

FORELESNING 12

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TMA4275 LEVETIDSANALYSE

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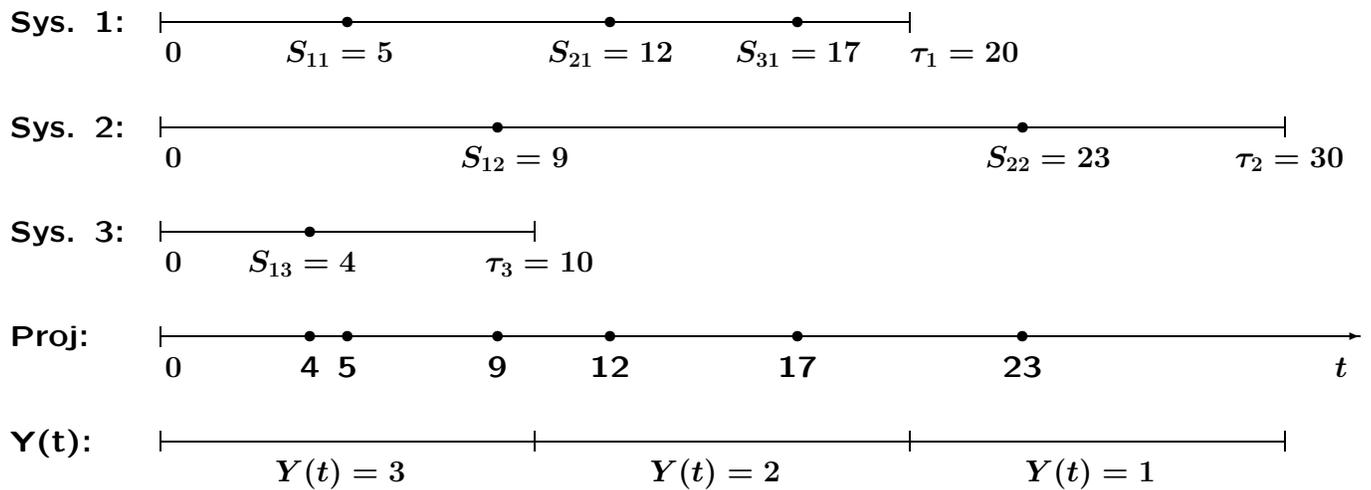
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SIMPLE EXAMPLE WITH THREE SYSTEMS



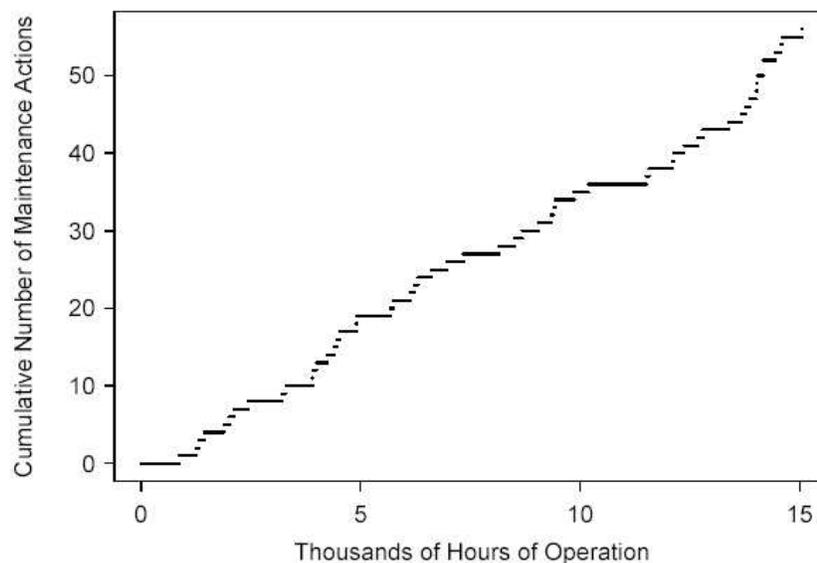
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Times of Unscheduled Maintenance Actions for a USS Grampus Diesel Engine

- Unscheduled maintenance actions caused by failure of imminent failure.
- Unscheduled maintenance actions are inconvenient and expensive.
- Data available for 16,000 operating hours.
- Data from Lee (1980).
- Is the system deteriorating (i.e., are failures occurring more rapidly as the system ages)?
- Can the occurrence of unscheduled maintenance actions be modeled by an HPP?

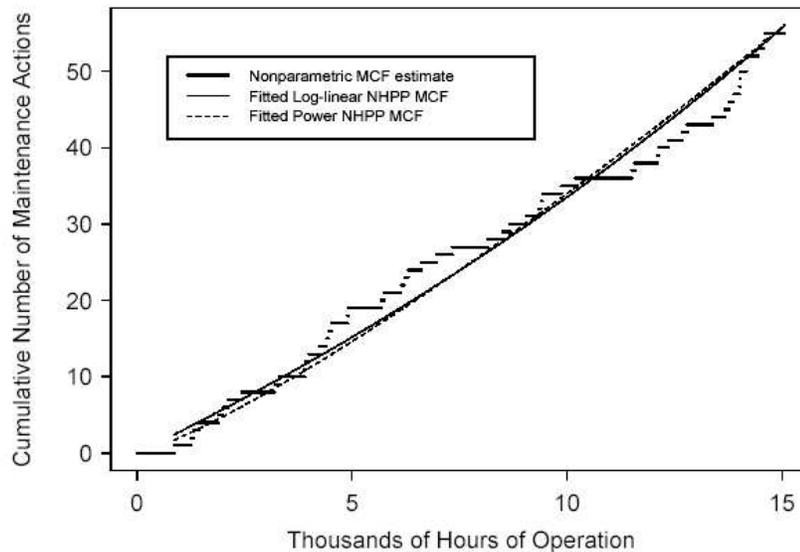
13

Cumulative Number of Unscheduled Maintenance Actions Versus Operating Hours for a USS Grampus Diesel Engine Lee (1980)



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Cumulative Number of Unscheduled Maintenance Actions Versus Operating Hours with Power and Loglinear NHPP Models for a USS Grampus Diesel Engine



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Results of Fitting NHPP Models to the USS Grampus Diesel Engine Data

- Both models seem to fit the data very well.
- For the power recurrence rate model, $\hat{\beta}=1.22$ and $\hat{\eta}=0.553$.
- For the loglinear recurrence rate model, $\hat{\gamma}_0=1.01$ and $\hat{\gamma}_1=.0377$.
- Times between recurrences are consistent with a HPP:
 - ▶ the Lewis-Robinson test gave $Z_{LR} = 1.02$ with p -value $p = .21$.
 - ▶ the MIL-HDBk-189 test gave $X_{MHB}^2 = 92$ with p -value $p = .08$.

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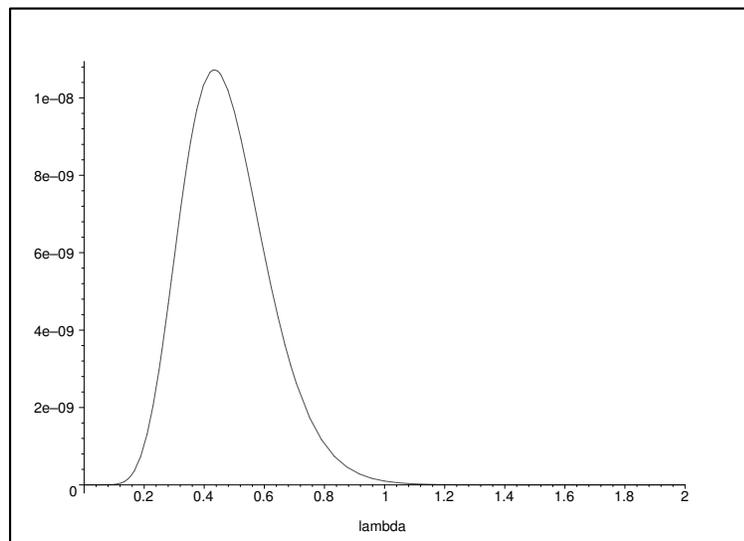
Life testing of $n = 13$ airplane components (Mann and Fertig, 1976), censored after failure number $r = 10$ (Type II-censoring), resulted in:

| j | Time (Y _j) | Censor |
|----|------------------------|--------|
| 1 | 0,22 | 1 |
| 2 | 0,50 | 1 |
| 3 | 0,88 | 1 |
| 4 | 1,00 | 1 |
| 5 | 1,32 | 1 |
| 6 | 1,33 | 1 |
| 7 | 1,54 | 1 |
| 8 | 1,76 | 1 |
| 9 | 2,50 | 1 |
| 10 | 3,00 | 1 |
| 11 | 3,00 | 0 |
| 12 | 3,00 | 0 |
| 13 | 3,00 | 0 |

Let the model be that $T \sim \text{eksp}(\lambda)$, i.e. the likelihood-function is

$$L(\lambda|\text{data}) = \lambda^r e^{-\sum_{j=1}^n y_j} = \lambda^{10} e^{-23.05}$$

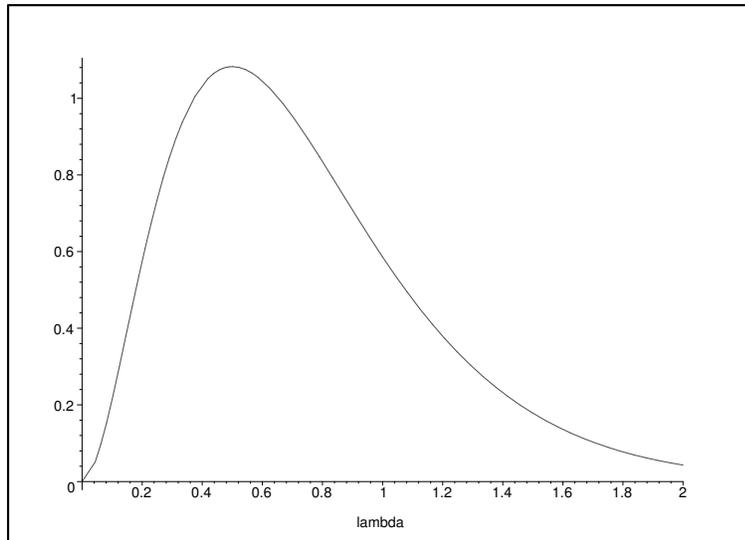
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Likelihood-function for airplane component data

$$\text{MLE: } \hat{\lambda} = 0.434$$

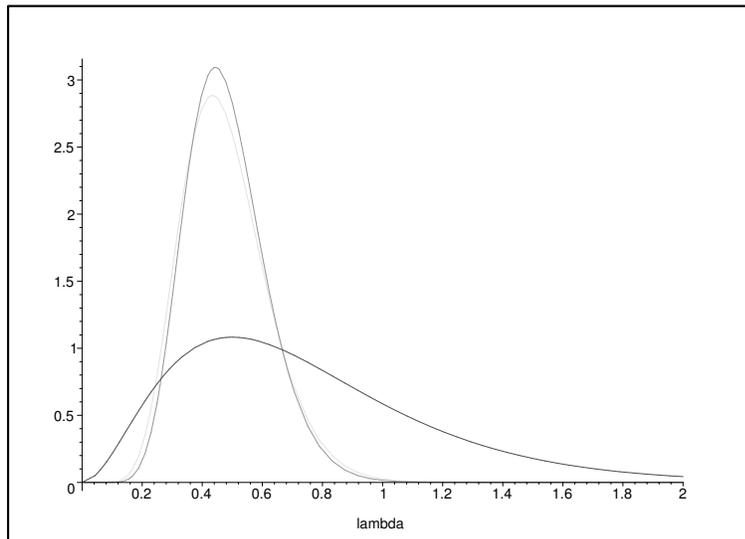
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**Prior distribution for λ in airplane component data,
 $\Lambda \sim \text{Gamma}(3, 4)$**

$$E(\Lambda) = 0.75, SD(\Lambda) = 0.43320$$

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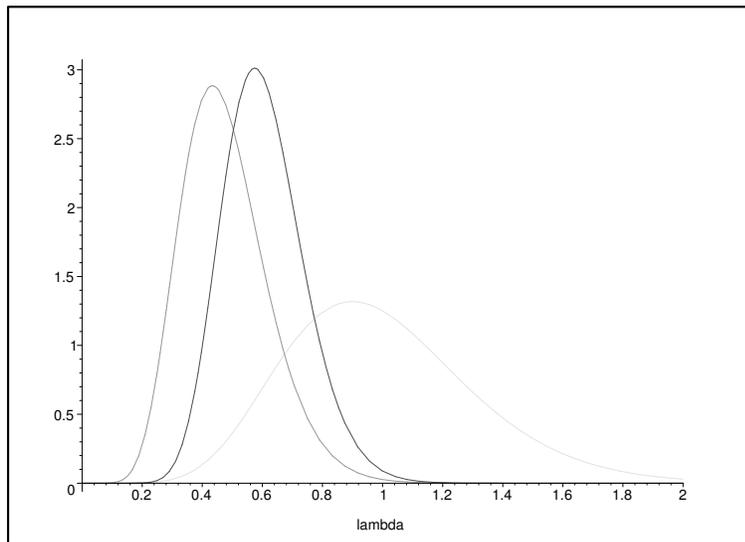


**Prior distribution ("lowest"), Likelihood-function
(normalized to density, "second highest") and Posterior
distribution ("highest") for λ in airplane component data.**

Posterior maximum is for $\lambda = 0.444$

Posterior expectation, i.e. Bayes-estimate is $\hat{\lambda}_B = 0.481$

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Alternative prior distribution (Gamma(10,10), "lowest"), Likelihood function (normalized to density, "second highest") and Posterior distribution ("highest") for λ in airplane component data.

Posterior maximum is now for $\lambda = 0.575$.

Posterior expectation, i.e. Bayes-estimate is now $\hat{\lambda}_B = 0.6051$