Contribution of RAMS Specifications to State of Good Repair (SGR)

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Topics

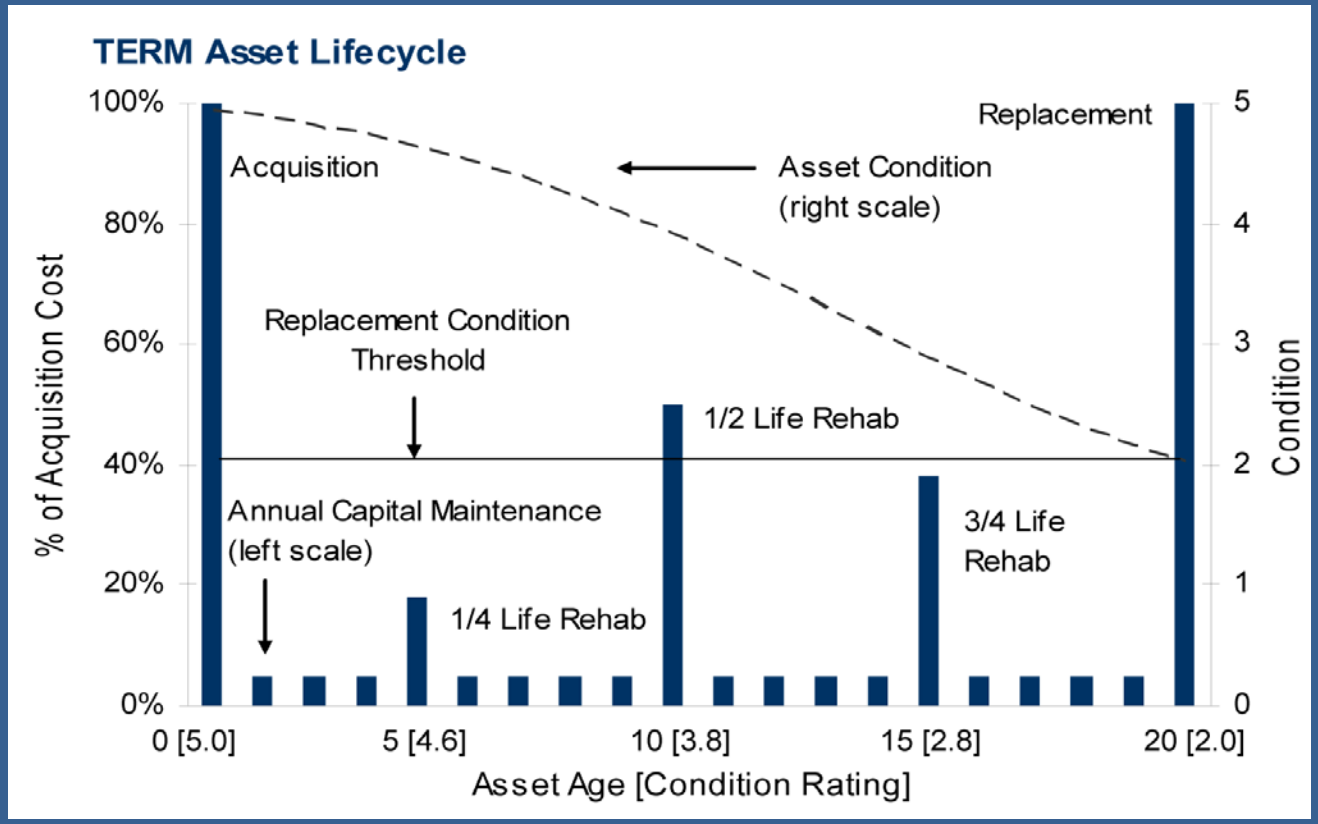
- Definitions
- Contribution of Reliability to system performance, Safety, and SGR
- Allowing equipment to fail
- Integrating RAMS into the system
- RAMS Specifications

Definitions: SGR

- FTA's Transit Economic Requirements Model (TERM) asset condition based on:
  - ◇ Type
  - ◇ Age
  - ◇ Maintenance History
  - ◇ Past utilization (e.g., life-to-date vehicle miles)
- Estimates Rehabilitation/Replacement needs/cost

Definitions: SGR (Cont'd)

- FTA's Transit Economic Requirements Model (TERM)



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Definitions: SGR (Cont'd)

- SGR "Working Definition": minimize asset life cycle cost while avoiding negative impact to transit service
- Need to address Availability during useful life
- Integrate RAMS to improve SGR

Definitions: Reliability

- Reliability (R): Probability of successfully performing designated function during a mission duration time, T
- Parameters: Mean Time Between Failures (MTBF) with Failure Rate λ, $\lambda = 1/MTBF$
- Example with constant failure rate
  $R = e^{-T/MTBF}$

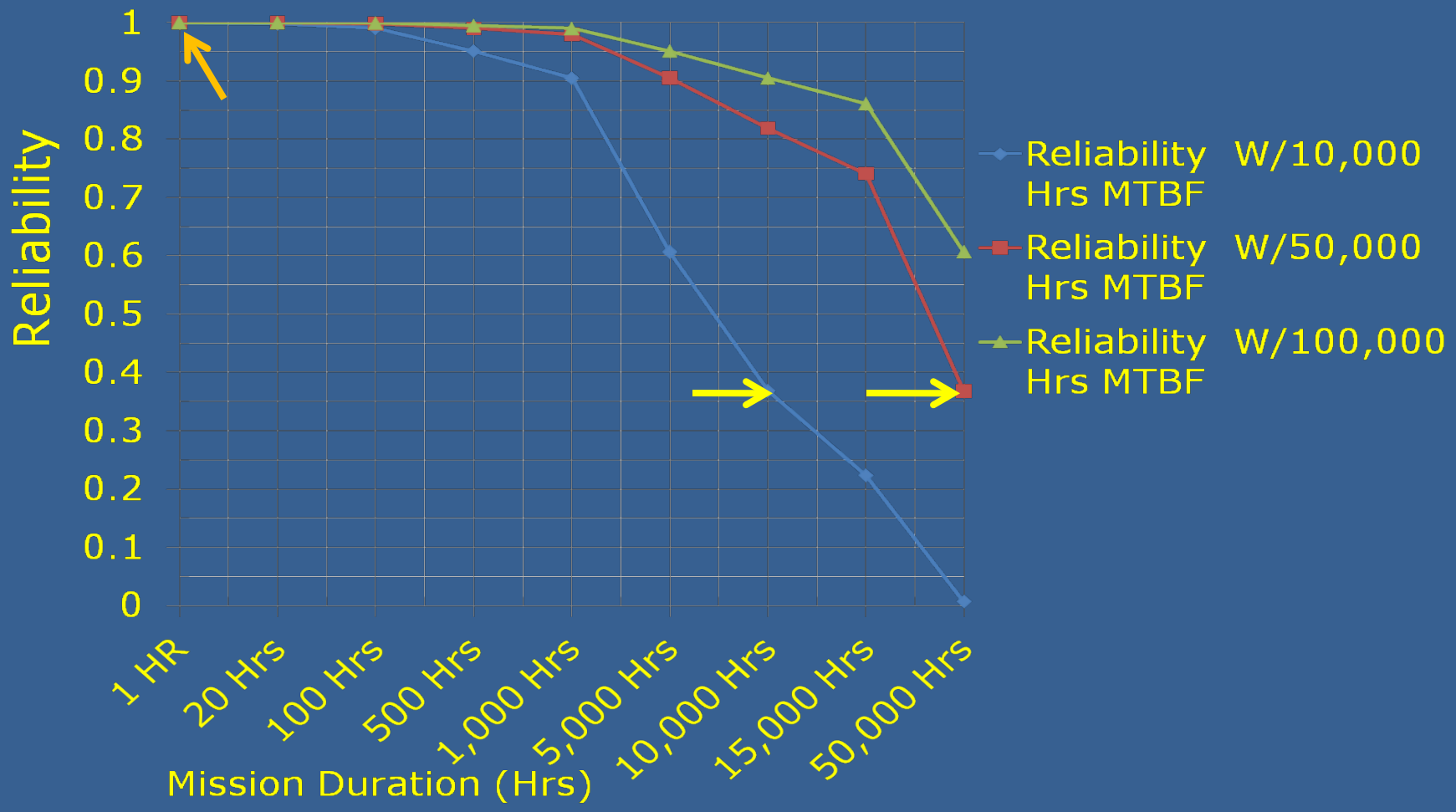
Examples of MTBF

For a System Operating 20 Hours/ Day		
MTBF (Operating Hours)	MTBF (Operating Days)	MTBF (Operating Years)
10,000	500	1.37
50,000	2,500	6.85
100,000	5,000	13.70

Reliability as a Function of MTBF and T

Reliability W/10,000 Hrs MTBF	Reliability W/50,000 Hrs MTBF	Reliability W/100,000 Hrs MTBF	Mission Duration, T (Hours)	Mission Duration, T (Days)	Mission Duration, T (Years)
0.999900	0.999980	0.999990	1 Hr	0.05 Days	0.000136
0.998002	0.999600	0.999800	20 Hrs	1 Day	0.002739
0.990050	0.998002	0.999000	100 Hrs	5 Days	0.013698
0.951229	0.990050	0.995012	500 Hrs	25 Days	0.068493
0.904837	0.980199	0.990050	1000 Hrs	50 Days	0.136986
0.606531	0.904837	0.951229	5000 Hrs	250 Days	0.684931
0.367879	0.818731	0.904837	**10000 Hrs**	500 Days	1.369863
0.223130	0.740818	0.860708	15000 Hrs	750 Days	2.054794
0.006738	**0.367879**	0.606531	**50000 Hrs**	2500 Days	6.849315

Reliability as a Function of MTBF and Mission Duration (Operating Hours)



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Reliability Benefits

- Longer equipment operating ("Up") time between failures
- Improved on-time performance, system availability and dependability
- Reduced corrective (unscheduled) maintenance
- Reduced preventive (scheduled) maintenance
- Reduced life cycle O&M cost

Design for Reliability

- Techniques for Designing for Reliability:
  - ◇ R Allocation/prediction using RBD, FTA
  - ◇ Failure Mode Effects and Criticality Analysis (FMECA)
  - ◇ Addressing physics of failure, stress, strength, derating, parts screening, material selection
  - ◇ Redundancy (active, standby, voting) subject to cost-benefit considerations

Relationship Between MTBF, Reliability and Preventive Maintenance

- An item has 37% probability to remain operational through its MTBF period
- For operationally-critical “single-point-failure” items, replacing item before reaching MTBF, during preventive maintenance (PM), increases revenue service reliability, safety, and minimizes unscheduled corrective maintenance, enhances SGR

Letting Items Fail Before Replacing

- Service delays, service unavailability
- Degraded performance, abnormal operating conditions requiring “failure recovery strategies”
- Higher safety risk exposure
- Liability claims resulting from higher risk and exposure to accidents
- Increased corrective (unscheduled) Maintenance

Letting Items Fail Before Replacing (Cont'd)

- Increased equipment/ systems deterioration/ damage beyond normal wear
- Added parts stress, cascading/ propagating failure modes/ effects, triggering additional failures
- Increased life-cycle cost

Letting Items Fail Before Replacing (Cont'd)

- Loss of public confidence
- Reduced ridership
- Reduced economic viability

Implementing Reliability in the System Life Cycle to Enhance SGR

- Initial procurement specifications
- Mid-life overhaul
- Parts procurement specifications
- Capital improvement projects (CIP)
- RDT during warranty period
- MTBF using maintenance management systems (MAXIMO, FRACAS)
- Preventive maintenance & replacing items before MTBF

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Availability: Integrating Reliability and Maintainability to Improve SGR

- Inherent Availability = MTBF/(MTBF+MTTR)
- MTBF= Mean Time Between Failures
- MTTR= Mean Time to Repair
- Other measures of Availability

Availability: Integrating Reliability and Maintainability to Improve SGR (Cont'd)

- Maximize Availability by:
- Increasing MTBF through design, specifications & Testing (RDT)
- Minimizing MTTR through design/ specifications & Testing (MDT)
- Flexibility in achieving high Availability for wide range of MTBF, MTTR values

Availability as a Function of MTBF and MTTR

Inherent Availability [MTBF/(MTBF+MTTR)]			
Availability W/10,000 Hrs MTBF	Availability W/50,000 Hrs MTBF	Availability W/100,000 Hrs MTBF	Mean Time to Repair, MTTR (Hrs)
0.999900010	0.999980000	0.999990000	1 Hr
0.999800040	0.999960002	0.999980000	2 Hrs
0.999700090	0.999940004	0.999970001	3 Hrs
0.999600160	0.999920006	0.999960002	4 Hrs
0.999500250	0.999900010	0.999950002	5 Hrs
0.999400360	0.999880014	0.999940004	6 Hrs
0.999300490	0.999860020	0.999930005	7 Hrs
0.999200639	0.999840026	0.999920006	8 Hrs
0.999000999	0.999800040	0.999900010	10 Hrs

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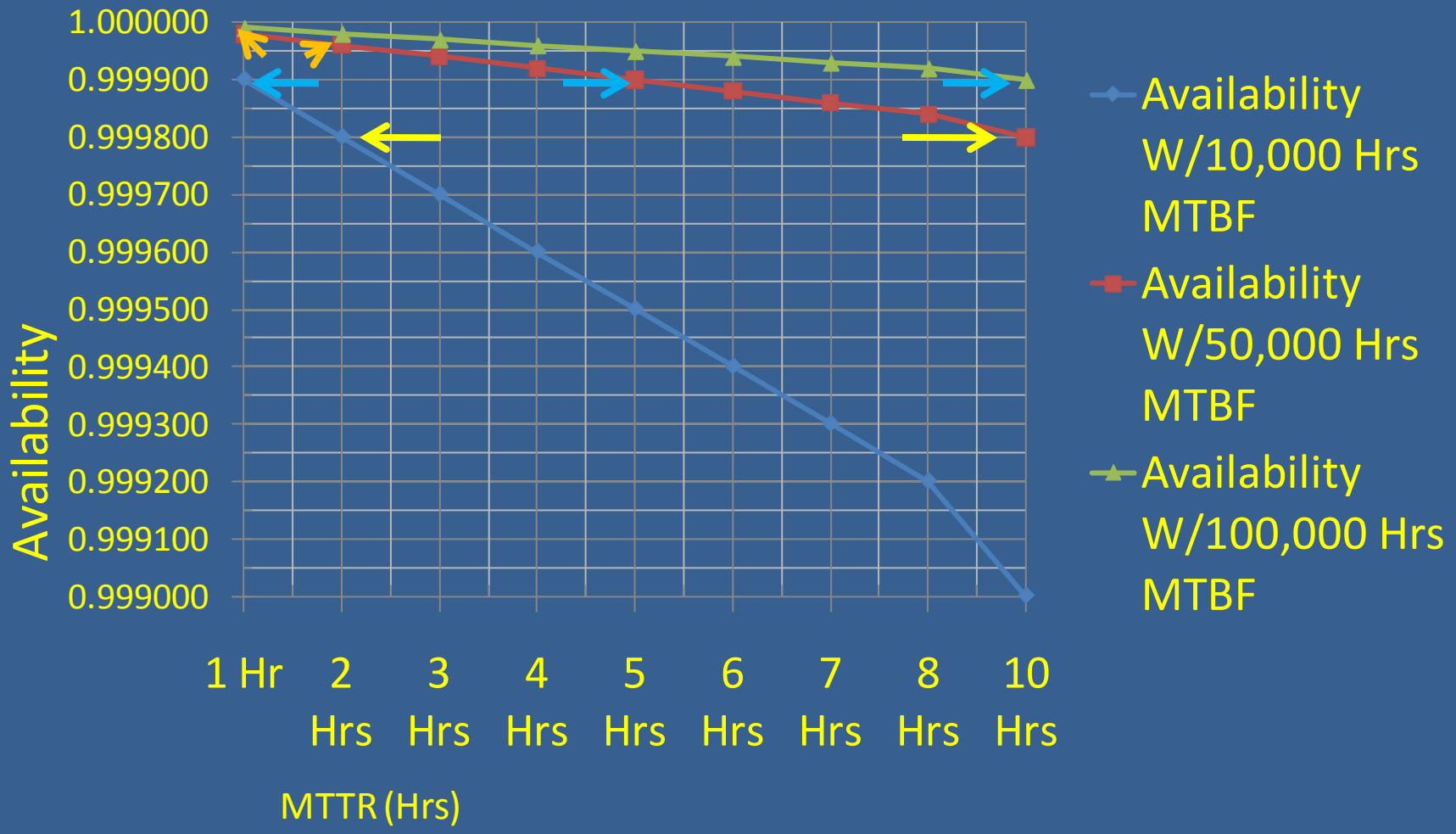
Availability as a Function of MTBF and MTTR



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Integrating Reliability , Availability, Maintainability and Safety (RAMS)

- Specify higher MTBF, lower MTTR, logistics support/ maintenance requirements
- Conduct RAMS analyses and testing
- Design out / reduce probability of unsafe/ operationally critical failure modes (FMECA, FHA, FTA)
- Incorporate redundancy and maintenance strategies to achieve higher service Reliability, Availability and Safety

Prioritizing RAMS Requirements in Contract Specifications

- Specify quantitative functional availability requirements for safety and operationally-critical systems:
  - ◇ Safety-critical on-demand/ low demand functions (“end-to-end”), e.g. 0.99999 or for continuous demand systems 10^{-8} F/Hr
  - ◇ Operationally-critical functions systems/ equipment (“end-to end”), Availability tailored to system operational needs
- Specify R.A.M and Safety program requirements

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QUESTIONS?

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