Validating Reliability Improvements of New Cable Designs

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Outline

- Verifying Performance Improvements on a Utility System
- Method
- Adjustments for the Utility Environment
- Example
  - Background of Self Healing Solutions
  - Duke Pilot Study
  - Performance Evaluation
  - Projections
- Conclusions

Introduction

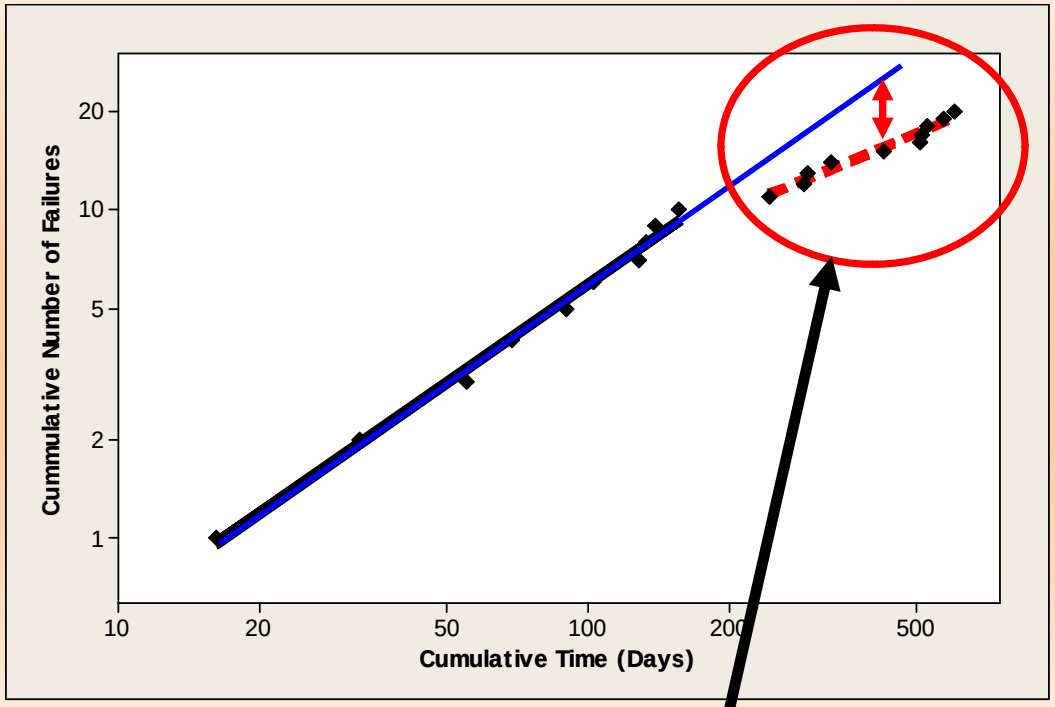
- New materials, installation methods, operational issues and cable designs are under constant refinement
- These are generally claimed to offer better performance than past iterations
- How can we verify that the performances are improved??

Introduction

- Pilot studies are often used

- BUT we need
  - control population – a basis for comparison
  - method to “scale up” projections
  - often forgotten
- Difficult to construct a “traditional control population”
- Trials carried out on “live” systems thus need to deal with:
  - Climate / weather issues
  - Different sizes
  - Multiple failure modes
  - Coarse data

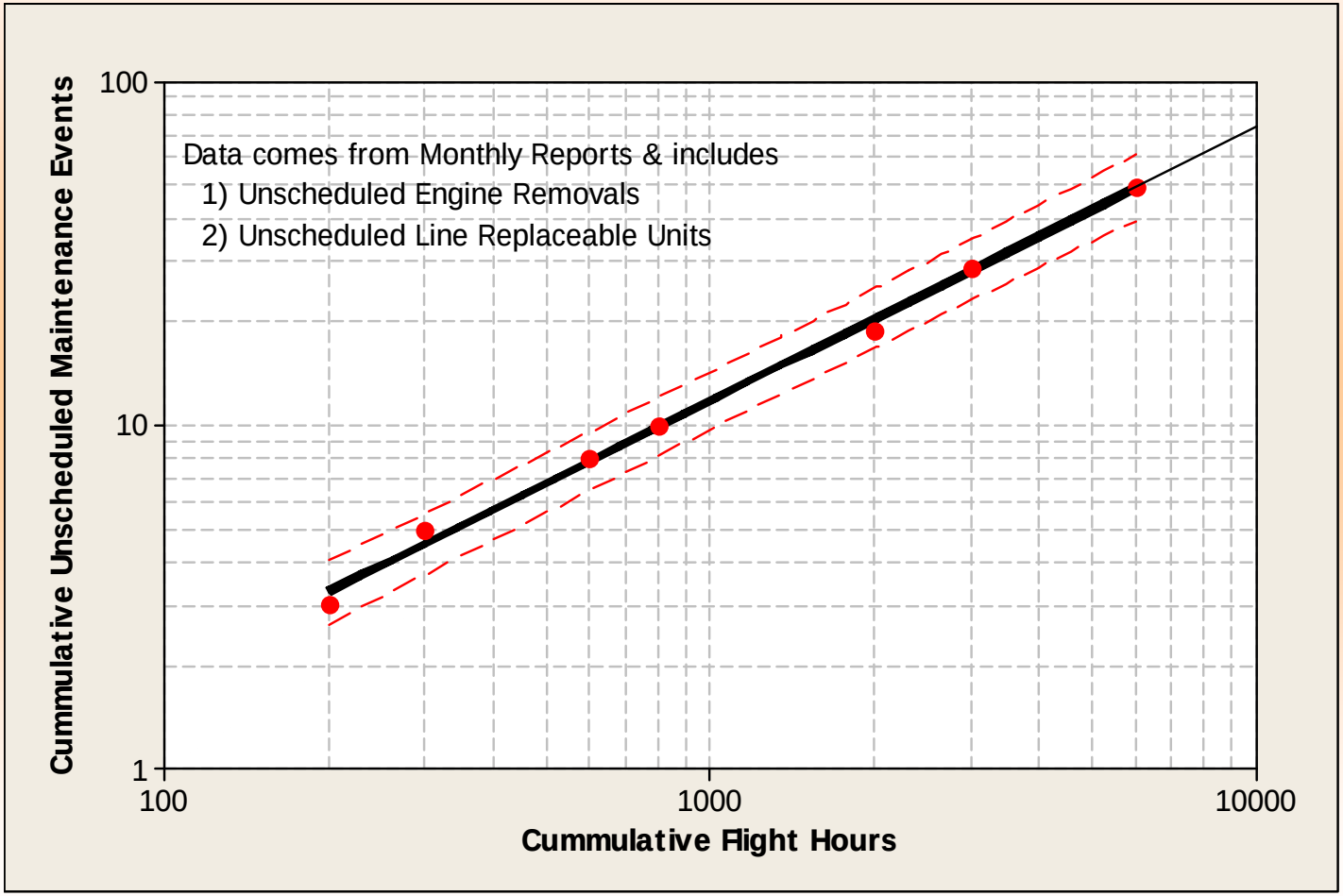
Crow-AMSAA Basics



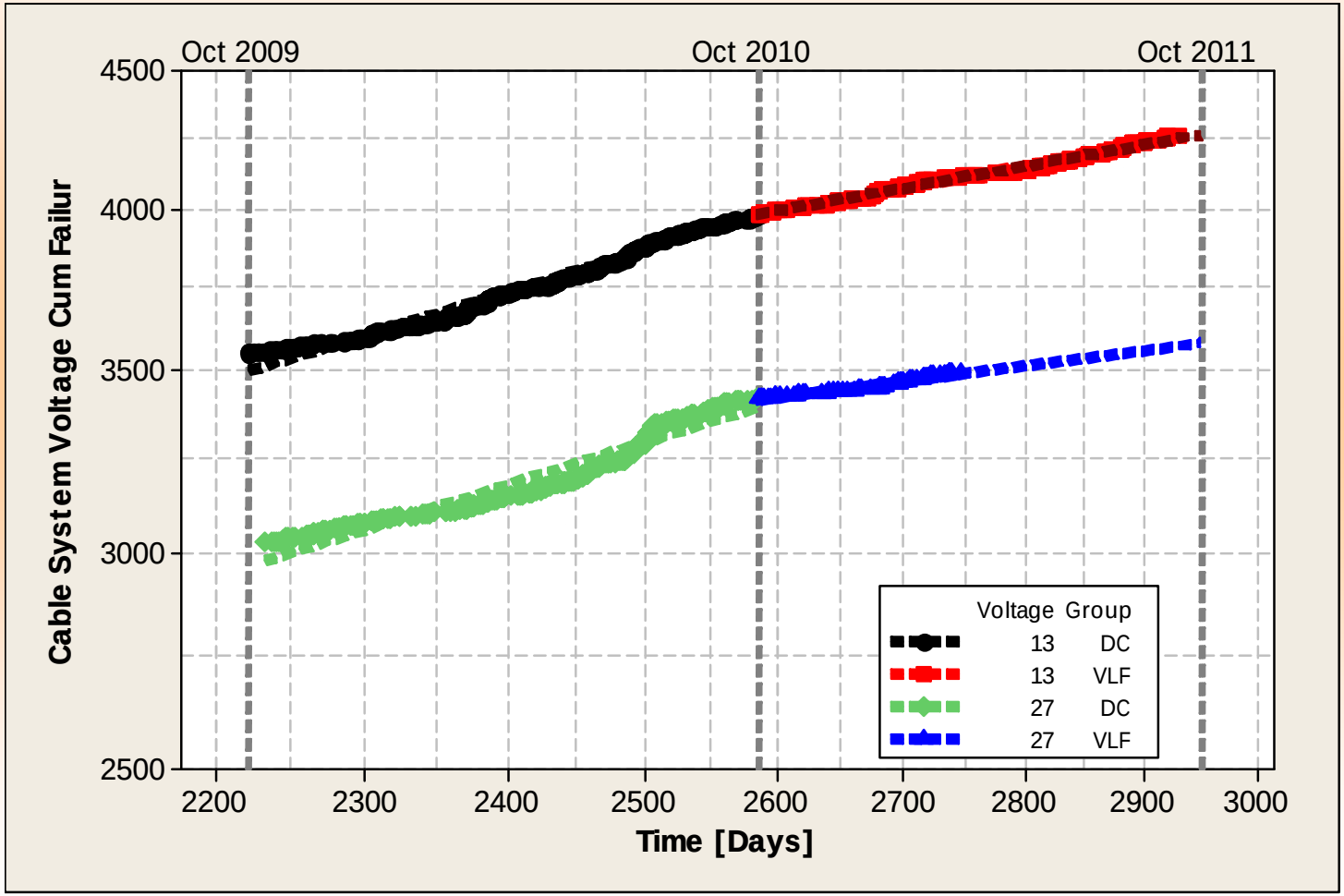
- Crow AMSAA plots cumulative number of failures against cumulative time
- Log / Log scales linearize the data
- The gradients/slopes show the Failure Rates
- Decreasing gradients show decreasing Failure Rates

The difference in slope between the two lines quantifies the improvement in reliability

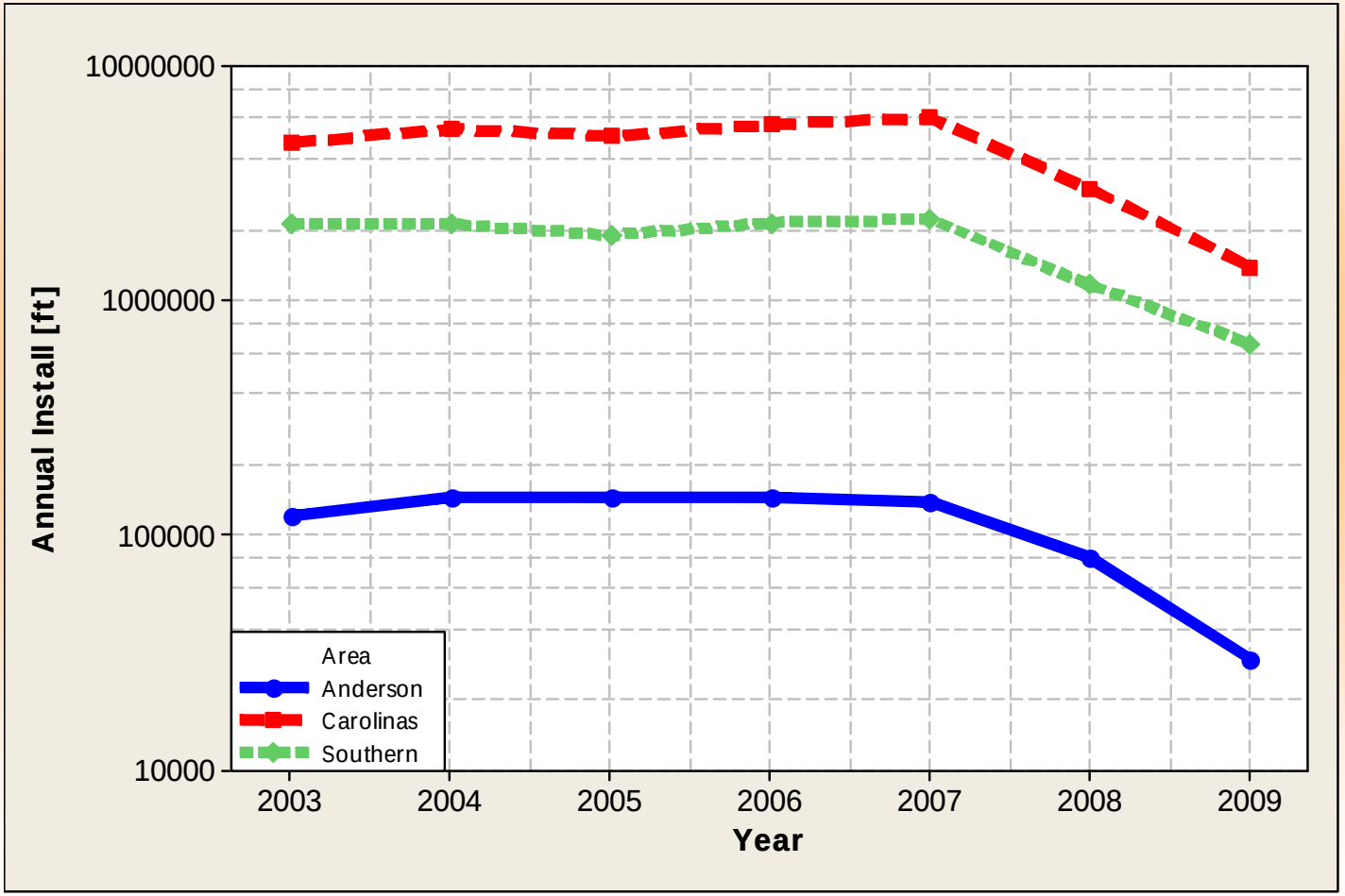
Aero Engine Example



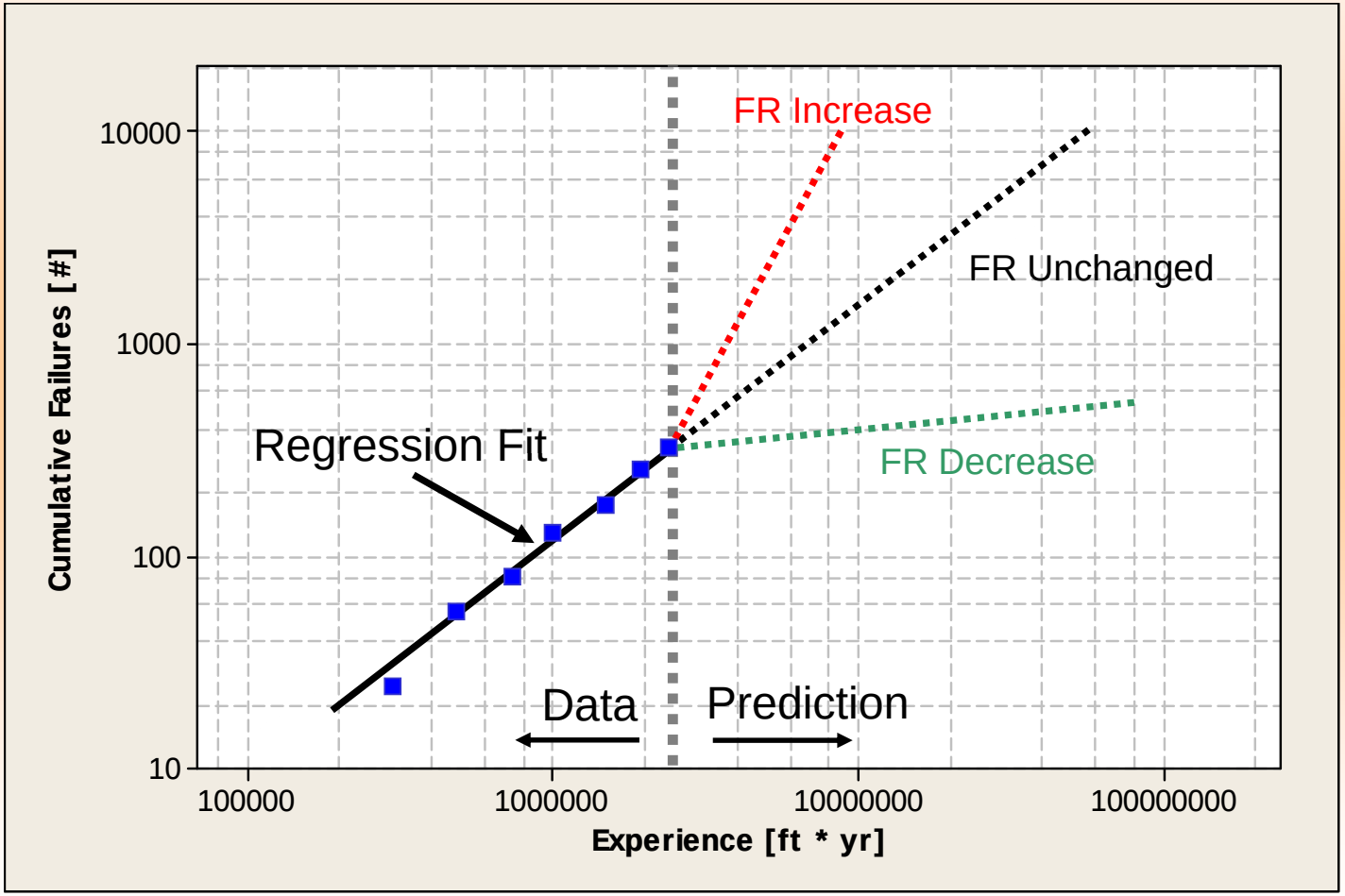
Con Ed DC vs VLF Hipots



Changing / Inconsistent Sizes



Crow-AMSAA


FR Increase
FR Unchanged
FR Decrease
Regression Fit
Data
Prediction
Cumulative Failures [#]
10000
1000
100
10
100000
1000000
10000000
100000000
Experience [ft * yr]

Duke 600V Pilot Study

Why do 600 V cables fail?

There are many potential reasons for 600 V cable to fail

- Dig-ins and damage caused by other utilities
- Lightning
- Improper installation
- Rodent Damage
- Incidental damage caused by property Owners
  - Landscaping
  - Installing shrubs & bushes

Why do 600 V cables fail?

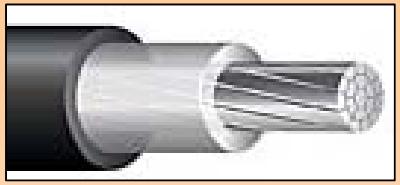
Installation Damage

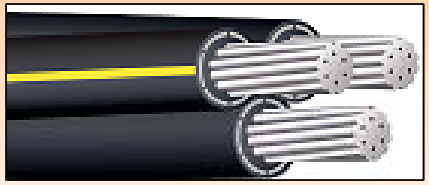
Rodent Damage

Corrosion Failures

Standard 600 V Cable

- There are 3 standard cable constructions used today for underground residential 600 V Cables
  - Standard single layer construction
    - Typically low density XLP
  - Abuse resistant
    - Medium Density and High Density XLP
      - Single layer
      - 2 Layer
  - Self Sealing cable constructions

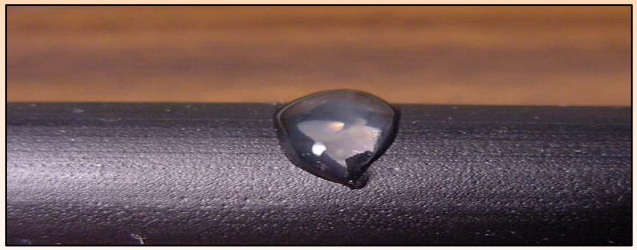


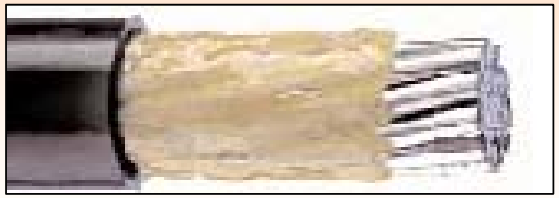


Self-Sealing Designs

Many different designs have been tried through the years

- Mastic in combination with XLP or PE insulation
  - Shrink back issues
- Thick fluid in combination with XLP or PE insulation
  - Fluid flow control issues
- Visco-Elastic sealant in channels within insulation
  - Material flow is controlled
  - Sealing is quick (30 min +/-)





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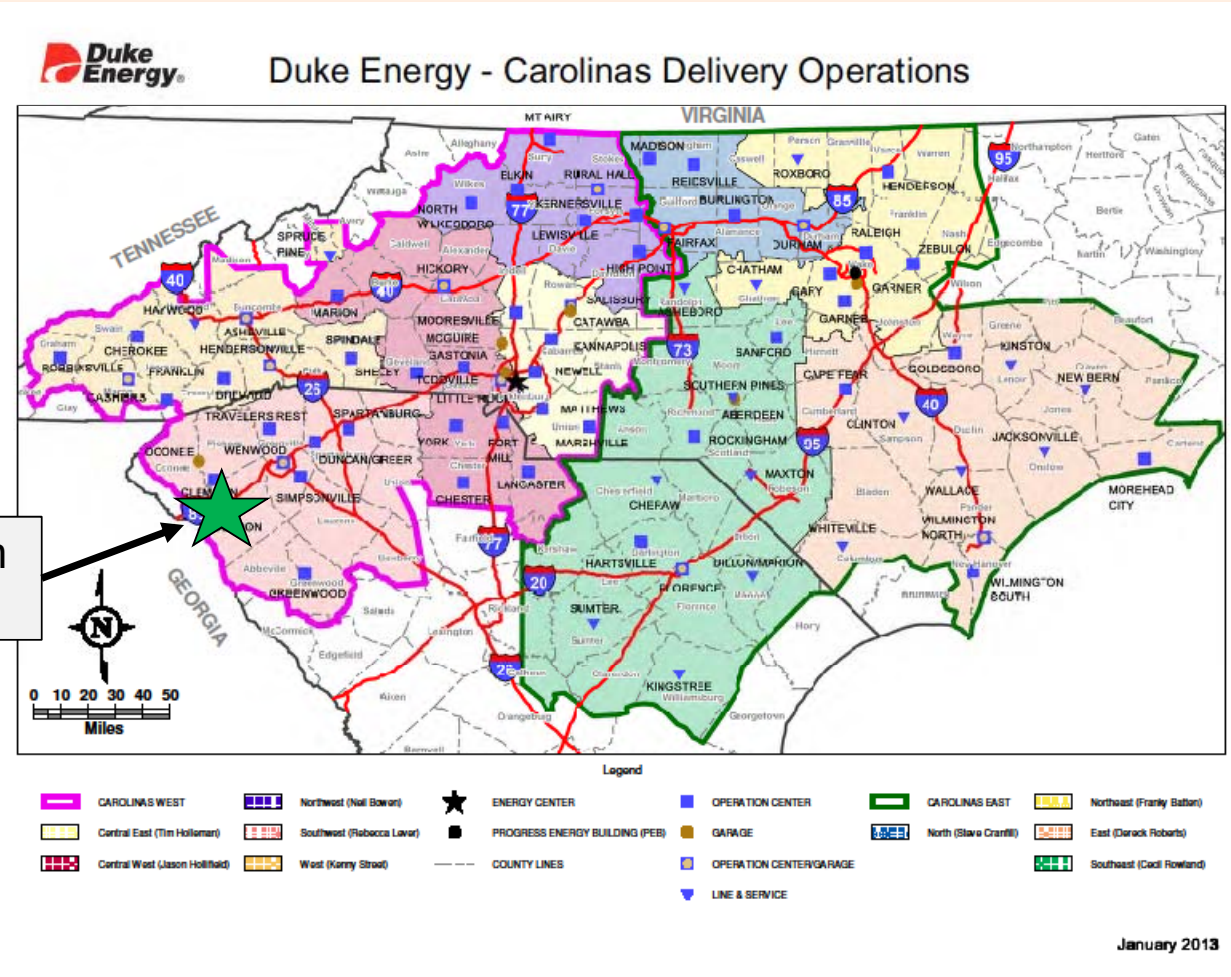
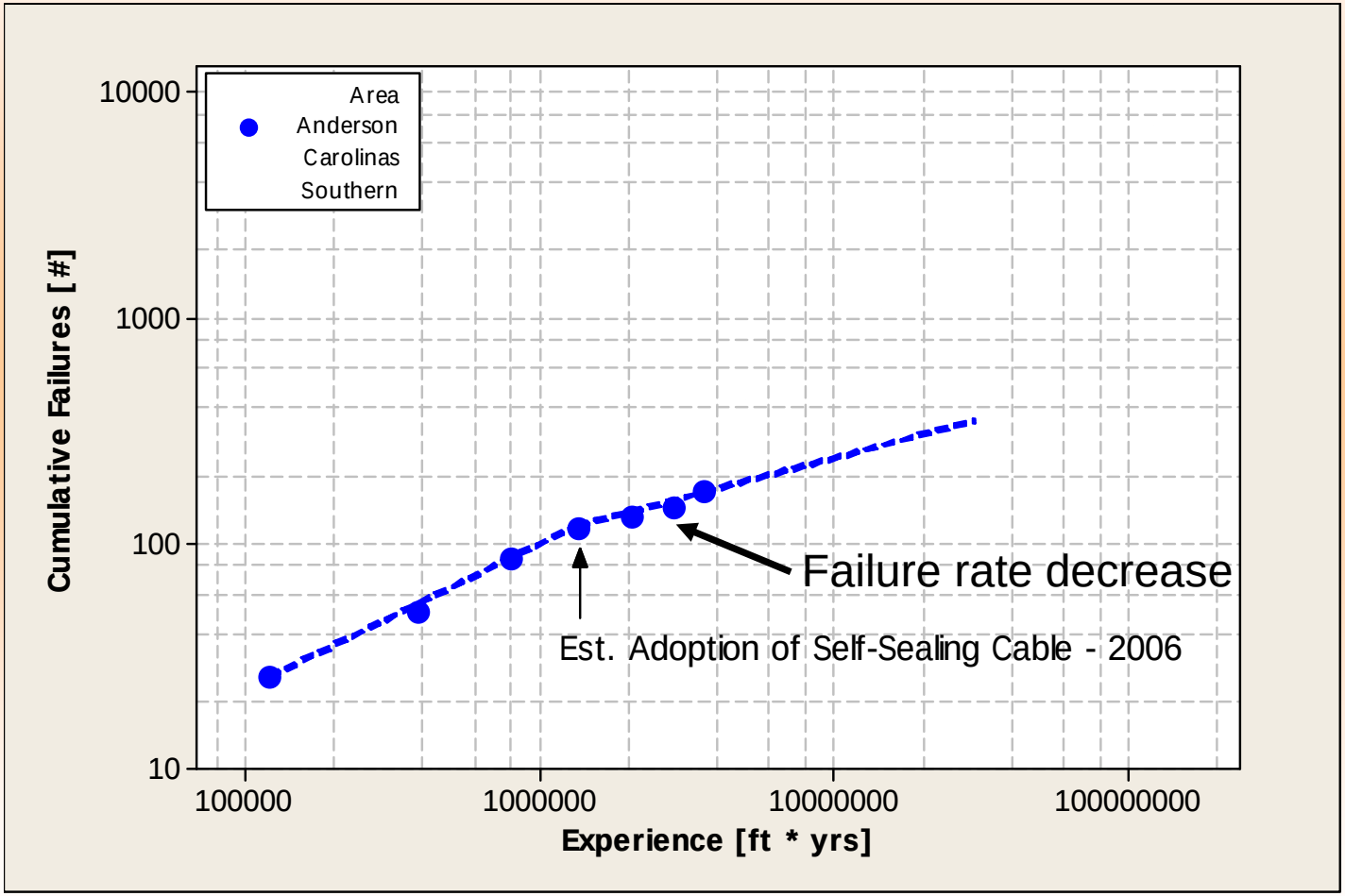
2/0 Pilot Program

Anderson

Duke Secondary Cable System



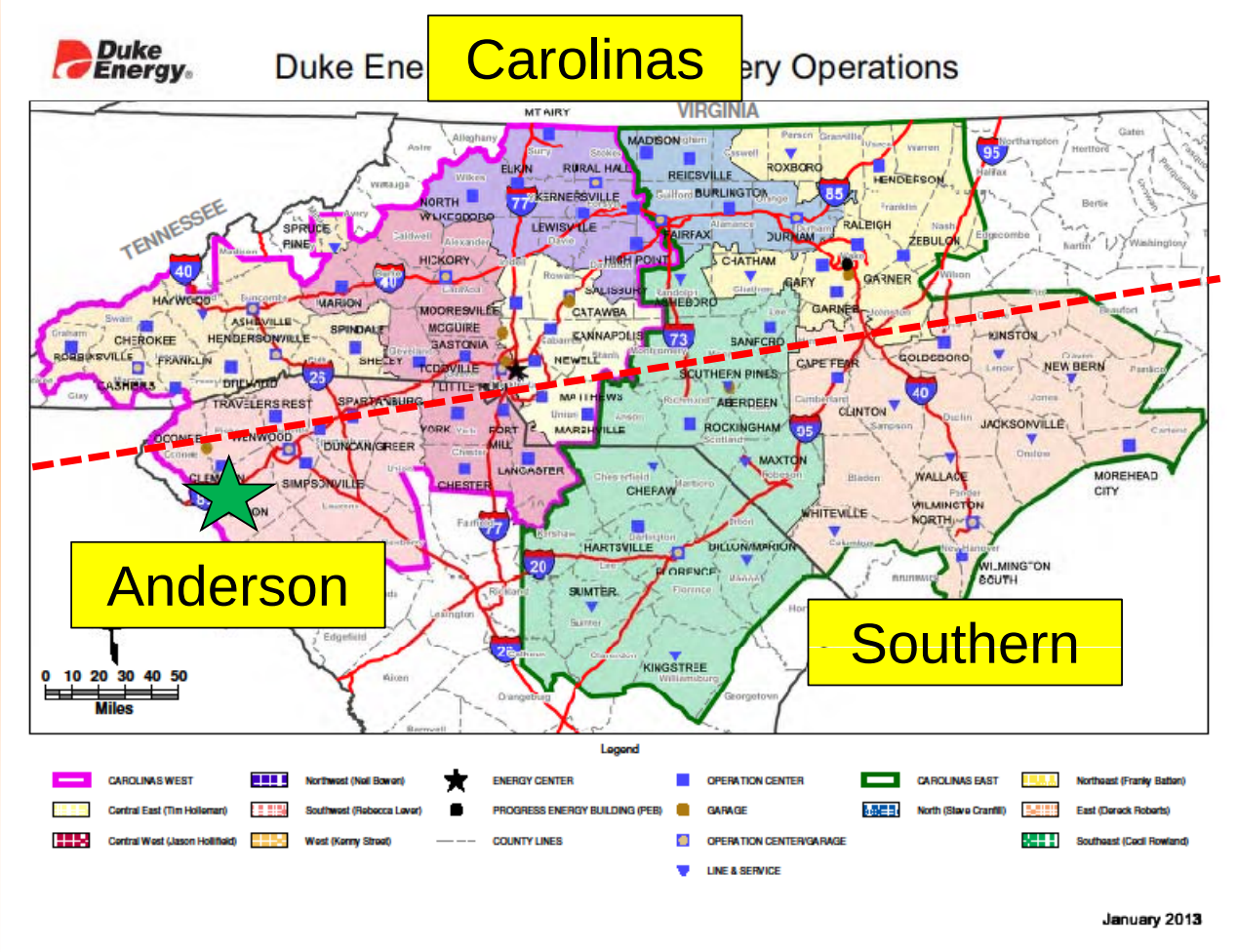
Failure Rate Changes



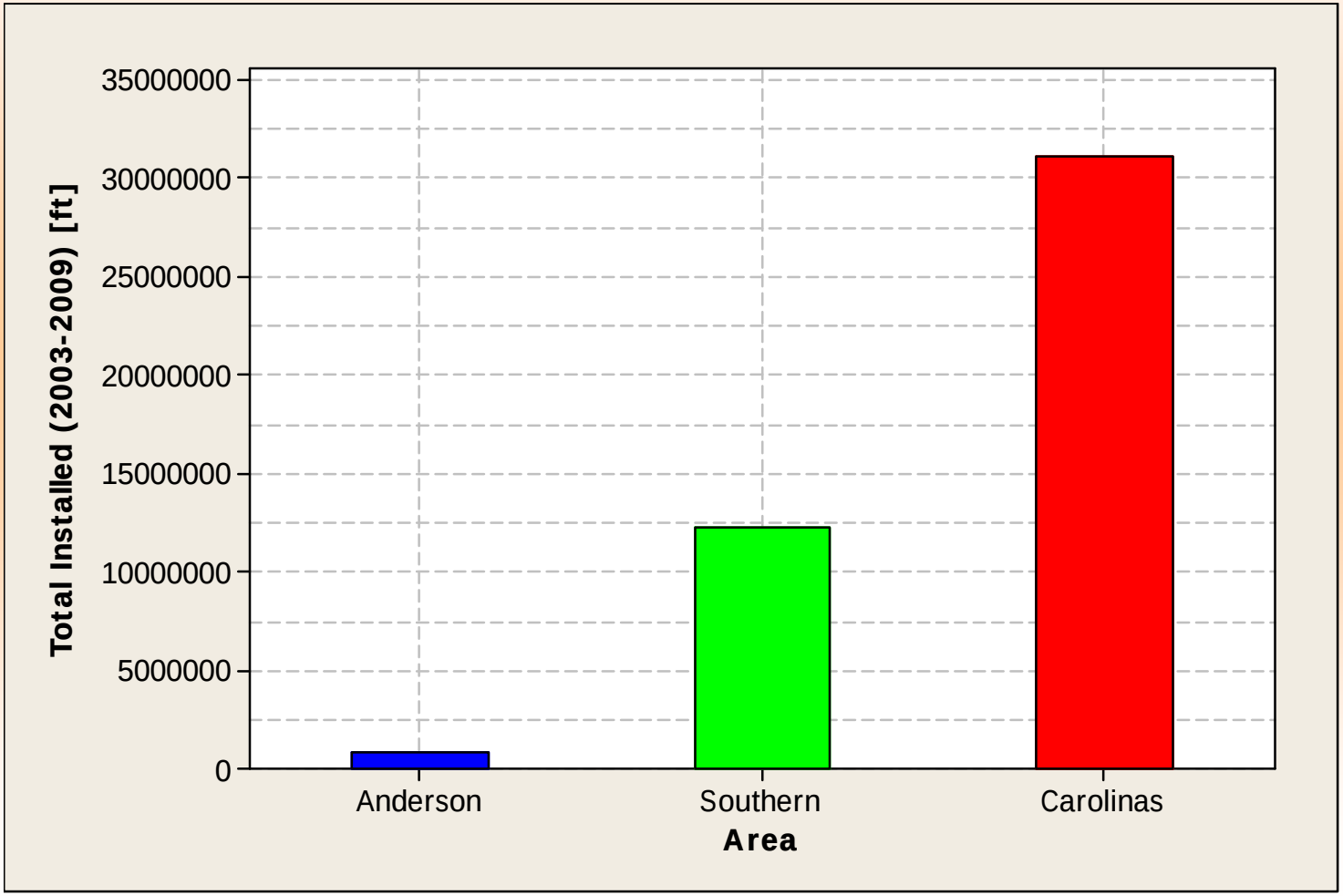
Control Populations ???

Was the change just luck or self sealing?

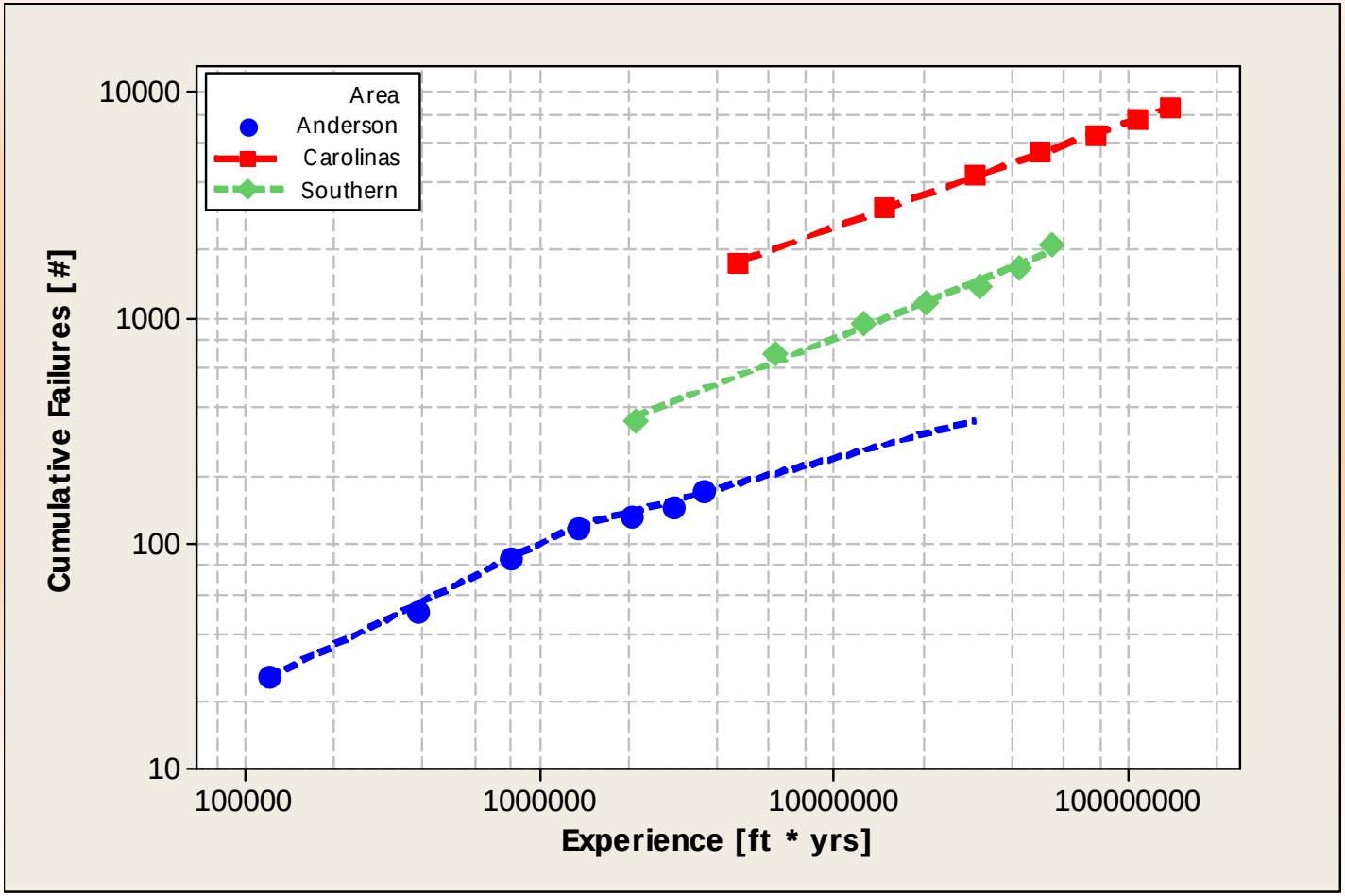
Map of Regions



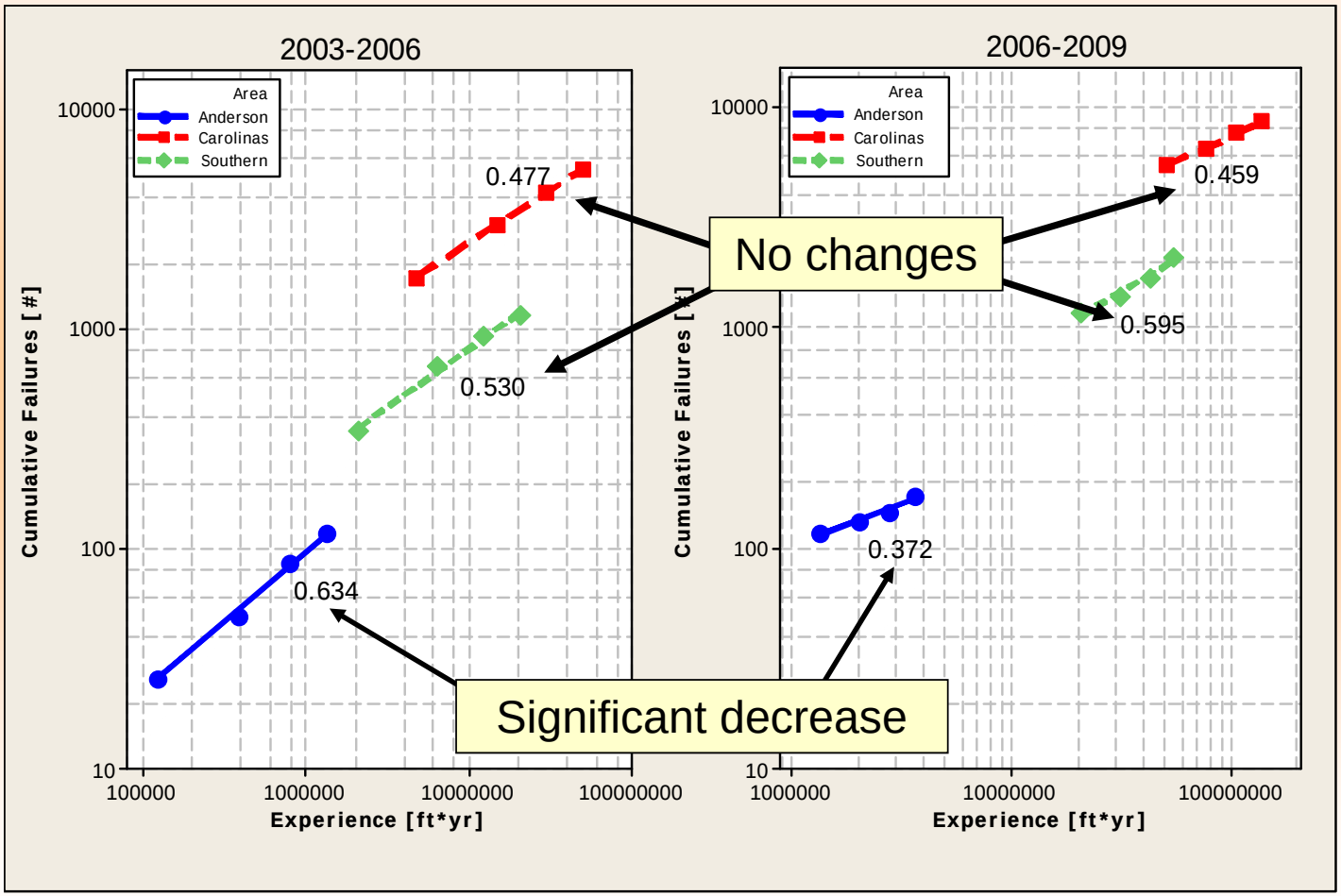
Duke Secondary Cable System - Areas



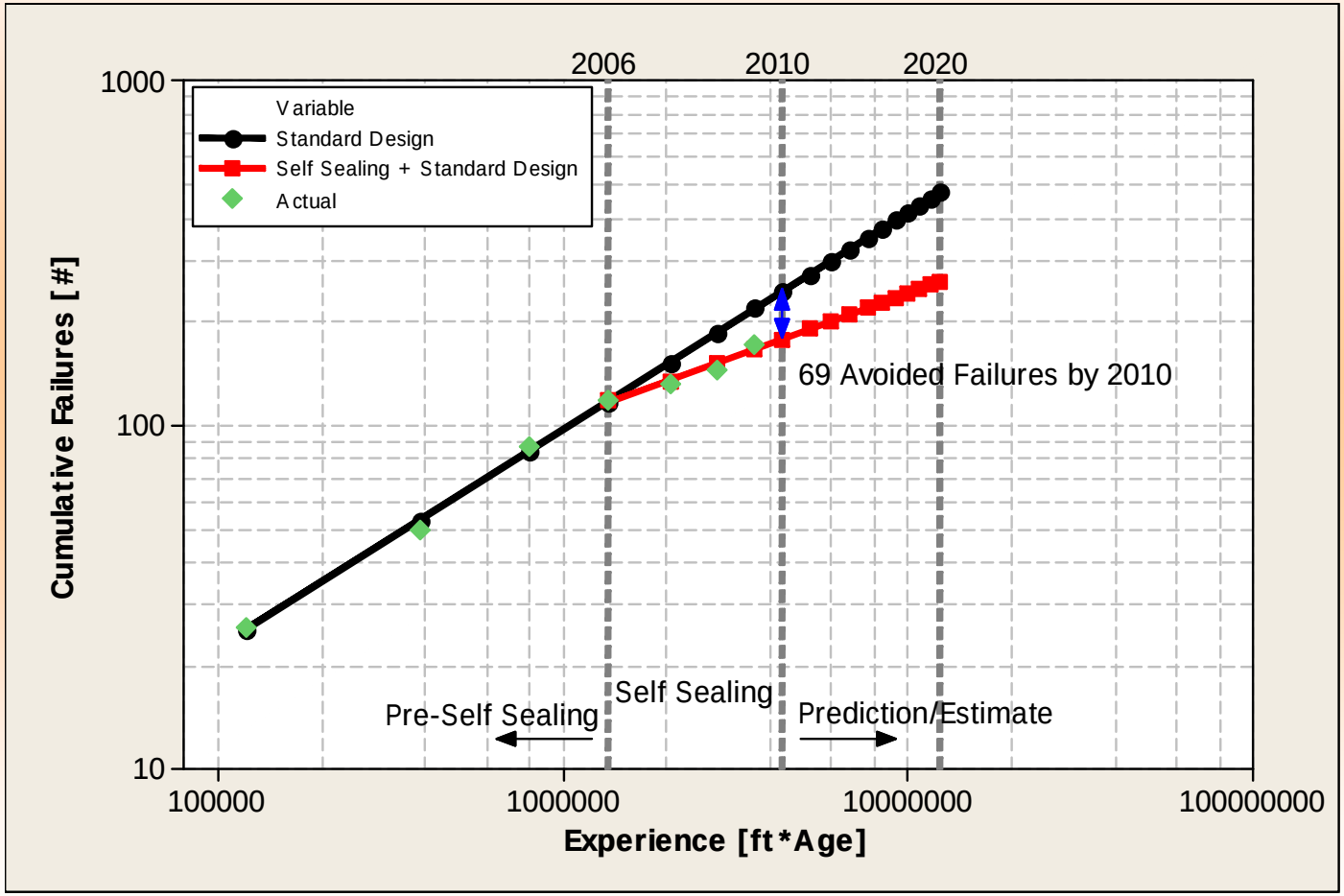
Failure Rate Changes



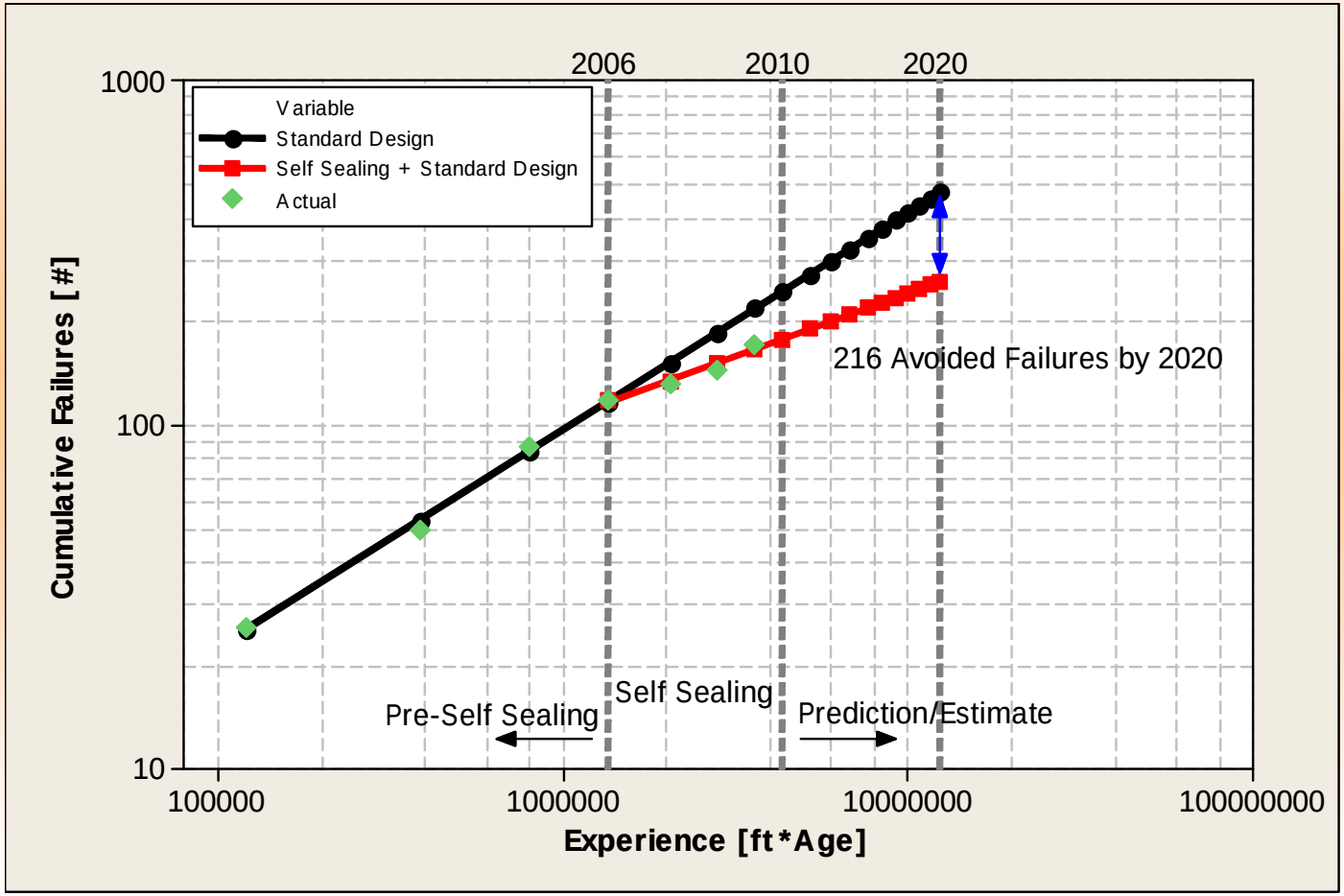
Gradients – Split at 2006



Impact Avoided Failures - 2010



Avoided Failures - 2020



Summary

- Crow-AMSAA method is useful for spotting improvements or reductions in reliability
  - Can be used to predict future performance
  - Can be used to predict “do nothing” performance
  - Does not require “age” information on population
  - Effective for economic decisions to be made
- Widely applicable
  - Field Testing
  - Overhead Connector Failures
  - Outage Prediction
  - Network Fires / Manhole Events
  - Secondary Cable Design Enhancements