FUNCTIONAL CAUSE ANALYSIS (FCA) ADAPTATION OF FMEA AND FTA: A CASE STUDY OF A CUBESAT

Alex Maxwell Silva Nascimento[1], Giuliani Paulineli Garbi[2], Marcos Aurelio Ferreira Dos Santos[3] and Manoel Jozeane Mafra de Carvalho[4]
[1]Graduate Program in Aerospace Engineering, Federal University of Rio Grande do Norte, Natal-RN, 59078-900, Brazil.
alexmsn097@gmail.com
[2, 3, 4]National Institute for Space Research, Northeast Regional Center, Natal-RN, 59076-740, Brazil.
[2]giuliani.garbi@gmail.com
[3]marcos.aurelio@inpe.br
[4]manoel.carvalho@inpe.br

ABSTRACT

Studies on satellites have progressed over the years, following technological advancements. Consequently, the concept of small satellites, known as CubeSats, emerged. Initially intended for academic purposes, these satellites gained prominence by assuming functions previously performed only by larger satellites. Despite this, CubeSats face significant challenges, such as low reliability in their missions, due to financial constraints, time limitations and lack of experience among their developers, especially in academic projects. Faced with these challenges, a need exists for methods and tools that facilitate development and improvement of the dependability of these missions, considering their difficulties. The objective of this work is to present an adaptation of traditional failure analysis tools, FMEA and FTA, as a more agile alternative for project failure analysis. Such objective is aimed to be accomplished using a case study in developing a CubeSat, aiming to simplify implementation and make the techniques more practical for teams with limited resources. The FCA has proven to be fully functional, as demonstrated in the case study, being as effective as traditional tools and providing a reduction of approximately 50% in the development stages and processes, thanks to its more objective and direct approach. In addition to the benefits obtained, the FCA has proven to be a tool of generic use, applicable to any project requiring an easy-to-use tool, with reduced application time and producing solid results, especially in teams with limited resources, thus promoting their success.

KEYWORDS: *Reliability. CubeSats. Failure analysis.*

I. INTRODUCTION

Studies related to satellites have evolved over time, encompassing purposes beyond those initially envisaged. This evolution has led to the development of new technologies, resulting in the creation of CubeSats, the main focus of this work. Initially conceived for academic purposes, CubeSats quickly demonstrated potential for applications beyond the academic environment, becoming an increasingly utilized space tool.

The objective was to develop a concept that would enable university groups not only to swiftly implement a small space mission but also to maximize their chances of hitching a ride on a secondary payload launch by standardizing interfaces and mitigating risks [1]. Like conventional satellites, CubeSats are composed of interconnected subsystems, whose primary objective is to execute their missions. [2].

CubeSats are a category of nanosatellites, with weights ranging between 1 and 10 kg, featuring a cubic shape with edges of 10 cm and a mass of up to 1.33 kg per unit. This configuration corresponds to the standard CubeSat unit, denoted as 1U, which can be combined to form units of 2U, 3U, and 6U [2]. The sizes of satellites can vary according to the mission for which they are designed and are influenced by various factors, such as the required payload capacity, the power needed for satellite operation, and the stability and durability required for orbit, among others [3].

After demonstrating their value as an educational tool, CubeSats have shown various other promising applications, including the miniaturization of systems and the use of Commercial off-the-shelf (COTS) devices and equipment, enabling their application in operational missions that previously required medium or large-sized satellites [4].

According to data from CGEE [2], the small satellite launch rate has grown exponentially in recent years, with one launch every two months in 2003 up to a rate of 24 launches per month in 2017. However, due to the accelerated growth in their utilization, CubeSats often exhibit low reliability, particularly in the initial phase of the mission, largely due to the use of Commercial off-the-shelf (COTS) components, which were not designed for the space environment, resulting in a high failure rate at the early stages of the journey [5].

Given the current reality, it is essential to conduct a failure analysis study, even at the design phase. Surch action provides practical guidance to development teams on potential risks, in a way that is feasible for any project.

The article is organized as follows: Section 2 showcases efforts and studies aimed at improving the success prospects of small satellite missions, either through the adaptation of systems engineering processes or the study of failure analysis. Section 3 presents the concepts of FMEA (Failure Modes and Effects Analysis) and FTA (Fault Tree Analysis), along with details of the tool introduced as another analysis alternative, FCA. Section 4 will provide details of the CubeSat which will subsequently be the subject of analysis in the case study, where both conventional tools and the proposed tool will be applied. Section 5 presents the results obtained from both analyses, followed by a comparative analysis between the two applications and a discussion of the advantages of the proposed tool and conventional ones in Section 6. The final section presents the conclusions drawn from the entire development and study, concluding with proposals for future work.

II. LITERATURE REVIEW

CubeSats exert significant influence in the academic field, being developed by students affiliated with renowned institutions and organizations. However, these students often have limited experience and financial resources. This lack of experience, resources, and proper guidance can lead to negligence in the development and reliability of CubeSats.[6]

Systems Engineering, along with the study of failure analysis, needs to be adapted for small-scale projects due to the inherent complexity of applying conventional methods. [6][7]

Following this premise, Timperley and Berthoud [8] proposed a Model-Based Systems Engineering (MBSE) approach to analyze reliability and develop failure mitigation strategies for the CubeSat payload. They utilized methodologies such as FMECA (Failure Modes, Effects, and Criticality Analysis) and FTA. Through FMECA, they identified the failure modes in the system, and based on these failure modes, the authors developed a fault tree to analyze the combinations of failures.

Yaman and Burunkaya [9] proposed a new hybrid approach for the analysis of failure modes, criticality, and effects, aiming to fill gaps left by the traditional method. According to the authors [9], the traditional method is susceptible to subjectivity in analysis. Therefore, they proposed an analytical approach that adjusts according to the level of detail of the integrated hardware group.

In the context of failures in small satellite missions, Albalooshi et al. [10] conducted a study on failure analysis and the development of mitigation techniques for the I2C Bus, a commercially available component used in CubeSat missions. They highlighted that failure in this component poses an almost inevitable risk for CubeSats.

In their study, Alessandro et al. [11] propose a semiquantitative approach for developing a space-based FMECA for use in the preliminary design stage of a CubeSat. The author introduces a new criticality indicator, in addition to the two widely used indicators for assessing satellite risks: severity and probability of occurrence. This proposed approach is detectability, which aims to address the difficulty of identifying failure modes during the design phase.

Similar to previous studies, this work aims to present an adaptation of failure analysis using traditional tools, FMEA and FTA, to improve the development and reliability of projects in a more agile and effective manner. This effort is particularly relevant for projects conducted by small teams with limited resources.

III. MATERIALS AND METHODS

The study of failure analysis is crucial for the development and progress of projects. Through it, it is possible to identify and correct issues before they occur, minimizing or preventing their impacts on subsequent stages, even on execution failure [12]. Space Product Assurance is the branch of the European Space Agency responsible for the study and analysis of failures for reliability and safety in design. The ECSS-S-ST-00C standard [13] describes this branch as a dedicated study to the planning and execution of activities aimed at ensuring that the design, controls, methods and techniques of a project result in a satisfactory degree of product quality.

3.1. FMEA – Failure modes and effects analysis

The FMEA [14] is defined as a qualitative method of reliability analysis that involves studying the potential failure modes of each analyzed item and determining the effects associated with each failure mode. FMEA finds applications in various sectors, including semiconductor equipment, hydraulic and pneumatic systems, electrical circuits, steel and automotive industries, among others.

The ECSS-Q-ST-30-02C standard, established by the European Space Agency (ESA), is a standard reference that contains all the definitions of the terms used in the FMEA tool, as well as the requirements for its application. Additionally, the standard provides valuable assistance by listing a variety of failure modes commonly found in components used in space projects [7]. Embedded within the realm of Space Product Assurance and the discipline of Dependability, this standard elaborately describes the process of using FMEA, its rules, and the application of the FMECA method.

In addition to the inherent characteristics of the tool, the standard suggests assigning severity to failure modes by providing definitions that are present in Table 1.

Table 1. Failure severity

Severity category	Severity level	Dependability effects
Catastrophic	1	Failure propagation
Critical	2	Loss of mission
Major	3	Major mission degradation
Minor or Negligible	4	Minor mission degradation or any other effect

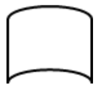
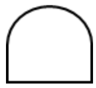
The outcome of failure analyses, conducted through the identification of their modes and effects, should adhere to the guidelines recommended by the applicable standard, resulting in the development of a comprehensive report documenting all relevant information. FMEA involves critical analysis levels, and the standard also sets forth precise criteria for defining criticality. These criteria include assessing the severity, probability of occurrence, and detection of the failure, whose definitions are based on fundamental principles outlined by the standard [7].

3.2. FTA – Fault Tree Analysis

Fault Tree Analysis is a widely chosen method for reliability and equipment failure analysis due to its distinction from other methods. In addition to facilitating analysis, this method reveals a clear cause-and-effect relationship of failures, providing a more comprehensive understanding of the functioning of the entire system or mechanism. This aspect makes Fault Tree Analysis especially useful when combined with other methods, such as FMEA [12].

The essence of FTA lies in the representation of undesirable events that may lead to catastrophic equipment failures, using logical gates (AND and OR) depicted by graphical symbols, which condition these events. They can be triggered by a series of subsequent events, determining the future progressions of the main event. Table 2 illustrates the graphical forms representing the logical gates that integrate the fault tree diagram, and Figure 3 represent of this constructed tree and how it integrates events and logical gates.

Table 2. Logical gates

Symbol	Name
	OU
	E

3.3. FCA – Functional Cause Analysis

The functional cause analysis is a tool derived from the adaptation of traditional methods, FMEA and FTA. Although these tools have demonstrated their effectiveness in large projects, their application can be challenging due to complexity, time requirements, and the demand for skilled labor, which can hinder projects with limited financial and time resources, in addition to the need for prior knowledge for their correct application. This situation is common in developing small projects, such as CubeSats, especially in academic contexts. The standard for the use and application of failure analysis tools, defined by the European Space Agency, suggests that these tools should be adapted and adjusted for smaller projects, further highlighting the importance of this work.

The main objective of the presented tool is to unify the key concepts of the traditional tools, FMEA and FTA, into a single one. The name of the presented tool carries one of its main characteristics, an analysis focused exclusively on functional failures rather than potential failures, restricting the analysis to failures that could terminate the mission and not only indicate failure possibilities.

The FCA analyzes the objectives of the item, followed by its functional failures and their effects. Then, it analyzes the previously described main causes. The main causes of the failure are referred to as primary hierarchical level causes; subsequently, if other causes result, they are listed as secondary, with the possibility of defining up to level 3. As based on a history of FTAs, it was found that the third level was sufficient for adequate analysis. The concepts are used in an optimized manner, yet concise and direct, aiming for results as promising as the traditional tools but in a more streamlined and practical way.

Concepts such as functional failures, failure events, causes of failures, and possible origins of primary causes are integrated into the proposed tool, as can be seen in the implementation steps described in Figure 1.

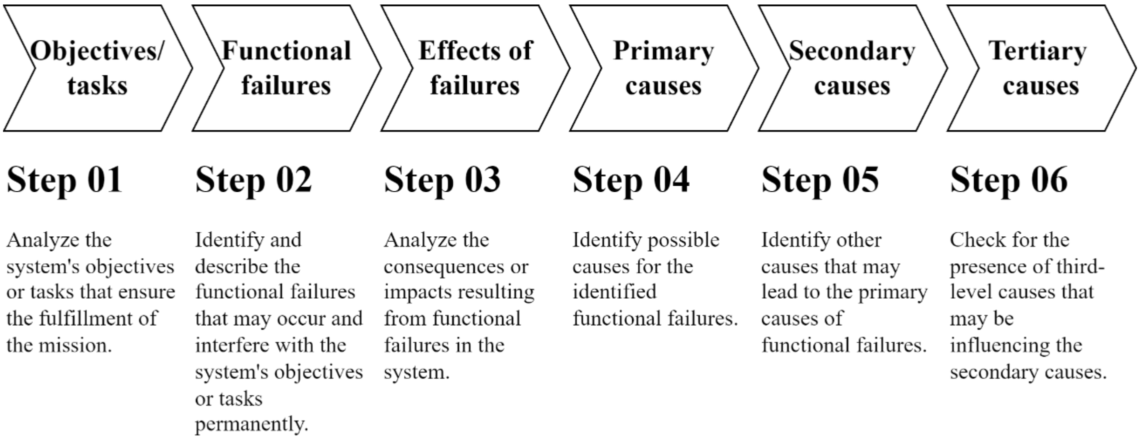


Figure 1. Deployment Steps of FCA

IV. CASE STUDY

A case study was conducted on a payload of CONASAT, a CubeSat developed in partnership between the National Institute for Space Research (INPE) and the Brazilian Space Agency (AEB). The payload in case this is EDC (Environmental Data Collector), object under analysis in this work.

4.1 CONASAT

The project aims to develop a new solution for environmental monitoring through CubeSat technology. It was created in line with the technological development program to serve future generations of nano and microsatellites, outlined in the Multi-Year Action Plan of the AEB, and the National Program of Space Activities of Brazil. This initiative is prompted by the outdated technology of the current system and the lifespan of Brazilian satellites, aiming to replace the Brazilian Environmental Data Collection System (SBCDA). The current system has been operational since 1993 and consists of approximately 800 PCDs (Data Collection Platforms).

Due to the outdated technology of the current SBCDA, the CONASAT Mission proposes to complement the space segment of the SBCDA using CubeSat standard nanosatellites.

4.2 EDC – Environmental Data Collector

The EDC, a CubeSat payload, was designed to receive signals from platforms. It can be found in Figure 2. Its primary objective is to serve as an SBCDA/ARGOS compatible receiver for standard CubeSat 1U or larger nanosatellites, to update and expand the SBCDA constellation.

The EDC demodulates and decodes signals from Platform Transmitter Terminals (PTTs) originating from the Environmental Data Collection Platforms of the SBCDA and ARGOS II systems in the 401.635 MHz ± 30 kHz band with a sensitivity of -132 dBm. It can decode up to 12 PTT signals simultaneously, append a header to the decoded messages with timestamp, frequency, and reception power, provide the decoded messages to the On-Board Computer (OBC) via I2C or UART/RS-485 interface, and deliver housekeeping information to the OBC via I2C or UART/RS-485 interface (current, temperature, ADC RMS level, PLL synchronization status, overcurrent, etc.). In Figure 2, we can see the EDC.

Figure 2. EDC (Environmental Data Collector)

4.3 Failure Analysis of the EDC: FMEA and FTA

The case study was conducted in two distinct parts. In the first part, traditional failure analysis tools were employed within the context of the EDC, following each step as advocated by relevant literature and standards.

After defining of the System, the EDC payload, the first step involved identifying the components to be analyzed. With the assistance of the development team, potential failures that could occur in these components were identified.

Once the failures with catastrophic potential in the payload were identified, the corresponding fault trees were developed. Despite the difficulties encountered in developing the FMEA and constructing the fault trees due to the scarcity of information, it was possible to develop analyses that highlighted even basic failures.

4.4 Failure Analysis of the EDC: FCA

The application of the proposed tool was conducted in collaboration with the same EDC development team. Following the outlined structure for the application of the proposed study, the first step, after defining the system to be analyzed (the payload EDC), was to establish the main objectives directly related to the functionality of the CubeSat, thus ensuring the mission's feasibility.

Once the objectives were defined, we proceeded to identify functional failures that could hinder the achievement of these objectives and, in some way, lead to mission failure. From these failures and their potential catastrophic effects, we detailed possible failure causes, including those derived from the primary class of causes.

Listing functional failures and defining their effects are among the most important steps in structuring the analysis, as functional failures encompass all possibilities of errors that could lead to the end of the previously listed objectives. Their effects arise as a better understanding of the consequences of functional failures on the system's operation.

Similar to the fault tree, defining the causes at the first hierarchical level is directly linked to the system's functional failures. Secondary-level causes are possibilities of causing primary-level causes to occur, and tertiary-level causes, if any, are possibilities of causes stemming from the secondary-level listing. These definitions aim to find possibilities of failure causes up to the third level. The levels themselves define the severity of the causes concerning to the system. The primary level being of highest importance/severity followed by levels two and three of importance/severity.

V. RESULTS

This section aims to present the results derived from the case study conducted on the EDC, using both traditional tools and the tool developed in this work.

5.1 Results obtained through FMEA and FTA

Following the steps and protocols established by the literature and standards found on failure analysis, specifically the methodologies for analyzing modes and effects and the fault tree, a study was conducted on the EDC payload mentioned in topic 3. The study began with a preliminary explanation with the responsible team to demonstrate and explain the entire methodology to be used, in addition to an explanation from the team about the entire EDC. FMEA is the first study to be applied, and the first step was to list the most relevant components of the system so that, from them, possibilities of failures could be found and, subsequently, the modes and effects of each of them. As planned, a list of relevant components for the system operation was made, along with their respective functions for better understanding.

After defining each component and its functions, it was time to identify the possible potential failures of these components, from the least severe to the most critical, highlighting the various forms of failure that could occur. Then, based on the failures identified by the responsible team, the modes and effects of the failures were determined. That is, how these failures manifest and what are the consequences of their occurrence, thus establishing information based on failures.

The specification of the level of criticality of each failure is a crucial step in failure analysis. However, isn't always possible to determine the criteria accurately, as they often require information that not all developers possess, such as a history of component failures to calculate the probability of occurrence, in addition to detailed familiarity with the design and components for estimating the probability of detecting failures when they occur. Therefore, based on the ESA standard, a simplified analysis of the criticality of failures was carried out for this study, which focused only on the severity level of failures, that is, on the severity of each of them, based on the parameters established in Table 01 of the ECSS-Q-ST-30-02C standard.

After conducting the failure analysis study, we identified a total of 39 possible failures in 13 distinct components of the EDC. Of these 39 failures, classified and based on Table 1, 4 were identified as the most critical, from which we built the FTAs. Through the FTAs, we identified the basic failures related to these most critical ones, thus concluding the study using traditional tools. Due to the extent of the tables and diagrams created, analyses were presented based on one of the components and one of the most severe failures, shown in Table 3 and Figure 3.

Table 3. Bus component FMEA

Components	Function	Failure	Failure Mode	Failure Effect	SN
Bus	Responsible for system communication and power supply	Overvoltage Power Supply	Component Damage	Component Damage	1
		The bus is in a condition different from the expected one and has current return.	Unexpected current return, improper voltage.	Component Damage	4
		Incompatibility of the EDC bus with the OBC bus	No communication occurs	No communication occurs	2
		Poorly soldered components	Short circuit between bus pins	Component burnout, no signal	2

			Communication failure and power-up	Inconsistency in the functionality of the soldered component	3
		Bus pin communication failure	Communication incompatibility with hardware	No communication occurs	3
		No communication between the bus and other components	No information arrives from the components, no response	No communication occurs	3

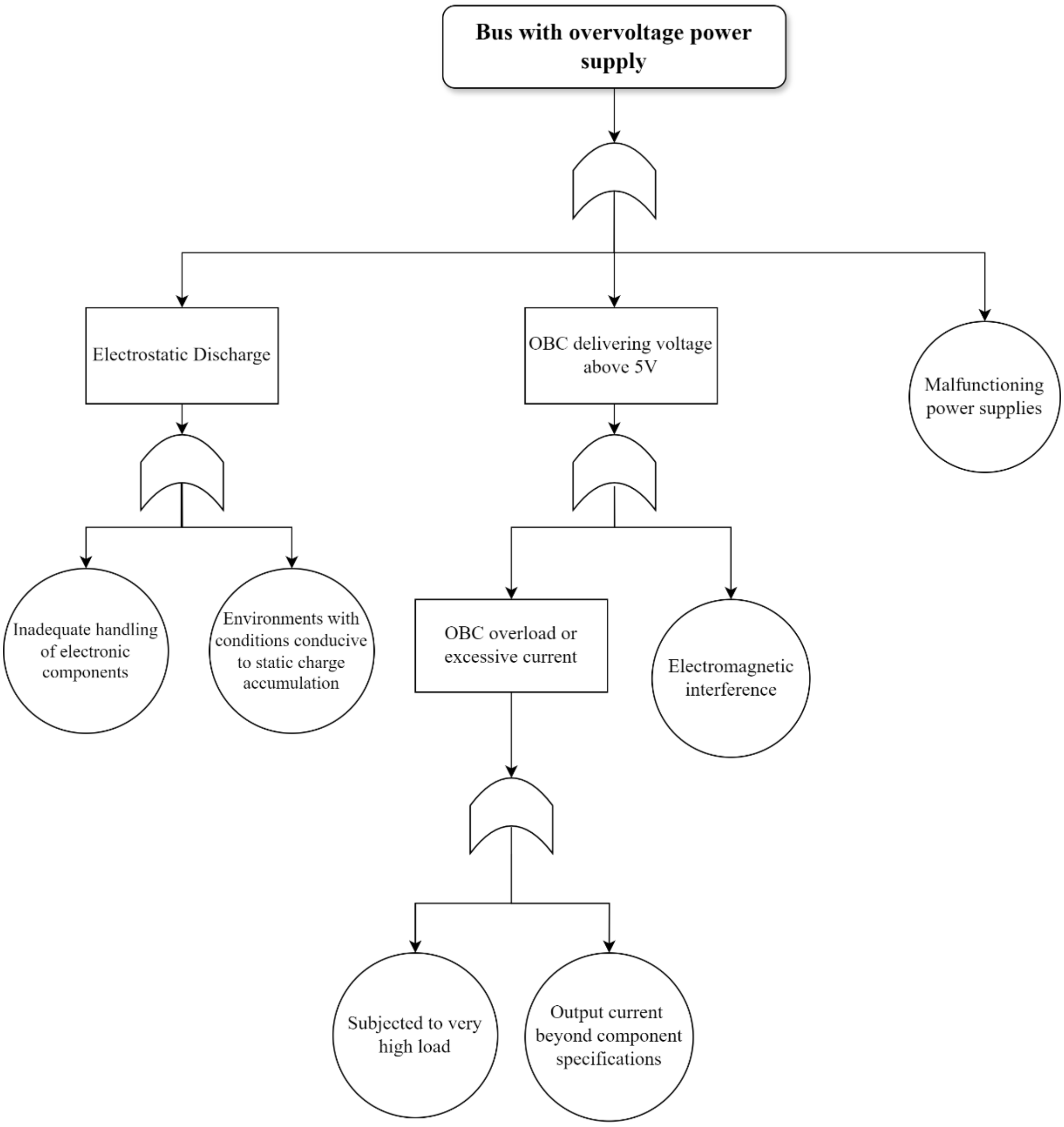


Figure 3. Bus component FTA

5.2 Results obtained through FCA

Subsequently, in the case study, the next step was to implement the proposed tool in this work and subsequently compare the processes and application stages. The proposed tool differs from traditional tools by listing only functional failures. Therefore, in conjunction with the responsible team, the EDC objectives/tasks were listed. From each identified objective, its functional failures were derived. This is because each objective defines the system's functionality and the functional failures associated with the objectives are those that prevent the mission from being fulfilled. Five main objectives related to the payload were analyzed, revealing functional failures linked to these objectives and 28 causes of functional failures. Among these, 13 were at the primary level, directly linked to failures and of higher severity, followed by 12 secondary level causes, related to primary ones and of moderate severity, concluding with 3 tertiary level causes of low severity. Like FMEA, FCA generates an extensive table, so Table 4 demonstrates one of the tasks/objectives analyzed.

Table 4. Bus component FCA

Task/ Objective	Functional Failure	Failure Effect	1st Causes	2nd Causes	3rd Causes
Turn on/off the EDC	EPS does not generate voltage of 5V and nor current 250mA for the EDC to turn on	Failure of interaction between EPS and EDC	Power supply failure due to electrical insufficiency	Failure in components such as batteries, voltage regulators or solar panels	Overload or short circuit
			Failure in the control circuits of the EPS	Failure in the switching of the control devices of the electrical power distribution	

VI. DISCUSSION

This section aims to report the comparative analysis between traditional tools (FMEA and FTA) and the tool presented in this work (FCA) for small projects, using the case study of CubeSat satellite development. For this comparison, the following parameters will be considered: functionality, number of steps and processes, accuracy, and scope in identifying failures, and finally the level of complexity of use.

The first parameter to be discussed in the comparative analysis is functionality. Both traditional and proposed tools have the function of finding failures and possibilities of failures in the analyzed item, whether it is a system or a machine/equipment. The tools meet user needs by providing failure information and generating relevant project information, and both have good usability features. Therefore, other aspects will determine which one will be more advantageous.

The second aspect to be analyzed is the number of steps and processes. In the application and development of the analysis using the two traditional tools, 12 steps are required to obtain complete information. In contrast, when using FCA, only 6 steps are necessary, resulting in a 50% reduction in the process and tool usage.

The third comparison addresses the level of accuracy and scope of the tools, as although both aim to analyze failures, they have different scopes. FMEA and FTA have a broader approach, examining all possible failures regardless of their relevance, while FCA adopts a more objective approach, focusing only on functional failures, which are essential for the system's operation. This provides a significant advantage in terms of applicability for small projects, considering their constraints.

The final aspect of comparison is the complexity of use. FCA has an advantage in this aspect, as mentioned in previous paragraphs, it is evident that it is less complex than traditional tools. This is reflected in the shorter time required for its application, the fewer steps involved, and its ease of use, making it accessible to anyone, even without in-depth knowledge of the subject.

Table 5. Comparative analysis of utilized methods

Aspects	FMEA and FTA	FCA
Functionalities	X	X
Steps and processes		X
Accuracy and scope		X
Complexities		X

Drawing from the discussed analyses and the results presented in Table 5, it becomes evident how the adaptation of the tool presented in this work is more advantageous for small projects, especially those involving students in development.

VII. CONCLUSION

The study of failure analyses using methods such as FMEA and FTA has proven to be extremely effective over time. Since their creation to the present day, their applications have consistently demonstrated their effectiveness. Therefore, it is important to clarify that this study aims not to replace the use of these tools but to optimize them, making them more accessible and easier to use in smaller projects, which often face resource constraints compared to large projects. The main objective is to improve failure analysis for small projects, such as CubeSat projects or other academic-level projects, aiming to increase their reliability with minimal system engineering during development.

FCA has demonstrated its functionality through the case study, proving to be as effective as traditional tools. Additionally, it reduces in 50% the number of development steps and processes thanks to its more objective and direct approach.

It is important to note that the use of FCA is not limited to any specific industry; it can be applied to any project that requires an easy-to-use tool, with reduced application time, and that produces solid results, contributing to project advancement. In summary, FCA has a generic use and can be applied in various areas.

For future studies, a possible research line could be the development of a reliability calculation method based on probabilistic mathematics.

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REFERENCES

[1]. Sweeting, M. N. (2018), Modern small satellites - changing the economics of space, Proceedings of the IEEE, v. 106, n. 3, pp. 343-361.

[2]. CGEE, (2018). “Centro de Gestão e Estudos Estratégicos: CubeSats”. Brasília, DF.

[3]. Florenzano, T. G. (2008), Os Satélites e Suas Aplicações, 1ª ed., São José dos Campos – SP.

[4]. Iossa, L. (2023). “Dependable design of an educational cubesat”. Politecnico Di Torino.

[5]. Villela, T. et al. (2019) “Towards the Thousandth CubeSat: A Statistical Overview”. International Journal of Aerospace Engineering, [S. l.], p. 1-13.

[6]. Analazi, A.; Straub, J. (2019) “Engineering Methodology for Student-Driven CubeSats”.

[7]. ECSS. EUROPEAN COOPERATION FOR SPACE STANDARDIZATION. ECSS-Q-ST-30-02C. Space product assurance – Failure modes, effects (and criticality) analysis (FMEA/FMECA). 2009.

[8]. Timperley, L.; Berthoud, L. (2022) "Reliability analysis and failure mitigation strategies for the prove pathfinder cubesat payload". IEEE Aerospace Conference (AERO), p. 18.

[9]. Yaman, N.; Burunkaya, M. (2021) "A new hybrid failure modes, effects and criticality analysis (FMECA) approach to be used in satellite equipment design". Journal of Polytechnic, vol.24, no.2, pp.733-743.

[10]. Albalooshi, A. *et al*. (2023) "Fault Analysis and Mitigation Techniques of the I2C Bus for Nanosatellite Missions".

[11]. Menchinelli, A. *et al*. (2018) "A Reliability Engineering Approach for Managing Risks in CubeSats".

[12]. Sakurada, E. Y. (2001) "As técnicas de análise dos modos de falhas e seus efeitos e análise da árvore de falhas no desenvolvimento e na avaliação de produtos". Florianópolis.

[13]. ECSS. EUROPEAN COOPERATION FOR SPACE STANDARDIZATION. ECSS-S-ST-00C. Description, implementation, and general requirement. 2020.

[14]. ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 5462: confiabilidade e mantenabilidade: terminologia. Rio de Janeiro, 1994.

Authors

Alex Maxwell Silva Nascimento: He is a master's student in Aerospace Engineering at the Federal University of Rio Grande do Norte (UFRN). He holds a Bachelor's degree in Mechanical Engineering from Universidade Potiguar (UnP) and a degree in Mechanics from the Federal Institute of Rio Grande do Norte (IFRN). This individual has experience in practical work and studies related to reliability, failure analysis, and industrial maintenance.

Giuliani Paulineli Garbi: He holds a Ph.D. in Engineering and Space Technologies from the National Institute for Space Research (INPE), a Master's degree in Mechanical Engineering in the area of Industrial Automation from the University of Taubaté (UNITAU), a degree in Electrical/Electronic Engineering from the University of Vale do Paraíba (UNIVAP), and a Technical degree in Electronics from the Prof. Everardo Passos Technical School (ETEP). Currently, he works as a Technologist at INPE in the area of Engineering of space, ground, and application segments systems. He is a lecturer in the Postgraduate Program in Aerospace Engineering at UFRN and in the Postgraduate Program in Biotechnology at UnP. He has industrial and academic experience in the following main subjects: Generation, Transmission, and Distribution of Electrical Energy; Generation of Electrical Energy from Renewable Sources; Industrial Automation; Analog, Digital, and Power Electronics Devices; Industrial Instrumentation; Robotic Devices; Classical and Digital Controllers; and Modeling of Complex Systems.

Marcos Aurelio Ferreira Dos Santos: He holds a Bachelor's degree in Electrical Engineering from the Federal University of Rio Grande do Norte (1984), a Master's degree in Sanitary Engineering from the Federal University of Rio Grande do Norte (2003), and a Ph.D. in Climatic Sciences from the Federal University of Rio Grande do Norte (2014). Currently, he is a Senior Technologist H-III at the National Institute for Space Research. He has experience in the area of Computer Science, with emphasis on Programming Languages, mainly working on the following topics: satellites, transmitters, rain gauge, tipping-bucket, and data collection. He has extensive experience with Environmental Data Collection Systems and Applied Sensors.

Manoel Jozeane Mafra de Carvalho: He is an Engineer, Federal Public Servant, and Senior Technologist at the National Institute for Space Research (INPE). He holds a Bachelor's degree in Electrical Engineering - Electronics from the Federal University of Rio Grande do Norte (1985), a Master's degree in Electrical Engineering from the Federal University of Rio Grande do Norte (1997), and a professional Master's degree in Aeronautical and Space Techniques from the École Nationale Supérieure de l'Aéronautique et de l'Espace, ENSAE – SUPAERO, France. He has experience in the field of Aerospace Engineering, primarily focusing on CubeSats, remote control, telemetry, satellite-based environmental data collection, and software-defined radio (SDR) implementations.