APPENDIX B

AVAILABILITY

B-1. Availability as a function of reliability and maintainability

The effects of failures on availability can be minimized with a "good" level of maintainability. Consequently, reliability and maintainability are said to be complementary characteristics. This complementary relationship can be seen by looking at a graph of constant curves of inherent availability (A_i). A_i is defined by the following equation and reflects the percent of time a product would be available if no delays due to maintenance, supply, etc. were encountered:

$$A_i = \frac{MTBF}{MTBF + MTTR} \quad \text{(Equation 1)}$$

where MTBF is mean time between failure and MTTR is mean time to repair

If a product never failed, MTBF would be infinite and A_i would be 100%. Or, if it took no time to repair the product, MTTR would be zero and again the availability would be 100%. Figure B-1 is a graph showing curves of constant availability calculated using equation 1. Note that you can achieve the same availability with different values of R&M. As reliability decreases, higher levels of maintainability are needed to achieve the same availability and vice versa.

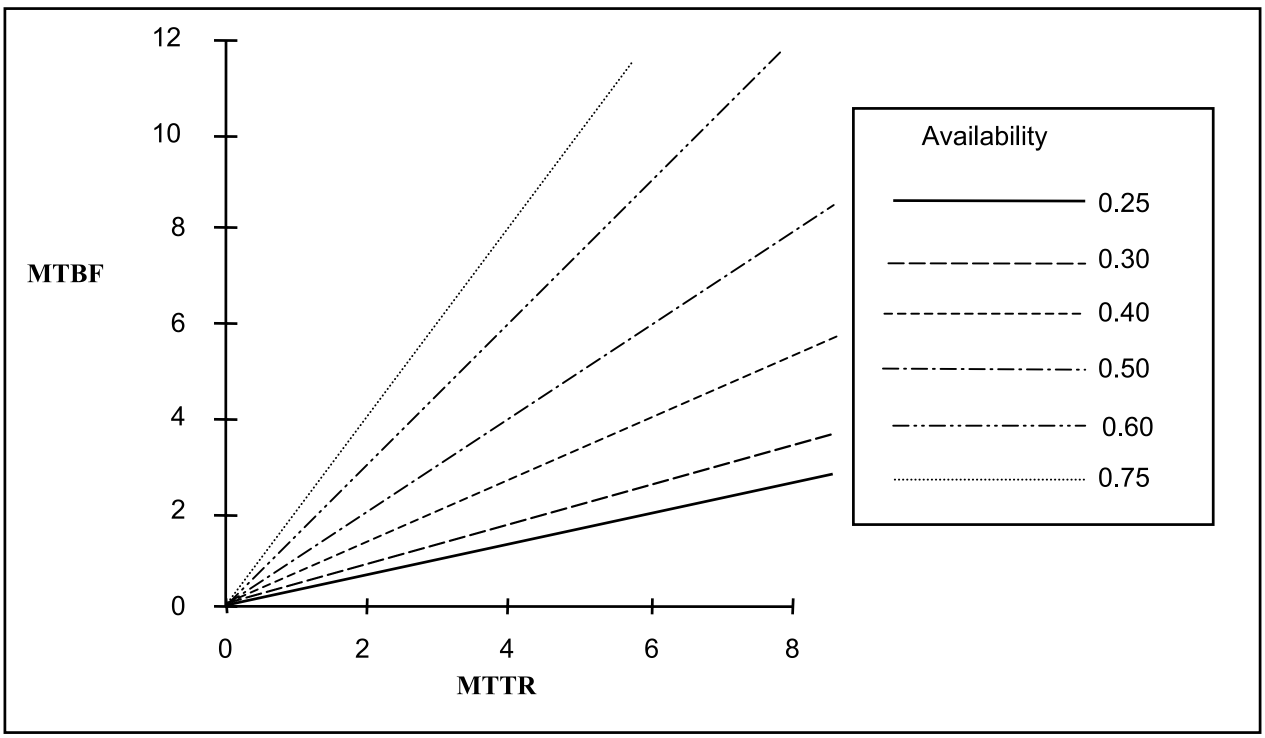

Figure B-1. Different combinations of MTBF and MTTR yield the same availability.

a. *Trade space.* This relationship between reliability and maintainability means that trades can be made to achieve the same level of availability. The range of allowable values of two or more parameters that satisfies some higher-level requirement is called trade space. If designers are having a particularly difficult time achieving a certain level of reliability, they can compensate by achieving a higher level of maintainability. Of course, the customer's top-level requirement had to have been availability. If reliability were the top-level requirement, then that is the level needed.

b. *Maximum repair time*. Even if a customer specifies availability as the top-level requirement, they may not be able to tolerate downtimes in excess of some value. In that case, in addition to specifying availability, the customer will specify a maximum time to repair. However, since time to repair is a variable, it is impossible to guarantee an absolute maximum. Therefore, a commonly used maintainability parameter is $M_{Max}(\varphi)$, where φ is a stated level of confidence. Thus, a requirement of $M_{Max}(95)$, = 6 hours means that 95% of all repairs must take less than 6 hours.

B-2. Availability as a function of logistics

Even if all reliability and maintainability requirements are met, it is possible that the availability achieved in actual use will be less than needed. The reason that this can occur is that when a failure does occur and spares are needed to make the repair, it is possible that the spares will not be available. Alternatively, the required maintenance personnel may not be available to make the repair, or they may not be adequately trained to make the repair in the optimum time. Consequently, the level of availability achieved in the field is a function not only of reliability and maintainability but also of logistics. Finally, availability is affected by all maintenance, preventive as well as corrective. So actual availability must take into consideration all maintenance performed. Thus, we must define availability in the field differently from Inherent Availability. This aspect of availability is called Operational Availability (A_o). A_o is estimated using the following equation:

$$A_o = \frac{\text{MTBM}}{\text{MTBM} + \text{MDT}} \text{ x } 100\%$$

(Equation 2)

where MTBM is mean time between all maintenance and MDT is mean downtime