Reliability Impact of Distributed and Renewable Energy Resources: Case Studies

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Background

- Long term goal is to combine information on performance with failure rate information
  - Assess current performance and reliability (on/off line)
  - Predict performance and reliability for optimum scheduled maintenance
  - Identify design improvements and additional data collection

- Review two recent examples involving the reliability analysis of complex systems

- Highlight the unique aspects of each problem and why specific approaches are taken.

- Introduce future work in the area of renewables: hydrogen fuel cells, solar wind, etc.

Outline

- Background
  - Reason for analysis
  - Analysis approach
  - Summary of results
- Q&A

Example 1: System Reliability

- **Goal:**
  - **Real time monitoring of performance using**
    - SCADA system
    - Failure data from specific and similar systems

    to *<u>anticipate</u>* when failures will occur

  - **How to *combine*:**
    - SCADA performance monitoring data
    - Component field failure data
    - Fleet information
    - Commercial test data

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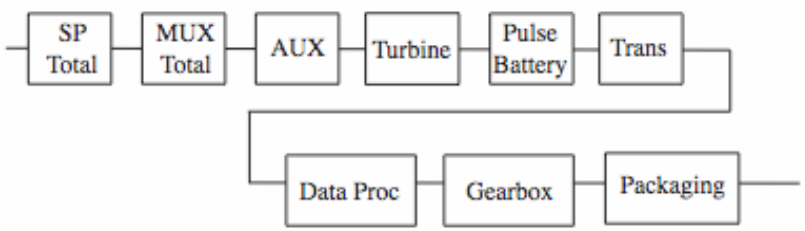
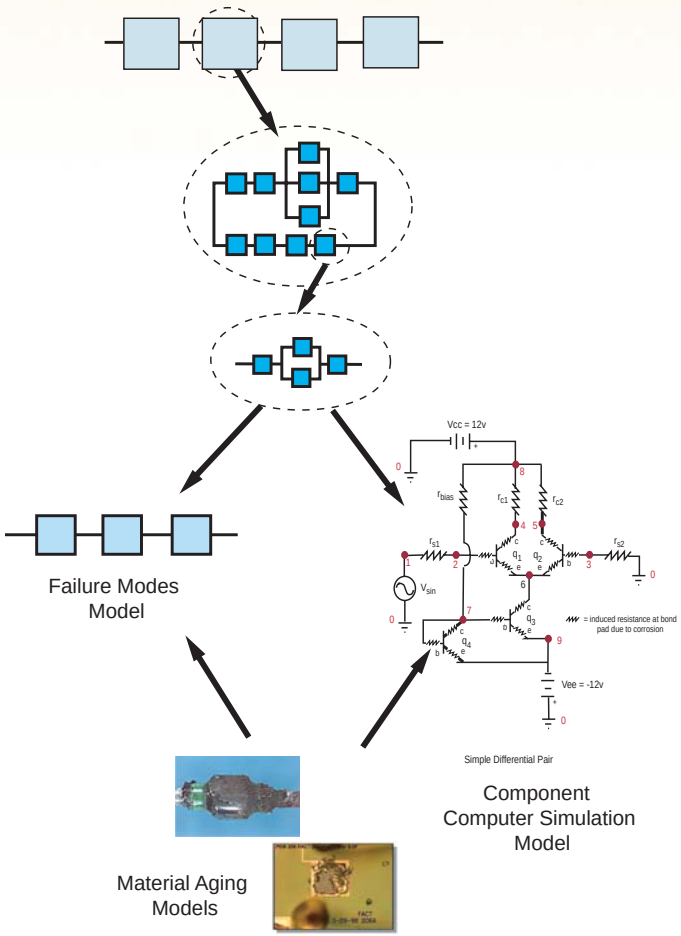
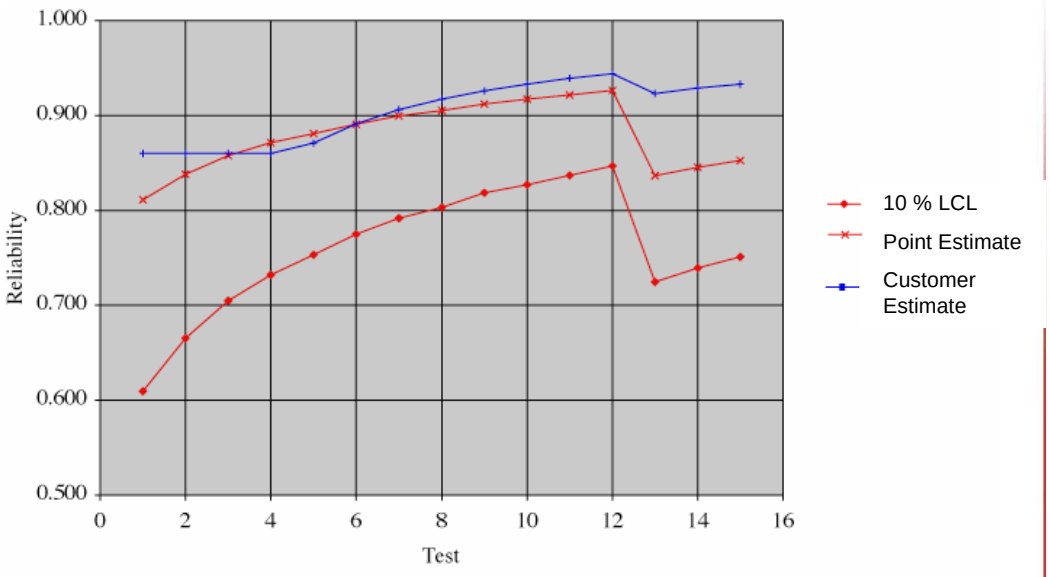




System Reliability Results

- **Issues:**
  - **Test data is available at both system and component level**
  - **Reliability assessment is sensitive to how system and component data is combined**
    - Issue is well recognized (and ignored) in reliability community after 1986 Challenger accident
    - Reliability estimates are typically optimistic
  - **No system level confidence interval available**
  - **SCADA information must be analyzed separately**

- **Results**
  - **Reliability estimates were more accurate using non-traditional methods and**
  - **Quantify sensitivity to data and assumptions**
  - **Identified unresolved problems before they became failure critical**

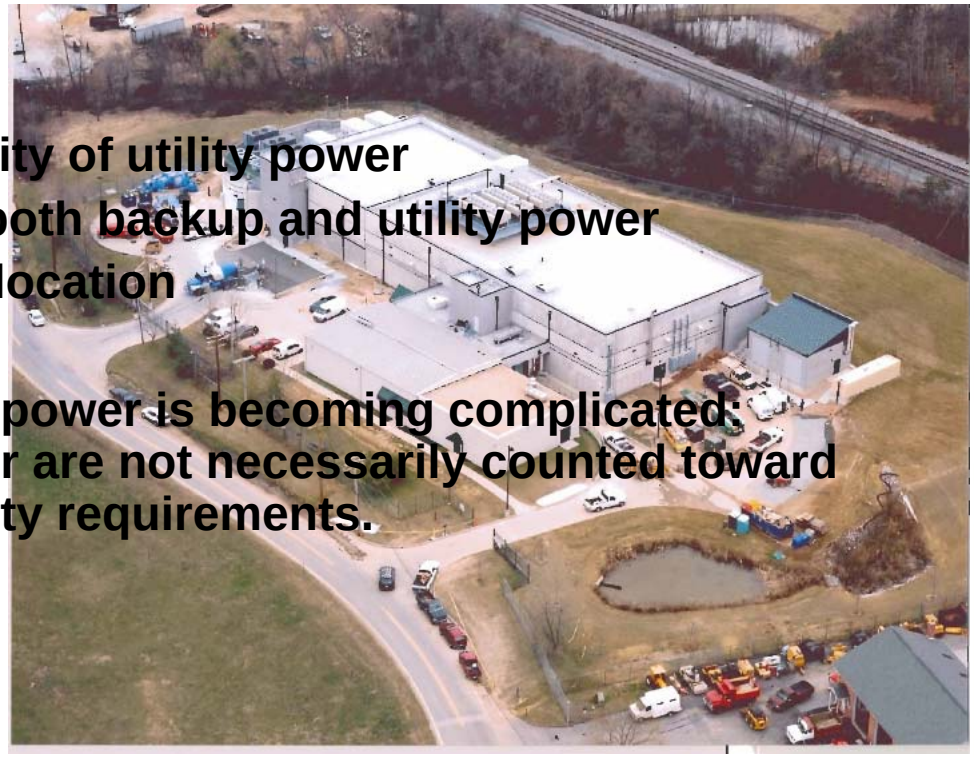


Example 2: Telecom Facility

- **Cooperative effort between:**
  - **Sprint/Nextel**
  - **NREL**
  - **Sandia**

- **Issues:**
  - **Large uncertainty in availability of utility power**
  - **Weather is a major factor in both backup and utility power**
  - **Telecom facility is in remote location**

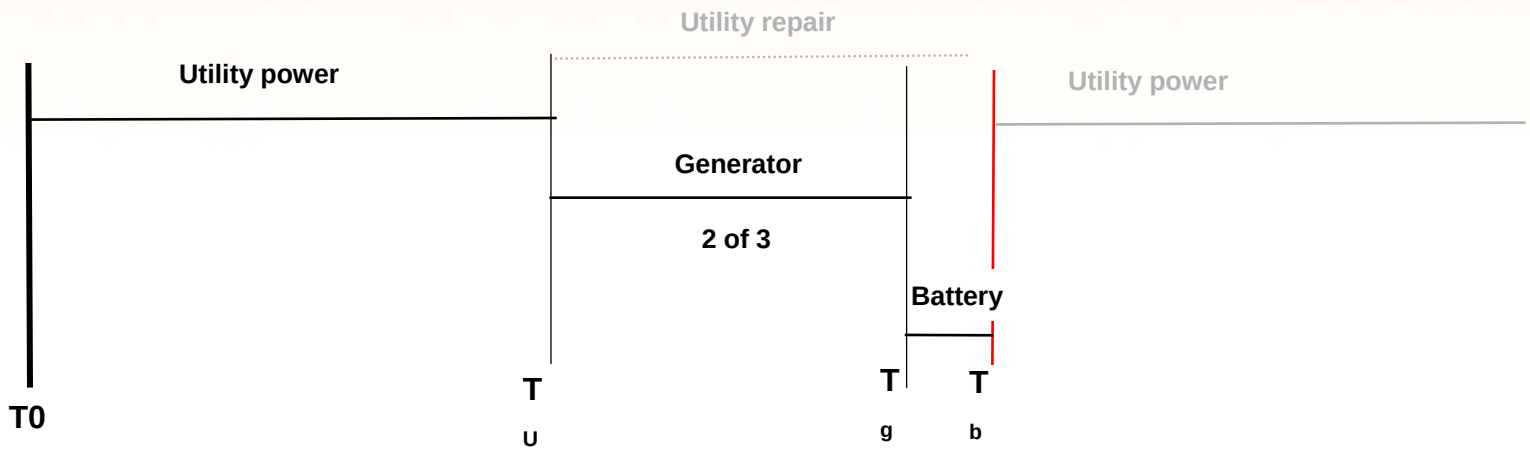
  - **Reliability reporting of utility power is becoming complicated: Utility outages due to weather are not necessarily counted toward state regulated utility reliability requirements.**



Alternative Approaches

- **Alternatives**
  - Fault trees
    - **Sequence of dependent events**
    - **Time of operation critical not just probability of operation**
    - **Difficult to extend to alternative power configurations**
    - **Repair time can not be considered**
  - Block diagrams (e.g. Weibull analysis)
    - **Pros: well established techniques**
    - **Cons: impossible to combine component data with system level data (beyond point estimates); difficult to handle repair/availability analyses**
  - Markov chain
    - **Pros: modeling is straightforward and able to capture both repair and operational states**
    - **Cons: requires constricting assumptions about failure and repair distributions; sensitivity analysis difficult**
  - Simple stochastic process
    - **Pro: model is easy to extend: to included repair if needed and include new power generation configurations (e.g. PEMs)**
    - **Con: slightly more complicated modeling**

Stochastic Process Approach



Everything functioning

<u>Initial</u> assumptions:

- **No repair**
- **Only interested in one-cycle**
  TF = Tu + Tg + Tb
- **Tu, Tg, Tb are all random variables**
- **TTF will be a random variable so risk will be stated as:**
  Probability that the system functions for at least time TF

Benefits

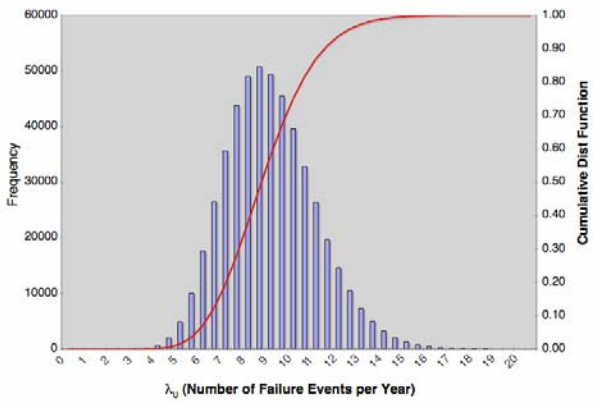
- **Easy to extend to include repair**
- **Alternative generation sources can be included**

Base Case: Utility Time to Failure

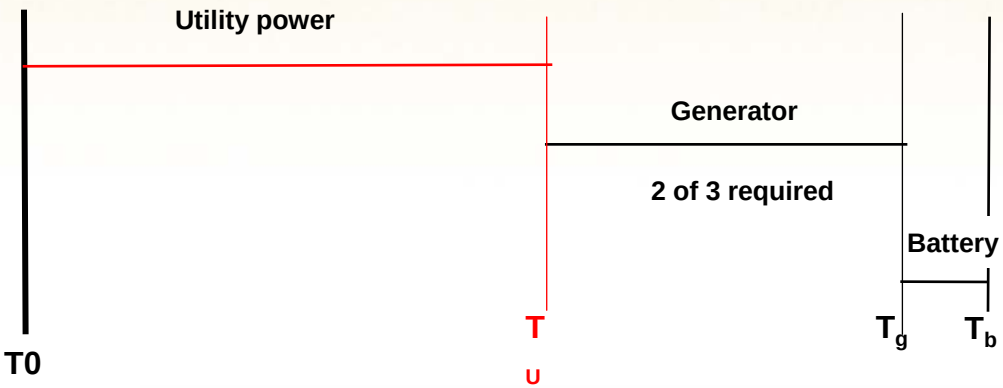
Utility Time to Failure

The rate at which utility failures occur is considered a random variable; e.g. the number of events each year is a random variable.

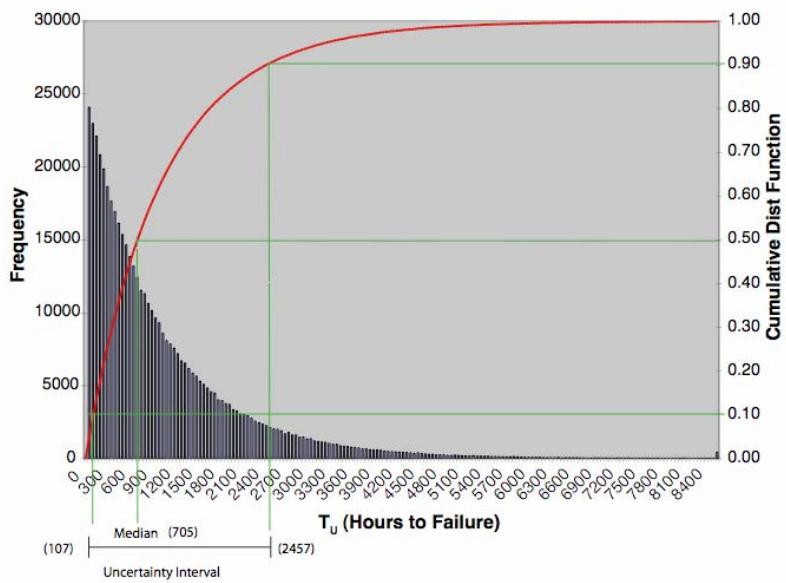
$\lambda_U \sim Gamma(\alpha, \beta)$



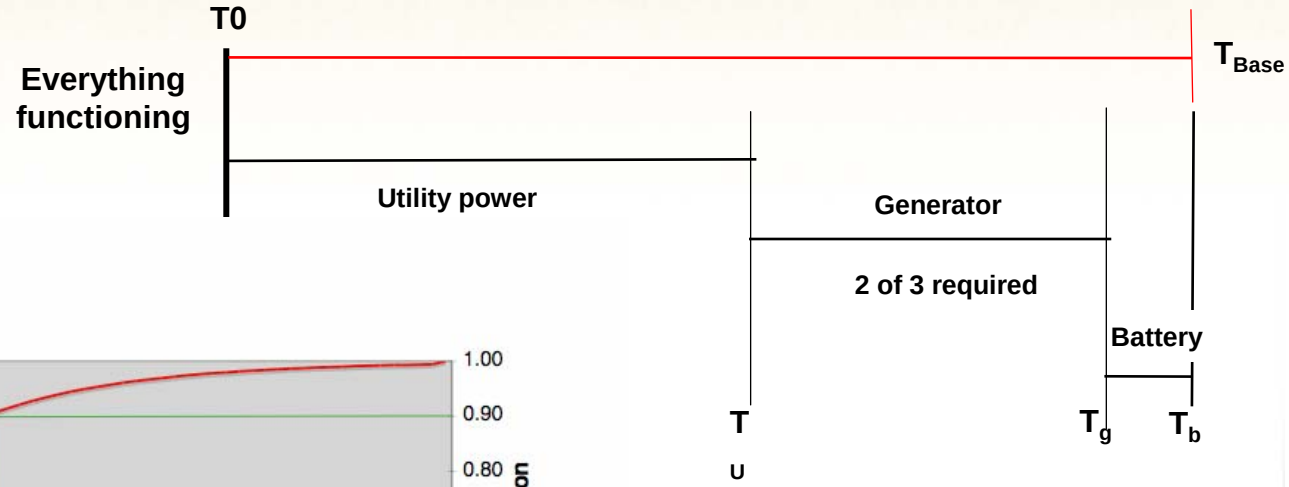
Since the number of utility failures per year is a random variable, the length of time that power is available from the utility is also a random variable. There is a 90% probability that it is less than 2470 hours and 90% probability that it is greater than 107 hours.

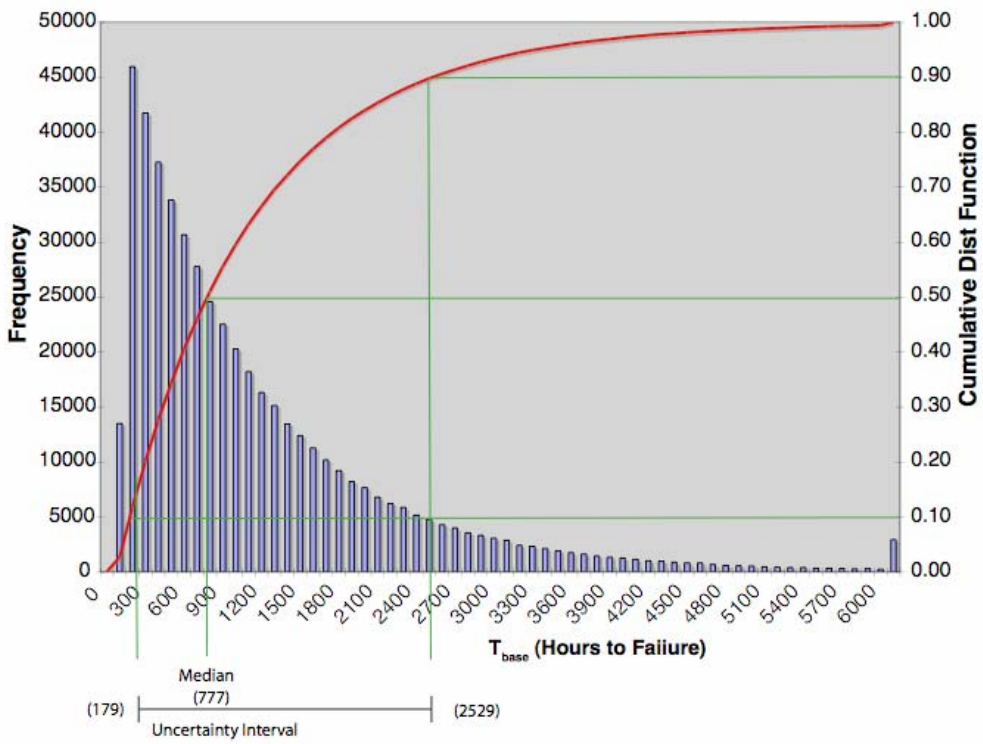


$T_U \sim Exponential(\lambda_U)$



Base Case: Time to Failure





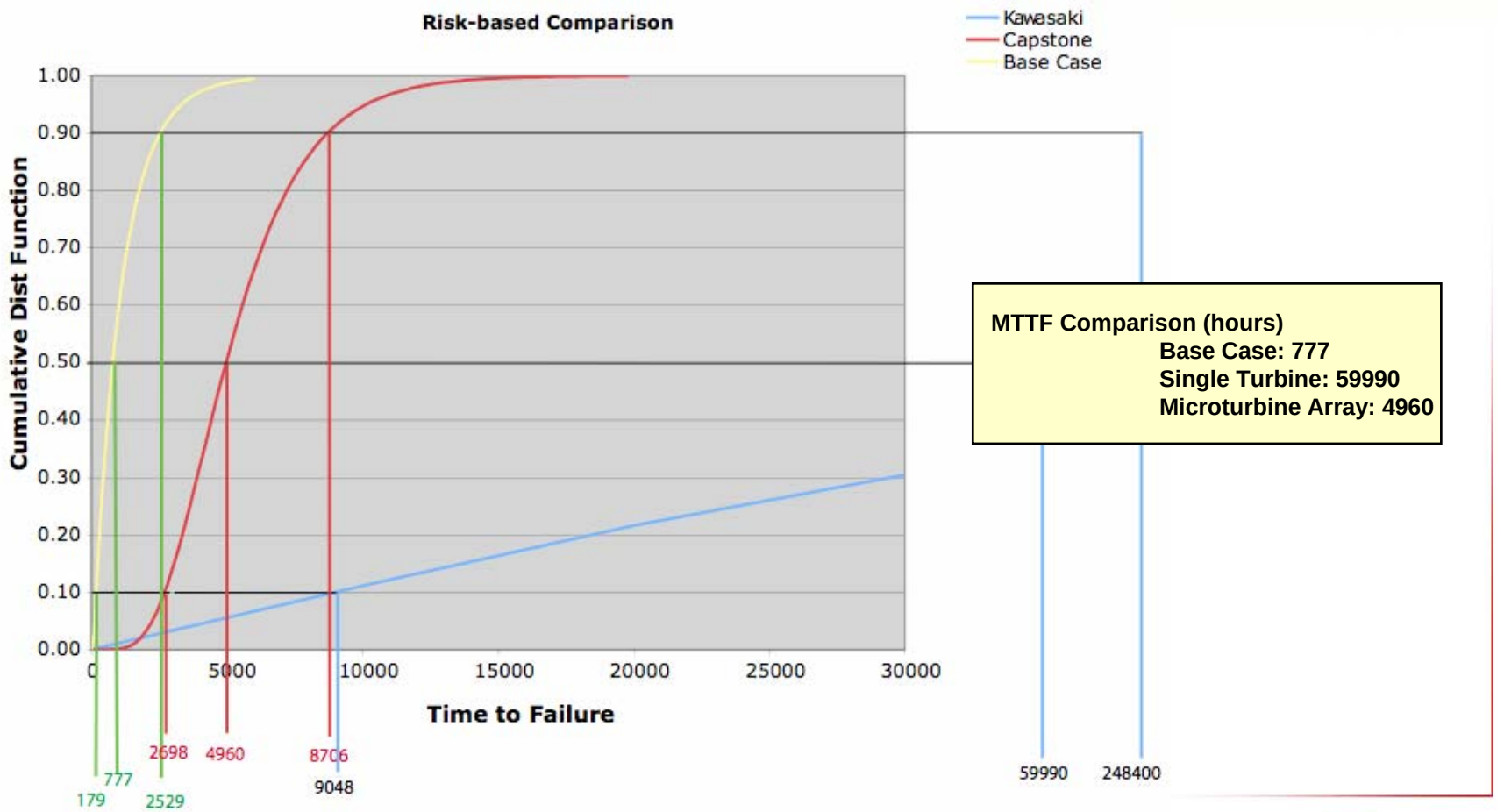
Alternative Configurations

- Change primary power from utility to on-site natural gas fueled system
  - Single large turbine
  - Array of microturbines

- Operate utility as "primary backup"
  - Keep diesel generators and batteries as backups
  - Future work: evaluate fuel cells to replace batteries

- New critical issues:
  - Natural gas availability
  - System operations
  - Microturbine array operations (cold vs hot standby)

Risk-based Case Comparison



Future Reseach

- **Cooperative effort between Sandia, NREL, Sprint/Nextel to identify optimum location and combination of renewables (wind, solar, hydrogen, thermal, etc.) to increase reliability and robustness of telecommunications network**

- **New methods for using real-time monitoring of sensor information to:**
  - **anticipate failure well in advance of actual event,**
  - **increased confidence in reliability estimates, and**
  - **optimally schedule maintenance and reduce operational costs**

Questions?
Sandia
Mountains