reliability.space – A New Reliability Prediction Methodology for Space Applications

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Reliability prediction of electronic components, new advances – June 15th 2021

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reliability .SPACE

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Introduction

– study objectives –

Study objectives

Two main objectives of the study

1) Develop a New Reliability Prediction Methodology
   - For space applications: reliability.space
   - To overcome the limitations of current RP practices
2) Prepare a Reliability Prediction Handbook
   - Describing the new methodology
   - As an input to ECSS handbook development

Project and Handbook scope

- Reliability Prediction
  - Availability, Maintainability and Safety out of scope
- Space applications
  - Reliability prediction for systems that operate in space – e.g. spacecraft
  - Focus on unmanned spacecrafts (technology coverage)

Handbook overview

– Methodology, Methods and Models –

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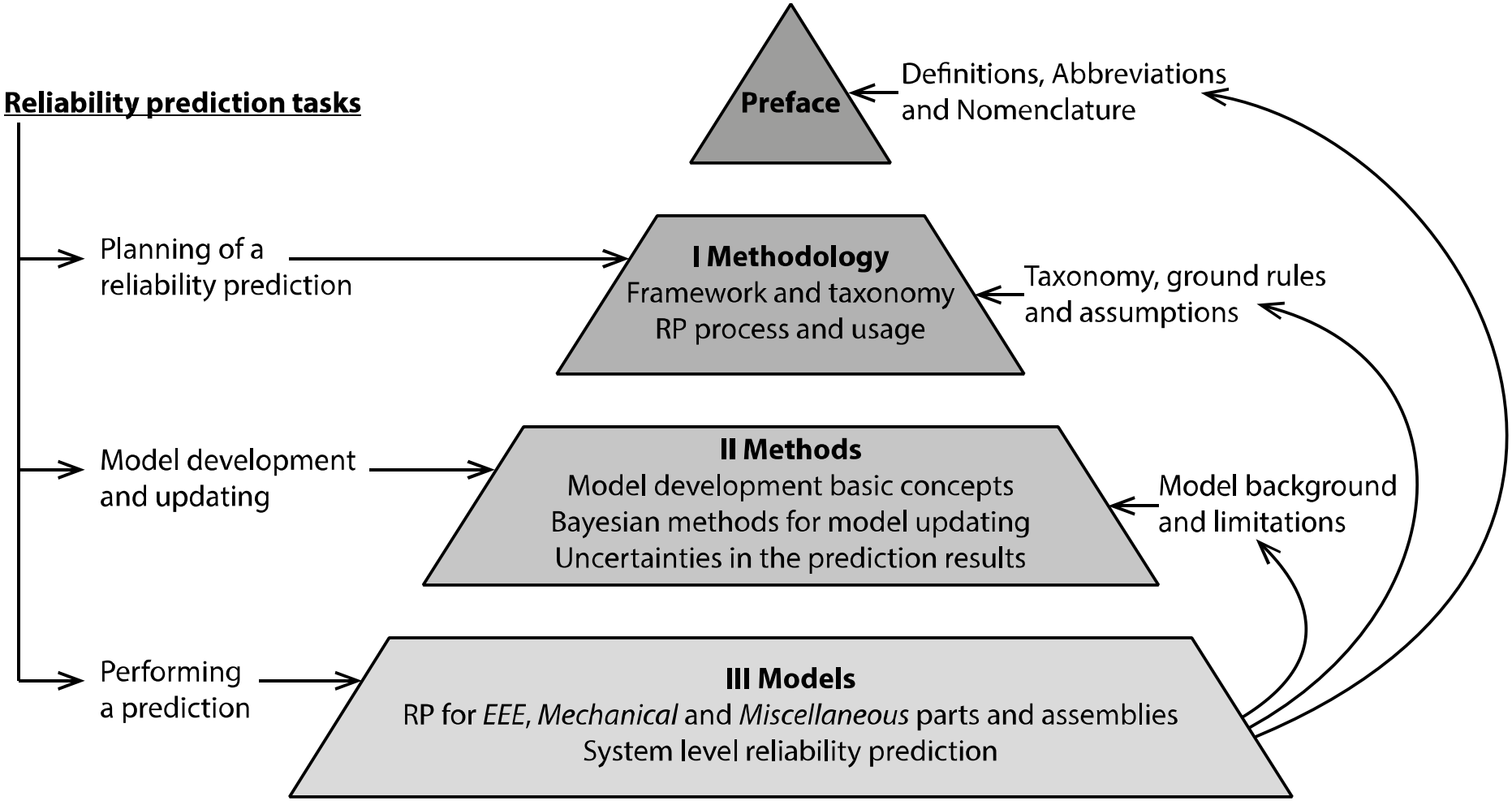
reliability.space handbook overview



+ Handbook Annex

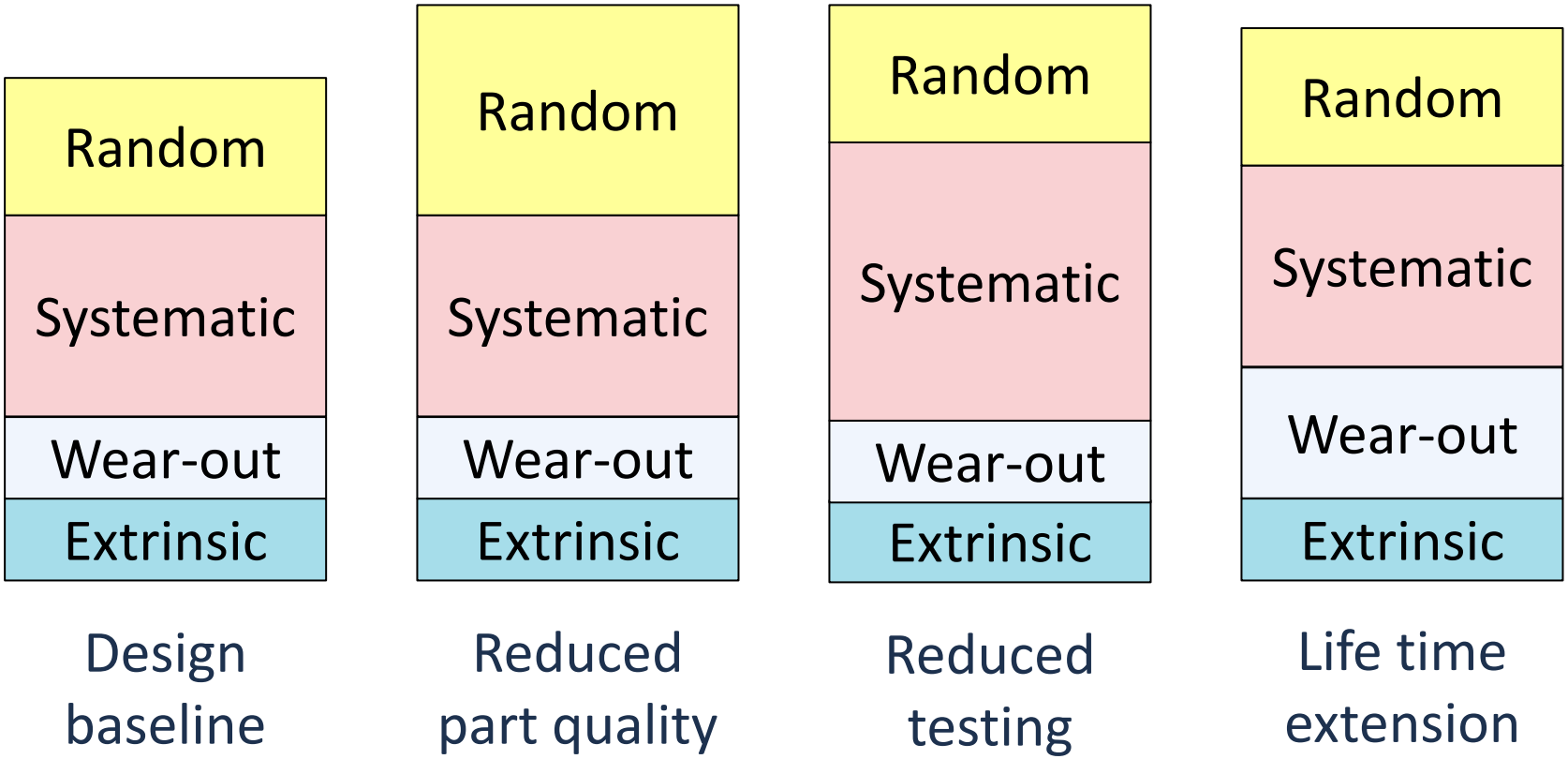
development and verification of the reliability.space methodology

Methodology: Root causes coverage

FAILURE CATEGORY	ROOT CAUSE	MITIGATION
RANDOM FAILURE (RF)	Root causes coverage is needed to design a reliable space system. But is it also necessary to make quantitative predictions for each category of failures? …it depends. **reliability.space approach:** • Required to be explicit on the root causes covered by the prediction • Guidance provided for different reliability prediction uses	Space qualification Part quality selection Derating Redundancy / Fault tolerance
SYSTEMATIC FAILURE (SF)		Robust design Quality assurance (during design, manufacturing and operations) Qualification & verification processes
WEAR-OUT FAILURE (WO)		Components and materials selection Design calculations and margins Lifetime qualification with margins
EXTRINSIC FAILURE (EX)		Components and materials selection Design calculations and margins Qualification and verification testing Thermal control Shielding (thermal, radiation, debris) Radiation engineering Debris impact predictions Avoidance manoeuvres …

Methodology: Root causes coverage

Relevance of different failure root causes by intended use of the RP

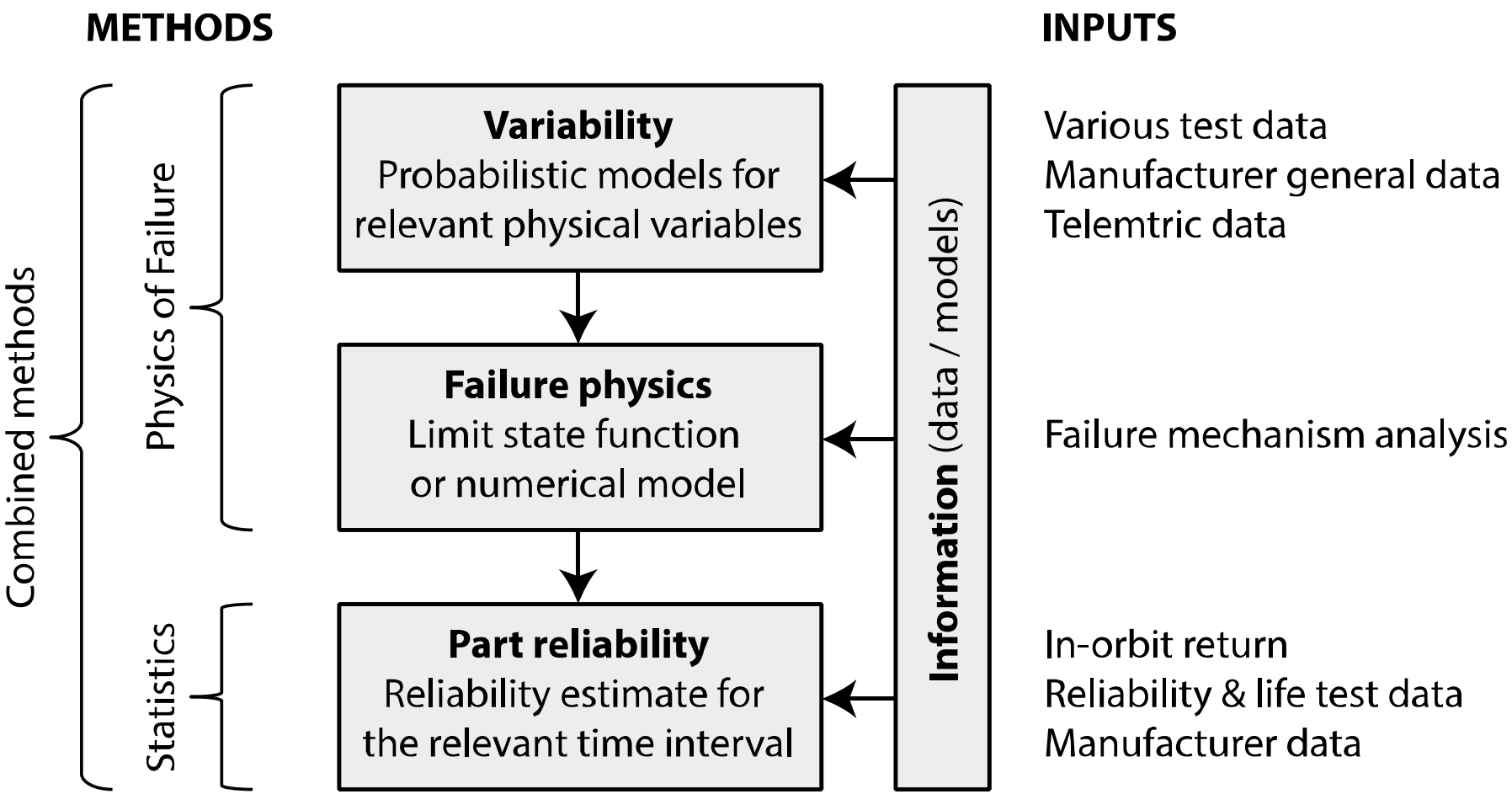


⇨ *Only the difference needs to be understood for trade-off decisions!*

⇨ *Focus on random failures as baseline, extensions depending on RP use*

Methods: RP methods and inputs

Making best use of the available methods and inputs



Models: EEE items

reliability.space approach for EEE components and assemblies

- Space customization of FIDES
  - RP methodology addressing Technology, Process and Use
  - Customization to improve applicability and practicality for Space

Intrinsic failure rate
Stresses & Technology
- Space mission profile definition
- Recommended models for EEE components
- Customization of factors for use conditions and over-stresses policy

Component quality
Component quality
- Space specific certification levels
- Component level tests for active components
- Manufacturer experience in space

Quality and control
Project life cycle QA
- Space customized process audit for supplier assessment
- Suggested default answers for space applications

- Consideration of additional failure root causes (wear-out, extrinsic)
  - Required only for certain technologies and trade-off decisions

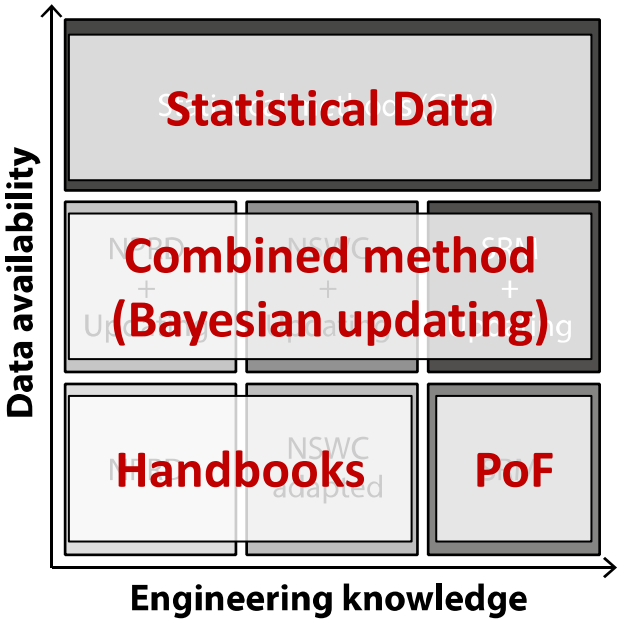
Models: Mechanical & Miscellaneous

Approach for Mechanical reliability prediction

Some specific challenges for Mechanical RP:

- Strong effect of design details and use conditions
- (Moderate) wear-out already during design life
- Parts and failure mechanisms specific to space

⇨ Approach making best use of all available information to improve coverage



Definition of a third category of items

<u>Miscellaneous items</u> are either parts or assemblies that can neither be classified as EEE or mechanical parts/units

- Wide range of technologies with specific failure mechanisms
- Often poorly considered in current reliability predictions

⇨ Standard model based on IOR for generic items: e.g. TWTA, SA cells, Thrusters, RW

⇨ Non-Standard model for specific items: e.g. Valves, Pyros, Non Explosive Actuators

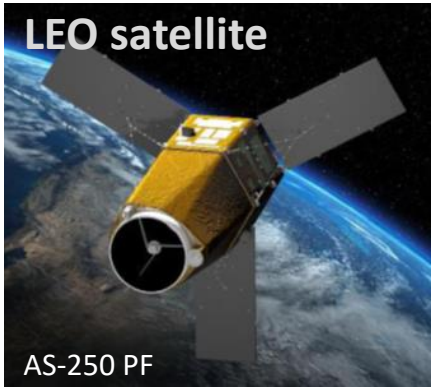
Proof of concept

– Conclusions from the Case Study –

Proof of concept results

Quantitative benchmarking

- Comparison of reliability predictions with IOR achieved reliability



⇨ Case studies selected to maximize IOR availability

⇨ Benchmarking with IOR and alternative methodologies (MIL-HDBK-217, FIDES, 217Plus)

Qualitative evaluation

- Qualitative assessment of the different methodologies based on a set of predefined criteria, along three axes:
  - Practicality: good (but MIL-HDBK-217 is easier to apply)
  - Applicability: very good (first methodology dedicated to space)
  - Pertinence: good (better than alternative methodologies)

Summary and conclusions

– reliability.space achievements –

Summary of achievements

Added values of the reliability.space methodology

- Framework and methodology entirely dedicated to space
- Models developed and consolidated with In Orbit Return
- Single methodology addressing all technical domains
- Closing gaps in elements coverage
  - Improved technology coverage for EEE components
  - New PoF based approach for Mechanical items
  - Dedicated modelling of Miscellaneous items
- Taking benefit from the Physics of Failure
  - Considering relevant environmental stressors in space
  - Capability to combine PoF with observations in a Bayesian approach
- Improving root causes coverage, with a clear framework to decide and communicate on the scope of the prediction
- Transparency of foundations, limitations and uncertainties

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