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SNL Approach to Reliability Verification During Product Development

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- On behalf of our nation, we anticipate and solve the most challenging problems that threaten security in the 21st century.
- The synergy and interdependence between our nuclear deterrence mission and broader national security missions forge a robust capability base and empower us to solve complex national security problems.

NW Reliability Analysis Approach

- The Sandia reliability analysis approach is tailored to support the unique aspects of the nuclear weapon assessment environment.
- This reliability analysis approach is different from that found in most textbooks due to a number of attributes.
  - high consequence function
  - high reliability requirement
  - dormant storage/short operating life
  - one-shot system

Assurance to Assessment

Reliability Assurance

Goal: <u>Improve inherent reliability</u> through preventing or removing defects so they are not present in the stockpile

Reliability Assessment

Goal: <u>Estimate inherent reliability</u> through detecting (or predicting) defects that are present in the stockpile

Inherent Reliability is a Function of (un)Reliability Contributions

$$R_{inherent} = R_{requirement} \times R_{design} \times R_{production} \times R_{sys\ int}$$

or

$$R_{inherent} \cong 1 - [F_{req't} + F_{design} + F_{prod} + F_{sys\ int}]$$

$F_{req't}$:

- Missed, wrong or changed lifecycle requirement
- Missed, wrong or changed flow down of requirements
- Missed, wrong or changed derived requirements
- Missed, wrong, or changed combination or sequence in environmental and/or operational requirements

F_{design}:

- No/low design margin
- Unable to predict performance or aging
- Bad/incompatible material choices including CTE mismatches
- Performance adversely affected by unspecified mfg parameters
- Missed critical mfg requirements
- Bad testers
- Unexpected internal system integration issues (e.g., tolerance stackup)

F_{prod}:

- Inadequate control of materials from suppliers
- Inadequate control of processes
- Unanticipated interactions between mfg processes
- Bad process monitoring and testers

$F_{sys\ int}$:

- Unanticipated external system integration issues
- Unanticipated impact of DoD changes
- Bad handling
- Exposure beyond STS
- Bad military procedures

How do we achieve high reliability?

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Product Reliability Requirement

- Allocate reliability requirements from system to components

- Understand user needs
- Ensure good requirements

Reliable Product

- Verify fielded reliability

- Reliability is assessable
- Residual risks to reliability are monitored

Verification

- Margin is maintained throughout levels of assembly
- Design life is achievable
- Manufacturing variation is controlled

- Design and Redesign for Reliability

- Understand and eliminate/mitigate failure modes
- Design in robustness to inputs and environments
- Remove life-limiters
- Design for manufacturing
- Design for surveillance

- Verify initial reliability

Robust Component Design

Producible Components

Find and Eliminate Sources of Failure

- There is uncertainty and unknowns that we cannot totally eliminate. Our reliability requirements acknowledge this fact.

- Reliability is about knowledge. Knowledge of our product's ability to achieve is operational goals

- First and foremost, as engineers, we must take positive, intentional steps to eliminate the root causes of failure.

- Focus needs to be on "how products will fail" not just "how products will work"

Approach to Verification

Problem Statement:

Impossible to "demonstrate" even moderately high reliability with high confidence with few units functionally tested

- Focus on reliability improvement and mitigating risks through reliability knowledge growth
  - Requirements that are well understood
  - Margin to possible variation in inputs and environmental conditions.
  - The ability to achieve its design life
  - Manufacturing variability controlled so as to minimize sources of defects
  - The ability to be monitored after it enters the field. This is accomplished by our surveillance program.

Ensure Requirements are Well Understood

- Requirements must be solid and Performance Parameters must be known:
  - What the important functions and outputs of components are and what key measurements are required to verify performance?
  - Environmental requirements well understood and documented
  - Inputs range from other components, levels of assembly, and external interfaces such as the aircraft/missile, handlers, ancillary equipment, etc.

If requirements are “broken” then our verification activities may be faulty

Ensure Margin

- Margin testing gives insight and confidence in how a product will perform to its requirements given extremes in both inputs and environments. It gives evidence for product robustness.
- Knowledge of Margin includes
  - Given input/environment requirements how do the outputs compare to the output requirements? (Performance Margin)
  - What is the entire input/environment space over which the outputs are still considered acceptable? (Design Margin)
- Margin testing and analysis must not only consider operational environments, but also non-operational environments (handling, transportation, and storage)

Ensure Design Life is Achievable

- Life requirement is usually stated as: The product shall be capable for a YY year stockpile life.
  - In addition some components have requirements regarding the number of operations of its service life.
- The design life requirement cannot be verified in a quantifiable manner. The key is to ensure that life-limiters have been avoided in the design.
- Material compatibility and aging studies must be conducted to ensure that possible degradation will not negatively impact design margin or give rise to catastrophic failure modes
- Thermal and mechanical stresses on the product must be considered both for dormant periods as well as the number of operations expected over the design life

Ensure Manufacturing Variation is Controlled

- Historically, defects introduced during manufacture are the most significant source of failures.
- The reliability goal from production is to ensure homogeneity of what is produced and design margin is retained.
  - This goal can be achieved by implementing the proper tools, techniques, testing, and data collection before and during production.
- Production processes should be characterized to ensure that defects will not be systematically introduced into delivered products
- Performance parameters must be monitored during production to catch negative trending (e.g. QMU, statistical process control)

Ensure Surveillance Program Addresses Reliability

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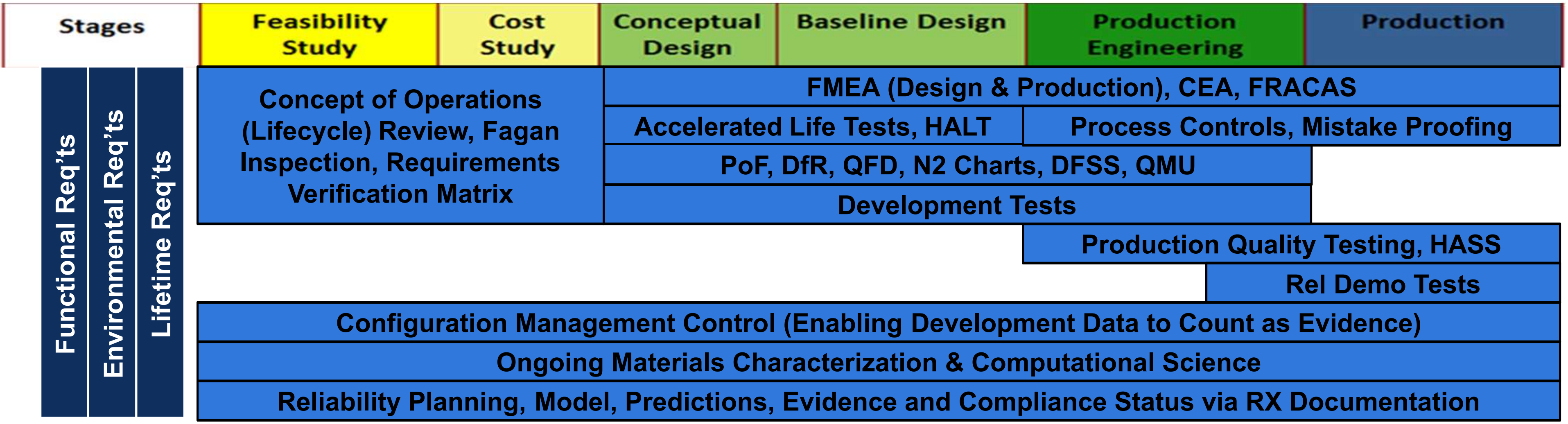
- For reliability purposes surveillance planning should address at least two aspects:
  - What data need to be gathered to assess the reliability model?
  - What data need to be gathered to address residual risks to product reliability?
- Surveillance data must be gathered to ensure that the reliability model is current and relevant
- All products are assumed to have some residual risk that will not be entirely mitigated before being fielded. We must be aware and monitor these risks to ensure that reliability is maintained throughout the program lifetime.

Some Tools to Consider for Reliability Assurance



Summary

- Focus of reliability assurance activities is to improve the inherent reliability of the system by preventing defects from entering into the stockpile
  - Requirements that are well understood
  - Durability and robustness to possible variation in inputs and environmental conditions.
  - The ability to achieve its design life
  - Manufacturing variability controlled so as to minimize sources of defects
  - The ability to be monitored after it enters the field.

Thank you for your time