Design-for-Reliability and Accelerated Testing of Electronic and Photonic Products: What Should Be Done Differently

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The recently suggested probabilistic design for reliability (PDfR) concept in electronics and photonics [1-4], which has been pursued by the author on a rather limited basis in the past [5-7] has its experimental foundation in highly-focused and highly-cost-and-time effective failure oriented accelerated testing (FOAT) [8-13], which is aimed at understanding the physics of the anticipated or occurred failures and at quantifying, on the probabilistic basis and to an extent possible, the outcome of the FOAT and the actual field performance of the product. Time and cost permitting, FOAT can be used also to obtain some statistical data, such as, e.g., an experimental bathtub diagram – the reliability "passport" of a mass-produced product. FOAT should be conducted for the most vulnerable element(s) of the product of interest, with consideration of its most likely application(s) and the most meaningful combination of possible stressors ("stimuli") [14].

FOAT cannot do without simple, easy-to-use and physically meaningful predictive modeling (PM) [15-25] that should be geared to a particular, relevant and more or less well established and trustworthy analytical relationship, such as, e.g., the recently suggested Boltzmann-Arrhenius-Zhurkov (BAZ) equation [26-30]. The PM effort should not be limited, however, to the application of BAZ or similar FOAT models, but should include also other, both analytical and computer-aided, modeling effort aimed at better understanding the reliability physics of the device of interest, at designing the most feasible and cost-effective product, and at bridging the gap between the FOAT data and the most likely operation conditions and situations. PDfR concept includes also subsequent sensitivity analyses (SA) activity that uses methodologies and algorithms developed as by-products at the FOAT and PM steps.

The concept and its applications might include and address, when appropriate, also human-in-the-loop (HITL) related situations, when the equipment-and-instrumentation's reliability and human performance contribute jointly to the success and safety of a particular mission or a situation [31-42]. The PDfR concept proceeds from the recognition that nothing and nobody is perfect and that the difference between a highly reliable and an insufficiently reliable product or HITL interference is "merely" in the level of the never-zero probability of failure. If this probability, evaluated for the anticipated loading conditions and the given time in operation, is not acceptable, SA can be effectively and economically employed to determine what could/should be changed to improve the situation.

The PDfR based analysis enables one also to check if the product is not over-engineered, i.e., is not superfluously robust for the given application [43-45]. If it is, it might be too costly. The operational reliability cannot be low, but does not have to be higher than necessary either: it has to be adequate for the given product and application.

When reliability, cost-effectiveness and time-to-market (completion) are imperative, ability to optimize reliability is a must [46-51]. No optimization is possible, of course, if reliability is not quantified. We show particularly that the optimization of the total cost associated with creating a product with an adequate (and high enough) reliability and acceptable (and low enough) cost can be interpreted in terms of the adequate level of the availability criterion.

The major PDfR concepts are illustrated in our analyses by practical examples. The emphasis is on the attributes of the powerful, flexible and fruitful Boltzmann-Arrhenius-Zhurkov (BAZ) model (equation) and its multi-parametric version. This model could be effectively used to analyze and design a product with the predicted, quantified, assured, and, if appropriate and cost-effective, even maintained and specified adequate (appropriate) probability of the operational failure [52-54].

It is concluded that the PDfR concept can be accepted and employed as an effective means for the evaluation of the operational reliability of electronic and optical materials and systems, and that the next generation of qualification testing (QT) specifications and practices for such products could be viewed and conducted as a quasi-FOAT that replicates the initial non-destructive segment of the previously conducted comprehensive and reliability-physics-based full-scale FOAT.

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