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Ticking Time-Bombs in Electronics and Photonics Systems and Networks

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The current survival pressures on companies to cut costs drives an environment to release products without adequate reliability assurance. We have moved from the early days of over-engineering, through the period of fit-for-purpose high reliability of electronics, to the hazardous situation of under-qualifying. The situation is compounded by the emergence of weak international “standards” which require inadequate testing (both statistical, and physical), and poor experimental evidence. Such defaulting on reliability assurance creates serious risks downstream to the systems and networks in which the products are installed. The continuing pressure for cheap products resulting in outsourcing to the professionally inexperienced further aggravates the problem, but does not obviate ownership of liability for products that fail.

Symptoms are starting to show. Even the great history of cost-effective reliability is being dented by failures of inadequately qualified components and subsystems and of outsourced, cheaply manufactured products. Network outages are occurring. Hard-drives in PCs have failed. IC Drive-controller packages have failed. Analog IC test systems have failed. “Qualifications” that did not provide reliability assurance have led to massive failure rates of cellular radio base stations, automotive IC failures despite supposed conformity to the automotive specifications, and the large-scale rollout of IP broadband networks are resulting in extensive failures of network routers. Some have led to major litigation, and massive compensation [Note 1]. And we wait for the next time-bomb to blow up. When will we learn again that cutting corners technically, and in costs, has consequences; “as we sow, so shall we reap.”

“Qualification” is the formal legal demonstration of survival to a series of stress tests conforming to specified standards, during which specific characteristics are measured to determine the product behaviour within or beyond the specified end-of-life limits, the black box approach. However, qualification does not provide reliability assurance, which is the outcome from a reliability development programme, and which must be part of the product development programme of every company.

When applying generic “standards” derived from work done elsewhere on technologies and products that are not identical to those being assured, it is important that the models be validated for the specific technology and manufacturer. Further, parameters such as Activation Energies for thermal acceleration of ageing according to the Arrhenius model, and Activity Coefficients for humidity acceleration of ageing according to the S-H HAST model, must be experimentally verified specifically for that product technology. There is no such thing as a universally applicable Activation Energy or Activity Coefficient. For instance, my own work, which established HAST and the S-H model as a method of humidity acceleration of ageing, was thoroughly verified with many combinations of temperature and humidity over 100 million device hours of experimentation over ten years at BT Laboratories. The model is demonstrably valid within the constraints specified. It is therefore inappropriate that the activation parameters be reused on other technologies without verification.

Examples of practical observations of the hazards that arise from inadequate qualification are given below.

Too small sample size

To assess the consequence of sample size, it is necessary to understand two statistical parameters.

One is Lot Tolerance Percent Defective (LTPD), which is a measure of the probable faults that may escape detection according to the sample size used in a test. In the telecommunications industry, high reliability was established by applying a range of overstress tests based on well characterised models of ageing, and sampled to a statistical standard of an LTPD better than 1%. Typically, 231 electronics devices were tested per overstress condition (i.e. total devices reliability tested per qualification exceeded 1500). This requirement is not met with the lowered standards which accept LTPD levels as high as 20, and sample sizes as low as 11.

The other statistical parameter is the FIT (originally “Failure unIT”, lately “Failures In Time”), where 1 FIT is 1 failure in 10^9 device hours. The FIT was created to obtain manageable numbers because major systems use millions of components required to function reliably for 10-20 years (80,000-170,000 hrs), or failure rates of parts per billion hours.

Table I illustrates the consequence on FIT rates of the two alternative LTPDs, and reveals the lack of assurance obtained from a LTPD of 20.

Table I. The Impact of Sample Size on FIT

Duration	Sample Size	Actual Failures	CL	FIT Estimate	Comments
5000	11	0	60	16728	Typical “standard” life test low sample size gives high FIT rate
5000	368	0	60	500	High reliability sample size to achieve 500 FITs at 60% CL

Incorrect assumption of Activation Energy

The S-H model which incorporates the Arrhenius model is

$$t_{amb}/t_s = \exp\{X[(RH_s)n-(RH_{amb})^n] + (E_A/k)(1/T_{amb}-1/T_s)\}$$

where EA is the activation energy, and X is the humidity activation coefficient, both of which are specific to each failure mechanism, and the applied stress conditions. An optimistic assumption of a high EA will result in an optimistic estimation of product lifetime in a base station, as illustrated in Table II.

Table II. Hast acceleration for 0.9eV and 0.6eV activation energies for station ambient of 70˚C & 41% RH vs. 130˚C & 85% RH

Activation Energy eV	Base Station Environment	Calculated Acceleration Factor	Predicted Lifetime for 96 hour test
0.9	70°C & 15% RH	2020	194000 (**22.1 years**)
0.9	70°C & 16% RH	1990	191000 (21.8 years)
0.9	50°C & 41% RH	7100	673000 (77 years)
0.6	70°C & 15% RH	455	43700 (**5.0 years**)
0.6	70°C & 16% RH	450	43200 (4.9 years)
0.6	50°C & 41% RH	850	82000 (9.4 years)

There are further unfortunate deceptions or self delusions practiced by those who carry out their own qualification.

When a low sample size of 11 is tested, no failures are permitted. So some companies pad the population with extra devices with the intention of getting 11 devices through the test without failure. However, it is a legal obligation to declare and report on all components placed on test, and all failures that occur. So 18 devices must be declared as the sample size, and 1 failure still constitutes a qualification failure! The other delusion is to find qualification reports strewn with statements designed to excuse specific failures as not genuine failures, such as “fibre inadvertently broken during handling for measurement, and “cause of failure not due to device.” Either instance is actually a qualification failure.

Where companies seek to streamline their reliability assurance programme, there are effective methods to do so. One I have established in industry and strongly recommend is the Building Blocks method. This is a structured method where the product is subdivided into its basic independently testable elements. Each element (Building Block) is individually Qualified, and the element qualification is held in a Library of Qualified Parts that may be reused in other products. At the higher level, only the additional build is qualified, and so on. This approach, illustrated in outline in Fig 1, streamlines the procedure both in depth of stress test at each level of build, the number of parts that are to be tested, and the avoidance of overkill in the type of stress that may be applied to the final build. Qualification of each level of build as shown in each branch of Fig 1, is maintained thereafter for as long as it is foreseen that this block is required for future products.

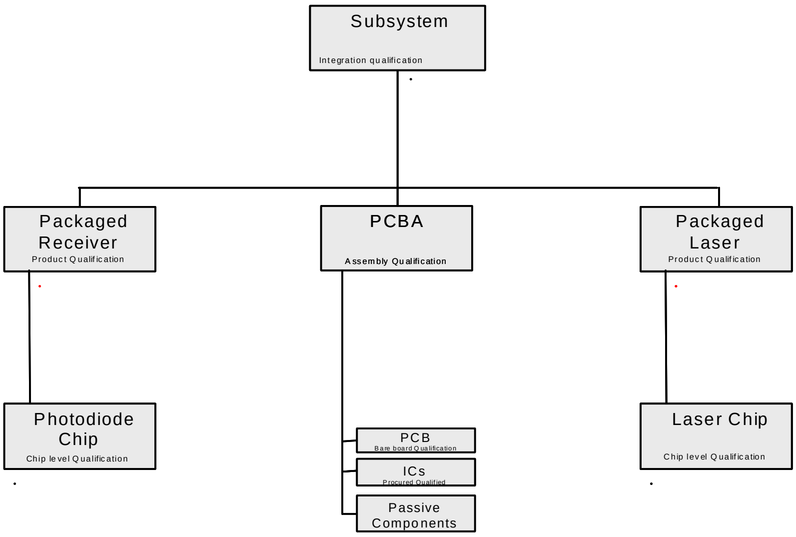

Fig. 1. The Building Block Method of Product Qualification.

Where poorly qualified products are used in systems and networks, the vulnerability of such systems and networks can be mitigated by designing-in fault-tolerance, which, of course, adds cost. While fault-tolerant networks incorporate primary, and secondary recovery capabilities, such recovery must ensure there are no common-mode hardware faults that compromise the recovery systems themselves, which can also arise where hardware component reliability is inadequate. Skills in reliability methodology do exist to provide adequate reliability assurance to safeguard modern networks. Ensuring that systems and networks meet the desired lifetimes requires either that product reliability is built-in and proven, or that the networks are built to be resilient, requiring investment.

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Who pays? In a market economy, the end-users must decide whether they want a reliable high Quality of Service, and be willing to pay the price. If we keep going for the cheapest, we may get the worst.

> Note 1. *Readers will appreciate that, while I have a solid base of evidence, which has been presented at expert witness hearings that eventually led to massive compensation payments, such evidence is naturally highly confidential and may not be divulged in open publications.*