Cable Diagnostic Focused Initiative

National Electric Energy Testing Research Application Center (NEETRAC)

PI: Rick Hartlein

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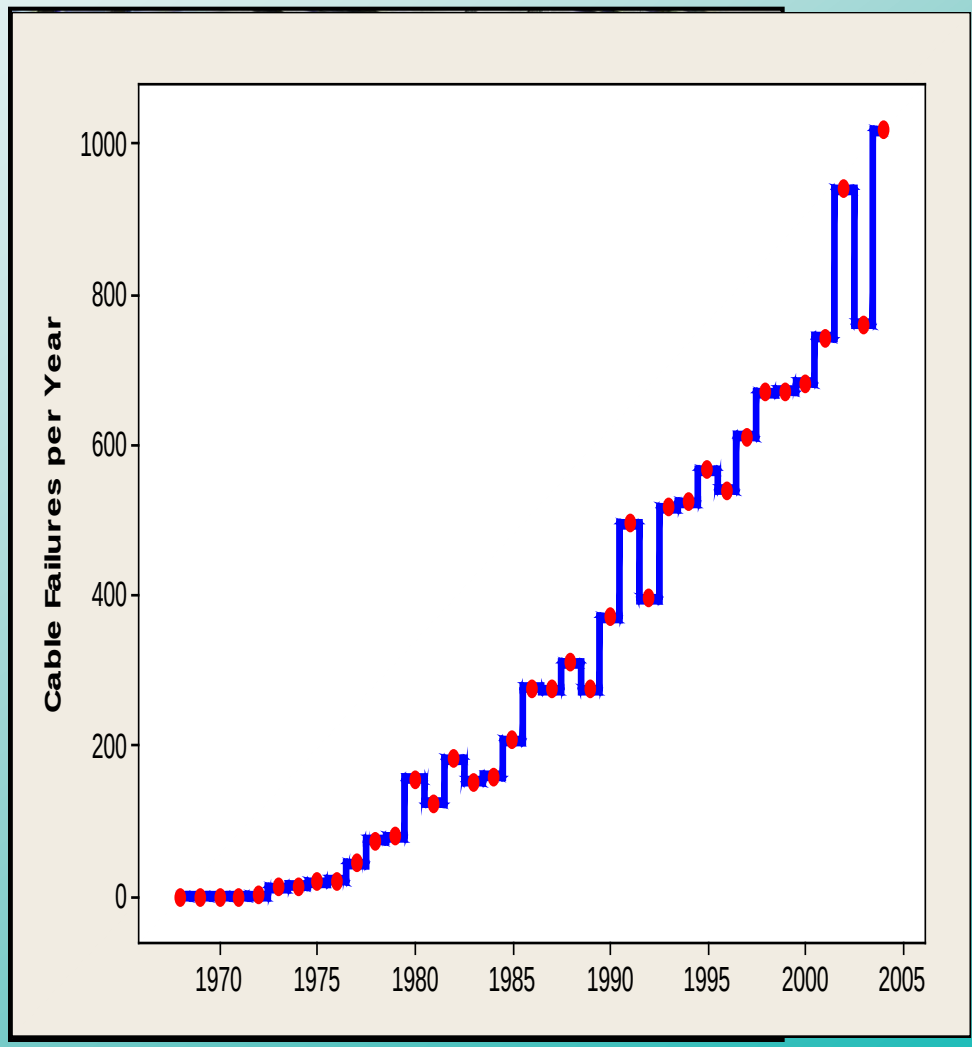
Why do we need diagnostics?

- Underground cable system infrastructure is complex and aging.
- Failures are increasing
- If not addressed then old infrastructure will not support future operation of the grid.
- Not enough money / manufacturing capacity to simply replace because they are old.
- Need diagnostic tools to prioritize Active Asset Management.
- Some tools are available, but there is significant mistrust and commercialism that has limited their effective deployment.



CDFI Team

NEETRAC

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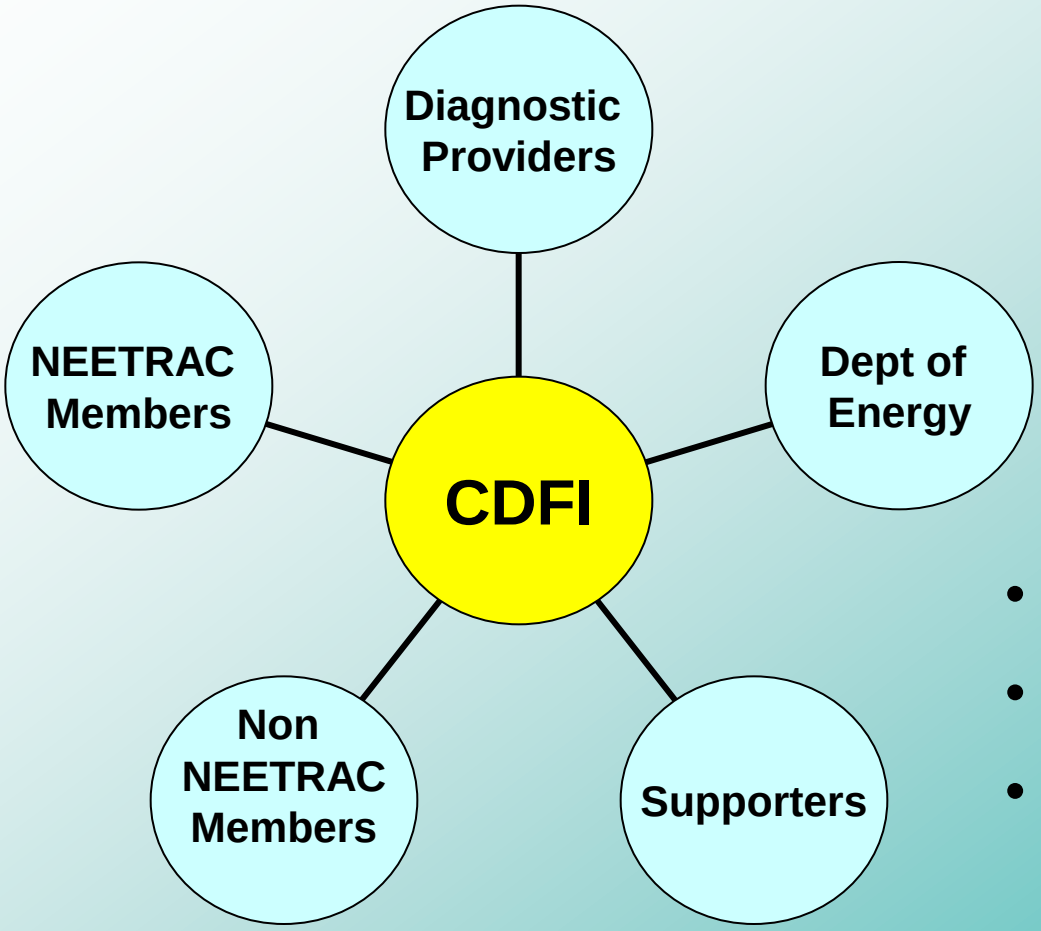
*PhD supported by CDFI

CDFI Partners



- 13 Electric Utilities
- 5 Manufacturers
- 6 Diagnostic Providers

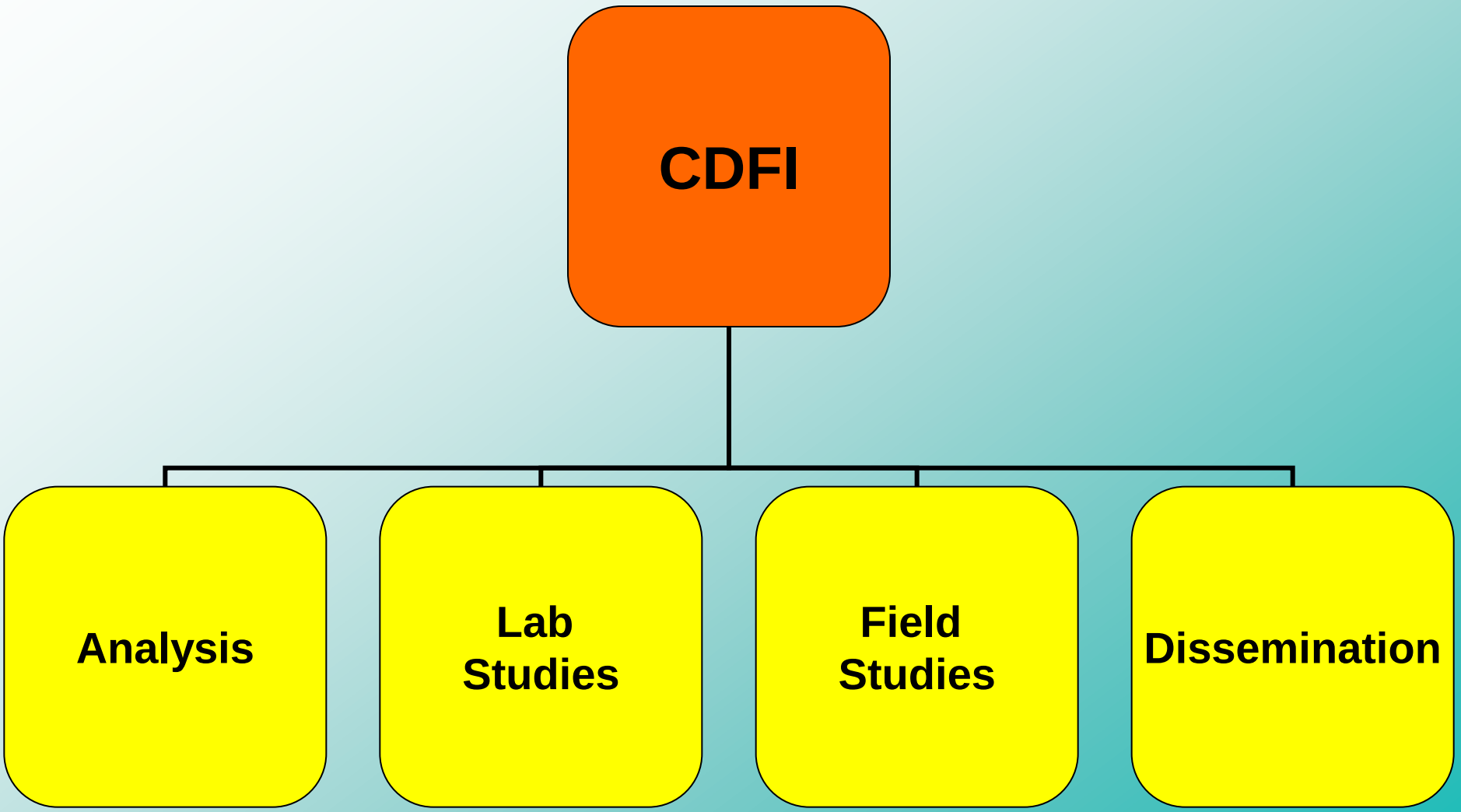
- DOE: $1,700,000
- Cost Chare: $1,275,000
- Total: $2,975,000

Participants

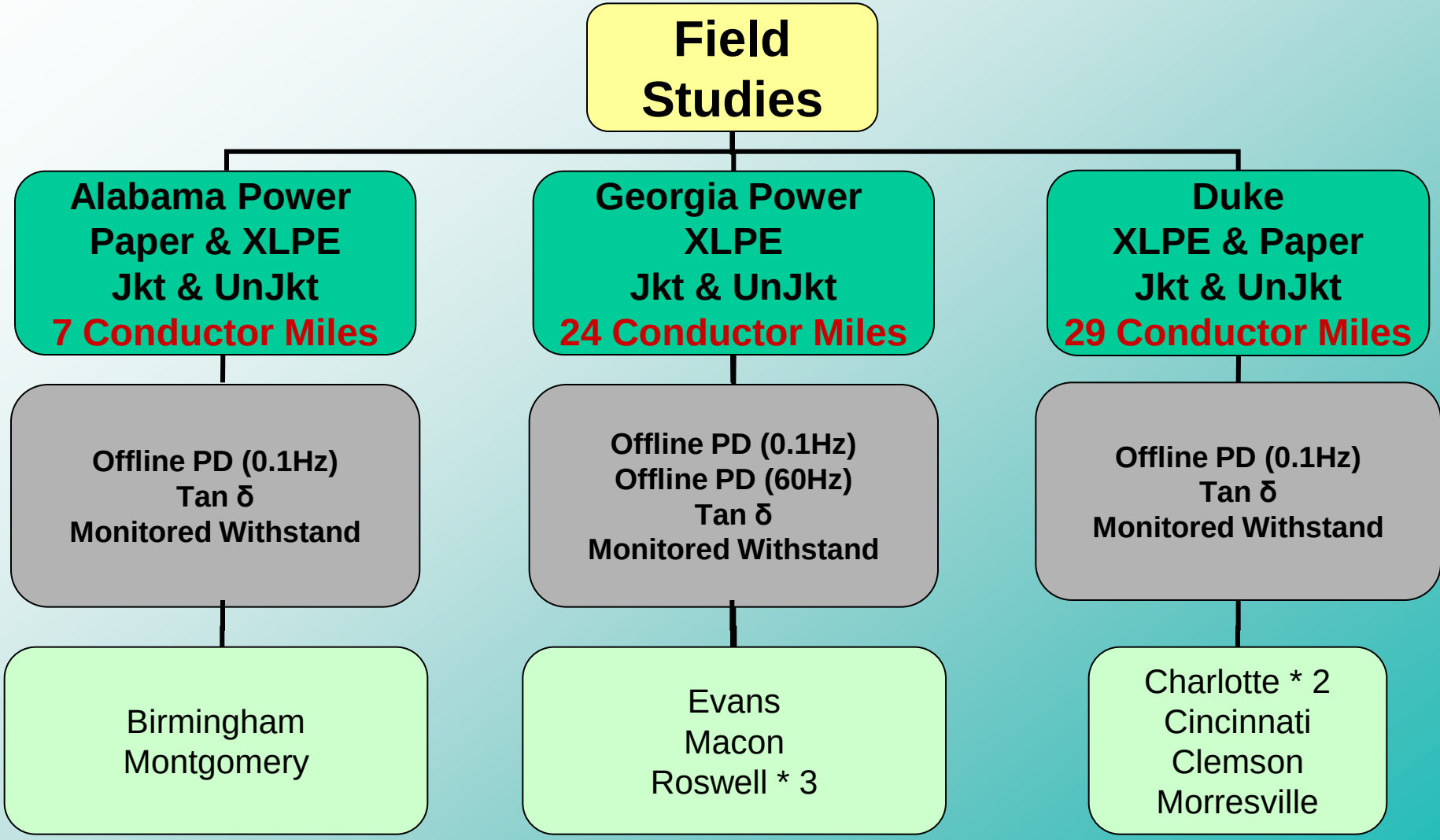
American Electric Power
Ameren
Cablewise / Utilx
CenterPoint Energy
Consolidated Edison
Cooper Power Systems
Duke Power Company
Exelon (Commonwealth Edison & PECO)
First Energy
Florida Power & Light
Georgia Tech
GRESCO
HDW Electronics
High Voltage, Inc.
HV Diagnostics

HV Technologies
Hydro Quebec
IMCORP
NRECA
Oncor (TXU)
PacifiCorp (added mid 2005)
Pacific Gas & Electric (added Jan 06)
PEPCO
Prysmian
Public Service Electric & Gas
Southern California Edison
Southern Company
Southwire
Tyco/Raychem

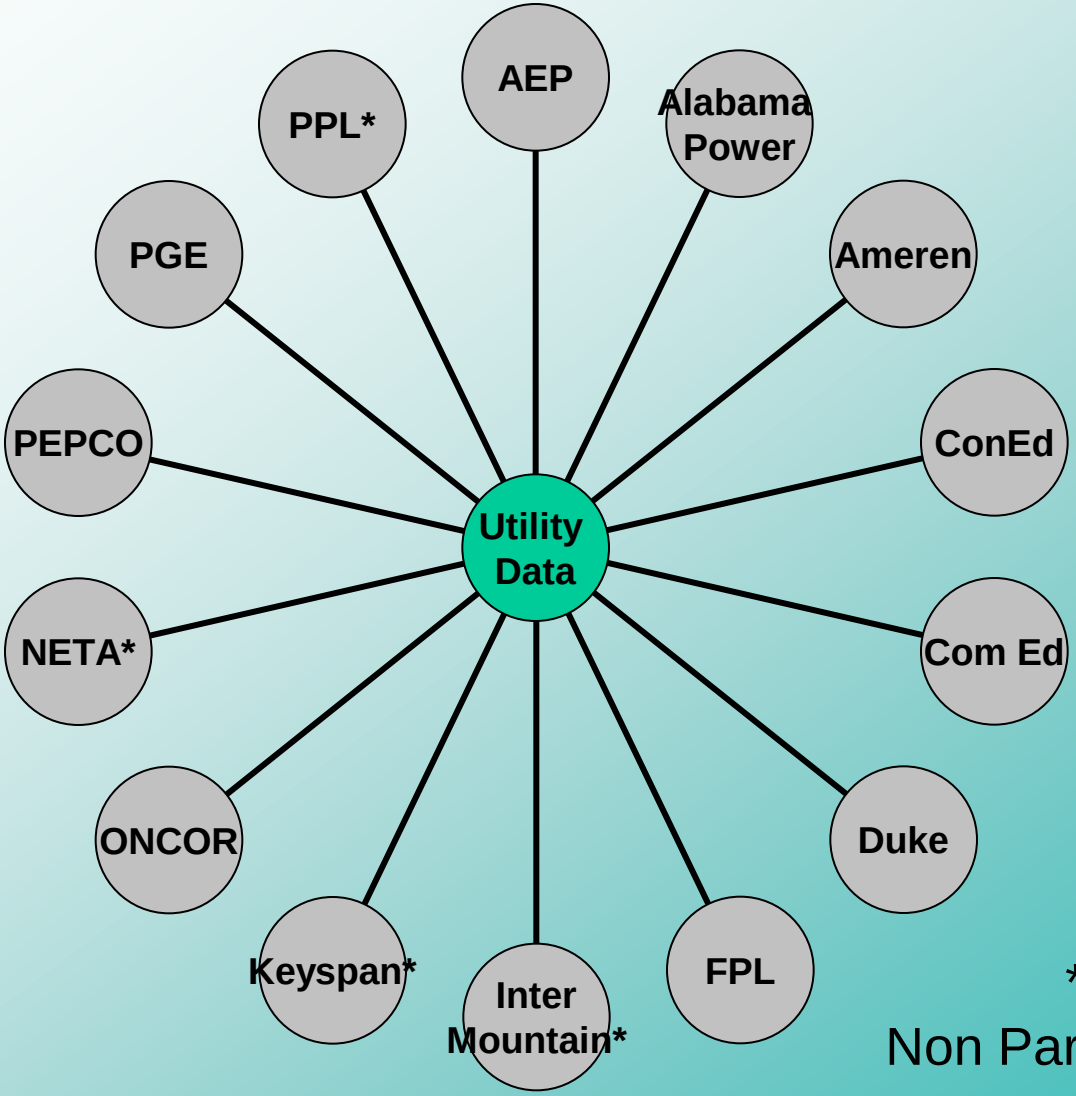
CDFI Activities



CDFI Activities



Diagnostic Data Obtained from Many Sources

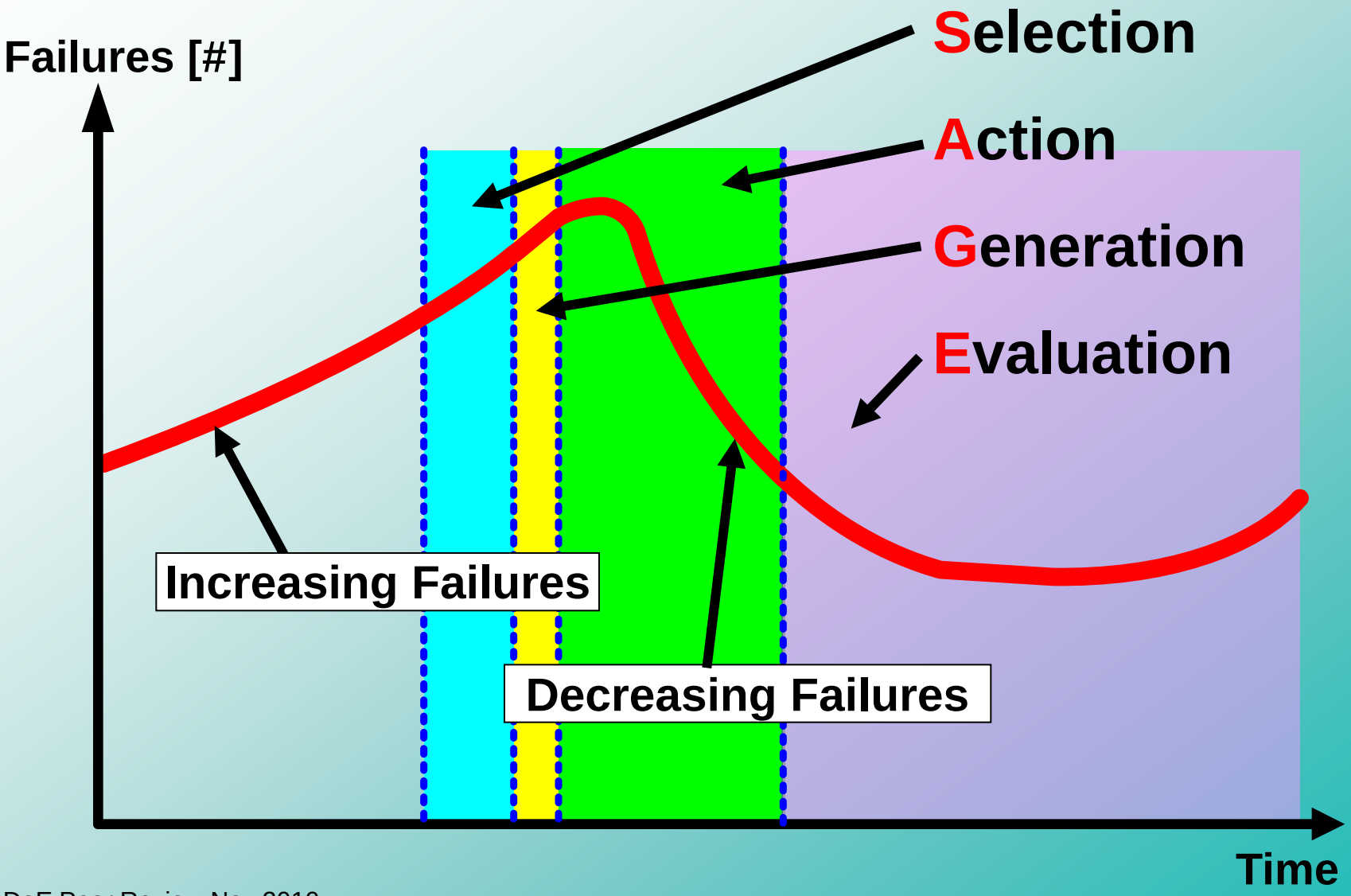


* Provided by
Non Participating Companies

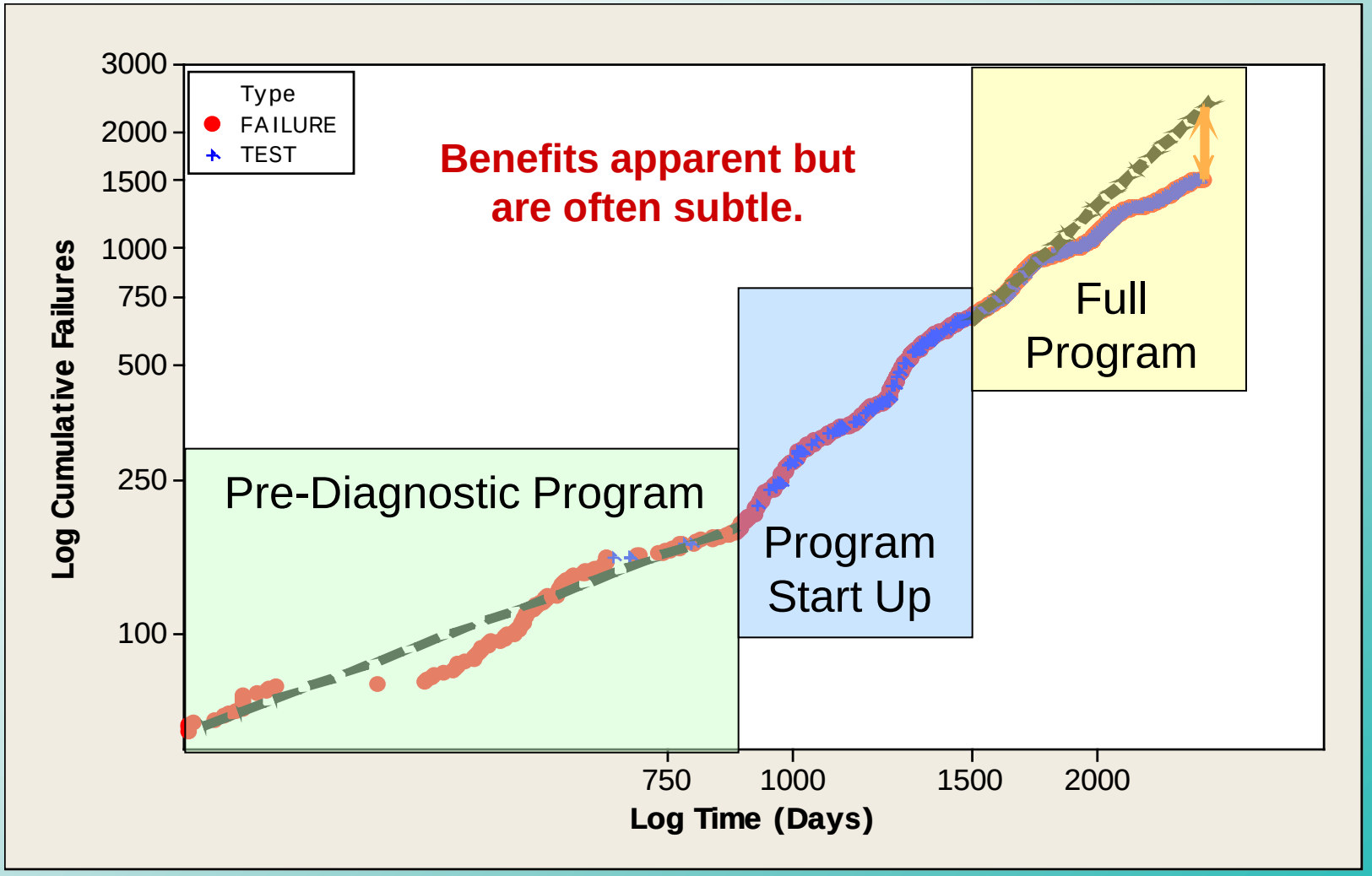
Significant Data Gathered

Data Type	Technique	Laboratory [Conductor miles]	Field [Conductor miles]
Diagnostic	DC Withstand	-	78,105
	Monitored Withstand	1.8	260
	PD Offline	4.8	490
	PD Online	5	262
	Tan δ	4.3	640
	VLF Withstand	4.6	9,900
	IRC	0.3	-
Service Performance	ALL	89,000	

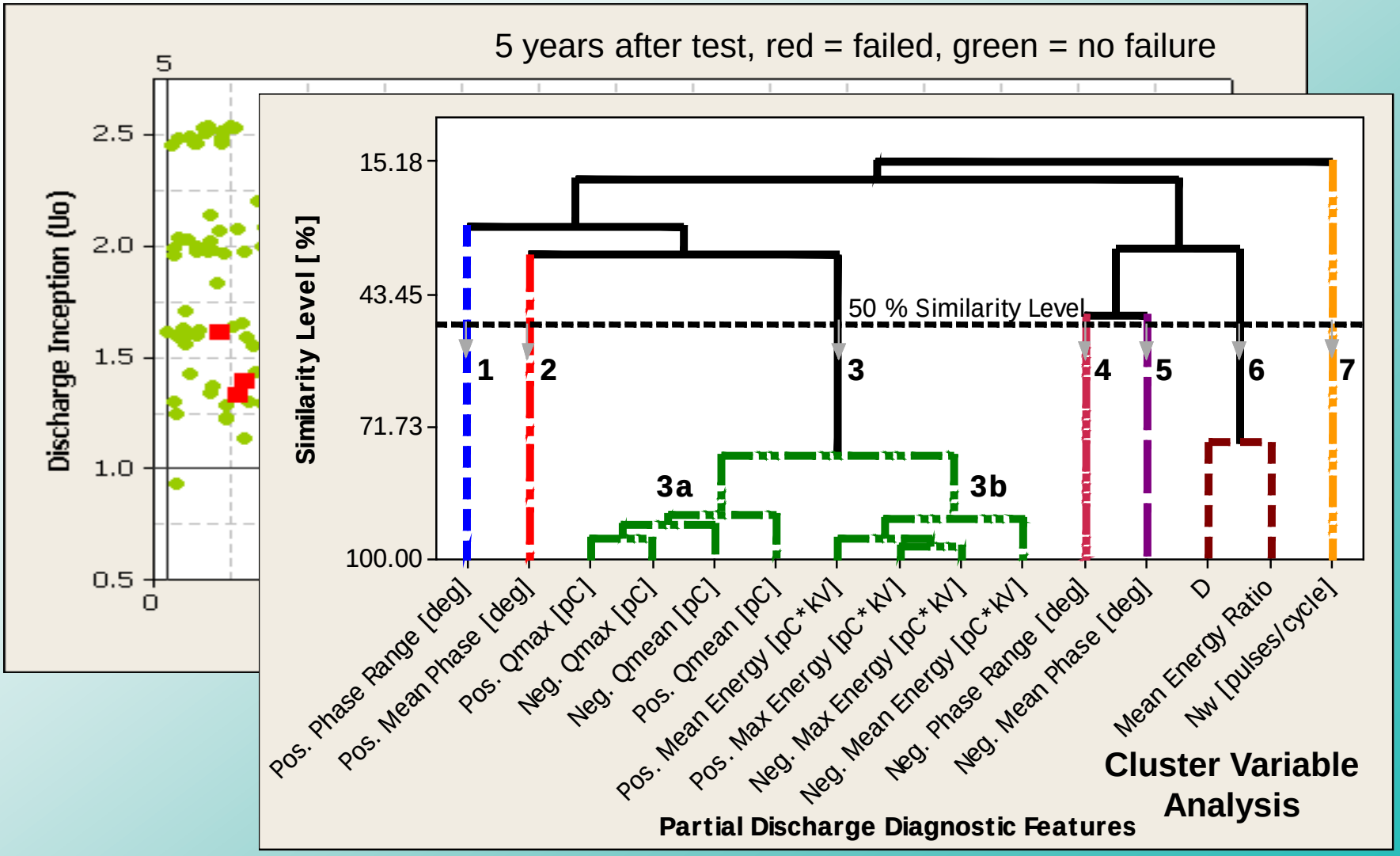
Diagnostic Testing Program (Approach is Important! - SAGE)



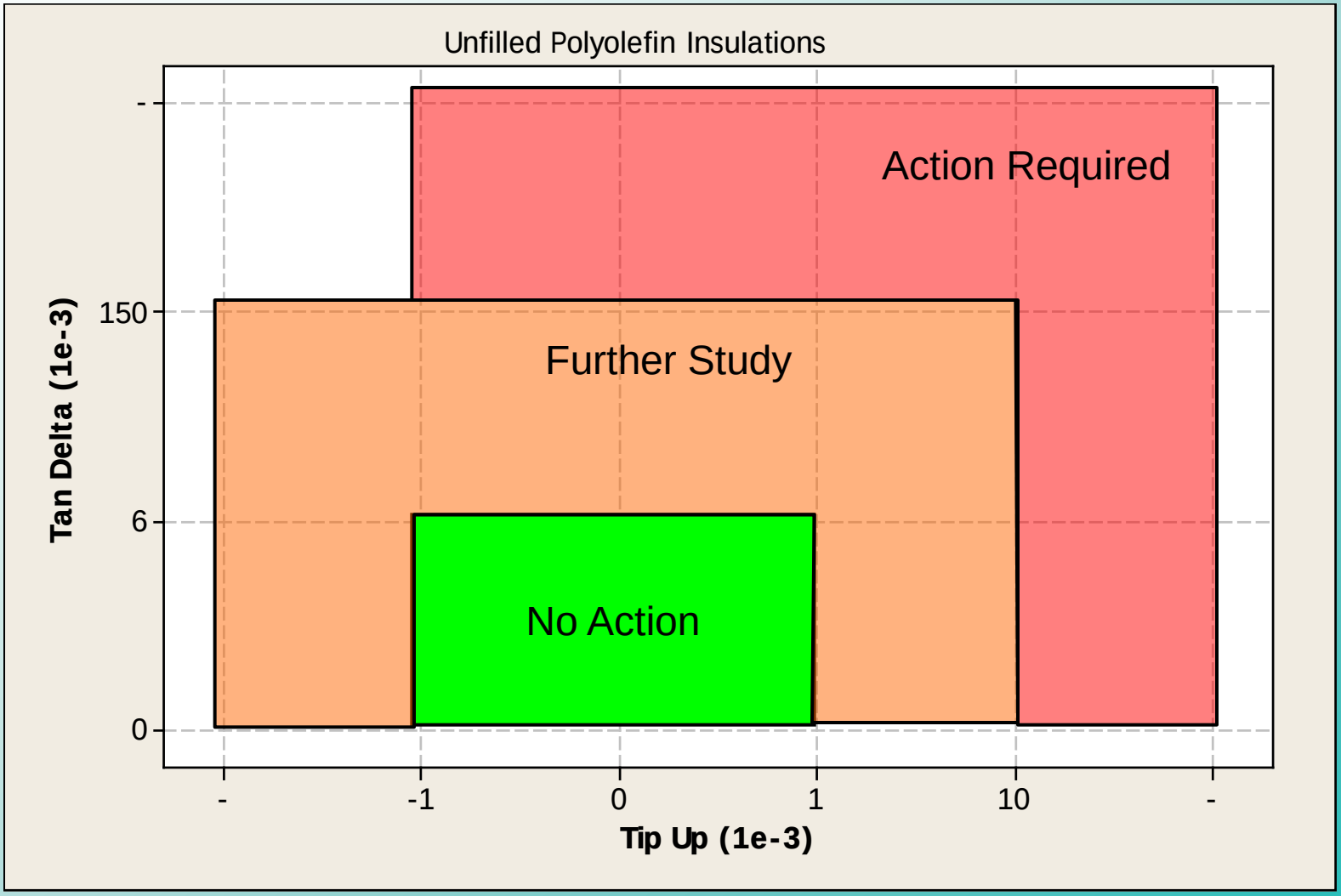
Cable System Phases - Actual Case



Interpreting Diagnostic Data – What we believed to be true was wrong! (Partial Discharge Example)

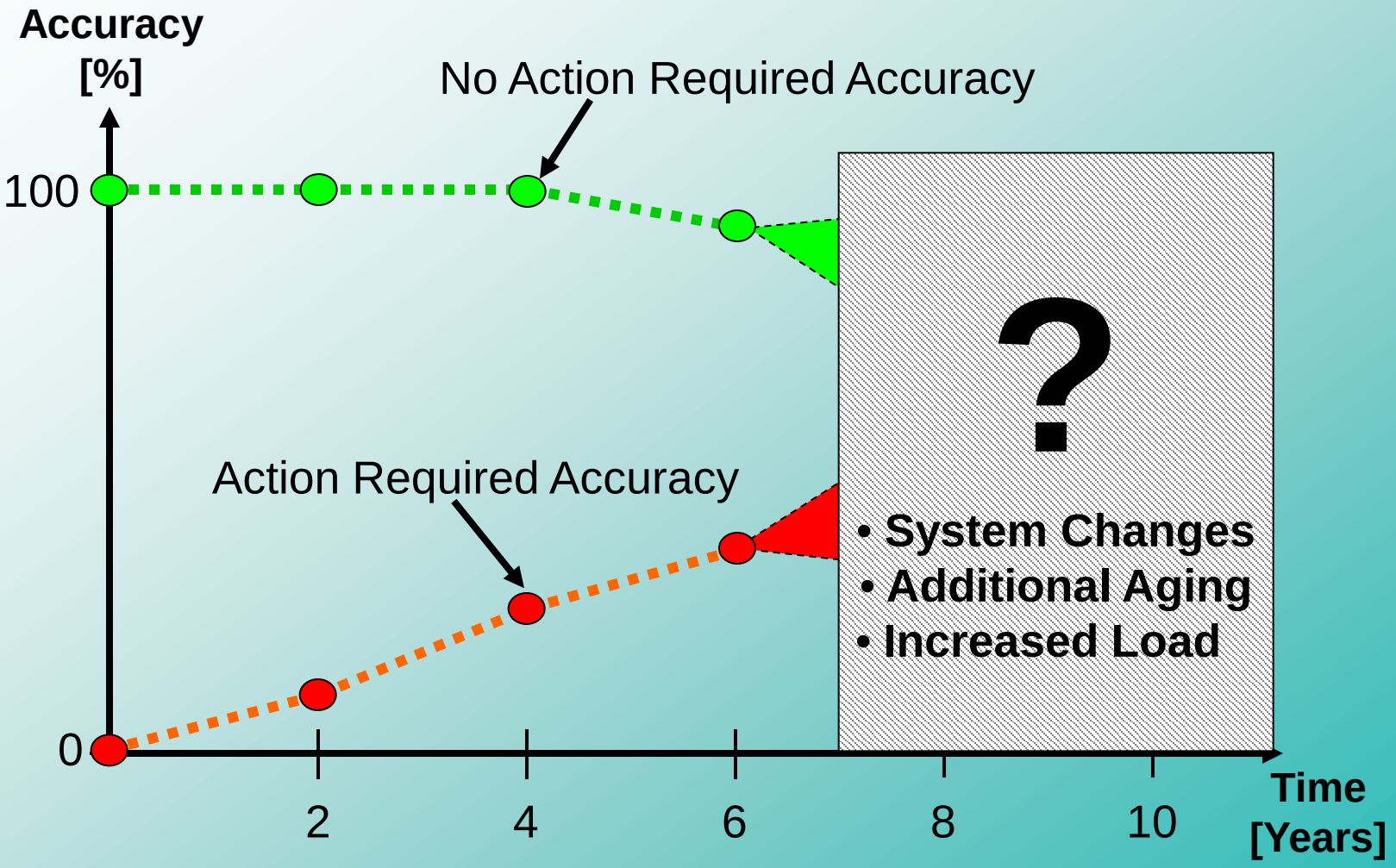


Interpreting Diagnostic Data (Tan δ)

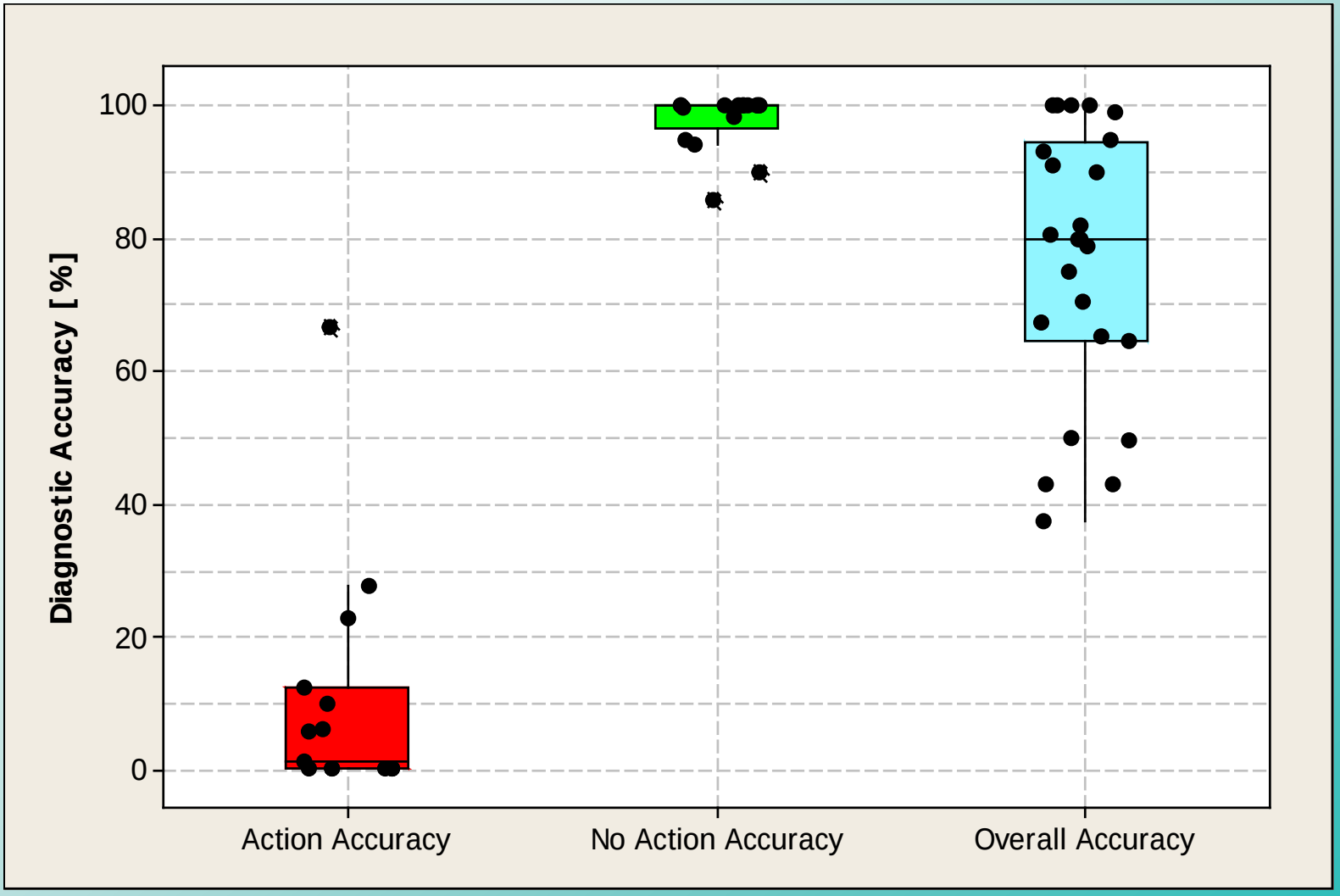


Defining Accuracy: Ability to Predict Failures

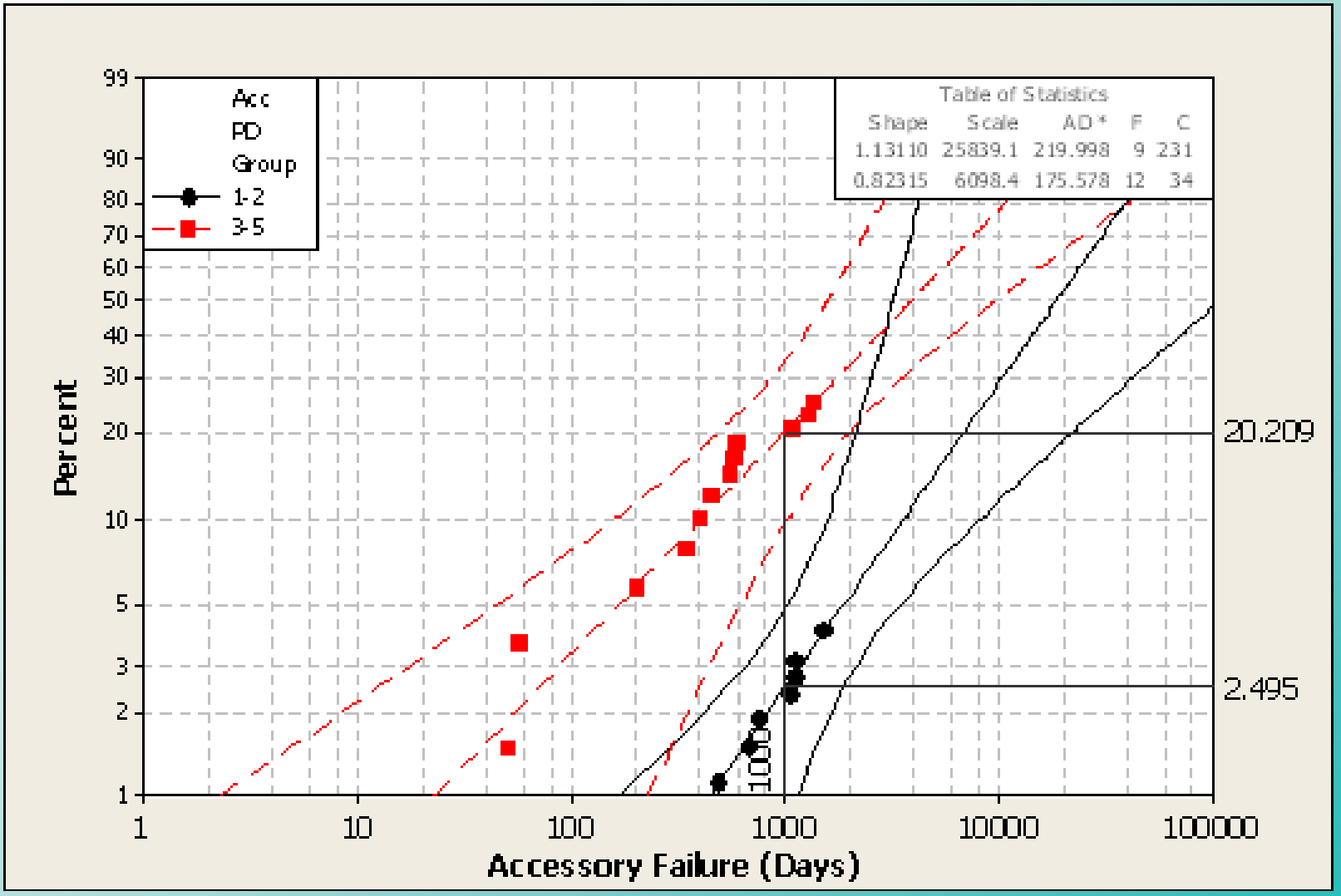
Accuracy – Failures over Time



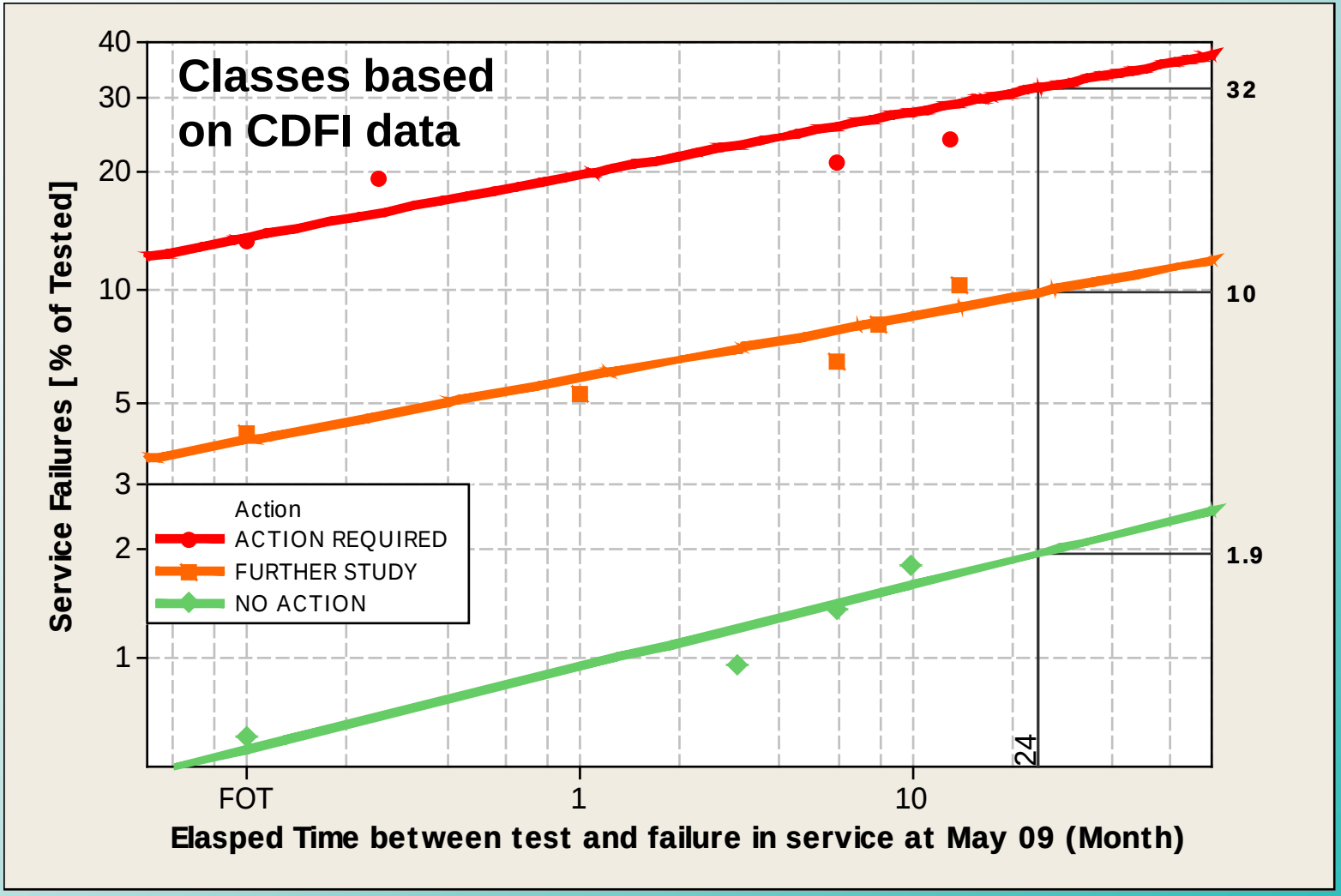
All Accuracies



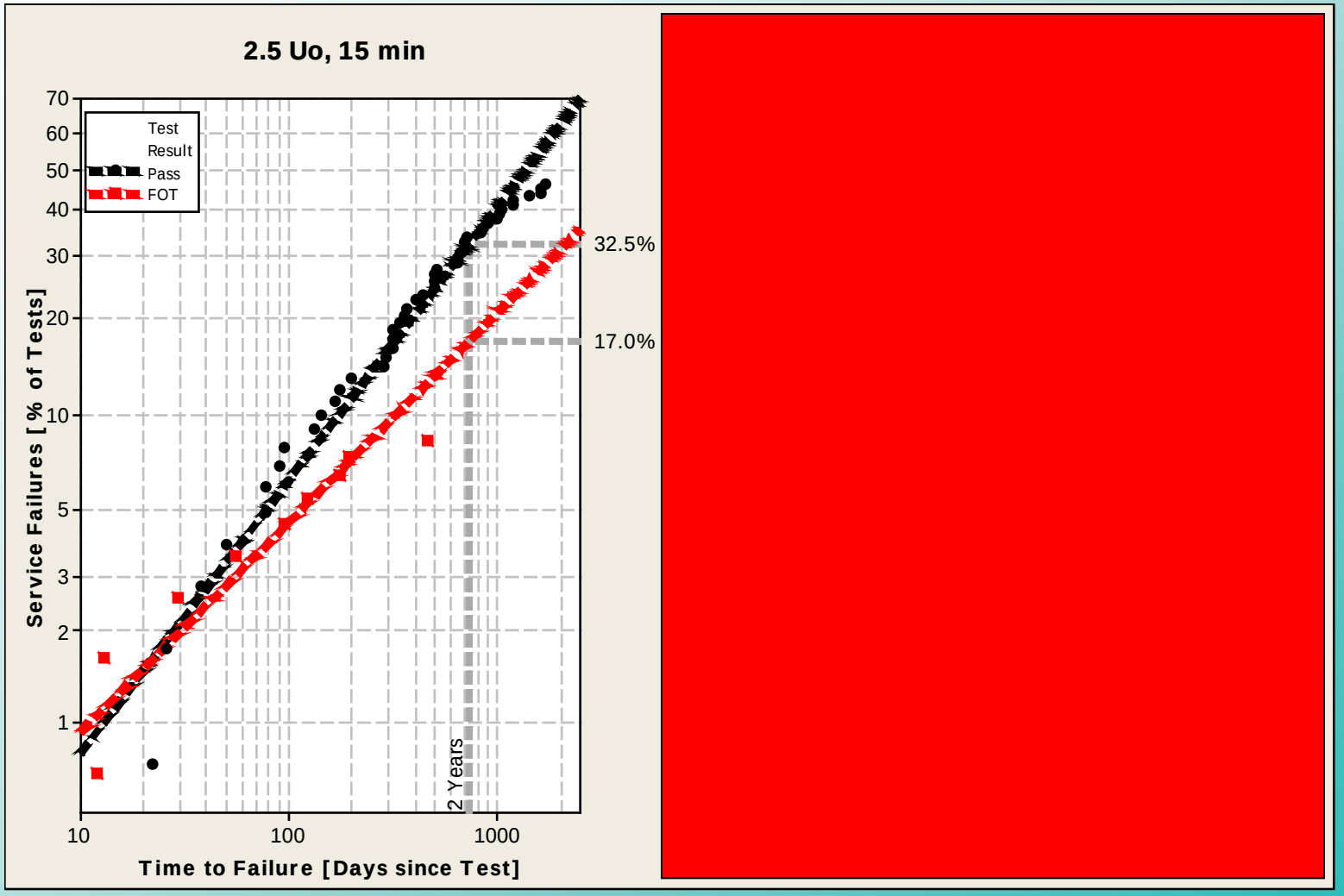
Accuracy – Probabilistic Approach (Partial Discharge Example)



Accuracy – Probabilistic Approach
Tan δ Example



VLF Withstand – Effectiveness & Application Time



Dissemination

1. First practical utility implementations of Monitored Withstand Diagnostics in the USA; Chris L Fletcher, Nigel Hampton, Jean Carlos Hernandez, Jeff Hesse, Michael G Pearman, Joshua Perkel, C Tim Wall, Walter Zenger; submitted to International Conference on Insulated Power Cables JICABLE11, Versailles France, June 2011; Abstract # 9
2. Challenges associated with the interpretation of dielectric loss data from power cable system measurements; J. Perkel, J.C. Hernández, R. N. Hampton, J. F. Drapeau, J. Densley; submitted to International Conference on Insulated Power Cables JICABLE11, Versailles France, June 2011; Abstract # 6
3. Application Of Artificial Intelligence To The Problem Of Selecting The Appropriate Diagnostic For Cable Systems; Yamille Del Valle, Nigel Hampton; submitted to International Conference on Insulated Power Cables JICABLE11, Versailles France, June 2011; Abstract # 3
4. Cable Fleet Management; RN Hampton, M Olearczyk, J Perkel, N Weisenfeld; IEEE Spectrum; Nov 2010
5. Experience of Withstand Testing of Cable Systems in the USA; Hampton, R.N..Perkel. J., Hernandez, J.C., Begovic, M., Hans, J., Riley, R., Tyschenko, P., Doherty, F., Murray, G., Hong, L., Pearman, M.G., Fletcher, C.L., and Linte, G.C.; CIGRE 2010, Paper No. B1-303
6. Characterization of Ageing for MV Power Cables Using Low Frequency Tan-delta Diagnostic Measurements; JC. Hernandez-Mejia, RG. Harley, RN Hampton, RA Hartlein; IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 16, Issue 3, pp. 862-870, June 2009.
7. Determining Routes for the Analysis of Partial Discharge Signals Derived from the Field; Hernández-Mejía, J.C.; Perkel, J.; Harley, R.; Begovic, M.; Hampton, N.; and Hartlein, R.; IEEE Trans. on Dielectrics and Electrical Insulation, December 2008, pp. 1517-1525.
8. Correlation between Tan δ Diagnostic Measurements and Breakdown Performance at VLF for MV XLPE Cables; Hernández-Mejía, J.C.; Perkel, J.; Harley, R.; Hampton, N.; and Hartlein, R.; IEEE Trans. on Dielectrics and Electrical Insulation, February 2009, pp. 162-170
9. Some Considerations on the Selection of Optimum Location, Timing, and Technique, for Diagnostic Tests, RA Hartlein, RN Hampton & J Perkel; IEEE Power Engineering Society (PES) General Meeting Panel Session Pittsburg 2008
10. Characterization of Aging in Medium Voltage Power Cables Using Low Frequency Tan-delta Diagnostics Features R.N. Hampton, R. Harley, R. Hartlein & J.C. Hernandez; IEEE Transactions in Power Delivery; submitted
11. Validation of the accuracy of practical diagnostic tests for power equipment; M. Begovic, RN. Hampton*, R. Hartlein, J.C. Hernandez-Mejia, and J Perkel; CIGRE 2008 Paris Study Committee D1 Paper 205
12. On Distribution Asset Management: Development of Replacement Strategies; Miroslav Begovic, Joshua Perkel, Nigel Hampton, Rick Hartlein; IEEE PES PowerAfrica 2007 Conference and Exposition; Johannesburg, South Africa, 16-20 July 2007
13. Practical Issues Regarding The Use Of Dielectric Measurements To Diagnose The Service Health Of MV Cables; R.N. Hampton, R. Harley, R. Hartlein & J.C. Hernandez; International Conference on Insulated Power Cables; JICABLE07, Versailles France, June 2007
14. Validating Cable “Diagnostic Tests”; M Begovic, RN Hampton, R Hartlein, J Perkel; International Conference on Insulated Power Cables; JICABLE07, Versailles France, June 2007

- **Periodic Update Meetings throughout the project**
- **Regional Meetings – San Ramon, CA, Atlanta, GA, Columbus, OH, New York, New York, IEEE Education Session, St. Petersburg, FL2009/2010**

CDFI - At the Beginning

- For many utilities, the usefulness of diagnostic testing was unclear.
- The focus was on the technique, not the approach.
- The economic benefits were not well defined.
- There was almost no independently collated and analyzed data.
- There were no independent tools for evaluating diagnostic effectiveness.

What We Now Know (1)

1. Diagnostics can work – they tell you many useful things, but not everything.
2. Diagnostics do not work in all situations.
3. Diagnostics have great difficulty definitively determining the longevity of individual devices.
4. Utilities HAVE to act on ALL replacement & repair recommendations to get improved reliability.
5. The performance of a diagnostic program depends on:
   - Where you use the diagnostic
   - When you use the diagnostic
   - What diagnostic you use
   - What you do afterwards

What We Now Know (2)

6. Quantitative analysis is complex BUT is needed to clearly see benefits.
7. Diagnostic data require skilled interpretation to establish how to act.
8. No one diagnostic is likely to provide the detailed data required for accurate diagnoses.
9. Large quantities of field data are needed to establish the accuracy/limitations of different diagnostic technologies.
10. *Important to have correct expectations – diagnostics are useful but not perfect!*

Reflections

- Approach to data analysis established in CDFI
- Standards upgraded (IEEE 400 series)
- Many questions answered, gaps remain:
  - Defining the Benefits
  - Identifying anomalies that lead to failure
- Answers will come with continued analysis of field test data (Diagnostic tests with circuit performance monitoring).
- The potential value of continued analysis is high
- New approaches appear promising
  - Monitored withstand (HV withstand + tan δ or partial discharge)
  - Combined diagnostics (simultaneous tan δ and partial discharge)
  - New technologies (oscillating wave, cosine VLF withstand)

CDFI Phase 1 / CDFI Phase 2

Element	CDFI Focus, Phase I	CDFI Focus, Phase II*
Voltage Level	MV	MV & some HV
Test Type	Condition Assessment	Condition Assessment & Commissioning / Recommissioning
Cable	Service Aged	Service Aged & Laboratory Testing of Service Aged
Diagnostics	Currently in use in US	Currently in use in US & those that might reasonably be used
Data	Utility Distribution System	Distribution, Industrial & Transmission
Lab Studies	Field Aged Cable	Cable & Accessories

***Approved in July of 2010**