Standardization training program
E-60 discipline: Control

Control Performance Standard
E-ST-60-10C
& ESA Pointing Error Engineering Handbook
ESSB-HB-E-003 Issue 1

European Space Agency

Control Performance Standard

E-ST-60-10C

The ECSS E60 branch

ECSS Standards **ECSS Handbooks** **ESA Handbooks**

E-60: Control

Dynamics and Control **Sensors and Actuators** **Special Applications**

E-60 Control Engineering

E-ST-60-10C Control performance ↔ E-ST-60-20C Star Sensors Terminology & Performance Specification

E-ST-60-30C Satellite AOCS Requirements

E-HB-60A Control Engineering Handbook

E-HB-60-10A Control Performance Guidelines

ESSB-E-HB-E-003 ESA Pointing Error Engineering

ESA-E-HB-E-XX ESA Pointing Error Mapping (not started)

Introduction
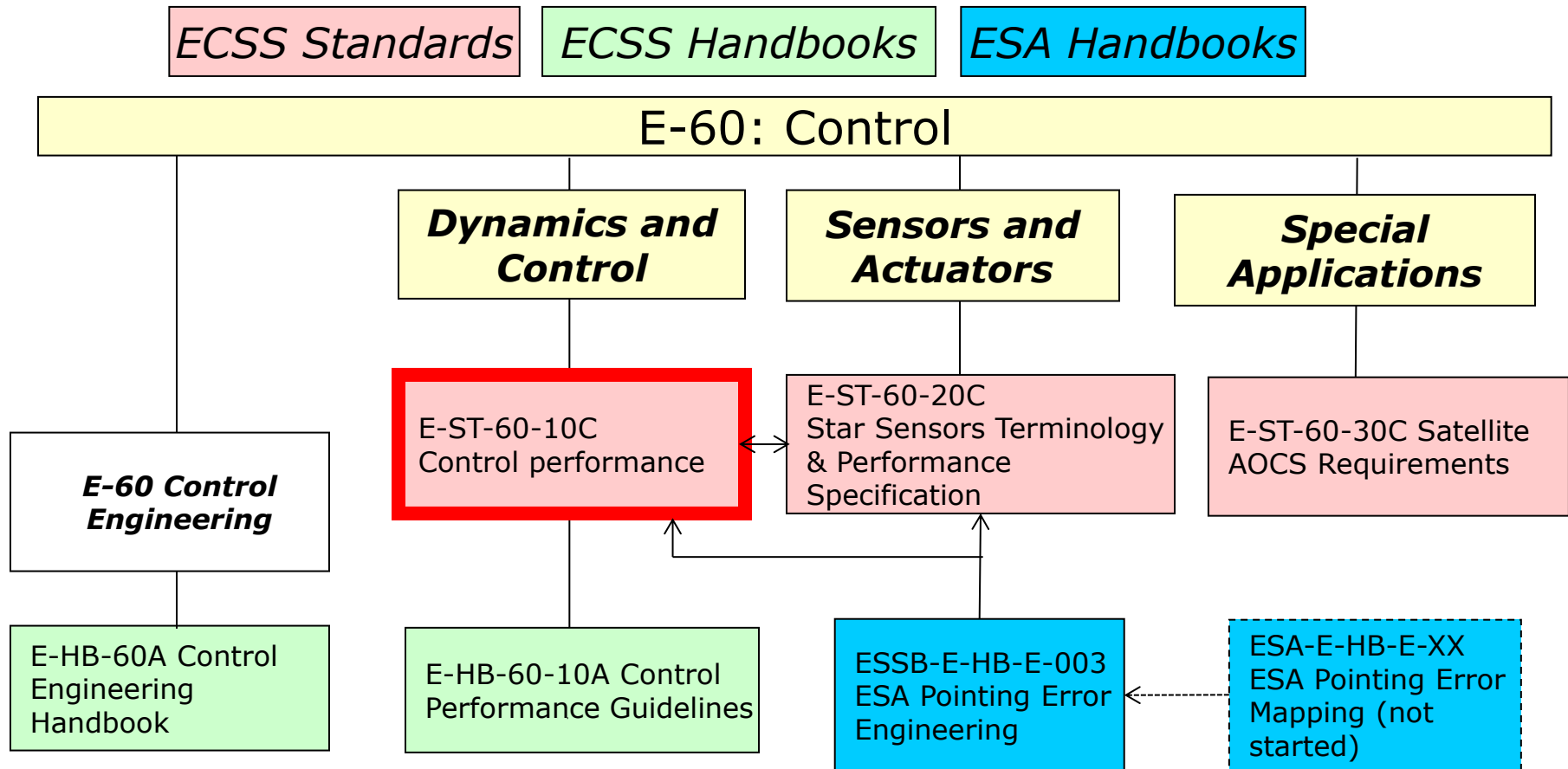
- The standard addresses the issue of control performance, in terms of definition, specification, verification and validation methods and processes.

  - It defines a general framework for handling **performance indicators**, which applies to all disciplines involving control engineering, 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 – mainly **stability and robustness**.

- Rules are provided for combining different error sources to build a **performance error budget** and use it to assess the **compliance** with a requirement.

  - Complementary material and guidelines for a step-by-step procedure for pointing error budgeting can be found in ECSS-E-HB-60-10A - Control Performance Guidelines and in ESSB-E-HB-003 – Pointing Error Engineering Handbook

  - For their own specific purpose, each entity (ESA, national agencies, primes) can further elaborate internal documents, deriving appropriate guidelines and summation rules based on the top level clauses gathered in this standard.

  - **Simplified summation rules are not endorsed by this standard**.

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Chapter 2
Normative references

Chapter 3
Terms, definitions and abbreviated terms

- **Definitions**
- **Terminology**

- **Use of performance indices**
- **Inputs to an error budget**
- **Worked example**
- **Correspondance with the Pointing Error Handbook**

E-ST-60-10C Control performance

Annexes
A to D

Chapter 4
Performance requirements and budgeting

- **Specifying a performance requirement**
- **Use of error budgeting to assess compliance**

Chapter 5
Stability and robustness specification

- **Overview**
- **Stability and robustness specification**

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Quick insight

- Chapter 3 gives the definition of control performance-related terms
  - Absolute knowledge error (AKE), absolute performance error (APE), error, error index, individual error source, knowledge error, …
- Chapter 4 treats performance specifications and rules for error budgeting
  - The main features of performance requirements specification are defined together with the fundamental rules for identification, characterisation, and combination of contributors of an error budget.
- Chapter 5 treats stability and robustness specification and verification
  - Stability and robustness concepts for linear systems are introduced and requirements for their specification and verification are defined
- Annex A provides guidelines on using performance error indices
  - Statistical elements are provided that are useful in formulating error requirements and using and building an error budget
- Annex B discusses common types of errors and rules to budget for them
  - Formulas (some exact, some approximate) are provided to show how typical errors are budgeted for depending on the index and statistical interpretation

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- Terminology (section 3)
  - Robustness: ability of a controlled system to maintain some performance or stability characteristics in the presence of plant, sensors, actuators and/or environmental uncertainties
  - Stability: ability of a system submitted to bounded external disturbances to remain indefinitely in a bounded domain around an equilibrium position or around an equilibrium trajectory
  - Stability margin: maximum excursion of some parameters describing a given control system for which the system remains stable
- The state-of-the-art for stability specification is not fully satisfactory.
  - A traditional rule exists, going back to the times of analogue controllers, asking for a gain margin > 6 dB, and a phase margin > 30°.
- A more consistent method is proposed for specifying stability and robustness (section 5.2)
  - For SISO loops **the gain margin, the phase margin and the modulus margin** shall be used as default indicators.
  - For MIMO loops the **sensitivity and complementary sensitivity functions** shall be used as default indicators.
  - If other indicators are selected by the supplier, this deviation shall be justified and the relationship with the default ones be established.

Stability and robustness verification

- In order to handle uncertainties (see the previous definition of robustness), **uncertainty domains** must be specified that consist of:
  - A list of uncertain parameters
  - For each of these parameters, an interval of uncertainty (or a dispersion) around the nominal value (in percentage or based on a statistical distribution)
  - When relevant, the root cause for the uncertainty (normally lack of characterisation, errors in parameters measurements, changes over life)
- A single uncertainty domain or reduced/extended domains may be defined
  - Nominal stability margins shall be demonstrated over the entire uncertainty domain (if a single domain is defined – section 5.2.6) or over the reduced domain (if reduced and extended domains are defined - section 5.2.7).
  - Degraded stability margins shall be demonstrated over the extended domain (section 5.2.7).
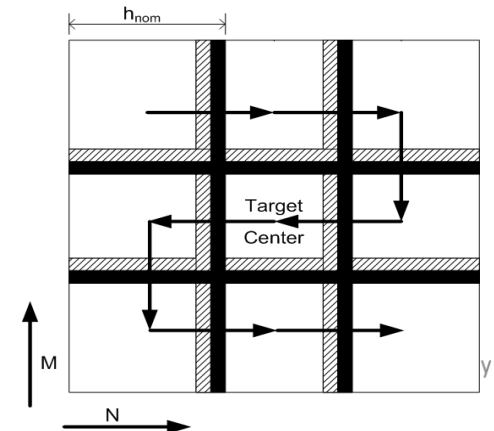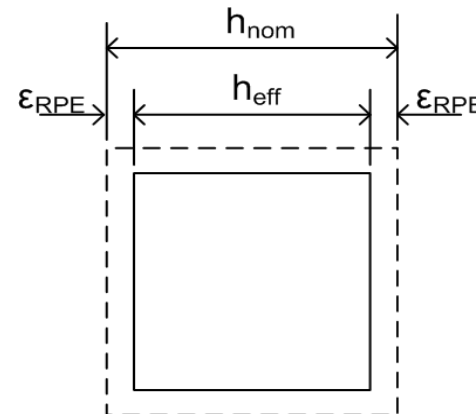
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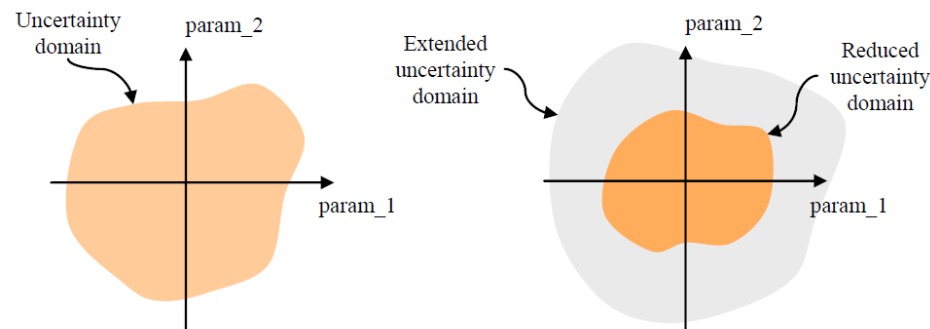
Terminology – Pointing Error Indices

- APE: instantaneous pointing at the right scene

- MPE: average pointing at the right scene

- RPE: stability during payload integration time

- PRE: overlapping of two observation series

- PDE: drift between repeated observations
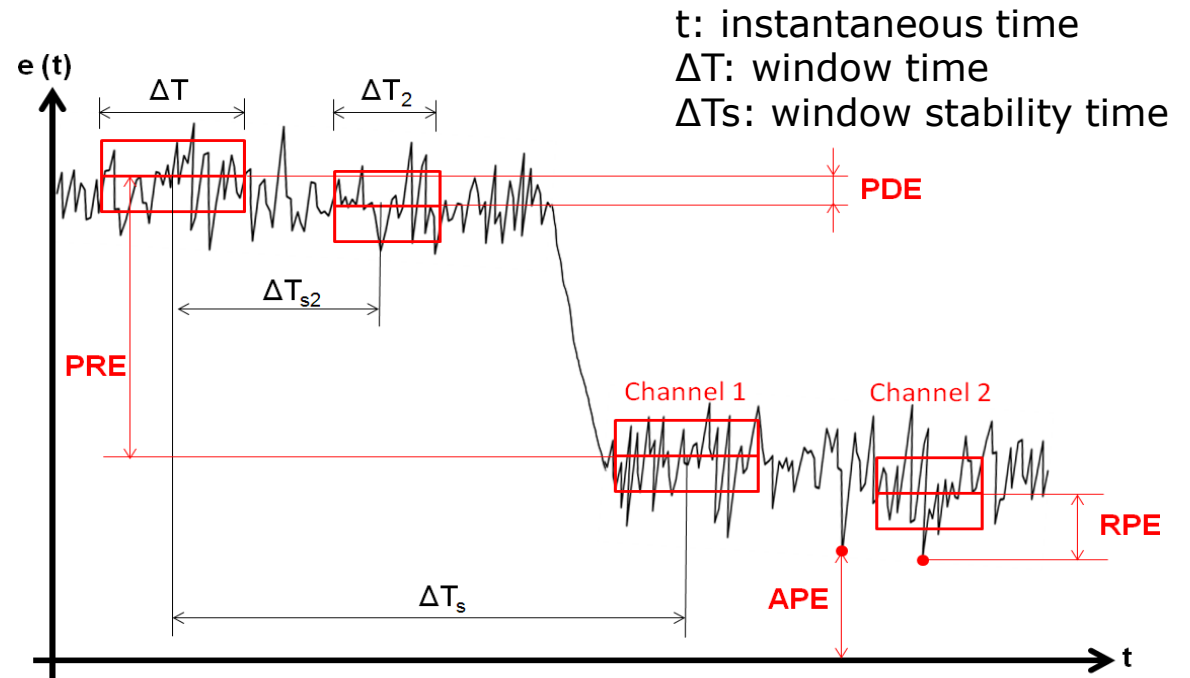
t: instantaneous time
ΔT: window time
ΔTs: window stability time

Specifying a performance requirement (section 4.1)

- Typical requirements:

  - **"The instantaneous half cone angle between the actual and desired payload boresight directions shall be less than 1,0 arcmin for 95 % of the time"**

  - **"Over a 10 second integration time, the Euler angles for the transformation between the target and actual payload frames shall have an RPE less than 20 arcsec at 99 % confidence, using the mixed statistical interpretation."**

- Although given in different ways, all have a common mathematical form:

$$prob\left(|X| < X_{\max}\right) \ge P_C$$

  - The physical quantity X is constrained in a precise way w.r.t. its time variation by means of **pointing error index** definition
    e.g. APE, MPE, RPE (absolute, mean, relative performance)

  - A maximum value X_{max} is specified, as well as the probability P_C that the magnitude of X is smaller than X_{max} : **confidence level**
    e.g. 95% (general case) or 2σ (Gaussian distribution)

  - Since there are various ways to interpret the probability, the applicable **statistical interpretation** is also given
    e.g. ensemble, or temporal, or mixed interpretation

  - The terms are defined in Chapter 3 and the concepts explained in Annex A

Using error budgeting to assess compliance (section 4.2)

- A common way to assess compliance is to compile an error budget
    - This involves **taking the known information** about the contributing sources, then **combining them** to estimate the behaviour of the overall performance error, which can then be compared to the original requirement.

    - It is important to emphasise that the common methods of budgeting are **approximate** only, and therefore **used with care**. They are based on the assumption from the central limit theorem that the distribution of the total error is Gaussian, and therefore completely specified by its mean and variance per axis.

    - It is not possible to give quantitative limits on its domain of validity: **a degree of engineering judgement is involved**.

Performance requirements
and budgeting

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Using error budgeting to assess compliance (section 4.2) (continued)

- Then contributing errors are classified into groups and characterised

  - A common classification is to distinguish between **biases, random errors, harmonic errors** with various periods, etc.

    – All errors which can potentially be correlated with each other shall be classified in the same group.

    – But a group shall not contain a mixture of **correlated** and **uncorrelated** errors

  - **The period of variation (short term, long term, systematic) is not a sufficient classification criterion**, as by itself it provides no insight into whether or not the errors can be correlated.

  - For each error source, a **mean** and **standard deviation** shall be allocated along each axis. Guidelines for obtaining these parameters are given in **Annex B** and are complemented by the methodology presented in the **Pointing Error Engineering Handbook**.

Conclusion

- The Control Performance Standard E-ST-60-10C provides a set of normative definitions, budget rules, and specification templates needed to manage performance aspects of control systems in the frame of space projects.

- The standard is split into two main clauses:
  - Performance error indices and analysis methods
  - Stability and robustness specification and verification for linear systems

- This normative standard is accompanied by the guidelines provided in ECSS-E-HB-60-10A - Control Performance Guidelines and especially in ESSB-E-HB-003 – Pointing Error Engineering Handbook

- This standard together with the Pointing Error Engineering Handbook provides all the mathematical elements to carry out pointing error budgeting activities

ESA Pointing Error Engineering Handbook
ESSB-HB-E-003 Issue 1

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Introduction
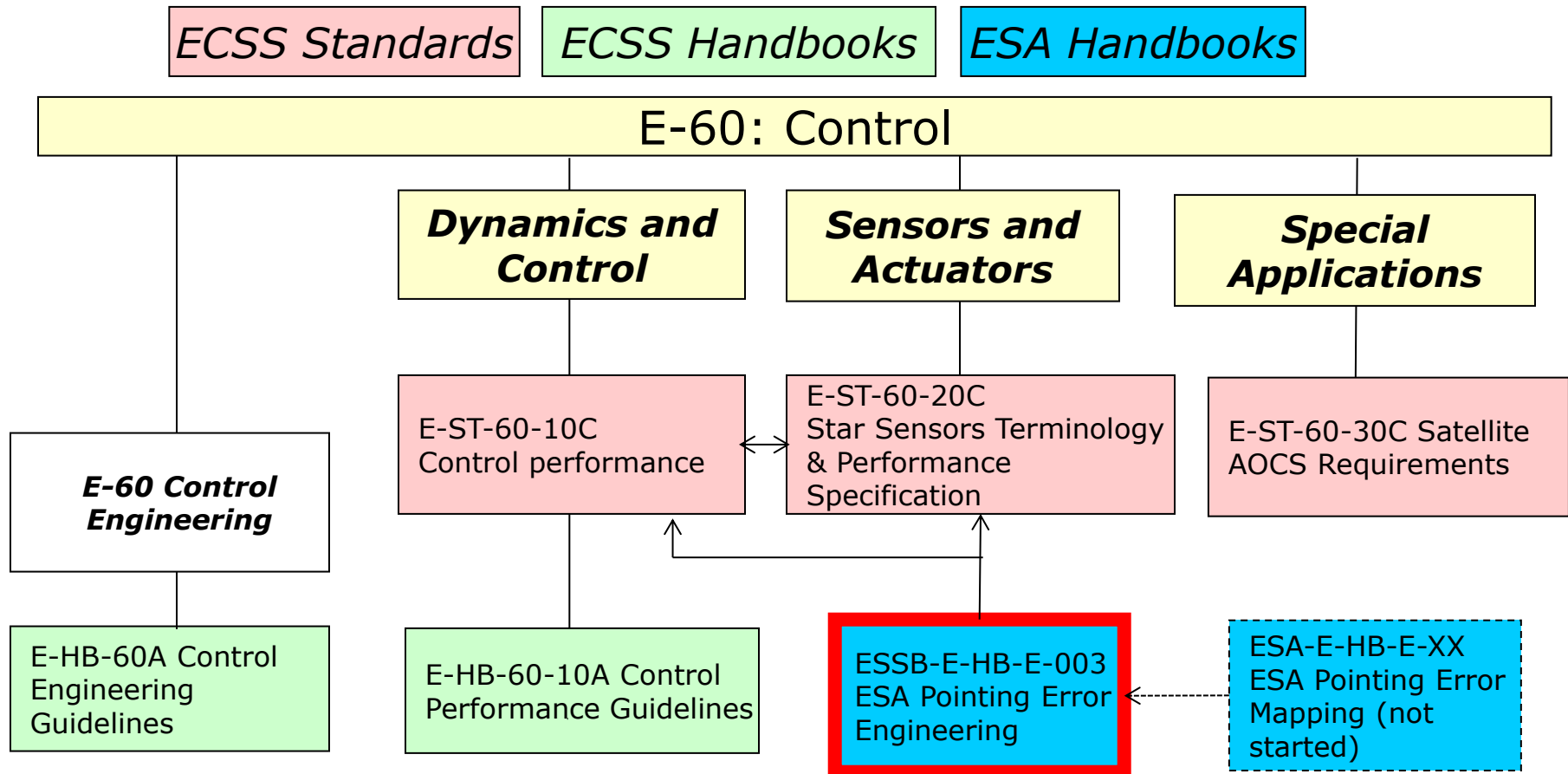
- This handbook provides a **consistent and mathematically justified set of guidelines and summation rules** to define an engineering process to build pointing error budgets.

- It embeds the elements of the E-ST-60-10C standard in a **step-by-step engineering process**, providing guidelines for:
  - Characterising pointing error sources
  - Analysing the pointing error source contribution to the ECSS pointing error indexes
  - Compiling system pointing error budgets

- It replaces the old ESA Pointing Error Handbook Ref. ESA-NCR-502 (19 Feb 1993)

- It was adopted in July 2011 in the **LEAS** (List of ESA Applicable Standards)

- A prototype of the accompanying tool PEET (Pointing Error Engineering Tool) has been developed in 2012

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Chapter 1,2
Scope & references

- **Scope**
- **ECSS standards**
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Chapter 3
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- **Analysis STep 1**
- **Analysis STep 2**
- **Analysis STep 3**
- **Analysis STep 4**

ESA Pointing Error Engineering Handbook

Chapter 7-11
Pointing error analysis methodology

Chapter 4
Pointing error: from sources to system performance

- **Pointing error sources and contributors**
- **Time-windowed pointing errors**

Chapter 6
Pointing error requirement formulation

- **Overview**
- **Specification parameters**
- **Notes**

Chapter 5
Pointing error engineering framework

- **Overview**
- **Methodology**
- **Framework elements**

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Quick insight

- **Chapter 4** introduces the fundamental definitions
  - Pointing error source (PES) and contributors (PEC), system transfers, time-windowed pointing errors, mathematical formulation of error indexes

- **Chapter 5** describes the pointing error engineering framework
  - The methodology of the engineering process for establishing pointing error requirements, their systematic analysis and eventually compliance verification and the related mathematical elements are described

- **Chapter 6** provides guidelines for pointing error requirements formulation
  - Includes notes on reference frames, statistical interpretation, evaluation period, level of confidence and requirement break-down and allocation

- **Chapters 7-11** define the step-by-step methodology for budget compilation
  - Pointing error source characterisation, pointing error source transfer analysis, error index contribution analysis, system pointing error evaluation

- **Annexes** support the main chapter and provide complementary information
  - Details on definition of pointing scene, examples on using statistical interpretations, notes on system norms, error metrics and summation rules

Background and Motivation

- The old ESA Pointing Error Handbook (ESA-NCR-502, 1993) introduced the basic concepts for pointing error budgeting and proposed:

  - an **exact method** for budget compilation (based on PDF characterisation via convolution of different errors, **hardly applicable in practice**)

  - **simplified summation rules** that (can lead to under- or over-estimates of the pointing performance and lack mathematical justification). Examples:

    - Herschel: $\sigma_{total} = \sigma_{Bias} + \sigma_{LongTerm} + \sigma_{ShortTerm}$ (RSS in each class)

    - Sentinel 2: $\sigma_{total} = \sigma_{ST} + \sigma_B + \sqrt{(\sigma_H^2 + \sigma_N^2)}$

    - MTG: $\sigma_{total} = \sigma_{ST} + \sqrt{(\sigma_B^2 + \sigma_H^2 + \sigma_N^2)}$

- **Simplified summation rules are not endorsed by E-ST-60-10C**, which foresaw the necessity of a complementary document:

  - "For their own specific purpose, each entity (ESA, national agencies, primes) can further elaborate internal documents, deriving appropriate guidelines and summation rules based on the top level clauses gathered in this E-ST-60-10C standard."

- Action from ESA Engineering Standardisation Board meeting ESB#40: «To draft and finalize a normative text to replace the ESA Pointing Error HB»

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Purpose and approach

- Purpose of ESA PEEH
  - Pointing Error Budgeting
  - Consistent with and elaborating the E-ST-60-10C ECSS (no additional clause, **no " shall"**)
  - To be used by ESA projects as an **applicable document complementing E-ST-60-10C**
- Approach and added value
  - **Generic process for any mission type and any design phase** through 4 Analysis STeps: AST-1 to -4
  - Added value of frequency domain analysis via PSD on stationary random processes: **windowing in time domain is equivalent to filtering in frequency domain**

AST-1: Pointing Error Sources Characterization
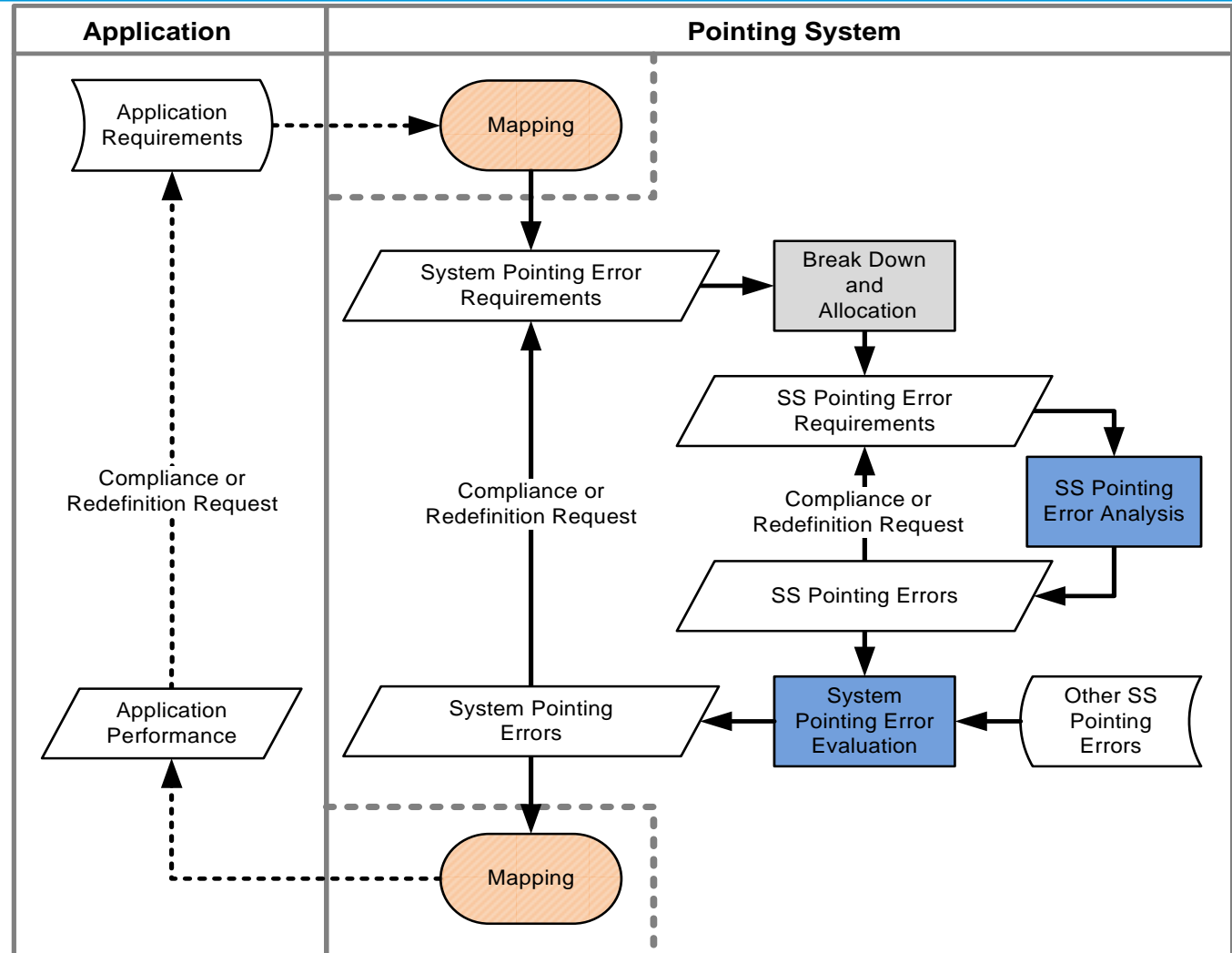
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AST-2: Pointing Error Sources Transfer Analysis

⬇

AST-3: Error Index Contribution Analysis

⬇

AST-4: System Pointing Error Evaluation
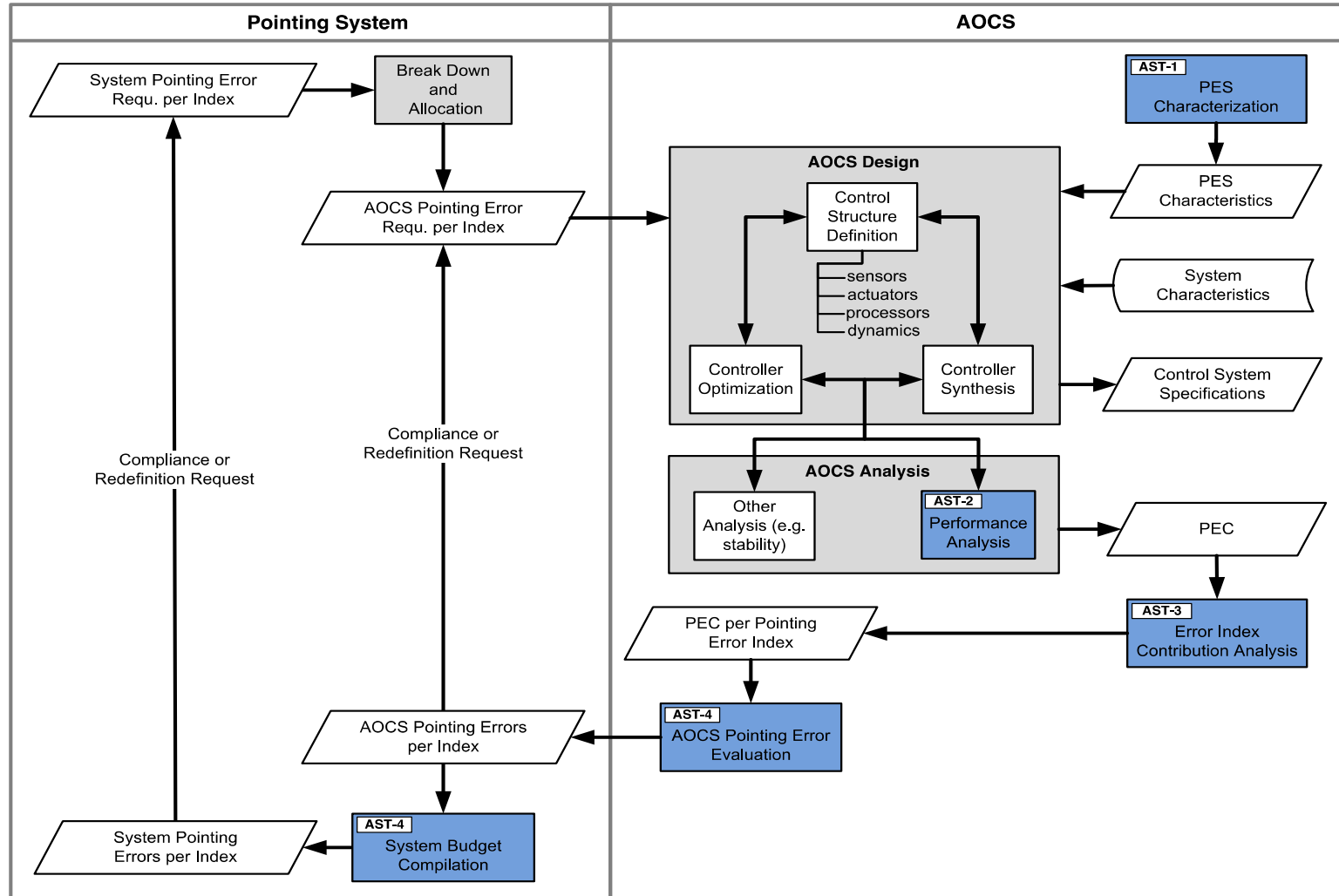
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Pointing Error Engineering Cycle

- Mapping from science requirements to spacecraft pointing requirements and identification of pointing error sources (PES) are strongly application specific steps and, as such, are currently excluded from PEEH


| Application	Pointing System
Application Requirements	Mapping
	System Pointing Error Requirements → Break Down and Allocation
	SS Pointing Error Requirements → SS Pointing Error Analysis
Compliance or Redefinition Request	Compliance or Redefinition Request — Compliance or Redefinition Request
	SS Pointing Errors
Application Performance	System Pointing Errors ← System Pointing Error Evaluation ← Other SS Pointing Errors
	Mapping

Pointing Error Analysis and Evaluation Methodology (1/2)

- **Simplified statistical method**: analysis via variance (σ) and mean (μ) and their summation per ECSS error index under the assumption of the central limit theorem, solid lines in figure

- **Advanced statistical method**: analysis by joint PDF characterisation via convolution of different error PDF p…(e), dashed lines in figure
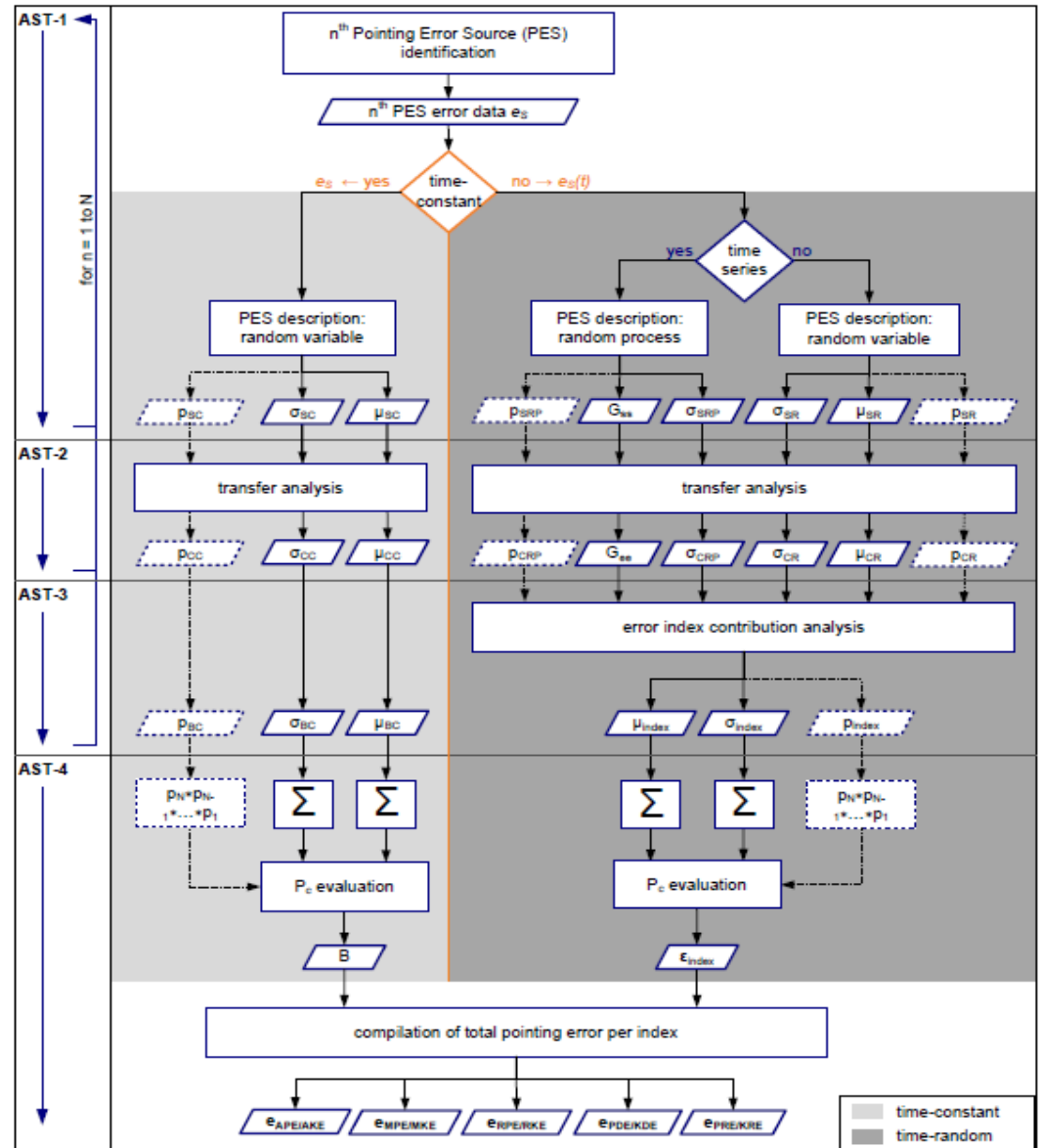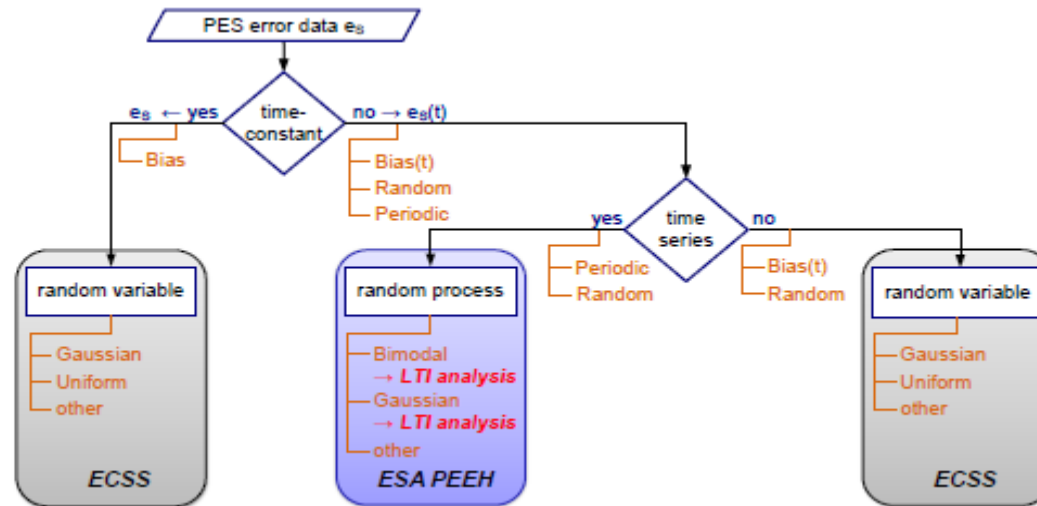
AST-1: PES Characterisation (1/3)

- First step for pointing error sources characterisation is their **categorisation into signal classes** (bias, periodic, random, etc.) that are analogous to those defined and considered in the ECSS standard
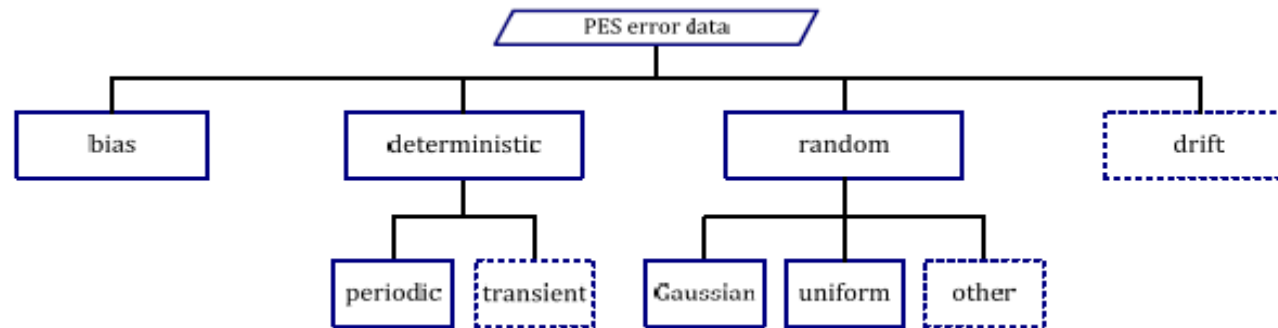
- PES data categorisation into signal classes allows simplifying the pointing error analysis **without loss of generality**

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- A decision tree is defined, which provides guidelines for selecting eligible mathematical elements to describe the signal-classified PES data

- Differently from the current approach in E-ST-60-10C, description of PES as stationary random process (together with characterising its PSD) allows **exact capture** of window and stability time properties.

- Example: 2 PES with temporal interpretation specified

| characterization steps	STR-Payload misalignment error	Gyro-Stellar Estimator (GSE) noise
temporal behavior	time-constant	time-random
signal class	bias	random
description	random variable	random process
reference document	*ECSS*	*ESA PEE Handbook*
characteristic data	$U(0, e_{max})$	$G(0, \sigma_G)$, G_{ee}
temporal interpretation	$p(e) = \delta(e_{max})$	$G(0, \sigma_G)$
AST-1 output data	$\boldsymbol{\mu(e) = e_{max}, \sigma(e) = 0}$	$\boldsymbol{\mu(e) = 0, \sigma(e) = \sigma_G, G_{ee}}$

AST-1: PES vs Statistical Interpretation

- ESA requirement must define the considered statistical population by specifying one of the three statistical interpretations introduced in ECSS-E-ST-60-10C:

  - **Ensemble** $\mathrm{Prob}\left[\,|e_{\max}(k)| < e_r\,\right] \geq P_c$ with $e_{\max}(k) = \max_t[\{e_k(t)\}]$
    i.e. WC time but error statistically averaged over a population of S/C

  - **Temporal** $\mathrm{Prob}\left[\,|e_{\max}(t)| < e_r\,\right] \geq P_c$ with $e_{\max}(t) = \max_k[\{e_k(t)\}]$
    i.e. WC S/C but error statistically averaged over time

  - **Mixed** $\mathrm{Prob}\left[\,|e(k,t)| < e_r\,\right] \geq P_c$
    i.e. time and ensemble considered concurrently (conditional probability)

- The PEEH highlights this **important feature**: the mixed interpretation automatically yields to the ensemble one if a PES does not randomly vary in time (time-constant , e.g. alignment bias) and to the temporal interpretation if it does not vary over the population (ensemble-constant, e.g. sensor typical noise).

PES (Pointing Error Source) → *transfer* → **PEC** (Pointing Error Contributor)

Transfer from a PES point of origin to the point of interest for error calculation:

- Coordinate frame transformation
- Closed-loop control system
- Thermo-structural transformation
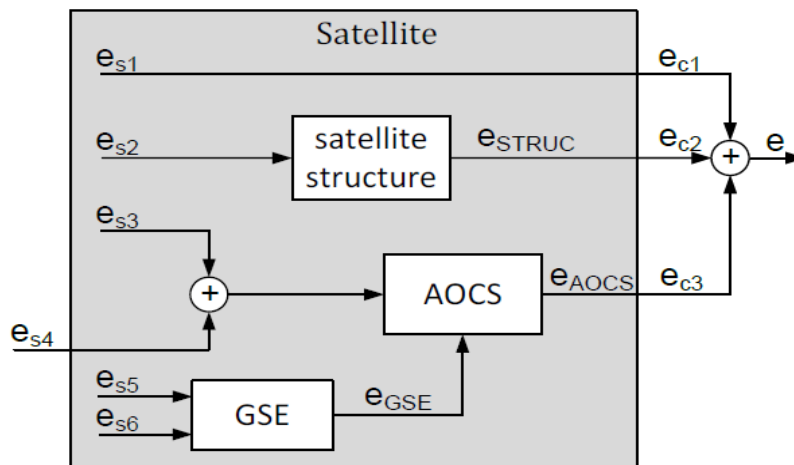
	PES
e_{s1}	STR-Pay. misalignment
e_{s2}	µVibrations
e_{s3}	thruster noise
e_{s4}	solar pressure noise
e_{s5}	*STR noise*
e_{s6}	*gyro noise*

- Transfer analysis of time-random PES described as random process can be performed in either time- or frequency-domain:
  - The time-domain approach relies on simulations that, based on the PES PDF or PSD, provide a statistical sample that can be used to characterise the PEC at the point of interest
  - The frequency-domain approach relies on linear transformation of statistical properties

- For LTI systems, the PSD transfer relation can be used:

$$G_{ee}(\omega) = \left| H(j\omega) \right|^2 G_{ss}(\omega)$$

- The **advantage of the frequency-domain approach** is that it can be **used to tune the system transfer function** *H* based on signal and system norms

- Time-domain approach is based on simulations and described in the ECSS standard
- Frequency-domain approach provides exact contribution analysis via PSD weighting functions

$$\sigma_e^2 = \frac{1}{2\pi} \int_0^\infty G_{ee}(\omega)d\omega$$

$$\sigma_{index}^2 = \frac{1}{2\pi} \int_0^\infty G_{ee}(\omega)F_{metric}(\omega)d\omega$$

Time-Windowed Error Metrics (Lucke et al. & Pittelkau)			
index:= metric		time domain	frequency domain
APE, AKE:= Absolute (ABS) Metric	$\sigma_{index}^2 :=$	$\sigma_{ABS}^2 = E\left[(e(t) - \mu_{ABS})^2\right]$	$= \frac{1}{2\pi} \int_0^\infty G_{ee}(\omega)d\omega$
MPE, MKE:= Windowed Mean (WM) Metric	$\sigma_{index}^2 :=$	$\sigma_{WM}^2(\Delta t) = E\left[\left(\langle e(t)\rangle_{\Delta t} - \mu_{ABS}\right)^2\right]$	$= \frac{1}{2\pi} \int_0^\infty G_{ee}(\omega)\ F_{WM}(\omega, \Delta t)d\omega$
RPE, RKE:= Windowed Variance (WV) Metric	$\sigma_{index}^2 :=$	$\sigma_{WV}^2(\Delta t) = E\left[\left\langle \left(e(t) - \langle e(t)\rangle_{\Delta t}\right)^2\right\rangle_{\Delta t}\right]$	$= \frac{1}{2\pi} \int_0^\infty G_{ee}(\omega)\ F_{WV}(\omega, \Delta t)d\omega$
PDE, PRD, KDE, KRE:= Windowed Mean Stability (WMS) Metric	$\sigma_{index}^2 :=$	$\sigma_{WMS}^2(\Delta t, \Delta t_s) = E\left[\left(\langle e(t)\rangle_{\Delta t} - \langle e(t - \Delta t_s)\rangle_{\Delta t}\right)^2\right]$ $\Delta t = \Delta t_1 = \Delta t_2$	$= \frac{1}{2\pi} \int_0^\infty G_{ee}(\omega)\ F_{WMS}(\omega, \Delta t, \Delta t_s)d\omega$
PDE, PRD, KDE, KRE:= Stability (STA) Metric	$\sigma_{index}^2 :=$	$\sigma_{STA}^2(\Delta t_s) = E\left[(e(t) - e(t - \Delta t_s))^2\right]$	$= \frac{1}{2\pi} \int_0^\infty G_{ee}(\omega)\ F_{STA}(\omega, \Delta t_s)d\omega$

Pointing Error Metric Weighting Functions F_{metric}

Windowed Mean (WM)

$$F_{WM}(\omega, \Delta t) = \frac{2(1 - \cos(\omega \Delta t))}{(\omega \Delta t)^2}$$

rational approximation:

$$\tilde{F}_{WM}(s, \Delta t) = \frac{2(s\Delta t + 6)}{(s\Delta t)^2 + 6(s\Delta t) + 12}$$

F_{WM} with $\Delta t = 0.18s$

Mean error: MPE, MKE

Windowed Variance (WV)

$$F_{WV}(\omega, \Delta t) = 1 - \frac{2(1 - \cos(\omega \Delta t))}{(\omega \Delta t)^2}$$

rational approximation:

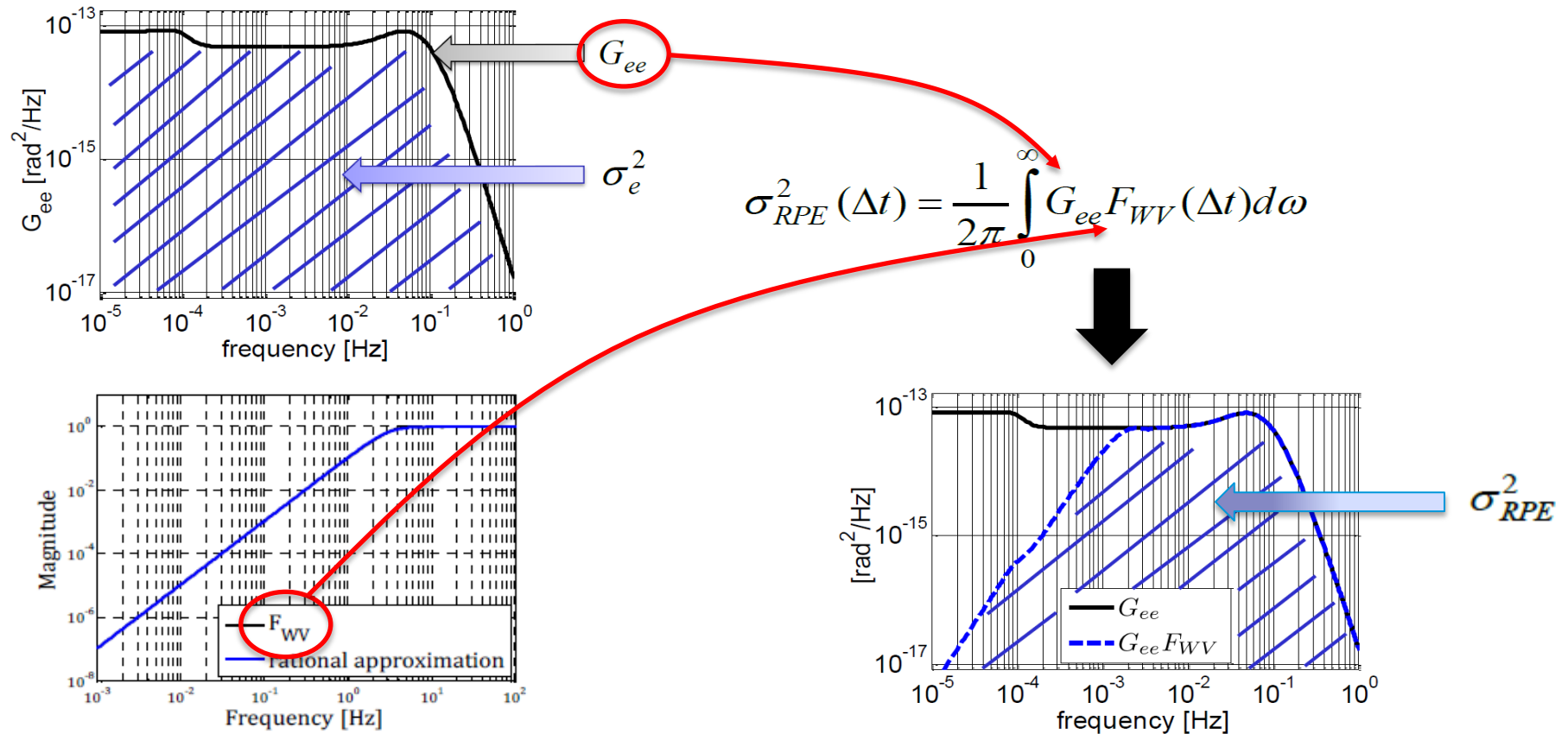$$\tilde{F}_{WV}(s, \Delta t) = \frac{s\Delta t(s\Delta t + \sqrt{12})}{(s\Delta t)^2 + 6(s\Delta t) + 12}$$

F_{WV} with $\Delta t = 0.18s$

Relative error: RPE, RKE

- Example: GSE noise contribution to RKE

$$\sigma_{RPE}^2(\Delta t) = \frac{1}{2\pi} \int_0^\infty G_{ee} F_{WV}(\Delta t) d\omega$$

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- The simplified statistical method is treated in detail in the PEEH

- In the simplified statistical method, time-constant and time-random error contributors (per index) are first summed separately

Time-Constant PEC: Summation and Level of Confidence Evaluation			
P_c evaluation	**summation**		
	$\mu_B = \sum_{i=1}^{N} \mu_i$		
$B \leq n_p \times \sigma_B + |\mu_B|$	$\sigma_B^2 \leq \sigma_c^2 + \sigma_{uc}^2$	correlated	$\sigma_c^2 \leq N \sum_{i=1}^{N} \sigma_i^2$ (*1) or $\sigma_c^2 \leq \left[\sum_{i=1}^{N} \sigma_i \right]^2$ (*2)
		uncorrelated	$\sigma_{uc}^2 = \sum_{i=1}^{N} \sigma_i^2$

B	bias	P_c	level of confidence:
σ^2	variance		
μ	mean	n_p	defines max. error complying with P_c requirement of a Gaussian distribution by $n_p \times \sigma$
N	number of summands		

*1: general worst case upper bound summation (see Annex for derivation).
*2: upper bound summation as in ECSS standard.

- Means are summed linearly
- Uncorrelated variances are RSSed
- Correlated variances summation is estimated by upper bound
- Formulas are valid under the assumption that the central limit theorem applies

TIME-RANDOM PEC: SUMMATION

statistics	summation		
μ_{index_sum}	$= \sum_{i=1}^{N} \mu_i$		
	group summation	*signal class groups*	
$\sigma^2_{index\_sum}$	$\leq \sum_{i=1}^{N} (\sigma^2_{uc})_i + \sum_{i=1}^{N} (\sigma^2_c)_i$	correlated	$\sigma^2_c \leq N \sum_{i=1}^{N} \sigma^2_i$ (*1) or $\sigma^2_c \leq \left[\sum_{i=1}^{N} \sigma_i \right]^2$ (*2)
		uncorrelated	$\sigma^2_{uc} = \sum_{i=1}^{N} \sigma^2_i$

σ^2	variance	N	number of summands
μ	mean		

*1: general worst case upper bound summation (see Annex for derivation).

*2: upper bound summation as in ECSS standard ⬜ suggested for periodic error summation.

- The applicable confidence level specified in the requirements is then incorporated in the error index evaluation

- Total pointing error per index is finally obtained as sum of time-constant (only for APE, AKE, MPE, MKE) and time-random partial sums

Time-Random PEC: Level of Confidence Evaluation		
index	P_c evaluation assuming applicability of central limit theorem	P_c requirement
$APE(\Delta t_D,)/$ $AKE(\Delta t_D)$	$\varepsilon_{index} = n_p \cdot \sigma_{index,sum}(\Delta t_D) + \left\| \mu_{index} \right\|$	
$MPE(\Delta t, \Delta t_D)/$ $MKE(\Delta t, \Delta t_D)$	$\varepsilon_{index} = n_p \cdot \sigma_{index,sum}(\Delta t, \Delta t_D) + \left\| \mu_{index} \right\|$	
$RPE(\Delta t, \Delta t_D)/$ $RKE(\Delta t, \Delta t_D)$	$\varepsilon_{index} = n_p \cdot \sigma_{index,sum}(\Delta t, \Delta t_D)$	$\text{Prob}\left(\left\| e \right\| < \varepsilon_{index} \right) \geq P_c$
$PDE(\Delta t, \Delta t_s, \Delta t_D)/$ $KDE(\Delta t, \Delta t_s, \Delta t_D)$	$\varepsilon_{index} = n_p \cdot \sigma_{index,sum}(\Delta t, \Delta t_s, \Delta t_D)$	
$PRE(\Delta t, \Delta t_s)/$ $KRE(\Delta t, \Delta t_s)$	$\varepsilon_{index} = n_p \cdot \sigma_{index,sum}(\Delta t, \Delta t_s)$	

e	pointing error	P_c	level of confidence
ε_{index}	max. time-random error compliant with P_c	n_p	defines error that complies with P_c requirement of a Gaussian distribution by $n_p \times \sigma_{index}$
μ_{index}	mean of time-random error		
Δt_D	drift re-set time		

Conclusions

- The ESA PEEH together with the ECSS standard E-ST-60-10C provides all the mathematical elements to carry out pointing error budgeting activities

- The exact capture of window time and stability properties that is allowed by the frequency domain methodology described by PEEH limits the risk of over- or under-estimates that is inherent in the simplified summation rules

- The frequency domain approach also makes the PEEH methodology a useful tool to complement the tuning activities on system transfer functions (typically attitude estimator, attitude controller, etc.)

- The PEEH methodology can be used to assist requirement breakdown and allocation activities by providing sensitivity evaluation of the pointing performance with respect to the PES

- PEEH has become an [AD] in ESA ITT's in association with the ECSS Control Performance Standard E-ST-60-10C

Way-forward

- Dissemination approach:
  - 2012/13 - Prototype of the accompanying SW tool PEET completed (see peet.estec.esa.int)
  - ESA PEEH is not on ECSS website, but can be found on peet.estec.esa.int
  - 2015 - ESA internal working group is finalising pointing budgets for application examples representative of Earth Observation, Science, and Telecommunications missions.
    They will be appended to a revised version of the Handbook.
  - 2016 – Fully functional operational version of the accompanying SW tool PEET will be completed
- As a result of the above and of PEEH use within ESA projects, further revisions of the PEEH and possibly of the ECSS Standard are possible.
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