RELIABILITY OF ONE-OF-A-KIND TRAINING SYSTEMS

Dr. H. H. Wolff
Technical Director

For some time I have looked with concern at the rapid increase in complexity of training systems reaching dimensions that raise the question of feasibility at the present state-of-the art. This increase in complexity makes it mandatory to take a very critical look at the feasibility of such a system in respect to the reliability that can be reasonably expected at the present state of the art of parts, assemblies, units, sets, subsystems, and systems.

We do not want to plan training systems that - at the present state of the art - just cannot give us the reliability we need for a satisfactory utilization.

This has to be considered especially in the case of those training systems that *simulate the combination of several operational systems* such as, for example; an aircraft carrier with several attached ships and aircraft.

Contrary to most operational equipment which has to be operative at essentially unpredictable times, training devices, equipment and systems in general are needed for periods that can be and usually are scheduled for a long time in advance.

Therefore, whereas, the reliability of operational equipment has to be measured against unpredictable operational periods, training equipment and systems reliability has to be measured against predictable scheduled use intervals. Whereas operational military equipment very frequently is using the most advance, borderline of the state of the art, as a surprise element in a conflict, training device equipment and systems have to be based on well proven state of the art to assure the uninterrupted availability during the scheduled training sessions.

Preventive maintenance and overhaul for operational equipment, even though planned will have to take place at irregular schedules, whereas, preventive maintenance and overhaul for training device equipment and systems can and should be scheduled at regular intervals or at regular predetermined times.

The most significant evaluation criterion for operational equipment is therefore the "mean-time-between-failures." The significant test criterion for training device equipment and systems is the availability during scheduled periods.

Contrary to practically every military equipment and system which is produced in quantity or at least in small production runs after one or more prototypes have been built,training systems, especially the large ones, are almost always procured as one of a kind without a prototype. And even if more than one system of the same type is procured, the first one, the first article, still has to be and will be used as an operational system. Furthermore, even if more than one system of essentially the same kind is procured, each and every individual system has to stand on its own and should be evaluation individually as far as its reliability is concerned, since follow-ons are almost always significantly different and should be tested only as individual products, for this and other reasons as will be discussed later.

All these reasons make it necessary to take a fresh look at the reliability area for training systems, that fall into this one-of-a-kind group.

We will use in the following terms as defined in MIL-STD-280 and MIL-STD-721A.

You may have noticed that I have used the term "subsystem" which is not defined in MIL-STD-280. Let me, therefore, introduce a training subsystem as a combination of two or more sets, generally physically separated when in operation and such other assemblies, sub-assemblies and parts necessary to perform an operational training sub-function or training sub-functions (Example: sonar training system in a Combat Information Center trainer).

To achieve the level of reliability needed for a satisfactory training system, reliability has to be engineered into the system and the steps to be taken are well laid down with sufficient flexibility to meet the needs of training systems procurement in MIL-STD-756A, supported by MIL-HDBK-217A. This standard provides for a feasibility prediction procedure for the conceptual or exploratory phase of product development (Par 5. 1) which should be required for and form a part of the proposal.

A second feasibility estimate (Par 5. 1. 1) should be required for submission in about 1 to 3 months after "go-ahead" date.

During the whole design and construction phase the continuous use of the design prediction procedure (Pars 5. 2 and 5. 2. 1) should be required and the findings should be submitted at specified times for approval.

All reliability calculations should be in accordance with the guidelines given in MIL-HDBK-217A.

All required estimate submissions should be included in the PERT diagrams to be submitted with the proposal and in the PERT diagrams to be submitted during the life of the contract.

Since a satisfactory level of availability is obviously a must, any indication given by the feasibility prediction or design prediction efforts that the minimum availability requirements may not be met has to be very carefully reviewed, since a complete reorientation of the approach to the training problem may be in order.

The reliability prediction is of course only a design tool and does not provide a parameter that we can really rely on.

We need therefore a test procedure that is suited to give to the project engineer who is responsible for the acceptance of the system, sufficient confidence that the system will serve its purpose with sufficient continuity.

Since the test proof of the mathematically evaluated reliability or availability-during-scheduled-periods of a given training equipment or system with a reasonably high confidence level would require a test schedule that exceeds by far a feasible test period, both from economical as well as from urgency considerations, the confidence level which has been preset for calculation purposes cannot be confirmed experimentally and has to be replaced by an experience confidence level.

Before we can discuss the proposed test philosophy we have to define precisely what we intend to convey by the term "availability."

We have used the term "availability" somewhat loosely in different connections and should therefore define an availability term that is useful for the evaluation of training devices.

Three different availability terms have been defined in MIL-STD-778, none of which describes the availability requirements for training equipment and systems since none of them refers to satisfactory operation during a specific date time interval.

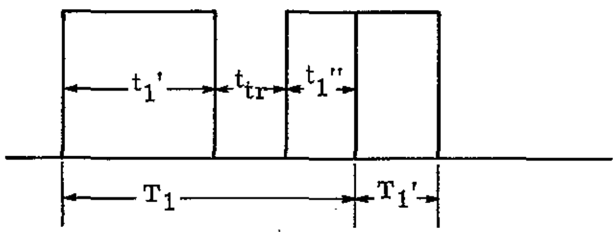
Availability is of course useless when the equipment or system is not needed and since in most cases training equipment and systems are needed only during prescheduled periods, we introduce and define the term:

Since the reliability acceptance test shall give to the project engineer sufficient evidence that the acceptance of the system and its transfer to the using activity will not lead to any valid complaints for quality reasons, sufficient flexibility must be given to the project engineer for defining the acceptance criteria of the specification.

The acceptance criterion canbe givenas a minimum value for the specific schedule availability $A_{s_{spec}}$

$$A_{s_{spec,}} = \frac{t_1 + t_2 + t_3 + \ldots + t_n}{T_1 + T_2 + T_3 + \ldots + T_n}$$

where $T_1, T_2, T_3 \ldots T_n$ are the preplanned course periods of one complete course (in time, preferably in minutes) and $t_1, t_2, t_3 \ldots t_n$ are the actually achieved operation times during these n planned course periods. In this case, a completion of the planned test syllabus by continuing the test beyond the planned test period will not count as operation time (see example below).



T_1 planned test (course) period

$t_1 = t_1' + t_1''$ achieved operation time during planned test (course) period.

t_{tr} time to repair

T_1' additional test (course) period to complete planned test (course) syllabus

This test procedure should be satisfactory as long as the planned course schedule time (sum of all course periods) has a reasonable minimum duration. Otherwise, testing over several course schedules should form the acceptance test so that the project engineer can release the equipment to the user with sufficient confidence after the tests have been completed in accordance with the specification.

Instead of using the achieved operation time during the planned schedule as the acceptability criterion, strictly the ratio of the number of achieved failure-free-operation periods to the number of planned operation periods may be chosen as test criterion. Since, in this case, availability in interrupted periods does not count the term"availability" may be confusing and better be replaced by the term "level of success." If we define this"level of success"

$$S = \frac{n_{FFOP}}{n}$$

where n_{FFPO} is the number of achieved failure-free operation (course) periods and n is the number of planned operation (course) periods, only the completely failure-free periods are counted. On the other hand, it would not matter how many failures

"Schedule Availability" as the probability that a system or equipment when used under stated conditions and in an ideal support environment (i.e., available tools, parts, manpower, manuals, etc.) shall operate satisfactorily during the planned operational use periods. It may be expressed as:

$$A_S = \text{Mean of} \left(\frac{\sum t}{\sum T} \right)_{\text{course}}$$

where $\sum$ T is the sum of all planned training (course) periods for a complete training course and $\sum$ t is the sum of all satisfactory on-time during these scheduled training (course) periods.

Though the Schedule Availability is again given as a statistical value, in this case with reference to a complete course, and would require even more test time for a proof of any given Schedule Availability with a reasonable confidence level, we can relax the confidence level requirements considerably if the test is inherently operation-realistic, contrary to the usual MTBF Tests.

The reliability acceptance test for training device equipment and systems should therefore consist of a realistic operation of the equipment under a realistic use schedule with reasonable preventive maintenance periods allowed, permitting, however, only an extremely small number of equipment breakdowns during a complete course schedule and here also limiting acceptable breakdowns to those which require a very short time-to-repair and very few manhours only and permitting only the use of replacement parts or part combinations in a limited number and at a limited cost.

This is not an excessive demand, since this availability test is not a type test but is concerned with the individual system under test only and shall not be used as favorable evidence for the reliability of additional systems of the same type.

The confidence in a continuous acceptable performance of the system under test can be based in part on the fact that all parts, assemblies, units, sets and subsystems have undergone a lengthy operational period during subsystem and system testing both in pre-acceptance and in acceptance test phases all of which serve as burn-in phase, and all parts that did not withstand the operational stresses they are normally exposed to have been eliminated and replaced.

At the same time none of the parts, assemblies, units, sets and subsystems should be operated under environmental conditions and at over voltages they will not be exposed to in foreseeable operation.

No accelerated life or longevity tests shall be conducted on items that will be or are incorporated in the subject system.

The test procedure for the reliability acceptance test should, therefore, consist of a detailed list of test periods, a detailed list of training exercises for each of these periods, the total length of the test program, a detailed permissable preventive maintenance schedule including the maximum number of permissable replacement items per failure and their maximum cost, the type and the maximum number of permissable breakdowns during test intervals, the maximum permissable manhours and time to repair for such breakdowns and the schedule for a continued testing in case the device equipment or system under test did not meet the specified conditions for the acceptance during the test program.

Though during the reliability acceptance test,realistic exercises shall be conducted which could be identical with those of the performance acceptance test program. It is not advisable to combine the two programs but rather conduct the availability acceptance test after the performance acceptance test to give the contractor sufficient opportunity to clean up those deficiencies in the design, that are requested by the performance testing project engineer.

occur in the not-failure-free operation (course) periods, though of course the test planned for such periods should be continued after interruption to syllabus completion if the required repair time permits to do so. If this criterion for acceptance is chosen, the minimum level of success required for the acceptance has of course to be specified.

Other acceptance criteria may be established if the level and the specific kind of complexity of the system and the applicable state of the art make this advisable.

The test plan has, of course, to be very detailed to give directives for all eventualities that can reasonably be expected during the quality acceptance test phase.

After the system has been delivered to be used for training detail usage logs shall be kept by the user to establish the operational usefulness.

The operational usefulness during a course, U can be defined by:

$$U = \frac{T_1 W_1 s_1 + T_2 W_2 s_2 + T_3 W_3 s_3 + \dots + T_n W_n s_n}{T_1 W_1 + T_2 W_2 + T_3 W_3 + \dots + T_n W_n}$$

wherein $T_1, T_2, T_3 \dots T_n$ are the planned training periods

$W_1, W_2, W_3 \dots W_n$ are weighting factors expressing the overall importance of the individual respective training period syllabus and

$s_1, s_2, s_3 \dots s_n$ are success factors expressing to what extent the training system availability did permit a completion of the planned respective training period syllabus within the preplanned training period.

Details of these parameters should be established by a NTDC-User Team.

So far this method of quality assurance has not been tried out but we plan to start its application in the very near future.

A considerably more detailed usage description in the specification will be needed both as far as the course schedule in time as well as the contents of each training session are concerned.

I am sure that the trainer industry concurs with us that a quality for one-of-a kind training syllabus measure is needed and we feel that the cooperation between industry and NTDC is a prerequisite for achieving this goal. I ask therefore for your cooperation in this venture.