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Space engineering - Control performance guidelines

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**CEN-CENELEC Management Centre:
Rue de la Science 23, B-1040 Brussels**

Table of contents

| | |
|--|-----------|
| European Foreword | 7 |
| Introduction | 8 |
| 1 Scope | 10 |
| 2 References | 11 |
| 3 Terms, definitions and abbreviated terms | 12 |
| 3.1 Terms from other documents..... | 12 |
| 3.2 Terms specific to the present handbook | 12 |
| 3.3 Abbreviated terms..... | 16 |
| 4 General outline for control performance process | 18 |
| 4.1 The general control structure | 18 |
| 4.1.1 Description of the general control structure – Extension to system level | 18 |
| 4.1.2 General performance definitions | 19 |
| 4.1.3 Example – Earth observation satellite | 20 |
| 4.2 Review of generic performance specification elements..... | 21 |
| 4.2.1 General..... | 21 |
| 4.2.2 Preliminary remark on intrinsic and extrinsic performance properties | 21 |
| 4.2.3 Examples of high-level performance requirements..... | 23 |
| 4.2.4 Formalising requirements through performance indicators | 25 |
| 4.3 Overview on performance specification and verification process | 27 |
| 4.3.1 Introduction | 27 |
| 4.3.2 Requirements capture & dissemination | 28 |
| 4.3.3 Performance verification..... | 29 |
| 4.3.4 Control performance engineering tasks during development phases | 31 |
| 5 Extrinsic performance – error indices and analysis methods | 38 |
| 5.1 Introduction..... | 38 |
| 5.2 Performance and measurement error indices | 38 |

CEN/TR 17603-60-10:2022 (E)

| | | |
|----------|---|-----------|
| 5.2.1 | Definition of error function | 38 |
| 5.2.2 | Definition of error indices..... | 39 |
| 5.2.3 | Common performance error indices | 39 |
| 5.2.4 | Common knowledge error indices | 41 |
| 5.3 | Formulation of performance requirements using error indices..... | 42 |
| 5.3.1 | Structure of a requirement..... | 42 |
| 5.3.2 | Choice of error function | 42 |
| 5.3.3 | Use of error indices | 43 |
| 5.3.4 | Statistical interpretation of a requirement | 43 |
| 5.3.5 | Formulation of Knowledge Requirements..... | 46 |
| 5.4 | Assessing compliance with a performance requirement | 46 |
| 5.4.1 | Overview | 46 |
| 5.4.2 | Experimental approach | 47 |
| 5.4.3 | Numerical simulations | 47 |
| 5.4.4 | Use of an error budget | 49 |
| 5.5 | Performance error budgeting | 50 |
| 5.5.1 | Overview | 50 |
| 5.5.2 | Identifying errors | 50 |
| 5.5.3 | Statistics of contributing terms | 51 |
| 5.5.4 | Combination of error terms..... | 52 |
| 5.5.5 | Comparison with requirements..... | 53 |
| 5.5.6 | Practical use of a budget (Synthesis) | 53 |
| 6 | Intrinsic performance indicators for closed-loop controlled systems..... | 56 |
| 6.1 | Overview | 56 |
| 6.2 | Closed-loop controlled systems | 57 |
| 6.2.1 | General closed-loop structure | 57 |
| 6.2.2 | General definitions for closed-loop controlled systems..... | 57 |
| 6.3 | Stability of a closed-loop controlled system..... | 59 |
| 6.4 | Stability margins | 60 |
| 6.4.2 | Stability margins for SISO LTI systems | 60 |
| 6.4.3 | Stability margins for MIMO LTI system – S and T criteria | 62 |
| 6.4.4 | Why specifying stability margins?..... | 64 |
| 6.5 | Level of robustness of a closed-loop controlled system | 65 |
| 6.6 | Time & Frequency domain behaviour of a closed-loop controlled system..... | 65 |
| 6.6.1 | Overview | 65 |
| 6.6.2 | Time domain indicators (transient) | 65 |
| 6.6.3 | Frequency domain performance indicators | 67 |

CEN/TR 17603-60-10:2022 (E)

| | | |
|----------------|--|-----------|
| 6.7 | Formulation of performance requirements for closed-loop controlled systems | 70 |
| 6.7.1 | General | 70 |
| 6.7.2 | Structure of a requirement..... | 70 |
| 6.7.3 | Specification for general systems (possibly MIMO, coupled or nested loops)..... | 71 |
| 6.7.4 | Example of stability margins requirement..... | 71 |
| 6.8 | Assessing compliance with performance requirements..... | 72 |
| 6.8.1 | Guidelines for stability and stability margins verification | 72 |
| 6.8.2 | Methods for (systematic) robustness assessment..... | 73 |
| 7 | Hierarchy of control performance requirements | 74 |
| 7.1 | Overview | 74 |
| 7.2 | From top level requirements down to design rules | 74 |
| 7.2.1 | General..... | 74 |
| 7.2.2 | Top level requirements..... | 74 |
| 7.2.3 | Intermediate level requirements | 75 |
| 7.2.4 | Lower level requirements – Design rules..... | 75 |
| 7.3 | The risks of counterproductive requirements | 76 |
| 7.3.1 | An example of counterproductive requirement | 76 |
| 7.3.2 | How to avoid counterproductive control performance requirements? | 76 |
| Annex A | LTI systems | 77 |
| A.1 | Overview | 77 |
| A.2 | General properties of LTI systems | 77 |
| A.2.1 | Simplified structure of a closed-loop controlled system | 77 |
| A.2.2 | Representation of LTI systems..... | 78 |
| A.3 | On stability margins of SISO and MIMO LTI systems | 80 |
| A.3.1 | Interpretation of stability margins..... | 80 |
| A.3.2 | Analysis of stability margins – some illustrations | 82 |
| Annex B | Appendices to clause 5: Guidelines and mathematical elements | 84 |
| B.1 | Error Indices with domains other than time | 84 |
| B.2 | Considerations regarding time intervals | 85 |
| B.3 | Relationship between error indices and physical quantities | 85 |
| B.4 | Statistics for Monte Carlo Minimum Number of Runs | 87 |
| B.5 | Determining the error PDFs | 88 |
| B.5.1 | Overview..... | 88 |
| B.5.2 | White noise | 88 |
| B.5.3 | Biases..... | 89 |

CEN/TR 17603-60-10:2022 (E)

| | | |
|----------------|---|-----------|
| B.5.4 | Uniform random errors | 90 |
| B.5.5 | Harmonic errors | 90 |
| B.5.6 | Drift Errors | 91 |
| B.5.7 | Transient Errors | 92 |
| B.5.8 | Others (General Analysis Methods) | 93 |
| B.5.9 | Distributions of Ensemble Parameters | 94 |
| B.6 | Mathematics of an Error Budget | 95 |
| B.6.1 | Probability distributions and the statistical interpretation | 95 |
| B.6.2 | Exact error combination methods..... | 96 |
| B.6.3 | Alternative approximation formulae | 97 |
| Annex C | Satellite AOCS case study | 98 |
| C.1 | Introduction..... | 98 |
| C.2 | Satellite AOCS architecture | 98 |
| C.3 | From Image quality to AOCS requirements..... | 98 |
| C.4 | Formulation of the requirements C.3a1 to C.3a4 using error indices..... | 101 |
| C.4.1 | General..... | 101 |
| C.4.2 | Choice of signal error function..... | 102 |
| C.4.3 | Choice of error indices and maximum values | 102 |
| C.4.4 | Assigning a probability density function (PDF) | 102 |
| C.4.5 | Choice of statistical interpretation (temporal, ensemble, mixed...) | 103 |
| C.4.6 | Requirements formulation | 103 |
| C.5 | Formulation of requirements C.3b1 and C.3b2 | 104 |
| C.6 | Control Performance verification principles..... | 104 |
| C.6.1 | Choice of verification method | 104 |
| C.6.2 | Compiling the error budget (requirements C.3a1 to C.3a4)..... | 105 |
| C.6.3 | Assessing compliance to control loop requirements C.3b1 and C.3b2 | 110 |
| C.7 | Performance budget examples | 111 |
| C.7.1 | Overview..... | 111 |
| C.7.2 | Pointing Knowledge Budget | 111 |
| C.7.3 | Pointing budget..... | 114 |
| C.7.4 | Pointing stability Budget (Requirements C.3a3 and C.3a4)..... | 116 |
| Figures | | |
| Figure 4-1 | General control structure, ECSS-E-HB-60A | 18 |
| Figure 4-2 | General control structure extended up to system level | 19 |
| Figure 4-3 | Example of requirements capture and dissemination for a typical AOCS case | 30 |

CEN/TR 17603-60-10:2022 (E)

| | | |
|------------|---|----|
| Figure 4-4 | Example of pointing performance verification, for a typical mission profile..... | 30 |
| Figure 5-1 | Illustration of the different ways of meeting a requirement..... | 44 |
| Figure 5-2 | Statistics for the different statistical interpretations. L-R: temporal interpretation, ensemble interpretation, mixed interpretation | 44 |
| Figure 6-1 | Simplified scheme for a closed-loop controlled system..... | 57 |
| Figure 6-2 | Example of gain and phase margins identification..... | 62 |
| Figure 6-3 | Illustration of the transient response indicators..... | 66 |
| Figure 6-4 | Bandwidth, cut-off frequency and rejection of resonances..... | 69 |

Tables

| | | |
|------------|--|----|
| Table 3-1: | Relationships of the definitions of the different kinds of performance, performance knowledge and their corresponding errors..... | 16 |
| Table 4-1 | Example of a control structure breakdown for an Earth observation satellite | 21 |
| Table 4-2 | Example of AOCS extrinsic and intrinsic specifiable performances | 22 |
| Table 4-3 | General template for building extrinsic performance indicators..... | 26 |
| Table 4-4 | Summary of control performance engineering tasks..... | 28 |
| Table 4-5 | Summary of the control performance management activities during the phases of mission development (guidelines only)..... | 31 |
| Table 4-6 | Control performance engineering inputs, tasks and outputs, Phase 0/A..... | 32 |
| Table 4-7 | Control performance engineering inputs, tasks and outputs, Phase B..... | 34 |
| Table 4-8 | Control performance engineering inputs, tasks and outputs, Phase C/D | 36 |
| Table 4-9 | Control performance engineering inputs, tasks and outputs, Phase E/F..... | 37 |
| Table 5-1 | Minimum number of simulation runs required to verify a requirement at confidence level P_c to a verification confidence of 95 %..... | 49 |
| Table 5-2 | Example of a table used for a performance budget (APE for Euler angles) | 55 |
| Table 6-1 | Formulas for the usual SISO stability margins..... | 61 |

European Foreword

This document (CEN/TR 17603-60-10:2022) has been prepared by Technical Committee CEN/CLC/JTC 5 "Space", the secretariat of which is held by DIN.

It is highlighted that this technical report does not contain any requirement but only collection of data or descriptions and guidelines about how to organize and perform the work in support of EN 16603-60.

This Technical report (CEN/TR 17603-60-10:2022) originates from ECSS-E-HB-60-10A.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

This document has been developed to cover specifically space systems and has therefore precedence over any TR covering the same scope but with a wider domain of applicability (e.g.: aerospace).

Introduction

This document focuses on the specific issues raised by managing all performance aspects of control systems in the frame of space projects. It provides a set of practical definitions, engineering rules, recommendations and guidelines to be used when specifying or verifying the performance of a general control system; attention was paid by the authors to keep the application field as open as possible, and not to restrict to a specific domain – such as spacecraft attitude control for example.

It is not intended to substitute to textbook material on automatic control theory. The readers and the users are assumed to possess general knowledge of control system engineering and its applications to space missions. Nevertheless when required – to avoid any risks of ambiguity for example, or for the clearness of the presentation – some basic definitions and rules are provided in dedicated annexes.

This document was originally intended to focus on the specific case of pointing systems and AOCS, starting from an existing ESA handbook [Pointing Error Handbook, ESA-NCR-502], to be updated, completed, and extended to be built up as an applicable ECSS document. But after reviewing the scope, this approach appeared somewhat restrictive:

- restricting performance concepts to “pointing” does not allow to deal with problems such as thermal control, position control (robotics), or more generally any other type of control systems, even though these problems share the same theoretical framework;
- AOCS is one major contributor to the overall system pointing performance, yet not the only one: misalignments, thermoelastic effects, payload behaviour, etc. all contribute to the final performance. This remark can be extended to general systems, considering that the controlled part is but one of the contributors.

Accounting for these remarks led to extending the initial scope of this document. The upgraded objective is to set up a generalised framework introducing performance definitions, performance indices and budget calculations. “Generalised” is understood here in two directions:

- transversally, so as to be applicable independently on the physical nature of the control system (not only pointing),
- and vertically, in the sense that in many practical situations the proposed definitions and techniques can also apply to any part of the system (basically to the controlled part, but not restrictively). This should assure consistency between the performances indices (error budgets) of the complete system and of the controlled system part. Motivation is also that dedicated but generic methods for budget breakdown can be applied on different levels i.e. on system level and on controlled system level.

NOTE 1 The idea of defining a general framework applying from equipment level to system level is driven by a concern for technical and conceptual consistency. In a later phase, relevant system aspects can be transferred or copied to the appropriate System Engineering standard – if found more convenient.

CEN/TR 17603-60-10:2022 (E)

NOTE 2 The general control structure from the Control Engineering handbook [ECSS-E-HB-60A, Figure 4-1] has been extended in support, showing also the system performance in the output (Figure 4-2 of this handbook)

NOTE 3 The objective of this document is not to cover the high level system or mission performance aspects, which clearly belong to a different category.

In addition to this will for general and generic concepts, a clause of this document covers the performance issues which are more specific for the controlled systems themselves (mainly involving feedback loops in practice) or which are based on well-known control methods. The need for this clause arises as such systems call for particular technical know-how and feature specific performance indicators that require additional insight. For example: stability and robustness properties, transient responses (settling time, response time etc.) and frequency domain indicators.

Although this document is designed to be as general as possible, clearly in practice pointing and AOCS issues are the most demanding space engineering disciplines in terms of control systems. They are covered by an informative annex of the document which declines the general concepts and illustrates how pointing issues can be managed as a special case of vector-type data on a high resolution Earth observation mission.

Driven by a similar concern for illustration on space engineering applications of practical interest, another annex of the document shows how to decline the general concepts to deal with the control performance issue arisen by robotics applications.

1

Scope

This Handbook deals with control systems developed as part of a space project. It is applicable to all the elements of a space system, including the space segment, the ground segment and the launch service segment.

It addresses the issue of control performance, in terms of definition, specification, verification and validation methods and processes.

The handbook establishes a general framework for handling performance indicators, which applies to all disciplines involving control engineering, and which can be declined as well at different levels ranging from equipment to system level. It also focuses on the specific performance indicators applicable to the case of closed-loop control systems.

Rules and guidelines are provided allowing to combine different error sources in order to build up a performance budget and to assess the compliance with a requirement.

This version of the handbook does not cover control performance issues in the frame of launch systems.

2 References

| EN Reference | Reference in text | Title |
|---------------------|--------------------------|--|
| EN 16601-00-01 | ECSS-S-ST-00-01 | ECSS System - Glossary of terms |
| EN 16603-10 | ECSS-E-ST-10 | Space engineering – System engineering general requirements |
| EN 16603-60-10 | ECSS-E-ST-60-10 | Space engineering – Control performance |
| EN 16603-60-20 | ECSS-E-ST-60-20 | Space engineering – Stars sensors terminology and performance specifications |
| TR 16703-60 | ECSS-E-HB-60 | Space engineering – Control engineering handbook |
| EN 16601-40 | ECSS-M-ST-40 | Space project management – Configuration and information management |

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