# New Reliability Prediction Methodology Aimed at Space Applications

## TN-02 Fact Sheet on the

## Approach for the development of the New Reliability Prediction Methodology

Under a programme of and funded by the European Space Agency

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| | | Pages: | 6 |
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| | **ESA Contract:**<br>4000121065/17/NL/PS<br>The view expressed herein can in no way be taken to reflect the official opinion of the European Space Agency. | Task contributors: | Airbus DS<br>Sarel Consult<br>Serma Technologies<br>Thales Alenia Space |
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## TN-2 Executive summary

The Technical Note TN-2 provides the findings and major results of the Task 2 prepared in the frame of the study "New Reliability Prediction Methodology Aimed at Space Applications", under a programme of and funded by the European Space Agency.

The objective of the study is the development of a new methodology for reliability prediction (RP) for space applications, aiming to overcome the limitations and shortcomings of the methods and approaches currently used in practice. The final outcome of the study will be a handbook for reliability prediction in space applications, which will serve as an input for the development of a new ECSS handbook. The role of the Technical Note TN-2 for the overall study is shown in Figure 1 below.

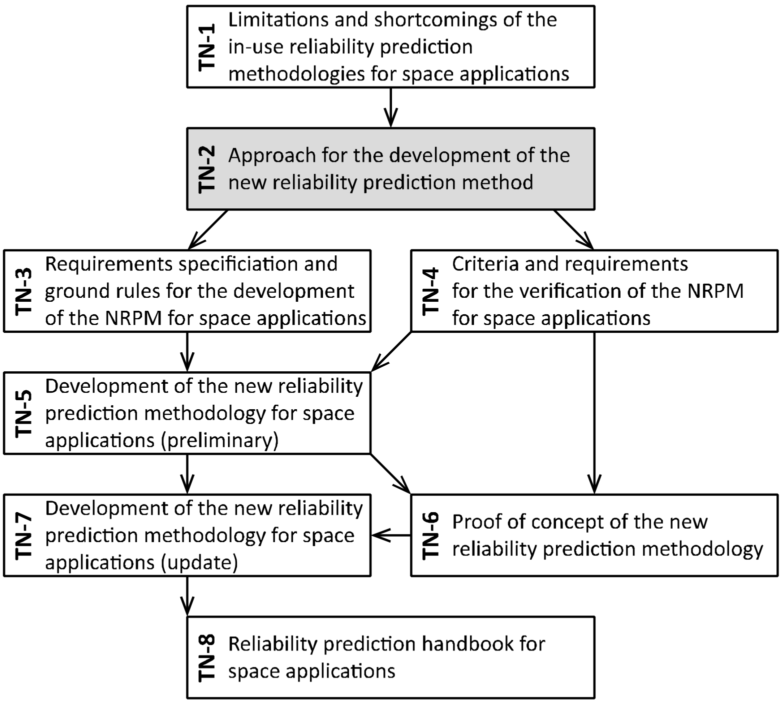


*Figure 1: Overview on the content and interrelation of the Technical Notes.*

The objective of TN-2 is to develop an approach for the improvement of the in-use methodologies. It is based on the assessment of limitations and shortcomings of the current reliability prediction approaches presented in TN-1.

TN-2 starts by formulating a vision for future reliability predictions in space applications, which is outlined below. Comparing Figure 2 with the status quo assessment in TN-1 (see TN-1 Fact Sheet for a short summary) clearly shows that the in-use reliability prediction methodologies are not fully in line with this vision. Considering the large number of limitations and gaps in the existing methodologies, it is clear that priorities need to be defined for the planning of the study, to get as close as possible to the vision. The focus should be driven by the needs and priorities of practical applications.

A sound reliability prediction methodology for space applications should:

- Support decision-making in all mission phases, from early development to safe disposal,
- Cover all spacecraft elements and technical domains,
- Account for improved performances and technical development,
- Provide approaches to consider also new – and future – technologies,
- Consider all relevant aspects of reliability and categories of failure,
- Account for different failure root causes and contributors,
- Consider different levels, from part to system,
- Generate credible results when compared to in-orbit feedback,
- Ensure consistency and reduce uncertainty in predictions by different manufacturers,
- Be transparent in terms of its foundations and underlying assumptions,
- Meet the needs of the space community and its different stakeholders,
- Be theoretically sound, but also pragmatic and practical to use,
- Be sustainable, providing efficient maintenance and update capabilities.

*Figure 2: A vision for the new reliability prediction methodology.*

The intended coverage of the new reliability prediction methodology is defined in terms of:

- *Failure root causes:* All potential failure root causes must be addressed in spacecraft design, and are considered by various design and quality assurance processes, but not necessarily in the frame of quantitative reliability prediction. Which root causes need to be modelled in a reliability context depends on the intended use of the prediction.
- *Spacecraft elements:* As a general rule, all spacecraft elements having a relevant contribution to the prediction or supported trade-off need to be considered. The focus of the new methodology will be on systems that operate in space (e.g. a spacecraft), it does not intend to treat aspects specific to the ground segment. In terms of coverage, it will be limited to unmanned spacecraft technology.
- *Methodology, methods and models:* The development of the new methodology will consider aspects of methodology, methods and models, as defined in Figure 3. In terms of overall coverage (spacecraft elements and failure root causes), some prioritization is needed at the level of models and data, but not at the level of methodology and methods.

Knowing what a prediction will be used for is important to develop and select suitable methods and models. The use of reliability predictions for decision support is therefore a central notion for the discussion of priorities in TN-2. In this context, a "decision" is understood as any kind of engineering, project management or business choice or trade-off for which reliability predictions can form a useful input.

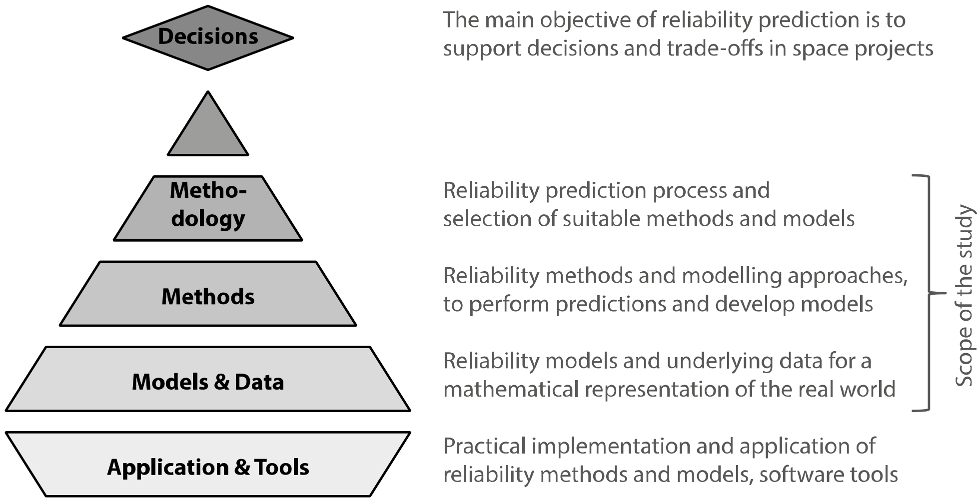


*Figure 3: Hierarchy of Methodology, Methods, Models and Data for reliability prediction to support decision-making and trade-offs in space projects.*

The following reliability prediction use cases have been identified, including both traditional ones as well as some "new stakes" becoming more relevant in current and future space applications:

- Establishment, management and verification of quantitative reliability requirements
- Input to the design, support trade-offs and comparisons
- Support decisions on the choice of engineering design margins
- Choosing a test strategy at part, equipment or higher levels
- Support business planning for single spacecrafts and constellations
- Health monitoring and decision-making on life time extensions versus safe disposal

Based on a consideration of these reliability prediction use cases, and making use of the classification of failures by failure root cause presented in TN-1 (summarized also in the TN-1 Factsheet), the following priorities can be derived for the development of the new reliability prediction methodology:

- **RANDOM** failure modelling is assigned highest priority among the failure categories, considering its relevance for all reliability prediction use cases.
- **SYSTEMATIC** failure modelling is assigned medium priority. Making use of qualitative methods to avoid design, manufacturing and operations errors is suitable for many applications, but there are also use cases (e.g. business planning at customer level, design of constellations) for which quantitative predictions could be helpful.
- **WEAR-OUT** failure modelling is assigned medium priority. Quantitative predictions are not needed when designing for a fixed specified lifetime, but can become relevant to support decision-making regarding satellite life time extensions, respecting future Space Debris Mitigation requirements.

- **EXTRINSIC** failure modelling is assigned lowest priority. Most space environmental effects can be either considered as contributors in the frame of random failure modelling, or (major) failures are successfully avoided by current design approaches.

In the following, the approach foreseen for the development of the New Reliability Prediction Methodology in Task 5 of this study is briefly outlined, first by failure root cause and then by technical domain (EEE, Mechanical, Miscellaneous) and level (elementary parts versus systems).

**Approach by failure root cause**

Based on these priorities, the main focus in the study will be set on the improvement of reliability predictions for random failures. The proposed approach for this failure category is further detailed by technical domain, as discussed below. For systematic and wear-out failure modelling, the intention is to make a first step towards quantitative reliability predictions considering these failure root causes, with dedicated but limited considerations per technical domain (not discussed below, for reasons of brevity). The consideration of extrinsic failures is low priority and will be based largely on industry best practice, as well as making use of specific capabilities of the modelling approaches proposed for random failure modelling, considering extrinsic environmental effects as stress contributors.

**Approach for EEE parts**

For the modelling of EEE parts, the FIDES reliability prediction methodology has been identified as a good candidate to achieve more realistic predictions compared to the in-use methodologies. The developments foreseen in the frame of the study will focus on the customization and simplification of FIDES for space applications, including the assessment of some new developments that are currently ongoing in a study led by the French Ministry of Defence, aiming at an update and extension of the FIDES guide to account for innovative technologies.

**Approach for Mechanical parts**

Current reliability predictions are very limited with respect to coverage of Mechanical parts, highlighting the need for improvements in this technical domain. The proposed approach takes basis in various methods from different sources, including some new developments from a previous ESA study focusing on reliability prediction for mechanical systems and parts.

**Approach for Miscellaneous items**

Besides the EEE and Mechanical domain, a third category of items (parts and assemblies) is considered, including items that are difficult to classify into one of the two previous categories, but also items that are either EEE or Mechanical by nature, but that are difficult to consider with the available modelling approaches. The general strategy foreseen for these “Miscellaneous” items is to investigate the possibility to derive reliability models from in orbit return data, combined with other modelling approaches as appropriate.

**Approach for reliability prediction at system level**

The available methods for consolidation of elementary reliability estimates in system level reliability prediction, such as e.g. fault trees or reliability block diagrams, are generally considered proven successful and already best practice for space applications. Specific considerations are needed when using these methods for different failure categories, e.g. the consideration of common cause effects for systematic failures or non-constant failure rates for wear-out failures. Some adaptation of methods used in other fields is foreseen to consider degraded system modes, importance measures for system optimization and phased mission approaches.