Reliability Validation Test Substantiation

Ing. Ronald Schop
Sr. Director Reliability
Holland Innovative BV

Introduction

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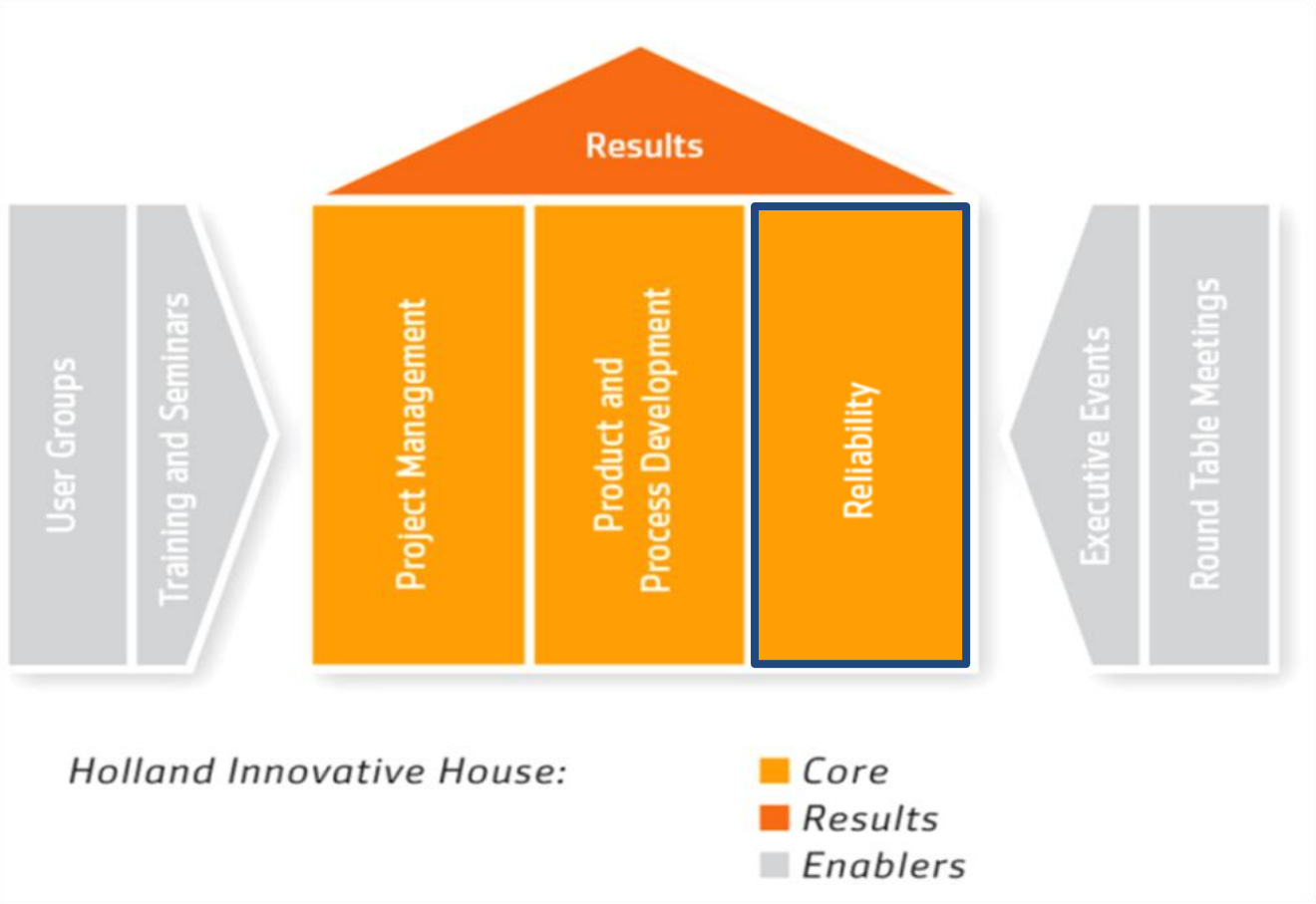


Subject

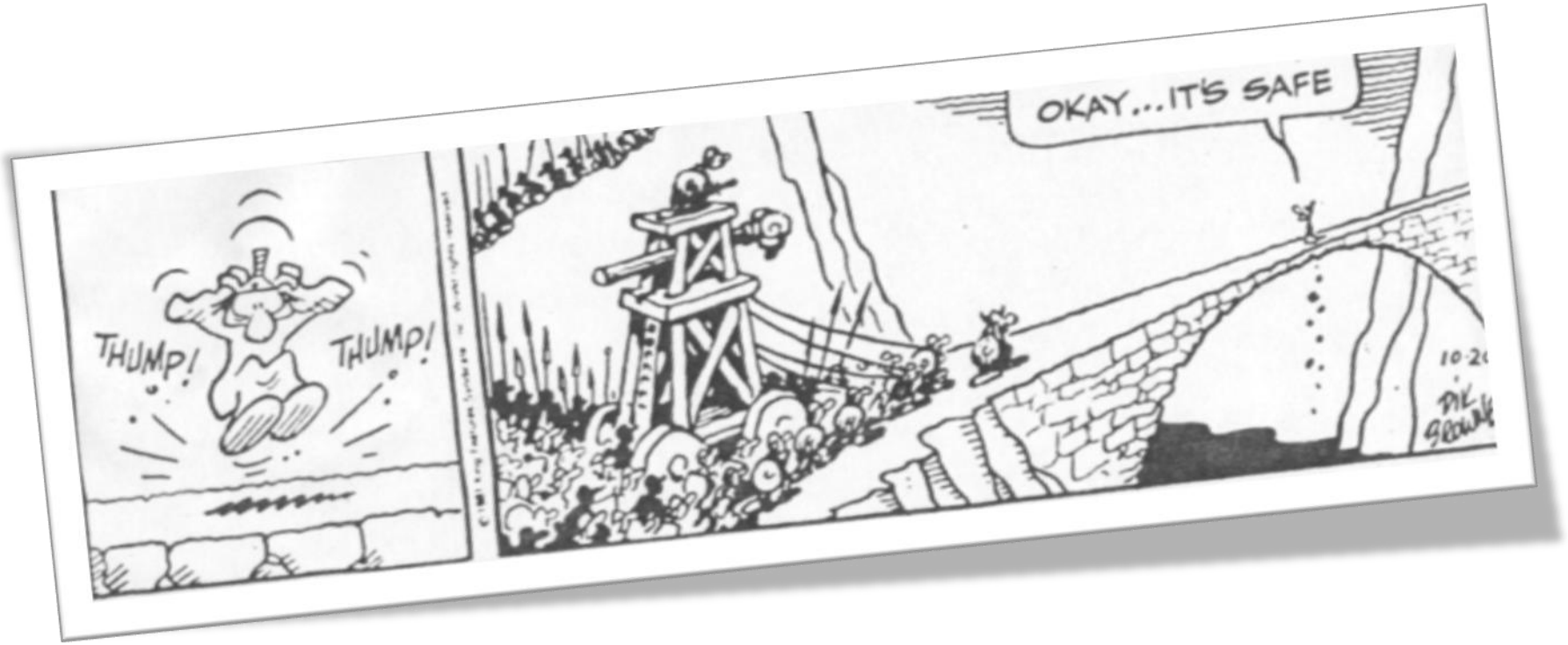
RVP - Reliability Validation Plan

Agenda

- Purpose of the RVP
- Method and Background
- RVP Interface
- RVP Results
- Summary

- Questions

Purpose of the RVP



From Subjective to Objective judgement

Purpose of the RVP

Awareness & Involvement

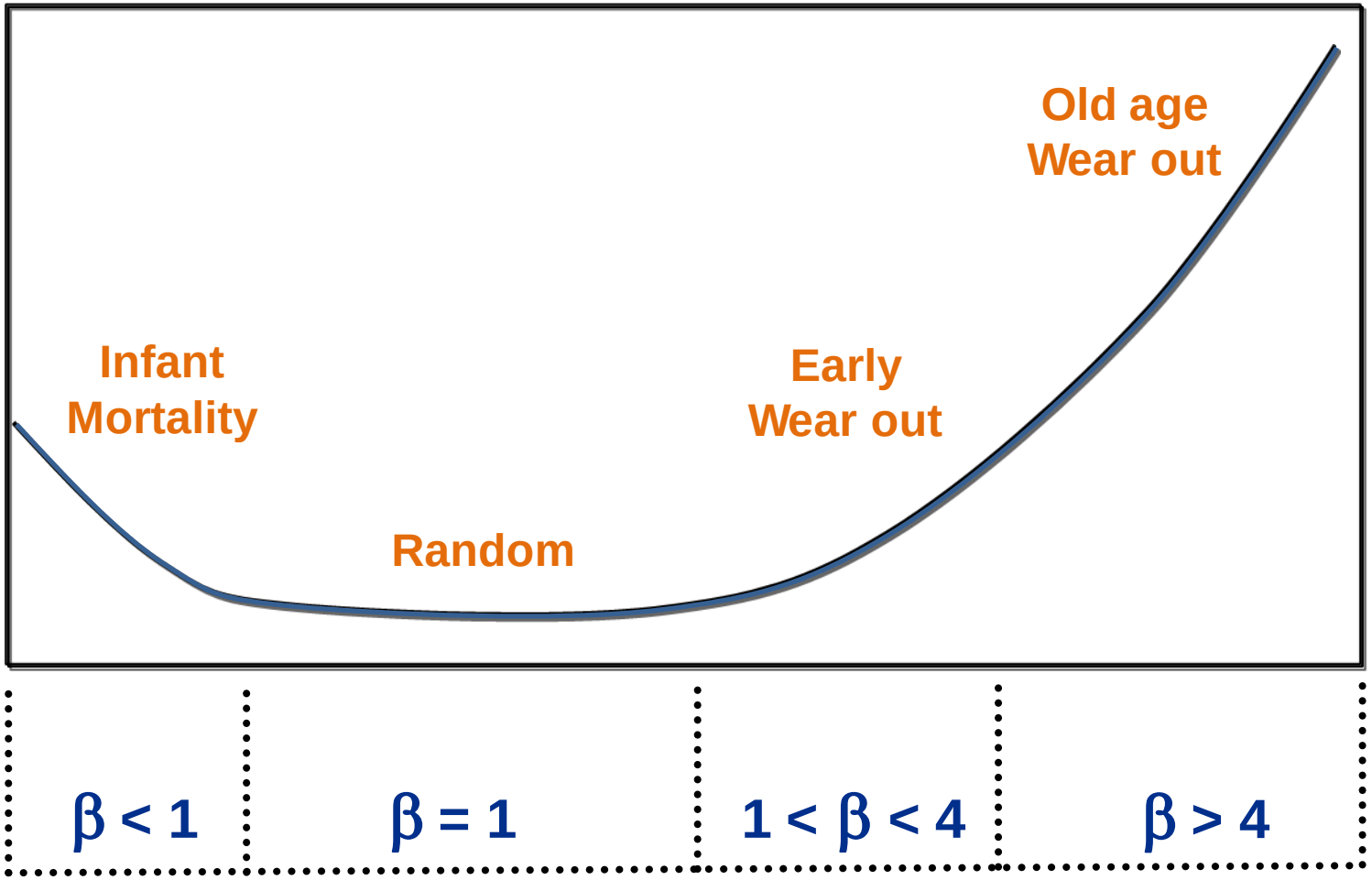
- **Aware that a Risk Mitigation Plan can be *Quantified***
- **Involved in the Risk Analysis & Mitigation process**

Method and Background

Weibayes Zero Failure Testing Principles

- Zero failures
- Weibull β is "known"
- First failure is imminent
- Minimal Reliability

Method and Background



Method and Background

Combination Weibull Distribution & Binominal Confidence = Probability calculations

$$R = e^{-\left(\frac{t}{\eta}\right)^{\beta}} \qquad 1 - C =$$

Method and Background

C. Julius Wang (1999)

Reliability Demonstration

$$R_T = \exp\left[\frac{\ln(1-C)}{n\left(\frac{t}{T}\right)^{\beta}}\right] \quad or \quad R_T = \exp\left[\frac{\ln(1-C)}{\sum_{i=1}^{n}\left(\frac{t_i}{T}\right)^{\beta}}\right]$$

Method and Background

Confidence Level Demonstration

$$C = 1 - R_T \sum_{i=1}^{n} \left(\frac{t_i}{T} \right)^{\beta}$$

Confidence = “Probability of Detection” (PoD)

Method and Background

Example: ***R_T = 0,95*** ***T = 100*** ***t_i = 150***

n = 10 ***Bèta = 2***

$$C = 1 - R_T \sum_{i=1}^{n} \left(\frac{t_i}{T} \right)^{\beta}$$

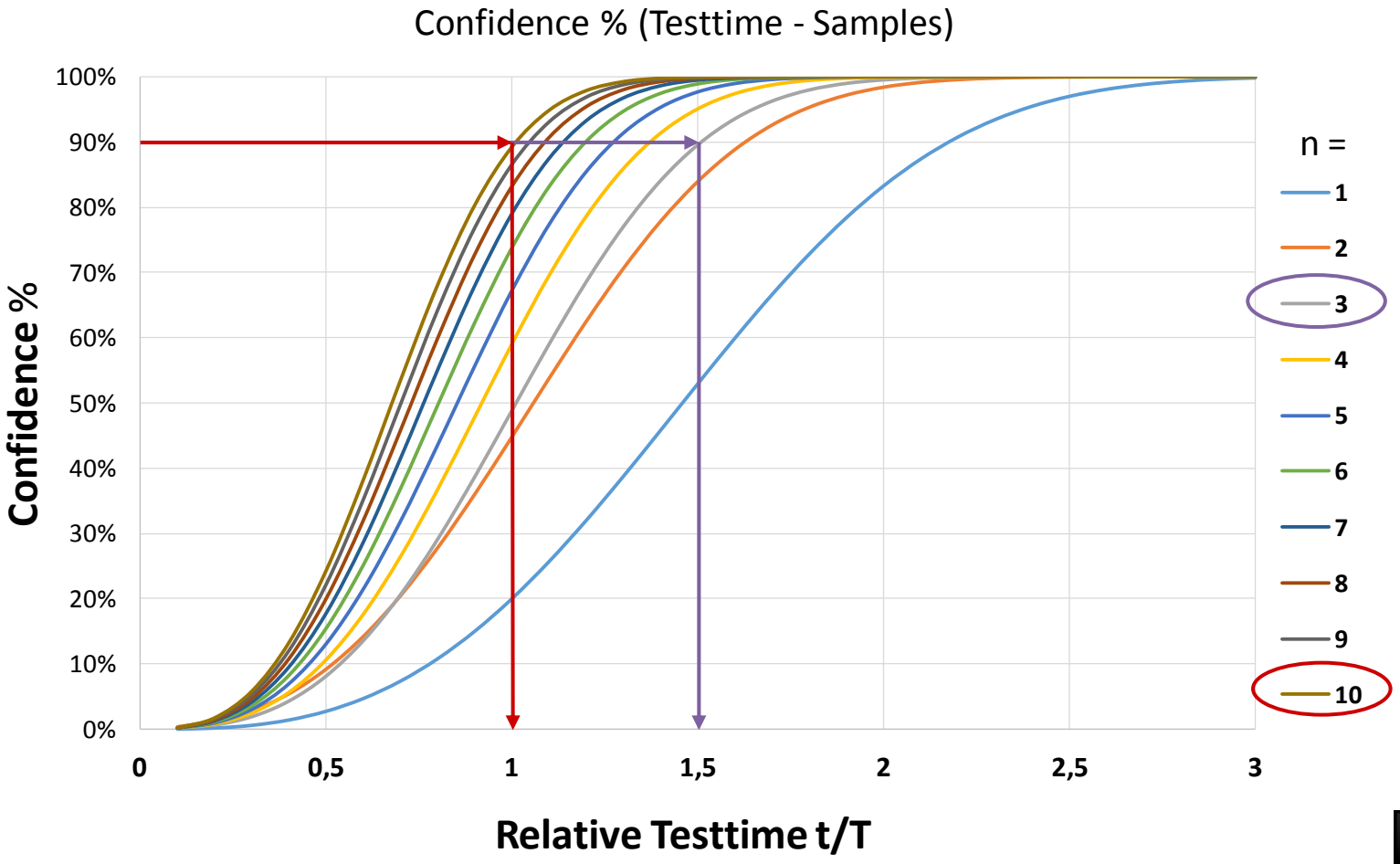
The “Confidence Level” = PoD = 68%

PoD = Probability of Detecting One or more failures, IF the Component Reliability @ time T is 0,95 or lower

Method and Background

Example: R=0,8 @Time T and Beta = 3

$$C = 1 - R_T^{\sum_{i=1}^{n}\left(\frac{t_i}{T}\right)^{\beta}}$$



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Method and Background

Test Credit

Non-testing activities; Engineering activities

Test Credit

Max. 50% Test Credit

Engineering Activity	Test Credit
Warranty Analysis of the previous design	5 %
Reliability Analysis previous design	5 %
Strength Calculations, Fatigue calculations	10 %
Stress measurements	5 %
FEM analysis + verification of stresses	10 %
FMEA completion	5 %
Laboratory test results	10 %

Test Credit

From Credit to Confidence

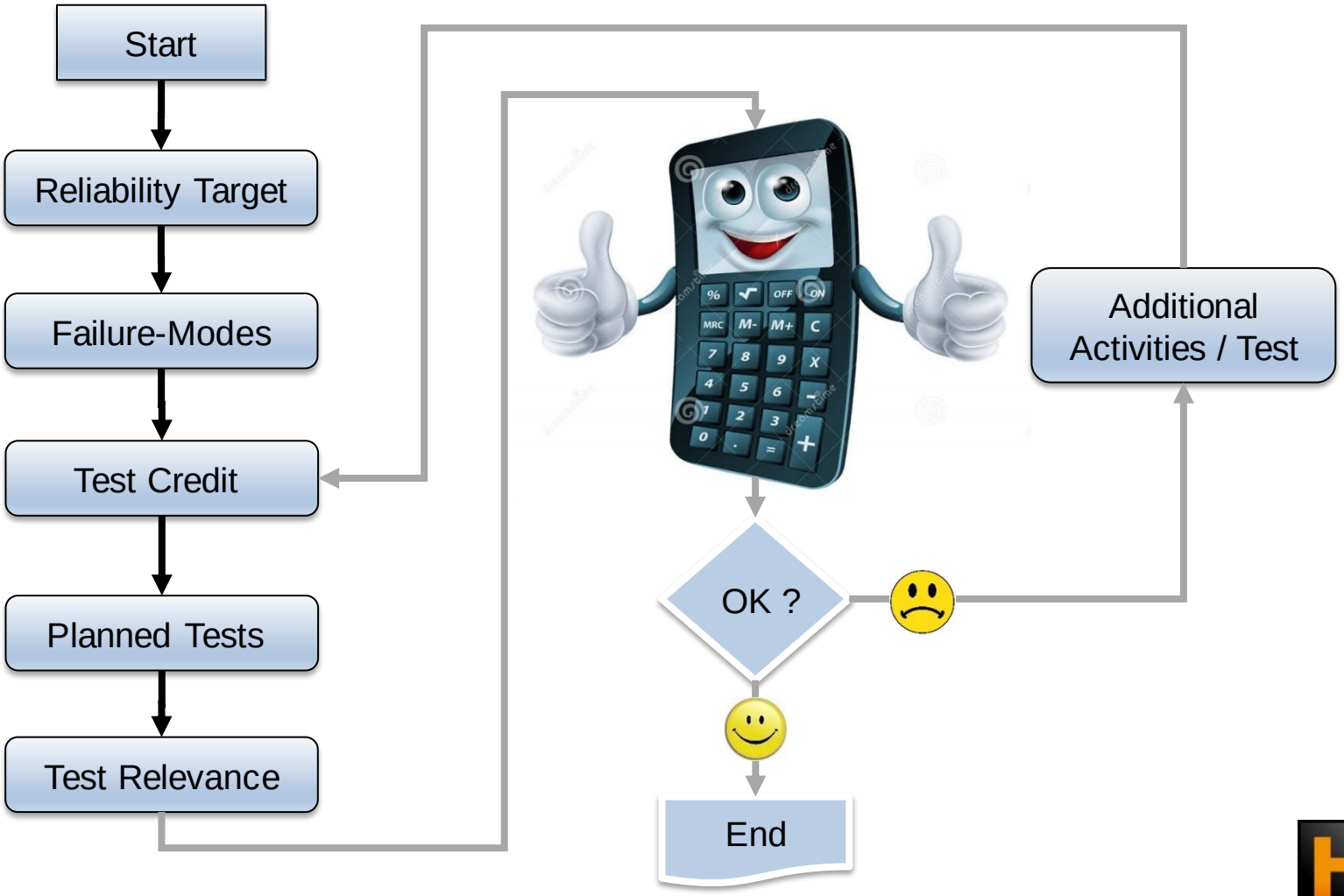
$$C_{Credit} = 1 - R_T^{\sum_{i=Credit}^{n} \left(\frac{t_{Credit}}{T} \right)^{\beta}}$$

from which:

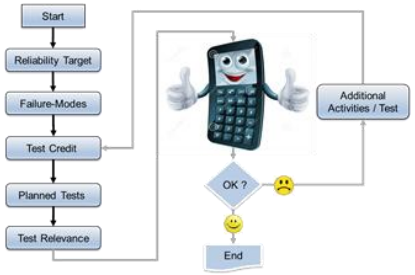
$$\sum_{i=credit}^{n} \left(\frac{t_{Credit}}{T} \right)^{\beta} = \frac{\ln(1 - Credit)}{\ln R_T}$$

The Test Credit is transformed to an equivalent test length t_{Credit}

RVP Flowchart



RVP Interface



Flowchart & Instructions | Reliability Validation Plan | PASSWORD

General Information:
Author: Engineer
Team: Team members
Approved: Reliability Engineer / Group leader

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Issue: | Department: | Reviewed: | Report No.:

Component / System: System Description | Additional Information: Supplier Info

1 – Start: General Information

Notes:	Description:	Owner:
1	Actions	
2		
3		
4		
5		

Reliability target:
Reliability target average population:
TARGET Set-Up
Desired confidence:
Application hours:
Reliability target: Max. 10,0% @hours 8.000 = Design Life
Reliability Target per failure mode: 10,0% @hours User Profile:

2 - Reliability Target

Reliability Validation Plan

Number of failure modes Identified: 3

Test Credit per failure mode:

4 – Test Credit

Failure modes according to risk analysis (FMEA / FMECA / Other...)

	Credit 1	Credit 2	Credit 3	Credit 4	Credit 5	Credit 6	Credit 7	Credit 8	Credit 9	Credit 10
	45%	8%	28%	0%	0%	0%	0%	0%	0%	0%
Failure-Mode Description	Infant Mortality: Process relate issues	Wear out. Abrasive wear due to high contact pressure.	Cavitation due to high fluid speed and / or contaminati on							
BETA	0,5	2,0	3,5	1	1	1	1	1	1	1

3 - Failure Modes + Weibull slopes

Notes:
1 - All calculations are based on "Zero Failure" tests. A redesign is appropriate the moment a failure mode is discovered during testing, unless the failure-mode is clearly accredit to the test methodology. Separate validation of the redesign is always required.
2 - All tests to be based on NOMINAL loads (50 Percentile).
3 - Acc. Factors to be explained in the remarks of column G.

FULL SCREEN

NORMAL SCREEN

Warning: Do NOT Cut and Paste yellow cells below! Formula's will be destroyed... ...

Test nr.	Description	No. Test	Test Time	Units	Acc. factor	Units	Eq. Field hours	Test Relevance for above mentioned failure mode									
1	Durability Test	8	150	Hrs	50	units/hr	7.500	0%	50%	100%	0%	0%	0%	0%	0%	0%	0%
2	Field Customer Test	5	1,0	yr	1500	hours/yr	1.500	100%	100%	100%	0%	0%	0%	0%	0%	0%	0%
3	Wear-out Labor Test	4	270	Hrs	50	hours/hr	13.500	0%	100%	50%	0%	0%	0%	0%	0%	0%	0%
4							0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
5							0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
6							0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
7							0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
8							0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
9							0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
10							0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

5 - Planned Test

6 - Test Relevance

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RESULTS	Probability of Detection Related to target per failure mode	Average	Probability of Detection (% Confidence) per failure mode.								
		76%	56%	81%	90%						
			PoD 1	PoD 2	PoD 3	PoD 4	PoD 5	PoD 6	PoD 7	PoD 8	PoD 9	PoD 10

7 - Results

1 – General Information

1 – Start: General Information

General Information:	Flowchart & Instructions	Reliability Validation Plan			PASSWORD
		COPYRIGHT: All Intellectual Rights belong to Weibull Reliability Engineering. Version RVP Master V.6.12 yr 2014 Weakset Link			
Author:	Engineer	Issue:		Department:	
Team:	Team members	Date:		Supplier:	
Approved:	Reliability Engineer / Group leader	Reviewed:		Report No.	
Component / System:	System Description	Additional Information:	Supplier Info		

Most important is to …

2 – Reliability Target

Notes

2 - Reliability Target

Reliability Target Average Population:

TARGET Set-Up					
Desired confidence:	90%				
Application Class:	2	See target setup sheet		Yr. Usage (Avrg.):	1,000 hours
Reliability Target: Max.	10.0%	@hours	8,000	= Time between overhaul (TBO)	
Reliability Target per Failure-Mode:	10.0%	@hours			

Enter Units:	hours	Enter / hr / cycles / km / etc. as appropriate	
Application Class	**Targets**		**Per Year: (Life= 8 years)**
1 - Low user	6,000	hours	750
2 - Medium user	8,000	hours	1,000
3 - Heavy user	10,000	hours	1,250
4 - Extreme heavy user	15,000	hours	1,875
Life time in years	8	years	

3 – Failure Modes or Mechanisms

Notes

2 - Reliability Target

3 - Failure Modes + Weibull slopes

Failure modes according to risk analysis (FMEA / FMECA / Other...)

Credit 1	Credit 2	Credit 3	Credit 4	Credit 5	Credit 6	Credit 7	Credit 8	Credit 9	Credit 10
Infant Mortality: Process relate Issues	Wear out. Abrasive wear due to high contact pressure.	Cavitation due to high fluid speed and / or contaminati on							
0,5	**2,0**	**3,5**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

4 – Test Credit

Notes

2 - Reliability Target

4 – Test Credit

Failure modes according to risk analysis (FMEA / FMECA / Other...)									
Credit 1	Credit 2	Credit 3	Credit 4	Credit 5	Credit 6	Credit 7	Credit 8	Credit 9	Credit 10
45%	8%	28%	0%	0%	0%	0%	0%	0%	0%

Per Failure Mode

Test Credit Calculator

4 – Test Credit Calculator

4 – Test Credit

Design Change Level

Engineering Activities

RVP Test Credit Calculator		Beta > 1			System / Component
Failure Mode:	Cavitation due to high fluid speed and / or contamination	Beta Check			
Beta value:	3,5	OK		Change Level	
				Pull down list	Remarks / Comments
MODE - Design Change Level		25 - 50%		<25%	
	< 25% = Existing Design with new application			25 - 50%	
	25 - 50% = Adaptation of existing Design			50 - 75%	
	50 - 75% = Large adaptation on existing Design			>75%	
	> 75% = New Design				
Activities		Applicable		Credit Division	Remarks / Comments
	Warranty Analysis	☑		5%	
	Reliability Analysis	☑		10%	
	D-FMEA completed	☐		15%	
	Mathematical Calculations	☑		10%	
	FEM / Modeling Analysis	☐		10%	
	FEM / Model Stress verification	☑		5%	
	Stress measurements	☐		5%	
	FRACAS in place	☐		5%	
	Laboratory tests	☐		10%	
	Others	☑		5%	Fluid measurements
				80%	
Reset All	Test Credit:	28%		CORRECTED	Back to MAIN

5 – Planned Tests

Notes

2 - Reliability Target

4 – Test Credit

3 - Failure Modes + Weibull slopes

5 - Planned Test

Equivalent Field hours per Sample

Test nr.	Description	Sample Size	Test Time	Units	Acc. factor	Units	Eq. Field hours
1	Durability Test	8	150	Hrs	50	units/hr	7.500
2	Field Customer Test	5	1,0	yr	1500	hours/yr	1.500
3	Wear-out Labor Test	4	270	Hrs	50	hours/hr	13.500

6 – Test Relevance

Notes

2 - Reliability Target

4 – Test Credit

3 - Failure Modes + Weibull slopes

5 - Planned Test

6 - Test Relevance

Test Relevance for above mentioned failure mode									
0%	50%	100%	0%	0%	0%	0%	0%	0%	0%
100%	100%	100%	0%	0%	0%	0%	0%	0%	0%
0%	100%	50%	0%	0%	0%	0%	0%	0%	0%

6 - Test Relevance

Test Relevance	How Suitable is a Test for the Failure Mode
0 %	Not Suitable at all
25 %	For a Small Portion Suitable
50 %	Partially Suitable
75 %	For a Large Portion Suitable
100 %	Fully Suitable

7 - RVP Output - Results

Notes

2 - Reliability Target

4 – Test Credit

3 - Failure Modes + Weibull slopes

5 - Planned Test

6 - Test Relevance

7 - Results

Probability of Detection Related to target per failure mode	Average	Probability of Detection (% Confidence) per failure mode.									
	76%	56%	81%	90%							
		PoD 1	PoD 2	PoD 3	PoD 4	PoD 5	PoD 6	PoD 7	PoD 8	PoD 9	PoD 10
Maximal failure rate per failure mode after completion of all tests (90% C)	Fail. Prob. % @ Design Life	Maximal failure (%) per failure mode (90% C)									
		25,5%	13,5%	9,9%	NA	NA	NA	NA	NA	NA	NA
		Graphics Total Overview									

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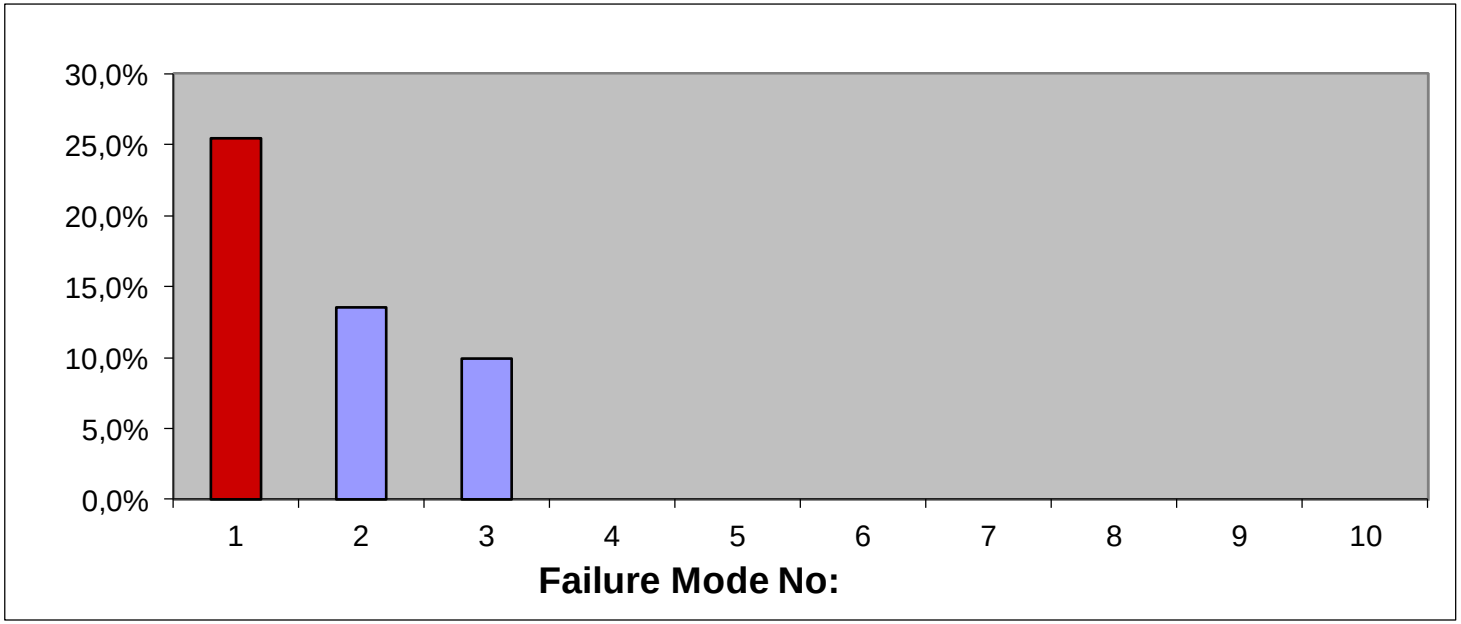
7 - RVP Detail Output



The Weak Spots of the Risk Mitigation plan

Summary

Questions

Ing. Ronald Schop

Ronald *is the Sr. Director Reliability at Holland Innovative with over 35 years Engineering experiences in the automotive, high-tech, and energy markets. He initiated Reliability Engineering within Product Development at several companies, leading to Design for Reliability and Robust Design in Programs. He developed new Reliability Tools and methods to increase the accuracy of product reliability forecast and verification.*

Ing. Ronald Schop
Sr. Director Reliability

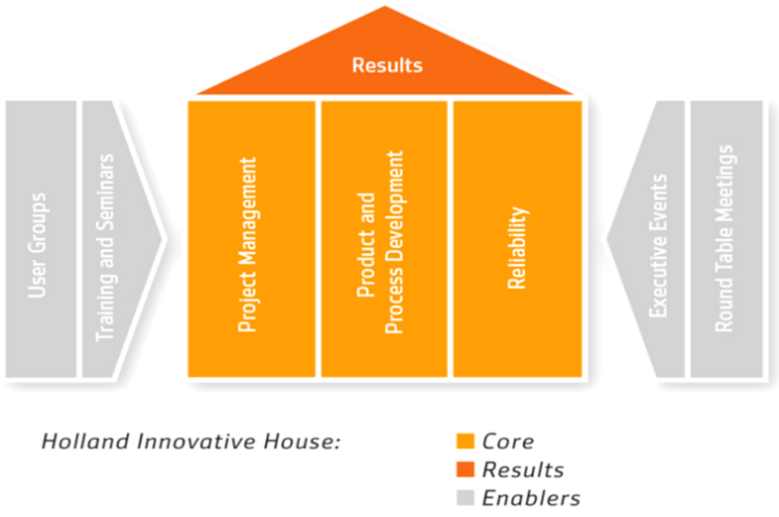
High Tech Campus 9
β-Technology Center
5656 AE Eindhoven

P.O. Box 7060
5605 JB Eindhoven
The Netherlands

T +31 40 8514 610
F +31 40 8514 619

M: +31 6 3835 8663

ronald.schop@holland-innovative.nl
www.holland-innovative.nl



Acronyms

RVP	*- Reliability Validation Plan*
DVP&R	*- Design Validation Plan & Report*
PoD	*- Probability of Detection*
DFMEA	*- Design Failure Mode & Effect Analysis*
R_T	*- Reliability at time "T"*
T	*- Design life or reliability demonstration time*
n	*- Sample size*
t_i	*- Total test time of each part*
β	*- Weibull shape parameter or Weibull slope*
η	*- Characteristic Life*
C	*- Statistical confidence level specified*

RVP Interface

General Information:	Flowchart & Instructions	Reliability Validation Plan		PASSWORD
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Author:	Engineer	Issue:	Department:	
Team:	Team members	Date:	Supplier:	
Approved:	Reliability Engineer / Group leader	Reviewed:	Report No.	
Component / System:	System Description	Additional Information:	Supplier Info	

Notes:	Description:	Owner:	Reliability target:				
1	Actions		Reliability target average population:				
2			TARGET Set-Up	Desired confidence:	90%		
3				Application Class:	2	See target setup sheet	Yr. Usage (Avrg.): 1.000 hours
4				Reliability target: Max.	10,0%	@hours 8.000	= Design Life
5				Reliability Target per failure mode:	10,0%	@hours	User Profile:

Reliability Validation Plan

Number of failure modes Identified: 3

Notes:
1 - All calculations are based on "Zero Failure" tests. A redesign is appropriate the moment a failure mode is discovered during testing, unless the failure-mode is clearly accredit to the test methodology. Separate validation of the redesign is always required.
2 - All tests to be based on NOMINAL loads (50 Percentile).
3 - Acc. Factors to be explained in the remarks of column G.

FULL SCREEN

Failure-Mode Description

NORMAL SCREEN

Warning: Do NOT Cut and Paste yellow cells below! Formula's will be destroyed... ...

Test nr.	Description	Sample Size	Test Time	Units	Acc. factor	Units	Eq. Field hours	Failure modes according to risk analysis (FMEA / FMECA / Other...)									
								Credit 1	Credit 2	Credit 3	Credit 4	Credit 5	Credit 6	Credit 7	Credit 8	Credit 9	Credit 10
						Test Credit per failure mode:		45%	8%	28%	0%	0%	0%	0%	0%	0%	0%
								Infant Mortality: Process relate Issues	Wear out. Abrasive wear due to high contact pressure.	Cavitation due to high fluid speed and / or contaminati on							
						BETA		0,5	2,0	3,5	1	1	1	1	1	1	1
								Test Relevance for above mentioned failure mode									
1	Durability Test	8	150	Hrs	50	units/hr	7.500	0%	50%	100%	0%	0%	0%	0%	0%	0%	0%
2	Field Customer Test	5	1,0	yr	1500	hours/yr	1.500	100%	100%	100%	0%	0%	0%	0%	0%	0%	0%
3	Wear-out Labor Test	4	270	Hrs	50	hours/hr	13.500	0%	100%	50%	0%	0%	0%	0%	0%	0%	0%
4							0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
5							0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
6							0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
7							0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
8							0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
9							0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
10							0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

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RESULTS

Probability of Detection Related to target per failure mode

Average	Probability of Detection (% Confidence) per failure mode.									
76%	56%	81%	90%							
	PoD 1	PoD 2	PoD 3	PoD 4	PoD 5	PoD 6	PoD 7	PoD 8	PoD 9	PoD 10

Reliability RESULTS

Maximal failure rate per failure mode after completion of all tests (90% C)

Fail. Prob. % @ Design Life

Maximal failure (%) per failure mode (90% C)									
25,5%	13,5%	9,9%	NA	NA	NA	NA	NA	NA	NA

Graphics Total Overview

Maximal failure rate total system after completion of all tests (90% C)

Reliability

Forecast Max. Failure % @ Design Life (90% C)

25,5%

Information

Book: “The New Weibull Handbook”; Dr. Robert B. Abernethy
Paper: “Two Useful Equations In Reliability Demonstration”; C. Julius Wang

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