International Journal of Advanced Engineering Research and Science (IJAERS)
ISSN: 2349-6495(P) | 2456-1908(O)
Vol-8, Issue-5; May, 2021
Journal Home Page Available: https://ijaers.com/
Journal DOI: 10.22161/ijaers
Article DOI: https://dx.doi.org/10.22161/ijaers.85.8

Selection and Customization of Product Assurance Requirements applied to Small Satellites

Inaldo Soares de Albuquerque[1], Alirio Cavalcanti de Brito[2], Leonel Fernando Perondi[2], Mauricio Goncalves Vieira Ferreira[2].

[1]SEGPR Department, National Institute for Space Research (INPE), São José dos Campos - São Paulo / Brazil
[2]National Institute for Space Research (INPE), São José dos Campos - São Paulo / Brazil

Received: 30 Jan 2021;
Received in revised form:
29 Mar 2021;
Accepted: 30 Apr 2021;
Available online: 11 May 2021

***Keywords*— Small satellite, Reliability, Selection of requirements, Product assurance.**

***Abstract*— The use of small satellites has become a technological trend in the aerospace sector. To guarantee the specified reliability, every space mission requires adequate product assurance requirements, so that the risks and costs of the program are at predefined levels. This article proposes a process for selecting and customizing product assurance requirements applied to small satellites, aiming gains in manufacturing time, scope or cost, without increasing the risk of project execution. The proposed process cannot affect the objective of the mission, ensuring that all requirements successfully established are met. For this, a combination of two methods is proposed: AHP-Sort and the Borda method. The AHP-Sort is a variation of the Analytic Hierarchy Process, known as AHP methodology. Its use is indicated for classification and reduction of alternatives. In this work, specifications defined by the stakeholders are used, such as risk, lifetime and type of mission, which will be analyzed under the degree of importance, pair to pair, which will allow the classification of satellites in A, B, C or D. Once those classes are defined, the requirements referring to the different disciplines of the product assuranceare alocated to each class, compatible with the risk margin accepted for the mission. To complete the selection and customization of product assurance requirements, the Borda method will be used for ordering and ranking the requirements of each product assurance discipline by specialists who will make an assessment, establishing notes for each requirement, which, after being compiled, will indicate the one's that must be apllied to each class of satellite.*

I. INTRODUCTION

1.1. Context

In the space area, the products are complex and require high reliability during the mission, therefore, it is extremely important that the organization maintains a rigorous process of selecting requirements for ensuring the quality of the product. The set of requirements derived from this reference will be used as a basis for the development of a specific product assurance plan for each project. Regardless of size, space system projects have the required quality according to their criticality, assessed through technical and managerial interests.

The complexity of managing a rigorous requirements selection process for space products makes this process expensive and time-consuming. To reduce the cost and / or time of manufacturing of the small satellites it is necessary to use a process of selection and customization of product assurance requirements, to define and accommodate the unique aspects of each program or project, in order to achieve the success of the mission in an efficient and economical way.

Product assurance requirements selection and customization allow programs and projects to be successful in achieving their goals and the key is to use the expertise effectively, reflecting lessons learned and best practices to achieve the desired benefits, eliminating unnecessary expenses.

The word customization is used in the sense of personalization, adaptation, adequation. In this way, to customize is to adapt something according to the necessity. It is the process used to relieve the stringency of the product assurance requirements, consistent with the objectives of the program or project and with acceptable risks and restrictions. Customization does not require exemptions or deviations, but significant customizations must be documented in the documentation control system (NPR 7123.1C, 2020).

[1] Although customization is expected for all sizes of projects and programs, small projects present opportunities and challenges that are different from those of large traditional projects, such as the space shuttle, the International Space Station, the Hubble Space Telescope and the Mars Science Laboratory.

1.2 Problem

The major problem identified is finding a consistent methodology in the literature in which it is clear what the assurance requirements of the product should be applied to small satellites. This definition is important to ensure that space products fulfill their defined mission objectives in a safe, available and reliable manner. (Albuquerque, I. S, Brito, AC, Perondi, LF, 2020)

Product assurance, systems engineering and project management are essential disciplines for the development of systems for mission critical applications. In the space area, products are complex and a rigorous selection process for defining product assurance requirements is necessary. If correctly and consistently defined, they will ensure that the product is safe and reliable.

Space projects have their quality defined according to the mission's criticality. The more critical the mission, the more complex the management of product assurance requirements will be.

Thus, it can be said that the greater the number of interfaces, both managerial and technical (product), the greater the effort required to guarantee the product necessary for success in a given enterprise.

1.3 Objective

The objective of this work is to show the possibility of defining mission classes according to the level of risk exposure, the manufacturing time and cost, and the process for the selection of product assurance requirements corresponding to each class, in order to obtain eventual gains in cost reduction or manufacturing time, in the development of missions according to the class in question. This article focuses on the selection and customization of the requirements of the product assurance disciplines allocated to the small mission class.

In order to achieve the objective of this article, the work was divided into two phases. The first phase, using the AHP-Sort method, will establish a ranking based on the mission risk, mission purpose and lifetime criteria, thereby making it possible to define the limits that establish the classes of satellites in the range A to D, TOR-2011 (8591) - 21, 2011

In the second phase, the Borda method will be used for ordering and ranking the requirements of each product assurance discipline. As described by Costa, H., G., (2014), McLean, (1990) and Barba-Romero, (1997). The main idea of this method is based on determining a combination of the individual ranking or ranking established by each of the decision makers in a global classification.

By making a selection and customization of the product assurance requirements associated with the execution of the project, it is possible, in principle, to generate gains in reducing costs and manufacturing time, as long as there are no impacts in the occurance of non-conformities during the system, subsystems and equipments verification phases[1].

II. METHODOLOGY AND WORK ORGANIZATION

2.1. Methodology

According to studies carried out by Popper (2003), scientific research is based on the logic of empirical methodology since it is characterized as a continuous, systemic and reflective sequence that aims to acquire knowledge through research.

This research shows that for small satellites, as they normally involve low costs and shorter development times, there is, in principle, scope for implementing a strategy described below.

The methodology is divided into three phases:

a) problem definition - there is no methodology for selecting product assurance requirements for small satellites;

---

[1]Upward part of the V diagram, reference of systems engineering.

b) bibliographic review - bibliographic review will be carried out on the classification of space missions and on product assurance requirements for space systems;

c) development of a proposal for the classification of space missions - work will be carried out to justify and define the classes of satellites and allocate quality requirements; In this phase of the work, a tool called "multicriteria of decision" (MCDA) will be used, which applies to situations in which several conflicting criteria need to be evaluated in order to make a choice between multiple alternatives.

The methodology proposed in this study essentially consists of a customization of product assurance requirements associated with the execution of the project, for small missions, in order to reduce the cost, the time of manufacture and / or the scope of the mission , without compromising its main objective. Thus, the basic premise for such requirements customization is that they do not affect the reliability of the system, fully preserving the systems engineering logic, in the sense that the system, subsystems and equipment requirements are all verified through testing.

To meet the objective, the application of AHP-Sort is used, which is a variation of the Analytic Hierarchy Process - AHP method. The use of AHP-Sort is indicated for classification and reduction of alternatives. In this work, some specifications defined by the stakeholders will be used, such as risk, lifetime and type of mission for the classification of satellites in classes A, B, C or D.

Once the classes of the missions are defined, the Bordamethod will be used to order and rank the requirements, of the product assurancedisciplines with the aid of questionnaires, to be completed by specialists. These data will be compiled and the result will indicate which requirements will be applied to each class of satellite.

2.2. Work Organization

To achieve the objectives proposed for this work, it is necessary to have a detailed and complete understanding of the concepts and rules applicable to the theme of this study. Basic concepts and an adequate bibliographic review aim to solidify the terminology and applications used in the space program.

The Sections I to III present the Introduction, Context, Problem, Objective, Methodology, work organization and Bibliographic Review. Section IV shows the application of the AHP-Sort method and bordamethod while section V presents the conclusions of the article.

III. BIBLIOGRAPHIC REVIEW

3.1. Product assurance requirements

The European Cooperation for Space Standardization (ECSS), considers the Product Assurance a discipline to support risk management, ensuring that space products carry out their approved missions in a safe, available and reliable manner (ECSS -S - ST - 00C).

ECSS presents the Product Assurance disciplines for the development of a space system, unlike NASA (National Aeronautics and Space Administration), which has the Mission Assurance discipline. In this case, NASA is explicit in that it covers all other disciplines through the independent application of scientific principles, engineering principles, quality standards and program management in order to achieve the mission's success (TOR-2007 (8546)-6018 REV. B).

With regard to adapting Product Assurance Requirements for space products, ECSS standards provide guidelines for adapting their requirements based on criticality categories. Some studies present other criteria to adapt the development processes.

3.2. Mission assurance guidelines for A-D mission risk classes

The NASA document, TOR-2011 (8591) - 21, is a document product of the 2010-2011 government and industry program, whose objective was to develop guidelines for defining characteristic profiles of the mission assurance processes for a given class of spacecraft risk (A, B, C or D), so as to serve as a recommended technical baseline to meet program needs, based on programmatic constraints and mission needs. This document provides mission risk class A to D profiles for USA space programs, considering factors such as criticality to the strategic plan of a specific government agency, national significance, availability of alternative opportunities, success criteria, investment, lifetime, mission and other factors.

The guidelines TOR-2011 (8591) - 21 provided in this document will serve as input for the requirements documents assessed in relation to the technical cost factors of a specific acquisition, as well as for the quantified risk and mitigation strategies to define the program baseline and risk requirements to meet the stated objectives of the mission.

3.3. AHP-Sort: an AHP- based method for classification problems

The AHP is a useful and widespread method for decisions making and solutions for the choice and classification of problems (Arueira, 2014). However, it is not suitable for classifying problems. In addition, another practical limitation of AHP is that a large number of alternatives implies in a large number of comparisons. This work uses AHP-Sort, a new variant of AHP, used to sort alternatives in a predefined ordered categories. According to Gujansky, (2014), in addition to this, the AHP-Sort requires much less comparisons than the AHP, which facilitates decision making on a scale. In this work, this approach is used to define and select the classes of satellites.

The main characteristics of profiles from risk classes A to D are described below:

- **Class A** - represents a mission with minimal practical risk, in which all possible ways are sought to reduce the program's risk exposure.
- **Class B** - it is low risk, with small commitments in applying mission assurance standards to balance programmatic trade-offs between minimum risk and lower cost for operating and demo systems.
- **Class C-** it represents moderate risk and transfers the government's burden of risk to the best practices of contractors for exploratory or experimental missions.
- **Class D** - represents the highest risk profile, usually for a year or less, on experimental missions, and completely changes the development to best contractor practices, with minimal government oversight.

3.4. Borda Method: sorting product assurance requirements

From the bibliographic study it has been concluded that applying the Borda Method in each of the disciplines of the Product Assurance, according to the ECSS, (2016), it is possible to define a ranking of the requirements allowing the selection of each assurance requirement of the product within the limits established for the satellite classes defined in the previous phase.

According to Silva, C., J. E. (2015) the Borda Method was presented by Jean-Charles Borda in 1781, in France, to be applied in committees composed of more than one individual (multidecisor problem). The central idea of this method is to establish a combination of the individual ranking or ranking established by each of the decision makers in a global ranking.

Within the scope of the ECSS standards (ECSS, 2016), the disciplines of product assurance are defined: 1) Quality Assurance (QA); 2) Product Assurance Management; 3) Electrical, Electronic and Electromechanical Components (EEE); 4) Processes, Materials, Mechanical Parts; 5) Software Product Assurance; 6) Dependability and 7) Safety.

The QA discipline was selected for this article. The requirements of the QA discipline are distributed according to table 3.1.

Table 3.1 Quality Assurance requirements

1.	Personnel training and certification
2.	Control of critical items
3.	Non-conformity control system
4.	Traceability
5.	Metrology and calibration
6.	Handling, storage, transport and preservation.
7.	Qualification process
8.	Quality requirements for procurement
9.	Receiving and inspection activities
10.	QA requirements for manufacturing, assembly and integration
11.	Manufacturing readiness reviews
12.	Cleaning and contamination control
13.	Specific requirements for assembly and integration
14.	Logbooks
15.	QA requirements for acceptance and delivery
16.	Project reviews

IV. APPLICATION OF METHODS AND RESULTS

4.1. Application of the AHP-Sort Method

During the life cycle of a project, in the definition of the mission, some product requirements are established, and the most common are: lifetime, purpose of the mission and acceptable risk. In the generic example, the requirements in table 4.1 were randomly defined.

Table 4.1 - Definition of the main satellite requirements according to TOR-2011 (8591) - 21

	CLASS A	CLASS B	CLASS C	CLASS D
LIFETIME	>7 years	<7 years	<4 years	<1 year
MISSION	Operational	Demonstrative	Exploratory	Experiment
RISK	Minimmum	Low	Moderate	High

To represent the problem, the hierarchical analytical structure of the problem was created with its criteria (requirements) and alternatives (classes) for all the disciplines that are represented according to Figure 4.1.

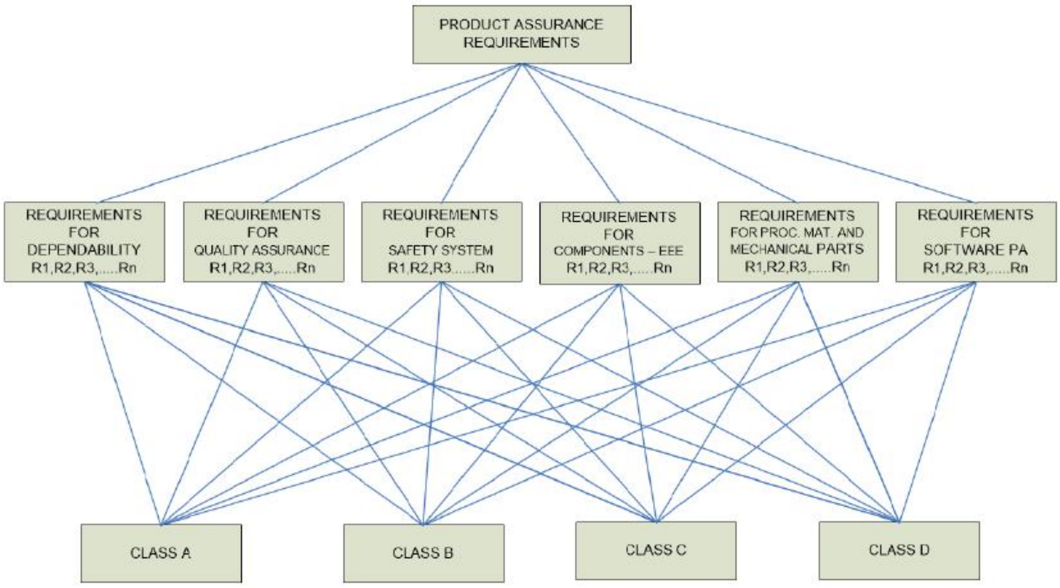

Fig. 4.1 - Analytical hierarchical structure of the problem

After defining the analytical structure of the problem, a study was carried out, as shown in Table 4.2, taking as an example four fictitious and random satellites in which three product assurance requirements have been applied: lifetime, mission and risk.

Table 4.2. Fictitious satellites

Alternative	Especification		
	Lifetime (years)	Mission	Risk
Satellite w	9	Operational	2,0
Satellite x	6	Demonstrative	3,0
Satellite y	4	Exploratory	7,0
Satellite z	1	Experiment	9,0
......			

Figure 4.2 illustrates the AHP-Sort process that will be applied for the classification of the satellites defined in table 4.2.

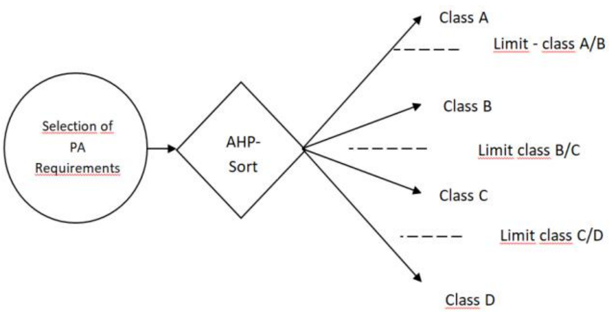

Fig. 4.2–AHP-Sort Process

Figure 4.3 shows the allocation of each requirement in the classes defined according to table 4.2.

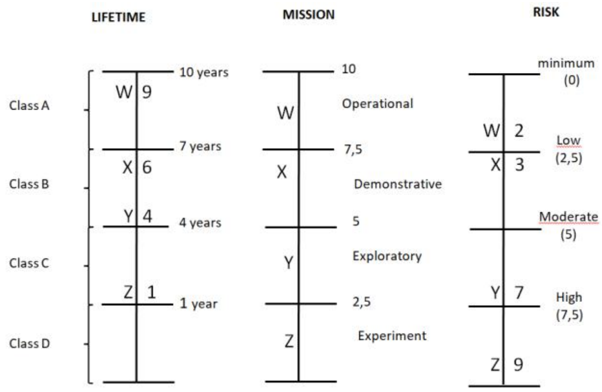

Fig. 4.3. Limiting Profiles for Each Class

To perform the pair-to-pair evaluation shown in Tabela 4.3, the fundamental Saaty scale was used.

Table 4.3. Fundamental scale of Saat (1991), adapted by author of arueira, 2014.

The Fundamental Scale for Pairwise Comparisons		
Intensity of Importance	**Definition**	**Explanation**
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one element over another
5	Strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
Intensities of 2, 4, 6, and 8 can be used to express intermediate values.		

In this work, the SuperDecisions software, a Multicriteria Decision Support tool, will be used to structure and optimize the Performance Evaluation, generating organized results.

Figure 4.4. presents the SuperDecisions software screen indicating the relationship between the objective, criteria and alternatives

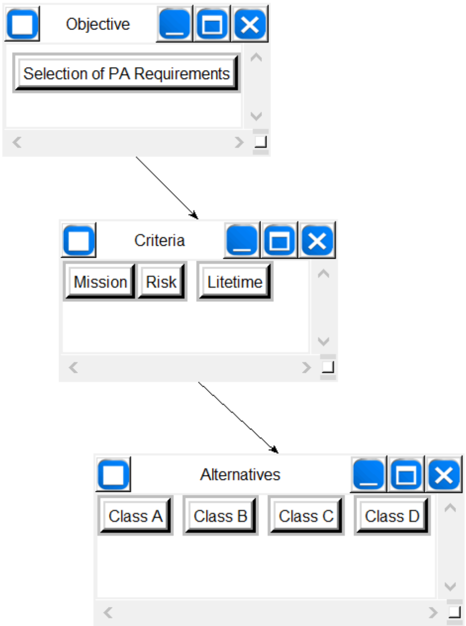

Fig. 4.4. Hierarchy presented by the SuperDecisions software.

According to Arueira (2014), the fundamental Saaty scale must be applied in the AHP method for the pair-by-pair comparison, the SuperDecisions software presents the table below, which is composed of three columns:

1. Choose - The degree of importance of each criterion is defined
2. Node Comparisons - Shows the pair-to-pair comparison
3. Results - This column shows the degree of importance of each criterion and also the value of the inconsistency of the judgment.

Inconsistency is an index that, according to Saaty, must be less than 0.1. In the example, 0.06239 was found, indicating that the comparison is acceptable. When this index is greater than 0.1 the comparison must be redone

The Figure 4.5.shown de *Pair-to-pair conparison of the criteria, using the Super Decisions software.*

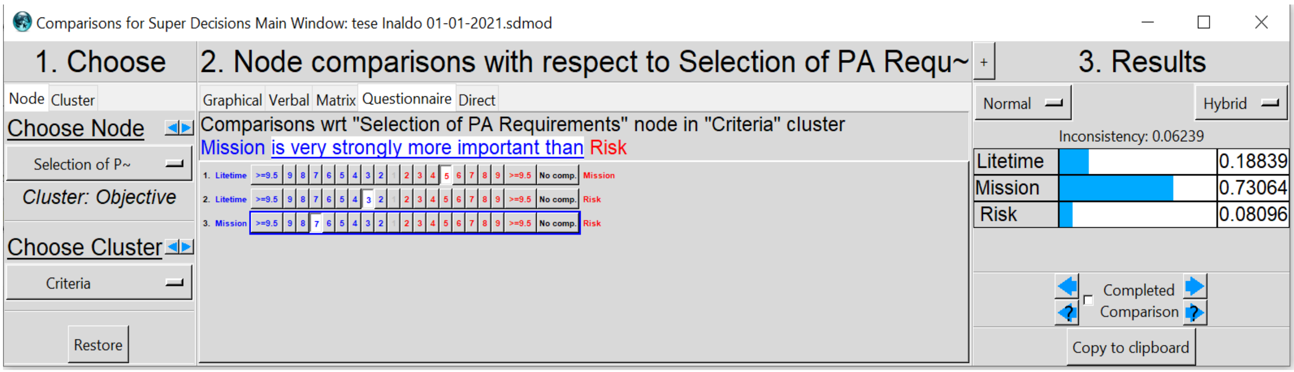

Fig. 4.5 Pair-to-pair comparison of the criteria, using the Super Decisions software

The Figure 4.6 shows the same result in matrix form

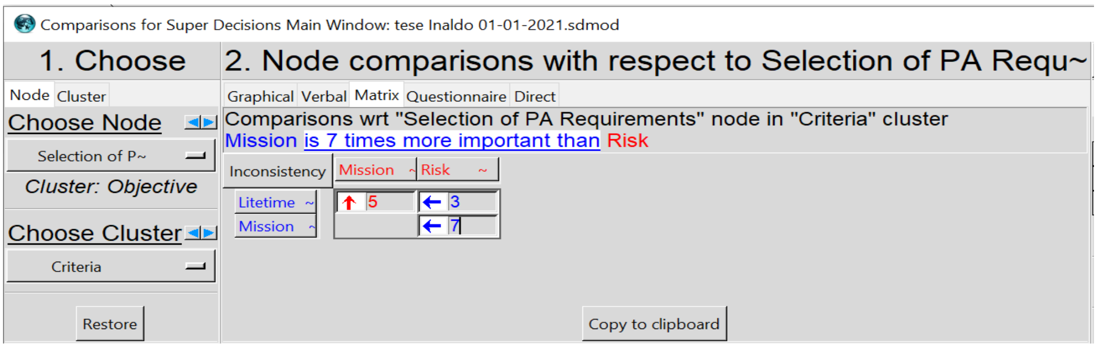

Fig. 4.6 Pair-to-pair comparison of the criteria, using the Super Decisions software

Next, it is necessary to judge the alternatives in relation to the limiting factors. In the exercise, the comparison matrix was judged by peers with all alternatives in relation to each of the limiting profiles of each class.

Using the data in table 4.1, a pair-to-pair comparison of the value of each alternative and the limiting profile of each class were performed.

Importance	Intensity	In favor of the alternative	In favor of the limiter
Equal	1	0,5000	0,5000
Small	2	0,6667	0,3333
Moderate	3	0,7500	0,2500
More moderate	4	0,8000	0,2000
Strong	5	0,8333	0,1667
More strong	6	0,8571	0,1429
Very strong	7	0,8750	0,1250
Much stronger	8	0,8889	0,1111
Extreme importance	9	0,9000	0,1000

Fig. 4.7. Values for judgments

The following table contains the complete judgment with all profiles and all classes in table 4.1.

Table 4.4 Judgments of the criteria in relation to the limiters

Criteria (limits Class A/B)

Alternative	>	Lifetime 7 years																	
Satellite x	6	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	0,75
Satellite w	9	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	0,6666667
Satellite y	4	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	0,3333333
Satellite z	1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	**8**	9	0,1111111
–																			

Alternative	>	Mission 7,5																	
Satellite x	6	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	0,3333333
Satellite w	8	9	8	7	6	5	4	3	2	1	2	3	**4**	5	6	7	8	9	0,6666667
Satellite y	2	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	0,1666667
Satellite z	1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	**8**	9	0.1111111
–																			

Alternative	<	Risk 2,5																	
Satellite x	3	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	0,3333333
Satellite w	2	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	0,6666667
Satellite y	7	9	8	7	6	5	4	3	2	1	2	3	4	5	6	**7**	8	9	0,125
Satellite z	9	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	**8**	9	0.1111111
–																			

Critérios (limit Class B/C)

Alternative		Lifetime 4 years																	
Satellite x	6	9	8	7	6	5	**4**	3	2	1	2	3	4	5	6	7	8	9	0.8
Satellite w	9	9	8	7	6	5	**4**	3	2	1	2	3	4	5	6	7	8	9	0,8571429
Satellite y	4	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	0.75
Satellite z	1	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	0,1666667
–																			

Alternative		Mission 5																	
Satellite x	6	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	0,6666667
Satellite w	8	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	0,5
Satellite y	2	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	0.25
Satellite z	1	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	0,1666667
–																			

Alternative		Risk 5																	
Satellite x	3	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	0.75
Satellite w	2	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	0,8333333
Satellite y	7	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	0.1666667
Satellite z	9	9	8	7	6	5	4	3	2	1	2	3	4	5	**6**	7	8	9	0,1428571
–																			

Critérios (limit Class C/D)

Alternative		Lifetime 1 year																	
Satellite x	6	9	**8**	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	0.8888889
Satellite w	9	9	**8**	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	0,9
Satellite y	4	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	0.8333333
Satellite z	1	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	0,5
–																			

Alternative		Mission 2,5																	
Satellite x	6	9	8	7	**6**	5	4	3	2	1	2	3	4	5	6	7	8	9	0.8571429
Satellite w	8	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	0,8333333
Satellite y	2	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	0.75
Satellite z	1	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	0,25
–																			

Alternative		Risk 7,5																	
Satellite x	3	9	8	**5**	6	5	4	3	2	1	2	3	4	5	6	7	8	9	0.8333333
Satellite w	2	9	**8**	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	0,8888889
Satellite y	7	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	0.6666667
Satellite z	9	9	8	7	6	5	4	3	2	1	2	3	**4**	5	6	7	8	9	0,2
–																			

After judging the criteria in relation to the limiting factors, the satellites were classified and, for that, it was necessary to aggregate the weighted local priorities that provide a global priority for each alternative, as an attribution of the alternative to its class through the global priority. These steps were performed for each alternative to be classified according to Table 4.4.

Table 4.5. Evaluation for Satellite Classification

Alternative	Criteria (class A)			Limiting Escore	Alternative Score	Class
	Lifetime	Mission	Risk			
	0,18839	0,73064	0,08096			
Satellite x	0,75000	0,33333	0,33333	**0,5882**	**0,4118**	
Satellite w	0,66667	0,66667	0,66667	**0,3333**	**0,6667**	**A**
Satellite y	0,33333	0,16667	0,12500	**0,8053**	**0,1947**	
Satellite z	0,11111	0,11111	0,11111	**0,8889**	**0,1111**	
...						

Alternative	Criteria (class B)			Limiting Escore	Alternative Score	Class
	Lifetime	Mission	Risk			
	0,18839	0,73064	0,72905			
Satellite x	0,80000	0,66667	0,75000	**0,3015**	**0,6985**	**B**
Satellite w	0,85714	0,50000	0,83333	**0,4057**	**0,5943**	**A**
Satellite y	0,75000	0,25000	0,16667	**0,6626**	**0,3374**	
Satellite z	0,16667	0,16667	0,14286	**0,8353**	**0,1647**	
...						

Alternative	Criteria (class C)			Limiting Escore	Alternative Score	Class
	Lifetime	Mission	Risk			
	0,18839	0,73064	0,72905			
Satellite x	0,88889	0,85714	0,83333	**0,1388**	**0,8612**	**B**
Satellite w	0,90000	0,83333	0,88889	**0,1496**	**0,8504**	**A**
Satellite y	0,83333	0,75000	0,66667	**0,2411**	**0,7589**	**C**
Satellite z	0,50000	0,25000	0,20000	**0,7070**	**0,2930**	**D**
...						

As shown in table 4.6. –The evaluation for classification of satellites, the four satellites under study were identified and the following classification was obtained:

Table 4.6. Final satellite ranking

Satellite W	Class A
Satellite X	Class B
Satellite Y	Class C
Satellite Z	Class D

4.2. Borda Method: Ordering product assurance requirements

For the second part of the problem, we will use the Borda method for ordering the requirements of each product assurancediscipline. The central idea of this method is to ranking established by each of the decision makers in a global ranking.

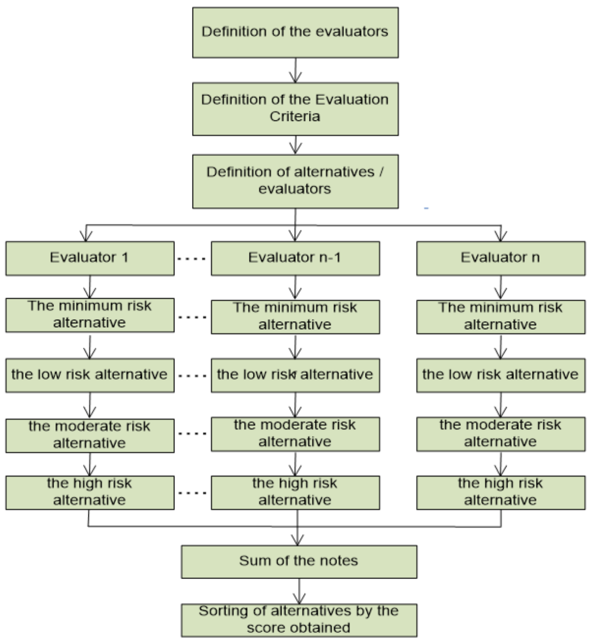

Fig. 4.8. Requirements ordering flowchart

The following steps are performed when applying the Borda method:

1. Define the evaluators or judges or members of the jury

2. Define the elements or alternatives to be ranked.
3. Obtain the assessments or judgments established by each decision maker for each of the alternatives.
4. Associate a score, order number or ranking score with each alternative, considering the individual judgments of each of the alternatives.
5. For each alternative, add the order numbers to obtain a global order number.
6. Obtain the final ordering of the alternatives, based on the global order numbers.

4.2.1. Borda Method: multidecisorproblem

According to Silva, (2015), to do the ranking, the Borda method will be used due to the simplicity and practicality of understanding the operations. After knowing this article in 1794, the French Academy of Sciences adopted the Borda method for counting the elections. This method remained in use until 1800, when it was discontinued.

Figure 4.9.presents the qualitative scale of the risk of the satellite mission objective. Using the risk values defined in this figure, an evaluation was carried out by three evaluators, whose result after being compiled allows to define which requirements should be allocated to each class of satellite.

Qualitative scale of mission risk	
A	Minimum risk mission
B	Low mission risk
C	Moderate mission risk
D	High mission risk

Fig. 4.9. Qualitative risk scale of the satellite mission objective

The flowchart steps in Figure 4.8 are described as follows:

1. The definition of the people who will participate as evaluators
2. The appraisers should be specialists in the space area, preferably with knowledge in systems engineering.
3. Definition of the evaluation criteria; Refer to Figure 4.9. "Quantitative Risk Scale for the Mission Objective" as a reference.
   a) note 4: if the requirement analyzed offers a minimum risk to the mission, choose class A;
   b) note 3: if the requirement analyzed offers a low risk to the mission, choose class B;
   c) note 2: if the requirement analyzed offers a moderate risk to the mission, choose class C;
   d) note 1: if the analyzed requirement presents a high risk for the mission, choose class D.
4. The appraiser must complete the spreadsheet with name, function, place of work and specialty, and vote on the alternatives by choosing the grade as defined in item 3;
5. The sum of the quantities of each type of evaluation will be carried out.
6. The result will be ordered reflecting the order of preference of the evaluators' alternatives.

In the proposed exercise, a total of three fictitious evaluators were used, as shown in table 4.7. The criteria were defined in item 4.2.1 and the product assurance requirements are described in Table 3.1. After the evaluators completed the questionnaires, the data were compiled and then the borda method was applied. The results of each requirement were compiled and through a mathematical formula the satellite classes were defined for each requirement.

Table 4.7. Evaluation of Product Assurance requirements

EVALUATORS		EV 1				EV 2				EV 3				Evaluation Result				Allocation of requirements			
		CL A	CL B	CL C	CL D	CL A	CL B	CL C	CL D	CL A	CL B	CL C	CL D	CL A	CL B	CL C	CL D	CL A	CL B	CL C	CL D
1.	Personnel training and certification	4	3			4	3	2		4	3	2		4	3	2	0	A	B		
2.	Control of critical items	4	3			4	3			4	3			4	3	0	0	A	B		
3.	Non-conformity control system	4	3	2		4	3	2		4	3	2		4	3	3	0	A	B	C	
4.	Traceability	4	3	2	1	4	3	2	1	4	3	2	1	4	3	3	3	A	B	C	D
5.	Metrology and calibration	4	3	2	1	4	3	2	1	4	3	2	1	4	3	3	3	A	B	C	D
6.	Handling, storage, transport and preservation.	4	3	2	1	4	3	2	1	4	3	2	1	4	3	3	3	A	B	C	D
7.	Qualification process	4	3			4	3			4	3			4	3	0	0	A	B		
8.	Quality requirements for procurement	4	3			4	3			4	3			4	3	0	0	A	B		
9.	Receiving and inspection activities	4	3	2		4	3	2		4	3	2		4	3	3	0	A	B	C	
10.	QA requirements for manufacturing, assembly and integration	4	3	2		4	3	2		4	3	2		4	3	3	0	A	B	C	
11.	Manufacturing readiness reviews	4	3	2		4	3	2		4	3	2		4	3	3	0	A	B	C	
12.	Cleaning and contamination control	4	3	2		4	3	2		4	3	2		4	3	3	0	A	B	C	
13.	Specific requirements for assembly and integration	4	3	2	1	4	3	2	1	4	3	2	1	4	3	3	3	A	B	C	D
14.	Logbooks	4	3	2	1	4	3	2	1	4	3	2	1	4	3	3	3	A	B	C	D
15.	QA requirements for acceptance and delivery	4	3	2		4	3	2		4	3	2		4	3	3	0	A	B	C	
16.	Project reviews	4	3	2		4	3	2		4	3	2		4	3	3	0	A	B	C	

EV - Evaluators, CL - Class

Below is the synthesized result of the product assurance requirements and their applications in the satellite classes studied in this article.

Table 4.8. Classification of requirements in the appropriate classes of satellites

1.	Personnel training and certification	A	B		
2.	Control of critical items	A	B		
3.	Non-conformity control system	A	B	C	
4.	Traceability	A	B	C	D
5.	Metrology and calibration	A	B	C	D
6.	Handling, storage, transport and preservation.	A	B	C	D
7.	Qualification process	A	B		
8.	Quality requirements for procurement	A	B		
9.	Receiving and inspection activities	A	B	C	
10.	QA requirements for manufacturing, assembly and integration	A	B	C	
11.	Manufacturing readiness reviews	A	B	C	
12.	Cleaning and contamination control	A	B	C	
13.	Specific requirements for assembly and integration	A	B	C	D
14.	Logbooks	A	B	C	D
15.	QA requirements for acceptance and delivery	A	B	C	
16.	Project reviews	A	B	C	

V. CONCLUSIONS

In this chapter, the main conclusions of this work related to the obtained results will be exposed and closing with the suggestions for future works.

In a scenario where the demand for redesign and process improvement is greater than the available resources, it is essential to decide which processes are most critical for the execution of the strategy. This decision cannot be made by a single manager, since the reality in organizations is of increasingly complex and transversal processes, that is, executed by several organizational units, many of them positioned in different Directories.

It is well known that the space sector is strategic for the country's growth, and that is why a space program that aims to empower the country is necessary, but to circumvent this scenario of scarce investments, the alternative found is to build medium and small satellites

This work aims to develop a selection and customization process for product warranty requirements applied to medium and small space missions, aiming at gains in manufacturing time, scope or cost, without promoting any additional risk to the mission. With smaller weights and reduced sizes, these satellites are suitable for use in various applications.

For the realization of this article, the application of two simple and well-known methods was used.

The AHP-Sort method for classification problems where missions will be classified according to the accepted margin for project execution risk, defined by stakeholders. AHP-Sort's main function is to classify the satellite in classes A, B, C or D.

The Borda method is also used, whose main function is the ordering of quality assurance requirements. The great advantage is that both methods are very simple to use, thus offering a great advantage for the space program.

Finally, the proposed process will be documented and will become a reference for the application of the selection of the requirements actually necessary for each class of mission, thus avoiding the use of requirements that demand high cost when deploying on exploratory satellites however, without jeopardising the reliability of the mission.

REFERENCES

[1] Aerospace Report TOR-2007 (8546) -6018 B, **Mission Assurance Guide**, the Aerospace Corporation., 2007

[2] Aerospace Report TOR-2011 (8591) -21, **Mission Assurance Guidelines for AD Mission Risk Classes**, Jun, 2011, Space and Missile Systems Center, Air Force Space, Command.

[3] Albuquerque, I. S, Brito, AC, Perondi, LF, **Selection and Customization of Product Assurance Requirements applied to Small Satellites.**, 2020.

[4] Arueira, A., B., **Application of the AHP Method for Evaluation of Conveyors**., 2014.

[5] Costa, H., G., **Voting Systems by the Borda Method**, 2014.

[6] ECSS - S - ST - 00C. Description, implementation and general requirements, "Noordwijk, The Netherlands: ESA – ESTEC, Requirements & Standards Division, 2008.

[7] Gujansky, G., **Determination of municipalities for the implantation of Senai operational units using a multicriteria decision support model**, 2014.

[8] NPR 7123.1C, NASA **Systems Engineering Processes and Requirements** Responsible Office: Office of the Chief., 2020.

[9] POPPER, KR **The logic of scientific research**. 10th ed. São Paulo: Cultrix, 2003.

[10] Silva, C., JE **Application of the Borda Method to assess collective decisions: A study on the assessment of critical processes affected by the strategy of a company in the electricity sector**, 2015.