SAND2006-5449C

Updating a User Friendly Combined Lifetime Failure Distribution

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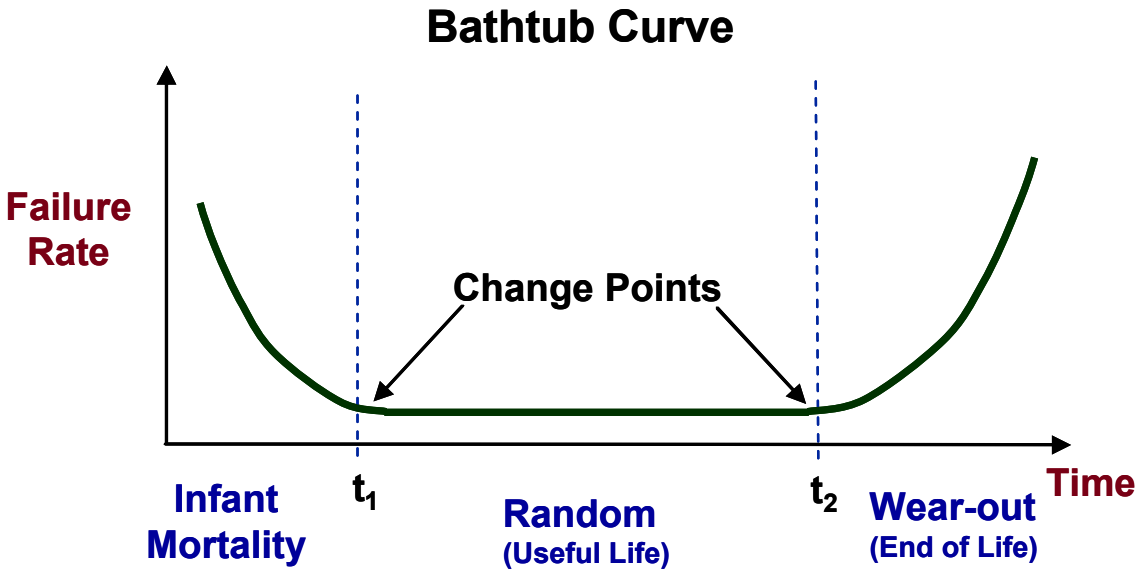
Outline

- Objective: Updating time-to-failure distributions
- Introduction
  - Bathtub Curve
- Combined Lifecycle (CMBL) Distribution
  - Advantage
  - Description
- Updating Methods
  - 4 Possible
- Results of Method 1
  - Convergence to Data
  - Additional challenges
- Summary
  - Future Direction

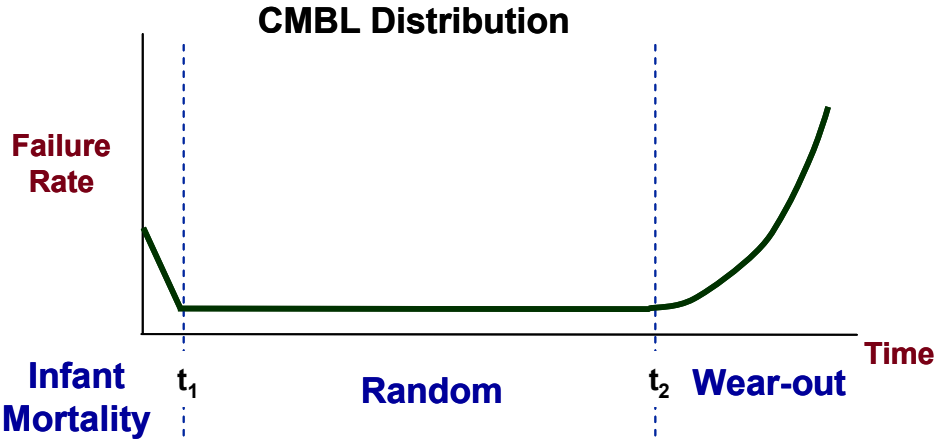
Bathtub Curve

- **Probability of failure over lifetime of component**
  - Usually modeled as Exponential
- **Useful for enterprise level and prognostic focused modeling**
  - Optimize supply/repair chain processes
  - Baseline for characterizing component health trends



CMBL Distribution

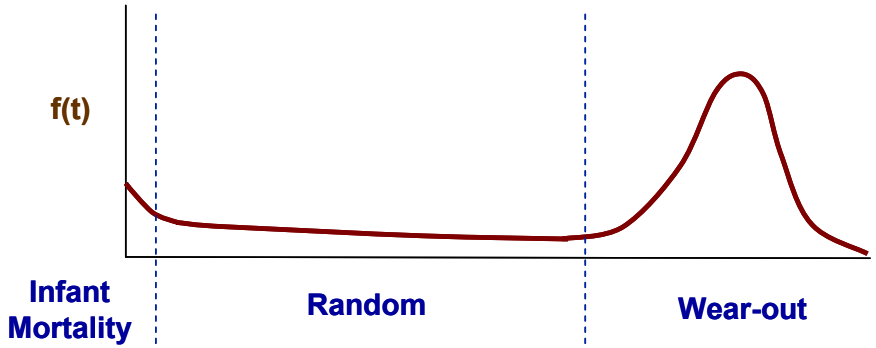
- **Advantages**
  - Common terms and approach
  - Easy to solicit expert opinion



- **Input Parameters**
  - Probability that the component will fail during infant mortality
  - Duration of infant mortality
  - Probability that failure will occur randomly
  - Mean of the normally distributed portion
  - Standard deviation of normally distributed portion

CMBL Distribution

$$f(t) = \begin{cases} \lambda_d e^{-\lambda_d t} & 0 \le t \le t_1 \quad \lambda_d = (mt + b) \\ \lambda_c e^{-\lambda_c t} & t_1 \le t \le t_2 \\ \dfrac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2\sigma^2}(t-u)^2} & t_2 \le t \le \infty \end{cases}$$



- **Definitions**
  - μ = mean of the normally distributed portion of the TTF distribution
  - σ = standard deviation of the normally distributed portion
  - λ_d = failure rate for the linearly decreasing failure rate portion
  - λ_c = failure rate for the constant failure rate portion
  - t_1 = burn-in duration (BID)
  - t_2 = transition from constant failure rate to the normal TTF portion
  - F_1 = fraction of failures occurring in the infant mortality portion
  - F_2 = fraction of failures occurring in the random failure portion

Updating Methods

- **Method 1**
  - Treat each section separately, use appropriate prior based on section
  - Modify the CMBL iteration procedure to get back input parameters
- **Method 2**
  - Model as a single distribution using Markov chain simulation
  - Use regression and curve fitting techniques to get back input parameters
- **Method 3**
  - Use Method 1 or 2 to get empirical distribution
  - Use empirical distribution with Markov chain simulation as next prior
- **Method 4**
  - Investigate possible closed form solution
  - Evaluate possible prior distributions to obtain closed form posterior

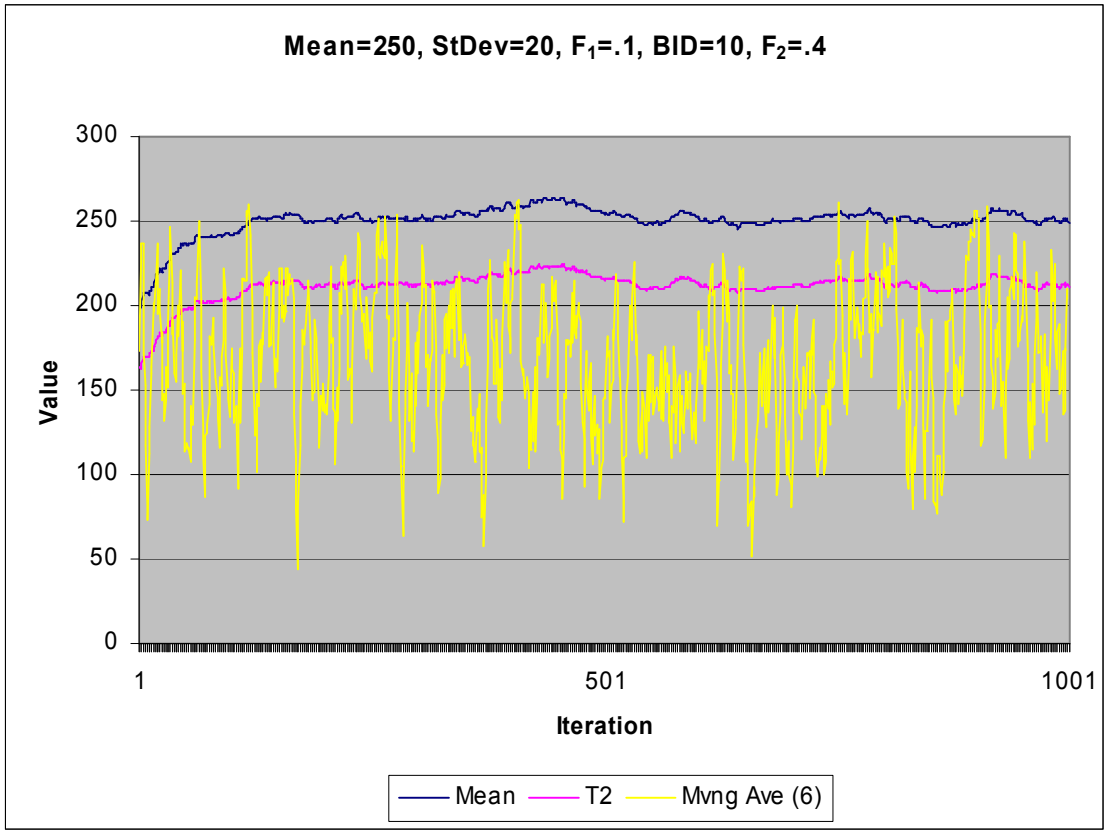
Method 1 Setup

- **Assumptions**
  - Treat each section separately, use appropriate prior based on section
  - Only random and wear out portions of distribution were evaluated
  - Used a Bayesian updating methodology, one data point at a time
  - Introduced a "weighting scheme" to reduce extreme values in data
  - The standard deviation was assumed known and held constant
- **Example Input Parameters**

	Baseline	Normal	Random
μ	200	250	150
σ	20	20	20
F_1	.1	.1	.1
F_2	.4	.4	.4
t_1	10	10	10

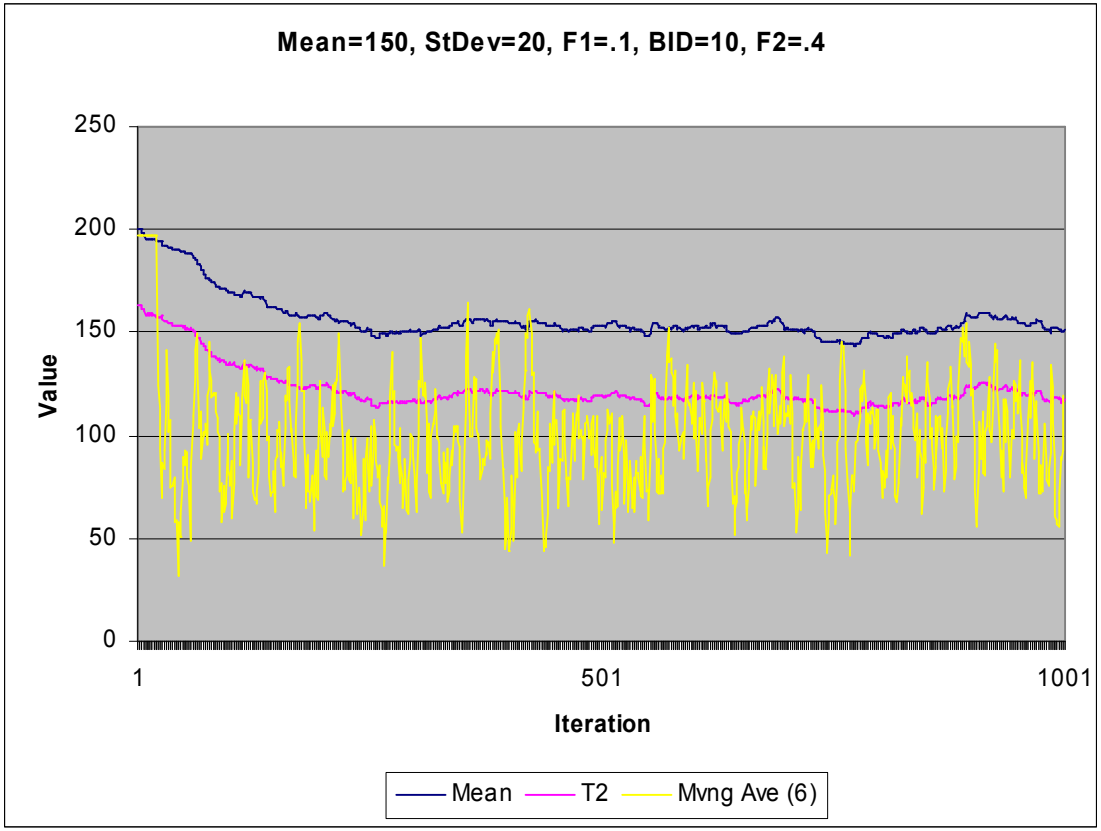
Method 1 Results

- **Mean increased to 250**
  - **Mean converged in about 200 iterations**
  - **t_2 converged to 212.3 vs calculated 210.9**



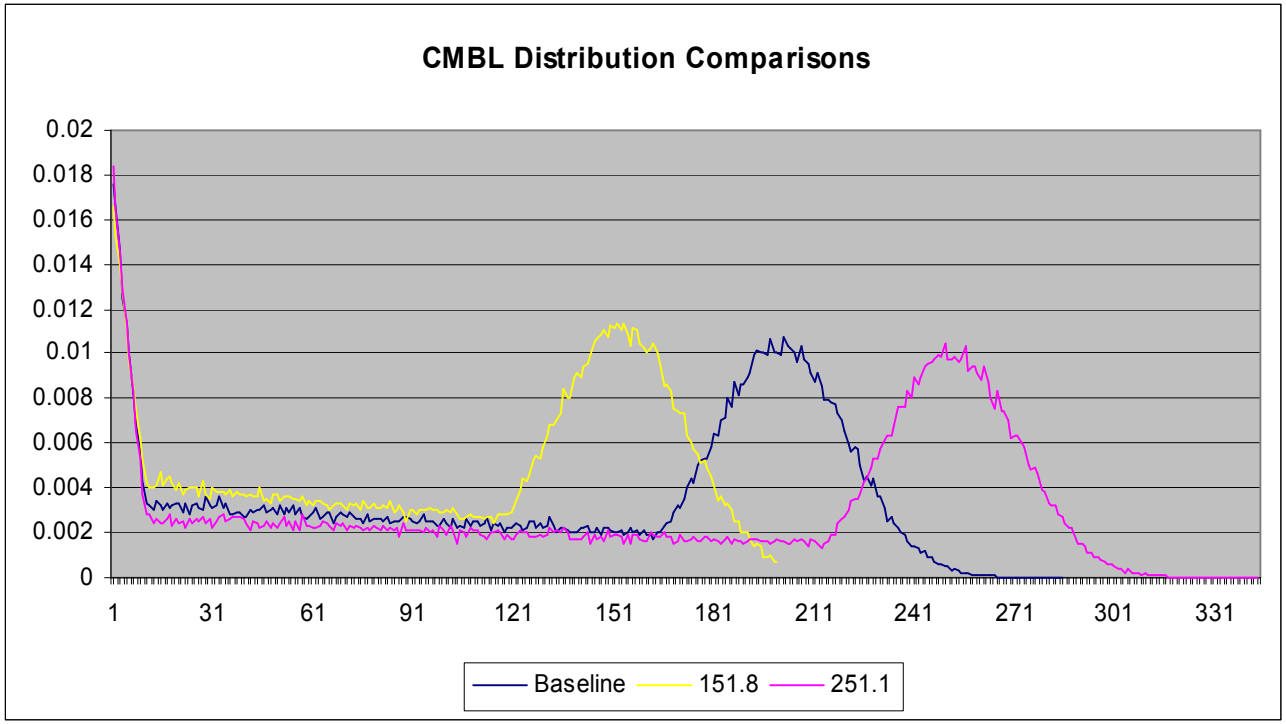
Method 1 Results

- **Mean decreased to 150**
  - **Mean converged in about 250 iterations**
  - **t_2 converged to 117.9 vs calculated 117.5)**



Method 1 Results

- **Results Comparison**
  - **Expected shift in distribution**



Summary

- **CMBL distribution useful for logistic support and PHM modeling**
  - Uses expert opinion, data from similar systems, scarce data
  - Updating methods will allow use throughout a components lifecycle
- **Method 1 looks promising**
  - Changes in the mean resulted in convergence to the distribution of the data
  - May apply to other sectional models
- **Future work**
  - Evaluate changes in F_2 and σ for Method 1
  - Include infant mortality in the updating process for Method 1
  - Evaluate Methods 2, 3, and 4
  - Investigate application to other types of lifetime failure models