Beta Prototype and Test Plan

Module 4C Simulating Product Use Conditions

Motivation

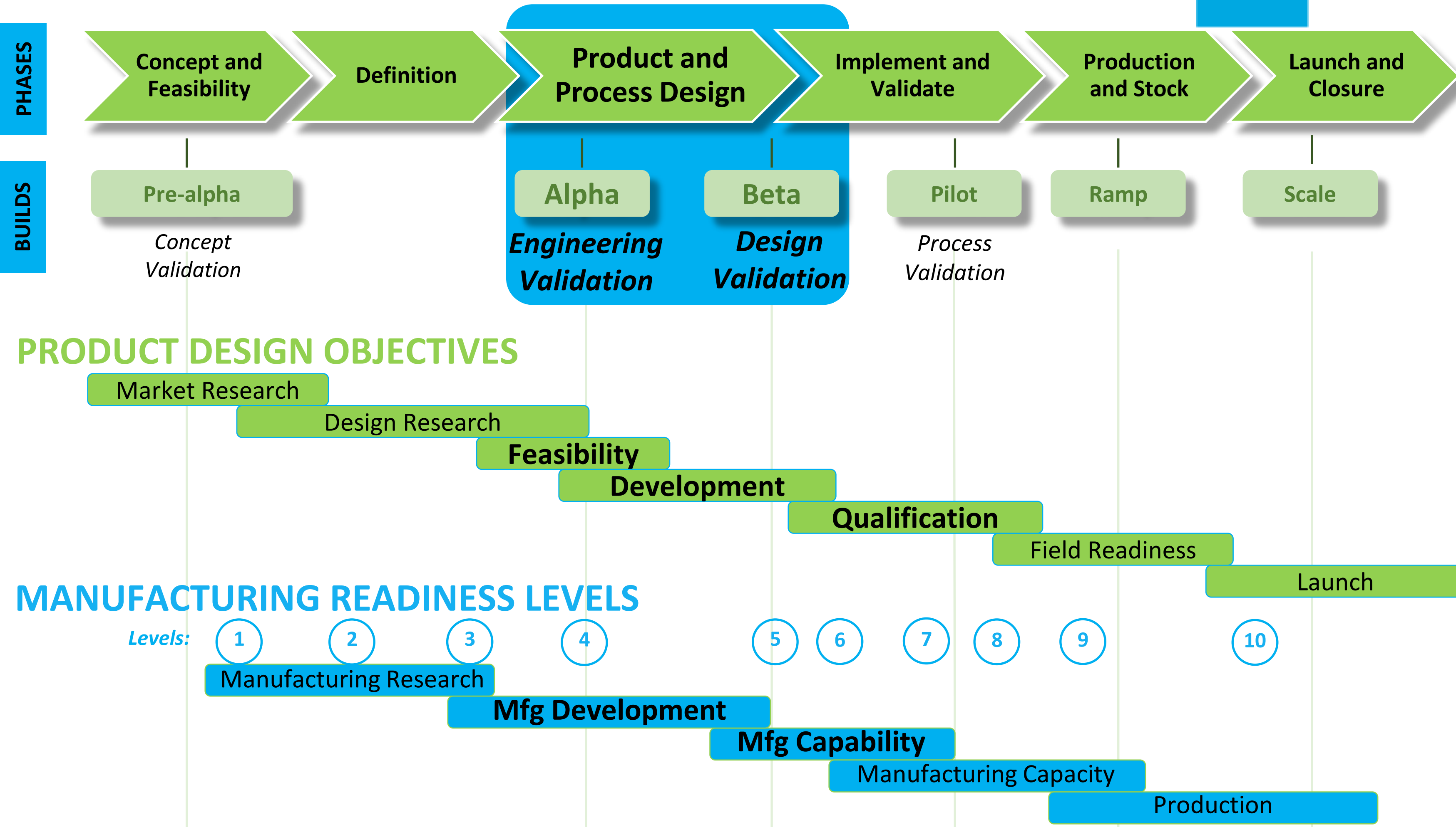
Why is this module important?

A proactive approach throughout product development lifecycle for predicting reliability is necessary to:

- Avoid discovering problems after the production ramp-up, when corrective action is much more expensive than if problems are discovered during the design phase
- Provide a mechanism for trade-off decisions between product cost on the bill of materials (BOM), warranty cost, and time-to-market impacts
- Product use simulation, when combined with testing or modeling, facilitates identification of potential failures (and their root causes) early in the product-development process

Simulating Product Use

Where does this fit into the development cycle?



Module Outline

- Learning objectives
- Reliability background and review
- Reliability block diagram
  - —Apportionments
  - —Confidence
- Further details
  - —Accelerated life testing (ALT)
  - —Reliability demonstration testing (RDT)
  - —Use modeling software
  - —Physical use testing
  - —Decision trade-offs

Learning Objectives

- LO1. Understand the purpose and value of product use simulation and testing
- LO2. Understand reliability block diagram and its function to guide use simulation and testing plans
- LO3. Understand basic tools and methods for simulating product-use conditions

Use Simulation Planning

Framework building

- Reliability is the survival likelihood at use time (“t”) for a defined set of environmental and use conditions (i.e., a, b, c, d)
- Use simulation improves reliability predictions throughout the development lifecycle and ensures that reliability goals will be met
- Use simulation is part of the reliability program plan that includes diverse activities and cross-team engagement throughout the entire development lifecycle

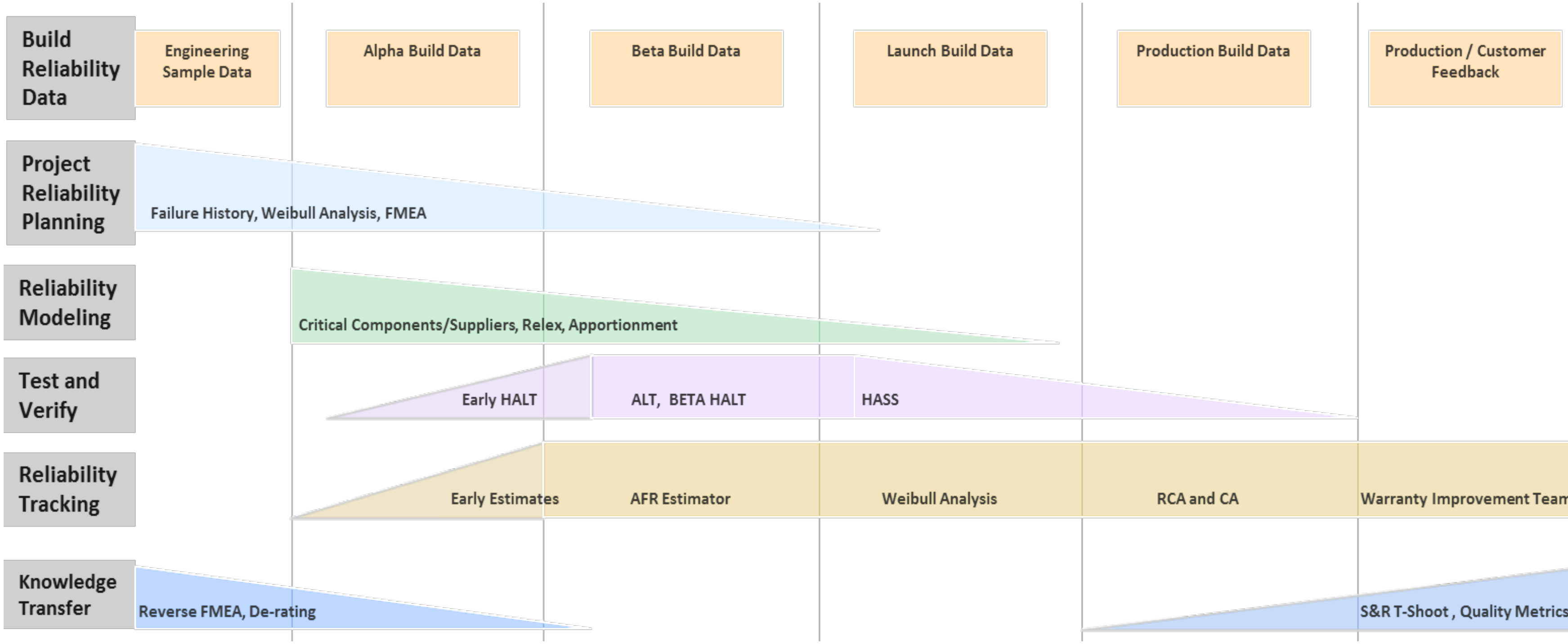
Reliability Overview

Key drivers and lifecycle review

PHASES	Concept and Feasibility	Definition	Product & Process Design	Implement and Validate	Production and Stock	Launch & Closure
RELIABILITY	Establish Preliminary Reliability Plans	Set the Reliability Goals for the Product(s)	Design and Implement the Reliability Case for the Product(s) to Support	Verify the Product Reliability from Initial Product Builds. Refine the Reliability Case	Validate Product Reliability from Initial Production	Validate Product Reliability from Production and Customer Feedback

Reliability Program Plan

Example



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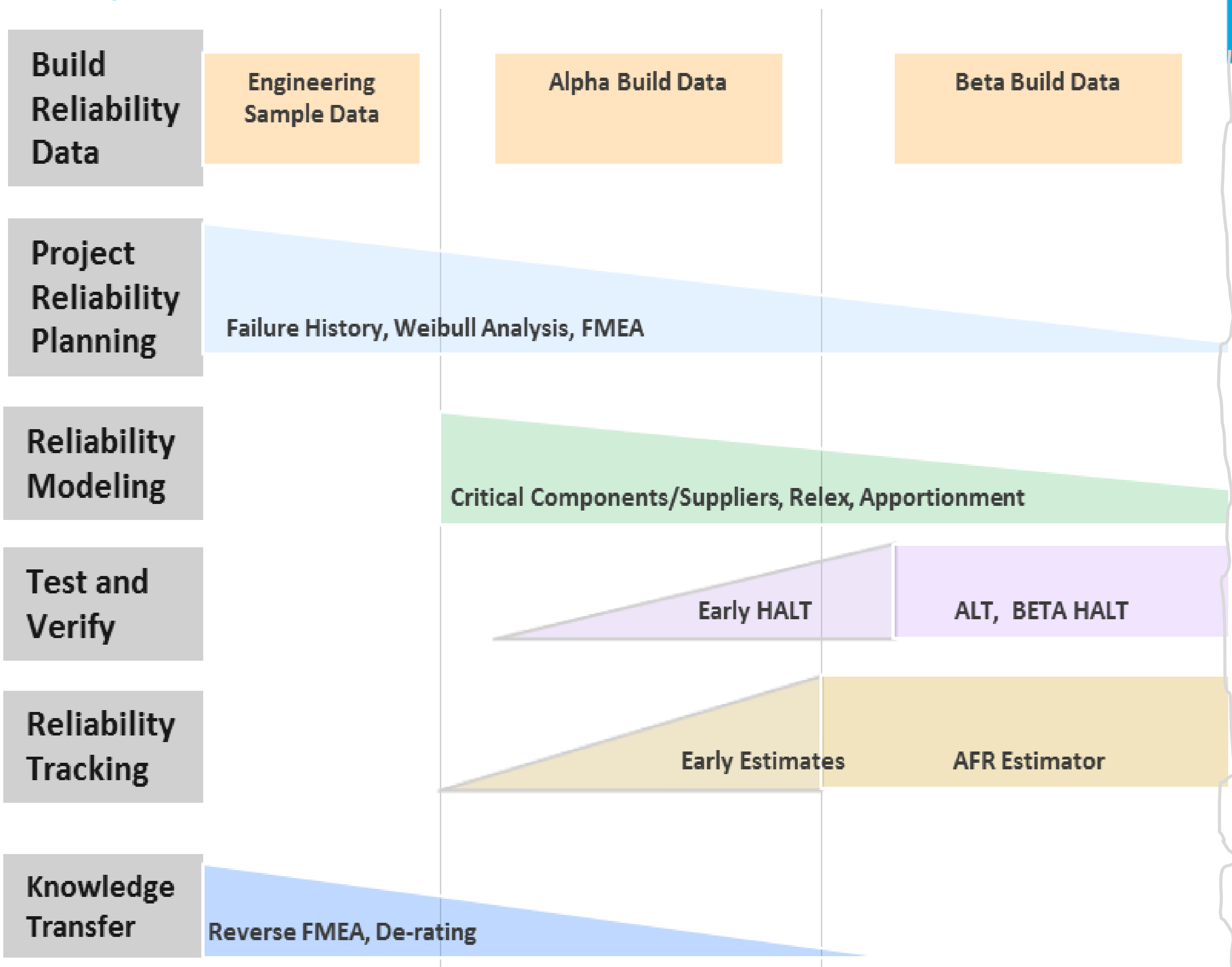
Reliability Program Plan

Example (cont.)



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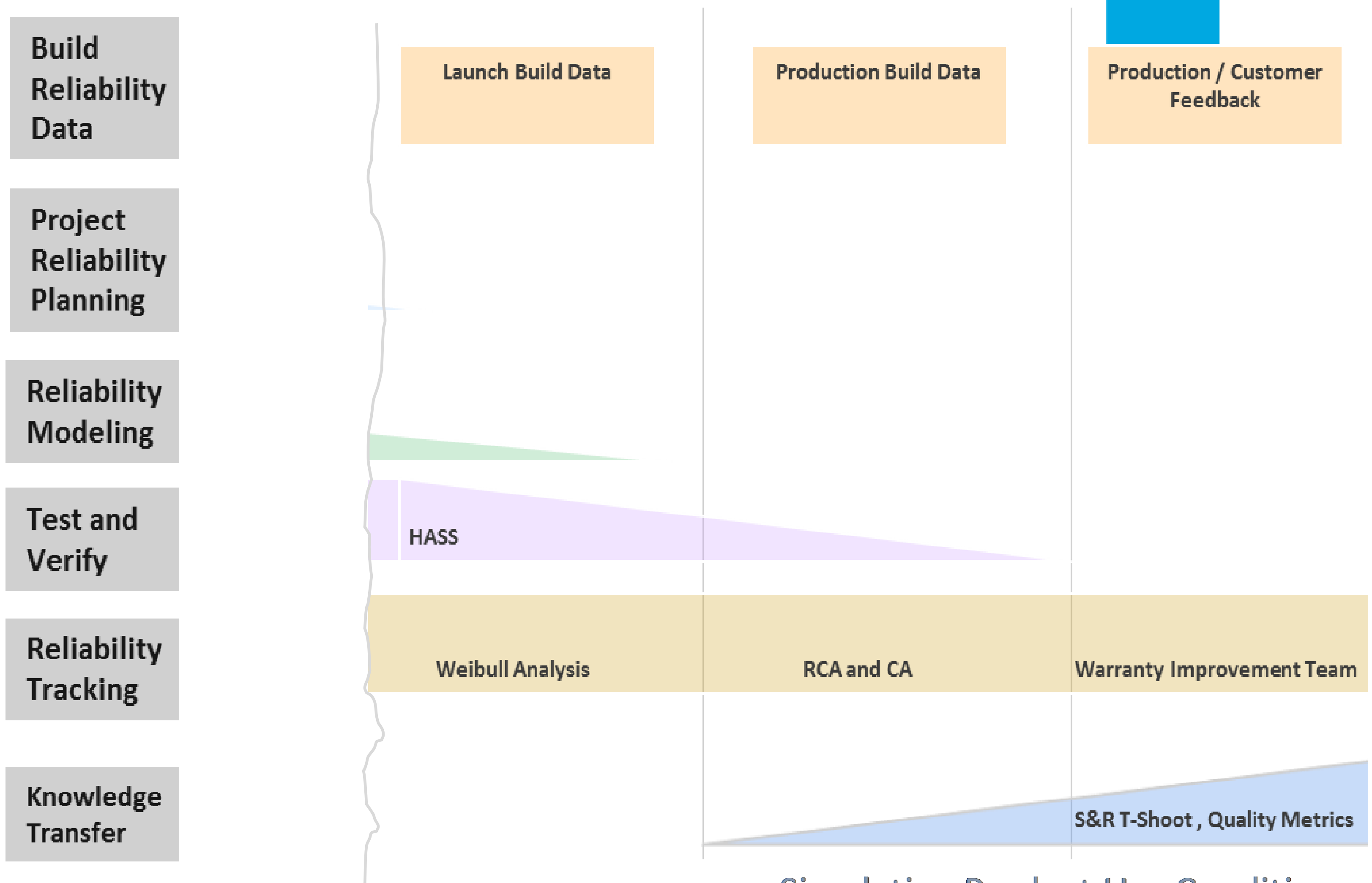
Reliability Program Plan

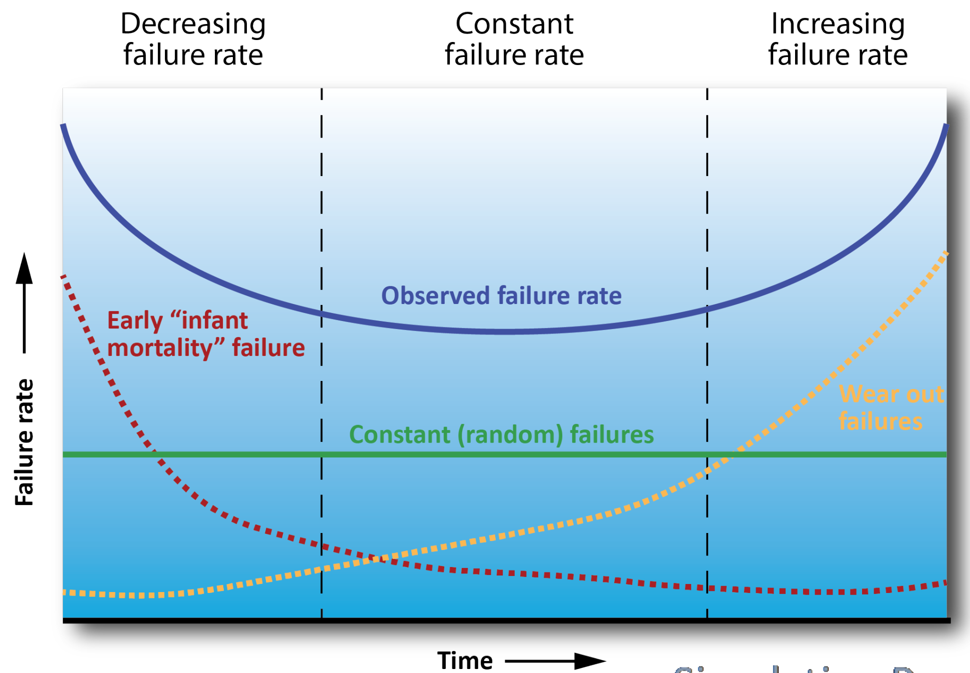
Example (cont.)



Reliability Bathtub Curves

Overview

- The bathtub curve is generated by mapping (1) the rate of early "infant mortality" failures when first introduced, (2) the constant rate of "random" failures during its useful life, and (3) the rate of "wear out" failures as the product exceeds its design lifetime



See Module 7C for more bathtub curves

Source: https://en.wikipedia.org/wiki/Bathtub_curve

Quality Goals

Review

- **Early failure rate (infant mortality)**: typically caused by manufacturing, assembly, shipping issues

Example: less than one percent in first 90 days

- **Design reliability goal (constant rate failures)**: typically drives the component selection and design strategy

Example: 90 percent system survivability at year five at 25°C (or other environment/use parameters)

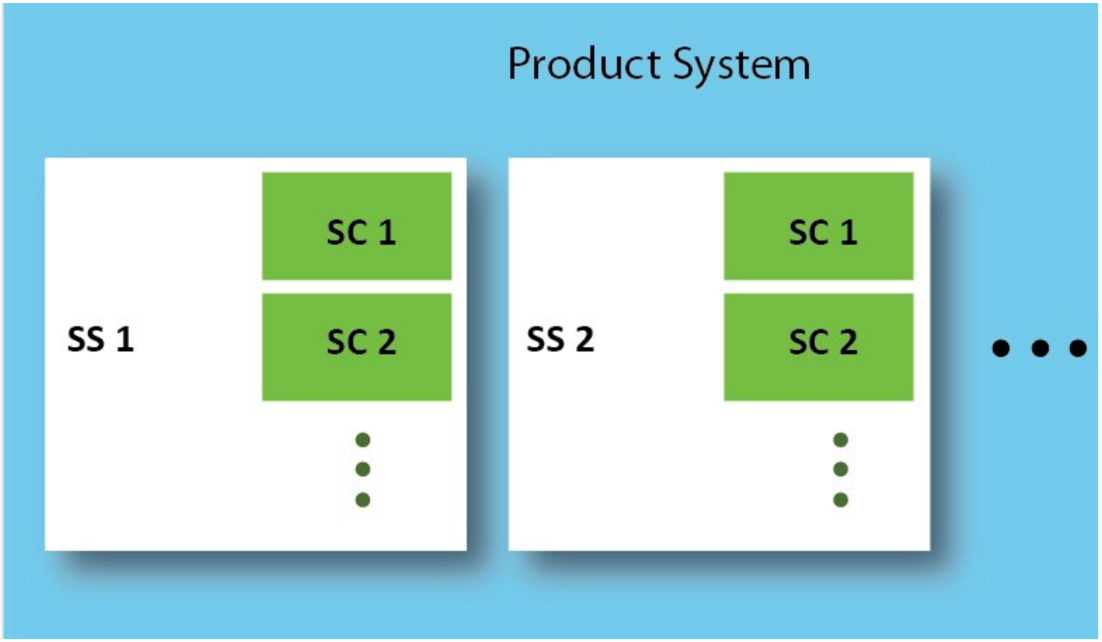
- **Design life goal (wear out)**: this is the point where the components selected will start to wear out

Example: seven years at 25°C (or other environment/use parameters)

Reliability Block Diagram

What it is and how to use it

- The reliability block diagram (RBD) is a graphical and mathematical model of system reliability given the reliability of the individual components or sub-assemblies



PS = product system
SS = sub-system
SC = sub-component

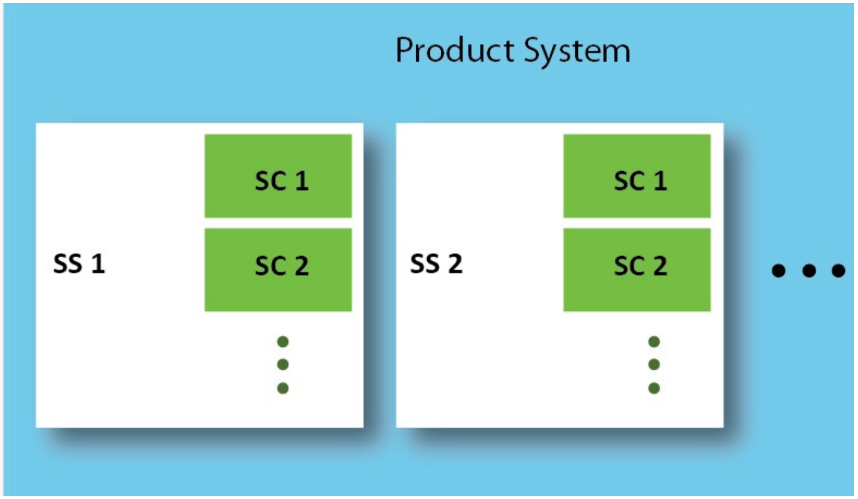
In partnership with reliability goals, the RBD is a critical tool for guiding use simulation and test plans

Reliability Block Diagram

How to calculate reliability

PS reliability = product of all SS reliability (SS1 x SS2 x SS3…)

SS reliability = product of all SC reliability (SC1 x SC2 x SC3…)



PS = product system
SS = sub-system
SC = sub-component

Reliability Block Diagram

Example – Apportionments

Basis for initial apportionment guesses during development:

- Component vendor data, past products, past experience, similar systems, etc.

- Survival likelihood (i.e., reliability) at year seven when operating at T = 25°C

SC1-80% x SC2-95% → SS1-76%

SC1-99% x SC2-90% x SC3-93% → SS2-83%

SS1-76% x SS2-83% → PS-63%

63% will make it to their seventh birthday without failure

Reliability Block Diagram

Example – Apportionments (cont.)

Activities during design and development to refine apportionment values:

- Performance and reliability simulation/modeling (i.e., Reliasoft BlockSim or Windchill RBD software)
- Empirical testing (i.e., accelerated life testing (ALT), highly accelerated life testing (HALT))

Validate apportionment predictions with beta product testing:

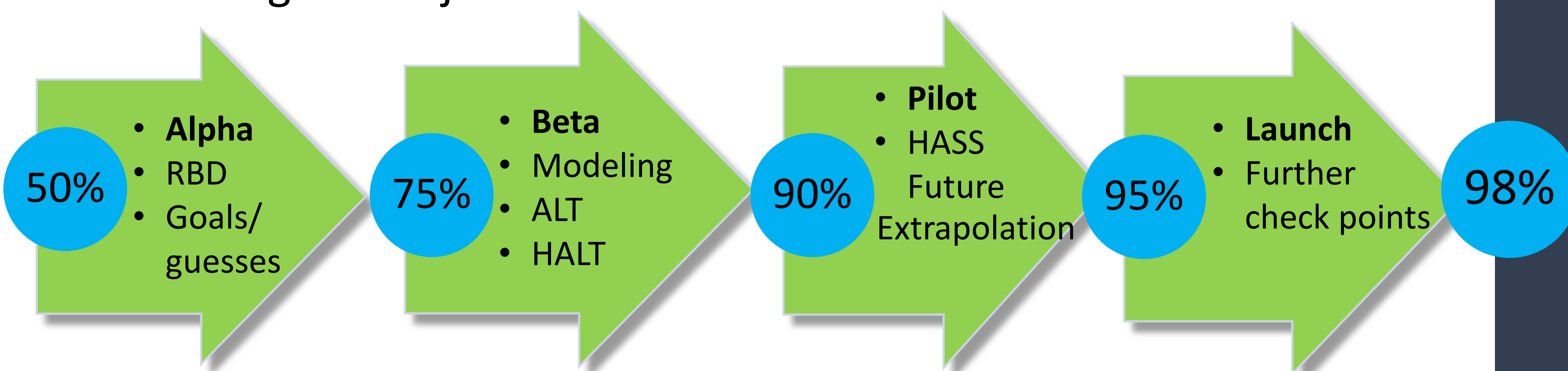
- Reliability demonstration tests (RDT)

Reliability Block Diagram

Confidence

- The confidence level that final product will meet reliability goals should increase throughout product lifecycle (example confidence numbers in figure below)
- Confidence levels and measurable data are part of decision “gates” to proceed to next build stage

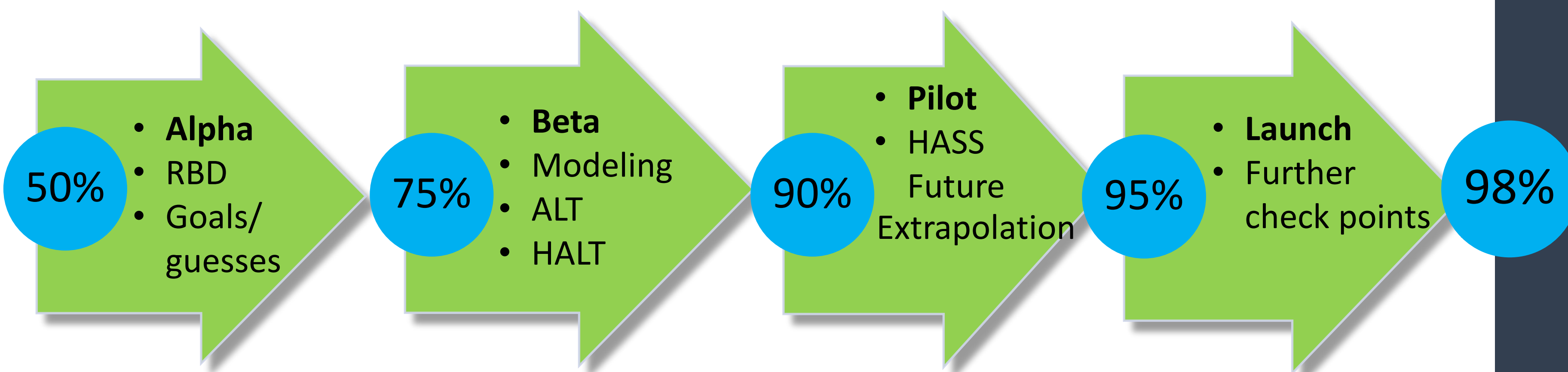
Tip: A product may require multiple alpha and/or beta version builds if “gate” objectives are not met with the first version



Reliability Block Diagram

Confidence (cont.)

- Assign proper ownership and accountability to ensure that problem identifications and corrective actions are performed early in the production cycle



Accelerated Life Testing

Basics

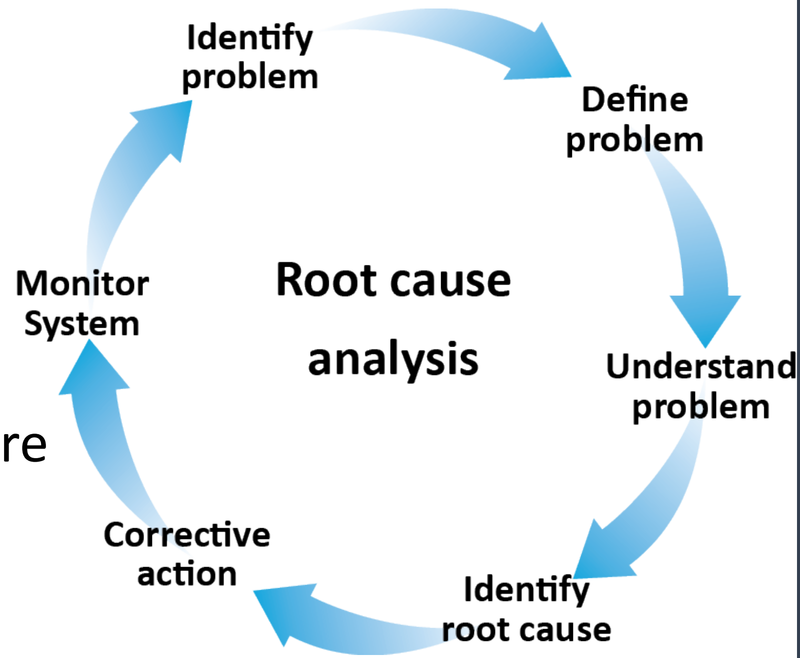
- ALT is a process of testing a product (component or subsystem) in an accelerated way to uncover failure modes quickly
- The product is subjected to various stressors (temperature, voltage, vibration, duty cycle, pressure, stress, strain, etc.) in excess of its normal operating parameters to accelerate failures

Accelerated Life Testing

Basics (cont.)

- ALT failures are followed by a root cause analysis and the options for corrective action
- Corrective actions in response to ALT failures are prioritized and then implemented in subsequent design and build cycles

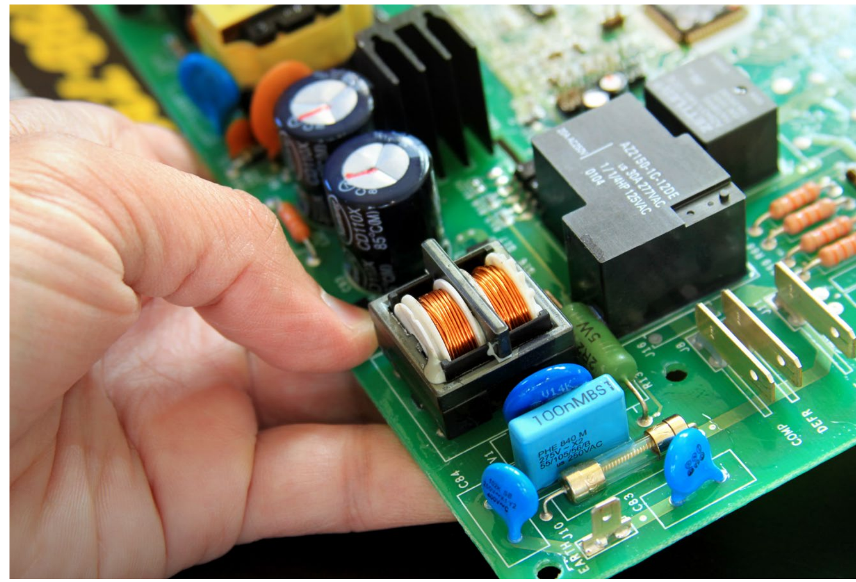
  Tip: In some cases, a product failure may not be corrected if an accelerated test failure mode is unlikely to occur in the field (each ALT failure presents an opportunity for cross-functional discussions about customer impact)



Reliability Demonstration Testing

Basics

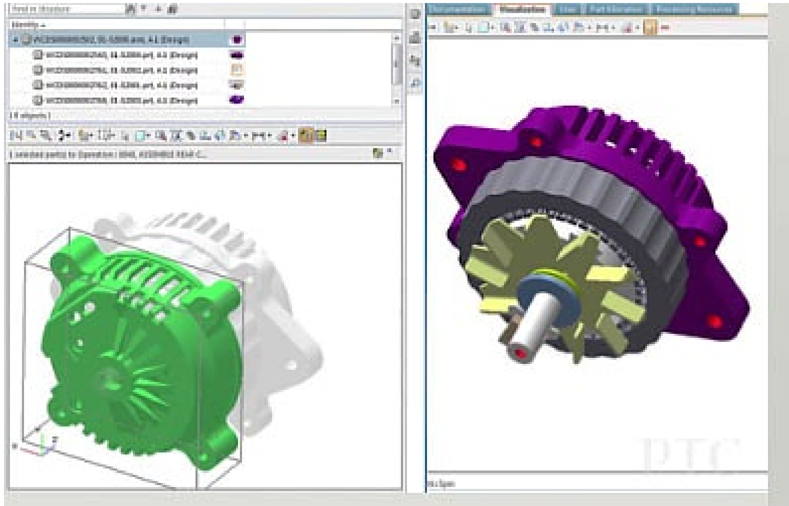
- RDT is a series of demonstrative activities used to validate confidence in a product's ability to meet its intended lifetime goals
- It is conducted before transition to pilot builds and implementation of a product's warranty/service plan
- Ideally, RDT is performed with a nearly complete product design (beta), and is built using the final manufacturing process (or as close as possible)



Modeling Software

Basics

- Electronic systems (for one example, Windchill): software to model components and conditions for predicting failures and reliability values
- Thermal, fluid, mechanical systems: extension beyond just performance modeling (i.e., with finite element software) to include failure mechanisms and predictions based on loading and use conditions
- Software systems: automated algorithm and use-case testing (i.e., typically custom developed in parallel with product software development efforts)



Physical Use Testing

Basics

- **Environment loading**: pressure, temperature, humidity, radiation, moisture, etc.
- **Electronic loading**: voltage, current, frequency, natural resonance, etc.
- **Mechanical loading**: thermal, fluid, and stress cycles
- **Functional loading**: repeated exposure through intended use functionality

Corrective Actions

Decision trade-offs

- Make engineering changes or revise goals when corrective action is required
- Alternative corrective action paths should be analyzed for impact to product cost on the BOM, warranty cost, time-to-market, etc.
- Additional investment efforts should add market value to product (market differentiation, customer satisfaction, etc.)

Corrective Actions

Decision trade-offs (cont.)

Every decision has cost implications:

- Qualitative or quantitative performance testing
- What data to collect? (e.g., functionality values, property measurements, and environment parameters)
- Automated or manual processes?
- Destructive or non-destructive tests? (x-ray, ultrasound, etc.)

Tip: During pre-launch testing, the goal is to take every test to eventual product failure in order to investigate root causes for potential corrective action. The only reason for non-destructive testing at this stage is to collect mid-life data points, or to prepare for post launch inspection procedures.

List Of Terms

In glossary

- **Engineering Validation** measures and analyzes the process, audits and calibrates equipment and creates a document trail that shows the process leads to a consistent result to ensure the highest quality products are produced. (Repeat from 2C)
- **Design Validation** is testing aimed at ensuring that a product or system fulfills the defined user needs and specified requirements, under specified operating conditions.
- **Feasibility** is the process in product life cycle which first translatesfeasible ideas into technically feasible and economically competitive product concepts, and then produces product concept through concept generation and selection. Two commonly used techniques to decide the best design candidate are design-to-cost and life-cycle-cost analyses. (Repeat from 2B)
- **Development** - The systematic use of scientific and technical knowledge to meet specific objectives or requirements.
- **Qualification** is either the process of qualifying for an achievement, or a credential attesting to that achievement
- **Manufacturing Development** or Engineering & Manufacturing and Development (EMD)phase is where a system is developed and designed before going into production. (Repeat from 2B)
- **Manufacturing Capability process** is a unique combination of tools, materials, methods, and people engaged in producing a measurable output; for example a manufacturing line for machine parts. All processes have inherent statistical variability which can be evaluated by statistical methods. (Repeat from 2B)
- **Field Readiness** is the stage of development just prior to final launch. It is time to review the Pilot run and determine if there are any “game stopper” issues. (Repeat from 4A)
- **Infant Mortality Failures or Early Failure Rate** is caused by defects designed into or built into a product and are completely unacceptable to the customer. To avoid infant mortalities appropriate specifications, adequate design tolerance and sufficient component derating can help, and should always be used, but even the best design intent can fail to cover all possible interactions of components in operation. In addition to the best design approaches, stress testing should be started at the earliest development phases and used to evaluate design weaknesses and uncover specific assembly and materials problems. (Repeat from 3E)

List Of Terms

In glossary (cont.)

- **Random failures** - Defect or failure whose occurrence is unpredictable in absolute sense, but is predictable in a probabilistic or statistical sense.
- **Wear Out Failures** are identified when failure is no longer random and greater than specified acceptability usually caused by stress exceeding strength. Wear Out Failures are characterized by an increasing failure rate with failures that are caused by the "wear and tear" on the product over time. (Repeat from 3E)
- **Simulation** - is the imitation of the operation of a real-world process or system over time.
- **Reliability Block Diagram (RBD)** - is a diagrammatic method for showing how component reliability contributes to the success or failure of a complex system.
- **Accelerated Life Testing** is the process of testing a product by subjecting it to conditions (stress, strain, temperatures, voltage, vibration rate, pressure etc.) in excess of its normal service parameters in an effort to uncover faults and potential modes of failure in a short amount of time.
- **Environment Loading** is testing product under the conditions in which it will receive in its final environment which may include pressure, temperature, humidity, radiation, moisture, etc.
- **Electronic Loading** is testing product under the conditions in which it will receive in its final environment which may include voltage, current, frequency, natural resonance, etc. To protect the power devices from damage, electronic loads usually have a pre-settable power limit.
- **Mechanical Load Testing** is to verify that all the component parts of a structure including materials, base-fixings are fit for task and loading it is designed for. Static testing is when a designated constant load is applied for a specified time and may be under the influence of thermal, fluid, and stress cycles.
- **Functional Load Testing** is focused on functional requirements of the product or system and done in accordance with your performance specifications or that of your customer.