHD	29	51,51815547	1,895789306	0,05798791	0,907104072
MTNC - PHS&T	46	51,51815547	3,007114072	0,002637408	0,134507794
MTNC - PSM	58	51,51815547	3,791578613	0,000149693	0,008981565
MTNC - SENG	42	51,51815547	2,745625892	0,006039559	0,283859275
MTNC - SEQ	14	51,51815547	0,915208631	0,360082115	0,947877781
MTNC - SS	5	51,51815547	0,326860225	0,743773606	0,947877781
MTNC - T&TS	23	51,51815547	1,503557036	0,132695461	0,947877781
MTNC - TECHD	22	51,51815547	1,438184991	0,150381573	0,947877781
PHS&T - PSM	12	51,51815547	0,784464541	0,432767581	0,947877781
PHS&T - SENG	4	51,51815547	0,26148818	0,793716063	0,947877781
PHS&T - SEQ	32	51,51815547	2,091905441	0,036446975	0,848457465
PHS&T - SS	41	51,51815547	2,680253847	0,007356635	0,331048568
PHS&T - T&TS	23	51,51815547	1,503557036	0,132695461	0,947877781
PHS&T - TECHD	24	51,51815547	1,568929081	0,116664465	0,947877781
PSM - SENG	16	51,51815547	1,045952721	0,295582862	0,947877781
PSM - SEQ	44	51,51815547	2,876369982	0,004022779	0,197116163
PSM - SS	53	51,51815547	3,464718387	0,000530787	0,030785645
PSM - T&TS	35	51,51815547	2,288021577	0,022136265	0,708360468
PSM - TECHD	36	51,51815547	2,353393622	0,01860293	0,64658751

Multiple comparison table Delphi - FWER (Hommel) Continuation					
ILS Elements	***Observed difference***	***Critical difference***	***Statistic***	***P-value***	***Adjusted P-value***
SENG - SEQ	28	51,51815547	1,830417261	0,067187569	0,926002074
SENG - SS	37	51,51815547	2,418765667	0,015573269	0,576210952
SENG - T&TS	19	51,51815547	1,242068856	0,214211158	0,947877781
SENG - TECHD	20	51,51815547	1,307440901	0,191063014	0,947877781
SEQ - SS	9	51,51815547	0,588348405	0,556298461	0,947877781
SEQ - T&TS	9	51,51815547	0,588348405	0,556298461	0,947877781
SEQ - TECHD	8	51,51815547	0,52297636	0,600990704	0,947877781
SS - T&TS	18	51,51815547	1,176696811	0,239316541	0,947877781
SS - TECHD	17	51,51815547	1,111324766	0,266428583	0,947877781
T&TS - TECHD	1	51,51815547	0,065372045	0,947877781	0,947877781

Multiple comparison table Content Analysis - FWER (Bonferroni)					
ILS Elements	***Observed difference***	***Critical difference***	***Statistic***	***P-value***	***Adjusted P-value***
Computer Resources - Design Influence	142,5	103,0363109	4,65775821	3,19671E-06	0,000210983
Computer Resources - Facilities & Infrastructure	15	103,0363109	0,490290338	0,623928463	1
Computer Resources - Maintenance	178	103,0363109	5,818112009	5,9516E-09	3,92806E-07
Computer Resources - Manpower & Personnel	84	103,0363109	2,745625892	0,006039559	0,398610897
Computer Resources - PHS&T	19	103,0363109	0,621034428	0,534576971	1
Computer Resources - Product Support Management	11,5	103,0363109	0,375889259	0,706999226	1
Computer Resources - Supply	35,5	103,0363109	1,1603538	0,245904789	1
Computer Resources - Support Equipment	30,5	103,0363109	0,996923687	0,318801553	1
Computer Resources - Sustaining Engineering	35,5	103,0363109	1,1603538	0,245904789	1
Computer Resources - Technical data	22,5	103,0363109	0,735435507	0,462074304	1
Computer Resources - Training & Training support	103	103,0363109	3,36666032	0,000760843	0,050215666
Design Influence - Facilities & Infrastructure	157,5	103,0363109	5,148048547	2,6321E-07	1,73719E-05
Design Influence - Maintenance	35,5	103,0363109	1,1603538	0,245904789	1
Design Influence - Manpower & Personnel	58,5	103,0363109	1,912132318	0,055859225	1
Design Influence - PHS&T	123,5	103,0363109	4,036723782	5,42028E-05	0,003577386
Design Influence - Product Support Management	154	103,0363109	5,033647469	4,81234E-07	3,17615E-05
Design Influence - Supply	107	103,0363109	3,49740441	0,000469809	0,031007397
Design Influence - Support Equipment	112	103,0363109	3,660834523	0,000251395	0,016592076
Design Influence - Sustaining Engineering	107	103,0363109	3,49740441	0,000469809	0,031007397
Design Influence - Technical data	120	103,0363109	3,922322703	8,76994E-05	0,005788162

Multiple comparison table Content Analysis - FWER (Bonferroni) Continuation					
ILS Elements	***Observed difference***	***Critical difference***	***Statistic***	***P-value***	***Adjusted P-value***
Design Influence - Training & Training support	39,5	103,0363109	1,29109789	0,196669736	1
Facilities & Infrastructure - Maintenance	193	103,0363109	6,308402347	2,8193E-10	1,86074E-08
Facilities & Infrastructure - Manpower & Personnel	99	103,0363109	3,23591623	0,00121253	0,080026955
Facilities & Infrastructure - PHS&T	34	103,0363109	1,111324766	0,266428583	1
Facilities & Infrastructure - Product Support Management	3,5	103,0363109	0,114401079	0,908919859	1
Facilities & Infrastructure - Supply	50,5	103,0363109	1,650644137	0,098811261	1
Facilities & Infrastructure - Support Equipment	45,5	103,0363109	1,487214025	0,136958293	1
Facilities & Infrastructure - Sustaining Engineering	50,5	103,0363109	1,650644137	0,098811261	1
Facilities & Infrastructure - Technical data	37,5	103,0363109	1,225725845	0,220301861	1
Facilities & Infrastructure - Training & Training support	118	103,0363109	3,856950658	0,00011481	0,007577482
Maintenance - Manpower & Personnel	94	103,0363109	3,072486117	0,002122837	0,140107247
Maintenance - PHS&T	159	103,0363109	5,197077581	2,02446E-07	1,33614E-05
Maintenance - Product Support Management	189,5	103,0363109	6,194001268	5,86557E-10	3,87128E-08
Maintenance - Supply	142,5	103,0363109	4,65775821	3,19671E-06	0,000210983
Maintenance - Support Equipment	147,5	103,0363109	4,821188322	1,42706E-06	9,41857E-05
Maintenance - Sustaining Engineering	142,5	103,0363109	4,65775821	3,19671E-06	0,000210983
Maintenance - Technical data	155,5	103,0363109	5,082676502	3,72153E-07	2,45621E-05
Maintenance - Training & Training support	75	103,0363109	2,451451689	0,014228128	0,939056477
Manpower & Personnel - PHS&T	65	103,0363109	2,124591464	0,033620717	1
Manpower & Personnel - Product Support Management	95,5	103,0363109	3,121515151	0,00179923	0,118749173
Manpower & Personnel - Supply	48,5	103,0363109	1,585272092	0,112904527	1
Manpower & Personnel - Support Equipment	53,5	103,0363109	1,748702205	0,080342509	1
Manpower & Personnel - Sustaining Engineering	48,5	103,0363109	1,585272092	0,112904527	1
Manpower & Personnel - Technical data	61,5	103,0363109	2,010190385	0,044411043	1
Manpower & Personnel - Training & Training support	19	103,0363109	0,621034428	0,534576971	1
PHS&T - Product Support Management	30,5	103,0363109	0,996923687	0,318801553	1
PHS&T - Supply	16,5	103,0363109	0,539319372	0,589666504	1
PHS&T - Support Equipment	11,5	103,0363109	0,375889259	0,706999226	1
PHS&T - Sustaining Engineering	16,5	103,0363109	0,539319372	0,589666504	1
PHS&T - Technical data	3,5	103,0363109	0,114401079	0,908919859	1
PHS&T - Training & Training support	84	103,0363109	2,745625892	0,006039559	0,398610897

Multiple comparison table Content Analysis - FWER (Bonferroni)Continuation					
ILS Elements	***Observed difference***	***Critical difference***	***Statistic***	***P-value***	***Adjusted P-value***
Product Support Management - Supply	47	103,0363109	1,536243059	0,124478779	1
Product Support Management - Support Equipment	42	103,0363109	1,372812946	0,169810505	1
Product Support Management - Sustaining Engineering	47	103,0363109	1,536243059	0,124478779	1
Product Support Management - Technical data	34	103,0363109	1,111324766	0,266428583	1
Product Support Management - Training & Training support	114,5	103,0363109	3,742549579	0,000182163	0,01202273
Supply - Support Equipment	5	103,0363109	0,163430113	0,870179795	1
Supply - Sustaining Engineering	0	103,0363109	0	1	1
Supply - Technical data	13	103,0363109	0,424918293	0,670896239	1
Supply - Training & Training support	67,5	103,0363109	2,20630652	0,027362545	1
Support Equipment - Sustaining Engineering	5	103,0363109	0,163430113	0,870179795	1
Support Equipment - Technical data	8	103,0363109	0,26148818	0,793716063	1
Support Equipment - Training & Training support	72,5	103,0363109	2,369736633	0,01780076	1
Sustaining Engineering - Technical data	13	103,0363109	0,424918293	0,670896239	1
Sustaining Engineering - Training & Training support	67,5	103,0363109	2,20630652	0,027362545	1
Technical Data - Training & Training support	80,5	103,0363109	2,631224813	0,008507774	0,56151306

Multiple comparison table Content Analysis - FWER (Simes-Hochberg)					
ILS Elements	***Observed difference***	***Critical difference***	***Statistic***	***P-value***	***Adjusted P-value***
Computer Resources - Design Influence	142,5	103,0363109	4,65775821	3,19671E-06	0,000179016
Computer Resources - Facilities & Infrastructure	15	103,0363109	0,490290338	0,623928463	1
Computer Resources - Maintenance	178	103,0363109	5,818112009	5,9516E-09	3,80903E-07
Computer Resources - Manpower & Personnel	84	103,0363109	2,745625892	0,006039559	0,259701039
Computer Resources - PHS&T	19	103,0363109	0,621034428	0,534576971	1
Computer Resources - Product Support Management	11,5	103,0363109	0,375889259	0,706999226	1
Computer Resources - Supply	35,5	103,0363109	1,1603538	0,245904789	1
Computer Resources - Support Equipment	30,5	103,0363109	0,996923687	0,318801553	1
Computer Resources - Sustaining Engineering	35,5	103,0363109	1,1603538	0,245904789	1
Computer Resources - Technical data	22,5	103,0363109	0,735435507	0,462074304	1
Computer Resources - Training & Training support	103	103,0363109	3,36666032	0,000760843	0,036520484

Multiple comparison table Content Analysis - FWER (Simes-Hochberg) Continuation					
ILS Elements	***Observed difference***	***Critical difference***	***Statistic***	***P-value***	***Adjusted P-value***
Design Influence - Facilities & Infrastructure	157,5	103,0363109	5,148048547	2,6321E-07	1,6319E-05
Design Influence - Maintenance	35,5	103,0363109	1,1603538	0,245904789	1
Design Influence - Manpower & Personnel	58,5	103,0363109	1,912132318	0,055859225	1
Design Influence - PHS&T	123,5	103,0363109	4,036723782	5,42028E-05	0,002981155
Design Influence - Product Support Management	154	103,0363109	5,033647469	4,81234E-07	2,88741E-05
Design Influence - Supply	107	103,0363109	3,49740441	0,000469809	0,023020643
Design Influence - Support Equipment	112	103,0363109	3,660834523	0,000251395	0,01282115
Design Influence - Sustaining Engineering	107	103,0363109	3,49740441	0,000469809	0,023020643
Design Influence - Technical data	120	103,0363109	3,922322703	8,76994E-05	0,004735769
Design Influence - Training & Training support	39,5	103,0363109	1,29109789	0,196669736	1
Facilities & Infrastructure - Maintenance	193	103,0363109	6,308402347	2,8193E-10	1,86074E-08
Facilities & Infrastructure - Manpower & Personnel	99	103,0363109	3,23591623	0,00121253	0,056988892
Facilities & Infrastructure - PHS&T	34	103,0363109	1,111324766	0,266428583	1
Facilities & Infrastructure - Product Support Management	3,5	103,0363109	0,114401079	0,908919859	1
Facilities & Infrastructure - Supply	50,5	103,0363109	1,650644137	0,098811261	1
Facilities & Infrastructure - Support Equipment	45,5	103,0363109	1,487214025	0,136958293	1
Facilities & Infrastructure - Sustaining Engineering	50,5	103,0363109	1,650644137	0,098811261	1
Facilities & Infrastructure - Technical data	37,5	103,0363109	1,225725845	0,220301861	1
Facilities & Infrastructure - Training & Training support	118	103,0363109	3,856950658	0,00011481	0,006084947
Maintenance - Manpower & Personnel	94	103,0363109	3,072486117	0,002122837	0,095527668
Maintenance - PHS&T	159	103,0363109	5,197077581	2,02446E-07	1,27541E-05
Maintenance - Product Support Management	189,5	103,0363109	6,194001268	5,86557E-10	3,81262E-08
Maintenance - Supply	142,5	103,0363109	4,65775821	3,19671E-06	0,000179016
Maintenance - Support Equipment	147,5	103,0363109	4,821188322	1,42706E-06	8,41963E-05
Maintenance - Sustaining Engineering	142,5	103,0363109	4,65775821	3,19671E-06	0,000179016
Maintenance - Technical data	155,5	103,0363109	5,082676502	3,72153E-07	2,27013E-05
Maintenance - Training & Training support	75	103,0363109	2,451451689	0,014228128	0,583353266

Multiple comparison table Content Analysis - FWER (Simes-Hochberg) Continuation					
ILS Elements	***ILS Elements***	***ILS Elements***	***ILS Elements***	***ILS Elements***	***ILS Elements***
Manpower & Personnel - PHS&T	65	103,0363109	2,124591464	0,033620717	1
Manpower & Personnel - Product Support Management	95,5	103,0363109	3,121515151	0,00179923	0,082764575
Manpower & Personnel - Supply	48,5	103,0363109	1,585272092	0,112904527	1
Manpower & Personnel - Support Equipment	53,5	103,0363109	1,748702205	0,080342509	1
Manpower & Personnel - Sustaining Engineering	48,5	103,0363109	1,585272092	0,112904527	1
Manpower & Personnel - Technical data	61,5	103,0363109	2,010190385	0,044411043	1
Manpower & Personnel - Training & Training support	19	103,0363109	0,621034428	0,534576971	1
PHS&T - Product Support Management	30,5	103,0363109	0,996923687	0,318801553	1
PHS&T - Supply	16,5	103,0363109	0,539319372	0,589666504	1
PHS&T - Support Equipment	11,5	103,0363109	0,375889259	0,706999226	1
PHS&T - Sustaining Engineering	16,5	103,0363109	0,539319372	0,589666504	1
PHS&T - Technical data	3,5	103,0363109	0,114401079	0,908919859	1
PHS&T - Training & Training support	84	103,0363109	2,745625892	0,006039559	0,259701039
Product Support Management - Supply	47	103,0363109	1,536243059	0,124478779	1
Product Support Management - Support Equipment	42	103,0363109	1,372812946	0,169810505	1
Product Support Management - Sustaining Engineering	47	103,0363109	1,536243059	0,124478779	1
Product Support Management - Technical data	34	103,0363109	1,111324766	0,266428583	1
Product Support Management - Training & Training support	114,5	103,0363109	3,742549579	0,000182163	0,009472454
Supply - Support Equipment	5	103,0363109	0,163430113	0,870179795	1
Supply - Sustaining Engineering	0	103,0363109	0	1	1
Supply - Technical data	13	103,0363109	0,424918293	0,670896239	1
Supply - Training & Training support	67,5	103,0363109	2,20630652	0,027362545	1
Support Equipment - Sustaining Engineering	5	103,0363109	0,163430113	0,870179795	1
Support Equipment - Technical data	8	103,0363109	0,26148818	0,793716063	1
Support Equipment - Training & Training support	72,5	103,0363109	2,369736633	0,01780076	0,712030404
Sustaining Engineering - Technical data	13	103,0363109	0,424918293	0,670896239	1
Sustaining Engineering - Training & Training support	67,5	103,0363109	2,20630652	0,027362545	1
Technical Data - Training & Training support	80,5	103,0363109	2,631224813	0,008507774	0,357326493

Multiple comparison table Content Analysis - FWER (Holm)					
ILS Elements	***Observed difference***	***Critical difference***	***Statistic***	***P-value***	***Adjusted P-value***
Computer Resources - Design Influence	142,5	103,0363109	4,65775821	3,19671E-06	0,000185409
Computer Resources - Facilities & Infrastructure	15	103,0363109	0,490290338	0,623928463	1
Computer Resources - Maintenance	178	103,0363109	5,818112009	5,9516E-09	3,80903E-07
Computer Resources - Manpower & Personnel	84	103,0363109	2,745625892	0,006039559	0,265740598
Computer Resources - PHS&T	19	103,0363109	0,621034428	0,534576971	1
Computer Resources - Product Support Management	11,5	103,0363109	0,375889259	0,706999226	1
Computer Resources - Supply	35,5	103,0363109	1,1603538	0,245904789	1
Computer Resources - Support Equipment	30,5	103,0363109	0,996923687	0,318801553	1
Computer Resources - Sustaining Engineering	35,5	103,0363109	1,1603538	0,245904789	1
Computer Resources - Technical data	22,5	103,0363109	0,735435507	0,462074304	1
Computer Resources - Training & Training support	103	103,0363109	3,36666032	0,000760843	0,036520484
Design Influence - Facilities & Infrastructure	157,5	103,0363109	5,148048547	2,6321E-07	1,6319E-05
Design Influence - Maintenance	35,5	103,0363109	1,1603538	0,245904789	1
Design Influence - Manpower & Personnel	58,5	103,0363109	1,912132318	0,055859225	1
Design Influence - PHS&T	123,5	103,0363109	4,036723782	5,42028E-05	0,002981155
Design Influence - Product Support Management	154	103,0363109	5,033647469	4,81234E-07	2,88741E-05
Design Influence - Supply	107	103,0363109	3,49740441	0,000469809	0,023490452
Design Influence - Support Equipment	112	103,0363109	3,660834523	0,000251395	0,01282115
Design Influence - Sustaining Engineering	107	103,0363109	3,49740441	0,000469809	0,023490452
Design Influence - Technical data	120	103,0363109	3,922322703	8,76994E-05	0,004735769
Design Influence - Training & Training support	39,5	103,0363109	1,29109789	0,196669736	1
Facilities & Infrastructure - Maintenance	193	103,0363109	6,308402347	2,8193E-10	1,86074E-08
Facilities & Infrastructure - Manpower & Personnel	99	103,0363109	3,23591623	0,00121253	0,056988892
Facilities & Infrastructure - PHS&T	34	103,0363109	1,111324766	0,266428583	1
Facilities & Infrastructure - Product Support Management	3,5	103,0363109	0,114401079	0,908919859	1
Facilities & Infrastructure - Supply	50,5	103,0363109	1,650644137	0,098811261	1
Facilities & Infrastructure - Support Equipment	45,5	103,0363109	1,487214025	0,136958293	1
Facilities & Infrastructure - Sustaining Engineering	50,5	103,0363109	1,650644137	0,098811261	1
Facilities & Infrastructure - Technical data	37,5	103,0363109	1,225725845	0,220301861	1
Facilities & Infrastructure - Training & Training support	118	103,0363109	3,856950658	0,00011481	0,006084947

Multiple comparison table Content Analysis - FWER (Holm) Continuation					
ILS Elements	***Observed difference***	***Critical difference***	***Statistic***	***P-value***	***Adjusted P-value***
Maintenance - Manpower & Personnel	94	103,0363109	3,072486117	0,002122837	0,095527668
Maintenance - PHS&T	159	103,0363109	5,197077581	2,02446E-07	1,27541E-05
Maintenance - Product Support Management	189,5	103,0363109	6,194001268	5,86557E-10	3,81262E-08
Maintenance - Supply	142,5	103,0363109	4,65775821	3,19671E-06	0,000185409
Maintenance - Support Equipment	147,5	103,0363109	4,821188322	1,42706E-06	8,41963E-05
Maintenance - Sustaining Engineering	142,5	103,0363109	4,65775821	3,19671E-06	0,000185409
Maintenance - Technical data	155,5	103,0363109	5,082676502	3,72153E-07	2,27013E-05
Maintenance - Training & Training support	75	103,0363109	2,451451689	0,014228128	0,583353266
Manpower & Personnel - PHS&T	65	103,0363109	2,124591464	0,033620717	1
Manpower & Personnel - Product Support Management	95,5	103,0363109	3,121515151	0,00179923	0,082764575
Manpower & Personnel - Supply	48,5	103,0363109	1,585272092	0,112904527	1
Manpower & Personnel - Support Equipment	53,5	103,0363109	1,748702205	0,080342509	1
Manpower & Personnel - Sustaining Engineering	48,5	103,0363109	1,585272092	0,112904527	1
Manpower & Personnel - Technical data	61,5	103,0363109	2,010190385	0,044411043	1
Manpower & Personnel - Training & Training support	19	103,0363109	0,621034428	0,534576971	1
PHS&T - Product Support Management	30,5	103,0363109	0,996923687	0,318801553	1
PHS&T - Supply	16,5	103,0363109	0,539319372	0,589666504	1
PHS&T - Support Equipment	11,5	103,0363109	0,375889259	0,706999226	1
PHS&T - Sustaining Engineering	16,5	103,0363109	0,539319372	0,589666504	1
PHS&T - Technical data	3,5	103,0363109	0,114401079	0,908919859	1
PHS&T - Training & Training support	84	103,0363109	2,745625892	0,006039559	0,265740598
Product Support Management - Supply	47	103,0363109	1,536243059	0,124478779	1
Product Support Management - Support Equipment	42	103,0363109	1,372812946	0,169810505	1
Product Support Management - Sustaining Engineering	47	103,0363109	1,536243059	0,124478779	1
Product Support Management - Technical data	34	103,0363109	1,111324766	0,266428583	1
Product Support Management - Training & Training support	114,5	103,0363109	3,742549579	0,000182163	0,009472454
Supply - Support Equipment	5	103,0363109	0,163430113	0,870179795	1
Supply - Sustaining Engineering	0	103,0363109	0	1	1
Supply - Technical data	13	103,0363109	0,424918293	0,670896239	1
Supply - Training & Training support	67,5	103,0363109	2,20630652	0,027362545	1

Multiple comparison table Content Analysis - FWER (Holm) Continuation					
ILS Elements	***Observed difference***	***Critical difference***	***Statistic***	***P-value***	***Adjusted P-value***
Support Equipment - Sustaining Engineering	5	103,0363109	0,163430113	0,870179795	1
Support Equipment - Technical data	8	103,0363109	0,26148818	0,793716063	1
Support Equipment - Training & Training support	72,5	103,0363109	2,369736633	0,01780076	0,712030404
Sustaining Engineering - Technical data	13	103,0363109	0,424918293	0,670896239	1
Sustaining Engineering - Training & Training support	67,5	103,0363109	2,20630652	0,027362545	1
Technical Data - Training & Training support	80,5	103,0363109	2,631224813	0,008507774	0,357326493

Appendix H – Notes for Deduction Method

See file on CD.

FOLHA DE REGISTRO DO DOCUMENTO

1. CLASSIFICAÇÃO/TIPO	2. DATA	3. REGISTRO N°	4. N° DE PÁGINAS
DM	14 de dezembro de 2020	DCTA/ITA/DM-70/2020	174

5. TÍTULO E SUBTÍTULO:

Model design recommendations for treating Rogue Units

6. AUTOR(ES):

Alexandre Dias Irigon

7. INSTITUIÇÃO(ÕES)/ÓRGÃO(S) INTERNO(S)/DIVISÃO(ÕES):

Instituto Tecnológico de Aeronáutica – ITA

8 PALAVRAS-CHAVE SUGERIDAS PELO AUTOR:

1. Rogue Unit. 2. Model design. 3.Integrated Logistic Support.

9.PALAVRAS-CHAVE RESULTANTES DE INDEXAÇÃO:

Rogue unit; Desenho de modelo; Suporte logístico integrado; Desenvolvimento de produtos; Engenharia.

10. APRESENTAÇÃO: **(X) Nacional ( ) Internacional**

ITA, São José dos Campos. Curso de Mestrado. Programa de Pós-Graduação em Ciências e Tecnologias Espaciais – CTE . Área de Gestão Tecnológica. Orientador: Prof. Dr. Fernando Teixeira Mendes Abrahão. Defesa em 06/11/2020. Publicada em 2020.

11. RESUMO:

O suporte logístico é geralmente relegado a uma segunda etapa durante o desenvolvimento de projetos ou produtos. No entanto, essa prática leva a um produto logisticamente imaturo no momento da entrega ao primeiro operador. Um desses problemas remonta ao gerenciamento de Unidades *Rogue*, um subconjunto de componentes cujas taxas de falha diferem de outros itens idênticos. Este fenômeno leva a uma diminuição na confiabilidade, disponibilidade, manutenibilidade, segurança e prontidão dos sistemas envolvidos. Este trabalho se propõe a desenvolver um modelo prescritivo, a ser aplicado durante a preparação, desenvolvimento e produção, para identificar, prevenir e tratar problemas relacionados a Unidades *Rogue* durante a fase do ciclo de vida em serviço. A metodologia proposta é delimitar o caso de estudo por meio de uma revisão completa da literatura, listar os elementos ILS mais relevantes através da opinião de especialistas e de análise de conteúdo, deduzir recomendações e validar as recomendações com Grupo Focal. As contribuições deste trabalho incluem a academia, com um modelo generalizável de geração de recomendações, a indústria, com a própria lista gerada, e o Governo, com orientações seguras sobre como melhorar seus processos de aquisição verificando a aplicação das recomendações geradas.

12. GRAU DE SIGILO:

(X) OSTENSIVO **( ) RESERVADO** **( ) SECRETO**