Reliability from Design Inception to Product Retirement

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Scope of Presentation

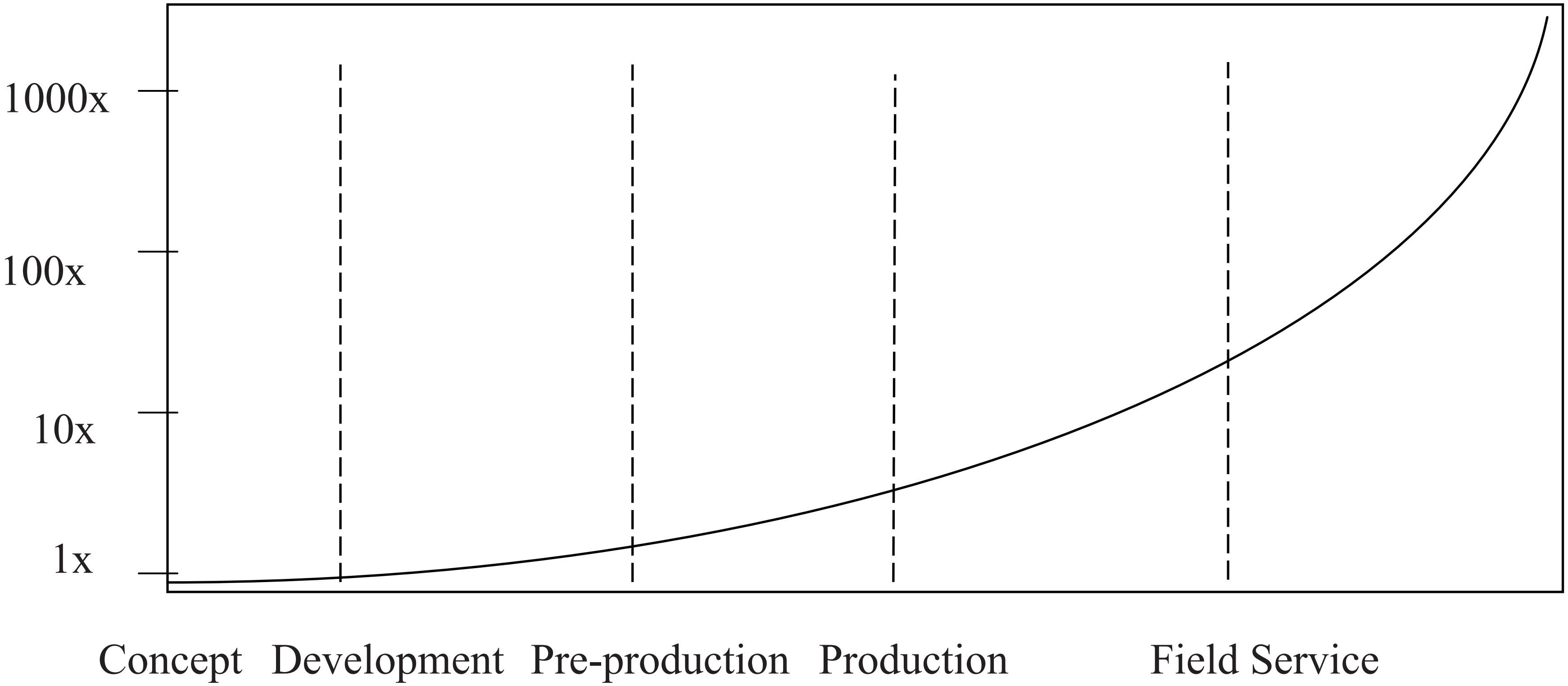
In this presentation, an outline of a cohesive structure for reliability throughout a product's life cycle is presented including the appropriate location and use of:

1. The Over Stress Tests,
2. Design Reviews,
3. FMEAs,
4. Reliability System Analysis,

Scope (Cont.)

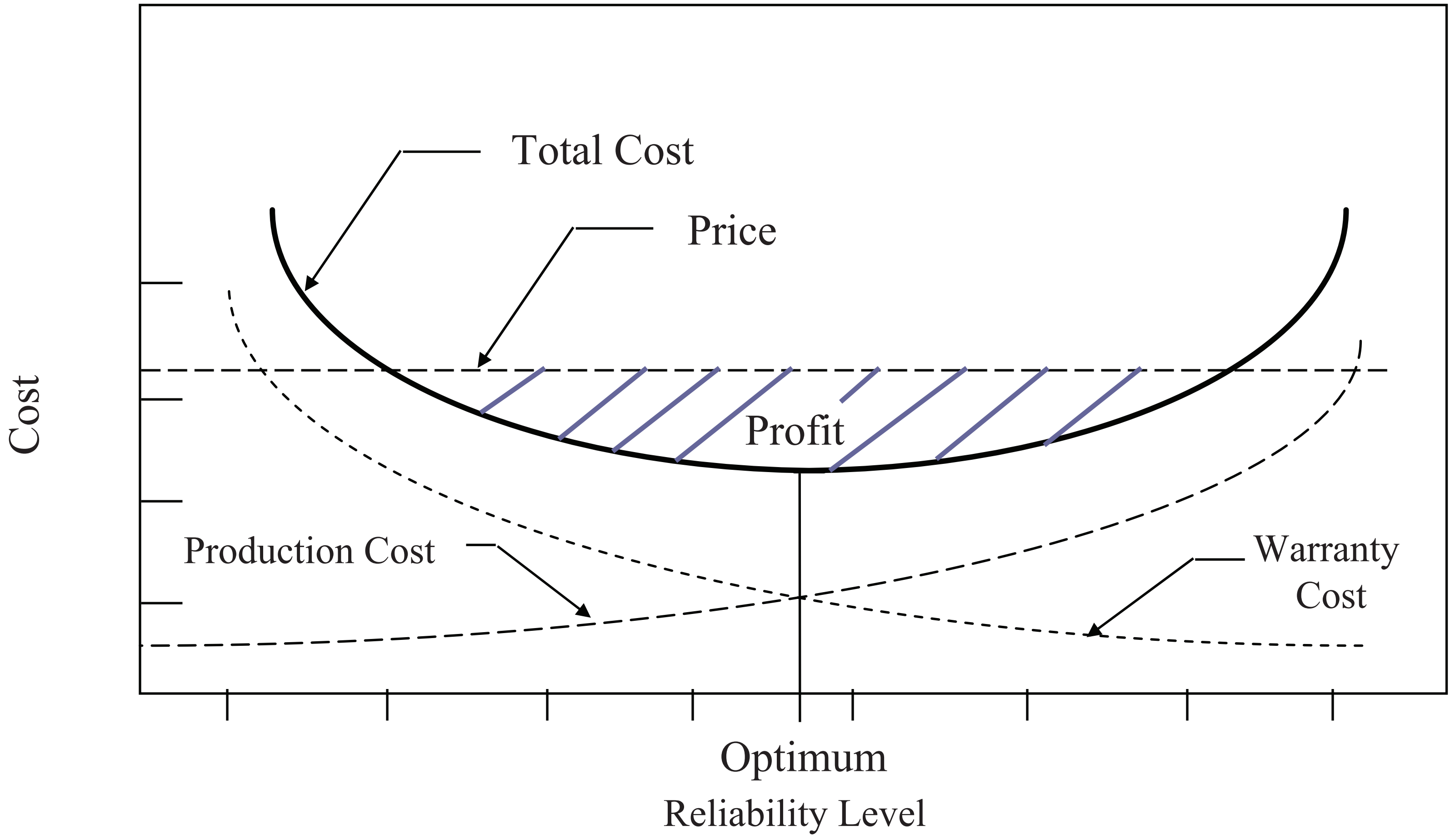
5. Accelerated Life Tests,
6. Real Time Life Tests,
7. Reliability Growth Tests, Burn-In
8. Field failures
9. Engineering change orders

Corrective Action Cost as a Function of Design Phase



The Earlier A Reliability Improvement Is Implemented,
The Lower The Cost Of The Corrective Action.

Figure 2, Impact of Reliability on the Producer



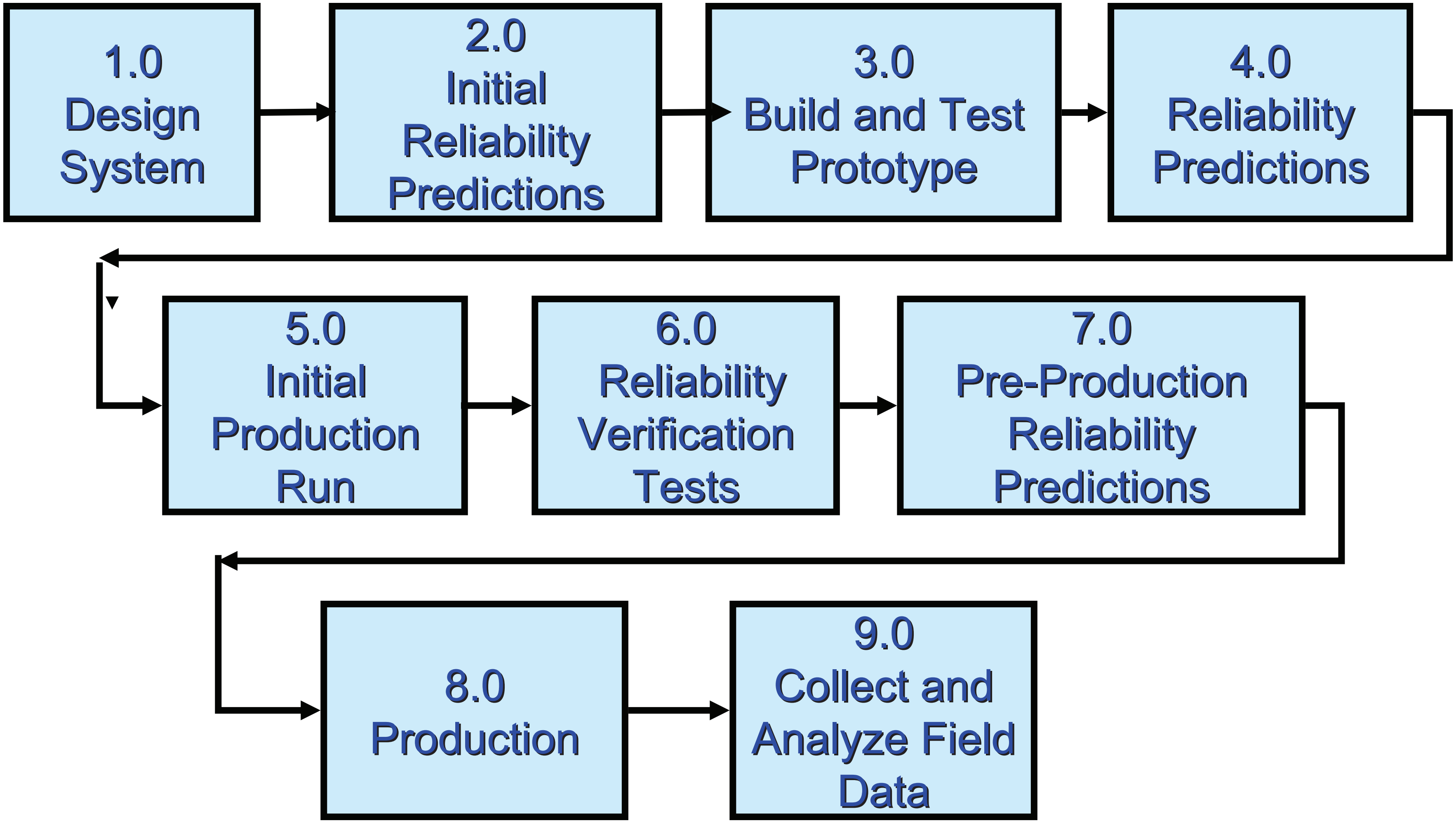
Highest Reliability Is Not Necessarily the Most Economical

Cost Benefit of Investment in Reliability

- A 5% increase in **Reliability Focused** development costs will return a 10% reduction in warranty costs.
- A 20% increase in **Reliability Focused** development costs will typically reduce warranty costs by Half.
- A 50% increase in **Reliability Focused** development costs will reduce warranty cost by a factor of Five .

Reference: The Cost and Benefits of Reliability in Military Equipment, Rand Corp, 1988

Reliability from Design Inception to Product Retirement



1.0
Design
System

2.0
Initial
Reliability
Predictions

3.0
Build and Test
Prototype

4.0
Reliability
Predictions

5.0
Initial
Production
Run

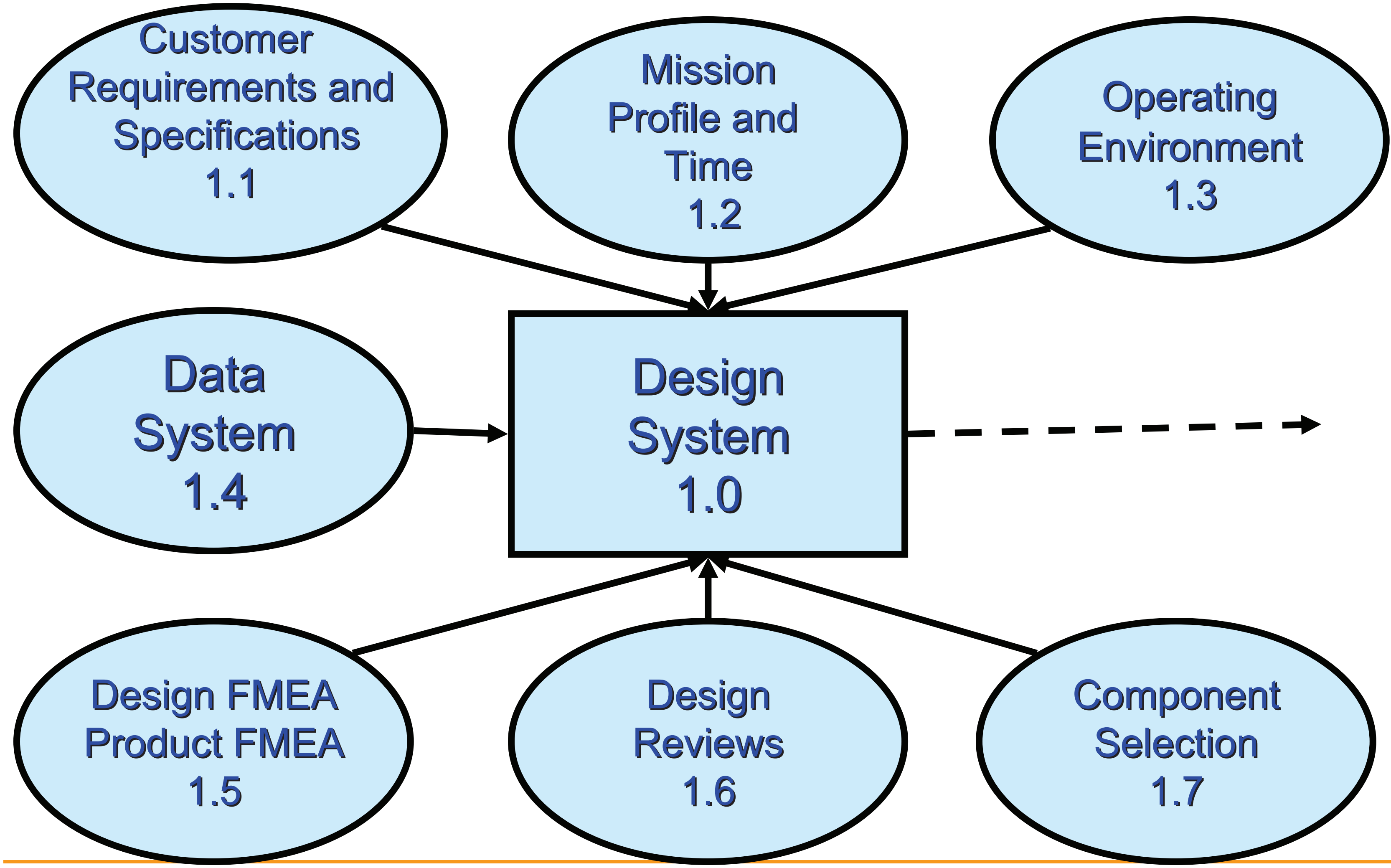
6.0
Reliability
Verification
Tests

7.0
Pre-Production
Reliability
Predictions

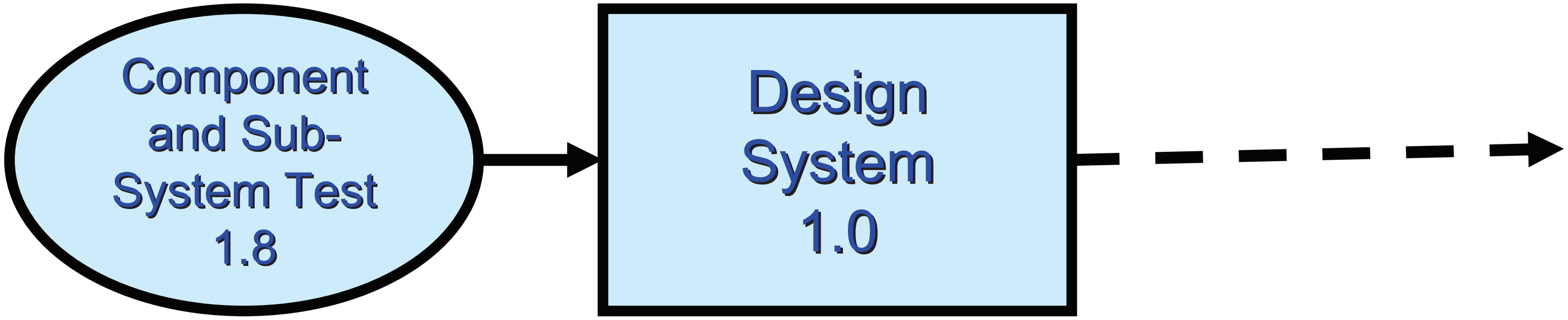
8.0
Production

9.0
Collect and
Analyze Field
Data

Design System 1.0



Design System, 1.0 Cont.



Customer Requirements and Needs, 1.1

- Reach a common understanding between buyer and supplier of reliability expectations early in relationship.
- Make reliability a high priority requirement in each specification development.
- Establish an agreed on mission profile, mission time and operating environment.
- Insure that both buyer and supplier recognize the cost of poor reliability.
- Understand that reliability is a long-term goal.

Mission Time 1.2

Mission time has to be measured in appropriate units. Some appropriate units are:

- Electronic devices - operating hours.
- Light bulbs - operating hours and on-off cycles.
- Hydraulic valves - actuations.
- Cars and trucks - miles.
- Airplanes - hours and up-down cycles.
- Others.

Example Mission Profile, 1.2

- The more information provided in the mission profile that is integrated into the design process, the more reliable the product.
- The following is a hypothetical example of a mission profile for valve designed to control the flow of oil from an underwater well head:

Example Mission Profile, 1.2 Cont.

1. The oil that flows through the valve is grit laden.
2. The oil temperature is 300 to 350 deg. F.
3. The relative oil pressure is 400 to 450 psi.
4. The oil flows at 100 to 120 ft. per sec.

Example Operating Environment, 1.3

The operating environment is sometimes more important than the mission profile as it has a greater effect on device life than mission profile. This is often the case for electronics. The following hypothetical example incorporates some of the *worst* possible operating conditions for an electronic device.

Example Operating Environment, 1.3 Cont.

The device is a controller for a radar in Alaska. It is mounted externally to the actual radar and controls the electric motors that determine the orientation of the radar.

1. The controller operates in an environment where the temperature varies from -60 to 105 deg. F..
2. The relative humidity can vary from 10% to 100%.

Example Operating Environment, 1.4 Cont.

3. The controller is subjected to acoustically generated broad band random vibration and low frequency sinusoidal vibration.
4. The controller operates in a salt spray and wind blown snow environment.

Mission Profile and Operating Environment, 1.2 - 1.3

Information on the mission profile and operating environment is best obtained by actual measurement, but this is not always possible. Hence, sources such as past history of similar products and expert opinion may have to be used. The more accurate the operational data, the more reliable the product will be.

Reliability Data System 1.4

A data acquisition system is an integral part of reliability design. All available in-house and externally available reliability data should be used in system design and for predicting the hazard rate (failure rate) and/or the reliability of components, subsystems, or systems.

Reliability Data System, 1.4 Cont.

- In-house reliability lab test reports.
- Field service reports on similar products.
- Safety analysis reports.
- Failure analysis reports.
- Manufacturing records.
- Quality control records.
- Suppliers of quality components.
- MIL-HDBK-217, etc.
- Others.

FMEA/FMECA, 1.5 Cont.

FMEA is a tool that has been adapted in many different ways for many different purposes. It can contribute to improved designs for products and processes resulting in higher reliability, better quality, increased safety, and reduced costs.

FMEA/FMECA, 1.5 Cont.

Failure modes can be described functionally and the functional system model can be analyzed early in the design phase of a product or process. Several software packages are available to aid in conducting FMEAs, such as the one by ReliaSoft.

Design Review Teams 1.6

- After a subsystem or system is designed the designers should present the design, with emphasis on why it will work, to a group of experienced engineers, including some from the outside,
- The review team should review the design in concert with a list of problems that have occurred in previous similar products.

Design Review Teams, 1.6 Cont.

- Design reviews are different from FMEAs in that they concentrate on actual physical functionality of the product.
- The primary objectives of design review teams are to obtain functionally superior and more reliable products at lower costs.

Component Selection, 1.7

- Since hardware reliability is a function of component reliabilities and their fitness for the task, component choice cannot be overemphasized.
- The choice is often between standard parts, which just meet the requirements, or special parts, which theoretically exceed the requirements but are unproven.

Component Selection, 1.7 Cont

- Component selection should be based primarily on in-house data on similar components.
- If information is not available on past similar components, derating or over-specification is dictated.
- If components are standard parts, estimated failure rates can sometimes be found in manufacturer's handbooks, commercial databases, or *Mil-Std Handbooks*.

Component Selection, 1.7 Cont.

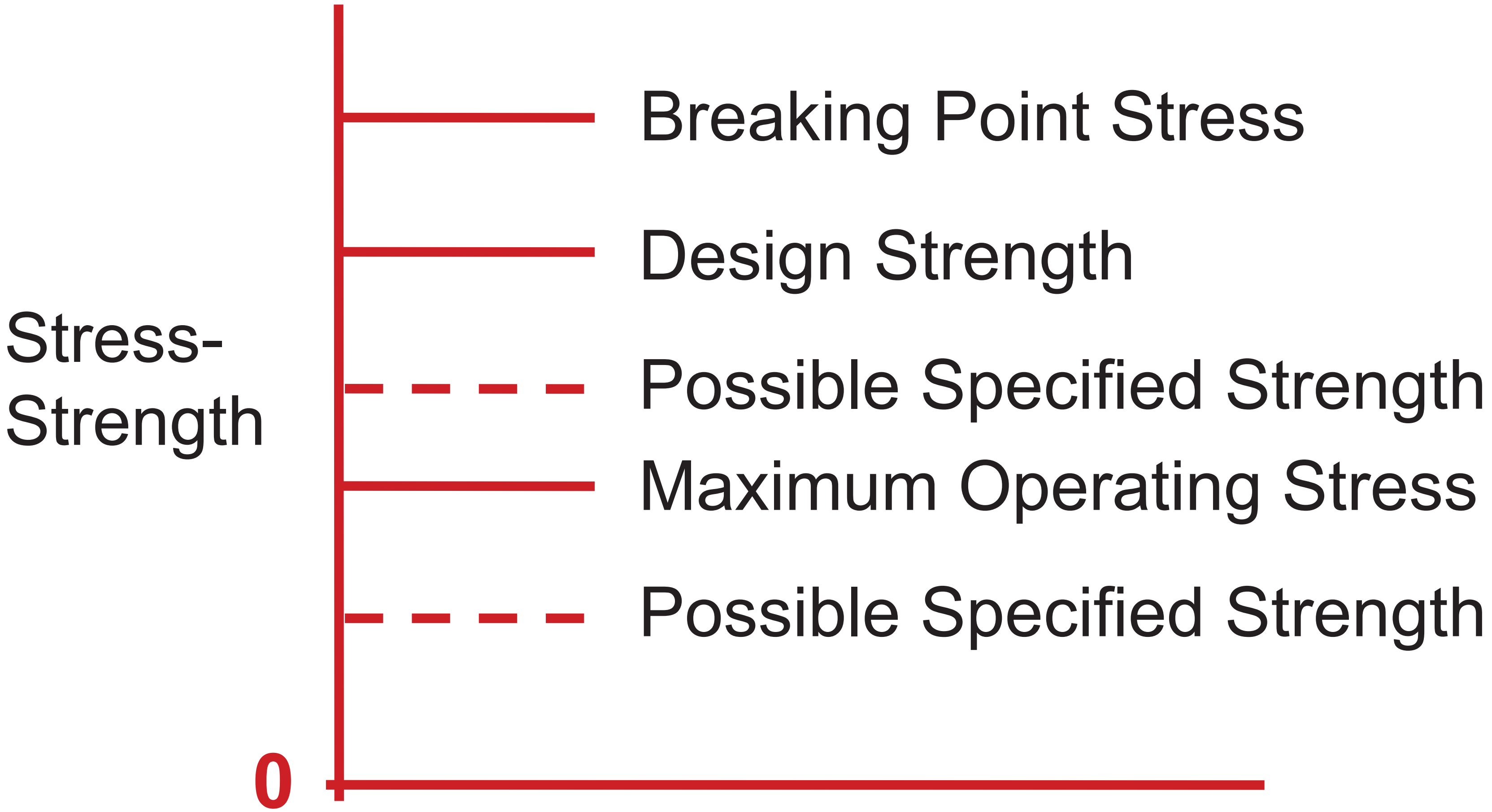
- All critical components and those where problems have occurred in the past should be subjected to component over-stress testing.
- The location of all components and sub-systems in the box should be reviewed to insure that the components most likely to fail are the most accessible.
- A high time-to-failure and a low time-to-repair are critical to high system availability.

Tests During Design, 1.8

The primary purposes of reliability and reliability related tests, conducted during the product design phase, are to:

1. Identify design changes necessary to insure a reliable product
2. To identify the stress levels necessary to cause failure (breaking point stress)
3. This latter knowledge is critical when designing the Accelerated Life Tests (ALTs) that come after design completion.

Hypothetical Stress-Strength Relationship



Stress-
Strength

Breaking Point Stress

Design Strength

Possible Specified Strength

Maximum Operating Stress

Possible Specified Strength

0

Types of Tests During Design, 1.8 Cont.

There are two primary types of reliability tests used during the design process. These are:

- Subsystem and system Highly Accelerated Life Tests (HALT),
- Component Over-Stress Tests.

These tests are similar in concept, but are performed at different times in the product design and consequently have somewhat different objectives.

Tests During Design, 1.8 Cont.

- Both of these types of tests are qualitative, not quantitative. They are intended to improve the product design, not provide direct reliability estimates.
- If well designed they should provide critical information necessary to design the subsequent quantitative tests.

Component Overstress Tests, 1.8 Cont.

- Component over-stress tests are conducted early in the design cycle. Hence, they cost less than subsystem and system level tests and can be run relatively quickly.
- All critical components should be over-stress tested and their strength improved to where it is considerably above the maximum operating stress level.

System and Subsystem HALT, 1.8

- HALT are conducted at the subsystem and systems levels. Because they occur further along in the product design process, they are more complex and cost more to conduct than component over-stress tests.
- If all components have been adequately over-stress tested, a HALT should identify only interface problems such as weak connectors, bad solder joints, incorrect tolerances and others.

Reliability Tests During Design, 1.8 Cont.

- After failure occurs, a failure mode analysis should be conducted.
- The product design should be improved to incorporate the changes dictated by the results of the over-stress tests and the subsequent failure mode analysis.
- The entire process should then be repeated until the product demonstrates that it meets or exceeds its design strength.

Tests During Design, 1.8 Cont.

- The first step in designing a HALT, or any other reliability-related test, is to take time to make sure that all factors have been considered.
- Time and money spent on a thorough test analysis and design will result in less costly tests that yield more information critical to a reliable design.

Tests During Design, 1.8 Cont.

- If frequent component failures occur during the HALT, the components have not been adequately over-stress tested.

- In the author’s opinion, HALT should use step-stress multi-environment tests, simultaneously incorporating all the stresses likely to occur in a product’s operation.

Tests During Design, 1.8 Cont.

- However, for complex products subjected to multiple stresses during operation, this may not be feasible due to the test complexity, the cost of running the test and the cost of building the test equipment to perform the test.
- In this situation, engineering analysis must determine which stress factors have to be tested simultaneously and which can be tested independently.

Tests During Design, 1.8 Cont.

- If a significant interaction effect occurs between the stresses, these stresses must be included in the same HALT.
- An example of such an interaction is a device that is subjected to both high pressure and extremely high temperatures during operation, such as superheated steam pipes.

Tests During Design, 1.8 Cont.

- The interaction is the reduction of strength, caused by the high temperatures, that causes a pressure induced failure. Hence, both temperature and pressure must be applied simultaneously

Product Design Strength

- Product design strength is initially established by analysis, and when possible, verified by component over-stress tests and subsystem and system HALT tests.

- The component over-stress tests and sub-system and system HALT tests should be designed looking forward to the Reliability Verification Tests.

Example Test, 1.8 Cont.

As a hypothetical example of a component level test procedure, consider the mission profile for the control valve previously described.

1. The oil that flows through the valve is grit laden.
2. The oil temperature is 300 to 350 deg. F.
3. The relative oil pressure is 400 to 450 psi.
4. The oil flows at 100 to 120 ft. per sec.

Example Test, 1.8 Cont.

- Engineering analysis concluded that there is also one critical operational environmental factor. Ocean currents cause flexing of the pipes that lead into and out of the valve.
- There are several questions that must be resolved by engineering analysis before a test is designed.

Example Test, 1.8 Cont.

1. Can and should any of these factors be eliminated from consideration?
2. Do any of these factors interact?
3. Is it physically possible and economically feasible to perform tests that include all the factors not previously eliminated by engineering analysis?

Example Test, 1.8 Cont.

Some of these might be eliminated from consideration as follows:

1. The pipe flexing problem could be resolved by attaching the pipes to the frame, but this must be done in a way that does not cause a compression/expansion problem due to external and internal temperature variation. If this temperature variation is small it may be ignored.

Example Test 1.8 Cont.

2. Engineering analysis indicates that oil temperature is not a significant factor, hence can be excluded.
3. Engineering analysis has concluded that test grit level can be kept constant, and a level is selected 20% above the measured maximum operating level.

Example Text, 1.8.

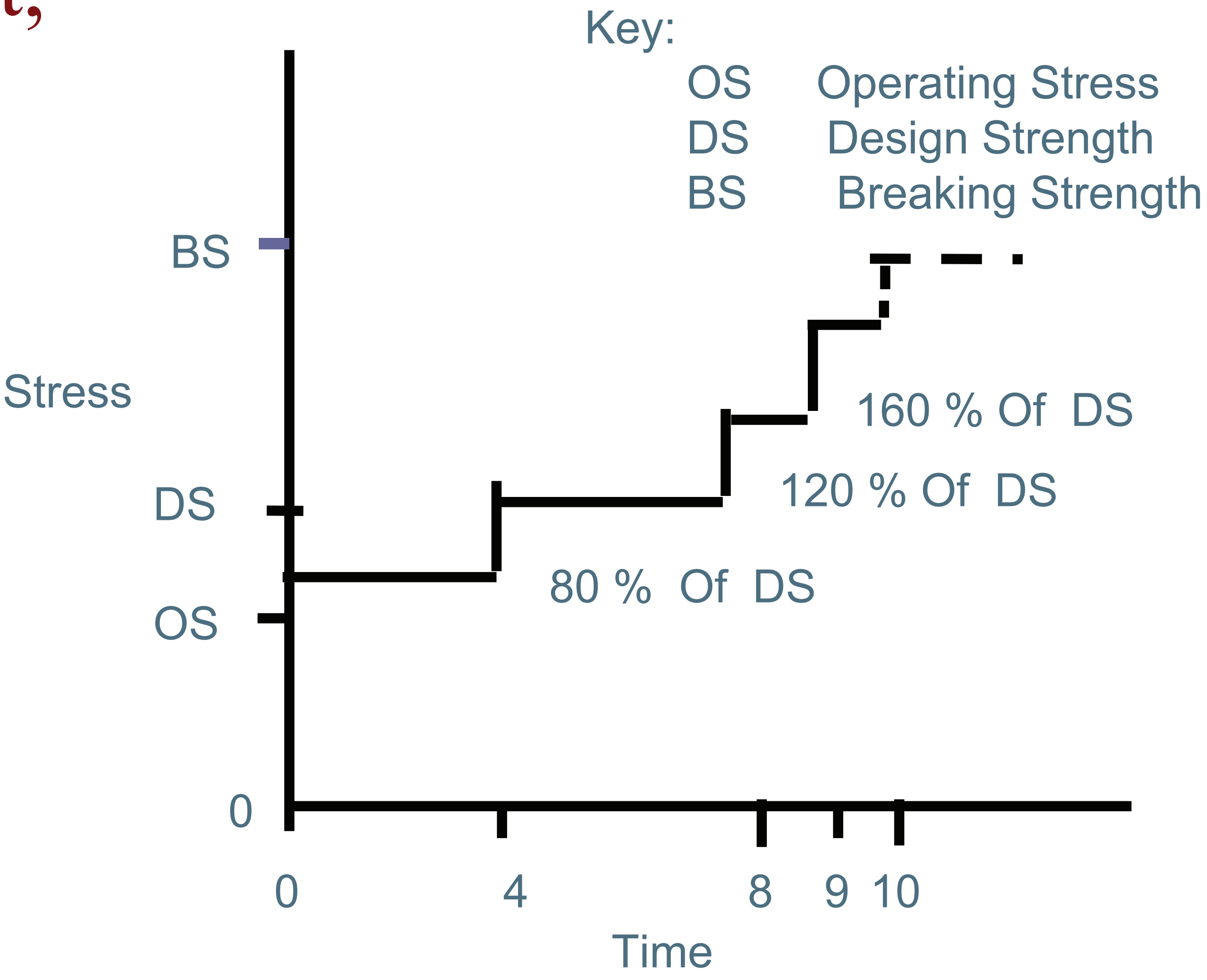
Hence, the only three factors that need to be considered in the over-stress test design are:

1. Oil pressure,
2. Oil velocity,
3. Grit level (constant)

Example Test, 1.8 Cont.

In the author's opinion, the following is a realistic hypothetical test design. Five components will be subjected to over-stress testing. Since oil pressure and oil velocity are physically dependent factors, they will be ramped up at the same time.

Example Step Stress Over-Stress or HALT Test,



Example Test, 1.8 Cont.

Testing is continued until all components fail or a component fails below the design strength. If a component fails below the design strength, testing is stopped, a failure mode analysis is conducted and corrective action is taken. This corrective action must result in a product design change or a manufacturing process change.

Example Test, 1.8 Cont.

The test sequence will be repeated with five new components that incorporate the changes instituted during corrective action. If all additional failures occur above the design strength, testing is stopped and the design is frozen. If no failures have occurred and testing has reached levels of 200% of design strength, testing is also stopped and the design frozen.

A Reliability Oriented Design Program

The following is a recommended list of the steps that should be taken to improve the reliability of products. It is organized in the sequence that each will occur in the life of a system. Each of these items should be converted to detailed instructions and/or actions to meet the specific needs of a particular system.

A Reliability Oriented Design Program (Cont)

1. Management must understand and support the effort.
2. Technicians and Engineers must receive training in the rudiments of applied reliability.
3. An in-house reliability database must be established that includes failure rates of components, their mission profile and operating environment.

A Reliability Oriented Design Program (Cont)

4. Both subsystem and system designs should be subject to FMEA.
5. After problems identified in the FMEA are addressed, the subsystem or system design should be subjected to a comprehensive design review.
6. To obtain an independent perspective, the review teams should include members that are not on the design team. The use of outside experts is usually cost effective.

A Reliability Oriented Design Program (Cont)

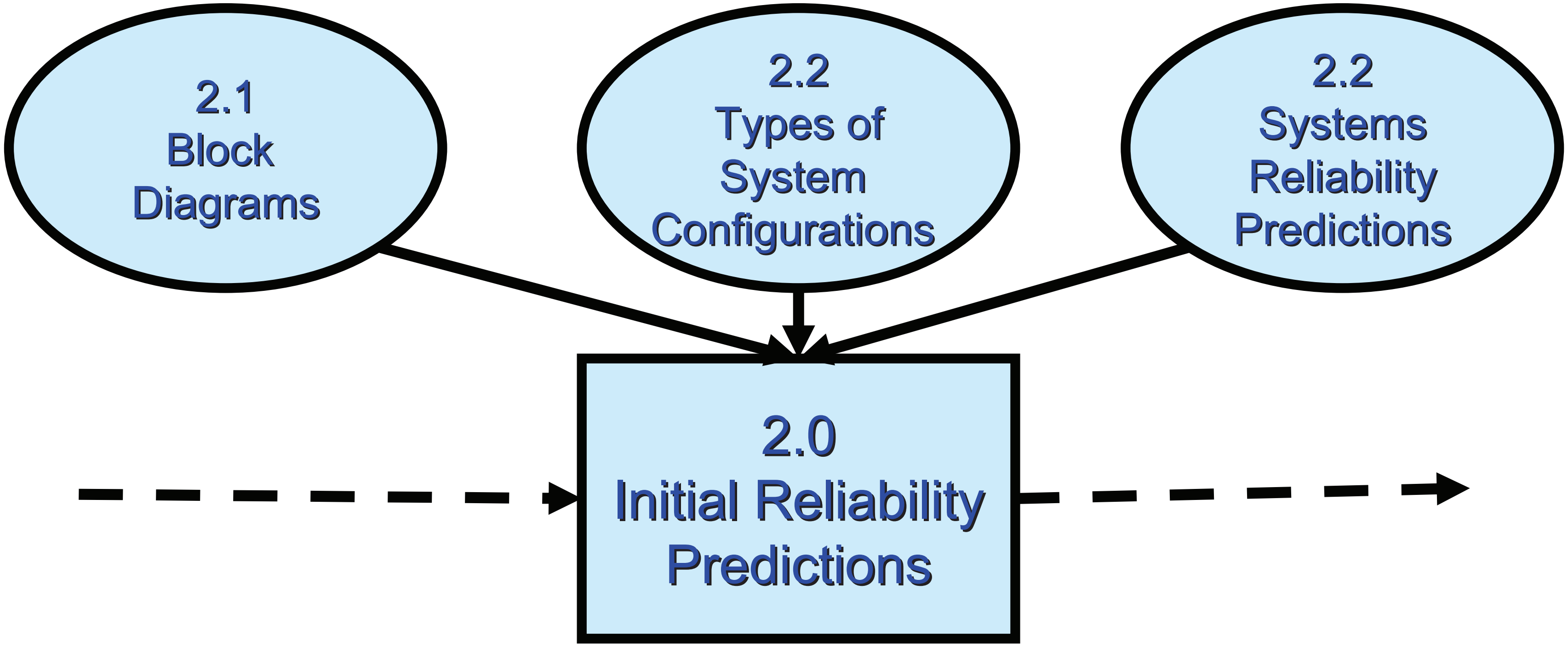
7. Components that need preventive maintenance should be readily accessible.
8. Component selection should be based primarily on in-house data on similar components. If information is not available on past similar components, over-specification is dictated.

A Reliability Oriented Design Program (Cont)

9. All critical components and those where problems have occurred in the past should be subjected to over-stress testing.
10. The location of all components and subsystems in the box should be reviewed to insure that the components most likely to fail are the most accessible. A high time-to-failure and a low time-to-repair are critical to high system availability.

Initial Reliability Predictions 2.0

Initial Reliability Predictions, 2.0

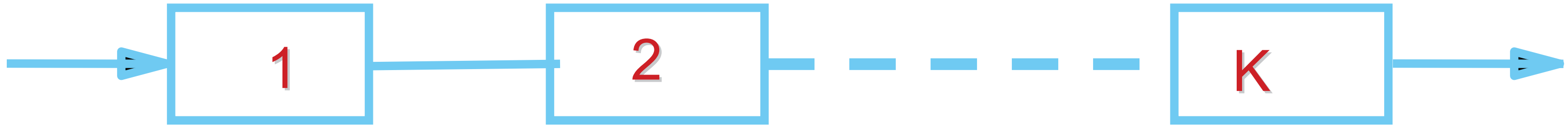


Block Diagrams, 2.1

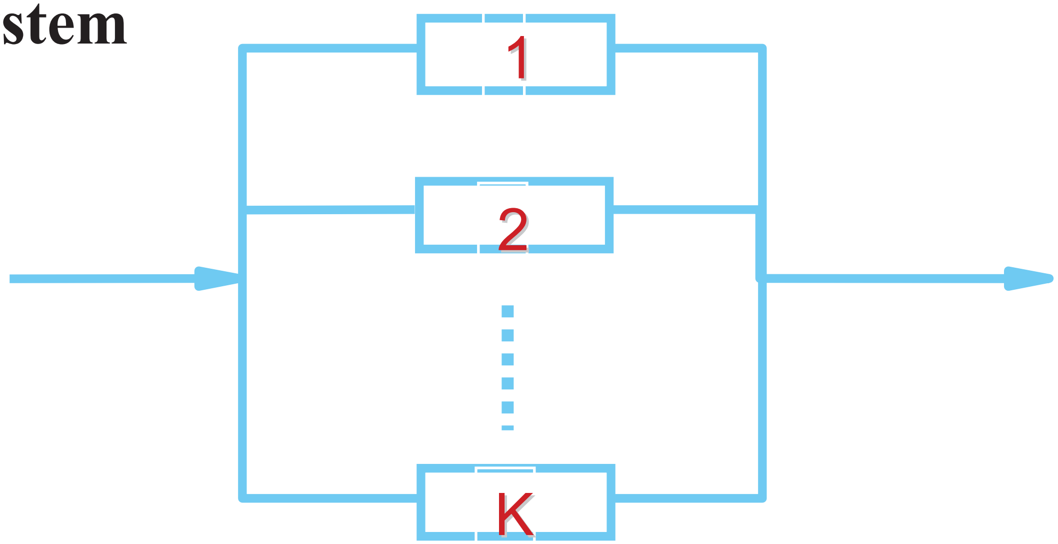
The system design reliability block diagram describes relationships between the system, its subsystems and/or components. The diagram aids in setting up the subsystem reliability goals, identifying methods of reliability improvement and obtaining system reliability estimates.

Types of System Configurations

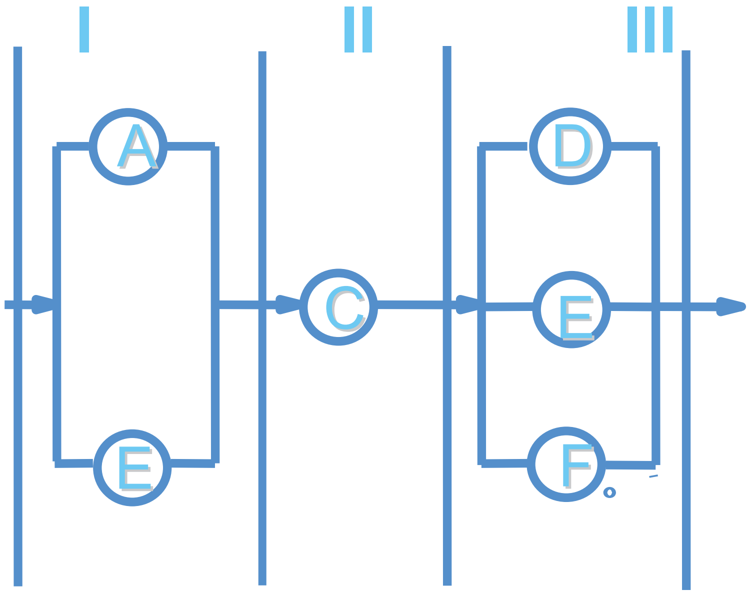
Series System



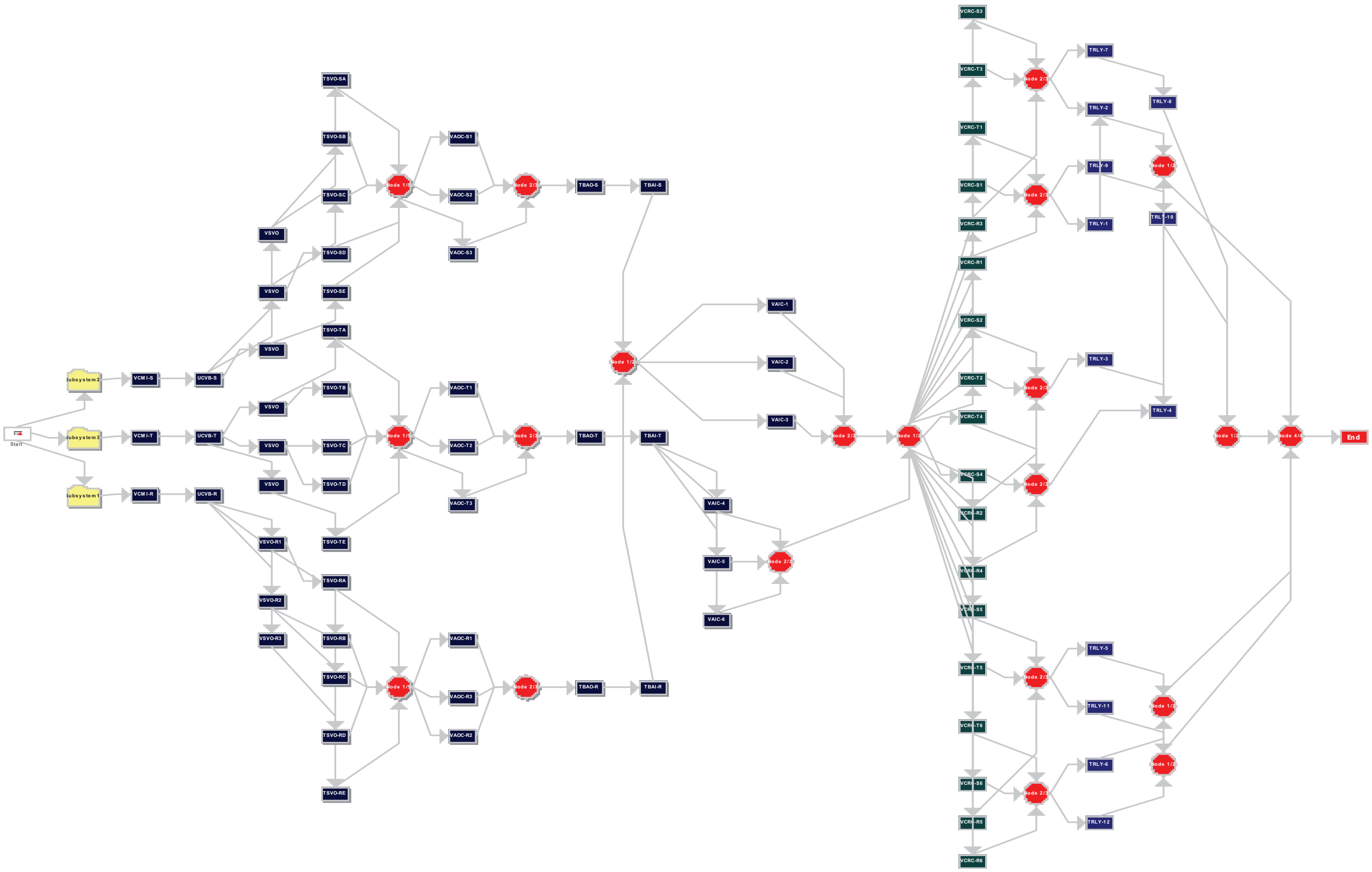
Parallel System



Parallel Series System Reliability Diagram



Complex Configuration



System Level Reliability Predictions

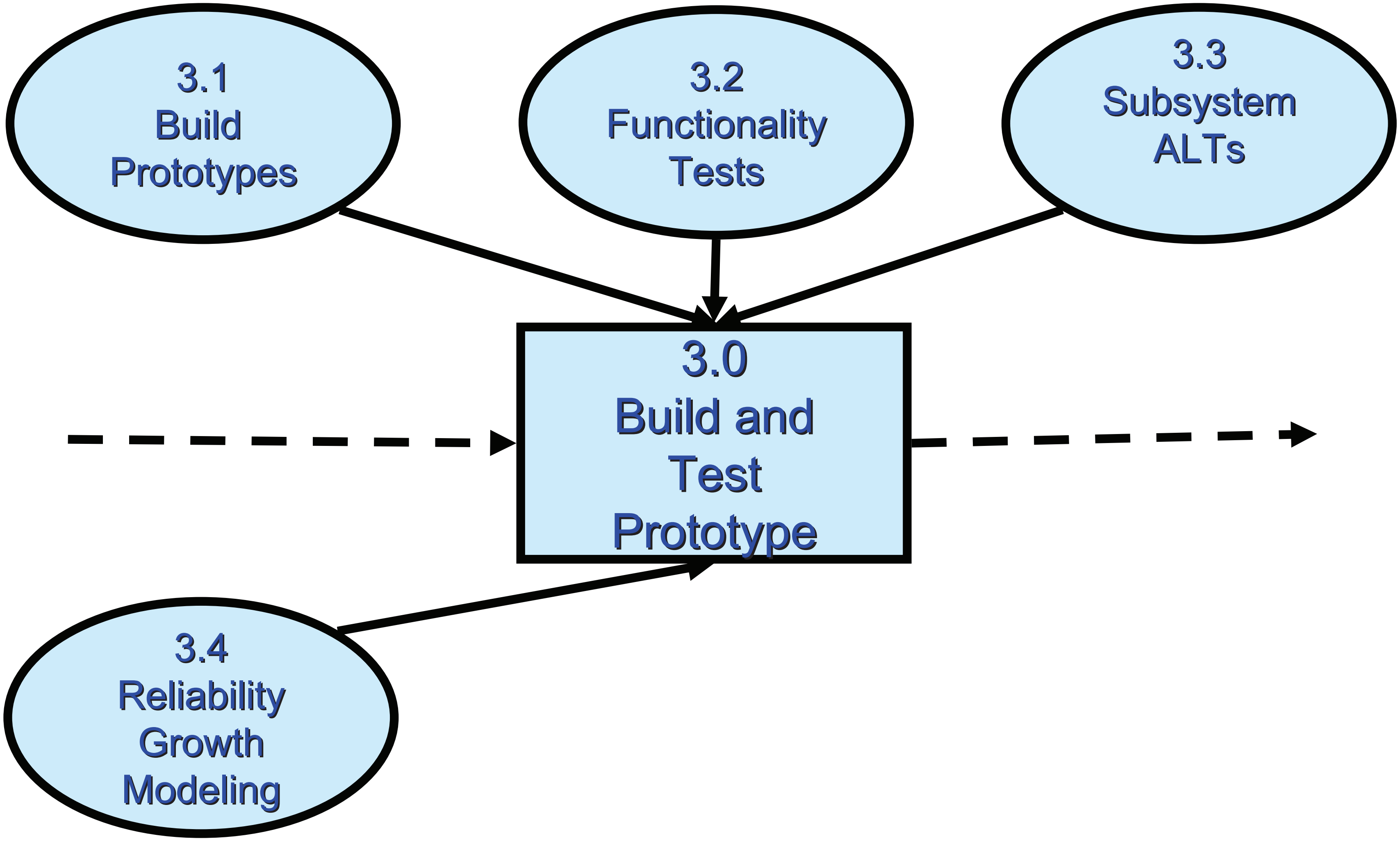
- Once a system level reliability block diagram is developed and component selection and testing is done, the component and/or subsystem reliability estimates can be incorporated in the system level block diagram to obtain a system level reliability prediction.
- There are several commercially available computer software packages to aid in System Reliability calculations. ReliaSoft's BlockSim is the newest and most comprehensive of these packages.

Systems Level Reliability Predictions, 2.0 Cont.

- When a system level estimate is obtained in this manner, there is always the possibility of interface failures that occur in the connections between components and/or subsystems.
- The overall system reliability and maintainability results from the inherent reliability of chosen components, their quantity, the method of interconnection, and the configuration - this is referred to as the *Design Reliability*.

Build and Test Prototype 3.0

Build and Test Prototype, 3.0



3.1
Build
Prototypes

3.2
Functionality
Tests

3.3
Subsystem
ALTs

3.0
Build and
Test
Prototype

3.4
Reliability
Growth
Modeling

Build Prototypes, 3.1

- The reliability and maintainability achieved in the field are usually less than the theoretical design levels and often less than the levels demonstrated during laboratory life tests.

- The primary consideration in building prototypes is to make them as similar as possible, physically, to the systems that will eventually come off the manufacturing line.

Functionality Tests, 3.2

- Comprehensive system level functionality testing is mandatory on prototype systems.
- It may not be possible to demonstrate reliability in the laboratory, but it is usually possible to demonstrate that the system will perform its intended function in the field.
- A test design team should be constituted to insure all possible in-the-field scenarios are incorporated. Emphasis should be placed on the likely sequencing of events.

ALT Tests, 3.3

- In the design of an ALT, knowledge of the product design strength relative to its mission profile and operating environment is critical.
- To obtain a reasonable acceleration factor, the product design strength must be considerably higher than the operational stress.

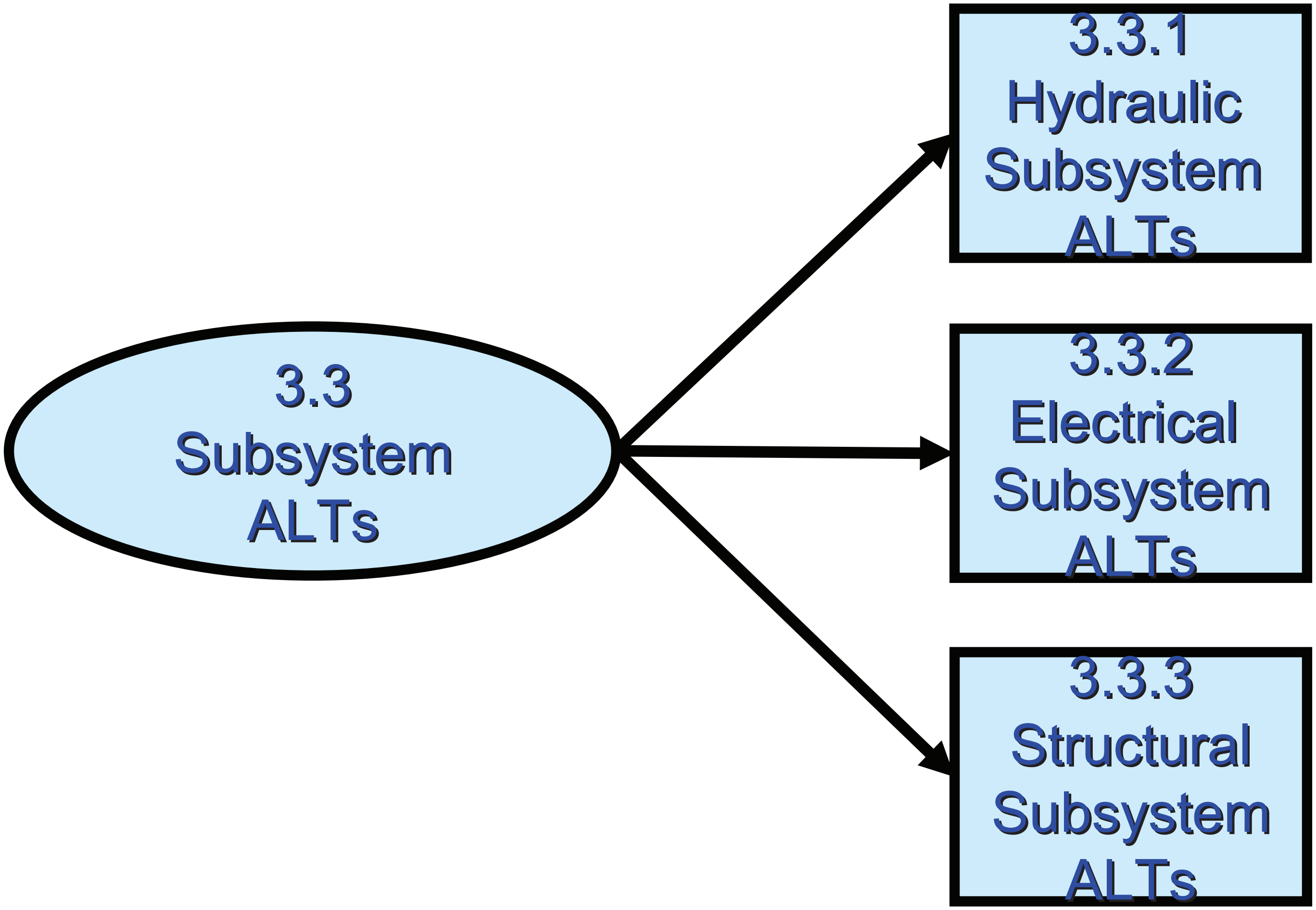
ALT Tests, 3.3 Cont.

- The tests are designed with test levels above the operational stress, but not much higher than the product design strength.
- Every different product will require an ALT designed to simulate its actual operational environment and mission profile.
- Some stress factors in the operational stress profile may be eliminated in the ALT design by an engineering analysis that indicates they are not likely to contribute to product failure.

ALT Tests, 3.3 Cont.

- The two primary types of ALTs covered in this report are increased stress tests and time compression tests.
- In a time compression test, the device is cycled at a significantly higher rate than the operational rate thus reducing the time necessary to cause failure.
- In an increased stress ALT, the test stress levels are significantly above the operating stress levels thus reducing the time necessary to cause failure.

Example of Subsystem Level ALT, 3.3


3.3 Subsystem ALTs

3.3.1 Hydraulic Subsystem ALTs

3.3.2 Electrical Subsystem ALTs

3.3.3 Structural Subsystem ALTs

Mission Profile, 3.3 Repeat

The following is a hypothetical example of an ALT for a hydraulic-actuated valve designed to control the flow of the oil from an underwater well head:

Hydraulic System Time Compression Example, 3.3.1

- The test will consist of cycling the hydraulic device at the highest rate that still insures correct operation.
- The ratio between the operational cyclic rate and the laboratory cyclic rate determines the acceleration factor.
- The system should be operating during the test and the test profile should simulate the actual operational environment.

Hydraulic Systems ALT Pressure Tests 3.3.1 Cont.

The primary accelerating factors are:

1. oil temperature and pressure
2. oil velocity and abrasiveness

The actual levels should be determined for each individual product based on data measured in the field, data obtained during the design process and data from the associated component over-stress tests and subsystems and systems HALT.

Electrical Systems ALT, 3.3.2

ALTs for electronic products are traditionally conducted with the product operating and subjected to some combination of temperature and broad band random vibration. However, it is the author's opinion that these tests should use the stresses the product will see in operation.

Electrical Systems ALT, 3.3.2 Cont.

Test levels should be established based on design strength, operational environment, and mission profile. Factors such as voltage and/or current, power surges, internal device temperature, vibration, shock, salt spray and humidity may apply. Sound engineering judgment should be used to determine which factors need to be considered in the ALT designs.

Structural ALTs, 3.3.3

Structural ALTs are usually conducted by loading the structure with significantly higher loads than it will see in operation. These loads can be either static or dynamic. For most large structures, the testing equipment will have to be built to run the test.

Structural ALTs, 3.3.3 Cont.

Dynamic loads are the most difficult to analyze as they cause fatigue failures. Most people think the age of an aircraft is the most important factor in failures. This may be true for engines, but most structural failures are fatigue failures caused by the compression and expansion of the aircraft body due to the up and down cycling.

Structural ALTs, 3.3.3 Cont.

Thus, a short haul Boeing 737 that, on the average, is subjected to 6 up and down cycles per day will fatigue at 6 times the rate of a Boeing 747 that, on the average, is subjected to only 1 up and down cycle per day. An ALT using the actual operational dynamic loading profile as a basis may be the most difficult test to conduct.

Structural ALTs, 3.3.3 Cont.

Vibration tests for large structures require special equipment such as thrusters to run. Usually, low frequency swept sinusoidal vibration is used. The test levels are set, considerably above the predicted operational levels, to accelerate time to failure. It is difficult to obtain reliability prediction information from these tests.

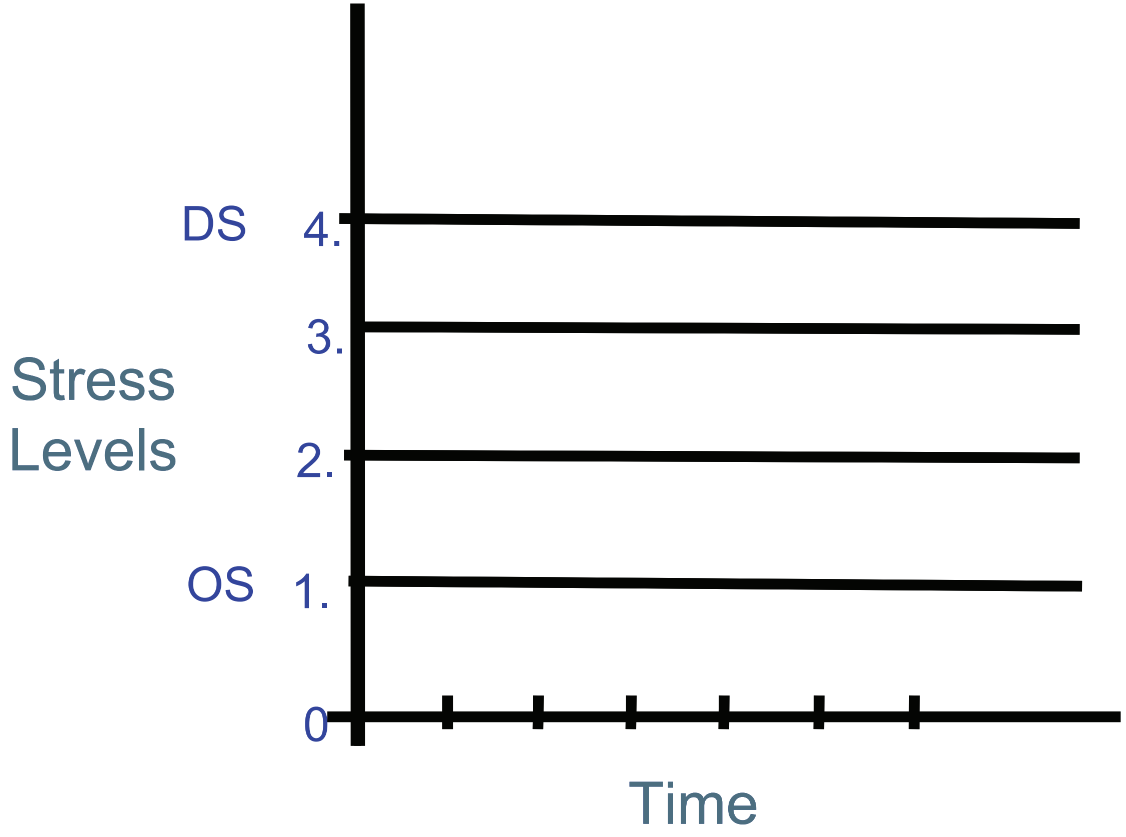
Structural ALTs, 3.3.3 Cont.

Consequently, their primary purpose is to insure that the natural frequency of the structure is not close to the operational excitation frequency or any of its harmonics. This problem can be solved by adjusting the stiffness of the structure, increasing the mass of the structure or adding damping to the structure.

Multi-Level Constant Stress ALTs

The author is a proponent of multi-level constant stress ALTs as they provide more information than many other types. The following is an example of one. There are software applications available to analyze these tests, such as ReliaSoft’s ALTA and ALTA PRO.

Example of Constant Stress ALT



Example of Constant Stress ALT, Cont.

Key:

OS	Operating Strength
DS	Design Strength

Stress Level 1	OS+..10(DS-OS), 10 Items On Test
Stress Level 2	OS+.50(DS-OS), 6 Items On Test
Stress Level 3	OS+.90 (DS-OS), 4 Items On Test
Stress Level 4	OS+1.3(DS-OS), 4 Items On Test

Reliability Growth Definition, 3.4

- Reliability growth is defined as the positive improvement in reliability, mean time before failures or failure rate.
- It can also be defined as the current assessment of reliability, mean time before failures or failure rate of a system or subsystem in order to establish trend data.

Reliability Growth

- During early development, the reliability of a system or subsystem is much lower than its potential value due to hardware design and manufacturing deficiencies.
- Predictions of potential reliability at some future time are most often based on present data or on past data from identical or similar systems.
- The reliability growth during testing is predicted using a model such as the AMSAA model.

Reliability Growth Definition, Cont.

- Reliability growth is the direct result of corrective action taken to remove defects in the future by changes in either the design and/or manufacturing techniques.
- The objective is for a subsystem or system to reach its potential reliability, mean time before failures or failure rate.
- There is software available to aid in reliability growth modeling, such as ReliaSoft's RGA 6.

Reliability Growth Models, 3.4 Cont.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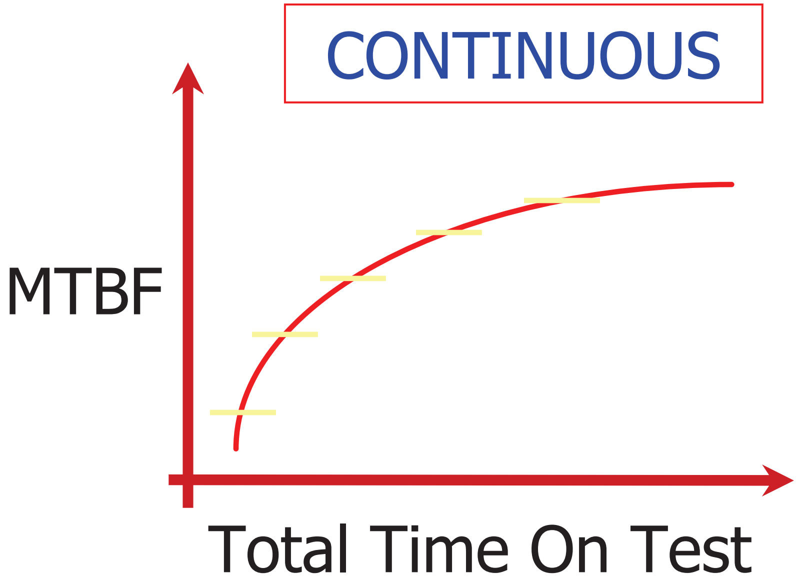
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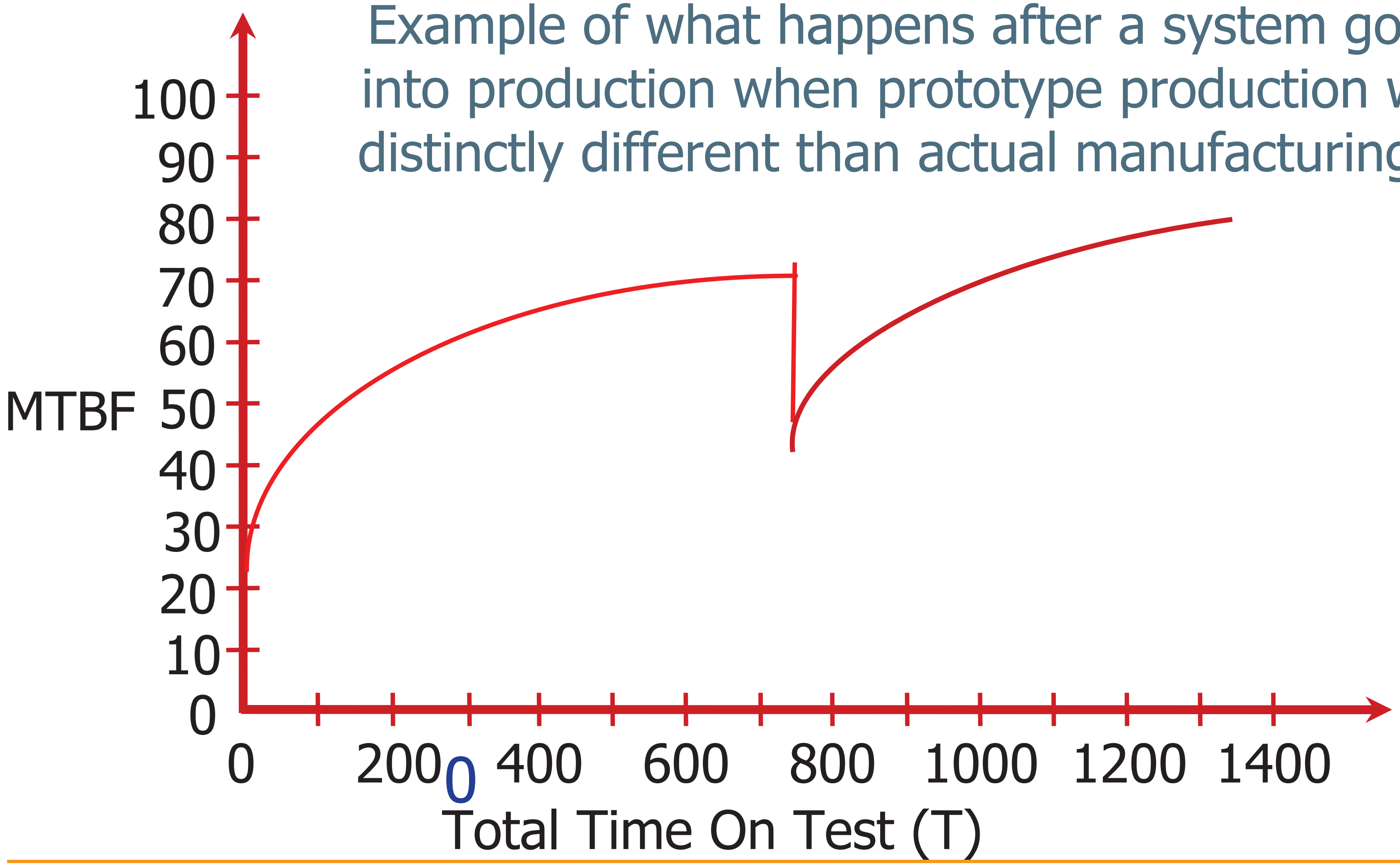
Reliability Growth Experience, 3.4 Cont.



Example of what happens after a system goes into production when prototype production was distinctly different than actual manufacturing.

Reliability Predictions
4.0

System Reliability Predictions, 4.0

- If system level reliability tests cannot be conducted because of the size and complexity of the system, the subsystem level test data will have to be used along with the system level reliability logic diagrams to get a system level reliability estimate.
- In this situation it is extremely important that the interfaces be given critical consideration during the product design process.

Initial Production Run
5.0

Initial Production Run, 5.0

- Initial production runs are usually made on high volume production to check out the operation of the production line and to test the product quality control procedures.
- Products produced late in this run may be of good enough quality to be used for reliability verification testing.
- If not, reliability verification testing will have to be done using products produced later in the production process.

Reliability Verification Tests
6.0

Reliability Verification Tests, 6.0

- These test are similar to those presented in section 4.0.
- The primary intent of these tests is to demonstrate a product reliability, not to improve it as during prototype testing.
- These tests can be either real-time or accelerated life tests.

Pre-Production Reliability Prediction 7.0

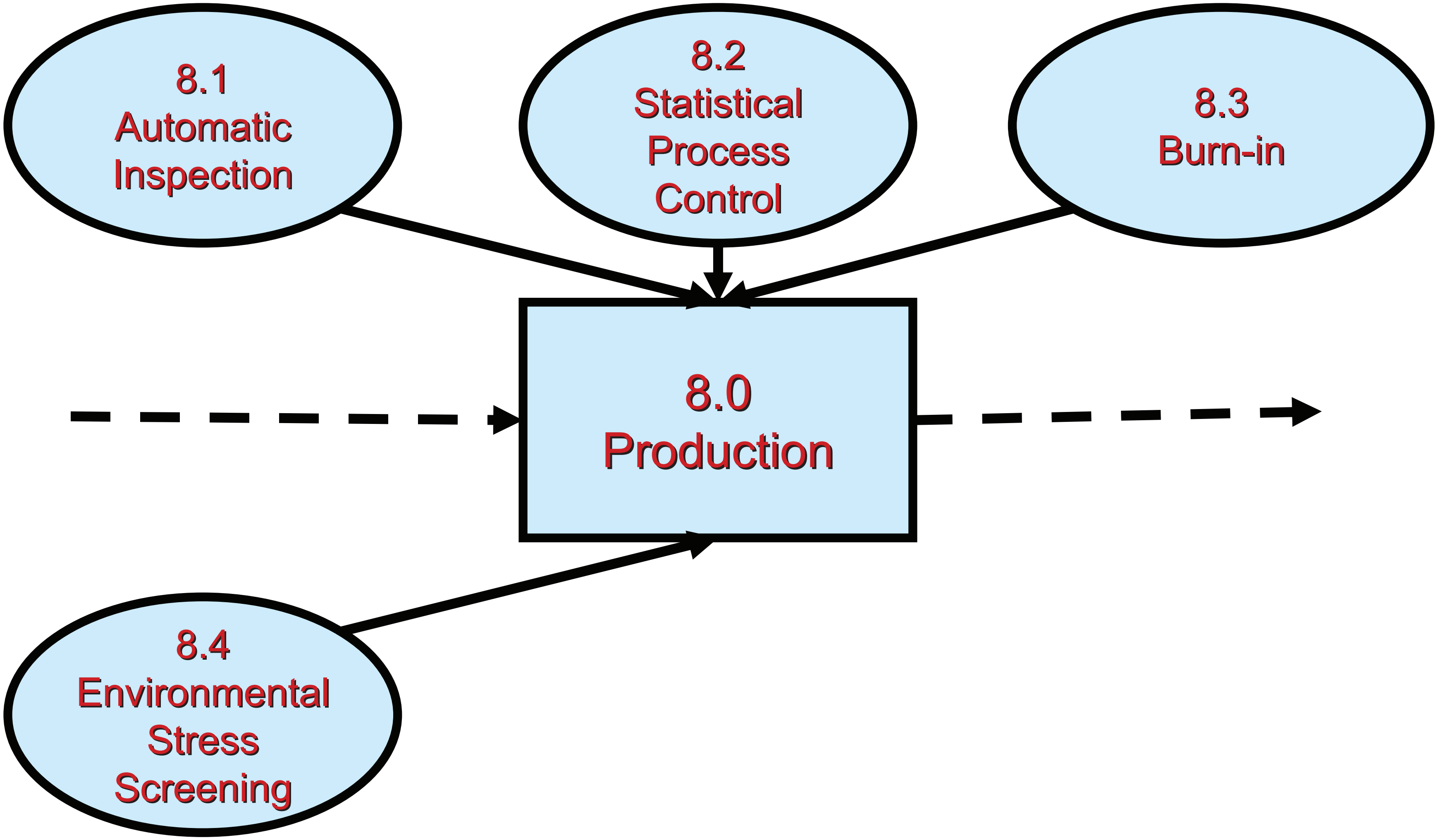
Pre-Production Reliability Predictions, 7.0

Pre-production reliability predictions are obtained using the same tools as those presented in section 2.0 on Initial Reliability Predictions and section 4.0 on Reliability Predictions.

Production

8.0

Production, 8.0



8.1
Automatic
Inspection

8.2
Statistical
Process
Control

8.3
Burn-in

8.0
Production

8.4
Environmental
Stress
Screening

Burn-In, 8.3

- Environmental Stress Screen (ESS) and burn-in are sometimes confused due to the fact that they both have the same goal: reducing the occurrence of early failures in the field.

- The major difference is that ESS is conducted using accelerated test conditions, whereas burn-in is conducted using operating conditions. In some cases an ESS may include stresses not seen in operation.

Defects

- Hard defects are those easily found during normal quality control procedures.
- Latent defects are those that can only be found through the use of stress screening.

Environmental Stress Screen, 8.4

- The Environmental Stress Screen process (ESS) transforms the latent defects into hard defects thus facilitating their elimination prior to the product entering the field.

- Different stress environments will detect different types of latent defects.

ESS, 8.4 Cont.

Screening can be performed at the component, subsystem or system level. Components are screened for a specified duration before being assembled into a sub-system. Defects introduced during the assembly of the components into a subsystem are screened at the subsystem level.

EES, 8.4 Cont.

- The author prefers an ESS stress level about halfway between the operating conditions and the design strength.
- ESS has an economic advantage over burn-in in that it detects defects in a much shorter time than burn-in.
- In both cases it is important that testing time is sufficient to detect most of the latent defects, but not long enough to significantly impact the product’s operational life.

ESS, 8.4 Cont.

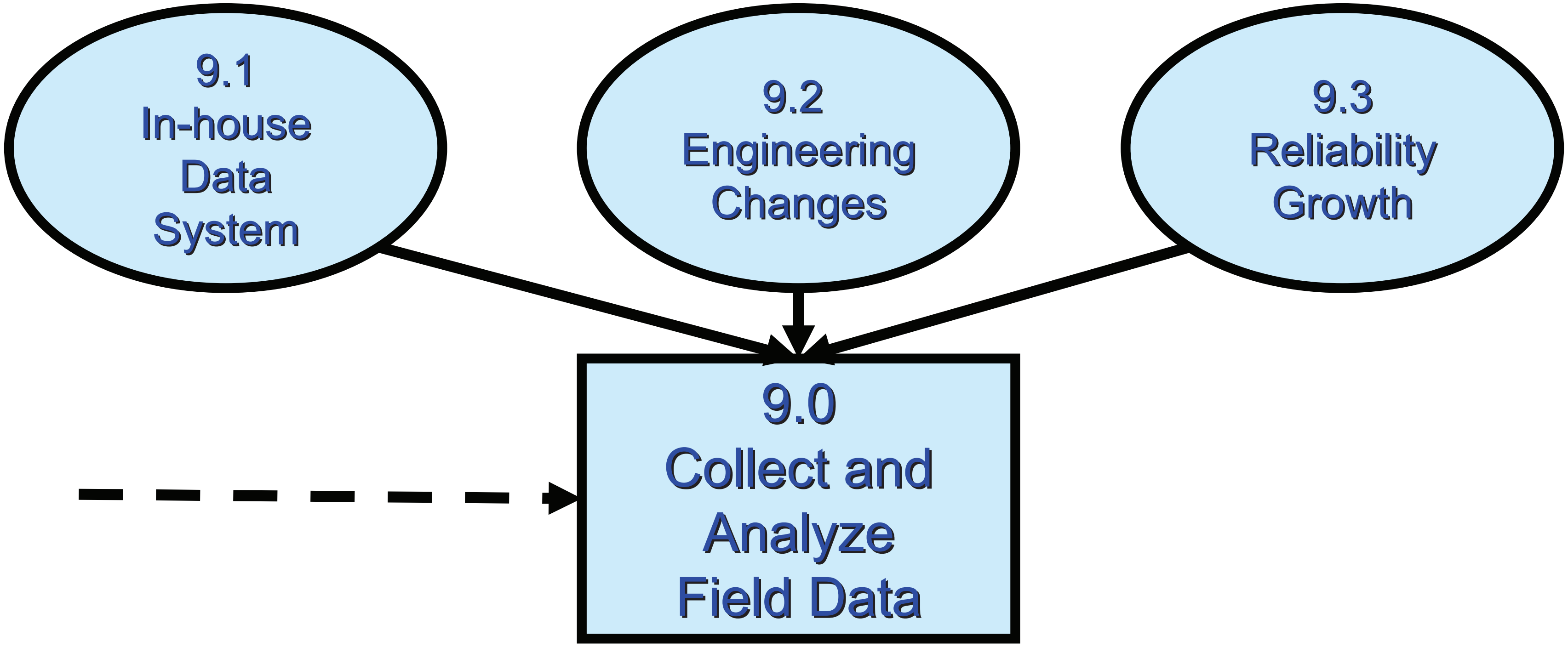
- Several recognized experts in the field have suggested that ESS detects only about 90% of the latent defects.
- Hence, it is extremely important that as information becomes available from the quality procedures and the ESS, the process design is continually upgraded to reduce the occurrence of all defects.

ESS, 8.4 Cont.

- It should be emphasized that both ESS and Burn-In are primarily quality procedures, not reliability procedures. They improve a product’s reliability by improving the product’s out-going quality and hence, reliability.
- Their intent is to insure that the outgoing product’s reliability is close to that estimated during the reliability evaluation tests.

Collect and Analyze Field Data 9.0

Collect and Analyze Field Data, 9.0



9.1
In-house
Data
System

9.2
Engineering
Changes

9.3
Reliability
Growth

9.0
Collect and
Analyze
Field Data

Data System 9.1

All data relevant to any maintenance, repair or re-design action should be recorded in the in-house data system for use in the design of future products.

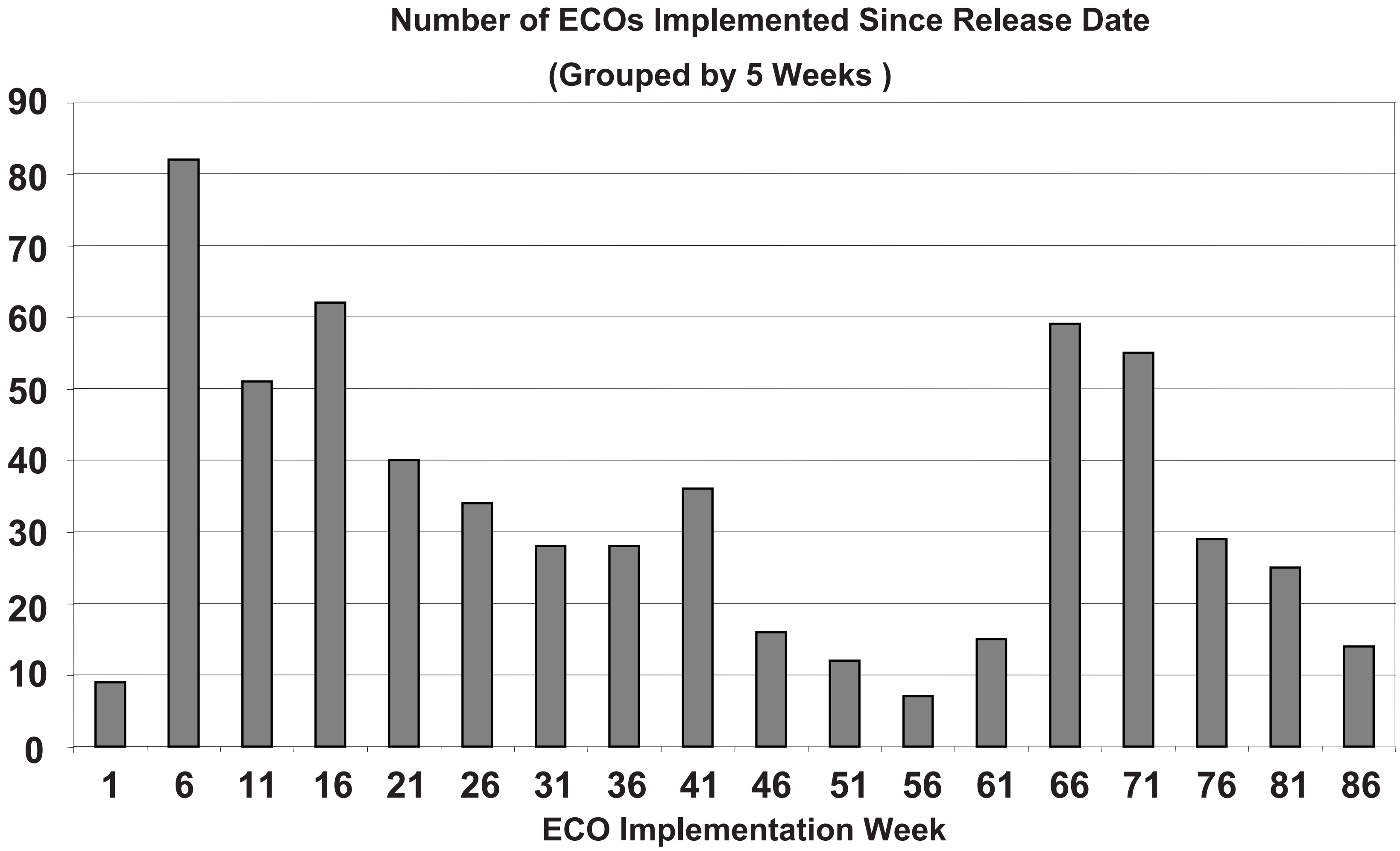
Engineering Change Orders, 9.2

- Failures that repeatedly occur in the field usually result in component upgrades or subsystem redesign.
- Before any system, subsystem or component is re-designed the following should be required:

Engineering Change Orders, 9.2 Cont.

- A detailed description of the mission time, mission profile and operating environment should be written.
- Design specifications should be written that include the concepts discussed in this presentation.
- The designer should be prepared to discuss why he/she thinks the redesign will be reliable.

Example of ECOs Implemented, 5 Week Intervals, 9.2 Cont.



Engineering Change Orders

In the late 1980s, IBM saw a similar trend in one of its products. Investigation indicated that 80% of all ECOs were the direct result of previous ECOs.

Reliability Growth, 9.3

- Both FMEAs and Design Reviews should be conducted on the redesigned component, subsystem or system.
- Reliability growth should be monitored for all systems in the field when design and manufacturing improvements are continuing to be made.

Summary

The following is a recommended list of the steps that should be taken to improve the reliability of products. Each of these items should be converted to detailed instructions and/or actions to meet the specific needs of a particular product.

1. Management must understand and support the effort.
2. Technicians and Engineering must receive training in the rudiments of applied reliability.

Summary (Cont.)

3. An in-house reliability data base must be established that includes failure rates of components, their mission profile and operating environment.
4. A list of component vendors that have delivered high quality components in the past should be compiled and made available to all design teams
5. Problems that have occurred on past products should be documented including successful engineering changes. This data must be readily available to designers. It is extremely important that past mistakes not be repeated in the future.

Summary (Cont.)

6. Resources must be committed to reliability early in a product’s developmental cycle.
7. Component selection should be based primarily on in-house data on similar components. If information is not available on past similar components over-specification is dictated
8. All critical components and those where problems have occurred in the past should be subjected to accelerated environment and/or time compression reliability demonstration testing.

Summary (Cont.)

9. The location of all components and sub-systems in the product should be reviewed to insure that the components most likely to fail are the most accessible. A high-time to failure and a low-time to repair are critical to high systems availability.
10. Components that need preventive maintenance should also be readily accessible.
11. Both sub-system and system designs should be subject to FMEA.

Summary (Cont.)

12. After problems identified in the FMEA are addressed, the sub-system or system design should be subjected to a comprehensive design review. To obtain an independent perspective, the review teams should include members that are not on the design team. The use of outside experts may be cost effective.
13. Where possible, sub-systems should be subjected to accelerated life reliability demonstration testing. Comprehensive sub-system functionality testing should always be done.

Summary (Cont.)

14. After a prototype tool is produced, a group of experienced engineers, including some from outside the organization, should review the product in concert with the list of previous problems.
15. Comprehensive systems level functionality testing is mandatory on the prototype products. It may not be possible to demonstrate reliability in the laboratory, but it is possible to demonstrate that the product will perform its intended function in the field. The design of these tests is critical. A test design team should be constituted to insure that all possible in-the-field scenarios are incorporated.

Summary (Cont.)

16. Initially, all products should be Burn-In-tested prior to shipping. This test should be similar to the functionality tests, but shorter in duration.
17. An inspection procedure should be established and applied to all production tools. The assurance of consistent high quality is mandatory.
18. Field service technicians and engineers should receive comprehensive training on product operation, preventive maintenance and corrective maintenance. Inspection and operating procedures must be in place to insure that improperly performed maintenance does not result in reliability problems. A small oversight by a field service technician or engineer, while performing in-field maintenance, can result in huge losses.

Summary (Cont.)

19. Once the product is in the field, detailed data collection is paramount. Actual time to failure data should be recorded to minimize warrantee costs, provide information for design changes in the present tool and to facilitate the design of reliabile future tools
20. When a significant failure occurs, a design review team should be instituted to review the present design to determine what action is mandated.

Summary (Cont.)

21. Once the product is in the field, detailed data collection is paramount. Actual time to failure data should be recorded to minimize warrantee costs, provide information for design changes in the present tool and to facilitate the design of reliable future tools.
22. All engineer change orders should be reviewed by a design review team before implemented. If the change is at the sub-system level, an FMEA is also recommended.
23. Data on the performance of all engineering changes should be recorded for future use.