LMI

GOVERNMENT CONSULTING

THE OPPORTUNITY TO MAKE A DIFFERENCE HAS NEVER BEEN GREATER

Predicting Reliability

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Review, MIL HDBK 217

$$\Lambda_s = \lambda_a + \lambda_b + \lambda_c + \lambda_d + \lambda_e$$

Where s = system and a,b,c,d,e are components

$$1/\lambda = \text{MTBF}$$

Environmental Factor - π_E

Environment	π_E
G_B	.5
G_F	2.0
G_M	4.0
N_S	4.0
N_U	6.0
A_{IC}	4.0
A_{IF}	5.0
A_{UC}	5.0
[illegible]	8.0

$$\lambda_p = \lambda_b \pi_T \pi_A \pi_R \pi_S \pi_C \pi_Q \pi_E$$

where:

λ_p is the part failure rate,

λ_b is the base failure rate usually expressed by a model relating the influence of electrical and temperature stresses on the part,

π_E and the other π factors modify the base failure rate for the category of environmental application and other parameters that affect the part reliability.

Example Basic System

- Sensor, sensor processor, main processor, power conditioning, motor, cooling fans
- High power, advanced technology
- Mounted on rugged platform

Comparing Apples and Oranges

- Vendor claims product meets threshold system reliability
- Demonstration project has low reliability

- Mission is multi-mode and vendor uses own values for duration in each mode, part by part
- Vendor uses physics of failure plus some experience
- Derates failure rates
- Applies reliability improvement projection based on DemVal hours
- Takes low power credit

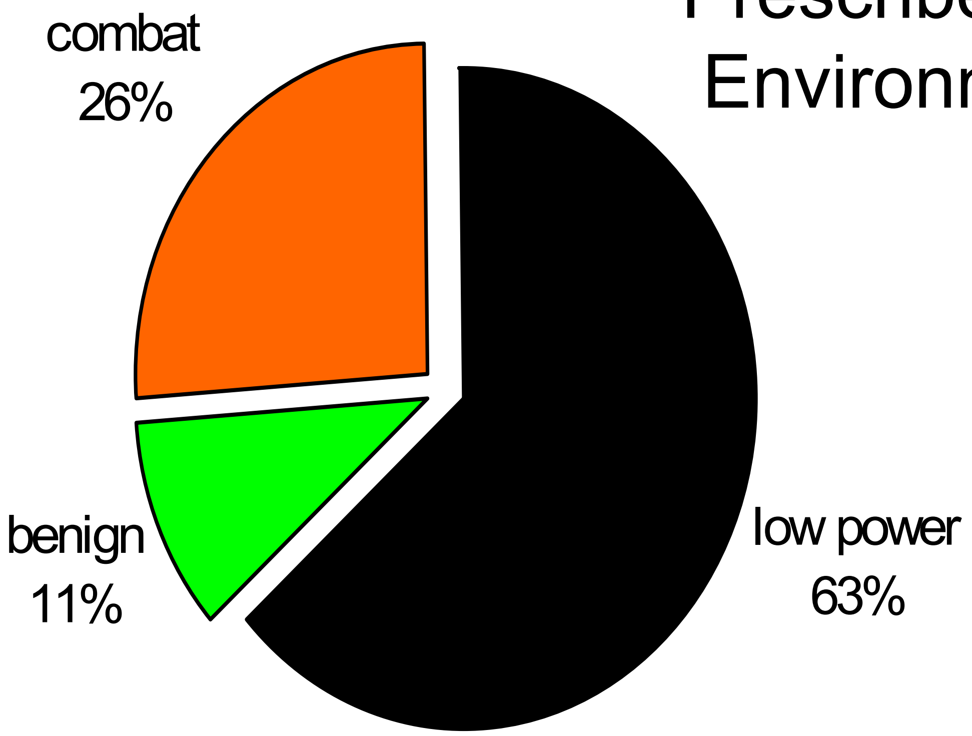
- Compare to x hours with y failures for system

Problem 1: Operating Mission Modes

- Operating mission has phases
  - Benign
  - Combat
  - Low power
- Different power issues, temperatures and stress/motion in each phase
  - Vendor estimated failure rates for each phase

Problem 1: Operating Mission Modes

Prescribed Operating Environment



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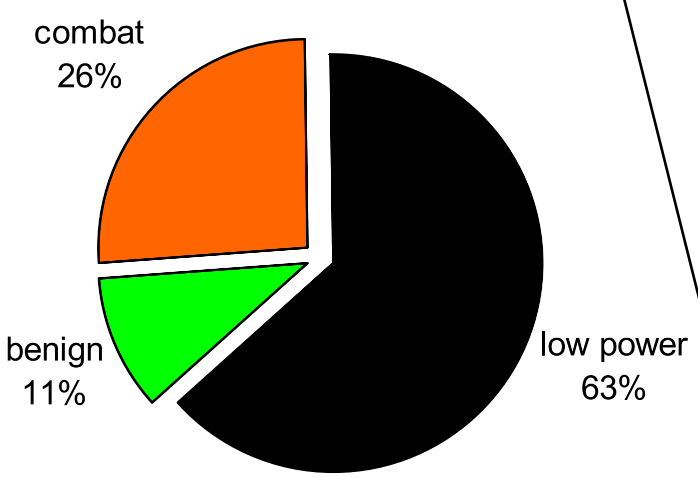
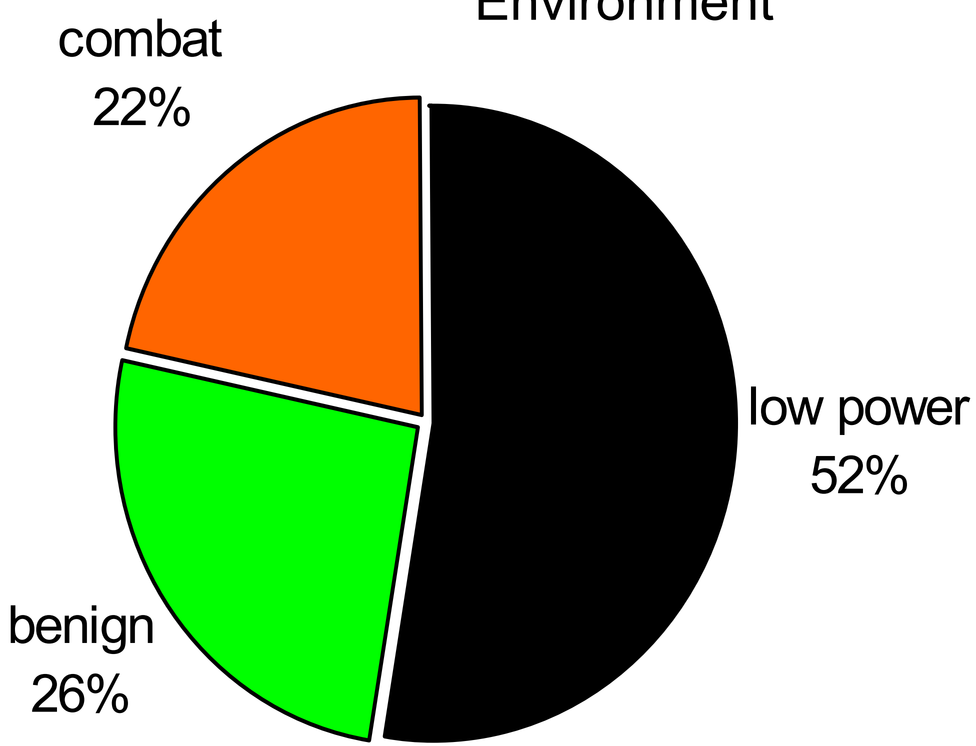


DemVal Operating Environment



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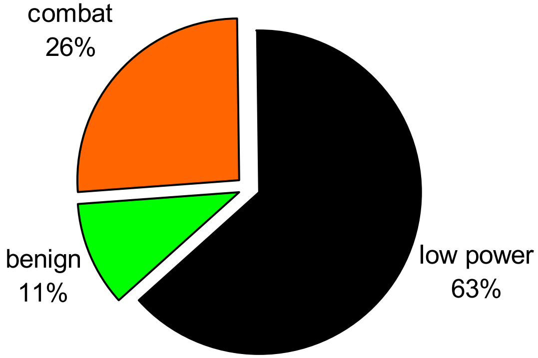

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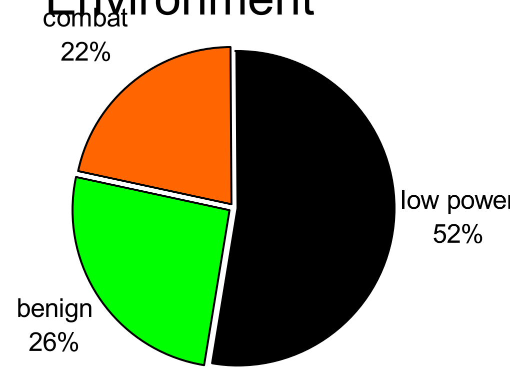
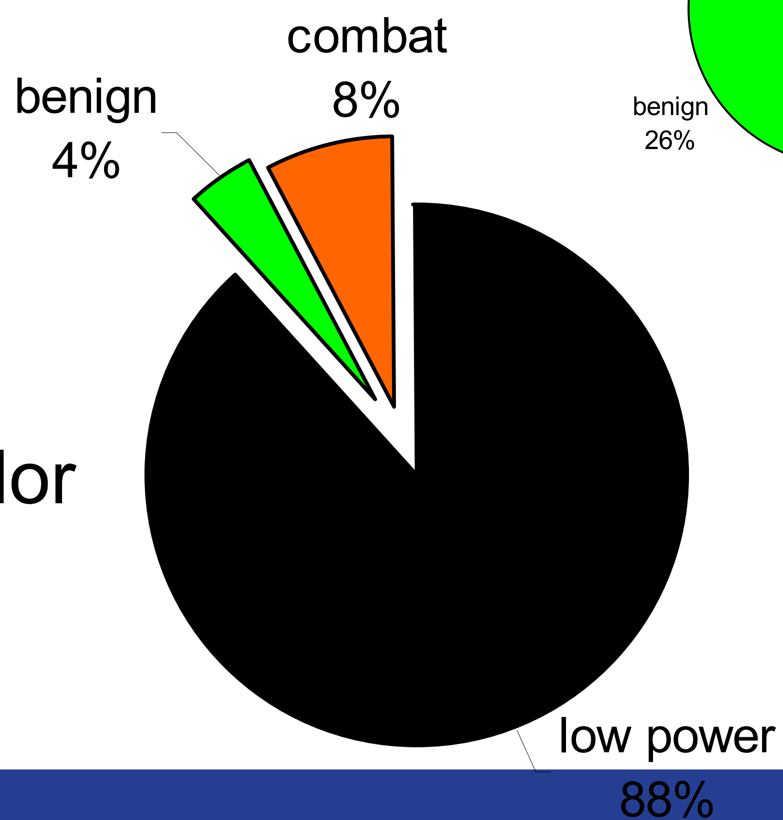




Basis of vendor Estimate

Issues

- Compare DemVal results to Vendor estimate
- Compare Vendor estimate to ORD
- Does low power generate less failures?
- Is thermal conditioning credit valid?
- Hindered by common LRU structure dictated by vendor competition
  - Some vendor subsystems have no comparison in cost model
  - Some subsystems in cost est do not exist in vendor architecture
- How to treat environmentally caused failures?
- Is the level of derating appropriate?
- What is the failure mode of the sensor (wearout vs stochastic)?
- Can we test wearout of the motor in a limited time period?

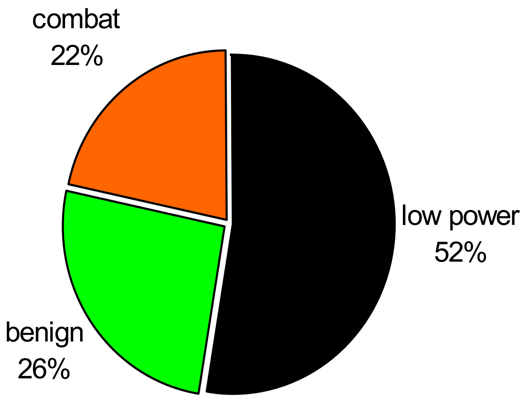
Initial Reliability Conclusions

- Credit for low power mode is reasonable
  - Valid method to extend life of high-failure, high cost items
  - Failures while dormant is active research field (no answers)
  - On/off cycling of the electronics is minimal
  - Industry standard of 5% of active failure rate
- Credit for thermal protection is reasonable
  - IAW MIL HDBK 217
- Estimation of expected life in components subject to wearout may have different standard

First Comparison

Apply Vendor Failure Rates to the Demonstration Mode Duration

Approach 2: Demonstration Operation Hours by Stated MTBF



* failure rates$_{mode}$ * total hours = failures

This number happens to be right… but is it useful?

And, how do we extrapolate this forward?

Subsystem Comparison

- Multiply vendor failure rates by time in mode to get failures and compare to actual failures
  - Repair record: we don't know what caused the first failure
- Derive MTBF by subsystem from DemVal and compare to vendor
  - How to treat low power time?
  - How to treat different thermal, shock environments?
  - If multiple subsystems are repaired in a depot visit, how can we ascribe failures?

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Assumptions

- If subsystem has power applied and can perform its function, it is accruing hours
- If it is partially functioning but cannot perform its mission, it is off
- Failures occur when on
  - Industry convention of 5% failure rate during off time

$$MTBF^* = \frac{\Sigma n(\text{elapsed time intervals})}{\text{failures during demonstration}}$$

* MIL HDBK 189

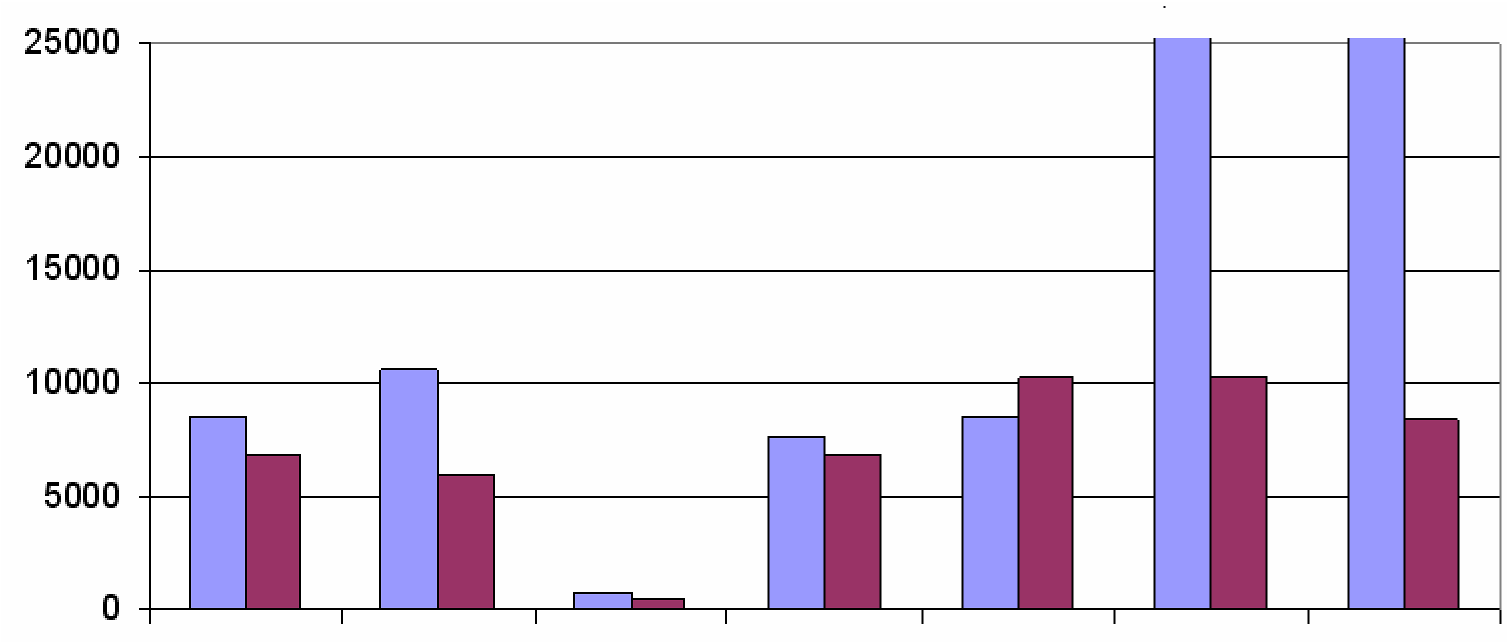
n = all units in demonstration evaluation

Defining Failures

- If a subsystem fails the induction test at the depot, then it has failed in the field
- If a subsystem fails due to environmental factors that are part of its normal operating environment then that is a failure of the unit
- Failure rates as a result of operations in the demonstration reflect lab-to-reality derate, thermal shocks and thermal conditioning and therefore do not need to be adjusted

Comparison by Subsystem

- Each bin is one subsystem; maroon results from DemVal; blue =prediction

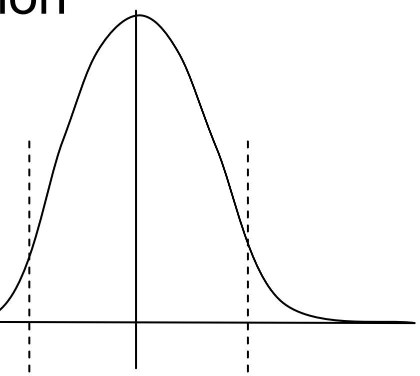


How much difference is too much?

Chi-Square

- Because small sample size in test and point estimate from vendor makes it difficult to estimate Gaussian standard deviation

$M_{confidence} = 2\,T / \chi^2_{2r+2}(\alpha)$



[time-terminated test]

T = time period (hours)

$(1-\alpha)$ = confidence level; for two-tailed, divide alpha by 2

e.g., for two-tailed 80% confidence, alpha = .10

$\chi^2_{2r+2}(\alpha)$ = Chi-Square distribution with 2r+2 degrees of freedom

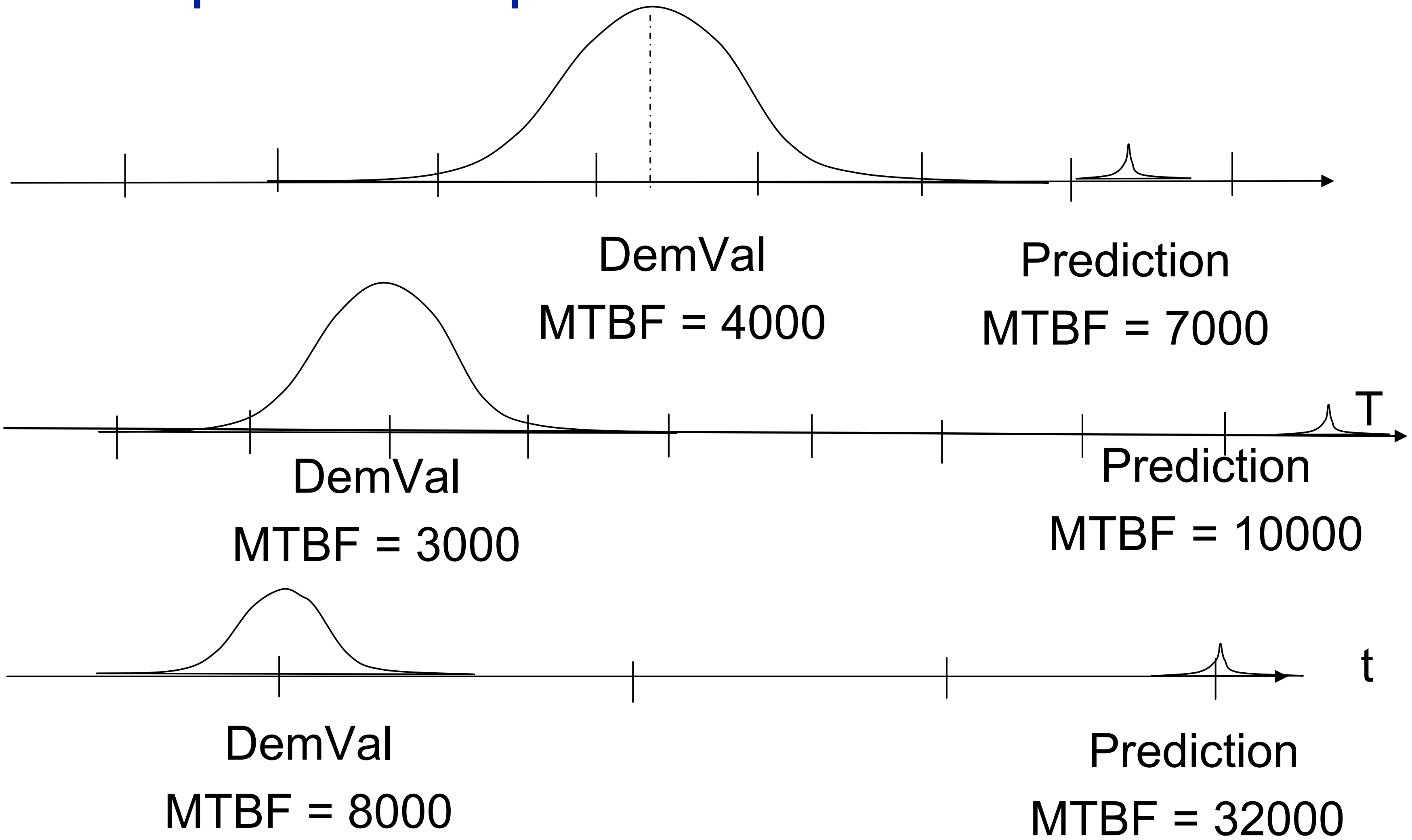
where r is number of failures under test

Use Lookup table for (.90, 2r+2), (.10, 2r+2)

For failure terminated test d.f. = 2r

Ref. Neubeck , 2004

Chi Square Comparison



Last Issue: What is the Reliability of a Nonfailed Subsystem?

- Concern about related failures in estimate
- Chi Square allows confidence intervals on zero failures but the estimates are several orders of magnitude away from DemVal period
- These subsystems have VERY high MTBFs
- Some had commercial equivalents

$$\Lambda_s = \lambda_a + \lambda_b + \lambda_c + \lambda_d + \lambda_e$$

- Derived our subsystem FRs, summed, and applied to ORD mission

Order of Magnitude MTBF Conclusion

Predicted MTBF With power and ORD adjustments	X
DemVal System Actual	50% X
DemVal with Adjusted Failures	65% X
Mission MTBF With power and phase adjustments	X

Percent of LCC that is due to MTBF

- 45% of O&S
- 47% of Procurement for spares
- O&S is 6 times Procurement