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Reliability Assessment of Dormant Storage Components



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Outline

- Background & Problem Statement
- Assessment Methods in Design
- Assessment Methods in Production
- Assessment Methods for Fielded Components
- Summary & Conclusions

Background & Problem Statement

- Some electronic/electromechanical components are required to be dormant in an unpowered state for years and then operate successfully for a short time period
- Environmental exposures over the component's lifetime may result in material properties degradation and a resulting shift in performance
- To ensure high reliability, ongoing assessment of these components is necessary to inform the need for upgrades or replacements
- Assessment methodologies that are used and have been proposed to maintain the reliability for this class of components will be discussed

Lifetime Environmental Exposures

Transportation: Shock & Vibration

Storage: Long Term Thermal Cycling, Humidity, & Ionizing Radiation

In use: Vibration, Shock & Thermal Shock

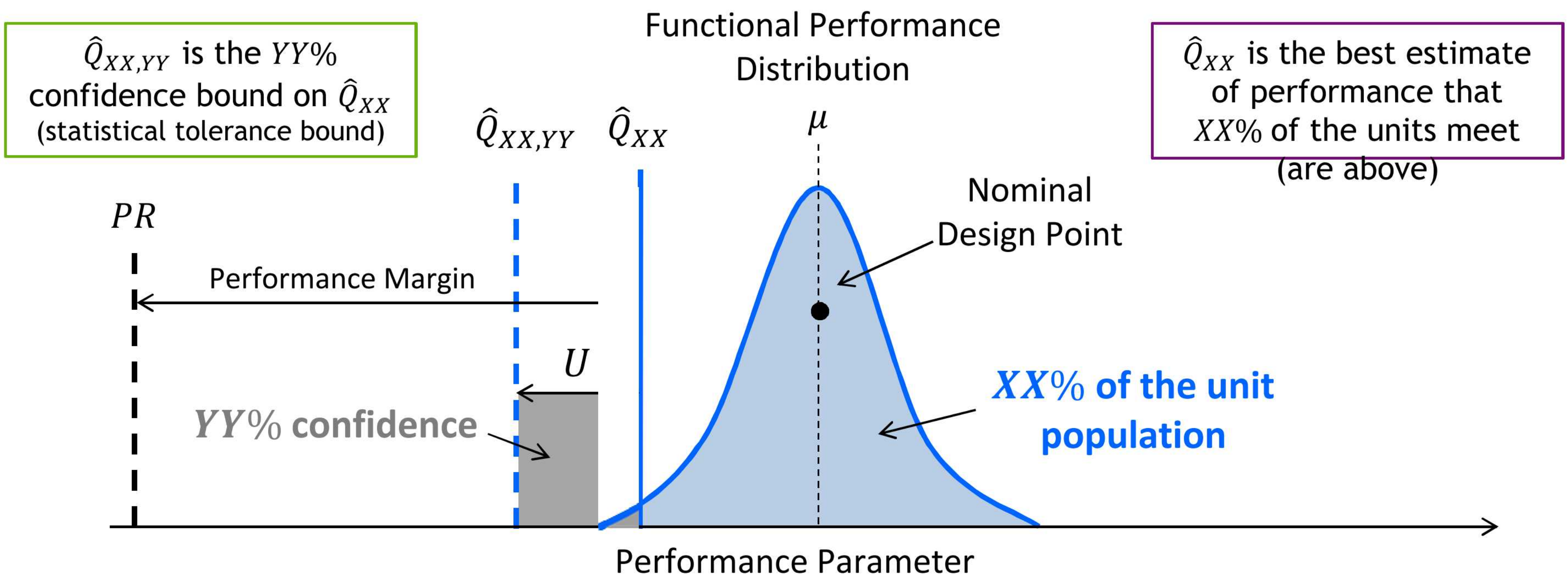
Assessment Methods in Design

Attributes Important to Inherent High Reliability in a Design

- Performance Margin
  - Identification of output measurements to judge sufficiency of successful function of the component within the system (Key Performance Parameters)
  - Statistical Analysis of KPPs
- Design (environmental) Margin
  - Precondition components one lifetime prior to margin tests
  - Mechanical (Vibration & Shock) – Step/Stress Tests
  - Thermal Cycling to multiple lifetimes
  - Radiation testing at piece part level & component level
  - Statistical Analysis of Data
- Materials Compatibility
  - Materials Selection
  - Independent Materials Review
  - Material Aging & Compatibility Tests

Statistical Framework for Assessing Performance Margin

Are we ***YY%*** confident that **at-least *XX*%** of the unit population will yield a response **greater than** the performance requirement ***PR***?

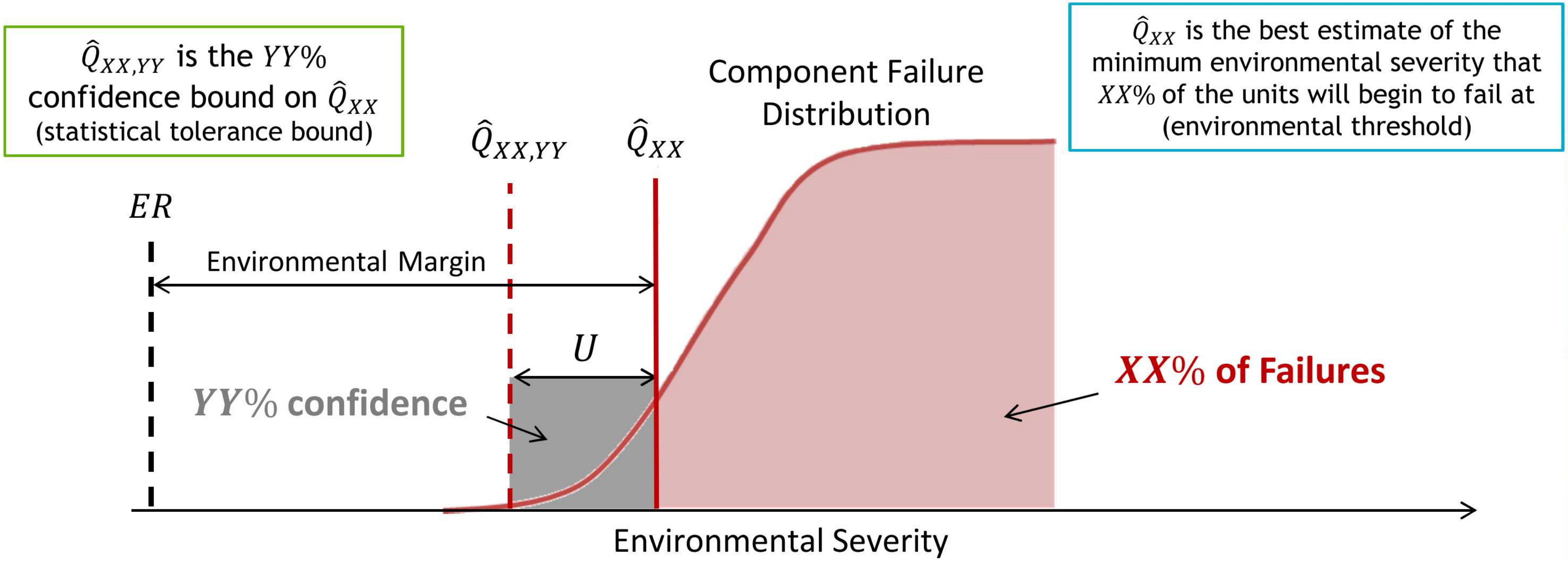


Statistical Challenges:

- Estimation of a parametric distribution requires unverifiable assumptions
  - Traditional goodness-of-fit tests are inadequate
- Quantile estimates require extrapolation outside of observable data

Statistical Framework for Environmental Margin

Are we ***YY*%** confident that **at-least *XX*%** of the unit population failures will be in an environment **more severe than** the maximum required environment ***ER***?



Statistical Challenges:

- Estimation of the component failure distribution with limited binary data
  - Highly robust components often lead to multiple censored observation
- Environmental severity is often a functional variable

Materials Compatibility

- Materials Selection
  - Material Science Experts available to advise design teams
- Independent Materials Review
  - Panel of materials experts aware of stockpile issues provide an independent review of manufacturing and component materials usage
  - Materials list provided to the independent panel by the design team
  - Panel provides a list of actions/suggestions to design team
  - All action/suggestion formally addressed by design team
- Material Aging & Compatibility Tests
  - All component piece parts, printed wiring boards, packaging materials, etc., sealed in an enclosure and iso-thermally aged for six months to one year
    - After completion piece parts are electrically tested and data are compared to prior baseline data
    - Destructive Physical Analysis performed on all materials to examine for degradation
  - Purpose of the test is to identify any life limiters

Assessment Methods in Production

- Once a component design is qualified it is necessary to evaluate that product being manufactured is similar to what was qualified
- Methods for Production Variation Controls
  - Statistical Process Control (SPC)
    - Establishing control limits on manufacturing process parameters based on prior data to identify variations in processes that may result in out-of-family product
    - A timely and efficient indicator of when manufacturing processes may be trending out of control
  - Environmental Stress Screening (ESS)
    - A 100% screen on product that consists of sequential or combined mechanical and thermal environmental exposures
    - Purpose is to identify and eliminate defective parts due to manufacturing errors
    - Screen is carefully designed to precipitate latent defects without significantly damaging the component
  - Destructive Sample Test (D-Tests)
    - A D-Test is a time-compressed emulation of all environmental exposure a component will experience over its lifecycle
    - Functional tests performed after environmental exposures
    - Component may be dissected and materials evaluated for degradation
    - For low rate production, the minimum sample size is at least one sample every 6 months of production

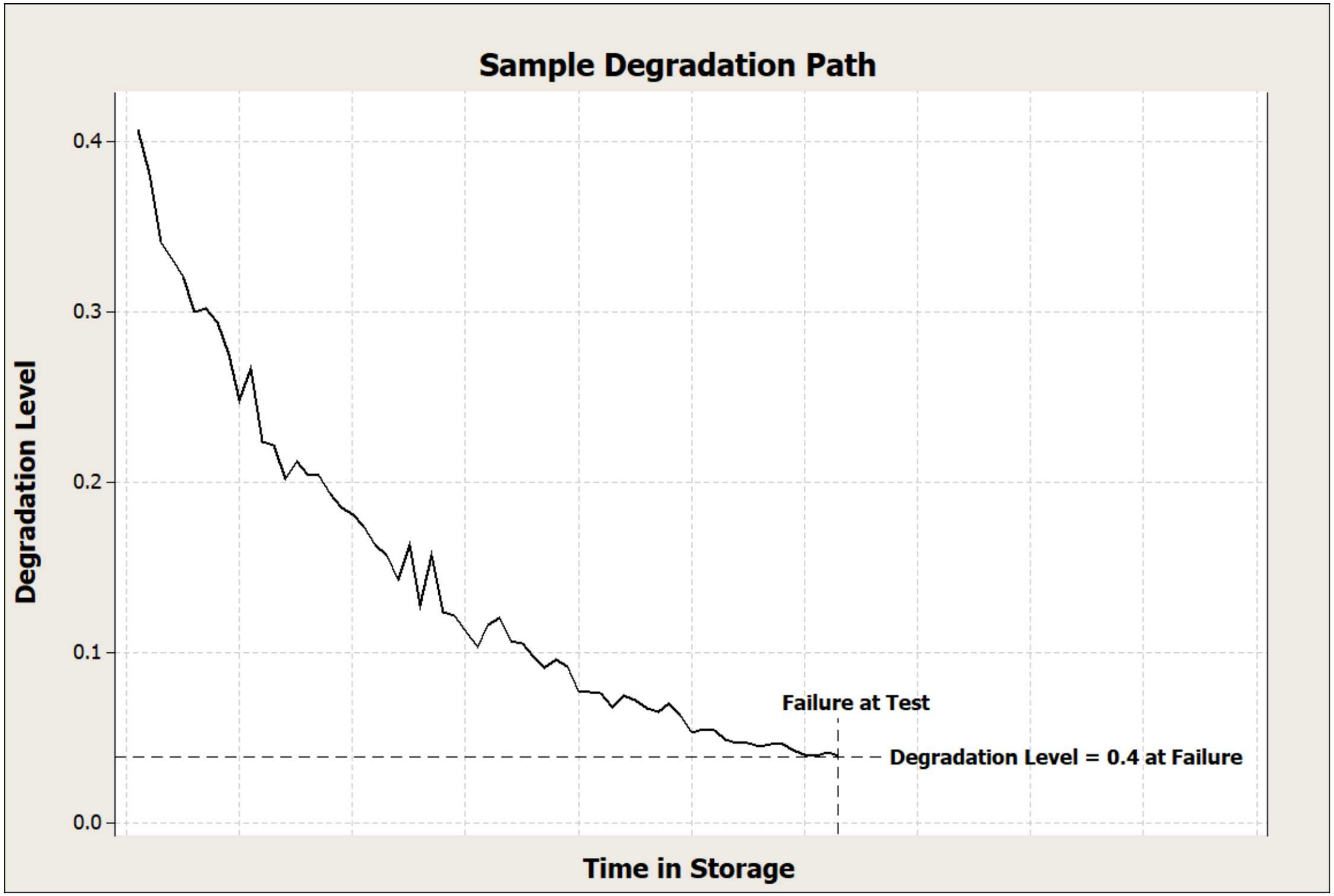
Assessment Methods For Fielded Components

- Degradation measures will be used to estimate performance and reliability of components that experience dormant storage environments
- Degradation measures are inherent in dormant storage components, where failure occurs due to accumulation of damage from environmental exposures

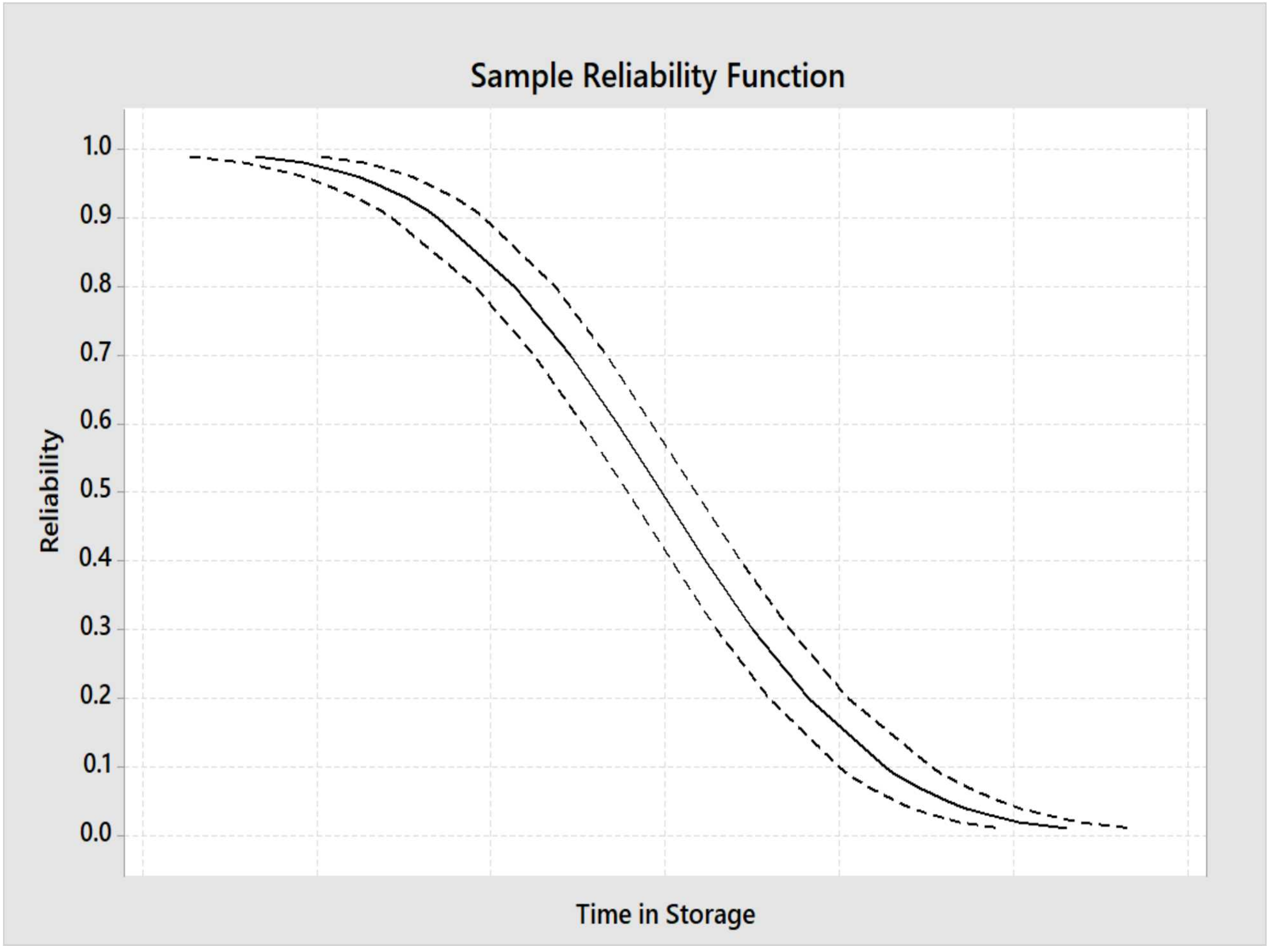
Several assumptions are usually made regarding a degradation measure:

1. The state (health) of the component can be characterized by a randomly changing time-dependent variable that we will denote y_t. The variable in theory must be non-decreasing, that is, the health of the dormant component cannot improve. In the context of dormant storage, the degradation variable is a measure of accumulated damage due to environmental exposures.
2. A failure of the component is defined as a certain catastrophic event ("hard" failure) whose probability of occurrence depends on the value of the variable y_t, or is defined as the variable y_t entering some critical region ("soft" failure).
3. The variable y_t is accessible for either continuous or discrete observations, i.e. a degradation "path" is obtainable.
4. The probabilistic laws governing the changes in the degradation measure y_t are known (physical model) or can be approximated (empirical model).

Example of Degradation Path



Example Reliability Function Derived from Degradation Measure



Reliability function based on degradation measure effect on performance

Summary & Conclusions

- This paper has described reliability assessment methods used to evaluate components that have long term unpowered storage
- To achieve high reliability, reliability assessment methods must be employed throughout the life cycle of a component:
  - Design,
  - Production, and
  - Storage
- These reliability assessment methods provide a critical capability to initially verify sufficiency of design and then detect and assess any ongoing degradation that may affect long-term reliability