2010 ARS, Europe: Berlin, Germany

Track 1, Session 2

Begins at 10:30 AM, Wednesday, April 7th

Supe-RPN – Optimal Prioritizing of Potential Failures Detected by FMEA

Alon Sneor

RAMS Consultant

&

Nadav Haas, Amnon Ganot

Orbotech Ltd.

Alon Sneor

Your Consultant

RAMS & Innovation

alon.sneor@gmail.com

+972-4-9531413 Cell +972-54-6457222

PRESENTATION SLIDES

The following presentation was delivered at the:

International Applied Reliability Symposium, Europe
April 7 - 9, 2010: Berlin, Germany
http://www.ARSymposium.org/europe/2010/

The International Applied Reliability Symposium (ARS) is intended to be a forum for reliability and maintainability practitioners within industry and government to discuss their success stories and lessons learned regarding the application of reliability techniques to meet real world challenges. Each year, the ARS issues an open "Call for Presentations" at http://www.ARSymposium.org/europe/presenters/index.htm and the presentations delivered at the Symposium are selected on the basis of the presentation proposals received.

Although the ARS may edit the presentation materials as needed to make them ready to print, the content of the presentation is solely the responsibility of the author. Publication of these presentation materials in the *ARS Proceedings* does not imply that the information and methods described in the presentation have been verified or endorsed by the ARS and/or its organizers.

Agenda

• Introduction – Analysis Framework	5 min
• DFMEA / PFMEA Overview	5 min
• RPN Computation and Prioritization	5 min
• RPN Drawbacks and Alternatives	5 min
• Supe-RPN at Orbotech	15 min
• Optimized Supe-RPN	10 min
• Summary	5 min
• Q & A, Discussion	10 min

Introduction

- Extended FMEA (D/P-FMEA) - part of a reliability analysis framework at Orbotech
  - Quick FMEA (QFMEA) of System / Sub-system
    - System / sub-system description and analysis
    - Major failure modes
    - Major corrective actions
  - Extended FMEA of selected sub-system
  - Action Items Meeting for Extended FMEA

DFMEA / PFMEA Overview

How can a (sub-) system fail?

What could the failure cause?

S everity

How often can the failure occur?

O ccurrence

How & when can we know about the failure?

D etection

P R I O R I T I Z A T I O N

How can the failure be eliminated / mitigated?

Action Items & Responsibilities

Typical format (Excel)

DFMEA / PFMEA Overview

- **P R I O R I T I Z A T I O N** - Dilemma
  - We can't treat all of the potential failures (PFs)
  - We can't afford to overlook significant PFs
  - We seek "good" prioritization of PFs
- What are SIGNIFICANT PFs ???

RPN Objective and Computation

- Objective
  - **R** isk **P** RIORITY **N** umber -

    Prioritize PFs

- Computation

  S everity X **O** ccurrence X **D** etection

RPN Characteristics

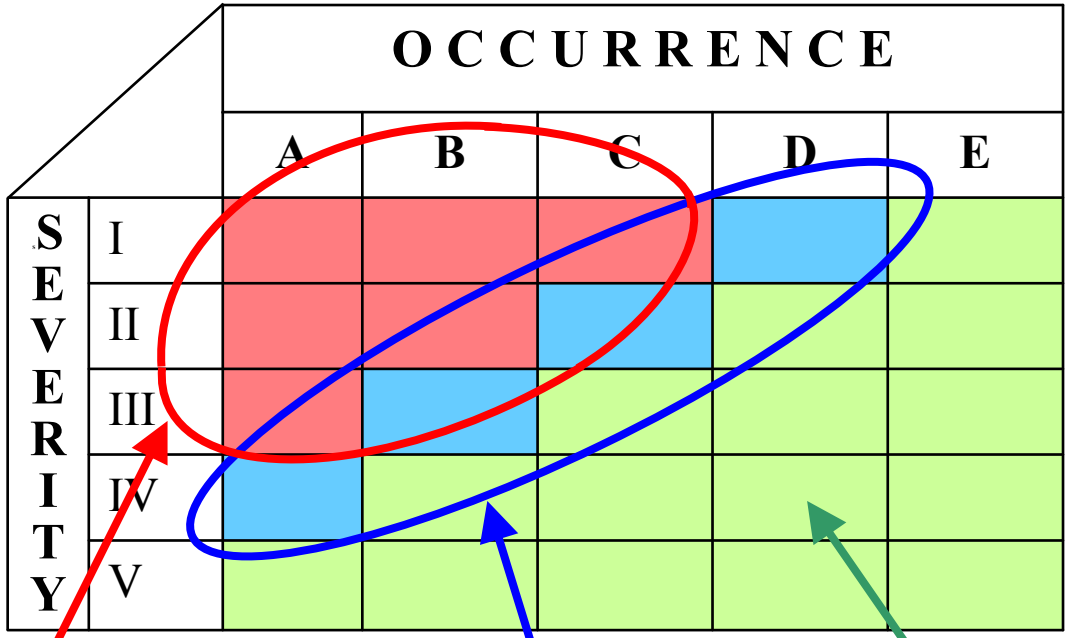
- It's a simple and intuitive tool !
- Standard RPN ranking
  - Linear scale (1-10, 1-5 etc.)
  - 10 = worst, 1 = best
  - Same scale **S**, **O** & **D**
- Prioritization schemes
  - Set cutoff value(s)
  - Top 10, Next 20, etc.
  - Pareto

Standard RPN Drawbacks

- **S**, **O** and **D** have same weight in the RPN
- Same RPN occurrences from very different **S-O-D**s require different treatments
- Many occurrences of same-value-RPNs in “main classification range”
- Main attempts to fix - Fuzzy, Cost, Expanded

Alternative Prioritization Technique

- **C** riticality **M** atrix Prioritization,
  S and **O** mapping only



Unacceptable Undesirable Acceptable

DFMEA / PFMEA / CM Summary

- Standard RPN prioritization tool:
  - Rationale & methodology
  - Characteristics
  - Prioritization dilemma
  - Prioritization schemes
  - Limitations

- CM - Rationale & methodology, characteristics

Supe-RPN Objective

- Improve prioritization by overcoming shortcomings of standard / linear RPN
  - Weighted **S**, **O** and **D**
  - Non-linear scales for better distinction
  - Incorporating a confidence level scale for the **O** ccurrence

Supe-RPN Ranking at Orbotech

	RANKINGS					
S	1	2	4	8	16	32
O	1	2	3	4	6	
D	1	3	9			

S - Exponential, 6 levels

O - Nearly linear

D - Exponential, 3 levels

S - Highest emphasis

O - Lowest emphasis

D - Highest level (9) close to S=8

Supe-RPN Ranking at Orbotech

Effect	Criteria: **Severity** of Effect	Rank
Human Safety	**Risk of personal injury to operator, to by-stander or to maintenance engineer**	**32**
Machine Safety	**Major damage to machine or any of its components**	**16**
General system failure	**Machine stopped for more than defined MTTR1 hours, or irreparable damage to product**	**8**
Local failure	Normal operation disrupted, within defined MTTR2 hours, or repairable damage to product	4
Reduced performance	Limping mode / partial performance	2
Operation OK, fix at next PM	Machine can function, but fault needs fixing in next preventive maintenance (PM)	1

Supe-RPN Ranking at Orbotech

Probability of Occurrence	**Occurrence** Evaluation Criteria	Rank
High occur. & high confidence	High probability of failure, high confidence in estimate	6
High occurrence	High probability of failure, medium confidence level	4
Medium occurrence	Medium probability of failure, medium confidence level	3
Low occurrence	Low probability of failure, medium confidence level	2
Very low occ. & high confidence	Very low probability of failure, high confidence level	1

Supe-RPN Ranking at Orbotech

Detection	Detection Evaluation Criteria	Rank
Impossible to detect	No means for detection, including internal diagnostics, BIT and external test equipment	9
Partially detectable	Detection partially possible, or detection possible part of the time	3
Full detectability	Detection possible all the time	1

Supe-RPN Ranking at Orbotech

- Criteria for treating PFs at Orbotech ("**red**")
  - PFs with RPN greater than or equal to **48**
  - PFs whose **S** rank is greater than or equal to **16**

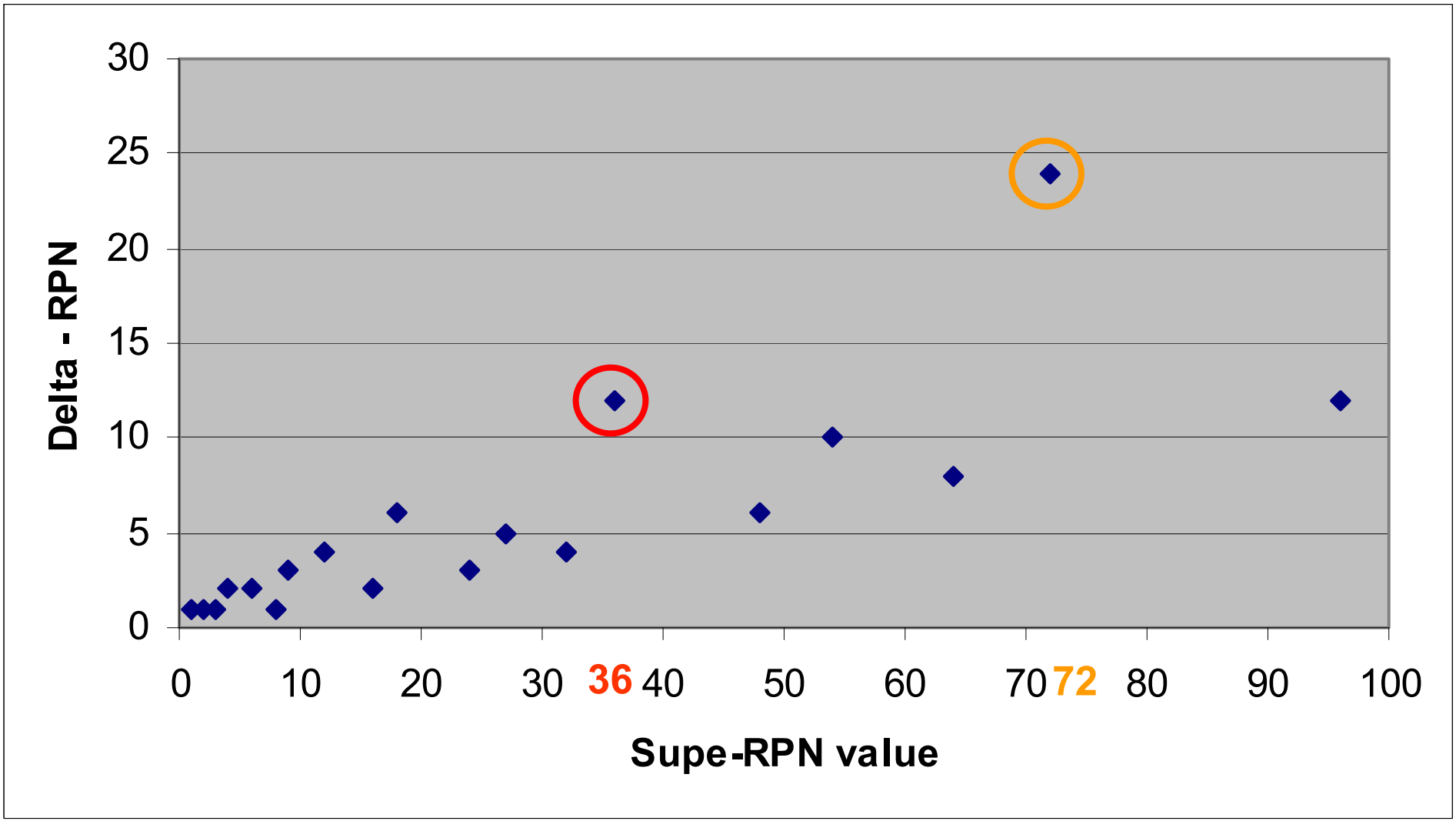
Supe-RPN - Numerical Properties

#	S	O	D	Supe-RPN
36	32	1	1	32
37	16	2	1	32
38	8	4	1	32
39	4	3	3	36
40	2	6	3	36
41	4	1	9	36
42	2	2	9	36
43	1	4	9	36
44	16	3	1	48
45	8	6	1	48
46	16	1	3	48
47	8	2	3	48
48	4	4	3	48
49	2	3	9	54
50	1	6	9	54

#	S	O	D	Supe-RPN
51	32	2	1	64
52	16	4	1	64
53	8	3	3	72
54	4	6	3	72
55	8	1	9	72
56	4	2	9	72
57	2	4	9	72
58	32	3	1	96
59	16	6	1	96
60	32	1	3	96
61	16	2	3	96
62	8	4	3	96
63	4	3	9	108
64	2	6	9	108
65	32	4	1	128

#	S	O	D	Supe-RPN
66	16	3	3	144
67	8	6	3	144
68	16	1	9	144
69	8	2	9	144
70	4	4	9	144
71	32	6	1	192
72	32	2	3	192
73	16	4	3	192
74	8	3	9	216
75	4	6	9	216
76	32	3	3	288
77	16	6	3	288
78	32	1	9	288
79	16	2	9	288
80	8	4	9	288

Supe-RPN – Δ-RPN



DFMEA Example from Orbotech

Function / **Pu**rpose/ **Pa**ramtrs	Poten-tial Failure Modes	Potentia l Failure Mech-anisms	Pot. Effcts of Failure: **L**ocal, **N**ext level, **S**yst. level	S	O	D	RPN	Recom-mended Corrective Actions
PU: Position-ing	SCM too low	Bad datum calibrtio n	**N**: Collision with border **S**: Damage to system	16	1	3	48	**Collision prevention** (Safety Dedicated Device) Test shot
		SCM 'crawls' down over tim e	**N**: Collision with casing **S**: Damage to system	16	2	3	96	**Collision prevention** (Safety Dedicated Device) Test shot
PU: firm attach-m ent	loose **SCM** attach-m ent (X,Y)		**N**: W rong inspection location **S**: Bad fram es	8	2	3	48	"Self lock" mechanism

Supe-RPN at Orbotech Summary

- Methodology
  - Goal – overcome standard RPN limitations
  - Unique ranking scales
  - Prioritization criteria ("**red**") PFs
  - Numerical properties and spread
  - Intuitive and easy to use

- Example of actual DFMEA worksheet

Optimized Supe-RPN - Goals

- Improvement goals, beyond Supe-RPN
  - "Inherent" cutoff values
  - High correlation with CM
  - Preferably – "stand alone prioritization tool"

Optimized Supe-RPN - Rankings

- **S – O – D** Rankings

	RANKINGS				
S	1	2	4	11	31
O	0.8	1.5	3.5	6.5	
D	1	3	9		

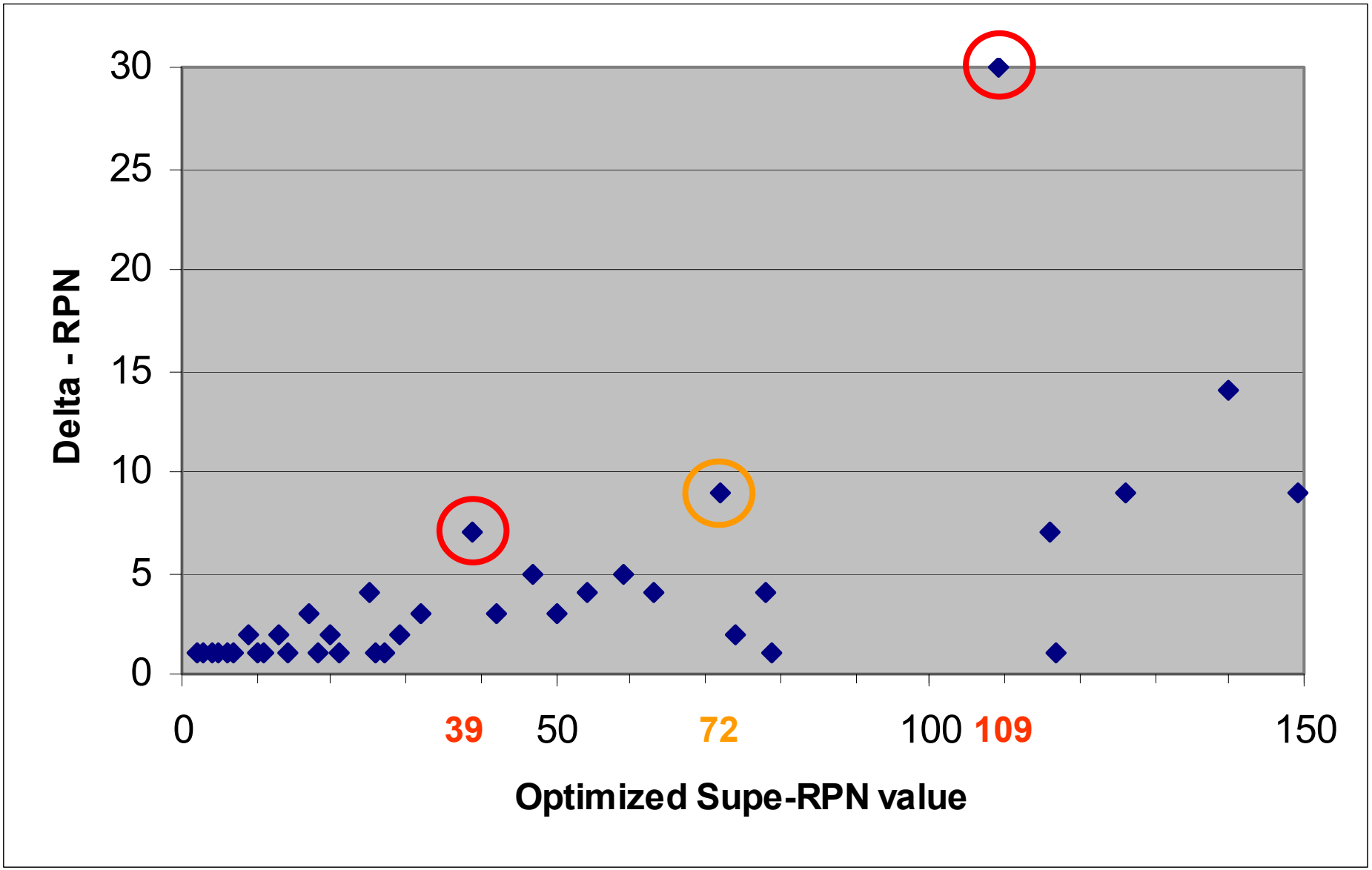
D - effect on criticality, for CM comparison

- **D** = 3 - 'neutral,' no effect
- **D** = 1 - less critical
- **D** = 9 - more critical

Optimized Supe-RPN - Numerical Properties

- Total of 60 values, 49 distinct (>80%) !
- Max. number of occurrences for every distinct value - 3 !
- “Inherent” cutoffs

Optimized Supe-RPN – Δ-RPN



Optimized Supe-RPN - Numerical Properties

#	S	O	D	O-S-RPN
16	4	0.8	3	10
17	1	3.5	3	11
18	2	6.5	1	13
19	4	3.5	1	14
20	2	0.8	9	14
21	1	1.5	9	14
22	11	1.5	1	17
23	4	1.5	3	18
24	1	6.5	3	20
25	2	3.5	3	21
26	31	0.8	1	25
27	4	6.5	1	26
28	11	0.8	3	26
29	2	1.5	9	27
30	4	0.8	9	29

#	S	O	D	O-S-RPN
31	1	3.5	9	32
32	11	3.5	1	39
33	2	6.5	3	39
34	4	3.5	3	42
35	31	1.5	1	47
36	11	1.5	3	50
37	4	1.5	9	54
38	1	6.5	9	59
39	2	3.5	9	63
40	11	6.5	1	72
41	31	0.8	3	74
42	4	6.5	3	78
43	11	0.8	9	79
44	31	3.5	1	109
45	11	3.5	3	116

#	S	O	D	O-S-RPN
46	2	6.5	9	117
47	4	3.5	9	126
48	31	1.5	3	140
49	11	1.5	9	149
50	31	6.5	1	202
51	11	6.5	3	215
52	31	0.8	9	223
53	4	6.5	9	234
54	31	3.5	3	326
55	11	3.5	9	347
56	31	1.5	9	419
57	31	6.5	3	605
58	11	6.5	9	644
59	31	3.5	9	977
60	31	6.5	9	1814

Optimized Supe-RPN - Compared to CM

		OCCURRENCE			
		6.5	3.5	1.5	0.8
SEVERITY	31	605, 644, 977, 1814	326, 347, 419	140, 149, 223	74 , 79
	11	202, 215, 234	109, 116, 126	47, 50, 54	25, 26 , 29
	4	72, 78, 117	39, 42, 63	17, 18, 27	9, 10, 14
	2	26, 39, 59	14, 21, 32	6, 9, 14	3, 5, 7
	1	(7), 13, 20	(4), 7, 11	(2), 3, 5	(1), 2, 2

Summary & Conclusions

- Supe-RPN - broke “deadlocks” of the standard RPN by setting:
  - Non-linear **S** & **D** rankings
  - Weighted rankings – **S** & **D** higher than **O**
  - **O**ccurrence confidence level – additional dimension
  - Improved / natural cutoff (Supe-RPN=48) – goes well with CM

Summary & Conclusions

- Optimized-Supe-RPN – “takes it to the limit”
  - Non-integer + unique rankings
    → 82% values distinct
  - “Natural” / “Inherent” cutoff values
  - Method of incorporating **D** into CM
  - 95% agreement with CM zones
  - 98% agreement with CM “treatment zone”

Summary & Conclusions

- Traits of Optimized / - Supe-RPN
  - Viable / optimized prioritizing tool
  - Simple !
  - Easy to “tune”
  - “Natural” / “Inherent” prioritization
  - “Stand alone” / “CM - Compatible”

Thank you for your kind attention

Q / A & Discussion

Suggested Questions for Discussion

- What **ARE** significant PFs ???
- How did **YOU** prioritize PFs,
  and how well did it work ???
- Is there a simple way of incorporating
  ROI / field failure data / economic aspects
  into RPN prioritization (besides **S**everity) ???

Where to Get More Information

- J1739 - Design and Process FMEA, SAE, July 1994.
- MIL-STD-1629 - Procedures for FMECA, DoD, November 1980.
- MIL-STD-882D, Standard Practice for System Safety, February 2000.
- J. B. Bowles, “An Assessment of RPN Prioritization in a FMECA”, Proceedings of the Annual Reliability & Maintainability Symposium, January 2003.

Alon Sneor

Alon Sneor was a senior RAMS engineer at Rafael Ltd.
He also worked as a RAMS consultant with Orbotech Ltd., helping Orbotech to establish its RAMS department, to define RAMS methodologies and to set up facilities (e.g. reliability lab).

Dr. Sneor has a Bs.C. and Ms.C. in Mechanical Engineering from the Technion and a Ph.D. in Mechanical engineering from the University of Texas at Austin. He has 23 years of experience in RAMS engineering and management, systems engineering and vibration analysis, measurement and testing.

Alon is married and has 3 daughters. He enjoys hiking, biking, swimming and music.

Contact info:

- e-mail – alon.sneor@gmail.com
- Phone - +972-4-953-1413
- Cell - +972-54-6457-222

Nadav Haas

Nadav Haas is RAMS & Standard Compliance Manager at Orbotech Ltd.

Nadav joined Orbotech in 2006 as a system validation engineer in the development of a new large-scale, multi-disciplinary machine for LCD production. In his role, he contributed significantly to the promotion of RAMS in Orbotech.

Prior to joining Orbotech, Nadav held different R&D positions in several high-tech companies, including physicist, systems engineer, project manager and product manager. Nadav holds a BSC in physics from Tel-Aviv University and an MSC in experimental physics from Bar-Ilan University.

Contact info:

- e-mail – nadav-ha@orbotech.com
- Phone - +972-8-942-3691

Amnon Ganot

Amnon Ganot is the RAMS expert at Orbotech Ltd. Amnon has been working at Orbotech for the last 19 years. Prior to being the RAMS expert, Amnon was the RAMS & Standard Compliance Manager of Orbotech. During his time as the RAMS & Standard Compliance Manager, he concentrated on developing methodologies for RAMS such as ALT, FMEA (Quick & Extended), DFM, DFR, Design for Standard Compliance, HALT, etc. Prior to the former job, he was, for more than 25 years, a project manager and systems engineer in multi-disciplinary projects in the medical, communications and industrial fields. In the last year, Amnon has been occupied as CTO of Gertron Ltd., performing RAMS consulting services. Amnon holds a B.Sc. in Electrical Engineering from the Technion Israel Institute of Technology. Amnon received his MBA in Marketing and IT from the Tel-Aviv University. Amnon is an ASQ CRE as well as an ISQ CRE.

Contact info:

- e-mail – amnon-g@orbotech.com
- Phone - +972-8-942-3737

Appendix

DFMEA Template Example

#	(Sub)-System Function	Potential Failure Modes (design defects)	Potential Failure Effects	SEV	Class	Potential Causes of Failure	OCC	Current Design Controls	DET	RPN
1										
2										
3										
4										
5										
6										
7										

Standard FMEA Severity Ranking

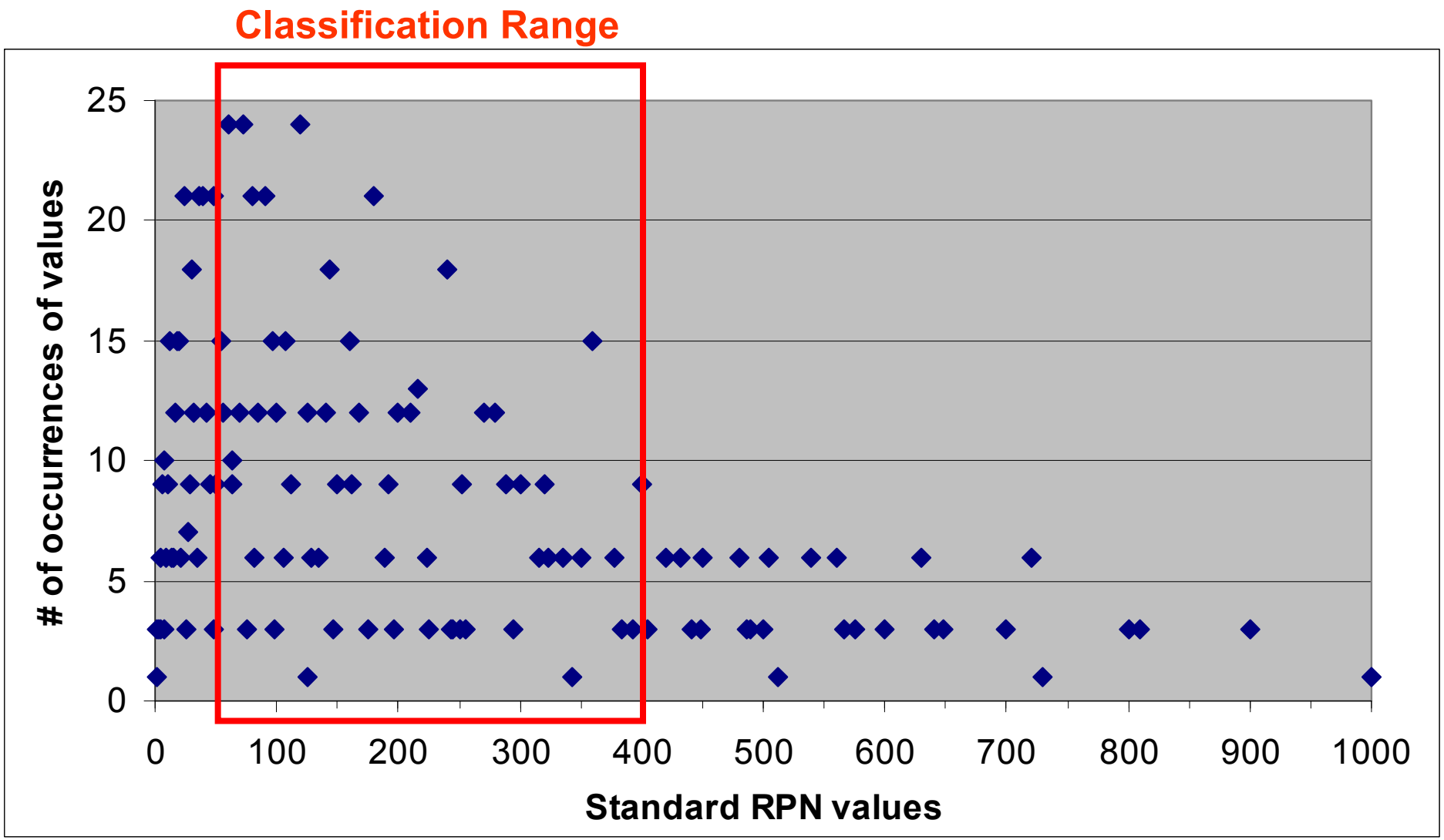
Rating	Description	Definition (Severity of Effect)
10	**Dangerously high**	Failure could injure the customer or an employee.
9	**Extremely high**	Failure would create noncompliance with federal regulations.
8	**Very high**	Failure renders the unit inoperable or unfit for use.
7	**High**	Failure causes a high degree of customer dissatisfaction.
6	**Moderate**	Failure results in a subsystem or partial malfunction of the product.
5	**Low**	Failure creates enough of a performance loss to cause the customer to complain.
4	**Very Low**	Failure can be overcome with modifications to the customer's process or product, but there is minor performance loss.
3	**Minor**	Failure would create a minor nuisance to the customer, but the customer can overcome it without performance loss.
2	**Very Minor**	Failure may not be readily apparent to the customer, but would have minor effects on the customer's process or product.
1	**None**	Failure would not be noticeable to the customer and would not affect the customer's process or product.

Combinations of Linear Scale RPN

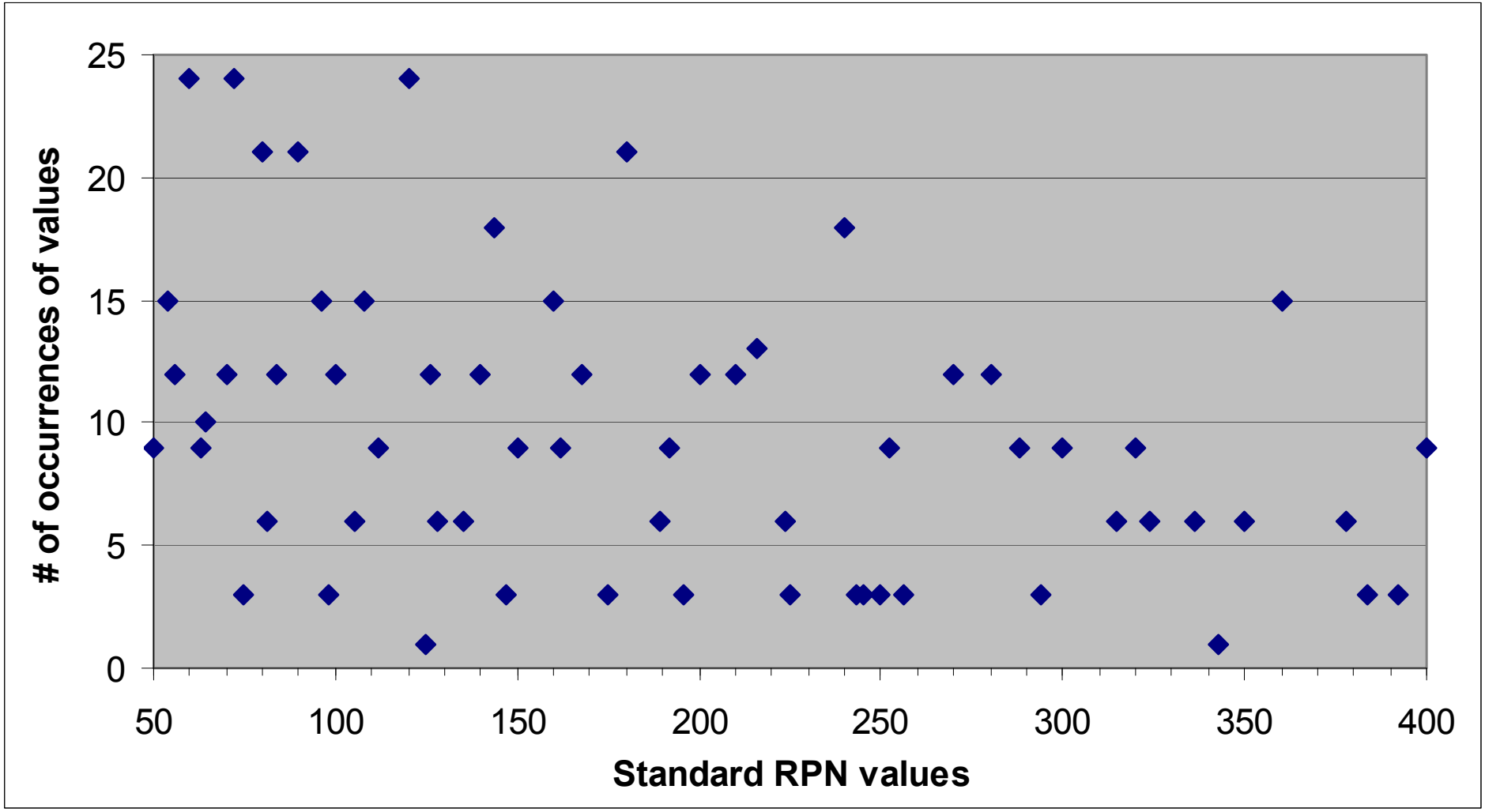
Severity	Occurrence	Detection	RPN
8	5	2	80
5	8	2	80
2	8	5	80
2	5	8	80

There are **21** **S-O-D** combinations of RPN = 80 !!!

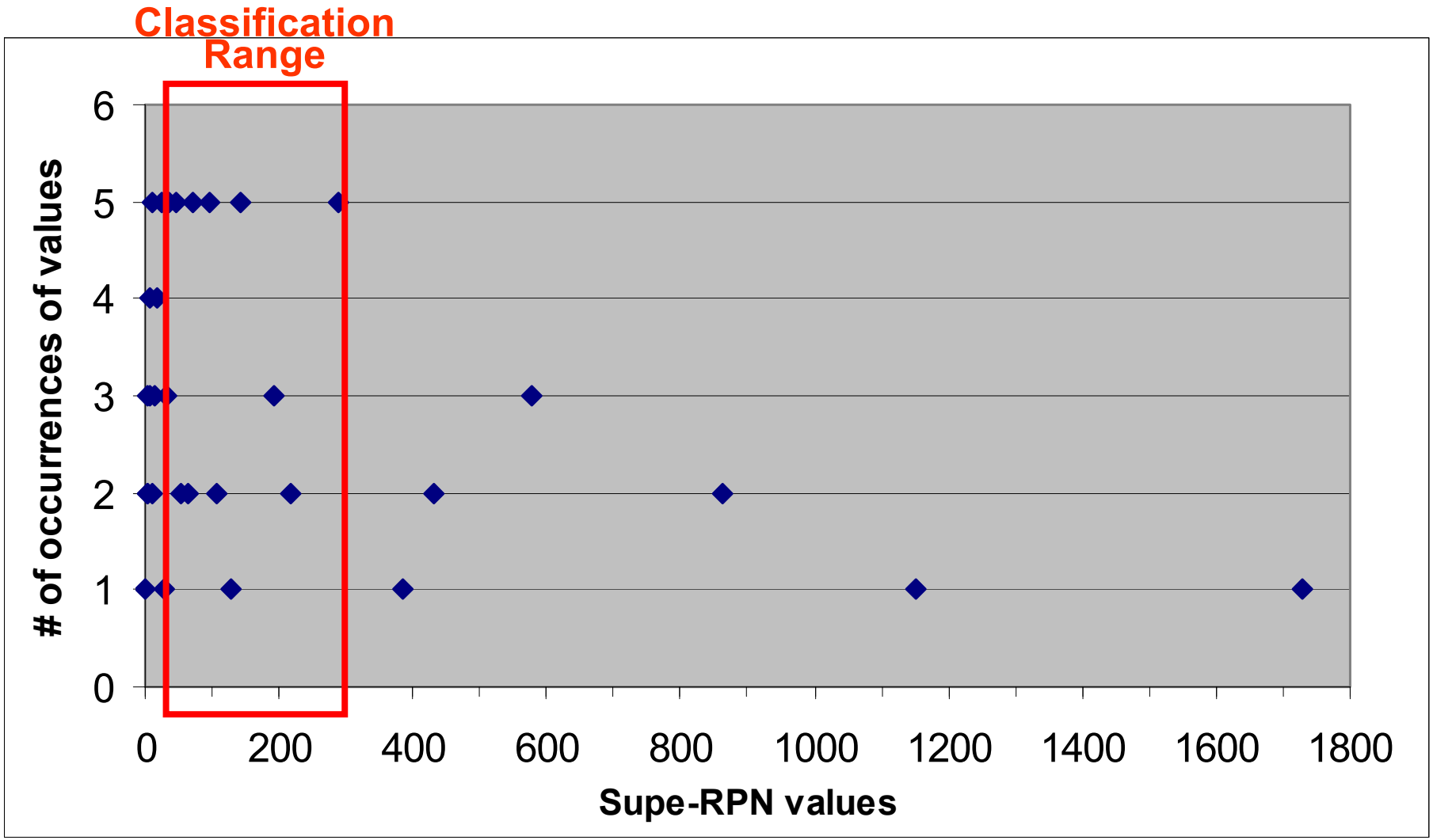
Standard RPN Full Range



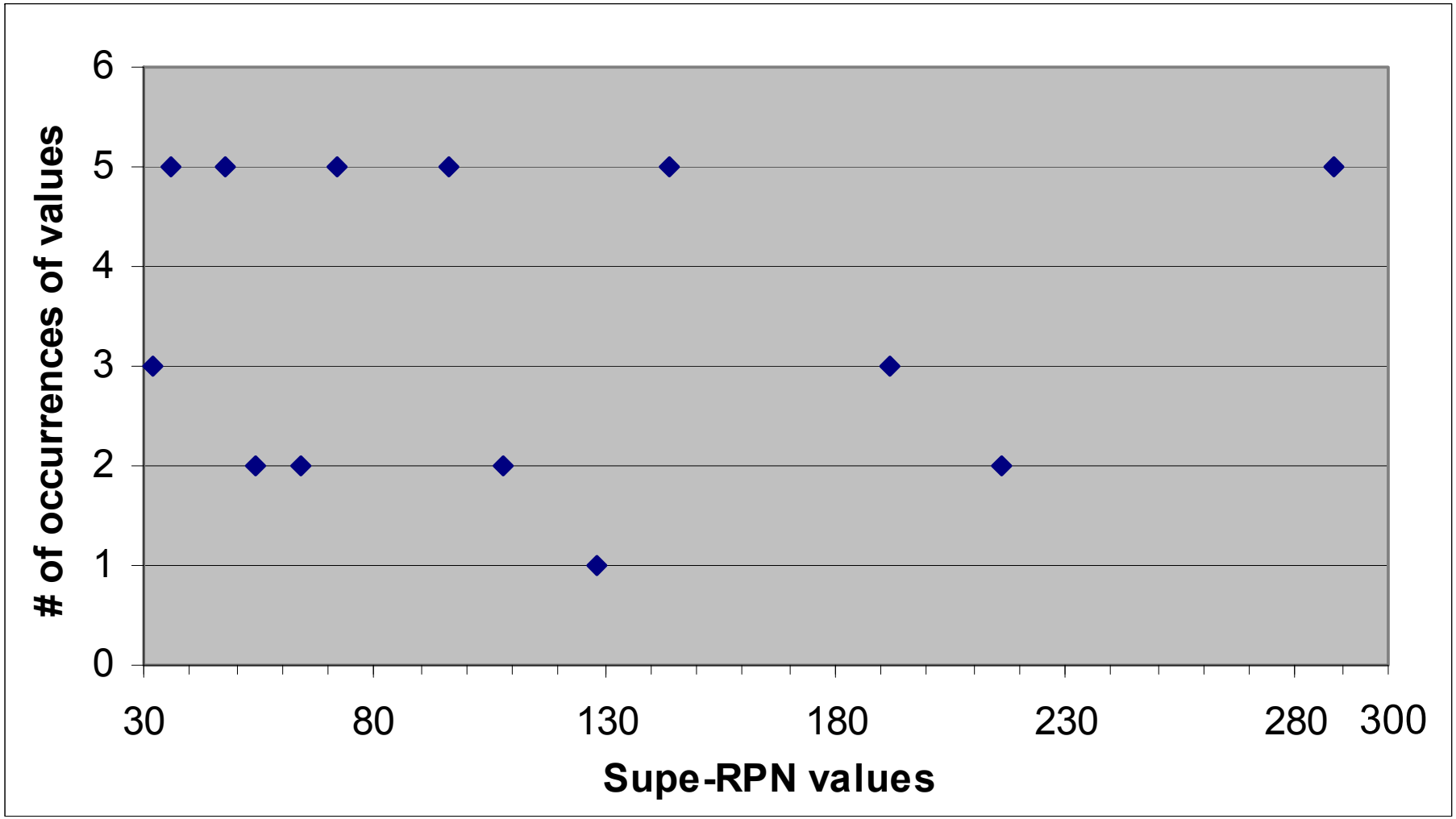
Standard RPN in Main Classification Range



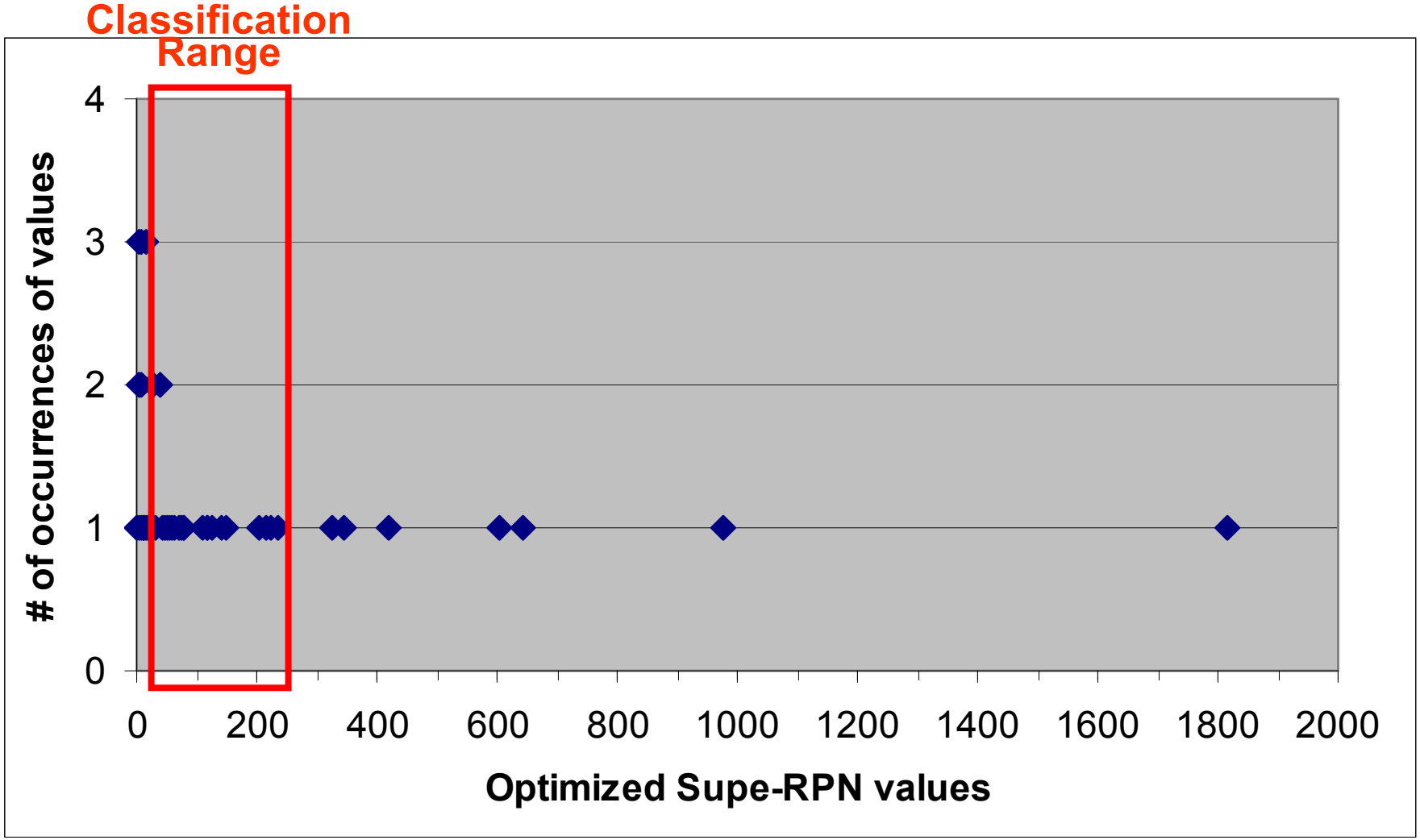
Supe-RPN in Main Classification Range



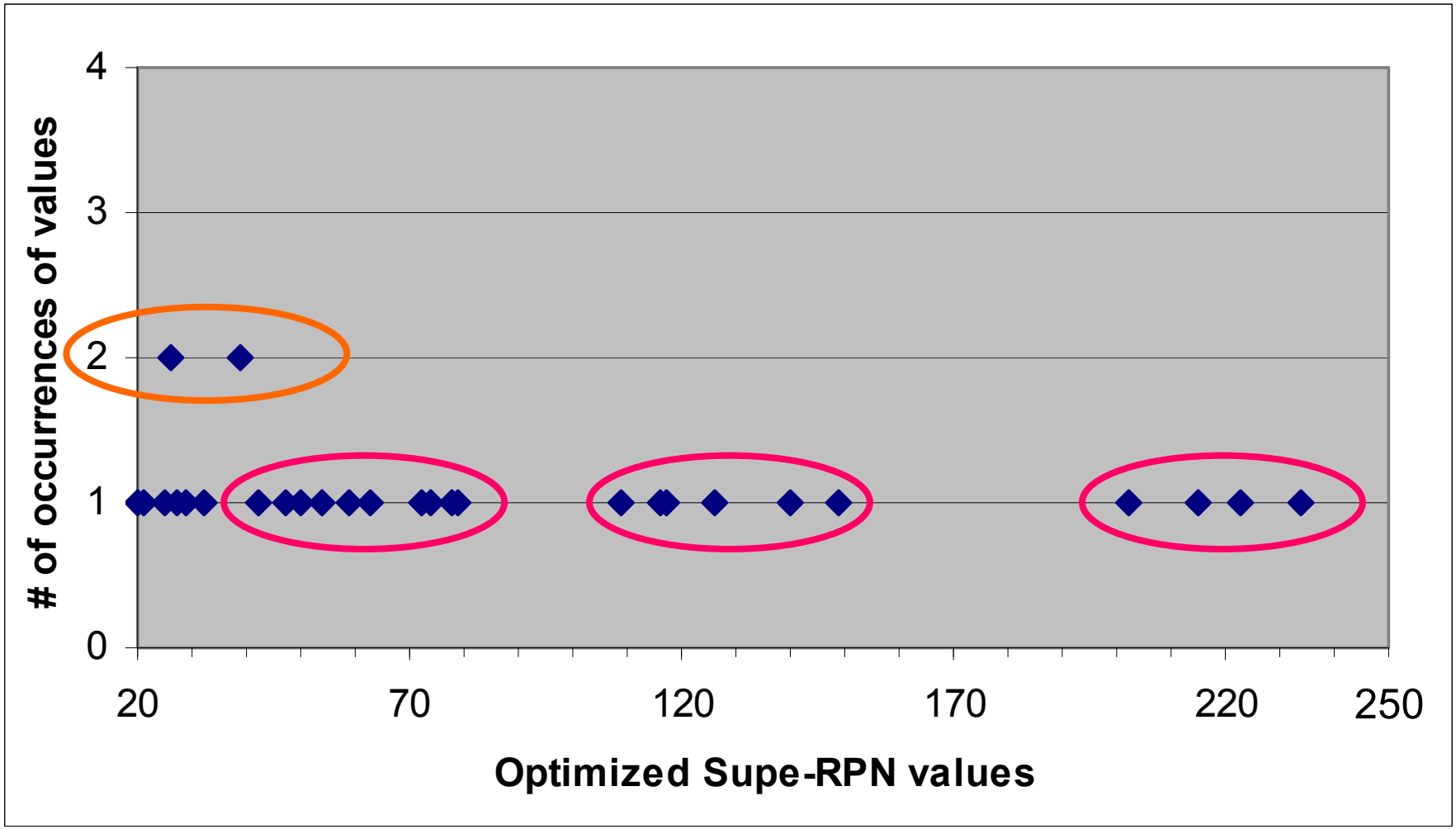
Supe-RPN in Main Classification Range



O-Supe-RPN in Main Classification Range



O-Supe-RPN in Main Classification Range



Effect of **D** on Criticality Mapping