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Probabilistic Design-for-Reliability Concept Changes the State-of-the-Art in Microelectronics and Photonics Engineering

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> *"The most important thing in life is to stop saying 'I wish' and start saying 'I will.'*
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> *Consider nothing impossible, then treat possibilities as probabilities".*
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> *Charles Dickens (1812-1870).*
>
> *"A pinch of probability is worth a pound of perhaps"*
>
> *James G. Thurber (1894-1961).*

The application of the recently suggested probabilistic design for reliability (PDfR) concept [1-5], an important extension of the design-for-reliability (DfR) effort (see, e.g., [6]), enables improving the state-of-the-art in electronics and photonics reliability engineering by establishing and assuring the adequate reliability level in many critical reliability tasks in these areas engineering. This is particularly important in various human-in-the-loop (HITL) [7-9] situations, when the reliability of the equipment/instrumentation, both its hard- and software, and human(s) performance contribute jointly to the outcome of a critical mission or an extraordinary situation. The PDfR concept provides a way to predict the, in effect, never-zero probability of the field failure of the product of importance by putting the reliability predictions and assurances on a well substantiated quantified "reliable" basis. The concept does that mostly on the basis of the highly focused and highly cost effective failure-oriented-accelerated-testing (FOAT) [10-14] conducted on the design stage of a new technology, new design, or a new application of the existing technology or design, when the highly popular today highly-accelerated-life-testing (HALT) [15] does not yet exist for this product and technology, and suitable best practices have not been developed. Note that there are also two other FOAT types: those that are almost always conducted at the post-manufacturing stage and known as burn-in tests (BITs) [16-18] and those that are quite often conducted on the product development stage, such as, e.g., shear-off and temperature cycling tests.

Application of Boltzmann-Arrhenius-Zhurkov (BAZ) constitutive equation [19] and particularly its multi-parametric extension [20-24] enables effectively quantify, on the probabilistic basis, the useful lifetime of an electronic or a photonic product. Clearly, the higher is this, actual or required, lifetime the higher is the probability of failure. It is the author's opinion and multi-years experience that successful and safe outcome of a microelectronics, photonics, micro-electronic mechanical systems (MEMS) and MOEMS (optical MEMS) undertaking of importance cannot be achieved and assured, nor even considerably improved, if the effort is not quantified, and if, because of numerous uncertain-and-inevitable intervening influences, such quantification is not done on the probabilistic basis. The projected probability cannot be high, of course, but should not be lower than necessary either: it should be adequate for the particular device, package, module, system and application. Products and missions that "never fail" are, as a rule, much more expensive than they could and should be. It has been shown that the minimum total cost of an electronic product has to do with its availability, which is the probability that the product is available to the user, when needed.

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It could be concluded that some type of predictive modeling should always precede any type of accelerated testing and that the analytical ("mathematical") modeling employed in the quite numerous recently conducted applications of the PDfR concept (see, e.g., [25, 26]) should always complement computer simulations: these two major modeling tools are based on different assumptions and use different calculation techniques, and if the output data obtained using these tools are in agreement, then there is a good reason to believe that these data are accurate and trustworthy.

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