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Features And Requirements For The Quality Of Software For Space Purposes

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Abstract

This article discusses the issues of software quality assurance for space purposes (SWSP). In order to establish the features and requirements for SWSP quality, their classification is carried out taking into account the purpose, operating conditions, reliability requirements, safety, etc. Features of the SWSP of critical application are analyzed. The general requirements and principles of quality assurance of the SWSP are grounded.

A wide range of requirements for SWSP quality, depending on their purpose, the principal features and operating conditions, leads to the need to adapt and detail the recommendations of existing basic standards that regulate the quality of software.

Keywords

software, space system, quality, safety, features, criticality category, requirements, principles of quality assurance.

1. Introduction

As practice shows, the safety and correctness of the space system's performance of the main objective function depends on a high degree from the characteristics of the software used in it. This gives rise to the need to provide software for space purposes (software for space purposes - SWSP) with specified properties of quality and safety, as well as the ability to withstand destruction, disrupt the functioning of the system and failures.

The situation becomes even more complicated when it comes to critical software, the correct functioning of which directly affects the success of the mission and the safety of the space system. To the quality and reliability of such SWSP are given particularly high requirements.

The features and quality characteristics of the SWSP depend on the purpose for which consumer and for what operating conditions they are intended. The same software product, produced for different purposes and under different conditions of use, may have several different representations and quality assessments. In accordance with the principal features of the software, the nomenclature and the values of the quality indicators required for its effective application by users, as well as the requirements for the verification process, should be selected.

In real projects, the notion of the quality of SWSP, the characteristics with which it is described, or how they should be measured and compared with the requirements of the terms of reference or specification [1], are often missing or not clearly defined.

In this regard, it is an urgent task to analyze the features of the SWSP in order to establish requirements for the characteristics of their quality.

The main goal of this work is the analyses of the features and justification the requirements necessary for building a SWSP quality model.

2. Analysis of the features of software for space purposes

In order to establish the characteristics and requirements for the characteristics of quality and safety, it seems reasonable to classify the SWSP taking into account their purpose, operating conditions, reliability requirements, safety, etc.
Given the existing approaches to the classification of software, it is advisable to classify the SWSP on the following grounds:

- membership of the SWSP in the objects of space technology;
- functional purpose;
- degree of approbation;
- Influence on safety.

By belonging to the objects of space technology, it is possible to distinguish SWSP:

- on-board control systems for manned and automatic space vehicles;
- on-board computer systems of carrier rockets, upper stages;
- technical and launching complexes, ground automated control systems for space vehicles, ground equipment and structures;
- payloads;
- experiments and modeling.

Belonging to the objects of space technique determines the specific requirements, for example, the safety requirements of the SWSP for space vehicles and payloads differ from the safety requirements of the SWSP for experiments and modeling.
The software, which is part of the on-board systems, traditionally has increased requirements for reliability and safety. In addition, important properties of such software include high quality, verifiable, consistent, reusable, fast integration with hardware, and the ability to transfer to other platforms [1].
According to the functional purpose, the SWSP is divided into:

- general (or system);
- Applied (or functional);
- technological (or instrumental), which is used in the development, testing and verification.

The "functional purpose" attribute specifies the specific requirements that are imposed on the tools needed to implement the respective functions, application (functional) software and general (system) software.
According to the degree of validity, the following types of SWSP are distinguished:

- New, developed for the first time;
- existing own (developed earlier) or existing acquired;
- configurable from standard modules.

The sign "degree of approbation" determines the scope of the requirements for the development and verification of the SWSP, depending on the belonging to the objects of space technology and destination, the safety category.
The development of new software requires a higher qualification of developers, greater material costs and efforts. Verification should be carried out after each stage of the software life cycle in full, with the level of independence conditioned by the security category of the software functions.
The development of a new software product has the advantage that verification process control can be performed at the beginning.
Reusing existing proprietary software has the advantage that the entire volume of software is always available. Additional costs are only required to create the necessary application changes to prepare the configuration data and additional verification.
For the existing software purchased, the source code and the primary documentation are, in most cases, not available for verification. In this case, an analysis of operational experience and functional testing is necessary.
The configurable software is developed using typical simple and reliable modules (basic processes, such as signal input, signal verification, initialization, logical control, data management, etc.). Integration of modules is carried out using standard models for setting up objects and processes and can be accompanied by the introduction of data to determine and change the characteristics for a particular object. Verification is carried out in full and on all ranges of input information, control constants and on the control ranges.
On the impact on security, the SWSP is distinguished, which:

- affects security (critical software);

- does not affect on safety.

The "influence on safety" sign specifies the requirements for SWSP the implementation of critical functions in accordance with the adopted hazard categories. For example, depending on the hazard category, there are different requirements for the volume, completeness, documentation of reporting and the independence of the verification process.

The term "safety-critical software" is usually understood as software that performs critical functions that are important to safety, the failure to perform which (loss or degradation) or its misuse can lead to catastrophic or critical consequences [2]. Sometimes the same term refers to programs developed in accordance with special standards adopted for critical areas.

The above classification of the SWSP is based on ISO / IEC TR 12182 [10], taking into account the designation, operating conditions, reliability requirements, safety and other features of the SWSP. The proposed classification is not exhaustive and does not automatically solve the problem of establishing the levels of requirements for SWSP.

Depending on the characteristics of the SWSP, to represent its most specific characteristics during classification there can be used a combination of several types. For example, when classifying by the type of application domain, additional requirements, such as "dependability requirements" or "security requirements", may be used, if necessary.

3. Features of the SWSP of critical application

Features and requirements for SWSP depend on the critical functions being implemented, the system security requirements (software and hardware complex), to which it belongs.

At present, there is a classification of critical software by the safety categories adopted for nuclear power plants, aviation and space systems [3-7]. These classifications are based on establishing the categories of danger of failures of systems or control object caused by the failure or failure of the software. The level of criticality or safety category of the software is determined by the severity of the consequences of its anomalous functioning, taking into account the probability of their occurrence.

In the European standard ECSS-Q-ST-80C [3] the following categories of criticality of the software for space purposes are defined (Table 1).

Table 1 - Criticality categories of the SWSP

Category	Characteristics
A	Software that, in the event of failure to perform or improper execution, or abnormal behavior, may cause or contribute to a system failure resulting in: *catastrophic consequences (loss of life, threat to their lives, destruction, loss of equipment);*
B	Software that, in the event of failure to perform or improper execution, or abnormal behavior, may cause or contribute to a system failure resulting in: *critical consequences (damage that does not threaten people's lives, significant damage to machinery, harmful effects on the environment);*
C	Software that, in the event of failure to perform or improper execution, or abnormal behavior, may cause or contribute to a system failure resulting in: *significant consequences (a significant reduction in the capabilities of the facility management or the ability of staff to cope with adverse regimes);*
D	Software that, in the event of failure to perform or improper execution, or abnormal behavior, may cause or contribute to a system failure resulting in: *minor or insignificant consequences (insignificant reduction of the safety of the management objects and requires actions of personnel that are feasible within their capabilities).*

4. General quality requirements for SWSP

The basis for the formation of requirements for SWSP is the analysis of properties that characterize the quality of its operation, taking into account its purpose and operating conditions. In accordance with the fundamental features of the SWSP, the nomenclature and the values of the quality indicators necessary for its effective application by users, which are subsequently reflected in the technical documentation and in the specification of the requirements for the final product, should be selected in the design process.

The nomenclature of SWSP quality indicators should be set taking into account:

- purpose and operating conditions;
- results of the analysis of the requirements of the user (customer), the tasks of quality management;
- the composition, structure and specificity of the properties described.

For each type (group), and sometimes a specific SWSP, it is necessary to establish its own nomenclature of quality indicators, taking into account the specifics of the purpose and conditions of use. Each quality indicator can be used if its metric is defined and a way of its estimation and comparison with the required reference value can be indicated.

Based on the analysis and generalization of the requirements of the standards ISO 25010, ECSS-Q-80, etc., and also the experience and recommendations for software development of the world's leading companies in the aerospace industry and nuclear energy in the USA, Europe, Russia, Ukraine, there can be recommend, in case of general requirements of SWSP quality there must be necessarily included the following indicators:

- functional suitability;
- reliability [2,3];
- survivability [2,3];
- functional safety [8].

Other quality characteristics should be specified when creating a specification or technical task for SWSP development. Table 2 gives an example of recommended quality characteristics for SWSP in various applications.

Table 2 - Example of recommended quality characteristics for SWSP in in various applications

Main characteristics of software quality	**The main types of SWSP for the field of application**				
	on-board control systems of spacecraft	on-board computer systems of launch vehicle	ground control systems	payloads	experiments and modeling
functional suitability	+	+	+	+	+
reliability	+	+	+	+	±
survivability	+	+	±	+	–
functional safety	+	+	+	±	–
dependability	+	+	±	+	–
security	+	+	+	+	±

«+»- mandatory application; «–»- application impractical; «±»- if necessary.

The software developer, after conducting a functional analysis of the requirements for the project, must determine the security categories of the SWSP functions performed and establish the category of its criticality (security category).In accordance with the criticality category of the SWSP, requirements for quality and safety characteristics, as well as requirements related to verification, validation and levels of evidence should be established.

For software critical use should be:

- possible sources of failure;
- the consequences of manifestation of software defects are determined;
- the necessary software is provided to eliminate common cause failures or reduce their effects to an acceptable level;

- an analysis of the impact of such software on security, documented the results of the analysis and taken measures.

The quality requirements of critical SWSP must be based on the implementation in full or reduced volume of the following functions:

a) forecasting the possibility of appearance (manifestation) of a defect and the occurrence of a failure due to this defect (fault forecasting);

b) prevention of appearance (manifestation) of a defect and occurrence of a fault (fault prevention);

c) detection of appearance (manifestation) of the defect, calculation error, fault (fault detection);

d) identification of the cause, type and location of the fault (fault diagnosis);

e) parrying the consequences of a defect and the occurrence of a fault (fault tolerance);

f) restoration of the computational process by forming the correct information or returning to the previous point and continuing the operation (fault recovery).

Taking into account the specifics of the SWSP as critical software, to ensure their reliability and security, the following principles should be adhered to: single failure, redundancy, independence, diversity, protection against common cause failures.

The priority quality requirement for the SWSP critical applications is quality assurance or dependability, by which is meant - the proven confidence of the software's ability to safely and securely perform the required functions in accordance with the purpose [2,3,9].

The requirements for the quality characteristics of the SWSP should be set taking into account a number of different factors: *technical* (the design novelty, the complexity and volume, the level of criticality, etc.), *operational* (designation of the SWSP, the number of potential users, the estimated use time, the limitation of operating modes, technical support), *organizational* (the amount of work and time required for the development of the SWSP, financial, human resources, the acceptable level of risk for the project, etc.).

Providing and confirming the quality of SWSP as a complex software with high quality requirements should be based on verification and testing qualities of the:

- requirements for SWSP;
- performance of the life cycle processes of the SWSP;
- finished software product and documentation;
- verification process.

The main and sufficient condition for SWSP quality assurance is a guarantee (proven certainty) of correct, reliable, reliable and stable performance of necessary functions within a given time, regardless of internal and external disturbances that have arisen.

5. Conclusion

The complexity of the process of development and maintenance of the SWSP is largely determined by the specific requirements imposed on their quality. The incompleteness, uncertainties and different interpretations in the definition and formalization of the quality characteristics of the SWSP and the required values leave a wide margin for arbitrariness in describing and evaluating their quality. These factors justify the need for the development and application of specific plans and programs, methodology and tools, formalized methods for describing and assessing quality, ensuring the required quality, reliability and safety of operation for each project of the SWSP. Methods for assessing the quality of SWSP should be based on the following main components:

- the quality model of the SWSP containing mechanisms for the formal determination of quality characteristics and their relations;
- the metric model of the SWSP, which forms mechanisms for measuring metrics of quality indicators;
- quality assessment methods that determine the quality assessment processes of the SWSP.

As the initial information for assessing the compliance of the SWSP with quality requirements, the system requirements, requirements for the SWSP, a description of its architecture, data, and program documentation should be used.

A wide range of quality requirements for SWSP, depending on their purpose, the principal features and operating conditions, leads to the need to adapt and detail the recommendations of existing basic standards that regulate the quality of software. First of all, this applies to SWSP critical applications.

In order to establish the features and requirements for the SWSP quality characteristics, their classification is proposed taking into account the purpose, operating conditions, criticality level, etc. The proposed classification allows determining the most important quality characteristics for a certain type of SWSP.

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