



UNITED STATES MARINE CORPS
MARINE CORPS OPERATIONAL TEST AND EVALUATION ACTIVITY
QUANTICO, VIRGINIA 22134-5017

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MARINE CORPS OPERATIONAL TEST AND EVALUATION ACTIVITY POLICY
LETTER 90-23

From: Director
To: Distribution List

Subj: RELIABILITY, AVAILABILITY, AND MAINTAINABILITY (RAM)
MEASURES OF EFFECTIVENESS (MOE) FOR INDEPENDENT EVALUATION
REPORTS (IERS)

Ref: (a) Memorandum of Agreement on Multiservice Operational
Test and Evaluation (MOT&E) and Joint Test and
Evaluation (JT&E) dtd 10 Apr 90
(b) DoD 3235.1-H Test & Evaluation of System
Reliability Availability and Maintainability
(c) USACDC Pamphlet No 71-1 dtd Jan 73

Encl: (1) IER Reporting Requirements Matrix

1. Purpose. To define terms based on the references and establish policy for the use of RAM MOE in preparation of Detailed Test Plans (DTPs) and IERS.

2. Definitions

a. Administrative and Logistics Down Time (ALDT). ALDT is the time spent waiting for parts, administrative processing, maintenance personnel, or transportation.

b. Automatic Fault Isolation Capability (AFIC). A function of built-in-test, AFIC is the product of percent isolation times percent detection.

c. Availability. Availability is the probability that an item is in an operable and committable state at the start of a mission when that mission is called for at a random point in time.

d. Built-in-Test (BIT). BIT consists of those features designed into a system to provide failure detection capabilities. It consists of diagnostic software or firmware, and hardware fault indicators.

e. Built-in-Test Equipment (BITE). BITE is equipment which has no mission functions but is built into an item to be used for

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testing; it requires operator action in order to be used (e.g., a set of test leads, a digital display).

f. Corrective Maintenance (CM). CM is that maintenance which is performed in response to a failure to restore equipment to a specified, mission capable condition. CM is unscheduled maintenance.

g. Failure Definition/Scoring Criteria (FD/SC). The FD/SC is a document jointly developed by Marine Corps Combat Development Command (MCCDC) (user), Marine Corps Research, Development, and Acquisition Command (MCRDAC) (materiel developer), and MCOTEA to define system failure definitions for use in RAM test incident scoring conferences. In the event of a multiservice Operational Test and Evaluation (OT&E), the FD/SC will be jointly developed by Service User, Materiel Developer, and Operational Test Activity representatives.

h. Maintenance. Maintenance encompasses all actions required to retain an item in, or restore it to, a specified condition. Maintenance includes troubleshooting, repair, and inspection.

i. Mean Down Time (MDT). The MDT is the sum of CM, Preventive Maintenance (PM), and ALDT divided by the number of corrective and PM actions. Include only those PM actions which render the item inoperable.

j. Mean Time Between Maintenance (MTBM). The MTBM is the sum of operating time (OT) and standby time divided by the number of CM actions.

k. Off-Equipment Repair. Off-equipment repair includes the repair of components which were removed from the system and replaced with similar components from stock resulting in the system returning to an operable state; repair of components made after a mission is complete and the system has been powered down; and repairs made to the components of the system while it is in operation and which do not impact the ability of the system to continue with its mission. Since off-equipment repair does not impact mission capabilities, it is not included in availability calculations.

l. On-Equipment Repair. On-equipment repair is repair which, once completed, returns a system from a non-operable, not mission capable state to an operable, mission capable state.

m. Operational Mission Failure (OMF). An OMF is any incident or malfunction that causes (or could cause) the

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inability to perform one or more designated mission-essential functions. These mission-essential functions must be specifically defined for each system in the FD/SC.

n. Operating Time (OT). OT is the time that the system is powered (turned on) and capable of performing mission essential functions. OT is equipment dependent and must be defined before the start of a test.

o. Percent of Correct Detections Given that a Fault Exists (%D). The percent of confirmed faults that the BIT system correctly detects (the number of faults detected by BIT divided by the total number of confirmed faults that should have been detected by BIT).

p. Percent False Alarms (%FA). The percent of BIT indicated faults where, upon investigation, no fault existed (the number of false alarms divided by the total number of faults detected by BIT).

q. Percent Isolation (%I). The percent of detected faults or failures that the BIT correctly isolates to a specified level of assembly (the number of correct isolations of a fault or failure divided by the number of correct detections).

r. Preventive Maintenance (PM). PM is the systematic inspection, detection, and correction or prevention of incipient failures either before they occur or before they develop into failures. Adjustment, lubrication, and scheduled checks are included in PM. For purposes of operational testing, only PMs specified by the technical manuals will be recorded.

s. Reliability. Reliability is the probability that an item or system will perform its intended function for a specified period of time (rounds fired, miles driven) and under stated conditions without failure.

t. Risk Factors. Risk factors are the possible errors in making a hypothesis-testing decision. The two type of errors associated to reliability testing are producer risk (α error) and government risk (β error).

(1) Producer Risk (α) is the probability of rejecting a good system.

(2) Government Risk (β) is the probability of accepting a bad system.

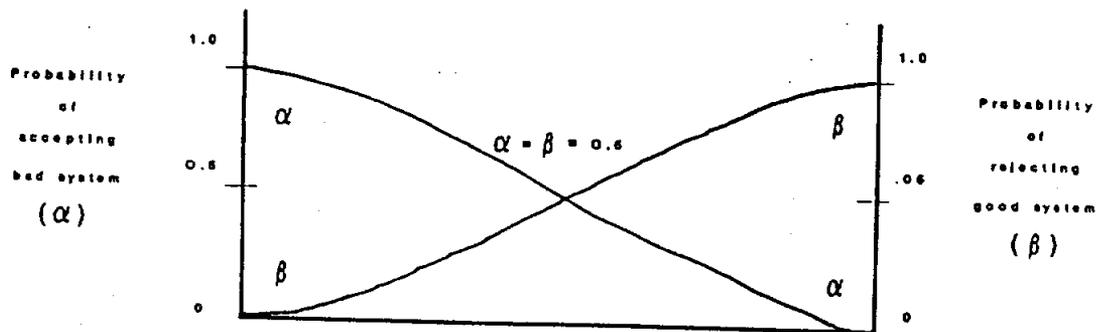
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(3) The following decision table depicts the relationship of α and β in reliability testing:

	Actually True	Actually False
To Accept	Correct (1- α)	Prob accept bad system β (Government Risk)
To Reject	Prob reject good system α (Producer Risk)	Correct (1- β)
Σ Probabilities	1.0	1.0

(4) There are two conditions that affect the values of α and β : fixed sample size and increasing the test size (test exposure).

a. With a fixed sample size (number rounds, hours, miles), if we decrease Producers Risk (α), the acceptance region becomes larger with a corresponding increase in Government Risk (β).



In other words, as the Producers Risk (α) decreases from 1.0, the Government Risk (β) increases. This results in a greater probability of rejecting a good system with a lesser probability of accepting a bad system.

b. With an increasing sample size, both Producer's Risk (α) and Government Risk (β) decreases. For example, we

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have 1000 rockets in a sample lot. We are interested in the reliability of the rockets to not fail when fired. If we test each rocket in the lot, our risk of accepting a bad rocket and rejecting a good rocket is zero since we tested every rocket. If we test less than the 1000 rockets, a sample, our risks, α and β , increase since we are accepting greater unknowns with decreasing sample sizes. The goal in testing is to test systems at an optimum statistical sample size based on sound statistical techniques which minimize the risks, α and β , and consider the cost of testing within the time and resource constraints imposed on MCOTEA. Based on operational requirements measures such as probability of rocket firing, we will determine the number of rockets required (sample size) to give a confidence level that the decision maker is willing to accept (with α and β minimized in relation to the confidence level).

u. Scheduled Maintenance. Scheduled maintenance is the same as PM.

v. Scoring Conference. The Scoring Conference is chaired by the MCOTEA OTPO, with membership consisting of MCRDAC (materiel developer), MCCDC (user), and the Test Director to classify RAM test incidents and assign chargeability. In the event of multiservice OT&E, the Chairman will be the lead service OTA with membership including Supporting Service OTA, Service User, Materiel Developer, the Test Director and sometimes the development tester.

w. Standby Time (ST). ST is time not operating and neither PM nor CM are being performed but it is assumed that the equipment is up and operable. ST is equipment dependent and must be defined before the start of a test.

x. Total Administrative and Logistics Down Time (TALDT). TALDT is the sum of clock hours spent in ALDT.

y. Total CM Time (TCM). TCM is the sum of clock hours spent in CM.

z. Total Operating Time (TOT). TOT is the sum of all the operating hours for the item or system.

aa. Total PM Time (TPM). TPM is the sum of all of the PM times for the item or system. Include only those PM actions which render the item or system inoperable.

bb. Total Standby Time (TST). TST is the sum of all the ST for the item or system.

cc. Unscheduled Maintenance Action (UMA). UMA is the same as CM.

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3. Measures of Effectiveness (MOEs). MOE's which can be used in the preparation of DTPs, and IERS are as listed below. An MOE is the measure by which a criterion is judged. It must be measurable, and ideally, quantifiable.

a. Achieved Availability (Aa). This MOE for availability is useful when the spare parts and resupply system for an item under test is not in place; it ignores the times associated with ST and administrative and logistics down time. The formula is:

$$Aa = \frac{TOT}{TOT + TCM + TPM}$$

b. Maintenance Man-Hours per Operating Hour (MMH/OH). This MMH/OH is a multiservice term equivalent to a Maintenance Ratio (MR) and will be used for all multiservice tests.

c. Maintenance Ratio (MR). This is an MOE for the amount of maintenance time, in man hours, expended per operating unit (defined as an hour, round, or mile). The maintenance time includes both CM and PM. The MR is computed for each level of maintenance and is also summarized for all levels of maintenance. The formula is:

$$MR = \frac{\text{Total man-hours of CM and PM}}{TOT}$$

The MR is replaced with MMH/OH for multiservice tests.

Note: Total man-hours of CM and PM is not equivalent to TCM and TPM. MR includes all CM and PM times regardless of effect on the item or system's operational state.

d. Maximum Time to Repair (MaxTTR). This is the time below which a specified percentage of all CM tasks must be completed. The specified percentage is usually 90 or 95, or as specified in the statement of Required Operational Capability (ROC). This MOE considers only on-equipment repairs and prescribes the maximum tolerable CM downtime for the system.

e. Mean Corrective Maintenance Time (MCMT). MCMT is the multiservice measure equivalent to mean time to repair and will be used in lieu of mean time to repair in the reports of multiservice tests.

f. Mean Cycles Between Operational Mission Failure (MCBOMF). MCBOMF applies to systems where the measure is in terms of cycles. For example, the cycles associated with the erection and

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teardown of a combat bridge or tent; the number of times that a crane raises and lowers a load, the number of rotation cycles that a tank turret must achieve before failure.

g. Mean Miles Between Operational Mission Failure (MMBOMF). MMBOMF applies to systems where the measure is in terms of miles. For example, the number of miles that a vehicle must achieve to determine the reliability of a vehicle's drive train or engine; the number of miles that a new vehicle armor system must sustain when driven over expected combat terrain to determine the effects of vibration on the attach points.

h. Mean Rounds Between Operational Mission Failure (MRBOMF). MRBOMF applies to systems where the measure is in terms of rounds fired. For example, the reliability associated with the barrel of an M16A2 rifle or the tube of a 155 howitzer.

i. Mean Time Between Failure (MTBF). The MTBF is the ratio of the Total Operating Time (TOT) of a system to the number of failures of a system. This MOE includes all failures of the system and is mathematically stated as:

$$\text{MTBF} = \frac{\text{TOT}}{\text{Total number of failures}}$$

j. Mean Time Between Operational Mission Failure (MTBOMF). This MOE is similar to MTBF except that attention is restricted to OMFs only. The formula is:

$$\text{MTBOMF} = \frac{\text{TOT}}{\text{Number of OMFs}}$$

k. Mean Time Between Unscheduled Maintenance (MTBUM). This MOE, used in multiservice tests, relates to CM time. The formula is:

$$\text{MTBUM} = \frac{\text{TOT}}{\text{Number of incidents requiring CM}}$$

Note: CM is the same as unscheduled maintenance.

l. Mean Time Between Unscheduled Maintenance Actions (MTBUMA). This is the same as MTBUM but has been used in Marine Corps unilateral tests.

m. Mean Time to Repair (MTTR). This is the Marine Corps equivalent to MCMT and is a measure of the average clock time spent performing on-equipment CM. The formula is:

$$\text{MTTR} = \frac{\text{Total CM clock hours of active on-equipment repair}}{\text{Number of CM Actions}}$$

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Although MTTR should be reported across all maintenance levels it can be applied to each maintenance level individually. (Comment: This is not a good measure of maintenance burden because it does not take into account the frequency of repair or the total man-hours spent on repair.)

n. Operational Availability (Ao). This MOE accounts for the variables used in computing Aa but adds TST and total ALDT (TALDT). The computed value will often be an upper bound for Ao because of necessary contractor provided maintenance at fourth or fifth echelon. The formula is:

$$Ao = \frac{TOT + TST}{TOT + TST + TCM + TPM + TALDT}$$

It is important to recognize that long periods of inactivity or ST can drive Ao to a number close to one; the less a system is operated, the higher the Ao. An alternative formula for Ao is:

$$Ao = \frac{MTBM}{MTBM + MDT}$$

o. Reference (b) provides additional MOEs that could be used in OT&E, broken down by subject matter, measure definition, limits on range of the measure, rationale for the measure, and a list of associated measures. The pamphlet is available in the Technical Support Branch. The categories provided within the pamphlet are as follows:

- (1) Doctrine
- (2) Organizational
- (3) Material
- (4) Logistics
- (5) C3
- (6) Firepower
- (7) Mobility
- (8) Intelligence

Reliability MOEs are dependent upon the required operational reliability of the system to be tested and can be expressed in terms of a probability or a specific characteristic of a system such as mean gallons between operational mission failure (MGBOMF) for a water purification pump. Whatever the MOE, associated data requirements must be specified which will allow the determination

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of the MOE that describes the criterion to be evaluated (e.g., beginning flow meter reading, ending flow meter reading, and number of operational mission failures).

4. Discussion. Effective testing and evaluation of a system can only be accomplished if all system peculiar terms and MOEs are defined and understood during the test design. Definitions and the selection of MOEs cannot be changed subsequent to the start of a test without running the risk of either invalidating the data already collected or biasing the subsequent data collection effort and analysis. Every IER should interpret the MOEs to present a meaningful picture of the impact of the evaluation to the decision makers.

a. Operational Mission Failure (OMF). An OMF is always system unique and must be explicitly defined; nothing about the definition can be left to the imagination. This definition is a part of the FD/SC published by the CG MCRDAC, but may also be contained in the ROC. The reported reliability of the system depends on the understanding and the interpretation of the FD/SC definition. Factors to be considered are the amount and type of degradation or loss of capability the system will be allowed before it is termed an OMF, the amount of redundancy in the system and the number of redundant components that can be lost before it is an OMF, and any time constraints associated either with the loss of capability or repair of redundant components.

b. Operating Time (OT). The period of time to be considered as OT must be carefully defined within the parameters of the system being tested; all possibilities must be considered in the definition. Examples are:

(1) If testing a vehicle that is sometimes used as a radio vehicle; obviously the transit time from points A to B is OT, but is engine run time to recharge the vehicle's battery subsequent to operation of the radio a part of OT?

(2) In the case of a radio, is OT the entire time that power is applied to the radio or only the time spent transmitting and receiving messages?

c. Standby Time (ST). ST must also be defined within the operating parameters of the system being tested. The effect of the definition of ST time on availability should be considered since long periods of standby can influence availability. In the case of a vehicle, is all time in the truck park considered ST? To assist in defining ST, look at the ratio of anticipated ST to OT; if the number is close to zero, OT greatly exceeds ST; if the ratio is close to 1.0, the two times are nearly equal; and the closer the ratio to 1.0, the more careful you will have to be in

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any use of an MOE that uses ST. It may be desirable to use an MOE for availability which excludes ST, such as Aa.

d. Crew Correctable Maintenance Action (CCMA). CCMA correctable maintenance actions are those which return a failed system to an operable condition within a specific period of time and using only "on-board" resources (tools, spares, and repair parts). An incident which is classified as a failure but which is fixed by the operator, or crew, within the specified time is not considered a failure charged to the contractor. An example would be an Armored Vehicle where any failure which is repaired by the crew using on-vehicle equipment in ten minutes or less is not charged to the vehicle and, in this case, did not enter the computation for MTTR, MaxTTR, Ao, or Aa. CCMA is equivalent to the term "immediate action" as applied to clearing stoppages of individual weapons. In most cases, restarts of embedded software would be considered CCMA if the action meets the specified constraints on time and resources.

Note: Recurring CCMA's may require a review of the FD/SC for upgrading to failure or OMF classification depending on the overall system impact on the operator, crew, resources, and mission performance.

e. Achieved Availability (Aa). This MOE includes both on and off system repair actions. Considerations in its use are shown below:

(1) Contractor Furnished Equipment (CFE). Since the normal supply system is usually not in place for operational tests, Aa is a good measure for availability in an IER. The lack of a realistic resupply system means that times collected for ALDT will not be representative of the system when fielded; accordingly, the Aa is the preferred MOE when constrained to only the CM and PM for the CFE. The Aa computed for CFE only will allow the decision makers to evaluate the contractor's performance in relation to the ROC.

(2) System. The Aa for the system consisting of CFE and GFE should be computed separately and collectively to show the impact of combining the CFE with GFE to form the system.

f. Maintenance Ratio (MR). The ROC statement frequently will not contain a criterion statement for the MR; however, the analyst should compute the MR so that the maintenance burden of the system, once fielded, will be available as a part of the decision making process.

(1) Contractor Furnished Equipment (CFE). Computation of the MR for CFE will show the effect on the workload of the maintenance personnel caused by the new item of equipment. The

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computation should be reported for each level of maintenance as well as for all levels of maintenance combined and should include CM and PM. The repairs for on-equipment repair should be combined with those for off-equipment repair to obtain the impact on the maintenance organizations.

(2) System. The MR should be computed for the system consisting of CFE and GFE in order to assess the total impact of the system on the maintenance workload at each level of maintenance and at all levels of maintenance.

g. Maximum Time to Repair (MAXTTR)

(1) Contractor Furnished Equipment. The MaxTTR should be stated for CFE and applies to on-equipment repairs only. It specifies that the system will be down for not more than the MaxTTR either 90 or 95 percent of the time, depending on the choice for the upper bound. The MaxTTR is interpreted as the maximum tolerable or upper bound on the repair time for the system.

(2) System. The MaxTTR for the system is also determined to find out if the critical element in down time for the complete system is CFE or GFE. If CFE, perhaps it can be reduced through equipment redesign or training; if GFE, it is doubtful that the MaxTTR for on-equipment time can be reduced.

h. Mean Time Between Operational Mission Failure (MTBOMF)

(1) Contractor Furnished Equipment. The determination of MTBOMF based upon CFE is essential for comparison to the criterion in the ROC because this criterion usually refers only to the CFE. The MTBOMF is a measure of the OT between mission critical failures and should be reported as a point estimate and at a Lower Confidence Level (LCL) usually selected as 90 percent. The meaning of the figure reported as the LCL, stated in non-technical terms, should be part of the IER.

(2) System. The presentation and discussion of system MTBOMF provides an indication of how well the item of equipment performs with regard to OMFs when the GFE is considered. The MTBOMF should be reported as a point estimate, as a LCL, and compared to the CFE information; if system results are less than those considering only CFE, then it should be pointed out that to increase MTBOMF will require improvements in GFE. The real meaning to a combat commander of the MTBOMF should be stated, i.e. What does an MTBOMF of 718 hours at a 90 percent LCL mean? (Ans: approximately 30 days of uninterrupted operation.)

i. Mean Time To Repair (MTTR). The MTTR should be reported for on-equipment repair of CFE unless it is stated in the ROC

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that the MTTR is to include GFE; in the latter case, both the system and the CFE only MTTR should be reported. This MOE should reflect corrective maintenance and be reported for each level of maintenance. It reflects the average repair time of the equipment. The separate computation of an MTTR which includes only CCMA should also be reported since maintenance action is performed although no failure is recorded.

j. Operational Availability (Ao)

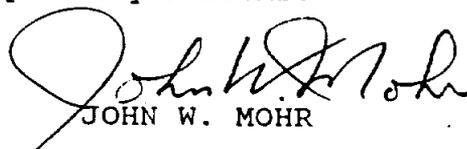
(1) Contractor Furnished Equipment. The majority of operational tests conducted by MCOTEA will have contractor provided depot level maintenance and may also have fourth echelon maintenance provided by the contractor. An interpretation associated with Ao must be presented in the IER for any system not fully supported by Marine resources. The Ao for CFE should be treated as an upper bound because contractor maintenance personnel will probably be better trained for the test than the Marine maintainers once the system is fielded.

(2) System. The presentation of system Ao provides the decision makers an indication of availability of the new system when all the variables associated with the GFE are included. This is a more realistic figure of availability for the field commander if he also recognizes that Ao is an upper bound on the availability of the system.

5. Action

a. Unilateral Tests. The test plans prepared by MCOTEA personnel will provide for the collection of data to support the MOEs identified in enclosure (1). These MOEs will be the minimum required for each unilateral IER, while additional MOEs presented in this paper may be included at the discretion of the project analyst and the OTPO.

b. Multiservice and Joint Tests. Test plans and IERs prepared as a part of a multiservice or joint test will substitute the appropriate multiservice terms for the corresponding Marine Corps unique terms.


JOHN W. MOHR

Distribution:
C plus (Director, Deputy Director, Scientific Advisor)
Program Analysts
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IER Reporting Requirements Matrix

MOE	Type of Test		On & Off Equipment		On Equipment	
	USMC	Multiservice	CFE	System	CFE	System
Aa	x				x	x
MMH/OH		x	x	x		
MR	x		x	x		
MaxTTR	x	x	x	x	x	x
MCMT		x			x	x
MTBF	*				x	x
MTBOMF**	x	x			x	x
MTBUM		x			x	x
MTBUMA	*				x	x
MTTR	x		x	x	x	
Ao	x	x			x	x

Note: * reported only if criterion in ROC

** or MCBOMF, MMBOMF, MRBOMF as appropriate

