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**LOG 203 Reliability and Maintainability course
manager**

DAU Mid-West Region

Lesson 1: Impacts of R&M on Logistics

DoD 5000.2 - R

Part 4 Program Design

4.3 Systems Engineering

4.3.6 Reliability, Maintainability and Availability

With regard to R&M and logistics:

“The PM shall ensure that (R,M&A) activities are established early in the acquisition cycle to assure meeting operational requirements and reduced life-cycle ownership cost.

... (R,M&A) requirements shall be ...defined for all elements of the system, including support and training equipment.

...Reliability requirements shall address ... logistics reliability. Maintainability requirements shall address servicing, preventive, and corrective maintenance.”

Acquisition Logistics Support Elements*

- ? Maintenance Planning
- ? Manpower and Personnel
- ? Supply Support
- ? Support Equipment
- ? Technical Manuals and Technical Data
- ? Training and Training Devices
- ? Computer Resources Support
- ? Facilities
- ? Packaging, Handling, Storage, and Transportation
- ? Design Interface

* Defense Acquisition Deskbook, Section 1.2.2.2.4

How the Reliability of Spares can Affect the Number of Spares Required

If bulb has reliability = .80 for a 3-hour mission; and the number of spares is as shown, the probability of mission success is:

0	.8000
1	.9784
2	.9983

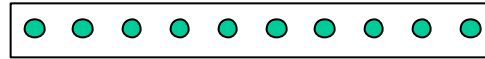
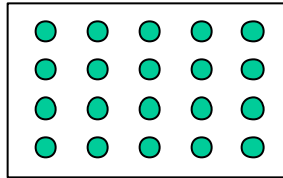
Same except .50 instead of .80

0	.5000
1	.8466
2	.9665

If the user requires 96% P(S), how many spares should they expect?

Supply Support: The Demand Rate Affects the Confidence Level for Spares

- A piece of equipment operates 24 hours a day.
- It contains 20 parts of a specific type. Ten spare parts are provided.



- Spares are procured and stocked quarterly. If the demand rate of the part is $\underline{1}$ per 10,000 operating hours, how confident can we be that we won't run out of spares?

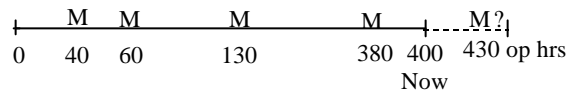
Ans. 99.5%

- If the demand rate is $\underline{3}$ per 10,000 hours of operation, what is the confidence level?

Ans. 25.5%

Maintenance Planning: MTBM Affects the Probability of Maintenance-Free Operations

- A product's MTBM is 100 hours based on field data:



What is the probability of operating 30 hours without requiring maintenance?

Ans. 73%

- If the MTBM is 200 hours, the probability increases to 86%!

Supply Support: Reliability Affects Inventory Management

The amount of inventory to be carried (at any level of maintenance) is influenced by the demand rate (a reliability factor).

Support Equipment: The R&M of Support Equipment Affect the Quantity Required

- How often the equipment fails (Reliability)

and

- How long it takes to get it fixed (Maintainability & Support)

Both effect the Quantity of Equipment required

Maintenance Planning: How R&M Affect a Maintenance Organization's Labor Requirements

Maintenance labor time for each personnel category or skill level may be expressed by maintainability factors such as:

- Maintenance man-hours per operating hour (MMH/OH).
- Maintenance man-hours per month (MMH/month).
- Maintenance man-hours per maintenance action (MMH/MA).

Facilities: R&M Affect Facility Sizing

Facilities for:

- maintaining systems;
- storing spares and repair parts;
- training maintenance personnel;

The sizing of a facility will be affected by predictions of how often products will fail (reliability) and how long it will take to restore them (maintainability and support).

PHST: How R&M Affect Transportation Requirements

- Transportation of:
 - Initial spares.
 - Follow-on spares.
 - Mobilization spares, maintenance personnel, test equipment, etc.

- Transportation factors include:
 - costs
 - time
 - capacity

These factors can be significantly effected by how often products fail (reliability) and how long it takes to restore them (maintainability and support).

Computer Resources Support: Reliability of Software is Important

- Mission equipment and support equipment depend on software.

- A software error can be critical to mission, safety, or cost of repair.

What do R&M Mean for Logistics?

- Improved R&M reduces the need for spares, inventory, training and support equipment, maintenance manpower, facilities, transportation, software, etc.
- So, R&M \uparrow \longrightarrow Support Costs \downarrow

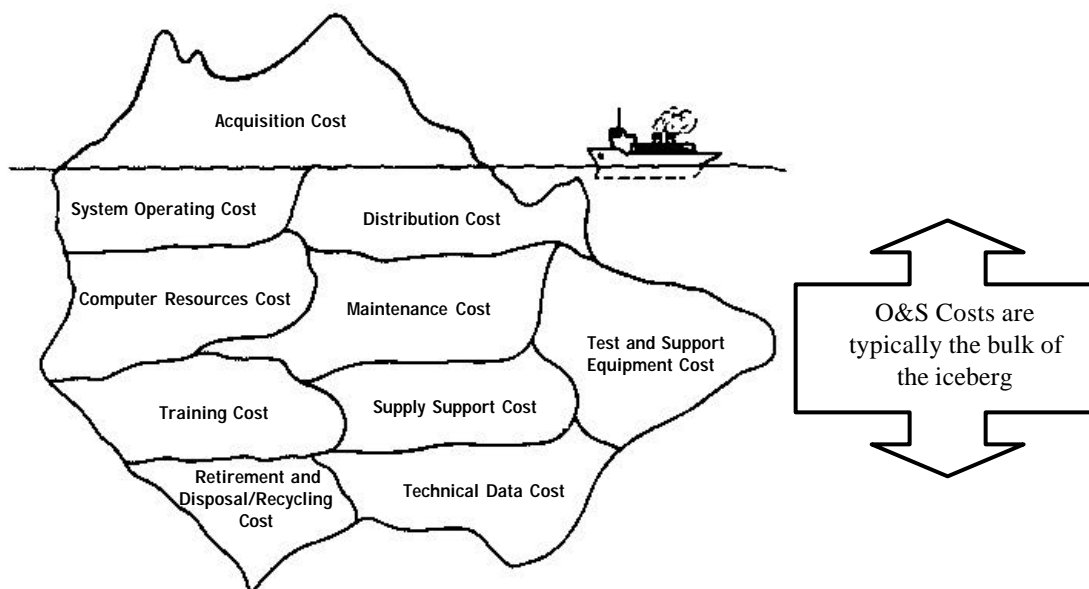
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R&M and Total Ownership Cost

“Total ownership cost (TOC) is defined as the sum of all financial resources necessary to organize, equip, and sustain military forces sufficient to meet national goals in compliance with all laws, all policies applicable to DoD, all standards in effect for readiness, safety, and quality of life, and all other official measures of performance for DoD and its components. It is comprised of the costs to research, develop, acquire, own, operated and dispose of defense systems, other equipment and real property, the costs to recruit, retain, separate, and otherwise support military and civilian personnel, and all other costs of business operations of the DoD.”

How do R&M effect TOC?

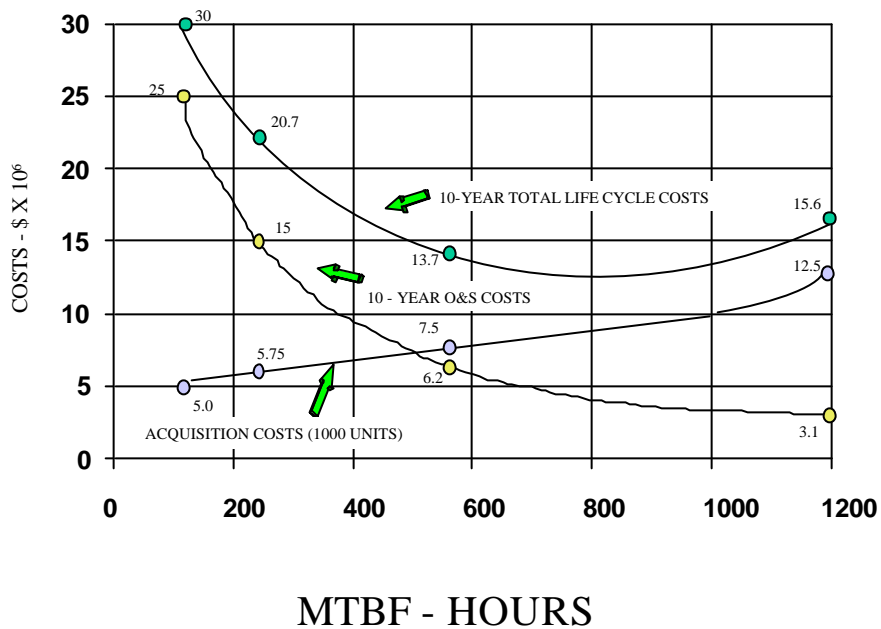
Life Cycle Costs



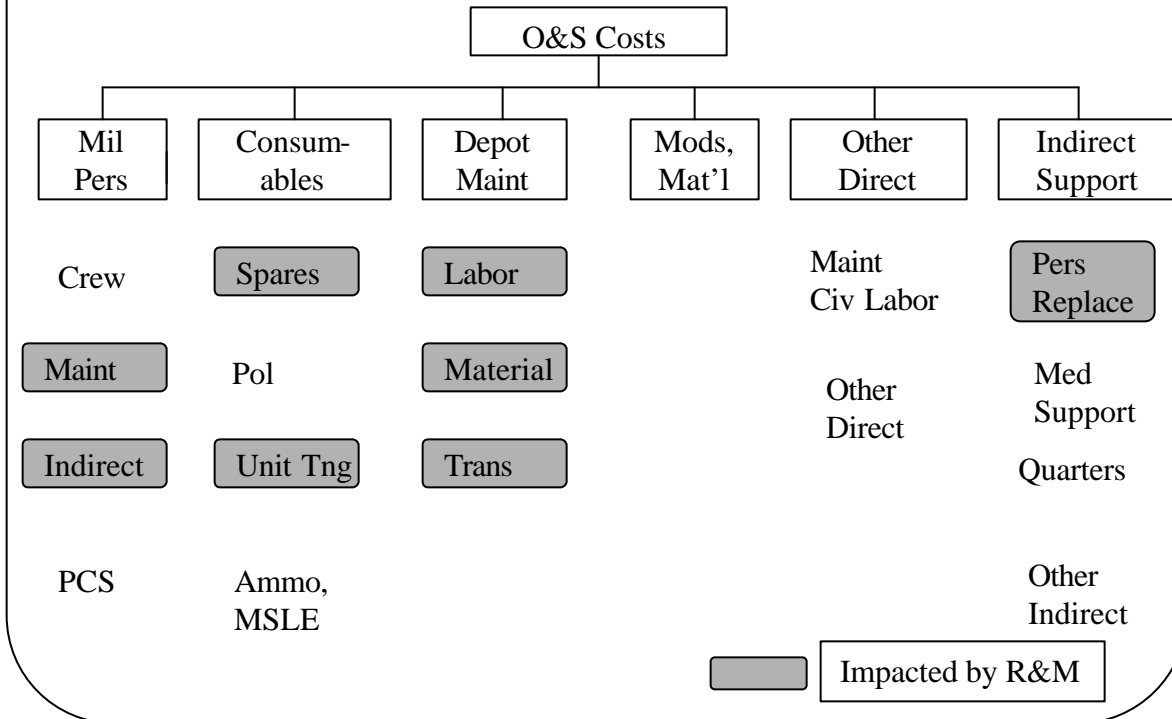
The Life Cycle Cost Iceberg (Adapted from "Life cycle Cost and Economics Analysis" by Fabrycky & Blanchard)

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How Reliability Benefits Logistics: Reduced O&S Costs



O&S Costs Elements



What is Reliability?

- The probability that an item will perform its intended function under stated conditions for a specified interval.
- Key elements
 - ? Reliability can be quantified
 - ? Reliability is linked to system performance
 - ? Conditions, environments effect reliability
 - ? Mission “duration” effects reliability

Mean Time Between (Some Event), i.e. MTB_

$$? \frac{\text{Total life units (in the period being evaluated)}}{\text{Total number of events}}$$

- Life units: accumulated stress

Example: A car travels 10,000 miles in two years and has its computer repaired twice.

Computer (MTBM) mean time between maintenance

? _____ miles ?

or _____ years ?

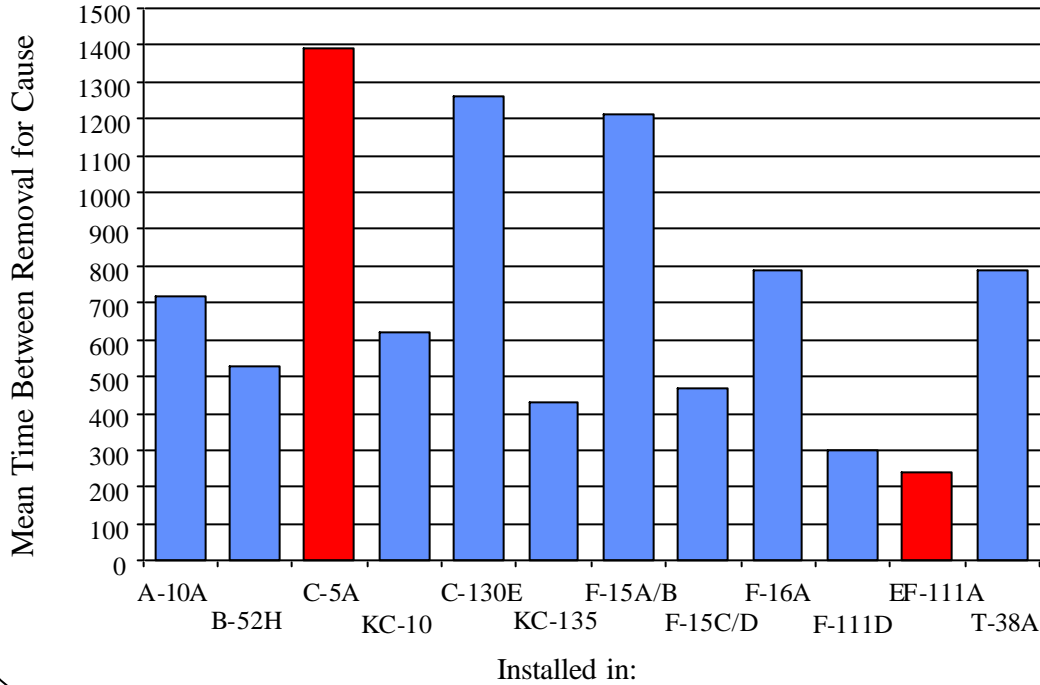
Logistics Reliability Parameters:

Mean Time Between Demands (MTBD): A measure of the system reliability parameter related to demand for logistic support: The total number of system life units, divided by the total number of item demands on the supply system during a stated period of time.

Mean Time Between Maintenance Actions (MTBMA): A measure of the system reliability parameter related to demand for maintenance manpower. The total number of system life units, divided by the total number of maintenance events (preventive and corrective) during a stated period of time.

Mean Time Between Removals (MTBR): A measure of the system reliability parameter related to demand for logistics support. The total number of system life units, divided by the total number of items removed from that system during a stated period of time. This term is defined to exclude removals performed to facilitate other maintenance and removals for product improvement.

Effect of Environment on Reliability MTBR Values for ARN-118 TACAN



Exercise: Understanding “Mean Time Between”

A fleet of trucks were retrofitted with new generators. Two years later, field data for the generators showed:

1,000,000 operating hours; and 100 truck breakdowns due to generator failure

There were 1200 maintenance “events” involving generators:

- 100 on-equipment repairs (turning wrenches, screwdrivers, etc.)
- 200 removals to facilitate other maintenance (50 of these resulted in damage to the generators!)
- 900 removals were forwarded to the depot for repair (of which 600 were identified as design or manufacturing related problems)

Calculate the following reliability parameters for the generator:

MTBM (TOTAL) =

MTBM (INHERENT) =

MTBR (TOTAL) =

MTBR =

MTBD =

MTBOMF =

MTBF: Not for ORD

“ORD requirements generally should not be in engineering terms i.e. not usually stated in terms of MTBF, MTTR etc.. These are spec requirements derived from the ORD. Logician needs to make sure that this translation is done in a manner that is technically sound whoever writes the spec.”

- OUSD(A&T)DTSE&E/SE, Mr. George Desiderio, (chairs DAU Acq Log course reviews); 18 Jun 1999

MTBF and Failure Rate

If failure rate is constant (often assumed for electronic devices; avionics boxes; complex system like aircraft, ship, tank):



Age (or other life unit)

Then, $MTBF = 1 / \text{failure rate}$

MTBM and Maintenance Rate

If maintenance rate is constant:



Age (or other life unit)

Then, $MTBM = 1 / \text{maintenance rate}$

MTBD and Demand Rate

If demand rate is constant:



Age (or other life unit)

Then, $MTBD = 1 / \text{demand rate}$

Reliability: Briefly ...

- Sustained Performance
- Performance over time
- Quality over time.

What is Maintainability?

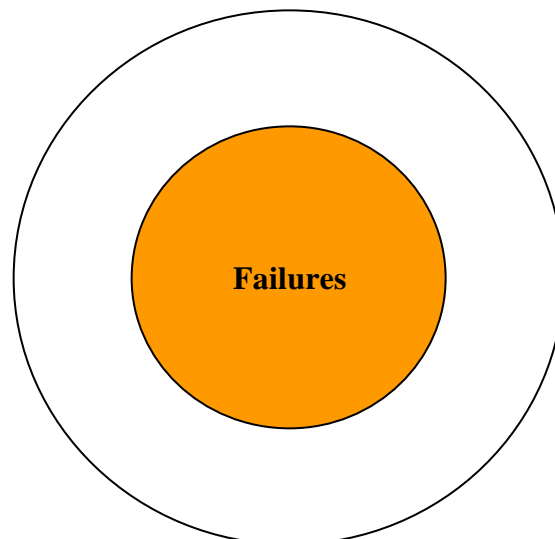
The relative ease and economy of time and resources with which an item can be retained in or restored to a specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair. In this context it is a function of design.

(MIL-HDBK-470A)

Major Concerns of Maintainability

- Diagnostics capability
 - Fault detection
 - Fault isolation
- Human Factors
 - Accessibility
 - Environments

Faults



Measures of Maintainability

- Diagnostics capability - generally expressed as a ratio of diagnostics related events to total events.

Example: Built-in-test fault detection %

$$= \frac{\text{Number malfunctions confirmed by built-in-test}}{\text{Total malfunctions observed by operator/technician}}$$

A truck malfunctioned a total of 25 times in 10 years. Only 5 of 25 malfunctions were indicated by BIT (warning lights and gages).

$$\text{Built-in-test fault detection \%} = \frac{\quad}{\quad} =$$

Measures of Maintainability (Cont'd)



- Workload - Incorporates effects of both diagnostics capability and human factors.

Example: Mean Repair Time (MRT)

$$? \frac{\text{Total elapsed time (or cumulative man-hours) for repairs}}{\text{Total number of repairs}}$$

- Repair of the 25 malfunctions above required a total of 100 man-hours.

$$\text{Mean repair time} = \frac{\quad}{\quad} =$$

Measures of Maintainability (Cont'd)

- Other measures of “Maintainability”

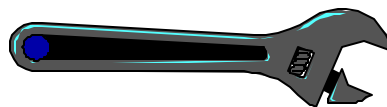
\bar{M} - Mean active maintenance time (corrective and preventive)

MCMT - Mean corrective maintenance time

MaxCMT₉₀ - Maximum corrective maintenance time (90%)

Maintainability: Briefly ...

rapid diagnosis and removal of faults



Logistics R&M Definitions from Army, Navy, Marine Corps, Air Force Operational Test Agencies

- a. Mean Time Between Unscheduled Maintenance (MTBUM): The total operating time divided by the total number of incidents requiring unscheduled maintenance.
- b. Mean Corrective Maintenance Time for Operational Mission Failures (MCMTOMF): The total number of clock-hours of corrective, on-system, active repair time, which was used to restore failed systems to mission-capability status after an operational mission failure (OMF) occurs, divided by the total number of OMFs.
- c. Mean Corrective Maintenance Time (MCMT): The total number of clock-hours of corrective, on-system, active repair time due to all corrective maintenance divided by the total number of incidents requiring corrective maintenance.
- d. Maximum Corrective Maintenance Time for Operational Mission Failures (MaxCMTOMF): That time below which specified percentage of corrective maintenance tasks must be completed to restore the system to operation after an Operational Mission Failure.
- e. Maximum Corrective Maintenance Time (MaxCMT): That time below which a specified percentage of all corrective maintenance tasks must be completed.

Logistics R&M Definitions from Army, Navy, Marine Corps, Air Force Operational Test Agencies (cont'd)

- f. Maintenance Ratio (MR): The most common expression for Maintenance Ratio (MR) is Maintenance Man-hours per Operating Hour, which is an indication of the maintenance burden associated with the system. The cumulative number of maintenance man-hours during a given period divided by the cumulative number of operating hours. If appropriate, other terms such as miles or rounds may be substituted for hours. Scheduled as well as corrective maintenance, in keeping with the users maintenance requirements, are included without regard to their effect on mission or availability of the system.
- g. Operational Availability (Ao): Ao is either the total uptime divided by the uptime plus downtime when operated in an operational mission scenario, or the number of systems that are ready divided by the number possessed.
- h. Percent of Correct Fault Isolation (and Correct Fault Location) given correct detection (Pc_{fi}): The number of correct fault isolations (and/or correct fault locations) divided by the number of correct detections times 100 (to express the quotient as a percent). "Fault isolation" and/or "fault location" must be clearly defined
- i. Measures of False Alarms (FA): False alarms are faults, where, upon investigation, it is found the fault cannot be confirmed. Measures of FA may be expressed as a total number, a percentage, a rate of occurrence, a probability of occurrence, etc. The selected measure must be clearly stated.
- j. Mean Time To Fault Locate (MTTFL): The total amount of time required to locate faults divided by the total number of faults.

Summary, Lesson 1: Impacts of R&M on Logistics

R&M reduce the requirements for acquisition logistics support elements and their associated costs!

