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Measures of Effectiveness Compendium

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Manned Systems Group
Systems Research Laboratory

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This report presents and defines a variety of Army-relevant measures of effectiveness (MOEs). They have been classified by general type of system and by function. The report also includes a cross-referenced index for alternate access and convenience. The report discusses the nature of MOEs and their relationship to operational testing.

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Human Factors in Training and
Operational Effectiveness

FOREWORD

Valid measures of effectiveness (MOEs) are central to the problem of testing and evaluating systems for the Army. Consideration of MANPRINT requirements early in the materiel acquisition process is pushing the current scope of MOE development to include human performance more explicitly. This has been one of the concerns of the Manned Systems Group of the Systems Research Laboratory of the U.S. Army Research Institute for the Behavioral and Social Sciences.

This document is primarily a collection of MOEs relevant to Army systems. The MOEs and their descriptions have been organized, referenced, and indexed to ensure easy access. They are intended as examples for developing more MOEs and for use in tests and evaluations. Furthermore, a review of the literature indicates several approaches to consolidating MOEs at lower levels of hierarchy and linking them to higher level MOEs.

This document should be of interest to those involved in system design and testing and evaluation (T&E). The narrative, in particular, is intended to promote recognition of manned system performance (human, hardware, and software) and resulting implications. The ultimate goal is that more sensitive MOEs be developed to encourage analysts and experts in system design and T&E to incorporate MANPRINT concerns in their efforts.

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MEASURES OF EFFECTIVENESS COMPENDIUM

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MEASURES OF EFFECTIVENESS COMPENDIUM

Introduction

There is increased interest in the testing and evaluation (T&E) community in the development of metrics for manned system performance. This interest, fostered in part by DOD Directive 5000.53 (which requires increased attention to manpower, personnel, training, and system safety in materiel acquisition), has led to the re-examination of traditional measures of system performance. The purpose of this report is to provide an updated set of these measures organized according to 13 classes of Army systems. The measures have been culled from various sources, but should not be considered a definitive list by any means. Rather, they are offered as examples of what one might use in tests and studies. Better or more appropriate MOEs should always be developed whenever possible.

The ensuing discussion in this initial section of the report covers the nature, development, and application of MOEs. More detailed discussion is available in reports by Connelly (1981), Erickson (1986), Grubbs (1979), Rau (1974), and TRADOC (1985).

Definition of Terms

What is a measure of effectiveness? For the purposes of this discussion, it is a quantitative indicator of the ability of a system to accomplish the task for which it was designed under a specified set of conditions. According to Erickson (1986), equivalent and related terms to 'measure of effectiveness' found in the literature include: measure of merit, figure of merit, performance criteria, effectiveness criteria, effectiveness criterion, criterion measure, and criterion (p. 7). In this report, 'measure of effectiveness' (MOE) will be used because it seems to occur more often than the others in the literature.

The term 'system,' as used in this report, refers to the hardware, software, and human (operator and maintainer). Most of the MOEs contained in this document have been drawn from sources that have traditionally viewed MOEs as relevant to equipment or materiel performance. The human component in system performance has rarely been acknowledged in the development of these MOEs. Hopefully, the greater sensitivity to the human performance in the T&E community, as well as quantitative techniques developed in the 1980s, will encourage a broader consideration of the human element in these MOEs.

Measurement Scales

Measuring a system's abilities means being able to distinguish between various values of the variables representing those abilities. The rules defining the assignment of an appropriate value determine the type of measurement scale.

A scale is a scheme for the numerical representation of the values. There are 4 types of scales: nominal, ordinal, interval, and ratio. They are distinguished from one another by ordering and distance properties inherent in measurement rules. The ratio scale is used most often for MOEs.

The nominal scale is seldom used because it is not suited to ranking values. Measurements with this scale consist of simply classifying items, identifying them as belonging to one of several categories.

When it is possible to rank-order observed values according to some criterion (a measure or standard by which performance of a system is evaluated), then you have an ordinal scale. That is to say, the values may be ordered in such a way that one observation represents more of a given variable than another observation. A good example is mental categories (i.e., I, II, III, etc.) that are bands of aptitude scores.

Interval measurement goes a step further by adding the notion of discrete distance or degree of difference between observations. Raw aptitude scores are an example of this. Such scores, however, cannot be compared by proportionate magnitude. That is to say, a person scoring 40 on an aptitude scale does not necessarily have twice the aptitude of a person scoring 20.

Length as measured in units, such as inches or meters, does have this property, as well as the existence of a zero point. These are what characterize ratio scales. A MOE such as "detection range" is obviously on a ratio scale. So is "percent false detections," because one result could be zero. On a ratio scale, if a force with System A kills 20 tanks and one with System B kills 10 tanks, then on the basis of the MOE, "enemy tanks killed," one can say that System A is twice as effective as System B.

<u>Levels of analysis</u>

It was indicated earlier that the set of measures presented in this document would focus on the operational level of a single system's capability to accomplish its mission. Dockery (1985, p.11), suggests that this level lies midway in a hierarchy of operational analysis between component and system equipment levels and division and theatre levels.

Analyses at higher levels, according to TRADOC Pam 11-8 (1985):

> ...measure end results, and measure those results in terms

> of the total force and not just the system under examination. They include: enemy casualties, friendly casualties, casualty ratios, rate of advance, time, and weight of ammunition expended.

Lower level measures use more detailed, hardware oriented performance characteristics. They usually represent performance against passive targets or in one-on-one duels. Examples of these measures include: rate of fire, lethality, kill rates per sortie, time to first acquisition, detection rate, etc. (pp. 2-7 through 2-8)

Furthermore, Rau (1974) has described MOEs for levels of single system or below in the following manner:

> At the lower levels the MOEs become less "effectiveness oriented" and more "performance oriented". For example, performance oriented MOEs are given by such quantities as detection range, tracking accuracy, and circular error probable (CEP), whereas the corresponding effectiveness oriented (or performance dependent) MOEs would be the probability of detection (a function of detection range), the probability of successful tracking (a function of tracking accuracy) and the probability of target kill (a function of weapon CEP). (p.20)

One conclusion to be drawn from all of this is that each level is characterized by a particular set of measures. The numbers of MOEs will vary according to the relative complexity of the system(s) under consideration. A highly complex one such as a C3I (Command, Control, Communications, and Information) system tends to require multiple MOEs because it is characterized by multiple missions, broadly defined functions, varying operations, and dispersed locations for its components.

Another conclusion is that MOEs at higher levels tend to encompass MOEs at lower levels or can be expressed as functions of lower level MOEs. It is important to know the relationship between MOEs of different levels, because higher level MOEs tend to be used for making acquisition decisions, while lower level MOEs tend to operate at the data collection level. Lower level MOEs are more readily obtained because of data availability. Consequently, to evaluate a higher level MOE one must know its relationship to the lower level ones. This suggests that the linkage between levels must be established not only conceptually, but quantitatively.

Sabat (1985) proposed that using a canonical parameter would create such a linkage. He developed a methodology (featuring a mathematical device, the Kalman filter algorithm) to relate performance measures of various support systems affiliated with a naval battle group (sensors, C^3I, and launch platform navigation) to the function of over-the-horizon targeting of an antiship missile. Other mathematical approaches to generating and consolidating MOEs rely on fuzzy set theory (Dockery, 1985) and Boolean and Markov processes (Connelly, 1981).

Test Conditions

In evaluating a system, possible sources of experimental bias must be either controlled or accounted for so that complete, accurate, and replicable measurement is achieved. Kaplan, Crooks, Sanders, and Dechter (1980) developed a list of many of these factors, both general and individual, some of which are presented in Figure 1. Further levels of detail, type or gradations of individual conditions, are presented in Appendix A.

Field Testing and Human Performance

Accounting for the aforementioned test conditions allows evaluators to focus on identifying problems according to three criteria: system functions, mission performance, and personnel response (Meister, 1985, p. 259). Criteria describing system functions include such aspects as reliability, maintainability, vulnerability, and cost of operation. Mission performance criteria include effectiveness in mission accomplishment, output quality and accuracy, reaction time, performance duration, queues, and delays. Personnel performance criteria describe operator and crew responses, such as: reaction time, accuracy, number of responses, response consistency, speed, etc.

It is not always easy to assign causality for a problem in a test to a particular type of performance, because the criteria are interrelated. In other words, the cause may not be attributable strictly to equipment failure, limits to equipment capability, or human error. In fact, the problem could be due to an interaction between man and machine.

For example, consider the function of target detection for a short range air defense system. Thermal sights, television cameras, and radar are some of the devices that may be used to aid the naked eye. Let's say that when using one or more of these, system operators have failed to detect some percentage of targets over the course of many test trials. There could very well be interaction between human behavior and "equipment" (hardware and software) that leads to deficiencies in detection. Such an interaction could be the process (or task, if you will) of adjusting the sensitivity of the device(s) during surveillance.

In an operational or field test, countless subtle and not-so-subtle interactions occur, not only between man and machine, but amongst the crew (obviously, for systems requiring more than one operator). One person's performance may be

> Weather . . . .

- Illumination
- Temperature
- Precipitation
- Wind
- Humidity

> Terrain . . . .

- Ground Slope
- Ground Surface
- Ground and Water Surface
- Obstacles

> Target . . . .

- Type
- Number
- Location
- Speed
- Direction of Motion
- Concealment

> Operational . . . .

- Crew
- Hardware
- Information Inputs

> Tactics . . . .

- Number of Systems Employed
- Speed
- Location
- Direction of Motion
- Concealment
- Crew Protection
- Amount of Automatic Functioning
- System Workload

Figure 1. Some of the sources of bias in testing. (Adapted from Kaplan, Crooks, Sanders, and Dechter, 1980, p. H4-4.)

enhanced, compensated for, or worsened by that of others. Such subtleties and relationships often require the help of subject matter experts to identify the nature of the behavior observed and determine errors that do not have a significant effect on system performance or mission outcome.

It's useful to keep in mind that measuring human performance in as dynamic an environment as a field test means that one should not expect to establish and validate causality as demonstrably as in a controlled experiment. Meister (1988) characterized the research process in an operational environment, saying that, "Masses of data must be collected to allow patterns of variable relationships to become apparent during the data analysis, which will be largely correlational." (p. 1171)

How to Use This Catalog

Classification System

This document contains MOEs and descriptions for most of them. Most MOEs are relevant to the system level of analysis. They have been grouped according to 13 classes of systems (adapted from Kaplan, et al., 1980) They are as follows:

1. air defense weapons
2. armored vehicles
3. aviation systems
4. battlefield communication systems
5. C^2 (C^3I) systems
6. combat/tactical support equipment (including engineering and mine warfare)
7. electronic warfare and intelligence systems
8. ground transportation equipment
9. infantry weapons
10. ordnance systems
11. target acquisition and/or designator systems
12. non-combat support systems
13. general

(For explanations of these system classes, see Appendix B.)

The next two sections in this document are organized according to this scheme. The section immediately following, lists MOEs and the section after that describes most of them. Within each system class, measures are grouped together by system function. The functions are listed below and have been adapted from Kaplan et al. (1980) and HARDMAN system analysis (US Army Research Institue, 1985):

1. weapon delivery (shoot)
2. maneuverability
3. communication
4. command and control
5. intelligence (includes reconnaissance and target acquisition & designation)
6. survivability (includes vulnerability)
7. battle support (includes engineering, transportation, and logistics)
8. electronic warfare (includes ECM)

Oftentimes, measures of effectiveness for a specific system are mentioned (e.g., surface-to-air missile, bucket loader). It should be noted that relationships between functions are not indicated. Take for example, the effect of maneuverability on survivability. On the battlefield, a vehicle that is faster and maneuvers evasively is harder to hit. Agility is less important for some ground transportation equipment than for armored vehicles.

The following figure shows how to read the section that groups MOEs.

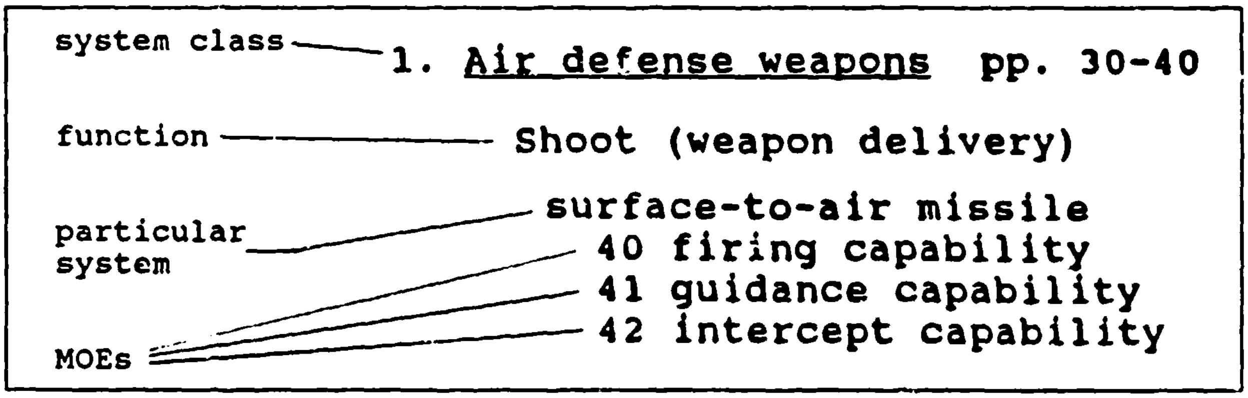


Figure 2. How to read the Section of MOE Groupings

The next section lists the same MOEs as before, but with explanations for most of them. Some MOEs are self-evident and are not described. (One such MOE is "percent of targets hit.")

When searching for particular MOEs for a class of systems or relevant to a certain system, use the section listing the MOEs. The explanations in the subsequent section enable one to confirm whether the MOEs are useful. As a further aid in locating particular MOE explanations, an index is provided.

In some instances, several MOEs may appear to describe the same phenomena, but may actually differ in subtle ways. Take, for example, the following three MOEs for an air defense missile system: probability of hit, probability of kill, and proportion of hostile aircraft successfully intercepted. They are certainly related to one another, but not synonymous. If we compare them to one another, we can see this. In a live fire situation, an aircraft might be hit by a missile, and yet not be killed (i.e., knocked out of the sky). So probability of hit is not the same as probability of kill.

In a dry (simulated) fire situation, a successful interception is a qualified hit, one that is based on various contingencies. In other words, several conditions have to be satisfied before the target could be judged as having been hit. (Basically, the aircraft should have been in the time-space envelope of vulnerability such that damage by the warhead would have occurred through impact or proximity explosion.)

MOE Groupings

1. <u>Air defense weapons</u> pp. 30-41

Weapon Delivery

generic

1 ammunition expenditure
2 burst radius
3 casualties per round
4 circular error probable (CEP)
5 degree of neutralization
6 (expected) fraction of target damaged
7 expected remaining target killing capability
8 firepower potential (area fire)
9 firepower potential (point fire)
10 kill rate
11 lethality
12 maximum effective range
13 mean offset error
14 mean rounds to first hit
15 mean time target engaged
16 military worth index
17 percent of basic load expended per hit
18 percent of near misses
19 percent of rounds hit
20 percent of target destruction
21 percent of targets hit
22 percent of time firing while moving
23 probability of hit (PH)
24 probability of a kill (P_k)
25 proportion of friendly aircraft not engaged
26 proportion of hostile aircraft successfully intercepted
27 rate of fire
28 rate of target destruction
29 required ammunition resupply rate
30 rounds per casualty
31 rounds per engagement
32 rounds to completion
33 time to first fire
34 weapon fractional kill value

anti-aircraft gun

35 CEP about the target
36 CEP about the mean point of impact
37 mean point of impact range
38 mean point of impact deflection
39 percent of sorties on which hits occur

surface-to-air missile

40 firing capability

41 guidance capability
42 intercept capability

command & control, target acquisition or fire control system
43 proportion of kills

anti-aircraft gun fire control system
44 initial salvo error in range
45 initial salvo error in deflection

Maneuverability
generic
46 agility
47 march rate
48 mean time to negotiate obstacles
49 mobility index (tracked vehicles)
50 mobility index (wheeled vehicles)
51 refueling rate
52 sustained speed

Intelligence
generic
53 acquisition rate
54 average tracking error
55 detection range
56 detection rate
57 frequency of elapsed times (from target detection to acquisition
58 frequency of elapsed times (from target acquisition to identification)
59 frequency of elapsed times (from target detection to fire)
60 maximum effective range of acquisition
61 mean target initial acquisition range
62 mean time to acquisition
63 mean time to initial acquisition
64 percent of targets successfully engaged
65 time to estimate range
66 percent of warning alerts detected or confirmed
67 probability of aircraft detection
68 single scan probability of detection
69 time to detection
70 time to identification

Survivability
generic
71 percent of time moving when exposed
72 vulnerability index

Battle Support
  missile
    73 missile preflight reliability

2. <u>Armored vehicles</u> pp. 42-52

Weapon Delivery

generic

1 ammunition expenditure
2 average time firing on moving target
3 casualties per round
4 circular error probable (CEP)
5 circular miss distance
6 degree of neutralization
7 (expected) fraction of target damaged
8 expected remaining target killing capability
9 firepower potential (area fire)
10 firepower potential (point fire)
11 firing rate
12 kill rate
13 lethality
14 maximum effective range
15 mean offset error (mean error or average miss distance)
16 mean rounds to first hit
17 mean time that target is engaged
18 military worth index
19 percent of basic load expended
20 percent of near misses
21 percent of rounds that hit
22 percent of target destruction
23 percent of targets hit
24 percent of time firing while moving
25 probability of hit (PH)
26 probability of a kill given a hit (P_K)
27 rate of fire
28 rate of target destruction
29 required ammo resupply rate
30 rounds per casualty
31 rounds per engagement
32 rounds to completion
33 time to estimate range
34 time to first fire
35 weapon fractional kill value

artillery & mortar rounds

36 burst radius

observer teams, equipment, and techniques

37 time to adjust
38 rounds to adjust

Maneuverability

generic

39 agility
40 distance from enemy when attacker stops
41 march rate
42 mean time to negotiate obstacles
43 mobility index (tracked vehicles)
44 mobility index (wheeled vehicles)
45 movement rate in mine fields
46 movement rate in normal combat
47 percent delay
48 percent moves completed on time
49 refueling rate
50 sustained speed

Intelligence
generic
51 CEP
52 detection range
53 mean time to acquisition
54 mean time to track
55 range of acquisition
56 time to detection
57 time to identification

Survivability
generic
58 area vulnerable to a specific attack
59 flammability
60 probability of survival
61 reliability of extinguishers
62 time moving when exposed, percent of
63 vulnerability in

Battle Support
generic
64 down time
65 mean maintenance time
66 mean miles between failure (MMBF)
67 mean time between any maintenance action (MTBAMA)
68 mean time between failure (MTBF)
69 mean time between maintenance (MTBM)
70 mean time between unscheduled maintenance action (MTBUMA)
71 mean time to repair (MTTR)
72 mean time to repair (actually achieved) (MTTR(A))
73 mean time to repair (inherent) (MTTR(I))
74 mean time to repair (operational) (MTTR(O))

gun
75 mean rounds between jamming

3. <u>Aviation systems</u> pp. 53-59

Weapon Delivery

generic

1 ammunition expenditure
2 casualties per round
3 CEP
4 degree of neutralization
5 distance from enemy when opening fire
6 (expected) fraction of target damaged
7 expected remaining target killing capability
8 firing rate
9 kill rate
10 lethality
11 mean offset error (mean error or average miss distance)
12 mean rounds to first hit
13 mean time target engaged
14 military worth index
15 percent of basic load expended
16 percent of near misses
17 percent of target destruction
18 percent of targets hit
19 probability of hit (PH)
20 probability of kill given a hit (P_k)
21 rate of fire
22 rate of target destruction
23 required ammo resupply rate
24 rounds per casualty
25 rounds per engagement
26 rounds to completion
27 time to estimate range
28 time to first fire
29 weapon fractional kill value

air-to-air missile

30 kill capability against airborne targets

air-to-ground ordnance

31 expected number of targets destroyed in time period
32 expected number of targets killed during system's lifetime
33 expected number of targets destroyed per sortie
34 expected number of aircraft lost per target destroyed

Maneuverability

helicopter

35 percent of track followed (nap-of-the-earth flight)

Intelligence
  generic
    36 detection range
    37 detection rates
    38 mean time to acquisition
    39 time to detection
    40 time to identification

  helicopter
    41 terrain recognition

Survivability
  generic
    42 area vulnerable to a specfic attack
    43 probability of survival

  attack helicopter
    44 exposure time

Battle Support
  generic
    45 mean flight hours between maintenance action
    46 mean time to repair - flightline (MTTRF)

  transport aircraft
    47 number of aircraft required

4. <u>Battlefield Communication</u> pp. 60-64

Communication

generic

1 communications performance index
2 mean time message delivery
3 message backlog
4 message rate
5 percent of communication links with alternate route
6 percent transmissions completed
7 signal to noise ratio (S/N)

data transmitter/receiver

8 bit error rate
9 mean character error rate
10 data rate achieved
11 gross error rate
12 percent of messages received
13 percent of messages received that were displayed accurately

data & voice communication system

14 grade of service:
balance of traffic
level of control signalling requirements
15 level of control signalling requirements

net

16 percent of net capacity utilization

polling network

17 network throughput connectivity

radio

18 mean error rate (reception)
19 percent of sentence intelligibility
20 percent of transmission detected (satisfactorily transcribed)
21 rhyme word interpretation probability

spread spectrum

22 anti-jamming benefit or margin estimate

satellite spread spectrum communications

23 SATCOM uplink channel capacity

voice network

24 grade of service (probability of connection)

voice systems

25 voice intelligibility threshold

Survivability
  generic
    26 communications interception susceptibility

  spread spectrum system
    27 anti-jamming performance criteria

5. <u>Command & control</u> (also C^3I) pp. 65-68

generic
1 changes per order
2 mean dissemination time
3 mean time message delivery
4 number (or proportion) of options remaining
5 number of orders issued for a given operation
6 percent of actions initiated by the time ordered
7 percent of messages completed
8 percent of orders for which clarification requested
9 percent of personnel informed
10 percent of planning time forwarded
11 percent of transmissions completed
12 proportion of fire requests beyond range
13 proportion of friendly elements engaged
14 repetitions per order
15 required number of commands
16 time from mission to order
17 time to decision (planning time)
18 warning/operation orders ratio

infantry unit
19 time to change formation

Communication
generic
20 C^2 communications performance index
21 communications system capacity
22 mean number of transmission required

telephone system
23 telephone channel capacity

Intelligence
generic
24 percent essential elements of information (EEI) met
25 time to estimate range

6. <u>Combat/Tactical Support Equipment</u> pp. 69-73

Maneuverability
  generic
    1 march rate
    2 mean time to negotiate obstacles
    3 mobility index (wheeled)
    4 mobility index (tracked)
    5 movement rate in normal combat
    6 movement rate in mine fields
    7 percent delay
    8 percent of moves completed on time
    9 refueling rate
    10 sustained speed

Battle Support
  generic
    11 down time
    12 mean maintenance time
    13 mean miles between failure (MMBF)
    14 mean time between any maintenance action (MTBAMA)
    15 mean time between failure (MTBF)
    16 mean time between maintenance (MTBM)
    17 mean time between unscheduled maintenance action (MTBUMA)
    18 mean time to repair (MTTR)
    19 mean time to repair (actually achieved) (MTTR(A))
    20 mean time to repair (inherent) (MTTR(I))
    21 mean time to repair (operational) (MMTR(O))

  bucket loader
    22 bucket loader effectiveness

  bulldozer
    23 bulldozer cubic movement rate

  compactor
    24 compacting rate

  grader
    25 grader spreading rate

  water distributor (sprinkler)
    26 water distributor area sprinkling rate

7. <u>Electronic warfare & surveillance systems</u> pp. 74-81

Intelligence

generic

1 probability of detection
2 proportion of targets detected

sensor

3 delay after detection

radar (detection)

4 average minimum (maximum) target detection range
5 cumulative distribution of maximum detection range
6 median detection range
7 90% cumulative detection range
8 median minimum detection range
9 blip/scan ratio

radar (tracking)

10 average index of track solidity
11 mean radar range resolution
12 mean radar range error
13 mean radar bearing resolution
14 mean radar bearing error
15 percent of restricted tracking runs

EW (Electronic Counter (Counter) Measures) system

16 average maximum intercept range
17 mean DECM (defensive ECM) burnthrough range
18 mean noise jamming burnthrough range
19 mean DECM reaction time
20 mean noise jamming reaction time
21 percent of correctly identified EMCON violators (or non-violators)
22 percent of signals identified that were unique IDs
23 percent of signals identified that were ambiguous IDs
24 percent of emitters identified that were unique IDs
25 percent of emitters identified that were ambiguous
26 percent of time that pulse repetition frequency (PRF) present
27 percent of time pulse width (PW) present
28 percent of time frequency present
29 percent of time scan information present
30 percent of successful communication interception attempts

ECM receiving antenna

31 mean (median) signal detection range
32 mean direction finding (DF) error
33 direction finding (DF) error probability

jammer (general)

34 comjam mission effectiveness (percentage)

35 communication error rate (intelligibility)

36 communications intelligibility vs. jamming/signal ratio

37 frequency of jamming reception

jammer (search-and-jam type)

38 jammer effectiveness

jammer(s)

39 multi-jammer effectiveness

repeater jammer

40 repeater jammer effectiveness area

Survivability

multi-user telecommunications circuits

41 jamming efficiency

8. <u>Ground transportation equipment</u> pp. 82-85

Maneuverability
  generic
    1 agility
    2 cruising (convoy) range
    3 march rate
    4 mean time to negotiate obstacles
    5 mobility index (tracked vehicles)
    6 mobility index (wheeled vehicles)
    7 percent delay
    8 percent of moves completed on time
    9 percent of unit at prescribed interval
    10 refueling rate
    11 sustained speed

Battle support
  generic
    12 down time
    13 mean maintenance time
    14 mean miles between failure (MMBF)
    15 mean time between any maintenance action (MTBAMA)
    16 mean time between failure (MTBF)
    17 mean time between maintenance (MTBM)
    18 mean time between unscheduled maintenance action (MTBUMA)
    19 mean time to repair (MTTR)
    20 mean time to repair (actually achieved) (MTTR(A))
    21 mean time to repair (inherent) (MTTR(I))
    22 mean time to repair (operational) (MTTR(O))

  cargo handling system
    23 cargo handling rate

  supply system
    24 supply throughput effectiveness

  transport system
    25 reduction in cube requiring transport

9. <u>Infantry weapons</u> pp. 86-92

Weapon Delivery (Shoot)

generic

1 ammunition expenditure
2 casualties per round
3 circular error probable (CEP)
4 circular miss distance
5 degree of neutralization
6 (expected) fraction of target damaged
7 expected remaining target killing capability
8 firepower potential (area fire)
9 firepower potential (point fire)
10 firing rate
11 kill rate
12 lethality
13 maximum effective range
14 mean offset error (mean error or average miss distance)
15 mean rounds to first hit
16 mean time target engaged
17 military worth index
18 percent of basic load expended
19 percent of near misses
20 percent of rounds that hit
21 percent of target destruction
22 percent of targets hit
23 percent of time firing while moving
24 probability of hit (PH)
25 probability of kill given hit (P_K)
26 rate of fire
27 rate of target destruction
28 required ammo resupply rate
29 rounds per casualty
30 rounds per engagement
31 rounds to completion
32 time to estimate range
33 time to first fire
34 weapon fractional kill value

mortar rounds

35 burst radius

observer teams, equipment, and techniques

36 time to adjust
37 rounds to adjust

Maneuverability
  generic
    38 march rate

  firing port gun
    39 time to emplace (disemplace)

Intelligence
  generic
    40 circular error probable (CEP)
    41 maximum effective range of acquisition
    42 mean time to acquire
    43 time to detection
    44 time to identification

Battle Support
  generic
    45 number of malfunctions
    46 number of rounds between malfunctions
    47 mean time to clear malfunctions

10. Ordnance systems pp. 93-102

Weapon Delivery
generic
1 ammunition expenditure
2 burst radius
3 casualties per round
4 circular error probable (CEP)
5 degree of neutralization
6 (expected) fraction of target damaged
7 expected remaining target killing capability
8 firepower potential (area fire)
9 firepower potential (point fire)
10 kill rate
11 lethality
12 maximum effective range
13 mean offset error (mean error or avg. miss distance)
14 mean rounds to first hit
15 mean time target engaged
16 military worth index
17 opening fire proximity
18 percent of basic load expended
19 percent of near misses
20 percent rounds that hit
21 percent of target destruction
22 percent of targets hit
23 probability of hit (PH)
24 probability of kill given a hit (P_k)
25 rate of fire
26 rate of target destruction
27 required ammo resupply rate
28 rounds per casualty
29 rounds per engagement
30 rounds to completion
31 time to first fire
32 weapon fractional kill value

chemical round
33 casualties per dose

multiple launch rocket system
34 hit probability

Maneuverability

generic

35 agility
36 march rate
37 mobility index (tracked vehicle)
38 mobility index (wheeled vehicle)
39 movement rate in normal combat
40 refueling rate

Target Acquisition

generic

41 accuracy of range estimation
42 detection range
43 detection rates
44 maximum effective range
45 mean (median) time to acquisition
46 rate of acquisition
47 time to detection
48 time to estimate range
49 time to identification
50 time between detection and firing

observer teams, equipment, and techniques

51 time to adjust
52 rounds to adjust

Survivability

vehicle

53 area of vehicle vulnerable to a specific attack
54 percent of time moving when exposed

Battle Support

vehicle

55 down time
56 mean maintenance time
57 mean miles between failure (MMBF)
58 mean time between any maintenance action (MTBAMA)
59 mean time between failure (MTBF)
60 mean time between maintenance (MTBM)
61 mean time between unscheduled maintenance action (MTBUMA)
62 mean time to repair (MTTR)
63 mean time to repair (actually achieved) (MTTR(A))
64 mean time to repair (inherent) (MTTR(I))
65 mean time to repair (operational) (MTTR(O))

11. <u>Target Acquisition & Designation Systems</u> pp. 103-109

generic

1 accuracy of identification
2 detail of identification
3 detection rate
4 detection time to range ratio
5 detection to recognition time
6 friendly/enemy detection ratio
7 identification to engagement time (firing reaction time)
8 location error to range ratio
9 maximum effective range
10 mean error
11 mean range of detection
12 mean time to acquisition
13 percent of correct locations
14 percent of successful identification
15 percent of targets acquired
16 percent of targets attacked
17 percent of targets detected in time
18 percent of time target tracked
19 percent of true detections
20 percent of false detections
21 percent of warning alerts detected or confirmed
22 probability of detection
23 proportion targets detected
24 range of detection
25 single scan probability of detection
26 time to detection
27 time to identify

air-to-ground or ground-to-air

28 slant range of detection

remotely piloted vehicle

29 ordnance call-in time
30 probability of (in)correct ordnance call-in
31 probability of (in)correct target designation
32 target acquisition time
33 target detection time
34 total mission time

12. <u>Noncombat Support Systems</u> pp. 110-111

generic

1 percent of time support available
2 ratio of support requests to completions

supply systems

3 percent of supply requests met

4 percent of supply requirements fulfilled
5 supply throughput effectiveness

cargo handling system

6 cargo handling rate

transport system

7 reduction in cube requiring transport

13. <u>General</u> pp. 112-114

1 actual/potential productivity ratio
2 human factors rating
3 number of additional missions capable
4 percent of tasks satisfied
5 percentage deviation in performance
6 time to completion

Maneuverability
7 closing time
8 percent of force completing move
9 percent moves within time

Command & Control
10 closing time

Survivability
11 probability of survival

Battle Support
12 item failure rate
13 mean time between failure (MTBF)

-1---------

AIR DEFENSE WEAPONS

Weapon Delivery

Generic

1 ammunition expenditure = $\frac{\text{amount of ammo fired(rounds, tons, DOA)}}{\text{elapsed time (days, hours, seconds)}}$

Note: Unit measure is DOA (Day of Ammunition) per day, tons per hour, rounds per second, etc.

---

2 burst radius is the distance from the center of the burst within which there is a specified weapon effect

---

3 casualties per round (indicates P_k)

---

4 CEP = Circular Error Probable is the radius from center of target of a circle that includes 50% of all observed locations. This measure is also known as the median offset error. That is the distance from center exceeded by 1/2 of the misses.

---

5 degree of neutralization

$$= \frac{\text{(number killed + number suppressed)}}{\text{total number in force}}$$

Note: "suppressed" means not operating.

---

6 (expected) fraction of target damaged

---

7 expected remaining target killing capability is the computation of utility value at a given point in time, taking into account both the expected remaining force size and the killing capability of that force size

$$= (Pk_a)(Es_a) + (Pk_b)(Es_b) + \ldots + (Pk_n)(Es_n)$$

where Pk = proportion of kills per attempt
Es = proportion of force size remaining at a given time or expectation of survival for each weapon

Note: This measure is especially useful in combining the effects of different weapons with the same mission.

[redacted]

8 firepower potential (area fire) is the product of mean lethal area and ammunition expenditure (AE).

$$= (AE)(LA_i)(L_i/T)$$

where:

AE = number of rounds fired

LA_i = lethal area of each type of weapon

L_i/T = fraction of the total basic load (T) for each type of weapon

Note: Since an average lethal area is part of the computation, the index is an arithmetic expectation subject to distortion for unusual conditions. Number of rounds fired is treated multiplicatively ignoring the lack of independence between rounds. Average lethal area may be a difficult input to obtain.

---

9 firepower potential (point fire) = (PM/ER)(R)(AE)

where:

ER = single-shot effective range

PM/ER = average kill probability = integral of ER

R = range

AE = ammunition expenditure

Note: Since an average kill probability over all ranges is part of the computation, the index depends on firing done at maximum effective ranges. The range value (R) cannot be a simple range, but must be a transform that gives greater value to shorter ranges (for example, the reciprocal of range). Number of rounds fired is treated multiplicatively, which ignores the lack of independence between rounds.

---

10 kill rate = (hit probability) x (probability hit is a kill) x (rate of fire)

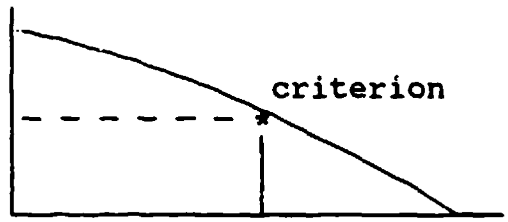
Note: This is a simplistic equation that makes certain assumptions such as: many targets or many trials, not overheating the weapon when continuing to fire it at a certain rate within a certain amount of time, and the time to switch from target to target is about the same.

---

11 lethality = kills / unit time (second, minute, hour, day or week)

---

12 **maximum effective range** is the longest distance at which a specified probability of kill or acquisition is achieved.



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13 **mean offset error** is the arithmetic average of all errors taken as distance from true location and taking direction into account. Errors have positive or negative values. (For example, errors beyond the location values are positive, and those falling short are negative. The formula is:

$$\frac{\text{(each offset distance, true location to reported location)}}{\text{number of reported locations}}$$

Note: The measure is useful in evaluating any system that includes accuracy of locating points and, at the same time, has the characteristic that positive and negative errors tend to cancel each other. For example, it can be used to compare accuracy of two systems in range estimation.

---

14 **mean rounds to first hit**

---

15 **mean time target engaged** is the average of the time periods a target is under fire.

Note: The measure subsumes certain components of placing fire such as target acquisition, communications, resupply, and command and control.

---

16 **military worth index** $= \sum_{i=1}^{n} [W_i \times Pd_i]$

where:

W = military worth of each target that can be defeated
P_d = probability of defeating each target

Note: It's difficult to assign military worth to different types of target because a common denominator must be delineated.

---

17 **percent of basic load expended per hit**

Note: Input unit of measure is rounds, tons, or DOA.

---

18 **percent of near misses**

---

19 **percent of rounds that hit**

---

20 **percent of target destruction**
where the unit of input measure could be:
number of personnel, number of vehicles, number of major weapons, square meters, number of buildings, number of oil tanks, length of road or track, etc.

---

21 **percent of targets hit**

---

22 **percent of time firing while moving**

---

23 **probability of hit (P_H) is the theoretical chance of hitting a target under stated circumstances if all unstated circumstances are random variables.**

$$P_H = \frac{\text{number of hits}}{\text{number of attempts}} \quad \text{or} \quad P(H) = \int_{-\infty}^{a} P(x)\,dx$$

In the latter case, P(H) is a probability density function, which is the number of hits for each value of another variable. To put it another way, the probability is the integral of the function for a given value of the other variable.

Note: The measure can be used to determine how many rounds or how long a period of time is required to reach a certain probability of hit, or probable numbers of hits.

---

24 **probability of kill given a hit is the theoretical chance of killing a target under stated circumstances if all unstated circumstances are random variables.**

$$P_K = \text{number of kills} \;/\; \text{number of hits}$$

This may also be computed as the integral of kills as a function of another variable, or as a combination of probabilities.

Note: The measure can be used to evaluate a firepower system, compare alternative firepower systems, or compute higher order measures such as number of kills, rounds required to kill, or probability of survival.

---

25 **proportion of friendly aircraft not engaged**

$$= \frac{\text{number of friendlies not engaged}}{\text{number of friendlies detected within range}}$$

26 **proportion of hostile aircraft successfully intercepted**

$$= \frac{\text{number of hostile aircraft successfully fired upon}}{\text{number of hostile aircraft correctly presented}}$$

where 'successfully fired' means that the fire unit was able to hit or damage the target as confirmed by sight or scoring process. This also means that the firing procedure was properly performed by the crew, and that the hostile aircraft was hit before its weapons could hit the fire unit. Correct presentation of aircraft refers to sufficient exposure and duration of exposure to fire unit.

---

27 **rate of fire**

$$= \frac{\text{the amount of ammo fired (rounds, tons, DOA)}}{\text{elapsed time}}$$

---

28 **rate of target destruction** is the proportion of attacked target destroyed per specified time period.

---

29 **required ammo resupply rate**

$$= \frac{\text{total number of rounds (or tons or DOA) required}}{\text{number of days in time period observed}}$$

Note: Unit measure of output is rounds (for single type of round) or tons (for several types of rounds). This measure can also be considered as a ratio between a predetermined "day of ammunition", which is meant to be the amount of ammunition required per day, and the actual amount of ammunition. In this form, the ratio is "DOA" per day.

---

30 **rounds per casualty**

---

31 **rounds per engagement**

---

32 **rounds to completion** is the number of rounds fired from initiation to completion of a task. The task may be to defeat a given target, suppress for a period of time, adjust or zero a weapon, or to acquire a first hit (rounds to first hit).

Note: If firepower is held constant, the measure can evaluate the resistance of the target.

---

33 **time to first fire** is the elapsed time from detection of a target to arrival of the reaction firing round on the target.

Note: This measures timeliness of fire. It subsumes the times required to recognize, identify and locate a target; communicate a fire request; and fire the weapon system;

and flight time of the projectile.

34 weapon fractional kill value is the fraction of enemy losses inflicted.

Note: It is not intended for comparisons by itself. It's intended mainly as a value to be used in more complex measures (such as loss exchange ratio and force effectiveness indicator) for assignment of values to weapons (P_k is a more flcxible measure for the same purpose.) It could, however, be used in a simple comparison with constant enemy initial strength and constant time period.)

Anti-Aircraft Gun

35 circular error probable (CEP) about the target

36 CEP about the mean point of impact

37 mean point of impact range

38 mean point of impact deflection

39 percent of sorties on which hits occur

Surface-to-Air Missile

40 firing capability

$= R_{sl} \times R_{fp} \times R_{mr} \times R_{hr} \times R_{fr}$

= launch phase success rate X GMFCS and p[illegible]nel success rate X missile reliability X homing succ[illegible] rate X fuze reliability

R_{sl} = number of successful launches / number of launch attempts

R_{fp} = number of valid tests / number of flight tests

R_{mr} = number of good missiles / number of missiles with opportunity to home

$$R_{hr} = \frac{\text{number of missiles which home to successful intercept}}{\text{number of missiles which do not fail}}$$

$$R_{fr} = \frac{\text{number of missiles with successful fuze operation}}{\text{number of missiles which home to successful intercept}}$$

41 **guidance capability** is the probability that missile will properly home to within a maximum miss distance, R, from the target.

$$= \frac{\text{number of times missile properly homed to within maximum miss distance R from target}}{\text{number of guidance attempts}}$$

---

42 **interception capability** is the probability that the system will not fail either before or during missile flight, and that the missile will home to a successful intercept with proper fuze action, or a direct hit is achieved, killing the target.

= P_{mr} [missile round success rate] X P_{fc} [fire control system reliability]

where:

$$P_{mr} = \frac{\text{number of missiles homing to successful intercept with proper fuze action, or a direct hit, killing target}}{\text{number of valid missile firings}}$$

$$P_{fc} = \frac{\text{number of times fire control system properly supported the missile firing independent of missile success or failure}}{\text{number of valid missile firings less undetermined failures}}$$

furthermore, $P_{mr} = P_{re} \times P_{ie}$

where:

P_{re} = missile reliability -- the probability that a missile will home successfully to the vicinity of the intercept region, given that the fire control system functions properly

= number of times missile homed successfully to vicinity of intercept region and fire control system functioned properly

/divided by/

number of missile homing attempts when fire control system functioned properly

P_{ie} = intercept effectiveness -- the probability that a reliable missile, having homed to intercept region with proper fire control system support, will enter region R (a specified maximum distance from target) and the fuze will function properly, or the missile will hit and destroy the target

= number of times missile miss distance didn't exceed R

/divided by/

number of times missile homed successfully to the vicinity of intercept region and fire control system and functioned properly

---

Command & Control, Target Acquisition or Fire Control System

43 proportion of kills

$$= \frac{\text{number of kills}}{\text{number of interceptor missile firings against strike aircraft}}$$

Note: It is a model derived quotient for test cases varying by ECM packages, penetrator flight paths, jamming, and drone flight paths.

Anti-aircraft Gun Fire Control System

44 Initial salvo error in range for given target range band

45 Initial salvo error in deflection for given target range band

---

MANEUVERABILITY

Generic

46 agility is measured by acceleration (or standard deviation of acceleration), quick turning capability, and small turning radius

47 march rate = distance traveled by a unit / elapsed time

48 mean time to negotiate obstacles

49 mobility index (tracked vehicles)

$$= \left(\frac{CPF \times WF}{TF \times GF} + BF - CF\right) \times EF \times TF$$

where:

CPF = contact pressure factor (pounds / square inch of track in contact with the ground)
WF = weight factor (gross weight in pounds)
TF = track factor (track width (inches)/100)

GF = grouser factor (height in inches)
BF = bogie factor = (gross weight (pounds)/10) x (number of bogies in contact with ground) x (area in square inches per track shoe)
CF = clearance factor = ground clearance (inches) / 10
EF = engine factor (horsepower per ton)
TF = transmission factor for hydraulic and mechanical systems

---

50 mobility index (wheeled vehicles) =

$$0.6 \left[\left(\frac{CPF x WF x WLF}{TF \text{ x } GF} - CF \right) \text{ x } EF \text{ x } TF \right] - 20$$

where:
CPF (contact pressure factor) =

$$\frac{\text{gross vehicle weight (pounds)}}{\text{tire width (inches) x rim diameter(inches) x number of tires}}$$

WF (weight factor) = pounds

TF (tire factor) = $\frac{\text{1.25 x tire width (inches)}}{100}$

GF (grouser factor) is for vehicle with or without chains)

WLF (wheel load factor) = $\frac{\text{gross vehicle weight}}{\text{number of wheels (single or dual)}}$

CF (clearance factor) = $\frac{\text{ground clearance (inches)}}{10}$

EF (engine factor) = horsepower/ton

Note: Factors 0.6 and 20 are used to scale down the mobility indexes of wheeled vehicles for purposes of comparison.

---

51 refueling rate = mean miles to refuel (includes idling time and travel on secondary roads)

---

52 sustained speed

INTELLIGENCE

Generic

53 acquisition rate

$$= \frac{\text{number of targets successfully acquired}}{\text{number of valid acquisition opportunities}} \times 100$$

---

54 average tracking error (degrees)

---

55 detection range

Note: This measure may be characterized by one or more of the following versions: average maximum, average minimum, median, median minimum, and cumulative distribution.

---

56 detection rate

---

57 frequency of elapsed times (from target detection to acquisition)

---

58 frequency of elapsed times (from target acquisition to identification)

---

59 frequency of elapsed times (from target detection to fire)

---

60 maximum effective range of acquisition is the longest distance at which a specified probability of acquisition is achieved.

---

61 mean target initial acquisition range for given target altitude

---

62 mean time to acquisition is the arithmetic average of the elapsed times to complete all successful acquisitions. Acquisition is defined as including detection, recognition identification, and location of the target. The number of successful acquistions must be large enough to average out large differences from chance factors in the situation.

$$= \frac{\text{elapsed time for each successful acquisition}}{\text{number of successful acquisitions}}$$

Note: This measure directly addresses the timeliness of acquisition. (It could also be in the form of median time to acquisition.) It applies only to the case of completed, successful acquisition and not to the expected time to acquire. Since it subsumes other time measures (such as time-to-detection), it is a grosser measure suitable for evaluating larger systems.

---

63 mean time to initial acquisition for given target altitude

64 percent of targets successfully engaged

65 percent of warning alerts detected or confirmed

$$= \frac{\text{number of warning alerts detected or confirmed}}{\text{number of warning alerts}} \times 100$$

66 probability of aircraft detection

$$= \frac{\text{number of detections}}{\text{detection opportunities}}$$

67 single scan probability of detection (as a function of target range and azimuth separation of target aircraft)

= number of aircraft identified / number of radar scans

68 time to detection

69 time to estimate range

= (time of estimation) - (time of detection)

70 time to identification

SURVIVABILITY

generic

71 percent of time moving when exposed

72 vulnerability index = 1 - [((4TH + NM) / ET) x (RF / RA)]

where:

TH = target hits (4TH means target hits are 4 times as valuable as near misses. This multiplier can be changed, according to assumptions.)
ET = exposure time
NM = near misses
RF = rounds fired
RA = rounds available

BATTLE SUPPORT

Surface-to-Air Missile

73 missile preflight reliability is the probability that the missile system will enter and complete all functions necessary for the successful launching of a missile (i.e., probability of success for a launch).

$= Pr_M \times Pr_{GSE}$

where:

Pr_M = missile reliability

Pr_{GSE} = ground support equipment reliability

-2-------------

ARMORED VEHICLES

WEAPON DELIVERY

Generic

1 **ammunition expenditure**

$$= \frac{\text{amount of ammo fired (rounds, tons, DOA)}}{\text{elapsed time (days, hours, seconds)}}$$

Note: Unit measure is DOA (Day of Ammunition) per day, tons per hour, rounds per second, etc.

---

2 **average time firing on moving target**

Note: The distance to be cleared must be specified in keeping with the nature of the firing. For example, in an artillery fire mission, the target can be a moving column of vehicles, and the specified distance for the last vehicle to move is 200 meters. This measure can be used to compare alternate procedures for acquiring an artillery target and calling and adjusting fire.

---

3 **casualties per round**

---

4 **CEP (Circular Error Probable)**

= 1.774 X square root of (the average miss distance)

Note: This measure is often used to measure accuracy of fire. [see explanation in Air Defense.]

---

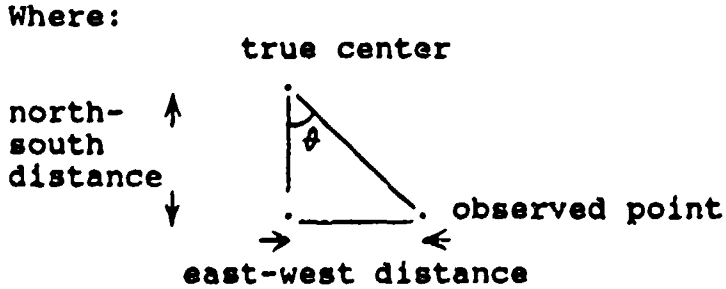
5 **circular miss distance** is the straight line distance from the observed point to the true center of target or

$$\left((\text{north-south distance})^2 + (\text{east-west distance})^2 \right)^{1/2}$$

or

$$(\text{north-south distance}) \div (\text{cosine of angle } \theta)$$

Where:



6 **degree of neutralization**

$$= \frac{\text{(number killed + number suppressed)}}{\text{total number in force}}$$

Note: "suppressed" means not operating.

7 **(expected) fraction of target damaged**

8 **expected remaining target killing capability** is the computation of utility value at a given point in time, taking into account both the expected remaining force size and the killing capability of that force size

$= (Pk_a)(Es_a) + (Pk_b)(Es_b) + \ldots + (Pk_n)(Es_n)$

where

Pk = proportion of kills per attempt
Es = proportion of force size remaining at a given time or expectation of survival for each weapon

Note: This measure is especially useful in combining the effects of different weapons with the same mission.

9 **firepower potential (area fire)** is the product of mean lethal area and ammunition expenditure (AE).

$= (AE)(LA_i)(L_i/T)$

where

AE = number of rounds fired
LA_i = lethal area of each type of weapon
L_i = fraction of the total basic load (T) for each type of weapon

Note: Since an average lethal area is part of the computation, the index is an arithmetic expectation subject to distortion for unusual conditions. Number of rounds fired is treated multiplicatively ignoring the lack of independence between rounds. Average lethal area may be a difficult input to obtain.

10 **firepower potential (point fire)** = (PM/ER)(R)(AE)

where:

ER = single-shot effective range
PM/ER = average kill probability = integral of ER
R = range
AE = ammunition expenditure

Note: Since an average kill probability over all ranges is part of the computation, the index depends on firing done at maximum effective ranges. The range value (R) cannot be a simple range, but must be a transform that gives greater value to shorter ranges (for example, the reciprocal of range). Number of rounds fired is treated multiplicatively, which ignores the lack of independence between rounds.

---

11 firing rate

---

12 kill rate = (hit probability) x (probability hit is a kill) x (rate of fire)

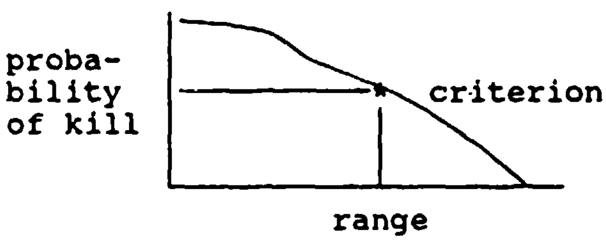
Note: This is a simplistic equation that makes certain assumptions such as: many targets or many trials, not overheating the weapon when continuing to fire it at a certain rate within a certain amount of time, and the time to switch from target to target is about the same.

---

13 lethality = kills / unit time (sec, min, hr, day, wk)

---

14 maximum effective range is the longest distance at which a specified probability of kill or acquisition is achieved



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15 mean offset error is the arithmetic average of all errors taken as distance from true location and taking direction into account. Errors have positive or negative values. (For example, errors beyond the location values are positive, and those falling short are negative. The formula is:

$$\frac{\text{each offset distance (true location to reported location)}}{\text{number of reported locations}}$$

Note: The measure is useful in evaluating any system that includes accuracy of locating points and, at the same time, has the characteristic that positive and negative errors tend to cancel each other. For example, it can be used to compare the accuracy of two systems in range estimation.

---

16 mean rounds to first hit

Note: This is rendered useless if a target is not hit. The measure seems quite applicable to an engagement situation with both sides attempting to obtain the first killing hit. This is typical of tank/anti-tank engagements.

---

17 **mean time target engaged** is the average of the time periods a target is under fire.

Note: The measure subsumes certain components of placing fire such as target acquisition, communications, resupply, and command and control.

---

18 **military worth index** $= \sum_{i=1}^{n} [W_i \times Pd_i]$

where: W = military worth of each target that can be defeated
P_d = probability of defeating each target

Note: It's difficult to assign military worth to different types of targets because a common denominator must be delineated.

---

19 **percent of basic load expended per hit**

Note: Input unit of measure is rounds, tons, or DOA.

---

20 **percent of near misses**

---

21 **percent of rounds that hit**

---

22 **percent of target destruction** where the unit of input measure could be: number of personnel, number of vehicles, number of major weapons, square meters, number of buildings, number of oil tanks, length of road or track, etc.

---

23 **percent of targets hit**

---

24 **percent of time firing while moving**

---

25 **probability of hit (P_H)** is the theoretic chance of hitting a target under stated circumstances if all unstated circumstances are random variables.

$$P_H = \frac{\text{number of hits}}{\text{number of attempts}} \quad \text{or} \quad P(H) = \int_{-\infty}^{H} P(x)\,dx$$

In the latter case, P(H) is a probability density function, which is the number of hits for each value of another variable. To put it another way, the probability is the integral of the function for a given value of the other variable.

Note: The measure can be used to determine how many rounds or how long a period of time is required to reach a certain probability of hit, or probable numbers of hits.

---

26 probability of kill given a hit is the theoretic chance of killing a target under stated circumstances if all unstated circumstances are random variables.

P_K = number of kills / number of hits

This may also be computed as the integral of kills as a function of another variable, or as a combination of probabilities.

Note: The measure can be used to evaluate a firepower system, compare alternative firepower systems, or compute higher order measures such as number of kills, rounds required to kill, or probability of survival.

---

27 rate of fire = the amount of ammo fired (rounds, tons, DOA) divided by elapsed time

---

28 rate of target destruction is the proportion of attacked target destroyed per specified time period.

---

29 required ammo resupply rate =

$$\frac{\text{total number of rounds (or tons or DOA) required}}{\text{number of days in time period observed}}$$

Note: Unit measure of output is rounds (for single type of round) or tons (for several types of rounds). This measure can also be considered as a ratio between a predetermined "day of ammunition" which is meant to be the amount of ammunition required per day and the actual amount of ammunition. In this form, the ratio is "DOA" per day.

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30 rounds per casualty

---

31 rounds per engagement

---

32 rounds to completion is the number of rounds fired from initiation to completion of a task. The task may be to defeat a given target, suppress for a period of time, adjust or zero a weapon, or to acquire a first hit (rounds to first hit).

Note: If firepower is held constant, the measure can evaluate the resistance of the target.

---

33 **time to estimate range** = (time of estimation) minus (time of detection)

---

34 **time to first fire** is the elapsed time from detection of a target to arrival of the reaction firing round on the target.

Note: This measures timeliness of fire. It subsumes the times required to recognize, identify and locate a target; communicate a fire request; and fire the weapon system; and flight time of the projectile.

---

35 **weapon fractional kill value** is the fraction of enemy losses inflicted

Note: It is not intended for comparisons by itself. It is intended mainly as a value to be used in more complex measures (such as loss exchange ratio and force effectiveness indicator) for assignment of values to weapons (P_k is a more flexible measure for the same purpose.) It could, however, be used in a simple comparison with constant enemy initial strength and constant time period.

Artillery & Mortar Rounds

36 **burst radius** is the distance from the center of the burst within which there is a specified weapon effect. The effect may be in terms of destruction of vehicles, killing of exposed personnel, a given concussion in terms of pounds per square inch, etc.

Observer Teams, Equipment, and Techniques

37 **time to adjust** is the elapsed time from start to completion of adjusting a fire mission.

---

38 **rounds to adjust** is the number of rounds fired in the course of adjusting a fire mission.

MANEUVERABILITY

Generic

39 **agility** may be measured by acceleration (or the std. deviation of acceleration), quick turning capability, and small turning radius.

---

40 **distance from enemy when attacker stops movement (kilometers from enemy)**

41 **march rate = distance traveled by a unit / elapsed time**

42 **mean time to negotiate obstacles**

$$= \frac{\text{each elapsed obstacle delay time}}{\text{number of obstacles}}$$

Note: This is really a measure of performance rather than a true measure of effectiveness, and therefore, should be applied to comparing mobility systems under the same conditions. It could be converted to a MoE bye taking total move time into account with obstacle delay time as 'percent delay', assuming that zero delay for obstacles is ideal performance.

43 **mobility index (tracked vehicles)**

$$= \left(\frac{CPF \times WF}{TF \times GF} + BF - CF\right) \times EF \times TF$$

where:

CPF = contact pressure factor (pounds / square inch of track in contact with the ground)
WF = weight factor (gross weight in pounds)
TF = track factor (track width (inches)/100)
GF = grouser factor (height in inches)
BF = bogie factor = (gross weight (pounds)/10) x (number of bogies in contact with ground) x (area in square inches per track shoe)
CF = clearance factor = ground clearance (inches) / 10
EF = engine factor (horsepower per ton)
TF = transmission factor for hydraulic and mechanical systems

44 **mobility index (wheeled vehicles) =**

$$0.6 \left[\left(\frac{CPF \times WF \times WLF}{TF \times GF} - CF\right) \times EF \times TF\right] - 20$$

where:

CPF (contact pressure factor) =

$$\frac{\text{gross vehicle weight (pounds)}}{\text{tire width (inches)} \times \text{rim diameter(inches)} \times \text{number of tires}}$$

WF (weight factor) = pounds

$$\text{TF (tire factor)} = \frac{1.25 \times \text{tire width (inches)}}{100}$$

GF (grouser factor) = height (inches) ... is for vehicle with or without chains

$$\text{WLF (wheel load factor)} = \frac{\text{gross vehicle weight}}{\text{number of wheels (single or dual)}}$$

$$\text{CF (clearance factor)} = \frac{\text{ground clearance (inches)}}{10}$$

EF (engine factor) = horsepower/ton

Note: Factors 0.6 and 20 are used to scale down the mobility indexes of wheeled vehicles for purposes of comparison.

45 movement rate in mine fields (percent of normal)

46 movement rate in normal combat (meters/second)

47 percent delay is the amount of delay in completing a move as a percentage of the total time to complete the move

$$= \frac{(A - S) - (O - S)}{O - S} \times 100$$

where:

S = start time,
O = ordered completion time
A = actual completion time

48 percent of moves completed on time

49 refueling rate = mean miles to refuel (includes idling time and travel on secondary roads)

50 sustained speed

INTELLIGENCE

Generic

51 CEP (Circular Error Probable)

$$= 1.774 \text{ X square root of } \frac{\text{(sum of distance of all misses)}}{\text{number of misses}}$$

Note: This measure is often used to measure target location.

52 detection range

Note: This measure may be characterized by one or more of the following versions: average maximum, average minimum, median, median minimum, and cumulative distribution.

53 mean time to acquisition (seconds, minute, hours, days)

54 mean time to track (seconds)

55 range of acquisition

56 time to detection

57 time to identification

SURVIVABILITY

Generic

58 area of vehicle vulnerable to a specific attack (square centimeters or square meters)

59 flammability is the time or tendency to flame based on live firings against vehicles loaded with ammo, hydraulic fluid, and fuel.

60 probability of survival (see aviation)

61 reliability of extinguisher (or extinguishing system)

62 time moving when exposed (percent of time)

63 vulnerability index = 1 - [((4TH + NM) / ET) x (RF/RA)]
where:

TH = target hits (4TH means target hits are 4 times as valuable as near misses. This multiplier can be changed, according to assumptions.)
ET = exposure time
NM = near misses
RF = rounds fired
RA = rounds available

BATTLE SUPPORT

Generic

64 **Down Time** is the time (hrs, frequency, duration) which an item is not in condition to perform its specified function

---

65 **Mean Maintenance Time** is the mean hours of preventive and corrective maintenance

$$= \frac{\text{total preventive and corrective maintenance time}}{\text{total number of preventive and corrective actions during a specified interval}}$$

---

66 **MMBF = Mean Miles Between Failure**

---

67 **MTBAMA = Mean Time Between Any Maintenance Action** (same as MTBF except that all maintenance actions are collected as data)

---

68 **MTBF = Mean Time Between Failure** is either a) the mean time a system functions until occurance of a failure requires corrective maintenance (characteristically over a two month period) or b) [total functioning life of a population of items] divided by [total number of failures within the population during a measurements cycle (time, cycles, miles, events, etc.)].

---

69 **MTBM = Mean Time Between Maintenance** is the mean of the distribution of time intervals between maintenance actions

---

70 **MTBUMA = Mean Time Between Unscheduled Maintenance Action** is the same as MTBM, except only unscheduled maintenance is collected as data.

---

71 **MTTR = Mean Time To Repair**

$$= \frac{\text{total corrective maintenance time}}{\text{total number of corrective maintenance actions during a specified interval}}$$

---

72 **MTTR(A) = Mean Time To Repair (Actually Achieved)**

$$= \frac{\text{total corrective and preventive maintenance time}}{\text{total number of corrective and preventive maintenance actions during a specified interval}}$$

---

73 MTTR(I) = Mean Time To Repair (Inherent)

$$= \frac{\text{total corrective maintenance time}}{\text{total number of corrective maintenance actions during a specified interval}}$$

---

74 MTTR(O) = Mean Time To Repair (Operational)

$$= \frac{\text{total corrective maintenance time}}{\text{total number of corrective, preventive, administrative, and support maintenance actions during a specified interval}}$$

Gun

75 mean rounds between jamming

-3------

AVIATION SYSTEMS

WEAPON DELIVERY

Generic

1 **ammunition expenditure**

$$= \frac{\text{total no. of rounds (tons or DOA) required}}{\text{no. of days in time period observed}}$$

Note: DOA means "Day of Ammunition"

---

2 **casualties per round**

---

3 **CEP (Circular Error Probable)**

= 1.774 X square root of (average miss distance)

Note: This measure is often used to measure accuracy of fire. [see explanation in Air Defense.]

---

4 **degree of neutralization**

$$= \frac{\text{number killed} + \text{number suppressed}}{\text{total number in force}}$$

Note: suppression means "not operating"

---

5 **distance from enemy when opening fire** (km)

---

6 **(expected) fraction of target damaged**

---

7 **expected remaining target killing capability** is the computation of utility value at a given point in time, taking into account both the expected remaining force size and the killing capability of that force size

$$= (Pk_a)(Es_a) + (Pk_b)(Es_b) + \ldots + (Pk_n)(Es_n)$$

where Pk = proportion of kills per attempt
Es = proportion of force size remaining at a given time or expectation of survival for each weapon

Note: This measure is especially useful in combining the effects of different weapons with the same mission.

---

8 **firing rate**

---

9 kill rate = (hit probability) x (probability hit is a kill) x (rate of fire)

Note: This is a simplistic equation that makes certain assumptions such as: many targets or many trials, not overheating the weapon when continuing to fire it at a certain rate within a certain amount of time, and the times to switch from target to target are about the same.

---

10 lethality = kills/sec

---

11 mean offset error (mean error or average miss distance) is the arithmetic average of all errors taken as distance from true location and taking direction into account. Errors have positive or negative values. (For example, errors beyond the location values are positive, and those falling short are negative.) The formula is:

$$\frac{\text{each offset distance (true location to reported location)}}{\text{number of reported locations}}$$

Note: The measure is useful in evaluating any system that includes accuracy of locating points and, at the same time, has the characterstic that positive and negative errors tend to cancel each other. For example, it can be used to compare accuracy of 2 systems in range estimation.

---

12 mean rounds to first hit

Note: This is rendered useless if a target is not hit. The measure seems quite applicable to an engagement situation with both sides attempting to obtain the first killing hit. This is typical of tank/anti-tank engagements.

---

13 mean time target engaged is the average of the time periods a target is under fire.

Note: The measure subsumes certain components of placing fire such as target acquisition, communications, resupply, and command and control.

14

$$\text{military worth index} = \sum_{i=1}^{n} [W_i \times Pd_i]$$

where:

W = military worth of each target that can be defeated
P_d = probability of defeating each target

Note: It's difficult to assign military worth to different types of targets because a common denominator must be delineated.

15 percent of basic load expended per hit

Note: Input unit of measure is rounds, tons, or DOA.

16 percent of near misses

17 percent of target destruction where the unit of input measure could be: number of personnel, number of vehicles, number of major weapons, square meters, number of buildings, number of oil tanks, length of road or track, etc.

18 percent of targets hit

19 probability of hit (P_H) is the theoretic chance of hitting a target under stated circumstances if all unstated circumstances are random variables.

$$P_H = \frac{\text{number of hits}}{\text{number of attempts}} \quad \text{or} \quad P(H) = \int_{-\infty}^{H} P(x)\,dx$$

In the latter case, P(H) is a probability density function, which is the number of hits for each value of another variable. To put it another way, the probability is the integral of the function for a given value of the other variable.

Note: The measure can be used to determine how many rounds or how long a period of time is required to reach a certain probability of hit, or probable numbers of hits.

20 probability of kill given a hit is the theoretic chance of killing a target under stated circumstances if all unstated circumstances are random variables.

P_K = number of kills / number of hits

This may also be computed as the integral of kills as a function of another variable, or as a combination of probabilities.

Note: The measure can be used to evaluate a firepower system, compare alternative firepower systems, or compute higher order measures such as number of kills, rounds required to kill, or probability of survival.

21 rate of fire $= \dfrac{\text{the amount of ammo fired (rounds, tons, DOA)}}{\text{elapsed time}}$

22 **rate of target destruction** is the proportion of attacked target destroyed per specified time period.

23 **required ammo resupply rate** =

$$\frac{\text{total number of rounds (or tons or DOA) required}}{\text{number of days in time period observed}}$$

Note: Unit measure of output is rounds (for single type of round) or tons (for several types of rounds). This measure can also be considered as a ratio between a predetermined "day of ammunition" which is meant to be the amount of ammunition required per day and the actual amount of ammunition. In this form, the ratio is "DOA" per day.

24 **rounds per casualty**

25 **rounds per engagement**

26 **rounds to completion** is the number of rounds fired from initiation to completion of a task. The task may be to defeat a given target, suppress for a period of time, adjust or zero a weapon, or to acquire a first hit (rounds to first hit).

Note: If firepower is held constant, the measure can evaluate the resistance of the target.

27 **time to estimate range**
= (time of estimation) - (time of detection)

28 **time to first fire** is the elapsed time from detection of a target to arrival of the reaction firing round on the target.

Note: This measures timeliness of fire. It subsumes the times required to recognize, identify and locate a target; communicate a fire request; and fire the weapon system; and flight time of the projectile.

29 **weapon fractional kill value** is the fraction of enemy losses inflicted
Note: It is not intended for comparisons by itself. It's intended mainly as a value to be used in more complex measures (such as loss exchange ratio and force effectiveness indicator) for assignment of values to weapons (P_k is a more flexible measure for the same purpose.) It could, however, be used in a simple comparison with constant enemy initial strength and constant time period.

Air-to-air Missile

30 kill capability against airborne targets

= R(r) x R(l) x R(g) x R(f) x R(le)

where:

R(r) = reliability of launching aircraft radar

R(l) = missile launch reliability

$$= \frac{\text{number of good launches}}{\text{number of valid attempts to fire}}$$

R(g) = missile guidance reliability

$$= \frac{\text{number of guidance successes}}{\text{number of good launches}}$$

R(f) = fuzing reliability

R(le)= lethality of warhead / fuze combination

Air-ground Ordnance

31 expected number of targets destroyed in a given period of time

32 expected number of targets killed during the systems lifetime

33 expected number of targets destroyed per sortie

34 expected number aircraft lost per target destroyed

MANEUVER

Helicopter

35 percent of track followed (nap-of-the-earth flight)

INTELLIGENCE

Generic

36 **detection range**

Note: This measure may be characterized by one or more of the following versions: average maximum, average minimum, median, median minimum, and cumulative distribution.

---

37 **detection rates**

---

38 **mean time to acquisition** is the arithmetic average of the elapsed times to complete all successful acquisitions. Acquisition is defined as including detection, recognition identification, and location of the target. The number of successful acquistions must be large enough to average out large differences from chance factors in the situation.

$$= \frac{\text{elapsed time for each successful acquisition}}{\text{number of successful acquisitions}}$$

Note: This measure directly addresses the timeliness of acquisition. It applies only to the case of completed, successful acquisition and not to the expected time to acquire. Since it subsumes other time measures (such as time-to-detection) it is a grosser measure suitable for evaluating larger systems. This measure could also be in the form of median time to acquisition.

---

39 **time to detection**

---

40 **time to identification**

Helicopter

41 **terrain recognition** which is dependent on levels of ambient illumination

---

SURVIVABILITY

Generic

42 **area vulnerable to a specific attack (square centimeters, square meters, etc.)**

---

43 **probability of survival** $= 1 - [(P_{k1})(P_{k2})\ldots(P_{kn})]$
where:

1 = probability of certain survival

$(P_{k1})(P_{k2})\cdots(P_{kn})$ = product of mutually exclusive probabilities of killing factors (factors like rounds fired, single shot hit, kill given a hit)

Attack Helicopter

44 exposure time = total elapsed time exposed to enemy acquisition.

Note: Exposure often occurs as line of sight or fire, but may include being within range of electronic detection. Exposure time is usually multiplied by probability of acquisition to determine loss in simulations.

BATTLE SUPPORT

Generic

45 mean flight hours between maintenance action

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46 mean time to repair - flightline ($MTTR_F$) is the mean probable time spent in flightline maintenance before system is returned to a ready-for-operation condition.

Transport Aircraft

47 number of transport aircraft required = $\frac{L \times T}{(AL \times U) \times A}$

where:

L = amount of load to be transported (tons or number of passengers)
T = round trip flying time
AL = allowable load per aircraft (tons or passengers)
U = utilization rate (hours per aircraft)
A = allowable time to complete transport task (hours)

-4----------------------

BATTLEFIELD COMMUNICATION

COMMUNICATION

Generic

1 **communications performance index**

$$= W_1(P_1/R_1) + W_2(P_2/R_2) + \ldots W_n(P_n/R_n) = \sum_{i=1}^{n} W_i(P_i/R_i)$$

where:

W_i = relative weight of each requirement
P_i = performance observed
R_i = requirement (or required performance)
requirements could be:
- direct communication capacity
- organic communication equipment
- conference call capability
- specific range
- security
- mobility
- message hard copy
- dependability
- vulnerability

---

2 **mean time for message delivery** (includes time waiting to get into communications system, time lost to unsuccessful attempts, time to copy, time to receive, and time to distribute from message center to addresses.)

NOTE: This MOE is usually broken down into types of messages: precedence (e.g., Flash, Immediate, Priority, Routine) means of transmission (e.g., radio, teletype, telephone, courier).

---

3 **message backlog** is the number of messages awaiting transmission.

Note: Peak Message Backlog is determined by looking at records of messages submitted and transmitted for various time periods.

---

4 **message rate**

Note: It may be more useful to divide this by maximum possible message rate. If data is available expressing cumulative messages transmitted as a function of time, the rate can be computed as the first derivative.

---

5 **percent of communication links with alternate route** is the percentage of all established node-to-node communications

links that also have an existing alternate route for communications.

Note: This measure is usually used to assess where difficulties in a communications system are, when difficulties are revealed by primary measures (such as percent of transmissions completed and mean delivery time).

6 **percent of transmissions completed**

7 **signal to noise ratio (S/N)**

$$= \frac{\text{intensity of signal}}{\text{total intensity of all other contributors}}$$

where intensity may be measured in terms of decibels for sound or brightness for light

Data Transmitter/Receiver

8 **bit error rate** (number of bits missed per second for a given data rate)

9 **mean character error rate** is the average number of character errors per 1000 character message

10 **data rate achieved** (words per minute)

11 **gross error rate** (percent of messages that have more than 10 character errors per 1000 character message) 12 mean character error rate (average number of character errors per 1000 character message).

12 **percent of messages received**

$$= \frac{\text{number of messages received}}{\text{number of messages transmitted}} \times 100$$

13 **percent of messages received that were displayed accurately**

$$= \frac{\text{number of accurately displayed messages}}{\text{number of messages received}} \times 100$$

Data & Voice Communication System

14 **grade of service** is determined by

- balance of traffic throughout network (average utilization of each node & link) and
- level of control signaling requirements (overall ratio of

control signaling to user message signaling)

15 **level of control signaling requirements** is the overall ratio of control signaling to user message signaling.

Net

16 **percent of net capacity utilization**

$$= \frac{\text{time net carries traffic (minutes)}}{\text{time net is observed (minutes)}} \times 100$$

Note: This can be used to assess the necessity of a net, but more often it is used to determine whether nets approach overloading. It is often most useful when looking at peak usage periods.

Polling Network

17 **network throughput connectivity** is the number of pairs of nodes that can exchange information. Maximum throughput = n(n-1), when a total of 'n' nodes are in a network. Actual throughput is calculated as a function of jammer-to-receiver distance and by assuming a 10 to 1 jammer-to-transmitter power output.

Note: This measure is appropriate for communication countermeasures.

Radio

18 **mean error rate (reception)** = number of words missed per 25-word message

percent of sentence intelligibility

20 **percent of satisfactorily transcribed transmission** is the percent of transmission detected which is satisfactorily transcribed into legible copy

$$= \frac{\text{number of detected transmission satisfactorily transcribed into legible copy}}{\text{number of detected transmissions}} \times 100$$

21 **rhyme word interpretation probability** is the probability that a rhyme word that is transmitted is correctly interpreted

= (1 - (average number of words wrong per N-word message)/N)

Spread Spectrum (pseudo noise encoding or frequency hopping)

22 spread spectrum, anti-jamming benefit (or margin estimate)

= 10 log (spread bandwidth or chip rate / 10 x information rate)

assuming:

a) 10 decibel output of s/n is necessary to maintain a satisfactory bit error rate

b) a one-to-one relationship exists between bandwidth and chip rate

Note: This shows that for a 20 decibel anti-jamming margin on a 16 kilo bits-per-second voice circuit, about 16 Megahertz of spread bandwidth is required.

Satellite Spread Spectrum Communications

23 SATCOM uplink channel capacity is a theoretical tool for analyzing throughput degradation due to jamming.

$$R = WS \,/\, [(E_b/N_o)(\gamma)(J+I+S) \times (1+(\kappa \times TW) / EG/L)]$$

where:

R = transmitted data rate capacity of a communications satellite uplink channel
W = spread spectrum bandwidth
S = uplink signal Effective Instantaneous Radiated Power (EIRP)
E_b/N_o = required post correlation signal-to-noise
γ = signal suppression in the transponder
J = jammer EIRP
I = sum of other uplink signals' EIRP
E = satellite full output downlink EIRP
L = downlink path loss
κ = Boltzmann's constant
G/T = receiver earth terminal figure of merit

Note: (EG / L x kappa x T) = (C / kappa x T) at the earth terminal if the earth terminal has the full satellite EIRP available as its signal power (C).

Voice Network

24 grade of service is the probability that a subscriber at any randomly chosen instant will be able to obtain a circuit connection to his party.

Voice Systems

25 **voice intelligibility threshold** is the maximum jamming intensity that a communication system can experience and still achieve transfer of useable information

---

SURVIVABILITY

Generic

26 **communications interception susceptibility** is the proportion of messages that can be intercepted.

Note: This measure results in the highest possible value, the highest theoretic proportion.

Spread Spectrum System

28 **anti-jamming performance criteria**

$P_E = .5e^{(-E_s/2J_o)}$

Where: P_E = final error rate after error control encoding/decoding
E_s = energy per information symbol = received signal power X symbol length
J_o = total jammer power + RF bandspread bandwidth

Note: This measure is used in theoretical analysis of anti-jam performance criteria, by helping to determine the limits of error rate for an assumed jammer power level.

-5---------------

COMMAND & CONTROL

Generic

1 **changes per order** is the means of the number of changes for each order issued (changes being those made before execution of the order is completed).

2 **mean dissemination time** is the time required to disseminate an order, directive or warning to all elements at the new lower echelon of command.

$$= \frac{\text{(each time approved)} - \text{(each time acknowledged)}}{\text{number of orders}}$$

Note: The value of this measure is usually in minutes. A convention must be established in case an element fails to receive an order.

3 **mean time for message delivery**

4 **number (or proportion) of options remaining**

$$= (d_1)(o_1) + (d_2)(o_2) + \ldots (d_n)(o_n) = \sum_{i=1}^{n} (d_i)(o_i)$$

Where:

d_i = number of decision points open
o_i = number of options for each decision point
n = number of decisions

Note: In the form "proportion of options remaining" the situation is compared to the number of options available before a decision was made.

5 **number of orders issued for a given operation**

6 **percent of actions initiated by the time ordered**

Note: If the order doesn't specify a distinct time, it is counted as initiated on time regardless of delay.

7 **percent of messages completed**

8 **percent of orders for which clarification requested** is the percentage of total orders issued (including fragmentary orders) for which any subordinate element requested clarification.

Note: This measure is used with a timeliness measure.

9 **percent of personnel informed**

$$= \frac{\text{number of personnel aware of item}}{\text{number of personnel asked}} \times 100.$$

10 **percent of planning time forwarded** is the percentage of total planning time available that an echelon allows to all lower echelons.

$$= \frac{R - O}{R - E} \times 100$$

where: R = time from receipt of a mission
E = time ordered to start execution
O = time of issuance of the related order to the next lower echelon

11 **percent of transmissions completed**

12 **proportion of fire requests beyond range** is the proportion of all fire missions requested (or required in the case of a simulation) that are not fired because target is beyond range.

13 **proportion of friendly elements engaged**

$$= \frac{\text{number of erroneous fires on friendly}}{\text{number of friendly elements}}$$

14 **repetitions per order**

$$= \frac{\text{sum of the number of repetitions issued each order}}{\text{number of orders issued}}$$

where repetitions could be those for part of an order and are those issued before execution of the order is completed.

15 **required number of commands** is the count of commands necessary to accomplish the stated mission.

16 **time from mission to order**

= (moment of issue of order) - (moment of receipt of mission)

Note: This includes planning time, decision time, and time to prepare and disseminate the order. It does not include soundness of the order.

17 **time to decision (planning time)** is the proportion of time from receipt of mission to time of executing action that is devoted to the commander's decision, or

$(t_o - t_r) / (t_e - t_r)$

where: t_r = time of receiving the mission
t_o = time order is approved
te = time execution of the ordered actions is to start

---

18 **warning/operation orders ratio** is the number of warning orders divided by the number of operation orders (including fragmentary orders).

Note: This measure is related to reaction time and has been used to measure level of training.

Infantry Unit

19 **time to change formation** is the elapsed time required to change a moving unit from one formation to another.

COMMUNICATION

Generic

20 C^2 communications performance index

$$= W_1(P_1/R_1) + W_2(P_2/R_2) + \ldots W_n(P_n/R_n) = \sum_{i=1}^{n} [Wi(Pi/Ri)]$$

where: W = weight, P = performance, R = requirement

Examples of system requirements are: direct communication capacity, organic communication equipment, conference call capabililty, specific range, security, mobility, message hard copy, dependability, and vulnerability, each of which is measured directly or rated by evaluators on a common scale.

---

21 **communications system capacity**

---

22 **mean number of transmissions required** is the average number of radio transmissions made each time a specified typed of action is executed.

Telephone System

23 **telephone channel capacity**

= percent of message demand on a telephone system that can be transmitted by the system

= (T/S X 100)/t

where: T = number of messages transmitted
S = number of messages submitted for transmission
t = measurement time period (in hours)

INTELLIGENCE

Generic

24 percent of essential elements of information (EEI) met
= (number of EE1 satisfied / number of EEI planned) X 100

---

25 time to estimate range
= (time of estimation) - (time of detection)

Note: The unit of measurement is usually seconds and fractions thereof.
This measure can be used to compare estimation times of means of range estimation (techniques, aids, rangefinders, trained personnel) to each other or to a standard. It is usually combined with accuracy of estimation or accuracy of firing.

-6------------------------------

COMBAT/TACTICAL SUPPORT EQUIPMENT

MANEUVERABILITY

Generic

1 march rate $= \dfrac{\text{distance traveled by a unit}}{\text{elapsed time}}$

---

2 mean time to negotiate obstacles

$$= \frac{\text{(each elapsed obstacle delay time)}}{\text{number of obstacles}}$$

Note: This is really a measure of performance rather than a true measure of effectiveness and ,therefore, should be applied to comparing mobility systems under the same conditions. It could be converted to a MoE bye taking total move time into account with obstacle delay time as 'percent delay', assuming that zero delay for obstacles is ideal performance.

---

3 mobility index (tracked vehicles)

$$= \left(\frac{CPF \times WF}{TF \times GF} + BF - CF\right) \times EF \times TF$$

where:

CPF = contact pressure factor (pounds / square inch of track in contact with the ground)
WF = weight factor (gross weight in pounds)
TF = track factor (track width (inches)/100)
GF = grouser factor (height in inches)
BF = bogie factor = (gross weight (pounds)/10) x (number of bogies in contact with ground) x (area in square inches per track shoe)
CF = clearance factor = ground clearance (inches) / 10
EF = engine factor (horsepower per ton)
TF = transmission factor for hydraulic and mechanical systems

---

4 mobility index (wheeled vehicles) =

$$0.6 \left[\left(\frac{CPF \times WF \times WLF}{TF \times GF} - CF\right) \times EF \times TF\right] - 20$$

where:

CPF (contact pressure factor) =

$$\frac{\text{gross vehicle weight (pounds)}}{\text{tire width (inches)} \times \text{rim diameter(inches)} \times \text{number of tires}}$$

WF (weight factor) = pounds

$$\text{TF (tire factor)} = \frac{1.25 \times \text{tire width (inches)}}{100}$$

GF (grouser factor) is for vehicle with or without chains)

$$\text{WLF (wheel load factor)} = \frac{\text{gross vehicle weight}}{\text{number of wheels (single or dual)}}$$

$$\text{CF (clearance factor)} = \frac{\text{ground clearance (inches)}}{10}$$

EF (engine factor) = horsepower/ton

Note: Factors 0.6 and 20 are used to scale down the mobility indexes of wheeled vehicles for purposes of comparison.

---

5 **movement rate in mine fields (percent of normal)**

---

6 **movement rate in normal combat (meters/second)**

---

7 **percent delay** is the amount of delay in completing a move as a percentage of the total time to complete the move

$$= \frac{(A - S) - (O - S)}{O - S} \times 100$$

Where:

S = start time,
O = ordered completion time
A = actual completion time

---

8 **percent of moves completed on time**

---

9 **refueling rate** = mean miles to refuel (includes idling time and travel on secondary roads)

---

10 **sustained speed**

BATTLE SUPPORT

Generic

11 **down time** is the time (hrs, frequency, duration) which an

item is not in condition to perform its specified function

---

12 **mean maintenance time** is the mean hours of preventive and corrective maintenance

$$= \frac{\text{total preventive and corrective maintenance time}}{\text{total number of preventive and corrective actions during a specified interval}}$$

---

13 **MMBF = Mean Miles Between Failure**

---

14 **MTBAMA = Mean Time Between Any Maintenance Action** (same as MTBF except that all maintenance actions are collected as data)

---

15 **MTBF = Mean Time Between Failure** is either a) the mean time a system functions until occurrence of a failure requires corrective maintenance (characteristically over a 2 month period) or b) [total functioning life of a population of items] divided by [total number of failures within the population during a measurements cycle (time, cycles, miles, events, etc.)].

---

16 **MTBM = Mean Time Between Maintenance** is the mean of the distribution of time intervals between maintenance actions

---

17 **MTBUMA = Mean Time Between Unscheduled Maintenance Action** is the same as MTBM, except only unscheduled maintenance is collected as data.

---

18 **MTTR = Mean Time To Repair**

$$= \frac{\text{total corrective maintenance time}}{\text{total number of corrective maintenance actions during a specified interval}}$$

---

19 **MTTR(A) = Mean Time To Repair (Actually Achieved)**

$$= \frac{\text{total corrective and preventive maintenance time}}{\text{total number of corrective and preventive maintenance actions during a specified interval}}$$

---

20 **MTTR(I) = Mean Time To Repair (Inherent)**

$$= \frac{\text{total corrective maintenance time}}{\text{total number of corrective maintenance actions during a specified interval}}$$

---

21 MTTR(0) = Mean Time To Repair (Operational)

$$= \frac{\text{total corrective maintenance time}}{\text{total number of corrective, preventive, administrative, and support maintenance actions during a specified interval}}$$

Bucket Loader

22 bucket loader effectiveness is the observed payload movement rate of bucket loaders as a proportion of maximum possible movement rate

$$= (M/T_O)/(C/T_C)$$

where:

M = amount of payload actually moved (cubic feet)
T_O = time operation observed for measure
C = capacity of bucket (cubic feet)
T_C = cycle time per bucket lift, including empty return time

---

Bulldozer

23 bulldozer cubic movement rate = (W X D X P)/T

where:

W = width of dozer blade (feet or meters)
D = working depth of dozer blade (feet or meters)
P = push distance (feet or meters)
T = turn-around time (cycle including shearing, loading, returning) in minutes

---

Compactor

24 compacting rate = number of square feet compacted per hour

---

Grader

25 grader spreading rate is the number of square feet of dirt spread over a given area in an hour.

= (W X L X E)/T

where:

W = width of working area (feet)

L = working distance (feet)
E = a working efficiency function
T = time worked (minutes)

<u>Water Distributor</u> (sprinkling)

26 **water distributor area sprinkling rate**

= (W x D)/T

Where: W = width of water sprinkler bar
D = distance traveled by distributor while unloading one tankful of water
T = turnaround time (time to fill, transport, empty and return)

-7-------------------------------------

ELECTRONIC WARFARE AND SURVEILLANCE SYSTEMS

Generic

1 **probability of detection**

$$= \frac{\text{number of detections}}{\text{number of detection opportunities}}$$

When detections are arranged as a function of another variable (such as a density function of time) the probability is computed as an integral with respect to a given value, as in the form:

$$P(x) = \int_{-\infty}^{x} p(t)\,dt$$

---

2 **proportion of targets detected**

$$= \frac{\text{number of targets detected}}{\text{number of total potential targets}}$$

Note: When a target is moving a rule has to be established for how often it becomes a "new" potential target. This measure is rarely used by itself; it is usually used with measures of timeliness and accuracy of detection.

Sensor (Detection)

3 **delay after a detection in resuming a search (minutes)**

Radar (Detection)

4 **average maximum (or minimum) target detection range (as a function of target altitude, target type, antenna polarization type, and antenna tilt angle)**

---

5 **cumulative distribution of maximum detection range** is the percent of runs on which detection was made by a given range (whereby first detection of an incoming aircraft is made by an alerted operator and confirmed by observation of 2 blips in any three consecutive scans)

---

6 **median detection range** is the range exceeded by 50% of observed detections, for a given radar mode, target type, and target altitude range.

---

7 **90% cumulative detection range** is the distance below which 90% of observed detections occurred, for a given radar mode,

target type, and target altitude.

8 **median minimum detection range** is the range exceeded by 50% of observed minimum detection ranges, for a given target altitude and elevation scan limit.

9 **blip/scan ratio** (as a function of range for a given target type, target altitude, target speed, antenna lobing, and radar mode)

$$= \frac{\text{number of times target radar return was present on scope for a given range band}}{\text{number of antenna scans in a given range band}}$$

<u>Radar</u> (Tracking)

10 **average index of track solidity** (as a function of slant range for a given target altitude, target type and antenna tiltangle)

$$= \frac{\text{number of blips observed in a given range band}}{\text{number of scans in a given range band}}$$

11 **mean radar range resolution** where range resolution is based on the range difference of the leading edge of 2 targets at the same bearing as the 2 target blips start to separate or merge.

12 **mean radar range error**

13 **mean radar bearing resolution** where bearing resolution is based on the bearing difference of 2 target centers which are at the same range as the target blips start to merge or separate

14 **mean radar bearing error**

15 **percent of restricted tracking runs**

$$= \frac{\text{number of runs which tracking held to a given range}}{\text{number of tracking runs x 100}}$$

<u>Electronic Warfare (Electronic Counter (Counter) Measures) System</u>

16 **average maximum intercept range** (as a function of relative bearing)

17 **mean defensive electronic countermeasures (DECM) burnthrough range**

Note: DECM modes of operation are either automatic or machine assisted

---

18 **mean noise jamming burnthrough range**

---

19 **mean DECM reaction time** (for a given mode of operation)
Note: This measure is the elapsed time from detection of the threat emitter to radiation against it.

---

20 **mean noise jamming reaction time**

---

21 **percent of correctly identified emission control (EMCON) violators (non-violators)**

$$= \frac{\text{number of correctly identified violators (nonviolators)}}{\text{number of unique friendly ID's}} \times 100$$

---

22 percent of signals identified that were unique ID's (ID's = identifications)

$$= \frac{\text{number of unique signal identifications}}{\text{number of signals identified}} \times 100$$

---

23 percent of signals identified that were ambiguous ID's

$$= \frac{\text{number of ambiguous signal ID's}}{\text{number of signals identified}} \times 100$$

Note: Ambiguous ID's include the categories of 'Ambiguous', 'Multiple Friendly', and 'Multiple Hostile', all of which require operational resolution of the ambiguity. Unkrown ID's are generic ID's for which there are no specific matches in the emitter library.

---

24 percent of emitters identified that were unique ID's

$$= \frac{\text{number of unique emitter ID's}}{\text{number of emitters identified}} \times 100$$

---

25 percent of emitters identified that were ambiguous ID's

$$= \frac{\text{number of ambiguous emitter ID's}}{\text{number of of emitters identified}} \times 100$$

---

26 percent of time that pulse repetition frequency (PRF) is present in unique ID's

= (number of times PRF present / number of unique ID's) x 100

27 percent of time that pulse width (PW) is present in unique ID's

= (number of times PW present / number of unique ID's) x 100

28 percent of time that frequency is present in unique ID's

$$= \frac{\text{number of times frequency present}}{\text{number of unique ID's}} \times 100$$

29 percent of time that scan information is present in unique ID's

$$= \frac{\text{number of times scan information present}}{\text{number of unique ID's}} \times 100$$

30 percent of successful communication interception attempts is the percentage of attempts to intercept communications that result in an interception.

ECM Receiving Antenna

31 mean (median) signal detection range

32 mean direction finding (DF) error

33 direction finding (DF) error probability is the probability of a DF error within 1 standard deviation of the mean DF error.

Jammer

34 comjam mission effectiveness (percentage)

$$= \frac{\text{total number of successful missions}}{\text{total number of missions}} \times 100$$

Note: A successful mission means one that may negate communications, delay communications, cause general confusion, misdirect stations, or deceive stations on the links.

35 communication error rate (intelligibility):

Note: For voice, it is the number of ideas received incorrectly over a range of jamming-to-signal (J/S) ratios. For data it is the number of bits received incorrectly over a range of J/S ratios.

36 communications intelligibility versus jamming/signal ratio

where:

intelligibility = percent of transmitted 2-digit random numbers correctly received

Note: the percentage of correct responses is plotted against various jamming-to-signal ratios. For each type of communications tested (i.e., jammed), a designated percent of correct responses is equated to a minimum intelligibility level.

---

37 frequency of jamming reception is how often jamming is initiated versus how often jamming is received

---

Jammer (search-and-jam type)

38 jammer effectiveness

= jammer utilization / average transmitter utilization

where:

jammer effectiveness = ϵ

jammer utilization = U, the fraction of time the jammer spends actually jamming victims (as opposed to searching for victims)

average transmitter utilization = [number of frequencies used by jamming victim (κ)] x [probability that the frequency is being used ($\lambda / \lambda + \mu$)],

where: λ = transition rate from frequency idle state to utilized state

μ = transition rate from frequency utilized to idle state.

therefore: $\epsilon = \mu / [\kappa (\lambda / \lambda + \mu)]$

$= \mu (\lambda + \mu) / \kappa \times \lambda$

assuming:

- jammer is of the search-and-jam type
- frequency space is divided into fixed channels for jammer search and jamming
- the beginning of transmission is modeled as a Poisson process

- transmission lengths have a negative exponential distribution
- frequency space is searched in a monotonic direction
- when a jammer detects that a victim has become idle, it immediately begins to search for another victim

---

Jammer(s)

39 jammer effectiveness

$$= \frac{\text{expected number of jammer transmissions}}{\text{expected number of transmissions}} \qquad \text{or}$$

$$\epsilon = \frac{\sum_{i=1}^{J} i \binom{k}{i} (A / 1-A)^{i} + \sum_{i=J+1}^{k} J \binom{k}{i} (A / 1-A)^{i}}{NA \sum_{i=1}^{k} \binom{k}{i} (A / 1-A)^{i}}$$

where: ϵ = jammer effectiveness
A = duty factors of each frequency
NA = expected number of transmissions
k = number of frequencies utilized
J = number of frequencies jammed

Note: This measure is used for determining a theoretical limit. It can also be used for a single search-and-jam jammer versus several communication frequencies.

Repeater Jammer

40 repeater jammer effectiveness area (theoretical) within which a repeater jammer could impact on a frequency hopping transmitter at a given frequency hopping rate.

The MOE is derived from:

$$\alpha \times t_{on} = (d_1/V) + \Delta + (d_2/V) - (2C/V)$$

where: α = a constant to represent the assigned coincidence of jammer pulse on transmitter pulse (0 < < 1)
t_{on} = on-time of frequency hopping transmitter or
= transmitter duty factor x pulse repetition time
d_1 = distance between jammer and transmitter
d_2 = distance between jammer and receiver

2C = distance between transmitter and receiver
Δ = jammer processing delay
V = wave propagation velocity (3 x 10^8 meters/second)

Repeater jammer geometry is then represented as an ellipse with the transmitter-to-receiver distance (2C) equal to the focal length. The major axis of the ellipse is defined as 2a and the minor axis as 2b, (where 2b = $d_1 + d_2$). Hence:

$$b = \sqrt{[(\alpha t_{on}V) / 2 - (\Delta V / 2) + C]^2 - C^2} \quad \text{and}$$

$$a = \sqrt{(b^2 + C^2)}$$

Note: This MOE could be changed to optimum jammer employment geometry or frequency hopping communications effectiveness.

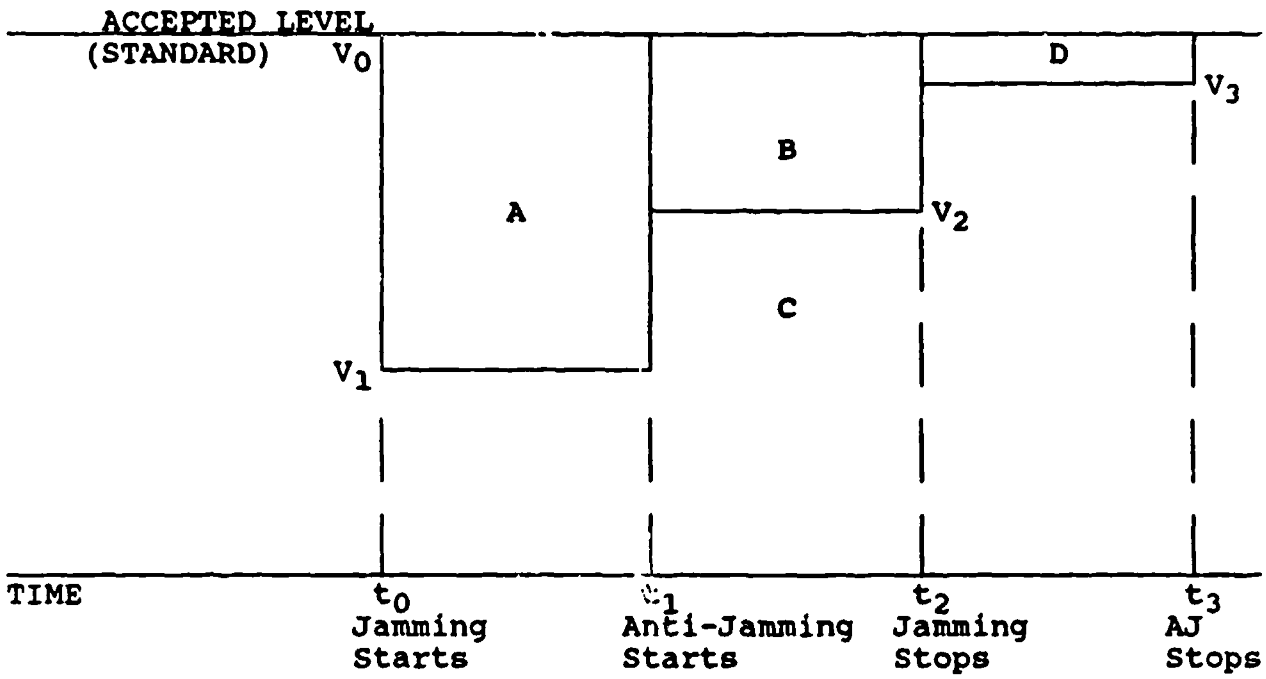
SURVIVABILITY

Multi-User, Telecommunications Circuits

41 jamming efficiency (μ_j) is the actual impact of a jammer measured against the potential impact of jamming.

$$\mu_j = \frac{A + B + D}{A + B + C}$$

Where A, B, C, & D are "areas" defined in the following illustration:



Where:

V_0 = Standard level-of-measure of system performance
$V_0 - V_1$ = Degradation due to jamming
$V_2 - V_1$ = Improvement due to Anti-Jam (AJ) protection
$V_0 - V_3$ = System Degradation due to AJ protection (no jamming)
$t_1 - t_0$ = Time required to recognize a jamming condition
$t_2 - t_0$ = Duration of the jamming condition
$t_3 - t_2$ = Time required to detect the absence of a jamming condition

Receiver efficiency (μ_r) may be expressed as:

$$\mu_r = \frac{C - D}{A + B + C}$$

$$= 1 - \mu_j$$

-8-----------------------------

GROUND TRANSPORTATION EQUIPMENT

MANEUVERABILITY

Generic

1 agility may be measured by acceleration (or the standard deviation of acceleration), quick turning capability, and small turning radius.

---

2 cruising (convoy) range is the maximum distance covered at a prescribed speed and a given type of surface

---

3 march rate = distance traveled by a unit / elapsed time

---

4 mean time to negotiate obstacles

$$= \frac{\text{(each elapsed obstacle delay time)}}{\text{number of obstacles}}$$

Note: This is really a measure of performance rather than a true measure of effectiveness, and therefore, should be applied to comparing mobility systems under the same conditions. It could be converted to a MoE by taking total move time into account with obstacle delay time as 'percent delay', assuming that zero delay for obstacles is ideal performance.

---

5 mobility index (tracked vehicles)

$$= \left(\frac{CPF \times WF}{TF \times GF} + BF - CF\right) \times EF \times TF$$

where:

CPF = contact pressure factor (pounds / square inch of track in contact with the ground)
WF = weight factor (gross weight in pounds)
TF = track factor (track width (inches)/100)
GF = grouser factor (height in inches)
BF = bogie factor = (gross weight (pounds)/10) x (number of bogies in contact with ground) x (area in square inches per track shoe)
CF = clearance factor = ground clearance (inches) / 10
EF = engine factor (horsepower per ton)
TF = transmission factor for hydraulic and mechanical systems

---

6 mobility index (wheeled vehicles)

$$= 0.6 \left[\left(\frac{CPF \times WF \times WLF}{TF \times GF} - CF \right) \times EF \times TF \right] - 20$$

where:

CPF (contact pressure factor) =

$$\frac{\text{gross vehicle weight (pounds)}}{\text{tire width (inches)} \times \text{rim diameter(inches)} \times \text{number of tires}}$$

WF (weight factor) = pounds

TF (tire factor) = $\frac{1.25 \times \text{tire width (inches)}}{100}$

GF (grouser factor) is for vehicle with or without chains)

WLF (wheel load factor) = $\frac{\text{gross vehicle weight}}{\text{number of wheels (single or dual)}}$

CF (clearance factor) = $\frac{\text{ground clearance (inches)}}{10}$

EF (engine factor) = horsepower/ton

Note: Factors 0.6 and 20 are used to scale down the mobility indexes of wheeled vehicles for purposes of comparison.

---

7 percent delay is the amount of delay in completing a move as a percentage of the total time to complete the move

$$= \frac{(A - S) - (0 - S)}{0 - S} \times 100$$

Where:

S = start time,
0 = ordered completion time
A = actual completion time

---

8 percent of moves completed on time

---

9 percent of unit at prescribed interval is the percentage of all elements (personnel, vehicles, or subordinate units as appropriate) at the prescribed interval for march.

Note: The tolerance limit for deviation from the prescribed interval must be established. Variation in actual interval is presumed one of the most sensitive indicators of difficulty in mobility. Whether the deviations come from problems in terrain, tactical action, training, or command & control, they are a measure of mobility effectiveness. This measure could be made more refined by computing the mean deviation from prescribed interval and dividing this by the interval ordered as a measure of "percent mean deviation from prescribed interval".

10 refueling rate = mean miles to refuel (includes idling time and travel on secondary roads)

11 sustained speed

BATTLE SUPPORT

Generic

12 down time is the time (hrs, frequency, duration) which an item is not in condition to perform its specified function.

13 mean maintenance time is the mean hours of preventive and corrective maintenance

$$= \frac{\text{total preventive and corrective maintenance time}}{\text{total number of preventive and corrective actions during a specified interval}}$$

14 MMBF = Mean Miles Between Failure

15 MTBAMA = Mean Time Between Any Maintenance Action (same as MTBF except that all maintenance actions are collected as data)

16 MTBF = Mean Time Between Failure is either a) the mean time a system functions until occurrence of a failure requires corrective maintenance (characteristically over a 2 month period) or b) [total functioning life of a population of items] divided by [total number of failures within the population during a measurements cycle (time, cycles, miles, events, etc.)].

17 MTBM = Mean Time Between Maintenance is the mean of the distribution of time intervals between maintenance actions

18 MTBUMA = Mean Time Between Unscheduled Maintenance Action is the same as MTBM, except only unscheduled maintenance is collected as data.

19 MTTR = Mean Time To Repair

$$= \frac{\text{total corrective maintenance time}}{\text{total number of corrective maintenance actions during a specified interval}}$$

---

20 MTTR(A) = Mean Time To Repair (Actually Achieved)

$$= \frac{\text{total corrective and preventive maintenance time}}{\text{total number of corrective and preventive maintenance actions during a specified interval}}$$

---

21 MTTR(I) = Mean Time To Repair (Inherent)

$$= \frac{\text{total corrective maintenance time}}{\text{total number of corrective maintenance actions during a specified interval}}$$

---

22 MTTR(O) = Mean Time To Repair (Operational)

$$= \frac{\text{total corrective maintenance time}}{\text{total number of corrective, preventive, administrative, and support maintenance actions during a specified interval}}$$

Cargo Handling System

23 cargo handling rate $= \frac{\text{amount of cargo handled}}{\text{number of time intervals}}$

Supply Systems

24 supply throughput effectiveness is the ratio of actual amount of cargo handling saved to the maximum possible cargo handling (tons-handling) saved.

Transport System

25 reduction in cube requiring transport is the proportional change in volume of payload awaiting delivery

$= ((C_2 - C_1)/C_1)$ / elapsed time

-9-------------

INFANTRY WEAPONS

WEAPON DELIVERY (SHOOT)

Generic System

1 ammunition expenditure

$$= \frac{\text{amount of ammo fired (rounds, ton, DOA)}}{\text{elapsed time (days, hours, seconds)}}$$

Note: Unit measure is DOA (Day of Ammunition) per day, tons per hour, rounds per second, etc.

---

2 casualties per round (indicates P_k)

---

3 CEP = Circular Error Probable is the radius from center of target of a circle that includes 50% of all observed locations. This measure is also known as the median offset error. That is the distance from center exceeded by half of the misses.

---

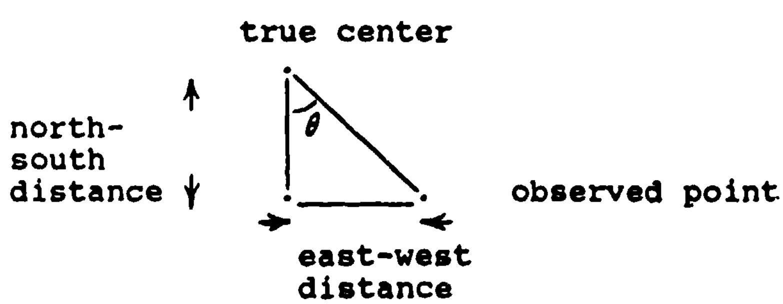
4 circular miss distance is the straight line distance from the observed point to the true center of target or

$$\left((\text{north-south distance})^2 + (\text{east-west distance})^2 \right)^{1/2}$$

or

$$(\text{north-south distance}) \div (\text{cosine of angle } \theta)$$

Where:



---

5 degree of neutralization $= \dfrac{(\text{no. killed} + \text{no. suppressed})}{\text{total no. in force}}$

Note: "suppressed" means not operating.

---

6 (expected) fraction of target damaged

---

7 expected remaining target killing capability is the computation of utility value at a given point in time, taking into account both the expected remaining force size and the killing capability of that force size

$$= (Pk_a)(Es_a) + (Pk_b)(Es_b) + \ldots + (Pk_n)(Es_n)$$

where

Pk = proportion of kills per attempt
Es = proportion of force size remaining at a given time or expectation of survival for each weapon

Note: This measure is especially useful in combining the effects of different weapons with the same mission.

---

8 firepower potential (area fire) is the product of mean lethal area and ammunition expenditure (AE).

$$= (AE)(LA_i)(L_i/T)$$

where

AE = number of rounds fired
LA_i = lethal area of each type of weapon
L_i = fraction of the total basic load (T) for each type of weapon

Note: Since an average lethal area is part of the computation, the index is an arithmetic expectation subject to distortion for unusual conditions. Number of rounds fired is treated multiplicatively ignoring the lack of independence between rounds. Average lethal area may be a difficult input to obtain.

---

9 firepower potential (point fire) = (PM/ER)(R)(AE)

where:

ER = single-shot effective range
PM/ER = average kill probability = integral of ER
R = range
AE = ammunition expenditure

Note: Since an average kill probability over all ranges is part of the computation, the index depends on firing done at maximum effective ranges. The range value (R) cannot be a simple range, but must be a transform that gives greater value to shorter ranges (for example, the reciprocal of range). Number of rounds fired is treated multiplicatively, which ignores the lack of independence between rounds.

---

10 firing rate

---

11 kill rate = (hit probability) x (probability hit is a kill) x (rate of fire)

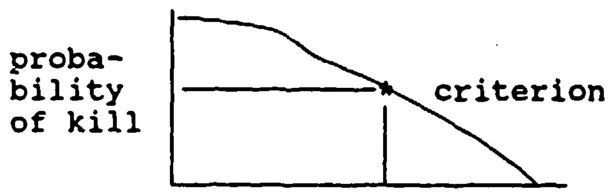
Note: This is a simplistic equation that makes certain assumptions such as: many targets or many trials, not overheating the weapon when continuing to fire it at a certain rate within a certain amount of time, and the time to switch from target to target is about the same.

---

12 lethality = kills / unit time (seconds, minutes, hours, days, weeks)

---

13 maximum effective range is the longest distance at which a specified probability of kill or acquisition is achieved.



---

14 mean offset error is the arithmetic average of all errors taken as distance from true location and taking direction into account. Errors have positive or negative values. (For example, errors beyond the location values are positive, and those falling short are negative. The formula is:

$$\frac{\text{each offset distance (true location to reported location)}}{\text{number of reported locations}}$$

Note: The measure is useful in evaluating any system that includes accuracy of locating point and, at the same time, has the characteristic that positive and negative errors tend to cancel each other. For example, it can be used to compare accuracy of two systems in range estimation.

---

15 mean rounds to first hit

Note: This is rendered useless if a target is not hit. The measure seems quite applicable to an engagement situation with both sides attempting to obtain the first killing hit. This is typical of tank/anti-tank engagements.

---

16 mean time target engaged is the average of the time periods a target is under fire.

Note: The measure subsumes certain components of placing fire such as target acquisition, communications, resupply, and command and control.

---

17 military worth index $= \sum_{i=1}^{n} [W_i \times Pd_i]$

where: W = military worth of each target that can be defeated
P_d = probability of defeating each target

Note: It's difficult to assign military worth to different types of target because a common denominator must be delineated.

---

18 percent of basic load expended per hit

Note: Input unit of measure is rounds, tons, or DOA.

---

19 percent of near misses

---

20 percent of rounds that hit

---

21 percent of target destruction where the unit of input measure could be: number of personnel, number of vehicles, number of major weapons, square meters, number of buildings, number of oil tanks, length of road or track, etc.

---

22 percent of targets hit

---

23 percent of time firing while moving

---

24 probability of hit (P_H) is the theoretic chance of hitting a target under stated circumstances if all unstated circumstances are random variables.

$$P_H = \frac{\text{number of hits}}{\text{number of attempts}} \quad \text{or} \quad P(H) = \int_{-\infty}^{n} P(x)\, x$$

In the latter case, P(H) is a probability density function, which is the number of hits for each value of another variable. To put it another way, the probability is the integral of the function for a given value of the other variable.

Note: The measure can be used to determine how many rounds or how long a period of time is required to reach a certain probability of hit, or probable numbers of hits.

---

25 probability of kill given a hit is the theoretical chance of killing a target under stated circumstances if all unstated circumstances are random variables.

P_K = number of kills / number of hits

This may also be computed as the integral of kills as a function of another variable, or as a combination of probabilities.

Note: The measure can be used to evaluate a firepower system, compare alternative firepower systems, or compute higher order measures such as number of kills, rounds required to kill, or probability of survival.

---

26 **rate of fire** = the amount of ammo fired (rounds, tons, DOA) divided by elapsed time

---

27 **rate of target destruction** is the proportion of attacked target destroyed per specified time period.

---

28 **required ammo resupply rate** =

$$\frac{\text{total number of rounds (or tons or DOA) required}}{\text{number of days in time period observed}}$$

Note: Unit measure of output is rounds (for single type of round) or tons (for several types of rounds). This measure can also be considered as a ratio between a predetermined "day of ammunition" which is meant to be the amount of ammunition required per day and the actual amount of ammunition. In this form, the ratio is "DOA" per day.

---

29 **rounds per casualty**

---

30 **rounds per engagement**

---

31 **rounds to completion** is the number of rounds fired from initiation to completion of a task. The task may be to defeat a given target, suppress for a period of time, adjust or zero a weapon, or to acquire a first hit (rounds to first hit).

Note: If firepower is held constant, the measure can evaluate the resistance of the target.

---

32 **time to estimate range** = (time of estimation) minus (time of detection)

---

33 **time to first fire** is the elapsed time from detection of a target to arrival of the reaction firing round on the target.

Note: This measures timeliness of fire. It subsumes the times required to recognize, identify and locate a target; communicate a fire request; and fire the weapon system; and flight time of the projectile.

---

34 **weapon fractional kill value** is the fraction of enemy losses inflicted

Note: It is not intended for comparisons by itself. It is intended mainly as a value to be used in more complex measures (such as loss exchange ratio and force effectiveness indicator) for assignment of values to weapons (P_k is a more flexible measure for the same purpose.) It could, however, be used in a simple comparison with constant enemy initial strength and constant time period.

<u>Mortar Rounds</u>

35 **burst radius** is the distance from the center of the burst within which there is a specified weapon effect. The effect may be in terms of destruction of vehicles, killing of exposed personnel, a given concussion in terms of pounds per square inch, etc.

<u>Observer Teams, Equipment, and Techniques</u>

36 **time to adjust** is the elapsed time from start to completion of adjusting a fire mission.

---

37 **rounds to adjust** is the number of rounds fired in the course of adjusting a fire mission.

<u>MANEUVERABILITY</u>

<u>Generic</u>

38 **march rate** = distance traveled by a unit / elapsed time

Note: This measure is obviously influenced by the portability of the weapon system, (i.e., size, weight, etc.), the terrain being traversed, and the type of transport vehicle if any.

<u>Firing Port Weapon</u>

39 **time to emplace (disemplace)** is the time required to install or remove the weapon.

INTELLIGENCE

Generic

40 **Circular Error Probable (CEP)**

$$= 1.774 \times \text{square root of } \frac{\text{(sum of distance of all misses)}}{\text{number of misses}}$$

Note: This measure is often used to measure target location.

41 **maximum effective range of acquisition**

42 **mean time to acquire**

43 **mean time to detection**

44 **mean time to identification**

BATTLE SUPPORT

Generic

45 **number of malfunctions**

Note: **Malfunctions include missile hangfires.**

46 **number of rounds between malfunctions**

47 **mean time to clear malfunctions**

-10-------------

ORDNANCE SYSTEMS

WEAPON DELIVERY

Generic

1 **ammunition expenditure**

$$= \frac{\text{amount of ammo fired (rounds, ton, DOA)}}{\text{elapsed time (days, hours, seconds)}}$$

Note: Unit measure is DOA (Day of ammunition) per day, tons per hour, rounds per second, etc.

---

2 **burst radius** is the distance from the center of the burst within which there is a specified weapon effect

---

3 **casualties per round** (indicates P_K)

---

4 **CEP = Circular Error Probable** is the radius from center of target of a circle that includes 50% of all observed locations. This measure is also known as the median offset error. That is the distance from center exceeded by half of the misses.

---

5 **degree of neutralization**

$$= \frac{\text{number killed} + \text{number suppressed}}{\text{total number in force}}$$

Note: "suppression" means not operating.

---

6 **(expected) fraction of target damaged**

---

7 **expected remaining target killing capability** is the computation of utility value at a given point in time, taking into account both the expected remaining force size and the killing capability of that force size

$$= (Pk_a)(Es_a) + (Pk_b)(Es_b) + \ldots + (Pk_n)(Es_n)$$

where

Pk = proportion of kills per attempt
Es = proportion of force size remaining at a given time or expectation of survival for each weapon

Note: This measure is especially useful in combining the effects of different weapons with the same mission.

8 firepower potential (area fire) is the product of mean lethal area and ammunition expenditure (AE).

$= (AE)(LAi)(Li/T)$

where:

AE = number of rounds fired
LA_i = lethal area of each type of weapon
Li/T = fraction of the total basic load (T) for each type of weapon

Note: Since an average lethal area is part of the computation, the index is an arithmetic expectation subject to distortion for unusual conditions. Number of rounds fired is treated multiplicatively ignoring the lack of independence between rounds. Average lethal area may be a difficult input to obtain.

---

9 firepower potential (point fire) $= (PM/ER)(R)(AE)$

where:

ER = single-shot effective range
PM/ER = average kill probability = integral of ER
R = range
AE = ammunition expenditure

Note: Since an average kill probability over all ranges is part of the computation, the index depends on firing done at maximum effective ranges. The range value (R) cannot be a simple range, but must be a transform that gives greater value to shorter ranges (for example, the reciprocal of range). Number of rounds fired is treated multiplicatively, which ignores the lack of independence between rounds.

---

10 kill rate = (hit probability) x (probability hit is a kill) x (rate of fire)

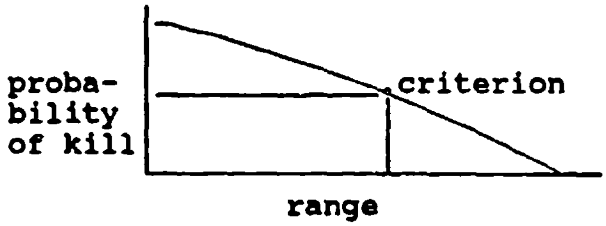
Note: This is a simplistic equation that makes certain assumptions such as: many targets or many trials, not overheating the weapon when continuing to fire it at a certain rate within a certain amount of time, and the time to switch from target to target is about the same.

---

11 lethality = kills/sec

---

12 **maximum effective range** is the longest distance at which a specified probability of kill is achieved



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13 **mean offset error** is the arithmetic average of all error taken as distance from true location and taking direction into account. Errors have positive or negative values. (For example, errors beyond the location values are positive, and those falling short are negative.) The formula is:

$$\frac{\text{each offset distance (true location to reported location)}}{\text{number of reported locations}}$$

Note: The measure is useful in evaluating any system that includes accuracy of locating points and, at the same time, has the characteristic that positive and negative errors tend to cancel each other. For example, it can be used to compare accuracy of two systems in range estimation.

---

14 **mean rounds to first hit**

---

15 **mean time target engaged** is the average of the time periods a target is under fire.

Note: The measure subsumes certain components of placing fire such as target acquisition, communications, resupply, and command and control.

---

16 **military worth index** $= \sum_{i=1}^{n} (W_i \times Pd_i)$

where:

W = military worth of each target that can be defeated

P_d = probability of defeating each target

Note: It's difficult to assign military worth to different types of targets because a common denominator must be delineated.

---

17 **opening fire proximity**

---

18 **percent of basic load expended per hit**

Note: Input unit of measure is rounds, tons, or DOA.

---

19 **percent of near misses**

---

20 **percent of rounds that hit**

---

21 **percent of target destruction** where the unit of input measure could be: number of personnel, number of vehicles, number of major weapons, square meters, number of buildings, number of oil tanks, length of road or track, etc.

---

22 **percent of targets hit**

---

23 **probability of hit (P_H)** is the theoretic chance of hitting a target under stated circumstances if all unstated circumstances are random variables.

$$P_H = \frac{\text{number of hits}}{\text{number of attempts}} \quad \text{or} \quad P(H) = \int_{-\infty}^{h} P(x)\,dx$$

In the latter case, P(H) is a probability density function, which is the number of hits for each value of another variable. To put it another way, the probability is the integral of the function for a given value of the other variable.

Note: The measure can be used to determine how many rounds or how long a period of time is required to reach a certain probability of hit, or probable numbers of hits.

---

24 **probability of kill given a hit** is the theoretic chance of killing a target under stated circumstances if all unstated circumstances are random variables.

$$P_K = \text{number of kills} \ / \ \text{number of hits}$$

This may also be computed as the integral of kills as a function of another variable, or as a combination of probabilities.

Note: The measure can be used to evaluate a firepower system, compare alternative firepower systems, or compute higher order measures such as number of kills, rounds required to kill, or probability of survival.

---

25 **rate of fire** = the amount of ammo fired (rounds, tons, DOA) divided by elapsed time

---

26 **rate of target destruction** is the proportion of attacked target destroyed per specified time period.

---

27 **required ammo resupply rate =**

$$\frac{\text{total number of rounds (or tons or DOA) required}}{\text{number of days in time period observed}}$$

Note: Unit measure of output is rounds (for single type of round) or tons (for several types of rounds). This measure can also be considered as a ratio between a predetermined "day of ammunition" which is meant to be the amount of ammunition required per day and the actual amount of ammunition. In this form, the ratic is "DOA" per day.

---

28 **rounds per casualty**

---

29 **rounds per engagement**

---

30 **rounds to completion** is the number of rounds fired from initiation to completion of a task. The task may be to defeat a given target, suppress for a period of time, adjust or zero a weapon, or to acquire a first hit (rounds to first hit).

Note: If firepower is held constant, the measure can evaluate the resistance of the target.

---

31 **time to first fire** is the elapsed time from detection of a target to arrival of the reaction firing round on the target.

Note: This measures timeliness of fire. It subsumes the times required to recognize, identify and locate a target; communicate a fire request; and fire the weapon system; and flight time of the projectile.

---

32 **weapon fractional kill value** is the fraction of enemy losses inflicted.

Note: It is not intended for comparisons by itself. It's intended mainly as a value to be used in more complex measures (such as loss exchange ratio and force effectiveness indicator) for assignment of values to weapons (P_k is a more flexible measure for the same purpose.) It could, however, be used in a simple comparison with constant enemy initial strength and constant time period.

Chemical Round

33 casualties per dose $= \dfrac{\text{number of casualties inflicted}}{\text{number of doses delivered}}$

Multiple Launch Rocket System

34 hit probability $= \dfrac{\text{number of salvo hits}}{\text{number of salvo fired}}$

MANEUVERABILITY

Generic

35 agility is measured by acceleration (or the standard deviation of acceleration), quick turning capability, and small turning radius

---

36 march rate

$$= \frac{\text{distance traveled by a unit}}{\text{elapsed time mean time to negotiate obstacles}}$$

---

37 mobility index (tracked vehicles)

$$= \left(\frac{CPF \times WF}{TF \times GF} + BF - CF\right) \times EF \times TF$$

where:

CPF = contact pressure factor (pounds / square inch of track in contact with the ground)
WF = weight factor (gross weight in pounds)
TF = track factor (track width (inches)/100)
GF = grouser factor (height in inches)
BF = bogie factor = (gross weight (pounds)/10) x (number of bogies in contact with ground) x (area in square inches per track shoe)
CF = clearance factor = ground clearance (inches) / 10
EF = engine factor (horsepower per ton)
TF = transmission factor for hydraulic and mechanical systems

---

38 **mobility index (wheeled vehicles) =**

$$0.6 \left[\left(\frac{CPF \times WF \times WLF}{TF \times GF} - CF \right) \times EF \times TF \right] - 20$$

where:

CPF (contact pressure factor) =

$$\frac{\text{gross vehicle weight (pounds)}}{\text{tire width (inches)} \times \text{rim diameter(inches)} \times \text{number of tires}}$$

WF (weight factor) = pounds

TF (tire factor) = $\frac{1.25 \times \text{tire width (inches)}}{100}$

GF (grouser factor) = height (inches) ... (for vehicle with or without chains)

WLF (wheel load factor) = $\frac{\text{gross vehicle weight}}{\text{number of wheels (single or dual)}}$

CF (clearance factor) = $\frac{\text{ground clearance (inches)}}{10}$

EF (engine factor) = horsepower/ton

Note: Factors 0.6 and 20 are used to scale down the mobility indexes of wheeled vehicles for purposes of comparison.

---

39 movement rate in normal combat (meters/second)

---

40 refueling rate = mean miles to refuel (includes idling time and travel on secondary roads)

TARGET ACQUISITION

Generic

41 accuracy of range estimation

---

42 detection range

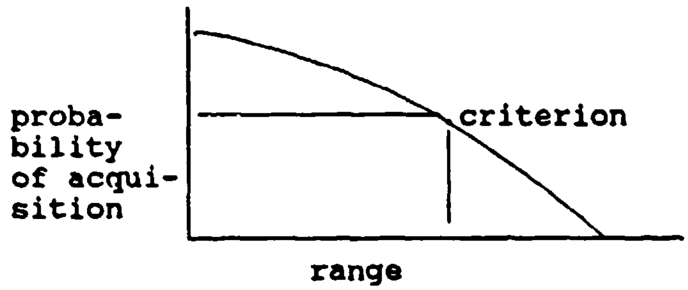
Note: This measure may be characterized by one or more of the following versions: average maximum, average minimum, median, median minimum, and cumulative distribution.

---

43 detection rates

---

44 **maximum effective range** is the longest distance at which a specified probability of acquisition is achieved.



45 mean (median) time to acquisition

46 rate of acquisition

47 time to detection

48 **time to estimate range** = time of estimation minus time of detection

49 time to identification

50 time between detection and firing

Observer teams, equipment, and techniques

51 **time to adjust** is the elapsed time from start to completion of adjusting a fire mission.

52 **rounds to adjust** is the number of rounds fired in the course of adjusting a fire mission

SURVIVABILITY

Generic

53 Area vulnerable to a specific attack

54 percent of time moving when exposed

BATTLE SUPPORT

Vehicles

55 **down time** is the time (hours, frequency, duration) which an

item is not in condition to perform its specified function

56 **mean maintenance time** is the mean hours of preventive and corrective maintenance

$$= \frac{\text{total preventive and corrective maintenance time}}{\text{total number of preventive and corrective actions during a specified interval}}$$

57 **MMBF = Mean Miles Between Failure**

58 **MTBAMA = Mean Time Between Any Maintenance Action** (same as MTBF except that all maintenance actions are collected as data)

59 **MTBF = Mean Time Between Failure** is either a) the mean time a system functions until occurrence of a failure requires corrective maintenance (characteristically over a 2 month period) or b) [total functioning life of a population of items] divided by [total number of failures within the population during a measurements cycle (time, cycles, miles, events, etc.)].

60 **MTBM = Mean Time Between Maintenance** is the mean of the distribution of time intervals between maintenance actions

61 **MTBUMA = Mean Time Between Unscheduled Maintenance Action** is the same as MTBM, except only unscheduled maintenance is collected as data.

62 **MTTR = Mean Time To Repair**

$$= \frac{\text{total corrective maintenance time}}{\text{total number of corrective maintenance actions during a specified interval}}$$

63 **MTTR(A) = Mean Time To Repair (Actually Achieved)**

$$= \frac{\text{total corrective and preventive maintenance time}}{\text{total number of corrective and preventive maintenance actions during a specified interval}}$$

64 **MTTR(I) = Mean Time To Repair (Inherent)**

$$= \frac{\text{total corrective maintenance time}}{\text{total number of corrective maintenance actions during a specified interval}}$$

65 MTTR(O) = Mean Time To Repair (Operational)

$$= \frac{\text{total corrective maintenance time}}{\text{total number of corrective, preventive, administrative, and support maintenance actions during a specified interval}}$$

-11-------------------------------------

TARGET ACQUISITION AND/OR DESIGNATOR SYSTEMS

Generic

1 **accuracy of identification (ID)** is the proportion of potential targets correctly identified. Correct ID may be defined as categorizing targets as either friendly or enemy or by type (e.g., aircraft, company CP, artillery position, etc.)

NOTE: The measure may be used to compare means of identification with each other or to a standard. How you define correct identification depends on circumstances. For example, moving target radars may be expected to identify tracked vehicles, but not distinguish between enemy and friendly.

---

2 **detail of identification** is a nominal measure of how many and which details of target ientifiction are accomplished. Details include:

- friend vs. foe
- type of target such as personnel, truck, tank or armor unit, field CP, logistical installation
- direction and rate of movement
- size of target
- activity (e.g., moving, digging in, firing)
- unit designation (e.g., 817 Armor Battalion) etc.

Note: There's a practical difficulty in eliciting all the details available unless a complete checklist is provided.
This measure's interval form is an attempt to quantify detail of identification so that a means may be said to identify four out of six details or, if details are ordered in importance, to reach the 4th level of details of identification.
The measure may be used to compare different means of identification as to detail. The measure would not ordinarily be used alone; it usually is used in conjunction with accuracy of identification and time to identify.

---

3 **detection rate** is the number of targets detected per time period.

Note: The measure may be used to discriminate among detection systems that are equal in terms of simpler measures such as % of targets detected or time to detection. The data, handled cumulatively, leads to probability of detection as a function of time.

---

4 **detection time to range ratio** is the quotient of time to detection divided by range at detection.

Note: The range at detection may be squared to take into account that a search for detection is an area search. The measure is especially useful when comparing detection systems and the competing systems are not attempting to detect precisely the same targets.

---

5 **detection to recognition time** is the elapsed time from the moment of detecting a target to the moment of recognition. Recognition is defined as sufficient information to classify a target as enemy.

Note: Times are often skewed to the high side, so that median times are often more useful than means.
Some detectors detect and recognize almost simultaneously while others (such as unattended seismic sensors, unaided ears, & radars) usually have a long gap between detection and recognition.

---

6 **friendly/enemy detection ratio** is the no. of friendly detections of enemy targets divided by the no. of enemy detections of friendly targets.

Note: This measure evaluates the effectiveness of friendly counterintelligence means such as camouflage, concealment, deception, and so forth. It is based on the premise that terrain and environmental factors are essentially the same for two forces in the same area, so an unusually low ratio would indicate lack of effectiveness in friendly countermeasures.

---

7 **identification to engagement time** (or firing reaction time) is the elapsed time from the moment of identification of a valid hostile target to the moment of engagement by fire.

Note: A convention has to be established to handle identifications that do not result in firing. Since time measures are characterized by a skew to the high side, medians are more often useful than means.
The measure represents the ability of a system to engage a threat once the threat has been identified as a target. The measure can distinguish between alternative target acquisition systems concerning the timeliness & value of capability of a unit's communications, command & control, and firepower to react to targets.

---

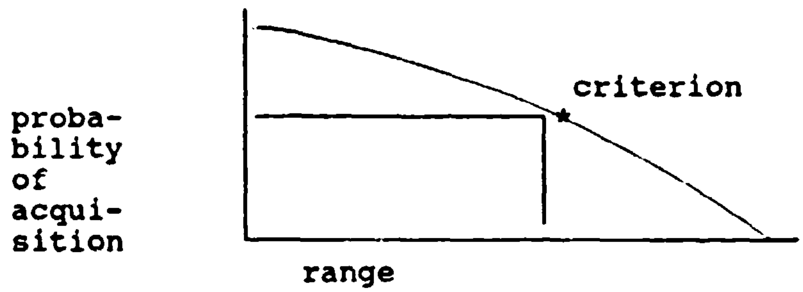
8 **location error to range ratio** is the quotient of location error (or distance of error) divided by range (from observer

to target). The ratio can be negative or positive depending on the way errors are measured.

Note: This is a measure of error of location, as an indicator of accuracy of location, but has the additional information of range, which allows the significance of the error to be considered.
The measure is useful in any comparison involving accuracy of location. It has been used to compare night vision devices in accuracy of target acquisition.

---

9 **maximum effective range** is the longest distance at which a specified probability of acquisition is achieved.



---

10 **mean error** is the arithmetic mean of all observed distances from reported values to the true value. This concept is also called "average miss distance". That is, it is the mean of all lengths of offset error when all offset errors are treated as positive values regardless of their vector.

Note: The measure could also be in the form of a median error, mean square error, standard deviation of error, geometric mean error, or quadratic mean error. This measure addresses the degree of error directly when the direction of the error does not matter. It is useful in any evaluation where accuracy of location is significant, as in the case of firing rounds at a target or in reporting the location of an enemy position.

---

11 **mean range of detection** is the arithmetic mean of all target detections.

NOTE: When moving targets or detectors are involved, range of detection is related to time from detection to contact. The measure may be used in any situation where detection is required for purposes of fire missions, maneuver, or general intelligence.

---

12 **mean time to acquisition** is the arithmetic average of the elapsed times to complete all successful acquisitions. Acquisition is defined as including detection, recognition identification, and location of the target. The number of successful acquistions must be large enough to average out large differences from chance factors in the situation.

$$= \frac{\text{elapsed time each successful acquisition}}{\text{number of successful acquisitions}}$$

(seconds, minutes, hours, or days)

Note: This measure directly addresses the timeliness of acquisition. It applies only to the case of completed, successful acquisition and not to the expected time to acquire. Since it subsumes other time measures (such as time-to-detection), it is a grosser measure suitable for evaluating larger systems.

---

13 **percent of correct locations** is the percentage of reported locations that are close enough to true locations to be counted as correct. The criterion for being close enough must be stated.

Note: This measure addresses accuracy of locating points, usually applied to locating of targets or other intelligence information. It's part of the acquisition process. The measure is not as refined as mean offset error or circular error probable, but is ordinarily relatively easy to obtain. It may be used in any situation where accuracy of locating points is an issue. It has been used, for example, to determine which night vision devices best provided target locations with criterion limits of 10 meters.

---

14 **percent of successful identification**

$$= \frac{\text{number of valid replies}}{\text{number of IFF interrogations}} \times 100$$

---

15 **percent of targets acquired** is the percentage of targets acquired out of all targets presented. Acquired is defined as detected, recognized, identified, and located. Targets presented is defined as all potential targets in the area of influence.

Note: This measure addresses effectiveness of target acquisition directly. It subsumes detection, identification, recognition, and location, and is, therefore, a more general measure for overall comparison of acquisition systems. It would ordinarily be used in conjunction with measures of accuracy and timeliness of acquisition.

---

16 percent of targets attacked is the percentage of all targets presented which are attacked.

Note: This measure goes beyond percent of targets detected to take into account the quality and timeliness of acquisition. Only targeting that goes all the way to an attack is counted. Targets which could be attacked but which are not attacked for tactical reasons depreciates the percentage.

---

17 percent of targets detected in time is the percentage of all potential targets detected within a specified time for detection of the target type.

Note: This measure is a convenient way of measuring the timeliness of detection when a criterion can be defined. While it is not as sensitive a measure as time-to-detection, it is much easier to measure.

---

18 percent of time that target is tracked is the total time a target is under observation, as a percentage of the total time the target is in the area of operations.

Note: The measure is often difficult to take because it sometimes requires collecting a set of short, elapsed times. It is less meaningful for stationary targets, but still valid. Target destruction must be treated as "leaving the area of operations (AO)."
The measure is an MOE rather than an MOP because the denominator is the theoretic 100% effectiveness.

---

19 percent of true detections is the percentage of all reported detections that are confirmed as true detections.

---

20 percent of false detections

$$= \frac{\text{(total reported detections)} - \text{(true detections)}}{\text{total reported detections}} \times 100$$

$$= \frac{\text{detections withdrawn or changed}}{\text{(total detections reported)} - \text{(true detections)}} \times 100$$

Note: A better measure would be time to (true) detection, but this measure may be useful when it is too costly to obtain time measures.

---

21 percent of warning alerts detected or confirmed

---

22 probability of detection

$$= \frac{\text{number of detections}}{\text{number of detection opportunities}}$$

when detections are arranged as a function of another variable (such as a density functio of time) the probability is computed as an integral with respect to a given value, as in the form:

$$P(x) = \int_{-\infty}^{x} p(t)dt$$

---

23 proportion of targets detected

$$= \frac{\text{number of targets detected}}{\text{number of total potential targets}}$$

Note: When a target is moving a rule has to be established for how often it becomes a "new" potential target. This measure is used to compare intelligence collection systems. It's usually used with measures of timeliness and accuracy of detection.

---

24 range of detection is the straight line distance from detector to target at the moment of first detection.

Note: If there is a difference in elevation, such as when either the detector or the target is an aircraft, it is called, the "ground range of detection." Computation may be complex if the two locations differ in two dimensions (such as two locations on a map) or three dimensions (such as aircraft & ground-point), and especially if one or both are moving. The measure has been used to discriminate among detection systems targeted gainst moving threats (such as aircraft) that might or might not approach the detector.

---

25 single scan probability of detection (as a function of target range and azimuth separation of target aircraft)

= number of aircraft identified / number of radar scans

---

26 time to detection is the elapsed time from presentation of the target until detection of it.

Note: This measures the effectiveness of search techniques and detection aids. Most problems in detection are assumed to contribute to lengthening detection time. This measure can be used to compare detection means (techniques, aids, trained personnel) to each other or to a standard when all targets are finally detected. If less than all targets are detected, this measure can be a supplementary measure to refine grosser measures of detection.

---

27 **time to identify** is the elapsed time to identification of a target as to friend or foe, or as to type.

= [time of identification] minus [time of detection (or presentation)]

Note: The measure can also be used in the form of mean or median time to identification.
There is a practical problem in employing the measure when there are instances of failing to identify, or erroneous identification that can't be corrected.
The measure may be used to compare means of identification (technique, aids, IFF systems, or trained personnel) with each other or to a standard. This measure will supplement accuracy of identification. If less than all targets are detected, it can help refine grosser measures of detection.

Air-to-Ground or Ground-to-Air

28 **slant range of detection** is the straight line distance between an aircraft and a ground-point at the moment of detection

$$= \frac{\text{height of aircraft (altitude)}}{\text{cosine of angle of air-to-ground line-of-sight}}$$

Remotely Piloted Vehicle

29 ordnance call-in time (seconds)

30 probability of (in)correct ordnance call-in

31 probability of (in)correct target designation

32 target acquisition time (time to acquisition)

33 target detection time (time to detection)

34 total mission time (seconds)

NONCOMBAT SUPPORT SYSTEMS

Generic

1 percent of time support is available

2 ratio of support requests to completions

Supply Systems

3 percent of supply requests met

4 percent of supply requirements fulfilled

5 **supply throughput effectiveness** is the ratio of actual amount of cargo handling saved to the maximum possible cargo handling (tons-handling) saved.

$$= cn - \sum_{i=1}^{n} (h_1 + h_2 + \ldots h_n) \; / \; c(n-2)$$

Where:

c = cargo (tons or other unit of measure)
n = number of possible handling points
h_1 = cargo handled at point 1 (in tons or whatever)
cn = maximum possible tons - handling
$2c$ = minimum (which is handling at first and last points only)
$c(n-2)$ = maximum possible savings

$(h1 + h2 + \ldots hn)$ = the sum of tons-handling at each point or the actual handling

Cargo Handling System

6 cargo handling rate $= \dfrac{\text{amount of cargo handled}}{\text{number of time intervals}}$

Transport System

7 reduction in cube requiring transport is the proportional change in volume of payload awaiting delivery

$= ((C_2 - C_1)/C_1 1)$ / elapsed time

where C_x is the volume (in cubic feet or meters) of payload at timepoint 'x'.

Note: The results of this measure are in terms of proportional reduction per time period, such as .25 reduction per day. The resolution of the measure depends, in part, on the precision of time measurement. The usefulness of the measure improves as the elapsed time lengthens, but the measure cannot be dissociated from the specified time interval because the rate of reduction may change.

GENERAL

1 **actual/potential productivity ratio**

= actual production / maximum potential output

applications include:

proportion targets detected
proportion moves completed by time ordered
proportion enemy force destroyed
proportion engagements won
proportion transmissions complete
operational availability

---

2 **human factors rating**

$= (X_1 - Y_1) + (X_2 - Y_2) + \dots (X_n - Y_n) / N$

Where:

X_n = rating from zero to one for favorable aspect of the nth quality
Y_n = rating from zero to one for unfavorable aspect of the nth quality

---

3 **number of additional missions capable = N-1**

Where: N = number of all types of missions that can be accomplished
1 = the one primary mission

---

4 **percent of tasks satisfied** $= (T_s / (T_s + T_n)) \times 100$

Where: T_s = number of tasks satisfied
T_n = number of tasks not satisfied

Note: The set of tasks varies in difficulty and represents the type of tasks expected (i.e., normally distributed). This measure should be used to compare similar systems.

---

5 **percentage deviation in performance**

$$= \frac{\text{(previous performance - current performance)}}{\text{previous performance}} \times 100$$

Note: Used in situations where performance should remain relatively constant

---

6 **time to completion** = elapsed time from start to finish of a task

---

MANEUVERABILITY

7 **closing time** (see explanation below)

---

8 **percent of force completing move** is the percentage of a force starting a move that arrives at the destination.

Note: It can be used for mobility difficulties such as terrain, tactical action, command & control problems, or training.

---

9 **percent of moves within time**

$$= \frac{\text{number moves completed by time ordered}}{\text{total number of moves}} \times 100$$

Note: A more refined form of the measure is "percent delay" in which the mean time of delay in completing each move is divided by the time required for the move.

COMMAND & CONTROL

10 **closing time** is the elapsed time between the first and last arrival at destination or rendevous point. Elements might be personnel, vehicles, subordinate units, or other appropriate things.

Note: A convention must be established for elements which fail to join the unit at all.
The measure may be used to compare alternative control systems. Under some circumstances it may be used to evaluate mobility.

SURVIVABILITY

11 probability of survival

$$P_s = 1 - P_d \times P_{a/d} \times P_{h/a} \times P_{k/h}$$

where:

P_d = probability of detection
$P_{a/d}$ = probability of being acquired given a detection
$P_{h/a}$ = probability of being hit given an acquisition
$P_{k/h}$ = probability of being killed given a hit

BATTLE SUPPORT

12 item failure rate = number of failures / increment of time

13 mean time between failure (MTBF) is the average elapsed time between failures

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Appendix A

Detailed Test Conditions[1]

1. Weather

A. Illumination

_1. full sunlight
_2. moonlight
_3. starlight
_4. dusk
_5. overcast, moonless night (pitch black)
_6. artificial lighting
_7. flares
_8. direct glare
_9. indirect glare (water, sand, clouds, etc.)

B. Temperature

_1. high
_2. low
_3. normal

C. Precipitation

_1. rain
_2. fog
_3. falling/blowing snow
_4. sleet
_5. sand storm
_6. no precipitation

D. Wind

_1. high head wind
_2. high tail wind
_3. significant swirling wind gusts
_4. cross wind
_5. no wind

E. Humidity

_1. high
_2. low
_3. normal

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[1]adapted from Kaplan, Crooks, Sanders, and Dechter (1980)

2. Terrain

A. Ground Slope

_1. flat
_2. low positive hilly
_3. low negative hilly
_4. high positive mountainous
_5. high negative mountainous

B. Ground Surface

_1. sandy
_2. rocky
_3. loam (deep soil)
_4. paved
_5. broken paved
_6. broken ground
_7. plowed fields
_8. bare packed
_9. vegetation covered

C. Ground and Water Surface

_1. light mud
_2. heavy mud
_3. dry
_4. water covered
_5. ice covered
_6. snow covered

D. Obstacles

_1. dense vegetation
_2. light vegetation
_3. hedge rows
_4. rivers
_5. man-made structures
_6. traps
_7. no obstacles

3. Target

A. Type

B. Number

_1. single target
_2. multiple simultaneous targets
_3. multiple sequential targets
_4. combination of multiple simultaneous and multiple sequential targets
_5. noise - number or percent of targets within nontarget background clutter

C. Location

_1. minimum range
_2. maximum range
_3. normal range
_4. azimuth and elevation target

D. Speed

_1. maximum speed
_2. minimum speed
_3. cruising speed
_4. radical alterations of speed
_5. stationary

E. Direction of Motion

_1. closing
_2. retreating
_3. crossing
_4. complex maneuver

F. Concealment

_1. concealed by physical means
_2. concealed by electronic means
_3. partially concealed
_4. concealed by smoke
_5. unconcealed

4. Personnel

A. Workload

_1. when personnel are only performing this issue
_2. when personnel perform all activities which might occur at the same time this issue is being performed

B. Duration of Preceding Work

_1. following no work
_2. following an extended period of work
_3. following a normal period of work

C. Protective Gear

_1. while wearing applicableprotective clothing/gear
_2. while wearing normal clothing/gear

D. Physical Strength

_1. with personnel with minimum strength
_2. with personnel with normal strength
_3. with personnel with optimum strength

E. Perceptual Ability

_1. with personnel with minimum perceptual ability(s)
_2. with personnel with normal perceptual ability(s)
_3. with personnel with optimum perceptual ability(s)

F. Experience

_1. with personnel with minimum experience
_2. with personnel with normal experience
_3. with personnel with optimum experience

G. Aptitudes

_1. with personnel with minimum applicable aptitudes
_2. with personnel with normal applicable aptitudes
_3. with personnel with optimum applicable aptitudes

H. Physical Size

_1. with personnel of minimum size
_2. with personnel of normal size
_3. with personnel of maximum size

5. Training

A. Institution

_1. with OJT-trained personnel
_2. with school-trained personnel
_3. with combination OJT and school
_4. with personnel without specific training
_5. with factory-trained personnel

B. Latency

_1. following a period of time without specific training or practice
_2. immediately following training
_3. with the normal period of latency

C. Team vs. Individual

_1. with personnel who have had only individual training
_2. with personnel who have had only team training
_3. with personnel who have had a combination of team and individual training

6. Operational

A. Crew

_1. with operational crew
_2. with minimum crew

B. Hardware

_1. with hardware fully up
_2. with partial breakdown
_3. with hardware fully down

C. Information Inputs

_1. with full information inputs
_2. with partial information inputs
_3. with no information inputs

7. Tactics

A. Number of Systems Employed

_1. single system
_2. multiple systems of same type
_3. multiple systems of different types

B. Speed

_1. maximum speed
_2. minimum speed
_3. cruising speed
_4. radical alterations of speed
_5. stationary

C. Location

D. Direction of Motion

_1. closing
_2. retreating
_3. crossing
_4. complex maneuver

E. Concealment

_1. concealed by physical means
_2. concealed by electronic means
_3. partially concealed
_4. concealed by smoke
_5. unconcealed

F. Crew Protection

_1. crew fully protected - buttoned up
_2. crew partially protected
_3. crew in least protected configuration
_4. NBC conditions

G. Amount of Automatic Functioning

_1. fully automatic
_2. semi-automatic
_3. manual mode

H. System Workload

_1. overloaded
_2. 100% loaded
_3. operationally loaded
_4. unloaded

Appendix B

System Class

1. <u>Air Defense Weapons</u> including missiles, guns, and high energy systems.

2. <u>Armored Vehicles</u> including battle tanks, fighting vehicles, reconnaissance behicles, armored personnel carriers, and anti-armor weapons (mounted).

3. <u>Aviation Systems</u> including helicopters and fixed-wing aircraft.

4. <u>Battlefield Communications Systems</u> including manportable radios, vehicle-portable radios, visual communications systems, and base radio systems.

5. <u>C^2(C^3I) Systems</u> including fire control systems.

6. <u>Combat/Tactical Support Equipment</u> including combat engineer vehicles, recovery vehicles, demolition equipment, and bridging equipment.

7. <u>Electronic Warfare and Surveillance Systems</u> including countermeasures equipment and sighting and surveillance equipment.

8. <u>Ground Transportation Equipment</u> including utility, medium, and heavy trucks.

9. <u>Infantry Weapons</u> including point target weapons, area target weapons, man-portable anti-armor weapons, and man-portable anti-aircraft weapons.

10. <u>Ordnance Systems</u> including tube and missile artillery.

11. <u>Target Acquisition and Designation Systems</u>

12. <u>Non-Combat Support Systems</u> including supply systems, cargo-handling systems, and automated bakeries.

13. <u>General</u>