HOW TO APPLY THE RELIABILITY & ROBUSTNESS PROCESS TO PRODUCT DESIGN WITHIN THE AUTOMOTIVE INDUSTRY

James F. Juricic
BSEE, MBA/TM
Reliability Engineer
R&R Process
OVERVIEW: THE RELIABILITY & ROBUSTNESS DESIGN PROCESS

The Reliability & Robustness Design process (R&R) was developed over the past decade as a way to improve the upfront, pre-production Quality & Reliability of new and/or existing designs.

The information presented here is a result of my experience working on contracts with major Automotive OEM’s.

It has been known for some time that much of the high warranty expenses associated with today’s designs are directly traceable back to the poor quality of the designs.

This coupled with the high cost associated with the prevalent thinking of trying to test, analyze, and then fix (TAF) Product designs in the Hardware stage rather than the more effective methods of Analyzing, Designing it right, and then Validating (ADV) prior to production has led to the development of the R&R approach to design.
OVERVIEW (CONT.)

The process is not proprietary and many of its elements are already in widespread use throughout industry. Recent developments at one OEM have led to the incorporation of the R&R Process into their “Design for Six-Sigma” Program.

What makes the R&R process unique is the way its elements are ordered and the disciplined approach used in its application. It acts as a guide to a designer’s thinking to ensure that all design factors, both positive and negative, have been considered and addressed.

It also uses a disciplined documentation structure to capture the entire design process and results for future designs and designers. One of its outputs is an R&R Evidence Book.

This book captures all of the eight R&R process steps that the process requires and acts as management’s proof that the design has been done right – the first time!

True, some of its elements, such as the P-Diagram and R&R Check sheet may be new to many design engineers but many others, such as the Potential Failure Mode & Analysis (PFMEA) and Design Validation Plan & Report (DVP&R) will be quite familiar.
Also new is that the process makes the Designer and not the Reliability Engineer the Owner of the process and consequently the responsibility for the Quality & Reliability of the design.

The Reliability Engineer assists the designer in his development of his knowledge base and in the application of the tools but the designer retains ownership of the “Inherent Design Reliability”. This cannot be emphasized too much.

**RELIABILITY CANNOT BE TESTED OR INSPECTED INTO A PRODUCT. RELIABILITY MUST BE DESIGNED INTO THE PRODUCT.**

This is called the “INHERENT DESIGN RELIABILITY”.

Everything that happens to a product after it leaves the designers hands will only DEGRAD the product. The reliability of a design CANNOT be raised above its Inherent Design Reliability.

Only the Design Engineer can change the Inherent Design Reliability, as only he knows the design in its every intimate detail. If all a Reliability Engineer does is product testing, reliability will never be achieved at the lowest possible cost.

He must also be involved in the design process by assuring that the design engineer knows how to design for Reliability and indeed does so. The Reliability Engineer should be a core team member and a partner to the Design function. As a member he provides input to the design activity but he does not own the design.
• My experience has shown that once a design engineer understands the process and has been guided through an actual case application, he will then embrace it, add it to his toolkit and become a strong champion for its use to improve the Quality, Reliability, and Robustness of future designs.
WHAT IS RELIABILITY & ROBUSTNESS?

• **RELIABILITY** involves the delivery of function over time.

• **ROBUSTNESS** involves the delivery of function without sensitivity to variation due to noise.

• Reliable and Robust products are Quality products that assure the customer that they will perform their intended function over their specified lifetime with minimum degradation in performance and maximum insensitivity to both internal and external noises.
THE STEPS OF THE R&R PROCESS

It should be pointed out at the onset that the R&R Process is a team activity and it must be done in a team environment for maximum effectiveness.

There are eight steps to the process:

(I) HISTORICAL RECORD EXAMINATION (QUALITY HISTORY)

(II) BOUNDARY DIAGRAM & INTERFACE ANALYSIS

(III) POTENTIAL DESIGN FAILURE MODE AND EFFECTS ANALYSIS (DFMEA)

(IV) PARAMETER (P) DIAGRAM

(V) RELIABILITY CHECKLIST (RCL)

(VI) DESIGN VALIDATION PLAN & REPORT (DVP&R)

(VII) ROBUST PLAN AND DEMONSTRATION MATRIX

(VIII) LESSON’S LEARNED
Reliability and Robustness Flow Chart

1. Identify Priorities (Historical Record)

2. Boundary Diagram & Interface Analysis
3. DFMEA

4. P-Diagram

5. Reliability Checklist

6. DVP&R

7. Reliability Demonstration Matrix (RDM)

8. Lessons Learned
If you are doing a new design to overcome a problem with an old design you should start by consulting the “Historical Record”. This consists of such documents as the Global 8d on the old problem (if one has been done) plus any “Lessons Learned” files such as prior “Things-Gone-Wrong” TGW, “Corporate Quality Information System” CQIS, FMEA’s, Warranty Analysis history, past test results, studies, reports such as a prior QFD etc. that may exist on the old design.

This will help to identify the failure mode's) and the failure mechanism's) and root cause's) so that they can be addressed in the new design. This can be your exact prior system or a similar system upon which your new design will be based. Additional risk items that one should also look at include: new technology, previous DV failures, and new or unusual applications not previously dealt with.

An ancillary activity would be to have the good fortune to have a completed Quality Function Deployment Study (QFD) on hand that captures the Voice-Of-The-Customer” (VOC). It helps assure that this voice has been driven into your design for maximum customer-satisfaction.

As a minimum, you should do an updated or new DESIGN FMEA specific to your new design (use your old system and/or Generic FMEA as a guide). You should include, in addition to all of the previously identified things that have gone wrong all of the new potential things that you believe could go wrong with the new design that have not been covered on the old FMEA.
(II) BOUNDARY DIAGRAM

This activity should then be followed with the development of a BLOCK DIAGRAM of your new proposed system.

It is called a “BOUNDARY DIAGRAM” because it serves to define the boundaries of the system that you are responsible for designing.

The Boundary Diagram should be used to develop both “INTERNAL INTERACTIONS” and “EXTERNAL INTERACTIONS” MATRICIES”.

These matrices will help you to better understand all of your interactions with other internal systems and their effects upon one another – either physical or signal-wise and how all of the forces external to your system interact to degrade your system operation over time.
A recent addition to the EQOS process is the Internal Interface Interactions Analysis Worksheet. It replaces the old Interface Matrix report. A portion of a sample worksheet is shown below. The Interface Analysis Worksheet takes the Boundary Diagram Interface Relationships and converts them to Noise Factor 5 noises. These noises are then fed into the P-Diagram and the Reliability Checklist for further analysis of their effects on the previously identified Failure Modes from the DFMEA.

<table>
<thead>
<tr>
<th>No.</th>
<th>INTERFACE ITEM (See Boundary Diagram)</th>
<th>INTERFACE</th>
<th>INTERFACE DESCRIPTION</th>
<th>INTERFACE TYPE: P = Physical Contact Ev = Vibrational Energy Transfer Eh = Heat Energy Transfer Ic = Clearance Issue Ie = Information Exchange M = Material</th>
<th>FUNCTIONAL TARGET (METRIC/RANGE IF KNOWN)</th>
<th>CONVERSION TO NOISE FACTOR (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 TO 3</td>
<td>LH COWL SCREEN TO RH COWL SCREEN</td>
<td>RH COWL SCREEN LOCATES TO LH COWL SCREEN BY WAY OF LOCATOR PINS AND NESTING FEATURE</td>
<td>P</td>
<td><strong>SECURE ATTACHMENT</strong></td>
<td><strong>1. (2 TO 3) LH COWL SCREEN TO RH COWL SCREEN: INSECURE ATTACHMENT</strong></td>
</tr>
<tr>
<td>2</td>
<td>2 TO 4</td>
<td>LH COWL SCREEN TO SOFT END</td>
<td>ATTACHES VIA CHEMICAL BOND</td>
<td>P</td>
<td><strong>SECURE ATTACHMENT</strong></td>
<td><strong>2. (2 to 4) LH COWL SCREEN TO SOFT END: INSECURE ATTACHMENT</strong></td>
</tr>
<tr>
<td>3</td>
<td>2 TO 5</td>
<td>LH COWL SCREEN TO WIPER PIVOT GIMP/CLOSEOUT</td>
<td>HEAT STAKE</td>
<td>P</td>
<td><strong>SECURE ATTACHMENT</strong></td>
<td><strong>3. (2 to 5) LH COWL SCREEN TO WIPER PIVOT GIMP/CLOSEOUT: INSECURE ATTACHMENT</strong></td>
</tr>
<tr>
<td>4</td>
<td>2 TO14</td>
<td>LH COWL SCREEN TO COWL LOWER &amp; FASTENER</td>
<td>ATTACHES WITH 2 SCRIVETS</td>
<td>P</td>
<td><strong>SECURE ATTACHMENT</strong></td>
<td><strong>4. (2 to14) LH COWL SCREEN TO COWL &amp; LOWER FASTENER: INSECURE ATTACHMENT</strong></td>
</tr>
<tr>
<td>5</td>
<td>3 TO 4</td>
<td>RH COWL SCREEN TO SOFT/HINGE COVER</td>
<td>CHES FIA CHEMICAL</td>
<td>P</td>
<td><strong>SECURE ATTACHMENT</strong></td>
<td><strong>5. (3 TO 4) RH COWL SCREEN TO SOFT END/HINGE COVER: INSECURE ATTACHMENT</strong></td>
</tr>
</tbody>
</table>
(III) PARAMETER (P) DIAGRAMS

Next comes the "P-DIAGRAM". P-Diagrams are best started at the SYSTEMS level as a “Structured Top-Down” activity with P-Diagrams at every level (systems, sub-systems, components).

If properly done, they totally define all of the significant noise factors and design control factors at every level that can affect your system’s functioning. Each level diagram serves as input to the next lower level diagram down to the component level. It is at the component level that much of the improvement in the Reliability & Robustness of the design can be accomplished.

Needless to say, the component supplier must therefore be intimately involved as a pivotal team player as he is the one that will be making many of the improvements as a result of the R&R analysis. It is therefore extremely important that the OEM works with the supplier and sees to it that he has the proper training and guidance in the use of the R&R process.

The P-Diagram brings together, on one sheet and helps to define and document your Control factors, Noise Factors, Input Driving Function's), the "Process" i.e. the "Energy Transfer Function", the "Ideal" output of your system, and the "Error States" or "Undesired" output's) -- i.e. "Failure Modes" (available from the 8d, FMEA, Testing and/or Warranty Analyses, etc.).
(III) PARAMETER (P) DIAGRAMS (CONT)

A primary benefit of the P-Diagram is to feed into the Noise Factor Management Matrix (aka Noise Management Check sheet – see below) the identified failure modes and noises so that they can be correlated to one another, strategies for dealing with their effects developed and DVP&R tests designed to demonstrate that the strategy used did indeed eliminate those effects.

A secondary benefit of the P-Diagram is that its output can also be used to further update your FMEA. This will help you define your testing requirements and whether further design constraints or modifications to your DVP&R are needed and perhaps negotiated.
CLASSICAL EXPERIMENTAL DESIGN

Somewhere during the development of all of the above, you may come to realize that it is necessary to do a “Classical Experimental Design Study" to identify the most significant Control Factors and their interactions – if you don’t already know what they are and their relative significance in your design.

A Classical Experimental Design Study is a time/cost efficient way to gather a large amount of information in a short period of time by avoiding the “test-one-variable at-a-time” approach. It is not always needed and depends upon what noise factor management strategy you decide to use.

It is often combined with a Taguchi Optimization Study to optimize the control factor settings once the proper controls have been identified. Where needed, it will help make your design more robust against the noises you have previously identified.
TAGUCHI DESIGN OPTIMIZATION STUDIES

You also might need to “Optimize” the "Signal-to-Noise Ratio“ of your design for maximum energy transfer of the 'Ideal' function by setting the operating values of those factors via a Taguchi "Parameter Design" Study.

If the desired design point and variation targets have not been attained through the Parameter Design Optimization Study, you then might want to do a "Tolerance Design" study. It sometimes is desirable to do both together.

The optimized values can then be examined in terms of cost effectiveness (i.e. the biggest “bang-for -the-buck”). By looking at your first, second, third, etc. “Optimized” Design choices, you can find out where the greatest “value-add” is to be had by comparison to the costs associated with the various design choices.

These are the activities that make your design “Robust” -- i.e. on-target with minimum variation and at the lowest possible cost. If done properly, you will have a design that is right on target, with minimum variation (and hence cost) and maximum (or near close to maximum) insensitivity to the identified noises from your P-Diagram analysis.
(IV) POTENTIAL FAILURE MODE AND EFFECTS ANALYSIS

The PFMEA is a living document. As such it can be used as an input to the P-Diagram and also receive output from the P-Diagram analysis.

Most companies today have extensive documentation as to exactly how to do an FMEA. However, my experience has shown that they are seldom done correctly and/or correctly integrated into the R&R process.

How to do an **AIAG Compliant DFMEA** is covered elsewhere in a training program that I have put together to train Release Engineers. I will state that it is important that what is learned as to new (or old) failure modes from the DFMEA analysis should also show up on the Noise Management Check Sheet.
When the team has completed the P-Diagram, they are then ready to develop a "Noise Factor Management Checklist" and Strategy to ensure that the design will be Robust against the identified noises. Here, they have a number of choices such as eliminating the noise altogether, ignoring the noise, compensate for the noise, or minimizing the design's sensitivity to the noise. There are five "basic" noise types of concern. They are:

1. **Piece-to-piece variation**: mostly in the manufacturing process.
2. **Customer Usage and Duty Cycle**: how does the customer actually use the Product – i.e. what does the Real World Usage Profile (RWUP) tell us about how our design will be affected in the field?
3. **External Environmental Noises**: use the External Interactions Matrix analysis for a checklist of the important External Environmental Noises that might affect the design.
4. **Internal Environmental Noises**: i.e. the system interactions that were previously identified as part of the Internal Interactions Matrix Study. NOTE: you need to circumscribe your system that you are designing in relation to all of the adjacent systems that the team believes are relevant to your systems’ operation).
5. **Wear out**: (This is the "Reliability" aspect of your design and is concerned with how your product ages and/or degrades in the field until "End-of-Life".)
(VI) DESIGN VALIDATION PLAN & REPORT (DVP&R)

You may already be familiar with the DVP&R. What is new is that the results from the Noise Management Check sheet are now used to tailor your DVP&R to ensure you are doing the right tests for the right reasons at the right time.

It also helps to examine your DVP&R process to ensure that the tests are appropriate for the process.

NOTE -- DO NOT engage in mindless testing just because you have always done testing at a certain point and in a certain way in the past.

Robust Design is a **NEW APPROACH** to the design process. It may use old processes but only after careful analysis to ensure the old test and/or process meets the new requirements for Reliability/Robustness.

Test only to gather information where you need it and are currently unable to get it any other way (such as through computer-driven paper studies). Always remember –

**TESTING COSTS TIME AND MONEY** -- Use it only where and when required and there is no other way to gather the required information.
KEY LIFE TESTING (KLT)

In the Automotive Industry, a KLT is often a requirement for signoff prior to production. It should be based on the previously identified failure modes in the old design plus any new failure modes that were identified on your PFMEA and as a result of your "P-Diagram” and Noise Factor Management Strategy analyses.

NOTE: A KLT is a “VALIDATION” test – DO NOT use it for Experimental Design or Design Optimization Studies.

They are entirely different tests for entirely different purposes.

A KLT is used to DEMONSTRATE that the product will not fail UNDER REAL WORLD CONDITIONS.

It has two key aspects that make it a KLT. It must be an **Accelerated Test** and it must be correlated with the **Real World Usage Profile** through the development of an appropriate "**Acceleration Factor**". *

*KLT Testing is not covered in this presentation.*
WHAT TO DO IF YOU DO NOT HAVE A KEY LIFE TEST?

Sometimes, if a KLT cannot be developed due to cost, timing or unavailability of field data, it may, however, be possible to demonstrate improvement of a NEW vs. an OLD design by running a comparison test for management’s approval.

Weibull plots are very effective for this purpose. A Weibull chart (or some sort of “Before/After” or “Old vs. New Design” chart) that compares the old product's life with the new product design's life is commonly used here as the "Validation Evidence" for presentation to management for sign-off.
(VII) ROBUST PLAN AND DEMONSTRATION MATRIX (RPDM)

The RPDM is a managerial summary of the R&R process.

It shows the Risk Analysis that was done, what R&R tools were used, what Noises were addressed, and what Validation Evidence was presented.

A new vs. old design comparison chart (preferably a Weibull) is often presented as the validation evidence.
(VIII) LESSON’S LEARNED

The final stage in the R&R process is to feed back to the appropriate people the lessons learned from the process.

This document provides input for upgrading the design specifications, standards, tests etc. It can also serve to identify non-value added operations and shortcomings.

It should be a written document that is short and informal and should be made part of the evidence book.
FINAL THOUGHTS

The R&R process can be applied across the board on every new design but it should be done selectively.

In addition, it needs to be started early in the program and integrated with the program planning and milestone reviews (APQP).

Obviously, carry-over designs with no new technology, applications, and test or field problems would not be good candidates -- especially when program resources are limited.

It has been said that good Engineering involves mastering the art of tradeoffs.

Common sense and good judgment are necessary.

In other words, when applying the R&R process to new or existing designs, pick your battles carefully.