Contribution of Technical and Human Factors to "*No Fault Found*" Events

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Multicomponent products that combine hardware and software (cars, airplanes, and telephones, to name a few) are everywhere in our lives. The commercial release of such products is a compromise between performance capabilities, competitive pricing, and time to market (Challa, Rundle, & Pecht, 2013). As product performance increases, system complexity and the number of failure modes also increase. Of particular importance are "No Fault Found" (NFF) events that occur when a user records a system error and subsequent investigations fail to uncover the reason for the system malfunction – the root cause is unknown (Jones & Hayes, 2001). NFF can result in high warranty costs, product recalls, and diminished reputation (Challa et al., 2013). Surprisingly, most organizations do not explicitly calculate the costs of NFF or use a framework to estimate them (Erkoyuncu, Khan, Hussain, & Roy, 2016).

A defining aspect of NFF is the discrepancy between actual and anticipated use conditions (Challa et al., 2013). Anticipated use is often defined by qualification, the passing of tests that demonstrate when a product meets nominal design and manufacturing specifications (Challa et al., 2013). A popular form of qualification is standards-based testing due to its speed, low cost, and applicability to many products (Challa et al., 2013). Standards such as Military Standard (MIL-STD) meet these criteria, but are often inappropriate for specific, actual-use conditions in the field. For example, the Ford Motor Company designed thick film integrated (TFI) ignition modules based on a set of laboratory standards. Cars used in hot climates experienced numerous failures that were initially classified as NFF (because these failures could not be reproduced under the milder laboratory conditions) (Thomas et al., 2002). One remedy to this problem would be to adopt more stringent engineering specifications for qualification.

In this research, we analyzed NFF across four industries – automotive electronics, aerospace, medical equipment, and consumer electronics. The analysis is based on four contributors to NFF: testing procedures, intermittent failures, environmental factors, and human factors. Intermittent failures are the re-appearance of equipment failure after remedial actions have taken place (Thomas et al., 2002). Environmental factors (also referred to as environmental monitoring) are the context (or "background") conditions in which the NFF event occurs. These factors can take on a variety of forms, from vibration and humidity in an aircraft to the diverse demographics of users of a consumer electronic product (Kim & Christiaans, 2016; Moffat, Abraham, Desmulliez, Koltsov, & Richardson, 2008). Case studies (representing each of the four industries) demonstrate that the existing strategies for reducing the occurrence of NFF events are limited.

Addressing the four contributors to NFF (testing procedures, intermittent failures, environmental factors, and human factors) allows for the development of a systematic approach to reduce these events. First, one must distinguish between "hard" and "soft" failures. Hard failures are technical or equipment reliability failures (den Ouden, Yuan, Sonnemans, & Brombacher, 2006; Kushniruk & Patel, 2004). Soft failures occur when products fail to meet usability expectations, despite functioning from a technical, reliability standpoint (den Ouden et al., 2006). Hard failures are relevant to the aerospace and automotive electronics industry case studies, while soft failures pertain to medical equipment and consumer electronics.

Analysis reveals a number of key insights, including the impact of proper failure classification (what is or is not a NFF event). Proper classification enables organizations to quantify how products perform in the field and which corrective actions are needed to improve reliability and usability.

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